COMPARATIVE STUDIES ON PHYSICAL, CHEMICAL AND BIOLOGICAL COMPONENTS OF SOME SELECTED TEMPLE TANKS IN GOA

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DOCTOR OF PHILOSOPHY IN ZOOLOGY

By

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CERTIFICATE

This is to certify that, **Mr. Kunja Datta Priolkar** has worked on the thesis entitled "***Comparative studies on physical, chemical and biological components of some selected temple tanks in Goa***" under my supervision and guidance.

This thesis being submitted to Goa University, Goa, for the award of degree of Doctor of Philosophy in Zoology, is an original record of the work carried out by the candidate himself and has not been previously submitted for award of any other degree or diploma of this or any other University in India or abroad.

Date:

Place: Goa University

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DECLARATION

I hereby declare that the thesis entitled, "***Comparative studies on physical, chemical and biological components of some selected temple tanks in Goa***" is my original contribution and the same has not been submitted on any previous occasion, for any other degree or diploma of this or any other University / Institute. The literature conceiving the problem investigated has been cited and due acknowledgements have been made wherever facilities and suggestions have been availed of.

Place: Goa University
Date:

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PREFACE

The freshwater is of vital concern for mankind, since it is directly linked to human welfare. Water, in its various forms, is a major element of all the components of the biosphere and one of the most needed factors for the existence of living organisms. Water is precious commodity for survival.

The aquatic ecosystem covers, a vast area and the organisms, occurring in this area, are under the influence of its physicochemical parameters. Plankton, both producers and consumers, play an important role in transformation of energy from one trophic level, to the next higher trophic level, ultimately leading to fish production, which is the final product of aquatic environment. The zooplankton in water forms, the main taxonomic groups. From ecological point of view, rotifers, cladocerans, and copepods are considered to be important components, which play a vital role in energy transformation.

Zooplankton diversity is one of the most important ecological parameters, in water quality assessment. Various indices like richness, diversity and evenness index can be calculated, when data on taxonomy of different zooplankton is available. The zooplankton composition, abundance and distribution are very sensitive to ecological changes, therefore, they are considered as, more ideal indicators of trophic state and aquatic ecosystem (Joseph and Yamakanamardi, 2011; Karuthapandi *et. al.*, 2013). The study of temporal and spatial distribution of zooplankton in relation to various physico-chemical factors forms an important aspect of the freshwater ecology, aimed at understanding life in water.

Most of the developing and underdeveloped countries come under tropical and equatorial regions. It may be for this reason that, studies on tropical and equatorial inland waters are relatively few, compared to those of temperate regions. In India, considerable work has been done on the ecology and seasonal distribution of plankton, than other tropical and subtropical countries. The first ecological study in India has been made by Prasad (1916), who worked on the seasonal conditions governing the pond life in Punjab. Pruthi (1933) and Sewell (1934) have studied the bionomics in fresh waters in relation to changes in physico-chemical conditions of a tank at Calcutta. From 1930 till date, several workers, in different parts of the country, have contributed to this field. Many of these pertain to the ecology of plankton and water chemistry in fish ponds, particularly in relation to fish culture (Ganapathi, 1940; Hora, 1951; Das, 1961; Rao, 1971; Khan and Siddiqui 1974; Sharma and Michael 1987; Battish, 1992; Steiner and Roy, 2003; Langer *et. al*., 2007; Raina *et. al*., 2013).

There are some reports on the seasonal studies of plankton, in relation to physico-chemical factors of tanks and lakes of Indian region (Das and Srivastav, 1956; Gouder and Joseph, 1961; Vashisht and Dhir, 1970; Chandrashekar and Kodarkar, 1994; Dhanapathi and Rama Sarma, 2000; Surana *et. al*., 2005; Tajgopal *et. al*., 2008; Rajagopal *et. al*., 2010; Sharma and Kotwal, 2011; Ramalu and Benarjee, 2013; Ansari and Khan, 2014).

The populations of zooplankton are subjected to extreme fluctuations, the causes of which have not been adequately understood. Though a good deal of information is available on the distribution of plankton, no comprehensive study seems to have been carried out earlier, to understand correlation between zooplanktonic populations and abiotic factors. An objective evaluation of the relationship of the population and the ambient conditions can however be made using the statistical tools.

According to Horne and Goldman (1994) ‘the most efficient method to advance knowledge in limnology is through comparative studies of different types of lakes within the same geographical area. There are no comparative studies on physical, chemical and biological components with special reference to zooplankton of freshwater bodies of small dimension in general and temple tanks in particular from state of Goa. On the contrary, in Indian inland waters in general and state of Goa in particular, research activities on zooplankton could not be carried out on par with the parts of the world. This may be due to various reasons like Goa getting liberated from Portuguese rule in the year 1961 and inclusion of the same in the Union of India, elevation to the statehood in the year 1987, non-availability of expertise, lack of funds, lack of infrastructure facilities etc., and has thus left a lacuna with regard to information on zooplankton and their world.

Thus, the present work was undertaken to study a few sacred temple tanks in Ponda taluka of Goa, with aim of contributing to the knowledge of freshwater biodiversity in Goa region.

Various physico-chemical factors were studied in relation to zooplankton. Also, the zooplankton diversity and distribution pattern in these areas were studied, which will help in locating the potential population centres of commercial zooplankton, such as copepod, cladocerans and rotifers. A compact evaluation of various diversity indices, numbers and evenness of zooplankton has also been studied. Apart from the above, the data was subjected to single linkage clustering and dendrograms were also prepared.

Apart from the general introduction, literature review, purpose of research, description of study area, materials and methods, as well as summary and bibliography, the thesis has been divided into three chapters.

The text of the thesis is as follows:

Chapter I

Chapter I deal with the study of physico-chemical parameters and zooplankton population of six freshwater bodies under study from Ponda taluka, Goa. It also provides information on monthly and seasonal variation of various physico-chemical and biological parameters under study and its statistical analyses to correlate the interrelationship between these parameters.

Chapter II

The second chapter provides information on zooplankton diversity, abundance, distribution pattern and seasonal variations of the zooplankton population etc. Further, a comparative picture of zooplankton diversity, abundance at different sites is also made available in the chapter.

Chapter III

The third chapter includes statistical analyses like various diversity indices in order to understand zooplankton dynamics. Further, the data was subjected to single linkage clustering to understand the similarity between zooplankton samples and their relative clusters.

INTRODUCTION

The term ecology was coined by German biologist Ernst Haeckel in 1869 (Odum, 1971). The study of ecology as a scientific discipline started during 19^{th} century and has now established itself as an honoured and respected discipline in biology. As the growth of ecology is very rapid and its scope is also expanding very fast, it is no longer restricted to realm of biology, but emerging as multidisciplinary science in depth and dimension so much so that it is considered science of synthesis.

Water is the prime necessity of life, without it, there would be no life. Most of the biological reactions use water as the medium. So, the study of water bodies is equivalent to the study of life (Dutta and Patra, 2013). The credit of pioneering scientific studies on freshwater impoundments goes to Forel (1892; 1895; 1904), who first used the term `limnology' which is now widely used to mean the study of freshwater ecosystem as a whole, but now a days it also includes inland salt water system (Welch, 1952).

Limnology covers study of lakes, ponds, reservoirs streams, rivers, wetlands and estuaries. Studies on fresh water bodies, natural or manmade have gained much importance in recent years mainly because of their multiple uses (Balakrishna *et. al.*, 2013). Today, limnology plays major role in water use and distribution as well as in wildlife habitat protection.

Water is essential natural source for sustaining life and environment (Pethe *et al.*, 2011). A basic feature of earth is abundance of water, which extends over 71% of its surface to an average depth of 3800m (Wetzel 2001). Out of which only 3% is freshwater and remaining is salt water. About 30.1% of freshwater occurs as ground water out of which a relatively small portion can be possibly put to use (Gleik, 1996). Ground water is the chief source of water in India and only 0.61% of total available water on the earth. Only 4% of freshwater is available in India inhibiting 14% of world population and also aquatic organisms (Pavendan *et. al*., 2011). Relatively small amount of water occurs in freshwater lakes, rivers and streams, barely 0.3% of the freshwater resource or <0.01% of the world's water resources. It has fundamental importance in maintenance and survival of terrestrial life.

India, apart from possessing rich mangrove areas, is a land of rivers, reservoirs, lakes, tanks and ponds and hence abounds in rich and diverse freshwater resources of the wetland type. The total water spread area is 4.5 million hectares (Srivastava *et. al*., 1985). Inland aquaculture resources cover about 3 million hectares (Mathew, 1975). These further include, about 0.72 million hectares of natural lakes and 2.0 million hectares of manmade reservoirs. In peninsular India alone, the seasonal and perennial tanks cover an area of 2,75,000 (Jhingran, 1988). Though the national policy on optimal utilisation of natural inland water resources (George and Sinha, 1975), a significant part of inland water resource has remained either unutilized or underutilized (Mathew, 1975; Sugunan, 1995).

The ubiquity of water in biota as the fulcrum of biochemical metabolism rests on its unique physical and chemical properties. These characteristics of water regulate the lake metabolism. The unique thermal density properties, high specific heat and liquid solid characteristics of water, allow the formation of stratified environment that controls extensively the chemical and biotic properties of lakes. Coupled with a high degree of viscosity, these characteristics have enabled biota to develop many adaptations that improve sustained productivity.

Natural lakes and reservoirs are distributed worldwide and exhibit variety in their limnological characteristics. Lakes are extremely heterogonous or patchy and their physical chemical and biological characteristics are extremely variable. They vary physically, in terms of light levels, temperature and water currents; chemically, in terms of nutrients, major ions and contaminants; biologically, in terms of structure and function as well as static versus dynamic variables such as biomass, population number and growth rates. However, even with varying dimensions, they are highly structured. From the perspective of eutrophication several limnological aspects are of particular importance. Physical factors of importance are size and depth, flushing rate and patterns of stratification and mixing.

The progress of a lake from young oligotrophic condition towards an aging, eutrophic condition is eutrophication process. Active biological communities develop and lake basins become shallower and more eutrophic as decaying plant and animal material accumulate at the bottom. Shallow lakes do not stratify and because of smaller lake volume, nutrient loading has larger impact that's why they are more productive, than deep lakes. Eventually, the aged lake "dies".

Eutrophication of aquatic ecosystem can greatly alter the structure of zooplankton communities (Ahangar *et. al*., 2012). Eutrophication affects the specific composition of zooplankton, through physical and chemical alterations of the environment. These changes also affect the phytoplankton composition, promoting changes in the quality and quantity of available food for the zooplankton population. The oligotrophic lakes are generally clear ,hypertrophic lakes are frequently turbid and shallow lakes at intermediate nutrient concentrations may exhibit either clear or turbid states (Scheffer *et. al*., 1993).

The major classes of tropical lakes include shallow, low land lakes; deep, high altitudinal lakes; rain forest lakes and man-made lakes. The characteristics of reservoir ecosystem are dependent on several characteristics of water; of these most important ones are the nutrient availability for phytoplankton production. This in turn, determines the level of animal production in the reservoirs (Hutchinson, 1967). Thus, for proper understanding of these ecosystems and its production potential, it is necessary to study the interrelationships and interactions among physicochemical and biological factors of the environment.

PHYSICO-CHEMICAL FACTORS:

In summer, as the temperature rises, the upper water layer becomes lighter than the water below making temperature differences between upper and lower water layers. This makes deep lakes physically stratified. Mixing of the upper and lower layers is prevented by this stratification which acts as a physical barrier for several months during the summer. When the temperature of the surface water equals the bottom water, very little wind energy is needed to mix the lake completely. The depth of mixing depends in part on the exposure of lake to wind.

Climate and basin geology of a lake fundamentally regulates its chemical composition. Each lake has an ion balance of major anions and major cations. Major ions are usually present in higher concentrations expressed as mg/L or ppm whereas, other ions, such as phosphate, nitrate and ammonium are present in lower concentrations expressed as µg/L or ppb levels.

Human beings can have profound influences on lake chemistry. Excessive landscape disturbance causes higher rates of leaching and erosion due to removal of vegetation cover, soil exposure and increased water runoff velocity. Lawn fertilisers, waste water and urban storm water inputs, all add micronutrients such as nitrogen and phosphorus, major ions such as chloride and potassium and in the case of highway and parking lot runoff, oils and heavy metals. Ions such as H^{+}, $So4^{-2}$ and No^{-3} are associated with acid rains. Mercury (Hg) is another significant air pollutant affecting aquatic ecosystems and can bio accumulate in aquatic food webs, contaminating fish and causing a threat to human and wildlife health.

Water bodies of small dimension like lakes, ponds, tanks etc., with high concentrations of Calcium (Ca^{+2}) and magnesium (Mg^{+2}) are called `hardwater' water bodies, while those with low concentrations of these ions are called `softwater' water bodies. Concentrations of these ions are associated with bicarbonate concentrations. The ionic concentrations influence the water bodies' ability to assimilate pollutants and maintain nutrients in solution. Both the concentrations of total dissolved salt and the relative ratios of different ions influence the species of organism that can best survive in the water bodies.

BIOLOGICAL FACTORS:

In lakes, there remain two major communities, if we reserve ponds and peat bogs to separate consideration. They differ in species composition, abundance of organisms, distribution of niches, productivity and physical characteristics (Kendeigh, 1961). In as much as these two communities correspond fairly well to the oligotrophic and eutrophic types of lakes, we may name them simply the oligotrophic and eutrophic lake biocies. Various facies of each community or intermediate types are affected by variations in the abundance of component species and correspond to difference in temperature, depth, fertility and other features of the habitat. The communities that occur in dystrophic lakes such as instance are an impoverished facies of the eutrophic lake biocies. In spite of taxonomic differences in constituent species, each lake biocies contains organisms, belonging to the same life forms and with similar mores so, they may be discussed together.

Depending largely on their morphological adaptations and behaviour, aquatic organisms are, for convenience, divided into plankton, neuston, nekton, and benthos, although the differences between the groups are not precise. Seston is collective term, that includes all small particulate matter, both living and non-living, that floats or swims in the water. Plankton are free floating or barely motile organisms, either plant (phytoplankton) or animal (zooplankton), that are readily transported by water currents. Most plankton are microscopically small, although some forms are visible to unaided eye. Species that can be caught with net are called net plankton, to distinguish them from the minute varieties that pass through no. 20 silk bolting cloth meshes. The latter include most protozoans, bacterial and fungal forms, collectively called nanoplankton. Organisms, that depend on the surface film for a substratum are called neuston and are more important in the quite waters of ponds than in lakes. Nekton are larger animals, such as fishes, aquatic birds, that are capable of locomotion independent of water currents. Benthos are the organisms, that are attached to or dependent on the bottom for support; there are sessile, creeping and burrowing forms.

Freshwater plankton (Welch 1952, Pennak 1946, Davis 1955) includes, representatives from the photosynthetic algae, Baccillariaceae (Diatoms), Myxophyceae (Blue-green), and Chlorophyceae (green), and occasional other forms, such as *Wolffia* among the higher plants; the non-photosynthetic bacteria and other fungi; and among the zooplankton are classes of Protozoa, except Sporozoa, Rotatoria, Entomostraca (especially Cladocera, Copepoda and Ostracoda), some immature Diptera, the statoblasts and gemmules of bryozoans and sponges, the rare freshwater jelly fish, *Craspedacusta*, and occasional aquatic mites, gastrotrichs and others.

Zooplankton are the primary consumers that graze on algae, bacteria and detritus. Secondary consumers, such as planktivorous fish or predaceous invertebrates, feed on zooplankton (Jack and Thorp, 2002). Unlike phytoplankton and plants, that are limited to the sunlit portion of the lakes, consumers can live and grow in all lake zones, although the lack of oxygen may limit their abundance in bottom waters and sediments. The benthic organisms migrate to upper waters at night to feed on zooplankton. The best known group of aquatic consumers is fish. They primarily eat zooplankton. Tertiary consumers that prey on the smaller fish include larger fish and other carnivorous animals.

Zooplankton by their heterotrophic activity plays a key role in cycling of organic materials in aquatic ecosystems and used as bio-indicators. The bio-indicators are evaluated through presence/absence, condition, relative abundance, reproductive success, community structure (i.e. composition and diversity), community function (i.e. trophic structure) or any combination thereof (Hellawell, 1986).

Most freshwater zooplankton are Crustaceans. Some common freshwater zooplankton taxonomic groups are Rotifers, Cladocerans and Copepods.

Characteristics of zooplankton groups:

(a) Rotifers: First discovered in 1600's by Leeuwenhoek, they were originally called "wheel animalcules" or "wheel animals" because their coronas look like turning wheels. This appearance is caused by rippling waves of tiny beating cilia that draw food into their mouths and provide a means of locomotion (Battish, 1992).

Rotifers are the smallest multicellular animals and occur worldwide in primarily freshwater habitats. They are important in freshwater ecosystems, as they occur in all biotypes. About 95% of the rotifers are encountered in freshwater, while 5% are from brackish or marine waters and most are free living.

All rotifers are distinguished into three classes, comprising about 120 genera and about 2000 species. The classes are: Monogononta, Bdelloidea and Seisonidea. These soft bodied invertebrates have been treated in details by Hyman (1951), Hutchinson (1967), Pennak (1978), Dumont and Green (1980), Wallace and Snell (1991).

Rotifers are multicellular animals with body cavities that are partially lined by mesoderm. These organisms have specialised organ systems and a complete digestive tract. Since these characteristics are all uniquely animal characteristics, rotifers are recognised as animals, though they are microscopic. They are pseudocoelomate microscopic organisms, about 40µm to 2mm long. However a few species, such as *Rotaria neptunia* may be longer than a millimetre.

Nearly all rotifers have chitinous jaws called trophy that grind and shred food. Rotifers are primarily omnivorous, their diet most commonly consist of dead or decomposing organic materials, as well as unicellular algae and other phytoplankton that are primary producers in aquatic communities. Rotifers are in turn prey to carnivorous, secondary consumers, including shrimp and crabs. Some species such as *Asplanchna,* preying on protozoa, other rotifera and microzoa, have been known to be cannibalistic.

Rotifers exhibit extreme sexual dimorphism. The males are very small, appear in summer and survive for few hours or days. Many rotifer species have no males (Genus: Rotaria). The females reproduce following the process known as parthenogenesis.

The species are tremendously varied and exhibit a range of morphological variation and adaptations. Most rotifers have one eye (*Euchlanis dilatata* Ehrenberg 1832), some have two (*Testudinella mucronata* Gosse 1886) and some sessile once are even eyeless (*Macotrachela quadricornifera* Milne 1886). The bodies of some species have telescopic segments (*Philodina citrina* Ehrenberg 1832) and they can expand and retract like a telescope, whilst others have slight segmentation (*Rotaria rotatoria* Pallas 1766). Some have a hardened skin, the lorica (*Anuraeopsis fissa* Gosse 1851), while others build themselves a tube to live in (*Floscularia ringens* Linnaeus 1758).

Rotifers have a rapid turnover and high metabolic rates and feed on detritus. These organisms are apparently the most sensitive indicators of water properties and one of the principle links in the food chain (Balakrishna, 2013). They are extensively cultured for use as fish feed.

(b) Cladocera: The Cladocerans are mostly found in freshwater, although eight species belonging to marine water and about 25 species belonging to family Polyphemidae, reported from Caspian Sea (Michael and Sharma, 1988). They usually inhabit every type of habitat, in the littoral, limnetic or benthic zones of freshwater lakes and ponds. They are intolerant to high salt concentrations in the medium, though there are species that frequently occur in brackish water habitat (Genus: Moina).

The Cladocera invariably constitute a dominant component of freshwater zooplankton and play an important role in the aquatic food chain and also contribute significantly to zooplankton dynamics, secondary productivity and energy flow in freshwater ecosystem. This is due to their rapid turnover rates, metabolism and capacity to build-up populations in short duration. They serve as food for both fry and adult fish and hence is cultured as supplementary food in aquacultures. This group feeds on smaller zooplankton, bacterioplankton and algae and are highly responsive against pollutants; this group even reacts against the low concentration of contaminants (Ferdous and Muktadir, 2009).

The crustaceans of order Cladocera is an interesting group, not only for taxonomic or distributional studies, but also in view of the ecological and reproductive strategies employed in their life cycles, with alternating gamogenetic and parthenogenetic phases. They are used in environmental toxicological studies, bioassay experiments, experimental models in ecological, embryological and population genetic studies. The family Chydoridae of Cladocera, due to its exoskeleton, remains well preserved and hence is used in studying the developmental history of lakes and reservoirs (Jairajpuri, 1991).

The chief characteristic of the water fleas is that, the main part of the body is enclosed in a kind of shell, with the appearance of two lids, but made of one piece. Their sizes differ from several hundred microns to more than five millimetres for the larger species. Most species are transparent, especially those, which inhabit the open waters, while others found among the weed beds of littoral and benthic zones are darkly pigmented with shades of yellow, brown or red.

They reproduce mostly parthenogenetically, *i.e*. the eggs develop without fertilisation. Parthenogenetic mode of reproduction is associated with favourable environmental conditions and switch to sexual reproduction is observed on exposure to unfavourable conditions like drying up of pond, low temperature, crowding, scarcity of food etc. during switch to sexual reproduction, as parthenogenesis declines, some of the eggs develop into males and fertilize haploid eggs. These special haploid eggs are called ‘resting eggs’ and a female produces one or two such eggs. Under favourable conditions the eggs hatch into females and the cycle goes on (Murugan *et. al*., 1998).

According to Raghunathan and Kumar (2002), the number of Cladocera species reported in India is 190 and the global diversity of cladocera is more than 600 species (Thirupathaiah *et. al*., 2011). The reported Indian taxa comprise of about 1/3rd of the world’s Cladoceran fauna. Out of these, the freshwater species represent eight out of 11 presently distinguished families of this order. Further, the distributions of many species are based on the examination of parthenogenetic females. The males of 11 taxa are also documented from India.

The Cladoceran fauna of India shows, a number of polar, arctic and temperate elements such as *Leptodora kindli, Polyphemus pediculus, Diaphnosoma brachycurum, Sida crystalline, Daphniopsis tibetana, Daphnia magna, Daphnia longispina, Ceriodaphnia* *quadrangular, Macrothrix laticornis, Macrothrix gronlandica, Alonella exigua, Pleuroxus aduncus, P. denticulatus, Indialona ganapati* seem to be endemic. In addition, and not surprisingly, tropical, subtropical and cosmopolitan species are well represented in the Indian fauna.

(c) Copepods:

Copepods have the toughest exoskeleton and the longest and the strongest appendages which help them to swim faster than any other zooplankton (Ferdous and Muktadir, 2009). The copepods are the largest and most diversified group of crustaceans. They comprise 70-80% of the total zooplankton population. At present, they include over 14,000 species, belonging to 2,280 genera and 210 families, inhabiting sea and continental waters, semi-terrestrial habitats or living in symbiotic relationships with other organisms. Copepods have colonised, virtually every habitat, from 10,000 m down in the deep sea to lakes 5,000 m up in the Himalayas, and every temperature regime from sub-zero polar waters to hot springs. They are considered the most plentiful multicellular group on the earth, outnumbering even the insects.

They virtually can parasitize or be the intermediate hosts of all the animal groups including mammalians and man. Copepods, that parasitize fish skin and gills are serious pests of commercial importance in both marine and freshwater fish farms.

The systematics of copepods has been subjected to numerous revisions. At present, according to Huys and Boxshall (1991), ten orders, viz., Misophrioida, Monstrilloida, Mormonilloida, Siphonostomatoida, Poecilostomatoida, Platycopioida, Calanoida, Harpacticoida, Gelyelloida and Cyclopoida are recognised.

Calanoids, cyclopoids and harpacticoids show remarkable ecological interest, since these orders form the first link of the aquatic food chains, from the microscopic phytoplanktonic algae up to the fishes and mammalians.

Calanoids are an essential part of the aquatic food chain and important as both predators and prey. Calanoid copepods are small crustaceans (0.3 to 2.5 mm), belonging to the family Diaptomidae but the genus Pseudodiaptomus Herrick belongs to the family Centripagidae, commonly found, as a part of free living zooplankton, in freshwater lakes and ponds (Battish, 1992). Calanoids are recognised by the position of the body articulation. They usually have an elongated body, long 1^{st} antennae and well developed 5^{th} legs. These and other characteristics separate them from the other freshwater copepod groups, the cyclopoids and harpacticoids (Battish, 1992).

An increasing number of harpacticoid and cyclopoid species are actually revealing their noteworthy importance as “pollution markers” in the environmental control of aquatic habitats, such as lakes, sprigs, rivers and superficial ground waters. The monitoring of the species change in calanoids can detect environmental changes, resulting from acidification or toxification (Marmorek and Korman, 1993).

Feeding habits differ in three orders of copepods. Cyclopoid copepods are commonly carnivorous (live on other zooplankton and fish larvae) though they also feed on algae, bacteria and detritus. The calanoid copepods are generally omnivorous (feed on ciliates, rotifers, algae, bacteria and detritus) however their food intake is dependent on their age, sex, season and food availability. The third group harpacticoid copepods are primarily benthic. Thus, their physical structures and versatile feeding habits ultimately assist them to hold up harsher environmental conditions as compared to other zooplankton. (Ferdous and Muktadir, 2009).

The ratio of calanoid/cyclopoid - cladocera is used as water quality indicator in limnological studies whereby, high values show oligotrophic conditions, while low value indicate hypertrophy (Ranga Reddy, 2001). Cyclopoids such as Microcyclops, Megacyclops Mesocyclops etc., are used in mosquito control as biological agents. Paracyclops find use in control of plant-parasitic nematodes. Copepods are claimed to be numerically the most abundant metazoans on earth and conservative estimations revealed that they likely outnumber the abundance of insects, representing one of the biggest sources of animal protein in the world and play a central role in the transfer of carbon from producers to higher trophic levels in most aquatic ecosystems (Shah *et. al*., 2013).

REVIEW OF LITERATURE

Studies on limnology and plankton, together have been gaining an ever-increasing importance in understanding the abiotic-biotic interrelationships as well as the basic productive features of impounded water bodies. From the exhaustive reviews on the status of limnological research in India (Gulati and Wurtz-Schulz, 1980; Michael, 1980; Gopal and Zutshi, 1998), it is evident that, most of the studies in freshwater impoundments, in the past have been short term classical observations, recording occurrences of biotic components and do not provide adequate and informative details about the habitat status or ecological significance. Planktonic organisms, by their abundance and or distribution served as valuable bio-indicators and thus, serve to help, in assessing the hygienic status of any freshwater habitat under consideration.

Plankton, both producers and consumers, play an important role in transformation of energy from one trophic level to the next higher trophic level. Since plankton provides the 'first link' in the food chain (Davis, 1955; Singh and Swarup, 1979; Wetzel, 2001), an insight into the distribution, composition and succession of plankton in perennial freshwater habitats, offers valuable clues for determining the fishery grounds, selection of suitable species for stocking and estimating the level of utilisation of the available food by the existing stock of fishes (Almazan and Boyd, 1978; Sugunan, 1980).

Blankaart (1768) was the first to observe the freshwater organisms. Lohmann (1911) showed the existence of the smallest group of plankton referred to as "nanoplankton". The size range of planktonic organisms was studied by Kofoid (1987). The first ecological study in India was made by Prasad (1916), who worked on the seasonal conditions governing the pond life in Punjab. Pruthi (1933) and Sewell (1934) have studied the bionomics in freshwaters in relation to changes in physico-chemical conditions of a tank at Calcutta.

Considerable literature on short term studies is available on general aspects of occurrence and distribution of plankton in the freshwater of India (Ganapati, 1943; Das and Srivastava, 1959; Zafar, 1964; Krishnamurty and Visvesvara 1966; Sreenivasan, 1967; Michael, 1968; Ganapati and Pathak, 1969; Munavar, 1970 ; Ghosh, *et. al*., 1974; Mathew, 1977; Singh and Swarup, 1979, 1980; Job and Kannan, 1980; Sugunan, 1980; Birasal *et. al*., 1987; Jakher *et. al*., 1990; Valecha *et. al*., 1991; Sugunan, 2000; Moorthy *et. al*., 2005; Kumar *et. al*., 2006; Mukhopadhyay, 2007; Vaidya and Yadav, 2008; Rajshekar, 2009; Kanagasabapathi and Rajan, 2010**;** Singh, 2011; Jadhav, 2012; Balakrishna, 2013; Sitre, 2014). Many of other studies pertain to the ecology of plankton and water chemistry in fish ponds, particularly in relation to fish culture (Ganapati, 1940; Hora, 1951; Das, 1961; Rao, 1971; Khan and Siddiqui, 1974; Sharma and Michael, 1987; Battish, 1992; Chandrashekhar and Kodarkar, 1996; Steiner and Roy, 2003; Kiran *et. al*., 2007).

Iyengar (1939) and Philipose (1940) have provided the earliest description of the algal communities in the inland water bodies, while Das and Srivastava (1955), have detailed the aspects of freshwater algal blooms. Munavar, (1970) has described the distribution of unicellular phytoplankton in the polluted and unpolluted water bodies around Hyderabad. The occurrence of freshwater algae in few habitats of Karnataka, have been described by Bharati and Bongale (1980). The phytoplankton of planned lakes has been studied by Khan and Siddiqui (1971); Jana *et. al*., (1980); Sharma *et. al*., (1982); Pant *et. al.,* (1985); Kumar and Dutta, (1991); Chattopadhyay and Banerjee, (2007); Karthi *et. al*., 2013.

Zooplankton, which occupy the secondary trophic status, in the food chain in the aquatic environments, play a key role in consuming the food, synthesized by the phytoplankton and transferring it to higher trophic levels. Protozoans, Rotifers and Crustaceans form the significantly dominant components of zooplankton population.

Swammerdan (1769) and Muller (1785) revealed the valuable information about the rotifer and cladocera. In 1886, Hudson and Goose wrote an invaluable monograph on rotifers. Many new species of cladocera, copepoda and rotifer from oriental regions have been described (Dadday, 1888). Contributions of Sars, (1901) were more than any researcher in the field of freshwater biology, especially cladocerans. Aspects on zooplankton distribution and abundance in freshwater habitats of India have been covered in the works of Ganapati, (1943); Michael, (1968); Sumitra, (1970); Victor and Michael, (1975); Murugan, (1976); Singh *et. al.*, (1980); Yousuf and Quadri (1981, 1983); Michael and Sharma, 1984.

The inland water bodies in India, except those situated at high altitude, exhibit distinct seasonal fluctuations in their physical, chemical and biological features. The physico-chemical factors influence the distribution, abundance and type of organisms of the reservoirs and these factors vary from one region to another. Research on physico-chemical parameters, on plankton was carried out on Nangal Lake by Tandon and Singh (1972). The limnological studies on freshwater lakes in Kerala state and the influence of water temperature, pH and dissolved oxygen on its productivity have been reported (John, 1975). Relationship between hydrobiological parameters and plankton community in West Bengal was reported by Tiwari and Sharma (1977) and Datta *et. al*., (1984). They recorded a direct relationship among temperature and salinity; pH; alkalinity, while the silicate concentration was responsible for high diatom abundance. Calanoida and Cyclopoida fauna of south India have been described by Ranga Reddy and Radakrishna (1984). 24 reservoirs in central India (Madhya Pradesh) were investigated for physico-chemical and biological features by Unni (1985). He found that these reservoirs differed in their size, physical features, chemical composition and vegetation. Similarly, seasonal variations in physico-chemical factors and plankton of tropical lakes in Madhya Pradesh and their interrelationships have also been reported (Mathew, 1985). Adoni and Joshi (1987) studied the geomorphological and physico-chemical features of three reservoirs, in and around Sagar (Madhya Pradesh).

In North India, a study was conducted, on the effect of physico-chemical factors on seasonal abundance, in ponds in Ludhiana. Abundance of some cladocera species with relation to factors such as transparency, temperature, dissolved oxygen, pH, etc., and food availability and temperature governed the population densities (Battish and Kumari, 1986). At the same time, Datta *et. al*., (1984, 1986), reported a similar study from West Bengal, where in, lower values of temperature, phosphate, salinity and higher values of dissolved oxygen favoured abundance.

Limnological survey of Mansarover reservoir in Bhopal has been reported by Adholia and Vyas (1991). Haque and Khan (1994) carried out an extensive study on distribution of zooplankton in freshwater plankton in Aligarh and discussed the physico-chemical factors responsible for the variation. Pandey *et. al*., (1994), observed majority of rotifers in rainy season, while during summer, cladoceran copepods were abundant. During the same study, which was carried out on the zooplankton fauna of Kosi swamp, they concluded that, the *Keratella* sp. was an indicator of eutrophication.

Das and Srivastav, 1956; Gouder and Joseph, 1961; Vashisht and Dhir, 1970; Chandrashekar and Kodarkar, 1994; Danapathi and Rama Sarma, 2000; Ibrahim, 2009; Ghantaloo *et. al*., 2011 also reported the seasonal studies of plankton in relation to physico-chemical factors of tanks and lakes of Indian region.

A perennial alkaline water tank in Gwalior exhibited a bimodal pattern for seasonal variation of zooplankton and rotifers were the dominant zooplankton (Kaushik and Sharma, 1994). Sharma (1995) has conducted limnological studies in small reservoir in Meghalaya. A study on diel variation and effect on physico-chemical parameters of zooplankton was reported from pond in Tamilnadu. 19 species, belonging to five groups, were identified. (Maruthanayagam *et. al*., 2001)

Seasonal variations in temperature, nutrients and biological productivity of Badhu reservoir in Bihar state has been studied by Verma and Datta Munshi (1984). The seasonal variations of the zooplankton, associated with the fluctuations of physico-chemical characteristics of the perennial water tank Matsya Sarovar, Gwalior, has also been reported (Kaushik and Sharma 1994). Similarly, studies on various aspects of freshwater bodies in Uttar Pradesh (Khan and Siddhiqui, 1974; Sharma and Pant, 1984a), Kashmir (Yousuf and Qadri 1984, 1985; Ticku and Zulshi, 1994) Delhi (Bagade and Verma, 1985), Kerala (Nasar and Nair, 1969; Khatri, 1988). Rajasthan, (Nasar, 1968; Khatri, 1992), Odisha (Pati and Sahu, 1993), West Bengal (Chakrabarthy and Saha, 1993; Bhumik, 1994), Himachal Pradesh (Sanjeev Kumar, 1994) and Assam (Hazarika and Dutta, 1994; Sharma and Husain, 2001) have been reported.

Apart from the above, Gouder and Joseph (1961), David *et. al*., (1974), Ayyappan and Gupta (1980) and Rao (1985) have reported a few limnological aspects of some ponds and tanks of Karnataka. Birasal *et. al*., (1987), investigated a few hydrological parameters of Supa reservoir in Western Ghat region. Seasonal variations in zooplanktonic population of Rangasagar lake of Udaipur was reported by Rao and Durve (1992), while the seasonal fluctuations in zooplankton abundance of lake Tasek in Garo hills were reported by Das *et. al*., (1996).

A comparative study of major reservoirs in Tamilnadu state has also been carried out by Sreenivasan (1970). He pointed out that, polluted reservoirs were more productive, than non-polluted ones. Studies on planktons of Chilwa lake, situated near a fertilizer factory near

Gorakhpur, were conducted by Sahai *et. al*., (1986). Similar studies on other polluted water bodies have been conducted (Kulshreshtha *et. al*., 1991; Gaur and Khan, 1996; Barauaha and Das, 2001). Rotifers and microcrustaceans, along with annelids and molluscs have been included under pollution indicator fauna (Saksena and Mishra, 1990).

Diversity of cladocera fauna in some freshwater bodies of Rajasthan was studied by Nayar (1971) and Rao and Durve (1989). Similar studies on zooplankton species in other parts of India were undertaken by Nasar (1975, 1977) in Bihar, Nasar (1975), Chakravaty (1990) in Bhagalpur, Sharma and Pant (1984b) in Uttar Pradesh, Mahoon *et. al*., (1985) in Punjab, Saha and Bhattacharya (1991) and Venkatraman (1995) in Tripura, Venkatraman (1999) in Andaman and Tamilnadu, Chauhan (1993) in Himachal Pradesh, Kaushik and Saksena (1994) and Sharma and Sharma (1990) in central India, Vyas and Adholia (1994) in Bhopal.

A study of wetland zooplankton of Howrah in West Bengal was undertaken by Venkatraman and Das (1993, 2001). Another report on the cladoceran community of Banori pond in West Bengal was given by Chadrashekar (1998). Zooplankton abundance from reservoir in Virla village (Madhya Pradesh) and their systematic account was surveyed by Pathak and Mudgal (2002). The study of zooplankton of a dam in Isapur village and the seasonal variations affecting the same were carried out by Pulle and Khan (2003). Comparative studies on zooplankton in Sagar and Engineering lakes were reported by Bais and Agarwal (1995).

Taxonomic studies on zooplankton have been reported from different parts of India by various workers. Sharma and Pant (1984a, b) studied the structure of zooplanktonic communities of lakes of Uttar Pradesh. Similar studies were done by Patil (1976) in Northern

India, Sharma (1978a, b) in West Bengal, Battish (1978, 1981) in the Punjab, Sharma (1980) in Orissa, Rane (1983, 1985, 1987); Rane and Jafri (1990) in Madhya Pradesh.

New species were identified and reported from deltaic regions of Krishna river by Durgaprasad *et. al*., (1986), Sikkim lakes by Venkatraman (1998) and from Nilgiri hills in Tamilnadu by Korinek *et. al*., (1999). 38 species of cladocera, including three new records to West Bengal one new record to India were reported from four perennial lakes and ponds of West Bengal (Venkatraman and Das, 2001).

Various ecological aspects of zooplankton have been a topic of study by several workers including Gulati, 1964; Kadar *et. al*., 1978; Dey and Mishra, 1978; Khan and Rao 1981; Verma and Dutta Munshi, 1987; Patil and Goudar, 1989; Malathi *et. al*., 1998; Annapurna and Chatterjee, 1999; Balamurugan *et. al*., 1999; Pawar and Pulle, 2005; Joshi 2011; Jadhav *et. al*., 2012.

Some recent works on freshwater bodies in India by Kaur *et. al*., (1996), Murugan *et. al.*, (1998), Altaff *et. al*., (2002), Soruba and Ebansar (2003), Pawar and Pulle (2005), Surana *et. al*., (2005), Govindaswamy *et. al*., (2008), Tajagopal *et. al*., (2008), Rajagopal *et. al*., (2010), Shaik *et. al*., (2010), Salve and Hiware (2010), Joshi (2011), Patil (2011), Singh (2011), Jadhav *et. al*., (2012), Kumar *et. al*., (2012), Dutta and Patra (2013) and Tyor *et. al*., (2014).

In spite of the above, as there are hardly any reports on the studies of temple tanks in general and Goa particularly, the present studies have been undertaken.

STATE OF GOA AND ITS TEMPLES

Goa, the land blessed with splendid scenic beauty, golden beaches, beautiful rivers and lakes and architectural splendours is undoubtedly a "Tourist's Paradise". The perfect words to describe Goa are - "The land of Sun, Sand and Sea". The second smallest Indian state (area wise) is also known for its unity in diversity. Goa is world renowned for its beaches and attracts innumerable domestic and foreign tourists every year. The perfect holiday in Goa for many tourists is to laze under the sun on the picturesque and romantic beaches of Goa. When you picture Goa the first thing that comes to your mind is pristine scenic beauty of the state that nature God has blessed on it. But yes, there's much more to Goa than it's beaches. The `tiny emarald' land can boast of its unique history and culture. The culture here shows the confluence of the east and the west. The state is home to both beautiful temples and magnificent churches.

The state's history dates back to 3rd century BC. Various dynasties such as Kadambas, Silaharas, Rashtrakutas, Chalukyas, Bahamani Muslims etc, have ruled Goa. But, the strongest influence was, that of the Portuguese. The state of Goa, was a Portuguese colony for 450 years till 1962. The Indo-Portuguese culture and architecture here speak for the Portuguese influence on the state. One can get a glimpse of the glorious history preserved in churches, forts, villages and cities. The city is also believed to have been a part of ancient India. In Indian epic Mahabharata it is known as *'Goparashtra' or 'Govarashtra'*. The city is referred to as city of cowherds.The people of this kingdom are strong, prudent and very hardworking. The kingdom of Goa is the most important in India. It is civilized, having famous orchards and water. In the sixties and seventies, it was, as we have remarked, a haven for the hippies. Since then Goa has moved on to full-fledged Statehood, its own Council of

Ministers, a magnificent new Assembly complex, its citizens among the most literate in the country with a per capita income the highest in the land.

The state of Goa covers an area of 3,702 sq. km. Panaji is the capital of Goa. A brief summary of the 2011 census: Goa's population is 14.57 lakhs with 7.4 lakh males and 7.17 lakh females. The sex-ratio (number of females per thousand males) in Goa is 960 in 2011. The density of population per sq km in Goa is 394 in 2011 as compared to 361 in 2001. The literacy rate is 87.4 per cent. 64.68 per cent of the population is Hindu, 29.86 per cent is Christian and Muslims are a minority of 5.25 per cent. Around 0.15 to 0.2 million of the total population are immigrants from around India, who have settled down in Goa. At present, Marathi and Konkani are two major languages of Goa. Hindi, the national language of India, is well understood in Goa. In major towns, English is widely used in writing and conversation.

The major rivers flowing through the state are Mandovi, Zuari, Terekhol, Chapora and Betul. The other major rivers include the Tiracol, Chapora, Sal and the Talpona. The state has a total forest cover of more than 1,424 sq. km covering almost one-third of the total area. Forests provide important products namely bamboo, Maratha barks, chillar barks and bhirand. These are of great economic value for rural mass. Coconut trees are present in almost the whole of Goa except in the upper regions. Goa's vegetation also includes cashew, mango, jackfruits and pineapples. Goa is rich in mineral resources. Major minerals include iron ore, manganese, ferro-manganese, bauxite and silica sand. Iron and manganese mining industries are the backbone of Goa's economy.

Goa, being a state of India, is home to a number of Hindu temples. Though the place is famous for its sun kissed sea beaches and historical churches, still the age old temples of

Goa attract tourists from various destinations. During the Portuguese reign, many of the temples located in Old Goa have been destroyed. Thus, most of the temples of Goa are presently found in the Ponda Taluka.

Similar to other Hindu temples in India, these temples are even dedicated to an individual deity. However, the architecture of these temples differs from other temples of India. Goan temples built in the form of traditional buildings give it a local look. Most of these temples are featured with "Deepa Stambha" or "Deepmal", which is a kind of 2 to 6 storied Lamp Tower. As a part of the Maratha influence, these lamp towers are decorated with oil lamps numbering to hundred or more. This gives a spectacular effect to the temples. The traditional Shikara is replaced by a dome in the temples in Goa. Apart from covering the main shrine, these domes reflect Mughal architectural style. Naubat Khana acts as another testimony of Mughal influence in the Goan temples. Naubat Khana is a kind of small tower located at the top of the main entrance of the temple where the drummer of the temple sits to beat the drum to the religious hymns. The curvilinear roofs of the main holy place of the temple reflects Portuguese or Christian architectural pattern though. Except in the case of a few village deities, the water tank existed in almost all temple precincts known and they were known as “Deva Talli”. The water is stagnant in most of the temple water tanks after the monsoon. At some places a stone built `Tulsi Vrindawan’ occupies the central space of the water tank.

Some of the deities were shifted due to religious torture of the Portuguese in the 16th century, but the water tanks still exist in the temple precincts. Some of them are in a bad condition and others have disappeared altogether. These water tanks are kept free from any nuisances and squalor.

A few of them have ritualistic significance. The water tank of the Mallikarjun temple at Ganvdongri-Canacona has the privilege of immersing the `Chumball’ which is performed by girls and the `Pello’ - typical headgear by the male youth, during the time of the annual festival - to become eligible for marriage. Washing clothes or taking a bath is prohibited in this water tank, other than the ritualistic bath of the `Gade’ - persons possessed by divine power, at the time of the annual festival known as `Bhonvor’. For conducting holy oath – `Praman Javop’, the accused person has to take a bath essentially in the temple tank of the Mahalsa at Mardol-Ponda.

One practice that is followed in a number of temples is known as `Ganthwal’, when a newly married couple visits the temple for the first time, their clothes are together in a knot and they walk in a procession, accompanied with traditional music, to the temple for `Darshan’. Prior to that, it is obligatory for both of them to have ceremonial bath in the temple tank. If the ritualistic bathing in not possible for whatever reason take for example the condition of water, the season, then a symbolic bath is given by the priest by sprinkling a few drops of that holy water on the couple.

At the time of the annual festival, a procession of the image of the deity in Sangod (`Naukarohan’) is a typical character in a number of temples, especially in the Ponda taluka. Sangod is an exclusive tradition in Goa’s temple heritage. For which two canoes are brought to the temple water tank from a distance, they are joined and a `Makhar’ - altar is erected on it. The entire water tank area is innovated by traditional lights - `Pantyo’ with firecrackers and other conventional fire work. The image of the deity is taken in a procession to the water tank and the deity placed in this `Makhar’. As history dates, the zealot Portuguese had made every attempt to destroy the Konkani Hindu culture including its temples, people back then felt unsecure to shelter themselves in the Portuguese territory leading them to ferry their deities across the Zuari and house their deities in Antruz (Ponda) . Thus, every Goan Saraswat temple in Ponda has a day to commemorate this act. Many find it as a cultural retrospect, since it enlivens the Goan identity of the 17th century. This festival is not common amongst the current contemporary Goan temples, but very much found in the ancient Goan Saraswat temples of Ponda.

PURPOSE OF STUDY

In India the freshwater constitutes rivers, streams, lake, wetlands, ponds and reservoirs. These freshwater bodies directly help in the growth of human civilization. The freshwater resource is becoming day by day at the faster rate of deterioration of the water quality is now a global problem. Zooplankton is regarded as valuable bio-indicators of water quality (Sladecek, 1983). Zooplankton are microscopic, free floating organisms occurred in all natural water bodies. They are a major mode of energy source between phytoplankton and other aquatic animals. They occupy an intermediate position in the aquatic food web.

The zooplankton community is influenced by the physico-chemical parameters of the water also bring about seasonal changes in their life process and population dynamics. Abiotic factors such as temperature, light, depth, oxygen, Co_2, pH, alkalinity, hardness and other mineral concentrations, along with suitable food availability are related to occurrence and abundance of zooplankton. It is believed that, single factor never acts independently as limiting factor but, only with interaction with others.

On the contrary, in Indian inland waters in general and state of Goa in particular, research activities on zooplankton could not be carried out on par with the parts of the world. In the Indian subcontinent a good deal of information is available on the distribution of plankton in water bodies of bigger dimension from various states of northern and southern India. But, scanty information is available on water bodies of small dimension and in state of Goa, the studies on water bodies like temple tank is almost does not exist.

Though there are some reports on limnology of some freshwater bodies of Goa region, no major study has been carried out on zooplankton of different water bodies. The limnological studies on the limited freshwater bodies of the state are confined to a few publications (Desai, 1987, 1995; Desai *et. al.*, 1995; Bandiwadekar and Desai, 1998; Walia

2000; Berde, 2004). All these studies were of relatively of short duration of about a year except for Berde (2004), each with slant on the effect of pollution due to mine effluents. Most of the water bodies in the state remain unexplored.

In the present study, an attempt has been made to fill this lacuna of information by studying the various physico-chemical factors in some sacred temple tanks of Ponda taluka of Goa state. Apart from the above, the zooplankton diversity and distribution pattern in these areas was also studied, which will help in locating the potential population centres of zooplankton such as copepods, cladocerans and rotifers. Apart from the above seasonal studies on zooplankton was also carried out. A compact evaluation of various diversity indices, numbers and evenness of zooplankton has also been studied.

Aim and Scope of the work

1. To analyze the freshwater bodies for various physical parameters such as temp., pH etc.

2. Analyze the water for chemical parameters such as alkalinity, DO., T.D.S., calcium, magnesium, phosphates, sulphates etc.

3. Analyze the water for biological parameters with special reference to zooplankton.

4. Further analyze the zooplankton, their diversity, community structure, distribution and species composition in these temple tanks.

5. To carry out seasonal studies to understand zooplankton dynamics.

6. To analyze the water bodies under study for bacteriological load.

MATERIALS AND METHODS

Physico-chemical parameters: For physico-chemical analysis of the water bodies, water from each of the six sacred temple tanks under study was collected. Collections were made by using plastic containers of two litre capacity. The plastic containers were rinsed thoroughly before use. The collected samples were analyzed by using standard methods (APHA, 1989; BIS, 1990). Water temperature at each sampling point was recorded on the day of collection using a centigrade thermometer. The hydrogen ion concentration (pH) was measured using a grip pH meter (Systronics). Turbidity was determined by using Nephelometric method (Elico CL 52 D). TDS and EC were analyzed using water analyzer (Elico PE 138).

Physico-chemical parameters such as alkalinity, chlorides, sulphates, phosphates, nitrates, nitrites, calcium, potassium, magnesium, total hardness, biological oxygen demand (BOD), chemical oxygen demand (COD), dissolved oxygen (DO), sodium etc. were analyzed in the laboratory, using standard methods (APHA, 1989; BIS, 1990).

The methods used for the analysis of physico-chemical parameters are entitled as given below.

Total Alkalinity (Phenophthalein and Methyl Orange)

Reagents:

i) 0. 1N Hydrochloric Acid

12N concentrated HCl (Sp. gr. 1.18) was first diluted 12 times and further diluted 10 times to make 0.1N solution. It was standardized against sodium carbonate solution.

ii) 0.05% Methyl orange indicator

0.5gm of methyl orange was dissolved in 100ml of distilled water.

iii) Phenophthalein indicator

0.5gm Phenophthalein was dissolved in 50ml of 95% ethyl alcohol and 50ml NaOH solution was later on added in it drop wise till the solution became light pink coloured.

iv) 0.1N Sodium carbonate

5.300gm of dried Na_2C0_3 was dissolved in distilled water to prepare 1000ml of solution.

Procedure:

(i) 100ml of sample was taken in a flask and 2 drops of Phenolphthalein indicator was added. If solution remains colourless, then phenolphthalein Alkalinity (PA) considered as nil.

(ii) After addition of phenolphthalein indicator colour of solution turned pink, then solution was titrated against 0.1N HCl till pink colour disappears and amount of titrant was noted (A).

(iii) 2-3 drops of methyl orange indicator was further added in the same sample and titration was continued with 0.1N HCl till yellow colour of solution turns pink again. The total amount of titrant was noted (B).The phenolphthalein Alkalinity (PA) and Total Alkalinity (TA) was calculated with the help of following formula;

$$\text{PA as CaCO3 mg/ L} = \frac{\text{(A x Normality) of HCL x 1000 x 50}}{\text{ml of sample}}$$

$$\text{TA as CaCO3 mg/ L} = \frac{\text{(B x Normality) of HCL x 1000 x 50}}{\text{ml of sample}}$$

Where,

A = ml of titrant used with phenolphthalein indicator.

B = ml of titrant used with phenolphthalein methyl orange indicator.

Dissolved Oxygen (DO)

For the determination of dissolved oxygen values Wrinkler Iodometric method was used.

Reagents:-

i) 0.025 N Sodium Thiosulphate ($Na_2S_2O_35H_2O$)

The 24.82gm of sodium thiosulphate was taken and dissolved in 1000ml of boiled distilled water and pallet of NaOH was added in it as stabiliser (Stock solution). This solution was diluted 4 times to make it 0.025N solution and kept in brown glass stoppered bottle.

ii) Alkaline potassium iodide solution

100 gm of KOH and 50 gm of KI was dissolved in 200ml of boiled distilled water.

iii) Manganous sulphate solution

100gm of Manganous sulphate was dissolved in 200ml of warm (80 or 90°C) distilled water and solution was filtered.

iv) Starch solution (Indicator)

1gm of starch was dissolved in 100ml of warm (80 0r 90^{0}c) distilled water and few drops of formaldehyde solution was added.

v) Concentrated Sulphuric acid (H_2SO_4)

Procedure:

(i) BOD bottles of known volume (300ml) was taken and filled with water samples and any bubbling was avoided. Trapping of air bubble was also avoided after placing the stopper.

(ii) 2ml of $MnSO_4$ and alkaline KI were added carefully and bottle was closed with stopper.

(iii) The bottle was shaken well and kept to allow the precipitate to settle down at bottom.

(iv) 2ml of concentrated H_2SO_4 was added to it and again shaken well to dissolve the precipitate completely.

(v) 10ml of this solution was taken and few drops of starch solution were added as in indicator. It was then titrated against Sodium thiosulphate till dark blue colour changes to colourless. Dissolved oxygen was calculated with the help of following formula;

$$\text{DO as mg/L} = \frac{(\text{ml x N}) \text{ of titrant x } 8 \text{ x} 1000}{V2 = \frac{(V1 - V)}{V1}}$$

Where,

V1 = Volume of sample water after placing the stopper

V2 = Volume of the part of content titrated

V = Volume of $MnSO_4$ and KI added

Bio-Chemical Oxygen Demand (BOD)

Reagents:

i) Phosphate buffer solution

8.5gm of KH_2Po_4, 21.75gm K_2HPo_4, 33.4gm Na_2HPo_4. $7H_2O$ and 1.7gm NH_4Cl was taken and dissolved in distilled water to prepare 1 litre of solution and pH was adjusted to 7.2.

ii) Magnesium Sulphate

82.5gm $MgSO_4.7H_2O$ was dissolved in distilled water and solution was made 1 litre.

iii) Calcium Chloride

27.5gm of anhydrous $CaCl_2$ was taken and dissolved in distilled water and solution was made 1 litre.

iv) Ferric Chloride

0.25gm of $FeCl_3$ 6 H_2O was dissolved in distilled water to make 1 litre solution.

v) 0.025 N Sodium Sulphite solution

1.575gm of Na_2SO_3 was taken and dissolved in 1 litre of distilled water.

Procedure:

(i) Dilution water was prepared by bubbling atmospheric air in distilled water for 30 minutes.

(ii) 1ml of each of phosphate buffer, Magnesium sulphate, Calcium chloride and ferric

chloride solutions were added in 1 litre of dilution water and mixed thoroughly.

(iii) The sample was neutralised to pH around 7.0 by using 1N NaOH or H_2SO_4.

(iv) A suitable dilution of sample was prepared according to the expected BOD range with the dilution water. The contents were mixed thoroughly by glass rod.

(v) The two sets of BOD bottles were prepared by filling the samples in them and one set was kept in BOD incubator at 20^oC for 5 days. The DO content in another set was determined immediately.

(vi) DO content of incubated bottle was determined after the completion of 5 days. BOD values were calculated with the help of following formula:

BOD as mg/L = D_o- D_5 x dilution factor

Where,

Do = Initial DO in the sample

D_5 = DO in the sample after 5 days incubation.

Chemical Oxygen Demand (COD)

Reagents:

i) 0.25 N Potassium Dichromate solution

12.259gm of $K_2Cr_2O_7$ was dissolved in distilled water and solution was made upto 1 litre.

ii) 0.025N Potassium Dichromate solution

100ml of 0.25N $K_2Cr_2O_7$ was diluted to make 1 litre solution.

iii) 0.1N Ferrous ammonium sulphate

39.2gm $Fe(NH_4)_2(SO_4)_26H_2O$ was dissolved in 100ml of water and 20ml of concentrated H_2SO_4 was added slowly in it. The solution was made up to 1000ml and standardized with $K_2Cr_2O_7$ by diluting 10ml of $K_2Cr_2O_7$ to 100ml then adding 30ml of concentrated H_2SO_4 and titrate it with Ferrous ammonium sulphate using ferroin as an indicator.

iv) 0.01N Ferrous ammonium sulphate

100ml of 0.1N Ferrous ammonium sulphate was diluted to 1000ml.

V) Ferroin indicator

1.485gm of 1, 10 – phenonthroline and 0.695gm of ferrous sulphate was dissolved in distilled water and solution was made 100ml. (freshly prepared at every time)

vi) Concentrated sulphuric acid having specific gravity 1.84.

vii) Solid Mercuric sulphate

viii) Solid Silver sulphate

Procedure:

(i) 20ml of solution was taken in COD flask and a pinch of silver sulphate and mercuric sulphate added to it. If the sample is expected to have COD values more than 50mg/L, then 10ml of 0.025N Potassium dichromate solution was also added. When chlorides are in higher amount in the sample $HgSO_4$ was also added to it and then solution was refluxed atleast for two hours in reflux assembly.

(ii) After refluxing the flask was removed and cooled. The distilled water was added to make 140ml.

(iii) 2-3 drops of ferroin indicator was added to it which was freshly prepared and mixed thoroughly, then titrated with 0.01N Ferrous ammonium sulphate till blue green colour turns to wine red.

(iv) A blank with distilled water was also run using same quantity of chemicals COD values were calculated with the help of following formula;

$$\text{COD as mg/L} = \frac{(b - a) \text{ x N of ferrous ammonium sulphate x 1000 x 8}}{\text{ml of sample}}$$

Where,

a = ml of titrant with sample.

b = ml of titrant with blank.

Total Hardness

The hardness was determined by EDTA method.

Reagents;

i) 0.01M EDTA solution

The 3.723gm of disodium salt of EDTA was dissolved in distilled water and volume of solution was made 1000ml.

ii) Buffer solution

16.9gm. of NH_4Cl was taken and dissolved in 143ml of concentrated ammonium hydroxide (NH_4OH) solution (a) 1.179gm of disodium EDTA and 0.780gm of $MgSo_4.7H_2O$ were dissolved in 50ml of distilled water (b). Both solutions (a) and (b) were mixed and was diluted with distilled water to prepare 250ml of solution.

iii) Eriochrome Black T indicator

0.40gm of Eriochrome Black T indicator was mixed with 100gm NaCl and grinded well.

iv) Sodium sulphide solution

5.0gm $Na_2S.9H_2O$ (or 3.7gm $Na_2S.5H_2O$) was dissolved in 100ml of distilled water and kept in tightly closed bottle.

Procedure:

(i) 50ml of sample was taken and 1ml of buffer solution was added. If the higher amounts of heavy metals are expected, 1ml of Na_2S solution was also added to it.

(ii) 100-200mg Eriochrome Black T indicator was added and then titrated against EDTA solution till red colour of solution turned blue.

The hardness was calculated with the help of following formula:

$$\text{Hardness as mg/L (CaCo3)} = \frac{\text{ml EDTA used x 1000}}{\text{ml of sample}}$$

Calcium

Reagents:

i) EDTA solution 0.01M: 3.723gm of disodium salt of EDTA was dissolved in distilled water and solution was prepared 1000ml.

ii) **1N Sodium hydroxide solution:** 40gm of NaOH was dissolved in distilled water and diluted to 1000ml.

iii) Murexide indicator: The 0.2gm of ammonium purpurate was mixed with 100gm NaCl and grinded well.

Procedure:

(i) 50ml of sample was taken and 2ml NaOH solution was added to it.

(ii) 100-200mg of murexide indicator was added in it and titrated against EDTA solution till pink colour turned to purple.

The calcium content was calculated with the help of following formula:

$$\text{Calcium (mg/L)} = \frac{\text{Volume of EDTA used x 400.8}}{\text{ml of sample}}$$

Magnesium

Reagents:

i) 0.01N EDTA solution

3.723gm of disodium salt of EDTA was dissolved in distilled water and solution was prepared 1000ml.

ii) Buffer solution

The 16.9gm of NH_4Cl was taken and dissolved in 143ml of concentrated ammonium hydroxide (NH_4OH) solution (a) 1.179gm of disodium EDTA and 0.780gm of $MgSo_4.7H_2O$ were dissolved in 50ml of distilled water (b).

Both solutions (a) and (b) were mixed and was diluted with distilled water to prepare 250ml of solution.

iii) Erichrome Black T indicator

0.40gm of Erichrome Black T indicator was mixed with 100gm NaCl and grinded well.

Procedure:

(i) The volume of EDTA used in calcium determination was noted.

(ii) The volume of EDTA used in calcium determination was then found out by taking same volume of sample as taken in the case of calcium content determination.

The amount of magnesium was calculated with the help of following formula;

$$\text{Magnesium as (mg/L)} = \frac{Y - X \times 400.8}{\text{ml of sample} \times 1.645}$$

Where,

Y = EDTA used in calcium hardness determination

X = EDTA used in calcium determination

Chloride

Reagents:

i) 0.02N Silver nitrate

3.400gm dried $AgNO_3$ was dissolved in distilled water and prepared 1000ml.

ii) 5% Potassium chromate

5gm of K_2CrO_4 was dissolved in 100ml distilled water.

Procedure:

(i) 50 ml of sample was taken and 2ml of k_2CrO_4 solution was added in it.

(ii) The contents were titrated against 0.02N $AgNO_3$ till permanent red tinge appears.

Chloride was calculated with the help of following formula;

$$\text{Chloride mg/L} = \frac{(\text{ml x N})\ \text{AgNO3 solution x 1000 x 35.5}}{\text{ml of sample}}$$

Potassium:

Apparatus and Reagents

i) Flame photometer (CL 361 Elico)

ii) Stock potassium solution (1000mg/L)

1.907gm of dried KCl was taken and dissolved in distilled water and solution was prepared 1000ml.

iii) Intermediate potassium solution (100mg/L)

100ml of stock potassium solution was taken and further diluted it 10 times to make volume 1000ml.

iv) Standard potassium solution (10mg/L)

100ml of intermediate potassium solution was diluted 10 times to make volume 1000ml.

Procedure:

The water samples were collected from selected sampling sites viz.1, 2, 3, 4, 5 and 6. Potassium was estimated by Flame emission photometric method. The instructions were strictly followed given by the manufacturer for selecting proper photocell, wavelength, slit width adjustment, fuel gas and air pressure, steps for warm up, correcting for interference and flame background, rinsing of burner, sample ignition emission intensity measurement. The blank and potassium calibration standard were prepared which in the applicable ranges i.e. 0-1, 0-10and 0-100mg/L. The flame emission photometer was adjusted with standard solution containing no potassium and emission was measured at 768nm and calibration curve of samples were determined using standard calibration curve and potassium in the samples were determined by the following formula.

K as (mg/L) = (mg/L K in diluted aliquot) x dilution factor

Where,

Dilution = ml of sample + ml of distilled water

Sodium

Apparatus and Reagents

i) Flame photometer (CL 361 Elico)

ii) Stock sodium solution (1000mg/L Na)

2.542gm of dried NaCl was taken and dissolved in distilled water and solution was prepared 1000ml.

iii) Intermediate sodium solution (100mg/L)

100ml of stock sodium solution was taken and further diluted it 10 times to make volume 1000ml.

iv) Standard sodium solution (10 mg/L Na)

100ml of intermediate sodium solution was diluted 10 times to make volume 1000ml.

v) Nitric acid HNO_3 concentrated

vi) Concentrated Hydrochloric acid

vii) 30% Hydrogen peroxide (H_2O_3)

viii) Concentrated Ammonium hydroxide

Procedure:

The water samples were collected from selected sampling sites viz.1, 2, 3, 4, 5 and 6. Sodium was estimated by Flame emission photometric method. The instructions were strictly followed given by the manufacturer for selecting proper photocell, wavelength, slit width adjustment, fuel gas and air pressure, steps for warm up, correcting for interference and flame background, rinsing of burner, sample ignition emission intensity measurement.

The blank and potassium calibration standard were prepared which in the applicable ranges i.e. 0-1, 0-10 and 0-100 mg/L. The flame emission photometer was adjusted with standard solution (containing no sodium) and emission was measured at 589nm and calibration curve of samples were determined using standard calibration curve and sodium in the samples were determined by the following formula.

Na as (mg/L) = (mg/L Na in diluted aliquot) x dilution factor.

Where,

Dilution = ml of sample + ml of distilled water.

Phosphate (Stannous Chloride Method)

Reagents:

i) Ammonium molybdate reagent: Dissolve 25gm of Ammonium molybdate $[(NH_4)_6Mo_7O_{24}.4H_2O]$ in 175ml distilled water. Continuously add 280ml conc. H_2SO_4 to 400 ml distilled water in a separate beaker, cool and add the molybdate solution to this acid solution and dilute to 1 litre.

ii) Stannous chloride solution: Dissolve 2.5gm fresh stannous chloride ($SnCl_2.2H_2O$) in 100ml glycerol. Heat in a water bath and stir with a glass rod.

iii) Stock phosphate solution: Dissolve 0.439gm of anhydrous potassium dihydrogen phosphate (KH2PO4) in distilled water and dilute to 1 litre. (1ml = 100µg).

iv) Standard phosphate solution: Take 10 ml of above stock solution and dilute it to 100ml. (1ml = 10µg)

NOTE:

- Acid washed glassware- Avoid commercial detergents containing phosphates.
- Clean all glassware with dilute HCl and rinse thorough with distilled water.

Procedure:

Take 100ml sample in a 250ml beaker; add 4ml ammonium molybdate reagent and 0.5ml stannous chloride reagent then mix it thoroughly. Note down the absorbance after 10 minutes, but before 12 minutes at 690nm by adjusting the spectrophotometer with the blank. The observations were compared with the standard curve to calculate phosphate content.

Standard curve was prepared between 0.0 to 1.0mg PO_4/L at the interval of 0.1 employing the same procedure as for the sample.

Calculation: PO_4 (mg/L) = Calculation factor x Absorbance x Dilution Factor.

Sulphate

Reagents:

i) Conditioning reagent

75gm of NaCl 30ml, conc HCl and 100ml 95% ethyl or isopropyl alcohol was taken and mixed in 300ml distilled water. 50ml of glycerol was also added in it and mixed thoroughly.

ii) Barium chloride: Crystals of $BaCl_2$

iii) Standard sulphate solution:

0.1479gm of anhydrous Na_2So_4 was dissolved in distilled water to make 1 litre of solution.

Procedure:

The water samples were collected from selected sampling locations viz. site-1, 2, 3, 4, 5 and 6. Sulphate was determined by turbidimetric method. Nephlometer was standardized strictly following the instructions given by manufacturer. Turbidity was measured using blank sample (sample without barium chloride). 100ml of sample (or a suitable alliquot) was taken and diluted to 100ml in 250ml conical flask. 2.0ml buffer solution was added and mixed. The sample was stirred on a magnetic stirrer during stirring a spoonful of $BaCl_2$ crystals was added. After addition of $BaCl_2$ crystals sample was stirred for 1 minute.

Turbidity of sample was measured at 5$\pm$0.5 minute after stirring. Sulphate (So_4) standard was prepared at 5mg/L increment in the range of 0.40mg/L of sulphate. Barium sulphate turbidity was developed for the standards.

Turbidity of standards was determined using above procedure and calibration curve were drawn between turbidity and sulphate concentration, mg/L and calculated by standard curve.

$$\text{Sulphate} = \frac{\text{optical density} \times 1000}{\text{Tan Q} \times \text{ml of sample}}$$

Nitrate

Reagents:

i) Brucine – Sulfanllic acid solution

1gm of brucine sulphate and 0.1gm of Sulfanllic acid taken and mixed in 70ml of hot distilled water. 3ml concentrated HCl was also added in it and volume was made into 100ml.

ii) Sulphuric acid solution

500ml of concentrated H_2So_4 was taken and added in 125ml of distilled water and cooled.

iii) Sodium chloride solution

300gm NaCl was taken and added in distilled water. The solution was diluted to 1 litre.

iv) Sodium arsenite solution

5.0gm of $NaASo_2$ was taken and dissolved in 1 litre of distilled water.

v) Standard nitrate solution (1 mg N/L)

0.722gm of KNO_3 was dissolved in distilled water (100mg N/L) and then it was diluted to 100 times to prepare a standard nitrate solution (1mg N/L).

Procedure:

The water samples were collected from selected locations Site-1, 2, 3, 4, 5 and 6. Nitrate was estimated by Brucine spectrophotometric method.

(i) Free chlorine interferes with the nitrate determination. If the sample is having residual chlorine, it was removed by addition of 0.05ml (one drop) of sodium arsenite solution for each 0.1mg of chlorine one drop was added in excess to a 50ml sample portion.

(ii) 10ml of sample or an aliquot diluted to 10ml in a 50ml test tube.

(iii) All the tubes were kept in a wire rack.

(iv) Rack was placed in a cool water bath and 2ml of Nacl solution was added to it.

(v) After mixing the content thoroughly 10ml of H_2So_4 was added.

(vi) 0.5ml of Brucine reagent was added and mixed thoroughly.

(vii) The rack was placed in hot water bath with boiling water, exactly for 20 minutes

(viii) The content again cooled in cold water bath and observations were noted at 410nm.

(ix) Concentration of NO_3-N was determined from the standard curve.

(x) A standard curve was prepared between concentration and absorbance by taking the dilutions from 0.1 to 1.0mg N/L at the interval of 0.1 employing the same procedure as for the sample.

Nitrite

Reagents:

i) Disodium ethylene diamine tetra acetic acid (Na_2 EDTA) solution

500mg of disodium salt EDTA was dissolved in 100ml of distilled water.

ii) Sulphanilic acid solution

600mg of Sulphanilic acid was taken and dissolved in 70ml of hot distilled water, 20ml of concentrated HCl was also added after cooling and solution was diluted to make volume 0f 100ml.

iii) α - Naphthylamine hydrochloride solution

600mg of α Naphthylamine hydrochloride was dissolved in distilled water, 1ml concentrated HCl was also added to it. The volume of solution was made into 100ml.

iv) Sodium acetate solution

16gm of anhydrous CH_3CooNa or 27.2gm of $CH_3CooNa_3H_2O$ was dissolved distilled water and 100ml solution was prepared.

v) Standard nitrite solution (1 mg/L NH_2- N)

1.232gm $NaNO_2$ was dissolved in distilled water and diluted to 1 litre (250mg/L NO_2-N). This solution was diluted 250 times (4 - 1000ml) standard solution having 1mg/L NO_2-N was prepared.

Procedure:

The water samples were collected from selected sampling sites viz. 1, 2, 3, 4, 5 and 6. Nitrite was estimated by using spectrophotometer. 50ml of sample was taken in a conical flask. 1ml of each EDTA, Sulphanillic acid, alpha Naphthylamine hydrochloride and Sodium acetate solutions were added in it. A wine red colour was developed in the presence of nitrites, and observations were taken at 520nm. The observations were compared with the standard curve to calculate nitrite content. Standard curve was prepared between 0.0 to 1.0 mg NO_2-N/L at the interval of 0.1 employing the same procedure as for the sample.

(B) Bacteriological analysis.

Test for Coliforms (Multiple tube dilution test - MTD)

Media and reagents:

a) Dilution water: To prepare stock phosphate buffer solution, dissolve 34gm of potassium dihydrogen phosphate (KH_2PO_4) in 500 ml of distilled water, adjust pH to 7.2 with sodium hydroxide solution (1N) and dilute to 1 litre with distilled water.

Add 1.25ml of stock phosphate buffer solution to 1 litre of distilled water. Dispense In amounts that will provide 18 $\pm$ 0.4ml or 9 $\pm$ 0.2ml in 150 x 25mm or 150 x 18mm test tubes respectively. Sterilize in autoclave at 1.02 $\pm$ 0.03kg/cm^2 gauge pressure (15 $\pm$ 0.5psi gauge pressure, 120˚C temperature approximately) for 15 minutes.

b) Mac Conkey broth: This is used as presumptive medium for the enumeration of coliform bacteria in water samples. Its composition is an as under:

Peptone	20gm
Lactose	10gm

Sodium chloride	5gm
Bile salt	5gm
Distilled water	1000ml

Dissolve all the ingredients and adjust the pH to 7.4. After adjusting the pH, add 1ml of 1 % alcoholic solution of bromocresol purple or 5ml of 1% aqueous solution of neutral red. This will be the single strength medium. Distribute 10ml of the medium into 150 x 15 mm test tubes and add Durham's tube (25 x 5mm) in an inverted position. Plug the tubes with non-absorbent cotton and sterilize at 115˚C for about 15 minutes (not exceeding 30 minutes) in the autoclave at 1.02 ± 0.03kg/cm^2 (15 ± 0.5 psi) gauge pressure. This medium is used for 1ml and decimal dilutions of the water sample. For 10ml and larger aliquots a double strength medium is used. For double strength medium add above ingredients in double the quantities in 1000ml of distilled water. This medium is dispensed into 10ml quantities in 150 x 18mm test tubes added with Durham's tube and sterilized.

c) Brilliant Green bile lactose broth (BGB): this medium is used as confirmatory test for coliforms as well as for faecal coliforms. Its composition as under:

Peptone	10gm
Lactose	10gm
Bile salt	20gm
Distilled water	1000ml

Dissolve all the ingredients and adjust the pH to 7.4. Add 1.33ml of 1% aqueous solution of brilliant green indicator. Distribute 4ml quantities into 150 x 12mm test tubes and add a Durham's tube to each. After plugging with non-absorbent cotton, sterilize at 1.02 ±

0.03 kg/cm^2 gauge pressure (15 ± 0.5psi gauge pressure, 120˚C temperature approximately) for 15 minutes in the autoclave.

d) Peptone water: This is used for indole test or for preparing a liquid culture of an organism. Its composition is as follows:

Peptone	10gm
Sodium chloride	5gm
Distilled water	1000ml

Dissolve all the ingredients. Adjust the pH to 7.4. Dispense 4ml medium into 100 x 12 mm tubes and plug with non-absorbent cotton. Sterilize in the autoclave at 1.02 ± 0.03kg/cm^2 gauge pressure (15 ± 0.5psi gauge pressure, 120˚C temperature approximately) for 15 minutes.

e) Mac Conkey agar: The medium is used for the completed test or for IMViC classification of coliforms. Its composition is as under:

Peptone	20gm
Lactose	10gm
Sodium chloride	5gm
Bile salt	5gm
Distilled water	1000ml

Dissolve all the ingredients and adjust the pH to 7.4. Add 10ml of 1% aqueous solution of neutral red indicator and 15gm of agar. Steam the medium for 15 to 30 minutes so that agar is dissolved properly and sterilize in autoclave at 1.02 ± 0.03kg/cm^2 gauge pressure

(15 $\pm$ 0.5psi gauge pressure, 120˚C temperature approximately) for 15 minutes. After sterilization, cool to 45˚C and prepare the plates by pouring 15ml of melted agar per plate.

Allow to solidify, invert and incubate at 37^{o}C for drying as well as sterility test.

f) Nutrient agar slants: Dissolve 1gm glucose, 5.0gm of peptone and 3.0gm of beef extract in 1000ml distilled water. Adjust the pH to 7.2, distribute in required quantity and add 15gm of agar powder. Sterilize at 1.02 $\pm$ 0.03kg/cm^2 gauge pressure (15 $\pm$ 0.5psi gauge pressure, 120˚C temperature approximately). Dispense while in the melted condition about 10ml of quantity into each tube (150mm x 15mm). Sterilize in the autoclave at 1.02 $\pm$ 0.03kg/cm^2 gauge pressure (15 $\pm$ 0.5psi gauge pressure, 120˚C temperature approximately) for 15 minutes. After sterilization slants are prepared by keeping the tubes in a slanting position and allow them to solidify. Unless they are to be used, they should be stored in a refrigerator.

g) Kovac's reagent: it is used for indole test. Its composition is as under:

Paradimethyl aminobenzaldehyde	5gm
Amyl alcohol or n-butanol	75ml
Conc. hydrochloric acid	25ml

Dissolve paradimethyl aminobenzaldehyde in amyl alcohol and then add 25ml of HCl. The reagent should be yellowish in color. Store in an ambered colored glass stopper bottle.

h) Gram staining reagents:

i) Crystal violet is used as primary stain.

Solution A – Crystal violet (85 % dye content) 2gm

Ethyl alcohol (95 %)	20ml
Solution B – Ammonium oxalate	0.8gm
Water	80ml

Mix solutions A and B in equal parts. It is sometimes found, however, that this gives so concentrated stain that gram negative organisms do not properly decolorize. To avoid this, dilute solution A as much as ten times. Use 20ml of this diluted solution and mix with solution B.

ii) Lugol's iodine – Dissolve 1gm of iodine crystals and 2gm of potassium iodide in 300ml of distilled water.

iii) Safranin is used as a counter stain. Dissolve 25gm of Safranin dye in 100ml of 95% ethyl alcohol. Add 10ml of the solution to 100ml of distilled water.

iv) Ethyl alcohol – 95%.

Note: Lugol's iodine is used as mordant and ethyl alcohol as a decolouriser.

Procedure: Shake the water samples thoroughly before making dilutions or before inoculation.

a) Presumptive test:

i) Use Mac Conkey broth. Inoculate a series of fermentation tubes with appropriate measured quantities of water to be tested. The concentration of nutritive ingredients in the mixture should be sufficient and according to requirements. Ten ml and above aliquots should be inoculated in double strength and 1ml and its dilution should be inoculated into single strength medium.

ii) Incubate all the test tubes at 37˚C for 24 to 48hrs. Examine each tube at the end of 24 ± 2hrs for gas production and if no gas has been formed, re-incubate for another 24hrs and at the end of 48hrs, examine again. Record the presence of or absence of gas at each examination of the tubes regardless of the amount.

iii) Formation of gas within 48 ± 3hrs in any amount, in the inner fermentation tubes, constitutes a possible presumptive test. The absence of gas formation at the end of 48 ± 3hrs of incubation constitutes a negative test.

b) Confirmed test: The medium used for confirmed test is BGB.

i) Submit all primary fermentation tubes showing any amount of gas at the end of 24hrs incubation to the confirmed test. If additional primary fermentation tubes show gas at the end of 48hrs incubation, these too shall be submitted to confirmed test. Use a sterile metal loop, 3 to 4mm in diameter to transfer one or two loopful of medium from the presumptive positive tubes to a tube of BGB broth. When making such transfers, gently shake the tube first or mix by rotating. Incubate the inoculated tubes at 37˚C for 48 ± 3hrs.

ii) The formation of gas in any amount in the Durham's tubes of BGB tube at any time within 48 ± 3hrs constitutes positive confirmed test.

c) Completed test

i) It may be applied to positive BGB tubes. Shake the tube, and streak with the help of loop on the Mac Conkey agar plates as soon as possible in such a way so as to get discrete colonies. Incubate the plates at 37˚C for 24 ± 2hrs.

ii) From each plate pick up typical or atypical colonies and inoculate lactose broth and nutrient agar slants. Incubate at 37˚C for 24 to 48hrs.

iii) Nutrient agar slants can be used for Gram stain. If organisms are Gram negative, non-spore forming bacilli and if gas is produced in lactose broth, the test is considered completed and the presence of coliform organisms is demonstrated.

iv) Gram stain technique – Prepare a thin smear of the growth from the agar slant on a clean glass slide. Air dry, fix by passing the slide through flame, and stain for 1minute with ammonium oxalate-crystal violet solution. Wash the slide in water, immerse in Lugol's iodine solution for 1minute. Wash the slide in water, blot dry; decolorize with ethyl alcohol for 30seconds, using gentle agitation. Blot and cover with counter stain for 10seconds with Safranin, then wash, dry and examine under oil immersion.

Cells which decolorize and accept the Safranin stain are pink in color and defined as gram negative in reaction. Cells which do not decolorize but retain the crystal violet stain and are deep blue in colour, defined as gram positive.

Computing and recording of MPN

The number of positive findings of coliform group organisms (either presumptive, confirmed or completed) resulting from the multiple portion decimal dilution planting should be computed as combination of the positives and recorded in terms of most probable number with the help of table (Appendix B).

Test for *E. coli*

E. coli is one of the members of faecal coliforms which ferment lactose with the production of gas at 44.5˚C within 24hrs, as well as produce Indole from Trytophone at 44.5˚C within 24hrs. Subculture from all the positive tubes of BGB at 44.5˚C (faecal coliforms) into tubes of peptone water. Incubate at 44.5˚C for 24 $\pm$ 2hrs. At the end of incubation period, test for indole production by adding a few drops of Kovac's reagent. Positive test will give pink colour while negative test will give yellow colour.

(C) Zooplankton studies.

Zooplankton samples were collected by means of a plankton hand net of bolting nylon cloth (mesh size 45µm). The net was prepared according to the design given by Welch (1952). Samples were collected by filtering 20 litres of water through net, from each water body in early morning hours (between 0800hrs to 1100hrs.), twice a month for a period of two years i.e. December 2009 to November 2011.

The procedures for collection, storage and analysis of samples were followed as described in standard methods (APHA, 1989). The zooplankton samples were preserved in 4% neutral formalin solution. The samples were tagged for biomass, taxonomical and numerical studies. The individual species of zooplankton were sorted out and their whole mounts were stained with Borax carmine, Lugol's iodine or methylene blue, according to the requirements.

Some species were dissected for taxonomically important body parts and processed in a similar manner. Pointed entomological forceps and needles were used for handling and dissecting the zooplankton. Some species were subjected for microscopic photography under suitable magnifications of stereoscopic microscope, inverted and trinocular microscopes.

The density of Zooplankton was expressed as organism per litre using "Lackeys" dropping method (1935) Using the formula:

$$N = (n \times C)\, 10 / Y$$

Where,

C = Total volume of concentrate in ml.

Y = Total volume of water filtered for sample in litres.

N = Number of zooplankton per litre.

n = Number of zooplankton counted in 0.1ml. concentrate.

Zooplanktons were identified up to species level, using standard literature (Pennak, 1953; Dumont and Tundisi, 1984; Michael and Sharma, 1988; Battish, 1992; Edmondson, 1992; Murugan *et. al*., 1998; Dhanpathi, 2000).

ANOVA (one-way) was used to ascertain the significance of temporal variations of different parameters. Ecological relationships between abiotic and biotic parameters were determined by Pearson's correlation coefficients (r) with two tailed significance during the study period. The data was subjected for richness index (Margalef's index) and various diversity indices, such as species diversity (Shannon's index), dominance (Berger-Parker's index, Simpson's index), evenness (Pielou's index) etc. The hierarchical cluster analysis, based on the community similarities, was done. Statistical analysis was done by using computer software Past version 3.01.

STUDY AREA:

Quite considerable amount of work has been carried out on zooplankton in other areas of the world. On the contrary, in Indian inland waters in general and state of Goa in particular, research activities on zooplankton could not be carried out on par with the parts of the world. This may be due to various reasons like Goa getting liberated form Portuguese rule in the year 1961 and inclusion of the same in the Union of India, elevation to the statehood in the year 1987, non-availability of expertise, lack of funds, lack of infrastructure facilities etc., and has thus left a lacuna with regard to information on zooplankton and their world.

Hence an attempt to study physico-chemical characteristics and biological diversity in six sacred temple tanks of Goa was carried out, with aim of contributing to the knowledge of freshwater biodiversity in Goa region.

Goa, one of the smallest states along the central west coast of India, is known nationally and internationally as tourist destination because of its sandy beaches, lush green hills, water bodies, culture and people. Goa is also known at national level as leading iron and manganese ore exporter. Goa is bound by Sindhudurg district of Maharashtra on the north, North Kanara district of Karnataka state on the south, Western Ghats on the east and Arabian Sea on the west. It has a coastal stretch of about 102 km from south to north. The area of the state consisting of two districts is approximately 3702Sq.kms. The maximum length and width are 105km (north-south) and 60km (east-west) respectively. The state is situated between $73^{o}40'$- $74^{o}20'$E and $14^{o}5'$- $15^{o}47'$N. A total of nine rivers, flow through the state of Goa. Of these Mandovi (61.6km long) and Zuari (62.4km long), rivers are most important and their basins occupy 69 % of total area. Along the coastal planes cultivated fields, khazan lands and ponds are common. The soil type differs from place to place. Laterite soil is present along Ghats, red gravel along river banks and alluvial soil from coastal belt.

The climate of Goa, a subtropical region, can be divided into four seasons. Summer from March to May, Pre-monsoon season with occasional showers at the end of May, South west monsoon from June to September, post-monsoon season from October to November and winter season from December to February. About an average of 3000mm of rainfall is received from south west monsoon. The temperature ranges between 35-37^{o}C during March to May and minimum is between 15-16^{o}C during January. The temperature profile shows, another temperature peak during October. Humidity in the state varies ranges from 75 to

95%. Average wind speed is about13kms/hr. blowing from the west in monsoons, east in summer and north east during winter.

STUDY SITES:

Site-1 (Shri Shantadurga Temple tank): Shri Shantadurga Temple is a large temple complex 33km from Panaji at the foothill of Kavalem village in Ponda Taluka, Goa, India. A small laterite mud shrine was built and the deity was installed, which was later converted into a beautiful temple, whose foundation stone was laid in 1730 and the temple was completed in 1738 and further renovated in 1966.

The current temple was constructed during the reign of Maratha ruler *Chatrapati* Shahu Raje of Satara about 1738 A.D. *Shri* Naroram Mantri (Naroram Shenvi Rege) originally from Kochar village in the Vengurla region was a *Mantri* (minister), in the *Chatrapati* Shahu's Court around 1723 A.D. He obtained finances to construct the new temple for the Devi from the *Chatrapati*. The temple construction started around 1730 A.D. and, with the help from other mahajans, the present beautiful temple was completed. Due to his efforts the village Kavalem was bequeathed to the temple authorities by Shahu Maharaja in 1739 A.D. the temple has beautiful temple tank in front.

Site-2 (Shri Ramnath Temple tank): The temple of Shri Ramnath is located in Ramnathi, Bandivade, in Goa. This temple belongs to the Goan Brahmin community. Similar to other temples, Ramnathi too incorporates the system of `Panchayasthan’, therefore this temple houses five main deities viz., Shri Ramanath (chief deity), Shanteri, Kamakshi, Laxmi Narayan, Ganapati. Temple has a temple tank in front at the entrance with clear water.

The original temple of Ramnathi in Goa was located in Loutolim in Salcette taluka, Goa. The Idol of Shri Ramnath was shifted to the present site in 16th century to prevent its destruction by the then Portuguese rulers. In May 2011, the Ramnathi temple completed 450 years of its existence at its present location.

Site-3 (Shri Naguesh Temple tank): Shri Naguesh Maharoudra temple is dedicated to Lord Shiva situated in Nagueshim village, about four kilometres to the east of Ponda. The temple lies in nature's beauty, being surrounded by betel nut trees, coconut groves (Kullagor) and lake of pure water. The presiding deity is Shri Naguesh Maharoudra and other deities are Shri Laxmi Narayan and Shri Ganapati. Shri Naguesh Maharoudra temple is situated on Farmagudi-Kavalem-Ponda road at about 800m from Farmagudi, a point 26.2kilometres away from Panaji on Panaji-Belgaum National highway

This temple, which faces west, has a beautiful tank in front, with a Nandi bull in black granite standing tall at its entrance. The tank water is ever flowing and crystal clear. The tank is considered to be very beautiful and therefore it is well known all over Gomantak and is considered to be a distinctive feature among some of the other temples. The temple tank has flowing water and is used for different purposes like swimming and bathing.

Site-4 (Shri Mahalaxmi Temple tank): The temple of Shri Mahalaxmi is located in Bandora village, of Ponda-taluka in Goa. The main Deity is Shri Mahalaxmi with Shri Narayan, Shri Baleshwar, Shri Ravalnath and Shri Narayan Purush.

Many accept Shri Mahalaxmi as Pallavi, their supporting deity, who is believed to have been released when the gods and demons were churning the ocean for amrita the nectar of immortality. Shri Mahalaxmi is the Goddess of power and strength and is believed to be an incarnation of 'Adishakti'-the supreme form of power and energy.

This is one of the ancient Kuladevata Temples. When Shri Naguesh was installed in Nagueshim, Ponda it was believed that close to it, Shri Mahalaxmi temple was erected. Therefore this temple too was saved from Portuguese atrocities as it was outside their domain. This is evidenced by a ‘Shilalekh’ of the year Saka 1335 (1413 A.D.) found in the wall of Shri Naguesh temple wherein a mention of both the temples is made in respect of certain gifts made to the temples. The reinstallation Ceremony for Shri Mahalaxmi Temple was performed in the year 1990.

There is a beautiful water tank on the right hand side of the temple. The water of this tank is pumped out to water the surrounding betel nut trees, coconut groves and other trees (Kullagor).

Site-5 (Shri Mahalsa Temple tank): Some believe that, the main temple of Goddess was originally located in Nepal during the `Kaliyuga'. Later she was moved to Aurangabad in Maharashtra. During the Mughal domination, Aurangabad fell under the Muslim rule and the idol was moved to a secret location in Goa. Afterwards, a small temple was built at Verna. Roughly a few hundred years later, the Portuguese conquered Goa and the temple was moved to Mardol, the present location.

Shri Mahalsa Temple complex also has a cluster of smaller temples of Santeri and Laxmi-Narayan who are worshipped daily along with Shri Mahalsa. The five main `ganas' of the Goddess namely Grampurush, Bhagwati, Dadh, Simha Purush and Mhal Purush are also located within the same temple premises and daily worship of all these deities is carried out before worshipping the main goddess.

The temple is famous in Goa for its huge brass bell. The bell does not have a ringer. The ringer was attached only when somebody wanted to testify. It was believed that, the goddess will punish the person by killing him/her in three days, who lied while ringing the bell. The belief was so strong that, during the Portuguese rule, the testimony in the temple was considered acceptable, in the court of law. It is also famous for its Brass `Divli' / Samai (oil lamp). The temple tank lies at the rear side of the temple, where rituals of the temple are carried out.

Site-6 (Shri Manguesh Temple tank): Shri Manguesh temple is located at Mangueshim in Priol, Ponda taluka, 22km from Panaji, the capital of Goa.

This temple is one of the largest, most enchanting, and serene and is one of the most frequently visited temples of Goa. The temple is dedicated to Lord Manguesh, an incarnation of Lord Shiva. He is a `kuldevta' (Family God) of many Hindus in Goa especially of Saraswat Brahmins.

The Mangesh `Linga' is said to have been consecrated on the mountain of Mangireesh (Mongir) on the banks of river Bhagirathi by Lord Brahma, from where, the Saraswat Brahmins brought it to Trihotrapuri in present day Bihar. They carried the `linga' to `Gomantaka' and settled at Kushasthali, the present-day Cortalim, establishing their most sacred and ancient temple of Mangesh on the banks of the river Gomati or Zuari as it is called today. Lord Mangesh is worshipped here in the shape of a Shiva linga.

The 400-year-old Shri Mangesh Temple is dedicated to Shiva and stands out with its simple and yet exquisitely elegant structure. The temple is noted for the pillars, which are considered to be the most beautiful among the temples in Goa. There is a prominent Nandi Bull, which is considered to be the `Vahana' (Vehicle) of Shiva. A beautiful seven-storied `deepstambha' (lamp tower), stands at the gates in the temple complex. The temple also has a magnificent water tank, which is believed to be the oldest part of the temple.

The `Sabha Griha' is a spacious hall, accommodates over 500 persons. The decor includes the chandeliers of the nineteenth century. The central part of the `Sabha Griha' leads to the `Garbha Griha' (sanctum sanctorum), where image of Lord Mangesh is placed. The temple has shrines of Parvati and Ganesha too. The other deities in the temple are Nandikeshvar, Gajana, Bhagavati and Gramapurusha. Other features worth mentioning is the ancient stone `devatas' housed in the subsidiary shrines, to the rear of the main building are Mulakeshwar, Virabhadra, Saanteri, Lakshminarayana, Suryanarayan, Garud and Kala Bhairav.

A: Maps showing the location of study sites.

PLATE 1

Site-1: Shri Shantadurga Temple tank, Kavalem.

Site-2: Shri Ramnath Temple tank, Ramnathi.

PLATE 2

Site-3: Shri Naguesh Temple tank, Nagueshim.

Site-4: Shri Mahalaxmi Temple tank, Bandora.

PLATE 3

Site-5: Shri Mahalsa Temple tank, Mardol.

Site-6: Shri Manguesh Temple tank, Mangueshim.

Months	Temperature ˚C			Relative humidity (%)			Rainfall (mm)
	Max	Min	Average	Max	Min	Average	
Dec-09	32.9	22.1	27.5	81	61	71	0
Jan-10	33.4	21.3	27.35	84	59	71.5	2.6
Feb-10	32.6	21.3	26.95	88	62	75	0
Mar-10	33.1	23.9	28.5	88	69	78.5	0
Apr-10	34.5	25.9	30.2	79	69	74	1.2
May-10	35.2	27.1	31.15	77	68	72.5	63.8
Jun-10	31.8	24.5	28.15	88	82	85	234.6
Jul-10	29.2	23.3	26.25	95	91	93	106.8
Aug-10	29.5	23.6	26.55	95	88	91.5	85
Sep-10	30.4	23.3	26.85	94	84	89	73.8
Oct-10	31.3	23.1	27.2	95	78	86.5	55.4
Nov-10	32.1	24	28.05	89	77	83	66.6
Dec-10	32.1	20.7	26.4	80	61	70.5	2.3
Jan-11	33.1	18.8	25.95	81	53	67	0
Feb-11	33.1	19.8	26.45	82	51	66.5	0
Mar-11	33.4	23.4	28.4	86	64	75	0
Apr-11	33.6	24	28.8	86	62	74	12.8
May-11	34.1	26.3	30.2	76	63	69.5	1
Jun-11	30.5	24.5	27.5	90	84	87	79.6
Jul-11	29.2	23.9	26.55	95	90	92.5	78.2
Aug-11	29.4	24.3	26.85	94	88	91	166.1
Sep-11	30.2	23.9	27.05	92	81	86.5	79.8
Oct-11	32.7	24.5	28.6	86	75	80.5	11.4
Nov-11	33.9	22.9	28.4	78	60	69	7

Table A. Meteorological conditions of Goa during study period (Dec. 2009 – Nov. 2011).

Source: Meteorological Department, Government of India.

Sites	Water spread area	Depth (Summer)	Depth (Rainy)	Latitude	Longitude	Altitude AMSL
Site-1	864 m^2	2.1 m	3.4 m	15˚ 23' 46.6" N	73˚ 59' 09.8" E	21 m
Site-2	344 m^2	1.9 m	2.9 m	15˚ 23' 56.6" N	73˚ 58' 54.8" E	39 m
Site-3	1107 m^2	2.6 m	3.8 m	15˚ 24' 26.8" N	73˚ 58' 59.4" E	20 m
Site-4	738 m^2	4.8 m	6.0 m	15˚ 24' 20.4" N	73˚ 58' 49.7" E	17 m
Site-5	900 m^2	4.1 m	5.2 m	15˚ 26' 24.4" N	73˚ 58' 19.4" E	38 m
Site-6	1275 m^2	3.2 m	4.3 m	15˚ 26' 43.2" N	73˚ 58' 01.2" E	31 m

Table B. Morphometry of the temple tanks (study sites) of Ponda taluka – Goa.

CHAPTER I

Zooplankton forms a major link in the energy transfer at the secondary level in the aquatic biosphere and their ecology is of considerable interest in assessing the production potential of the water bodies. In natural lakes and ponds of the tropics as in the other aquatic ecosystems, zooplankton occupies a central position between the autotrophs and other heterotrophs and forms an important link in aquatic food webs.

In present work, a comparative limnological study was carried out to present a snapshot of zooplankton communities and their relations to physico-chemical factors to test whether there exists a consistent relationship between zooplankton and trophic status among temple tanks. The results of the physico-chemical and biological analysis of these temple tanks are presented below:

Site-1 (Shri Shantadurga Temple tank, Kavalem): Fig 1.1.1 depicts the Physico-chemical data for Site-1. As seen in the figure, maximum surface water temperature of 29.5˚C was recorded in May 2011 and minimum of 27˚C was recorded in December 2009, November 2010, August 2011 and September 2011. The pH ranged between 7.26 in the month of January 2011 and 5.26 in September 2010. Alkalinity was recorded maximum at 41mg/L in April 2010, June 2010 and minimum at 30.5mg/L in September 2010. A maximum concentration of 50.12mg/L observed for total hardness in February 2010, while, in April 2010, minimum concentration of 30.13mg/L was noted. The calcium content in the temple tank water, ranged between 6.41mg/L measured in April 2010 and 14.03mg/L in March 2010. Chloride was minimum in September 2010, with the concentration being 10.42mg/L, while maximum concentration of 33.73mg/L was seen in April 2010. Magnesium content was in the range of 1.95mg/L and 4.62mg/L in March 2011, May 2011 and August 2010, respectively. Maximum Turbidity was measured at 9.2NTU in December 2010 and minimum found in February 2011 at 0.6 NTU. The phosphates showed its lowest concentration at 0.008mg/L in the month of September 2010, while in June 2011, its content was maximum at 0.240mg/L. Sulphates ranged between 1.63 and 8.24mg/L measured in October 2010 and January 2010, respectively. A maximum EC was recorded in January 2010 of 166µS/cm and minimum of 112µS/cm in November 2011. TDS ranged between 63mg/L measured in March 2011and 105mg/L in May 2010. The sodium content at Site-1 ranged between 8.00mg/L measured in June 2011 and 19.30mg/L in April 2010. Potassium was minimum in December 2010 with concentration being 2.6mg/L while maximum concentration of 6.10mg/L in June 2011. Nitrates ranged between 1.08mg/L in February 2010 and 0.06mg/L in May 2010, November 2011. The nitrites showed its lowest concentration at 0.001mg/L in February, June, September and October 2010. While in January, 2010 its content was maximum at 0.020mg/L. DO ranged between 3.34mg/L in September 2010 and 10.20 in June 2011. BOD of 0.40mg/L was observed in January, April, June 2010 and maximum of 0.80mg/L was observed in September 2011. COD recorded between 5.30mg/L in October 2010 and 14.30mg/L in September 2010.

Coliforms bacteria were analysed twice during study period from all the sites. Most probable number (MPN) for coliforms in Site-1 was 1050$\pm$777 coliforms/100ml.

The zooplankton density was highest during January 2010 with rotifers and copepoda being the major contributing groups (Fig.1.2.1.). During the months of January 2010, highest number of zooplankton i.e., 199 individuals/ L were encountered. Lowest number was seen in September 2010 with the count being 0.15 individuals/L.

The zooplankton species encountered during the period from December 2009 to November 2011 in the temple tanks were rotifer, cladocera, cyclopoida, calanoida, copepoda larvae. Figure 1.2.1 shows zooplankton abundance in Shri Shantadurga Temple tank, Kavalem for December 2009 to November 2011. During study period rotifers were found in the range of 0 (September 2010, October 2010, July 2011, September 2011) to 97 (January 2010) individuals/L. Cladocerans were between 0 (August 2010, September 2010, October 2010, November 2010, April 2011, June 2011, August 2011) and 12 (March 2010) individuals/L. The density being low during the wet season of the year, Copepods ranged between 0.15 (September 2010) and 172 (November 2011) individuals/L. Calanoids and cyclopoids were absent during the wet season, but nauplia were present throughout the study period. Copepoda larvae were present in the range of 0.15 (September 2010) to 170 (November 2011) individuals/L and were present throughout the year, with higher number being present in January 2010, February 2010, April 2010, March 2011, April 2011, October 2011 and November 2011. Harpacticoid was observed during April 2010, May 2010, December 2010, January 2011, March 2011, and November 2011 with very low density of 1 or 2 per 20 litres. Ostracods were present in March 2011 and November 2011 i.e. 01/20 L. The highest density was of Copepods and lowest density was of Cladocera. The percentage of zooplankton occurrence was in the following decreasing order Copepoda (78.55%) > Rotifera (16.92%) > Cladocera (9.53%).

Table 1.3.1 gives the Pearson’s bivariate correlation applied for above physico-chemiacal and biological parameters. Rotifers show strong positive correlation with sulphate, nitrate and nitrites at 0.01 significant levels. Also total zooplankton abundance show positive correlation with sodium and nitrates at 0.05 significant levels.

Site-2 (Shri Ramnath Temple tank, Ramnathi): Fig 1.1.2 provides information on the Physico-chemical data for Site-2. As seen in figure, maximum surface water temperature of 30˚C was recorded in March, April 2010, April 2011 and minimum of 26.5˚C was recorded in Aug 2011. The pH ranged between 7.13 in the month of February 2011 and 5.25 in June

2011. Alkalinity was recorded maximum at 45mg/L in June 2010, August 2011 and minimum at 25mg/L in June. A maximum concentration of 48.16mg/L observed for total hardness in March 2010, while in April 2010 minimum concentration of 26.20mg/L was noted. The calcium content in the temple tank water ranged between 4.81mg/L measured in April 2010 and 12.02mg/L in January 2011. Chlorides was minimum in September 2010 with the concentration being 7.65mg/L, while maximum concentration of 26.63mg/L was seen in April 2010. Magnesium content was in the range of 1.25mg/L and 6.32mg/L in February 2011 and March 2010, respectively. Maximum Turbidity was measured at 14NTU in March 2010 and minimum found in October 2010 at 0.2NTU. The phosphates showed its lowest concentration at 0.008mg/L in the month of September 2010, while in June 2011, its content was maximum at 0.240mg/L. Sulphates ranged between 1.63 and 8.24mg/L measured in October 2010 and January 2010, respectively. A maximum EC was recorded in January 2010 of 166 µS/cm and minimum of 112µS/cm in November 2011. TDS ranged between 63mg/L measured in March 2011and 105mg/L in May 2010. The sodium content at site - 2 ranged between 8.00mg/L measured in June 2011 and 19.30mg/L in April 2010. Potassium were minimum in December 2010 with concentration being 2.6mg/L while maximum concentration of 6.10mg/L in June 2011. Nitrates ranged between 1.08mg/L in February 2010 and 0.06mg/L in May 2010, November 2011. The nitrites showed its lowest concentration at 0.001mg/L in February, June September, October 2010 while in January 2010 its content was maximum at 0.020mg/L. DO ranged between 3.40mg/L in November 2010 and 10.13 in February 2010. BOD of 0.40mg/L was observed in January, April, June 2010 and maximum of 0.90mg/L was observed in August 2011. COD recorded between 5.30mg/L in October 2010 and 14.30mg/L in September 2010.

Coliforms were analysed twice during study period from all the sites. MPN count for Site-2 was 26.5$\pm$4.94 coliforms/100ml.

The zooplankton density was highest during December 2009 with copepoda being the major contributing group. During the month of December 2009, highest number of zooplankton i.e. 308 individuals/L were encountered. Lowest numbers of zooplankton were seen in August 2010 with the count being 0.75 individuals/L.

The zooplankton species encountered during the period from December 2009 to November 2011 in the tank were rotifer, Cladocera, cyclopoida, calanoida, copepoda larvae. Figure 1.2.2 shows zooplankton abundance in Site-2 (Shri Ramnath temple tank, Ramnathi) for December 2009 to November 2011.

During study period rotifers were found in the range of 0 (June 2010 to December 2010, February 2011, March 2011, June 2011, July 2011 and September 2011) to 90 (November 2011) individuals/L. Cladocerans were between 0 (July 2010 to September 2010 , November 2010, December 2010, July 2011 to September 2011) and 54 (December 2009) individuals/L. The density being lower during the wet season of the year, Copepods ranged between 0.75 (August 2010) and 212 (December 2009) individuals/L. Rotifers and cladocerans were absent during the wet season but nauplia along with other copepods were present throughout the study period. Copepoda larvae were present in the range of 0.35 (August 2010) to 77 (November 2011) individuals/L and were present throughout the year with higher number being present in February 2010, January 2011, February 2011, May 2011, and November 2011. Harpacticoids were observed only in January 2010. Ostracod was only present in August 2011 (01/20L). The highest density was of Copepods and lowest density was of Cladocera. The percentage of zooplankton occurrence was in the following decreasing order Copepoda (79.86%) > Rotifera (11.83%) > Cladocera (8.30%).

The Pearson's bivariate correlation for Site-2 is given in Table: 1.3.2. Statistically significant positive correlation was demonstrated by Cladocera with turbidity at 0.01 significant levels.

Site-3 (Shri Naguesh Temple tank, Nagueshim): Fig 1.1.3 depicts the Physico-chemical data for Site-3. As seen in the figure, maximum surface water temperature of 30˚C was recorded in May 2011 and minimum of 27 ˚C was recorded in August 2010 and August 2011. The pH ranged between 6.98 in the month of January 2011 and 5.16 in December 2009. Alkalinity was recorded maximum at 35 mg/L in February 2010, July 2010 and minimum at 10mg/L in March 2011. A maximum concentration of 36.60mg/L observed for total hardness in April 2011, while in December 2010 and May 2011 minimum concentration of 24.16mg/L was noted. The calcium content in the temple tank water ranged between 4.41mg/L measured in April 2010, January 2010 and 12.02mg/L in April 2011. Chloride was minimum in April 2011 with the concentration being 6.98mg/L, while maximum concentration of 26.63mg/L was seen in December 2009. Magnesium content was in the range of 1.46mg/L and 4.26mg/L in May 2011 and January 2010, March 2011 respectively. Maximum Turbidity was measured at 9.3NTU in July 2010 and minimum found in March 2011 and April 2011 at 0.5NTU. The phosphate showed its lowest concentration at 0.009mg/L in the month of September 2010, while in January 2010, its content was maximum at 0.120mg/L. Sulphate ranged between 1.8 and 6.3mg/L measured in March 2011 and October 2011, respectively. A maximum EC was recorded in June 2011 of 136 µS/cm and minimum of 85µS/cm in January 2011. TDS ranged between 45mg/L measured in February 2011, March 2011 and 79mg/L in June 2011, August 2011. The sodium content at site 3 ranged between 6.92mg/L measured in October 2010 and 15.20mg/L in June 2010 and January 2011. Potassium was minimum in November 2011 with concentration being 2.40mg/L while maximum concentration of 8.00mg/L in July 2010. Nitrates ranged between 0.09mg/L in September 2010 and 0.98 mg/L in December 2010. The nitrites showed its lowest concentration at 0.0003mg/L in Mach 2010 while in February 2010 its content was maximum at 0.034mg/L. DO ranged between 2.30mg/L in September 2010 and 9.10 in July 2010. BOD of 0.30mg/L was observed in September 2010 and maximum of 0.70mg/L was observed in March 2010, May 2010 and May 2011. COD recorded between 4.8mg/L in January 2010 and 15.25mg/L in June 2011. MPN count for site-3 was 1600 coliforms/100ml. The zooplankton density was highest during October 2011 with copepoda being the major contributing group. During the months of October 2011, highest number of zooplankton i.e., 10.25individuals/L were encountered. Lowest number was seen in September 2010 with the count being 0 individuals/L. MPN of coliform for site-3 was 910$\pm$975 coliforms/100ml.

The zooplankton species encountered during the period from December 2009 to November 2011 in the tank were rotifer, cladocera, cyclopoida, calanoida, copepoda larvae. Figure 1.2.3 shows zooplankton abundance in Shri Naguesh Temple tank, Nagueshim, for December 2009 to November 2011. During study period rotifers were found in the range of 0 (January 2010, June 2010 to January 2011 and April 2011 to September 2011) to 0.95 (October 2011) individuals/L. Cladocerans were between 0 (February 2010, May 2010, June 2010, September 2010 to December 2010, February 2011, June 2011, November 2011) and 0.8 (May 2011) individuals/L. Copepods ranged between 0 (August, September 2010) and 9.3 (October 2011) individuals/L. Rotifers were absent during the wet season. Calanoids were present throughout the study period but cyclopoids were absent during most of months of study period (May 2010 to November 2011). Copepoda larvae were present in the range of 0 (December 2009, June, August, September 2010, January, April, October 2011) to 3.3 (February 2010) individuals/L. Harpacticoids was observed in March, August 2010, January, March, July, November 2011 with very low density 1 or 2 per 20 litres. Ostracods were present in January, April, December 2010, April, May, July September and November 2011 i.e. with very low numbers 01 0r 02 per 20 litres. The highest density was of copepods and lowest density was of rotifers. The percentage of zooplankton occurrence was in the following decreasing order Copepoda (85.53%) > Cladocera (9.57%) > Rotifera (4.89%).

The values obtained for Pearson's bivariate correlation for physico-chemical parameters and zooplankton abundance in Site-3 is given in Table: 1.3.3. Cladocerans showed statistically significant positive correlation with temperature and negative correlation with sulphate, both at 0.05 significant levels.

Site-4 (Shri Mahalaxmi Temple tank, Bandora): Fig 1.1.4 exhibits the data on Physico-chemical data for Site-4. As seen in the figure, maximum surface water temperature of 30˚C was recorded in April 2010 and minimum of 26.5˚C was recorded in November 2011. The pH ranged between 5.25 in the month of December 2009 and 6.9 in June 2011. Alkalinity was recorded maximum at 39mg/L in October 2010 and minimum at 26mg/L in May 2011. A maximum concentration of 39.2mg/L observed for total hardness in October 2010, while in April 2010 minimum concentration of 29.14mg/L was noted. The calcium content in the temple tank water ranged between 5.21mg/L measured in November 2011 and 12.02mg/L in November 2010. Chlorides was minimum in November 2011 with the concentration being 8.88mg/L, while maximum concentration of 30.18mg/L was seen in February 2010. Magnesium content was in the range of 1.34mg/L and 7.05mg/L in January 2011 and March 2010, respectively. Maximum turbidity was measured at 11.7NTU in June 2010 and minimum found in May 2010 at 0.8NTU. The phosphates showed its lowest concentration at 0.010mg/L in the month of September 2010, while in May 2011, its content was maximum at 0.220mg/L. Sulphates ranged between 2.37 and 7.60mg/L measured in September January 2011 and June 2011 respectively. A maximum EC was recorded in June 2011 and August 2011 of 140µS/cm and minimum of 98µS/cm in November 2011. TDS ranged between 53 mg/L measured in May 2011and 90mg/L in May 2010. The sodium content at Site-4 ranged between 8.9mg/L measured in November 2010 and 16.20mg/L in January 2011. Potassium was minimum in December 2009 and August 2011 with concentration being 2.8mg/L, while maximum concentration of 5.20mg/L in October 2010 and November 2010. Nitrates ranged between 0.02mg/L in April 2011 and 0.42mg/L in March 2010. The nitrites showed its lowest concentration at 0.0003mg/L in December 2009 while in March 2010 its content was maximum at 0.11mg/L. DO ranged between 2.24mg/L in December 2010 and 10.97 in February 2010. BOD of 0.40mg/L was observed in April 2011 and maximum of 0.80mg/L was observed in January 2010, March 2010, December 2010 and July 2011. COD recorded between 6.40mg/L in January 2010, April 2010, May 2010 and 20mg/L in September 2010. MPN count of coliforms for Site-4 was 920$\pm$961 coliforms/100ml.

The zooplankton density was highest during June 2010 with rotifers being the major contributing groups. During the months of June 2010, highest number of zooplankton i.e., 84 individuals/L were encountered. Lowest number were seen in December 2009 with the count being 2.10 individuals/L.

The zooplankton species encountered during the period from December 2009 to November 2011 in the tank were rotifer, cladocera, cyclopoida, calanoida, copepoda larvae. Figure 1.2.4 shows zooplankton abundance in Shri Mahalaxmi Temple tank, Bandora, for December 2009 to November 2011.

During study period rotifers were found in the range of 0 (August and September 2011) to 61.50 (June 2010) individuals/L. Cladocerans were between 0 (September 2011) and 13.50 (February 2010) individuals/L. Copepods ranged between 1.05 (December 2009, July 2011) and 48.95 (May 2010) individuals/L. Representatives of all groups (calanoida, cyclopoida, Nauplii, Cladocera and rotifera) were present throughout the study period. Harpacticoids was observed in April, July, August, September, December 2010, March 2011, with very low density 1 or 6 per 20 litres. Ostracods were present in April 2010, March and November 2011 i.e. with very low numbers 01 0r 02 per 20 litres. The percentage of zooplankton occurrence was in the following decreasing order Copepoda (41.65%) > Rotifera (38.95%) > Cladocera (19.40%).

The physico-chemical parameters and zooplankton population of Site-4 were subjected to Pearson's bivariate correlation and the results are given in Table: 1.3.4. A strong positive correlation was observed between rotifers and turbidity at 0.01 levels. The positive correlation of cladocera group was observed with pH, turbidity and sodium at 0.05 significant levels. Total zooplankton abundance demonstrated positive correlation with pH, turbidity and sodium at 0.05 significant levels. Copepods were positively correlated with TDS at 0.05 levels.

Site-5 (Shri Mahalsa Temple tank, Mardol): Fig 1.1.5 depicts the Physico-chemical data for Site-5. As seen in the figure, maximum surface water temperature of 30˚C was recorded in April 2010 and minimum of 26.5˚C was recorded in January 2011. The pH ranged between 6.75 in the month of April 2010 and 5.57 in December 2009. Alkalinity was recorded maximum at 112mg/L in January 2011 and minimum at 39.0mg/L in January 2011. A maximum concentration of 92.19mg/L observed for total hardness in July 2011, while in November 2011 minimum concentration of 63.31mg/L was noted. The calcium content in the temple tank water ranged between 16.30mg/L measured in September 2010 and 26.45mg/L in February 2010 and March 2011. Chloride was minimum in September 2010 with the concentration being 21.98mg/L, while maximum concentration of 56.80mg/L was seen in January 2011. Magnesium content was in the range of 2.68mg/L and 10.46mg/L in July 2011 and November 2011, respectively. Maximum Turbidity was measured at 12.6NTU in July

2010 and minimum found in January 2011 at 0.3NTU. The phosphates showed its lowest concentration at 0.006mg/L in the month of September 2010, while in August 2011, its content was maximum at 0.530mg/L. Sulphates ranged between 4.14 and 10.56mg/L measured in April 2010 and January 2010, respectively. A maximum EC was recorded in January 2011 of 380µS/cm and minimum of 231µS/cm in December 2010. TDS ranged between 119 mg/L measured in December 2010 and 250 mg/L in January 2011. The sodium content at Site-5 ranged between 12mg/L measured in July 2010, June 2011 and 29.30mg/L in January 2011. Potassium was minimum in July 2011 with concentration being 4.0mg/L while maximum concentration of 20mg/L in January 2011. Nitrates ranged between 0.08mg/L in April 2011 and 1.36mg/L in September 2010. The nitrites showed its lowest concentration at 0.002mg/L in April 2010, while in February 2011 its content was maximum at 0.21mg/L. DO ranged between 1.62mg/L in September 2010 and 10.12mg/L in February 2011. BOD of 0.7mg/L was observed in September 2010 and maximum of 1.4mg/L was observed in July 2011. COD recorded between 7.29mg/L in August 2010 and 28.8mg/L in January 2011. MPN count of coliforms in Site-5 was 885$\pm$1011 coliforms/100ml.

The zooplankton density was highest during November 2011 with copepoda being the major contributing group. During the months of November 2011, highest number of zooplankton i.e., 203.85 individuals/L were encountered. Lowest number was observed in July 2011, with the count being 5.4 individuals/L.

The zooplankton species encountered during the period from December 2009 to November 2011 in the tank were rotifera, cladocera, cyclopoida, calanoida, copepoda larvae. Figure 1.2.5 shows, zooplankton abundance in Shri Mahalsa temple tank, Mardol, for December 2009 to November 2011.

During study period rotifers were found in the range of 0 (June 2010 and July 2011) to 40.50 (March 2011) individuals/L. Cladocerans were between 0 (July, August 2010 and August 2011) and 60.15 (March 2010) individuals/L. Copepods ranged between 4.65 (July 2011) and 152 (November 2011) individuals/L. Representatives of all groups (calanoida, cyclopoida, Nauplii, Cladocera and rotifera) were present throughout the study period. Copepoda larvae were present in the range of 1.05 (September 2010) to 82.4 (July 2010) individuals/L. Harpacticoids were observed in December 2009, January, September 2010, January 2011 with very low density 1-7 per 20 litres. Ostracods were present only in March 2010. The percentage of zooplankton occurrence was in the following decreasing order Copepoda (68.56%) > Cladocera (20.43%) > Rotifera (11.01%).

Table 1.3.5 gives Pearson's bivariate correlations applied for data of Site-5. As seen in the table, copepods showed positive correlation with turbidity at 0.01 significant levels and magnesium at 0.05 levels. Cladocerans demonstrated positive correlations with EC and chlorides at 0.05 significant levels. Total zooplankton abundance also showed positive correlation with turbidity at 0.05 significant levels.

Site-6 (Shri Manguesh Temple tank, Mangueshim): Fig 1.1.6 shows the Physico-chemical data for Site-6. As seen in the figure, maximum surface water temperature of 30˚C was recorded in April 2010 and minimum of 26.5˚C was recorded in February 2010, February 2011 and August 2011. The pH ranged between 5.75 in the month of December 2009 and 07 in April 2010. Alkalinity was recorded maximum at 45mg/L in June 2010 and minimum at 14mg/L in October 2011. A maximum concentration of 92.17mg/L observed for total hardness in June 2011, while in September 2011 minimum concentration of 29.14mg/L was noted. The calcium content in the temple tank water ranged between 4.81mg/L measured in March 2010 and 12.83mg/L in June 2011. Chloride was minimum in November 2010 with the concentration being 8.88mg/L, while maximum concentration of 26.63mg/L was seen in February 2010. Magnesium content was in the range of 1.26mg/L and 4.86mg/L in February 2011 and March 2010 respectively. Maximum Turbidity was measured at 11NTU in June 2010 and minimum found in April 2011, June 2011 at 0.4NTU. The phosphate showed its lowest concentration at 0.004mg/L in the month of February 2010, while in August 2011, its content was maximum at 0.240mg/L. Sulphate ranged between 1.99 and 6.67mg/L measured in January 2011, July 2011 and January 2010, respectively. A maximum EC was recorded in January 2011 of 195µS/cm and minimum of 116µS/cm in December 2010. TDS ranged between 60mg/L measured in December 2010 and 130mg/L in May 2010. The sodium content at site-6 ranged between 4.81mg/L measured in March 2010 and 18.40 mg/L in June 2010. Potassium were minimum in November 2011 with concentration being 2.0mg/L while maximum concentration of 8.80mg/L in September 2010. Nitrates ranged between 0.83mg/L in June 2010 and 0.08mg/L in September 2010. The nitrites showed its lowest concentration at 0.00mg/L in March 2010 while in February 2010 its content was maximum at 0.234mg/L. DO ranged between 2.44mg/L in September 2010 and 10.6mg/L in October 2011. BOD of 0.50mg/L was observed in August 2010 and maximum of 0.90mg/L was observed in July 2011. COD recorded between 7.82mg/L in November 2010 and 25.8mg/L in January 2011. MPN count of coliform for Site-6 was 1250±494 coliforms/100ml.

The zooplankton density was highest during December 2010, with rotifers being the major contributing group. During the months of December 2010, highest number of zooplankton i.e., 148 individuals/L were encountered. Lowest number was seen in September 2011 with the count being 1.60 individuals/L.

The zooplankton species encountered during the period from December 2009 to November 2011 in the tank were rotifera, cladocera, cyclopoida, calanoida, copepoda larvae.

Figure 1.2.6 shows zooplankton abundance in Shri Manguesh temple tank, Mangueshim, for December 2009 to November 2011.

During study period rotifers were found in the range of 0 (May 2011) to 107 (December 2010) individuals/L. Cladocerans were between 0 (August, September 2011) and 9 (June 2010) individuals/L. Copepods ranged between 1.30 (September 2011) and 85.75 (May 2010) individuals/L. Representatives of all groups (calanoida, cyclopoida, Nauplii, Cladocera and rotifera) were present throughout the study period. Harpacticoids was observed in March, May, August 2010, January, July 2011, with very low density 1 to 6 per 20 litres. Ostracods were present only in May 2011. The percentage of zooplankton occurrence was in the following decreasing order Copepoda (61%) > Rotifera (33.13%) > Cladocera (5.86%).

Table 1.3.6 gives the Pearson's bivariate correlation applied for above mentioned physico-chemical and biological parameters. Rotifers show strong negative correlation with DO at 0.01 significant levels. Also total zooplankton abundance show negative correlation with DO and positive correlation with alkalinity, both at 0.05 significant levels. Copepods show positive correlation with TDS, EC and magnesium at 0.05 significant levels.

Table 1.2.3 shows average physico-chemical and biological parameters during study period. One way ANOVA at $P < 0.01$ shows significant difference in the monthly concentration of all parameters except pH, turbidity, nitrite, DO during the study period and within the sites. Temperature shows significant difference among different sites at $P < 0.05$.

DISCUSSION

Assessment of the water generally involves analysis of physico-chemical and biological parameters in an aquatic ecosystem and reflects its abiotic and biotic status. Each parameter plays its role in regulating the ecosystem of the water body. The concentration of the various constituents along with factors such as rainfall, agricultural runoffs are also of equal importance. The changes in one factor are directly or indirectly related to other factors.

Temperature is considered an important factor controlling the functioning of the aquatic ecosystem. Temperature of water in temple tanks of Goa was on the higher side during summer. Temperature has been considered as one of the primary factors to cause the abundance of zooplankton in freshwaters particularly in shallow waters where bottom exhibit considerable variations in temperature, especially with the progression of the warm season (Moitra and Bhattacharya, 1965, Ahangar *et. al*., 2012). Temperature controls development, growth, reproduction, shape of the body and distribution of the species (Caramujo and Boavida, 1999; Xie and Chen, 2001).

The pH of tropical water bodies is influenced by its surroundings and hence differs from one water body to another. World health Organization (WHO) has recommended water of pH range of 6.5-8.5 suitable for drinking purposes. According to Kurbatova, (2005) and Roychoudhury *et. al*., (2013), the pH range was between 6.0 to 8.5 indicate medium productive nature of a reservoir; more than 8.5 highly productive; and less than 6.0 low productive nature of a reservoir. In case of all the sites under study the average pH during different seasons at all sites ranged between 5.9 to 6.5, indicating, medium productive nature of the water bodies under study.

Site-3 (Shri Naguesh Temple tank) was the most acidic of all the temple tanks under study, followed by Site-4 and Site-5. High acidity of Site-3 water during post- monsoon i.e.

August may be due to runoff from the surrounding regions. Almost all sites the pH became acidic, after rainy season, may be due to runoff.

Alkalinity or more recently referred acid neutralising capacity is the buffering capacity of carbonate system or the capacity to neutralise strong inorganic acids. Hydroxides, borate, silicate, phosphate and sulphide, though present in small quantity in freshwater, form the sources of alkalinity. The total alkalinity of freshwater lakes is often very low, thus making them poorly buffered and susceptible to acidification (Wetzel, 2001). Eutrophic water bodies have high values of alkalinity. WHO has prescribed 120mg/L as the alkalinity level, which shows signs of nutrient richness. Water bodies having total alkalinity above 100 mg/L can be considered productive in nature (Raina *et. al*., 2013), only seen during some months in Site-5.

Hardness of water is related to the calcium and magnesium salts. These together with bicarbonates and carbonates give rise to temporary hardness, whereas with sulphates, chlorides and other anions constitute the permanent hardness (Wetzel, 2001).

Lower values of alkalinity and hardness were found at Site-3 and were highest at Site-5. This value coincided with pH values. The temple tanks i.e., Site-1, Site-2, Site-5 had higher values of alkalinity and hardness as compared to other sites. Thus the buffering capacity of these sites being more, the pH of this water bodies was also on higher side. However, among all the freshwater bodies taken together, Site-5 showed highest alkalinity and hardness values. Lowest values for alkalinity and hardness were recorded for Site-3. The lower values during rainy season may be due to dilution of the water bodies with rain water.

As observed by Gupta and Sharma (1994), bicarbonates are responsible for the alkalinity of the water body, while pollution due to organic matter was found to be responsible for high alkalinity values by Phillips (1977), as seen in Site-5.

Calcium is one of the major ions influencing the biotic fauna of freshwater bodies and is very reactive, exhibiting marked seasonal dynamics. Calcium affects growth and population of freshwater flora and fauna. Crustaceans and invertebrates with calcified exoskeletons require calcium and form a determining factor in zooplankton community structure (Hessen, 2003). However, the amount taken up by the biota is so less that cannot be detected by routine analyses methods (Wetzel, 2001). In the present study it was observed that calcium content was higher during winter at all sites except Site-3. High values may be attributed to decomposition of macrophytes and allochthonus supply. So also, due to less water resulting in evaporation of water, there is concentration of ionic content. Similarly reported by Sharma *et. al.*, 2011. Yet another possibility is the contribution of molluscans, in the process of synthesising shells.

Chloride is an important factor among the essential ions determining the freshwater body status. In all the water bodies, the chlorides were in higher concentration during summer. The highest chlorides were recorded at Site-5 and lowest at Site-2. Higher chloride concentration during the summer is because of the high temperature and consequent evaporation, similarly reported by Sharma *et. al.*, 2011. High chlorides are taken as an indication of pollution arising from animal origin (Munawar, 1970).

Magnesium is required by plants as a micronutrient universally. It is more soluble than calcium. Magnesium was on higher side during dry season as compared to wet season at all sites except Site-1 and Site-3. High values in summer and winter was observed which may be due to the water level being low in summer, followed by winter and low values due to dilution in monsoon.

Phosphate is an indicator of pollution and involved in the eutrophication process of water bodies (Wetzel, 2001). Phosphate enters the freshwater bodies as phosphorus from atmospheric precipitation, ground water and surface runoff. During the present study, except for Site-3 and Site-4, all temple tanks showed high concentration of phosphates during monsoons, due to washing off nutrients from surrounding into water body. Similar results were seen by Berde (2004). Contrary to this observation, Singh and Singh (1999); Sharma *et. al*., (2011) found an increase in phosphates during summer and attributed it to high rate of evaporation resulting in concentration. The probable reason for high values in monsoons is addition of nutrients from domestic sewage, surface runoff from agricultural land containing fertilisers, while the low levels during dry seasons may be due to utilisation of phosphates by plankton fauna and macrophytes. As observed by Campbell (1978), surface runoff can be a major source of enrichment to water bodies.

The sulphate was more during summer season at all sites except Site-3 and Site-4. Higher values in summer can be attributed to decrease in water level, which increases concentration. Site-3 showed higher concentration during winter and rainy season, while Site-4 showed higher concentration during rainy season. High values during rainy season, may be because of addition of nutrients due to surface runoff from surrounding agricultural land.

DO levels were always above 3mg/L in all sites throughout study period. Tarzwell (1957) reported that for supporting life, minimum of 3mg/L DO is required (Devi *et. al.*, 2013). Most of the sites recorded higher DO in summer season and low in rainy season. The BOD value is well below 1mg/L except at Site-5, where it crossed 1mg/L four times during study period. The BOD value do not indicates any pollution in the aquatic systems, which adversely affects the water quality and biodiversity. COD varied from 4.8 to 28.8mg/L at the different sites. The values of COD indicate good water quality, as water pollution which is related to sewage effluents, industry or agricultural practices in almost nil. The monthly mean variations in EC and TDS followed similar trend. The lower EC values were recorded at Site-3 and highest at Site-5. High conductivity and TDS at Site-5 indicate the organic pollution. Both conductivity and total dissolved solids promoted high zooplankton growth and abundance (Mustapha, 2009). Turbidity ranged from a minimum of 0.2NTU (Oct.'10, Site-2) to maximum of 14NTU (March '10, Site-2). Highest concentration of TDS increases water turbidity, this in turn decreases the light penetration, thus affects the photosynthesis, thereby suppressing the primary producers in the form of algae and macrophytes (Majagi and Kumar, 2009).

Nitrate average values for summer and winter season were almost similar for all sites and average concentration was higher in Site-1 to Site-4 than, rainy season. In Site-5 and Site-6 average concentration of nitrate was higher in rainy season. Higher values during dry season can be attributed to low water levels due to evaporation and in rainy season may be due to input through rain water from surrounding. Nitrite concentration was very low i.e., below 0.01mg/L in Site-1 to Site-4. Site-4, Site-5 and Site-6 showed highest average concentration of nitrite during summer season may be due to same above said reason.

Sodium was on higher side during dry season as compared to rainy season, at all sites, may be due to concentration of water due to evaporation. Potassium levels were on higher side during rainy season in Site-1, Site-2, Site-3 and Site-6, due to input through rain water from surrounding. Site-4 and Site-5 showed higher concentration of potassium during dry season, i.e., winter and summer respectively, which can be attributed to low levels of water during dry season.

Overall the ionic concentrations were in following order Site-5 > Site-1 > Site-6 > Site-4 > Site-2 > Site-3 (Fig. 1.1.7.). Site-5 showed highest measured concentrations of most of the parameters, indicating the most nutrient–rich water body; while Site-3 the least nutrient rich water body under study.

All the physico-chemical parameters studied from all sites are well within permissible limits prescribed by Indian Standards (IS) and Indian Council for Medical Research (ICMR) for drinking water. Site-5 shows all these parameters on higher side as compared to other sites under study. As far as bacteriological studies are concerned, all the sites show the presence of coliforms above the permissible limits prescribed by IS and ICMR for drinking water.

In deciphering trophic status and bio-monitoring of aquatic habitats, zooplankters play a vital role (Raina *et. al*., 2013). The biodiversity and distribution of zooplankton in aquatic ecosystem depend mainly on the physicochemical properties of water. Temperature, light, nutrient levels are usually the influencing factors, with temperature having the greatest effect. Most of the water bodies studied showed higher abundance values during summer followed by winter except Site-1 and Site-6 which showed higher abundance in winter, followed by summer. According to Holz *et. al.,* (1990), increase in temperature and high evaporation, during summer, enhances the rate of decomposition, due to which; the water becomes nutrient rich resulting in increase in population density of zooplankton. The warm summer surface water temperature and higher pH (Padate *et. al*., 2014) preferred by the zooplankton were also noted during this study and hence their higher density and diversity during the said period. Whereas low population density during monsoon may be attributed to the dilution factor by rain and high water level. Thus seasonally, total zooplankton recorded bimodal peaks during summer and post-monsoon (winter) with trough during monsoon. This bimodal pattern of total zooplanktonic fluctuations is well supported by the findings of Tripathi *et. al*., 2006; Salve and Hiware, 2010; Raina *et. al*., 2013; Sharma *et. al*., 2013; Slathia and Dutta, 2013; Padate *et. al*., 2014 and Tyor *et. al*., 2014.

Copepods were found to be dominant in all the freshwater bodies studied and dominance was seen during all seasons. The most abundant zooplankton group in all the water bodies was copepoda (copepoda larvae, cyclopoida and calanoida). Copepods reproduce all throughout the year. This was evidenced by the presence of the larval forms, nauplii and copepodite, and the appearance of number of oviparous individuals in all the months during the present study. The results are corroborated with the view of Padate *et. al*., (2014). It can be inferred from this data that, the copepoda group has adapted to the changes occurring throughout the year in the water bodies and thus found during all the seasons.

Among the copepoda population, all groups were observed during all seasons however, cyclopoids were very low or absent during rainy season at all sites. Eutrophication leads to decrease in the percentage of calanoid copepod, while promotes the development of cyclopoid copepod (Padate *et. al*., 2014). During present studies, calanoid copepods were maximum indicating oligotrophic nature of all water bodies studied. Also Kurasawa (1975) reported that, copepods are found to be dominant in oligotrophic lakes (Karuthapandi *et. al*., 2013).

The copepods dominated all the sites and all the seasons. Copepods showed two peaks, one in the summer and another in winter. Highest abundance was always seen in summer at all sites except at Site-1, which showed higher abundance in winter. Least abundance was seen at all sites during rainy season. The high water level and cover in the monsoon and post monsoon spreads the copepods causing their lower density in post monsoon.

Low abundance of copepods during some periods may also be due to predation by fish. Large pigmented eye or gut filled with pigmented food makes the copepods visible prey (Wetzel, 2001).

Similarly Sharma and Saxena (1983); Chauhan (1993); Xie and Chen (2001); Sharma *et. al*., (2010) and Sharma and Pachuau, (2013) have reported copepod dominance during limnological studies of freshwater bodies. Population rises to higher level in the winter as result of favourable environmental condition including temperature, DO and availability of abundant food in the form of bacteria, nanoplankton and suspended detritus. Edmondson (1965) and Baker (1979) have also confirmed these findings.

The second most abundant zooplankton group was rotifera at all sites except at Site-5. Rotifers are prominent group among the zooplankton of a water body irrespective of its trophic status. This may be due to the less specialized feeding, parthenogenetic reproduction and high fecundity (Rajshekhar *et. al*., 2009). They increase in large quantity rapidly under favourable environments conditions (Thirupathaiah, 2011). Rotifers dominance was seen in winter at Site-1, Site-2 and Site-6, while at Site-3, Site-4 and Site-5 in summer season. Summer dominance of rotifers has been reported by Sharma *et. al.*, (2010). Jayabhaye and Madlapur (2006), have reported that, higher rotifer population occurs during summer might be due to hypertrophical conditions of the water body at high temperature and low level of water. Least number of rotifers in rainy season at Site-1, Site-2 and Site-5 were observed while at Site-3 and Site-4 in winter season. Low population density during monsoon and post monsoon may be attributed to the dilution factor by rain and high water level (Akbulut, 2004 and Mulani *et al.,* 2009). Site-6 showed least number of rotifers in summer season.

Cladocerans were the third abundant group at all sites except at Site-5 where cladoceran was second most abundant. Cladocerans showed its peak abundance during dry seasons except at Site-4, which had highest Cladocerans population, during rainy season.

Three types of abundance patterns were seen. Abundance during rains was observed at Site-4 (Shri Mahalaxmi Temple tank); winter abundance was found at Site-2, Site-3, Site-5 and Site-6 while at Site-1 summer abundance was observed.

Food supply also plays a vital role in the density of cladocera (Singh, 2000). Pulle and Khan (2003) reported the cladoceran dominance during winter, thus supporting the present findings and the factors favouring this abundance are temperature and availability of abundant food in the form of bacteria, nanoplankton and detritus. While the dominance of cladocerans in summer, has been reported by Sharma *et. al.,* (2010). In summer, the rising temperature increases the density of algae, detritus as well as bacteria, the major food for cladocerans that ultimately leads to increase in overall density of cladocerans (Padate *et. al*., 2014). Chakravarty (1990) on the other hand, reported numerical superiority of cladocerans in summer and rainy season.

Low densities during the other periods may be due to predation by copepod (Hessen, 2003). Another reason may be the positive phototactic swarming from littoral areas to pelagic zone (Kairesalo and Pentilla, 1990).

Dominance of copepods throughout the year has been reported by Ayyapan and Gupta (1980) and Vyas and Adholia (1994). The productivity of lakes generally tends to be very high, particularly in tropical regions, during low water periods (summer). Planktonic crustaceans are commonly abundant during these periods but experience severe decline during high water periods of inundation when inorganic suspended particles are high and phytoplankton production low (Padate *et. al*., 2014).

Harpacticoids and ostracods were present in very low numbers and were not frequently detected during the study period. Chourasia and Adoni (1987) have also reported similar findings. Most of the freshwater ostracods are bottom dwellers, although some appear occasionally in plankton samples (Ansari and Khan 2014).

Of the water bodies studied Site-3 (Shri Naguesh Temple tank) had the least zooplankton abundance followed by Site-4 (Fig. 1.2.7.). Highest zooplankton abundance was observed in Site-5 followed by Site-2. Similarly most of the physicochemical parameters were lowest at Site-3 and highest at Site-5 than other sites, indicating least nutrient richness at Site-3 and most nutrient richness at Site-5. High zooplankton densities in general, during summer may be due to concentration of water because of evaporation, while the low densities in rains may be due to dilution effects of heavy rains, low nutrients and phytoplankton (Bais and Agarwal, 1995). The abundance and distribution pattern of each and every species show direct relation to seasonal effect (Maruthanayagam and Subramanian, 2001).

In present study total zooplanktonic population shows positive correlation with sodium and nitrates in Site-1, with pH, EC and sodium in Site-4, with turbidity in Site-5 and with alkalinity in Site-6 at 0.05 significance level. Salaskar and Yeragi (2003) reported negative correlation of total zooplankton with nitrate, TH and phosphate. Srivastava (2002) observed inverse relationship between zooplankton and turbidity. Positive correlation between total zooplankton and potassium, TH was recorded by Jhingran (1997). Slathia and Dutta observed negative correlation between total zooplankton and pH, water temperature.

Zooplankton groups shows correlation with different parameters at different sites. Positive correlation between turbidity and various groups of zooplankton at 0.01 significance level was seen at different sites. Correlation of cladocera (Site-2), rotifera (Site-4) and copepoda (Site-5) with turbidity was observed. Chandraseker (1996) showed that the water temperature, turbidity and transparency and dissolved oxygen were favouring rotifer population.

Pearson's correlation between physico-chemical parameters and zooplankton from different sites has revealed mostly insignificant results of coefficient of correlation (r) (Table 1.3.1 to 1.3.6). This indicates that, no single factor is strong determinant for zooplankton abundance in these study sites and a sum total of a number of factors are responsible for their diversity and density. Slathi and Dutta (2013) also had reported similar results.

Site-1 Months	Temp. ˚C	pH	TDS mg/L	EC µS/cm	Turb. NTU	Alkalinity mg/L	Chloride mg/L	Phosphate mg/L	Sulfate mg/L	Calcium mg/L	Sodium mg/L	Potassium mg/L	Nitrate mg/L	Nitrites mg/L	mg mg/L	TH mg/L	DO mg/L	BOD mg/L	COD mg/L
Dec.'09	27.0	6.01	100	149	5.0	39.5	23.80	0.040	6.94	13.23	14.00	4.40	0.25	0.005	2.31	42.57	9.30	0.6	9.60
Jan. '10	27.5	6.63	84	166	2.1	36.5	24.85	0.120	8.24	11.62	16.60	4.80	0.98	0.020	2.19	38.15	6.70	0.4	6.34
Feb.	28.0	6.85	82	147	7.8	38.0	24.85	0.028	5.28	13.63	15.50	5.10	1.08	0.001	2.80	50.12	6.70	0.6	12.80
Mar.	28.5	6.22	81	161	8.3	35.0	24.85	0.036	6.30	14.03	16.00	5.20	0.98	0.002	2.43	45.22	8.40	0.6	6.40
Apr.	29.0	6.10	93	160	7.5	41.0	33.73	0.100	3.64	6.41	19.30	5.20	0.11	0.003	3.40	30.13	9.07	0.4	6.40
May.	29.0	6.90	105	161	2.1	32.0	12.43	0.080	5.86	11.22	12.60	3.80	0.13	0.002	3.89	44.16	9.10	0.5	9.60
Jun.	28.0	7.08	89	147	8.1	41.0	19.53	0.010	3.94	12.02	16.70	5.40	0.09	0.001	3.65	45.29	5.27	0.6	10.60
Jul.	28.0	7.05	78	130	6.9	39.0	15.20	0.020	4.20	10.65	11.20	4.20	0.15	0.006	3.40	40.63	3.60	0.4	11.30
Aug.	27.5	6.01	72	130	2.3	35.0	21.30	0.160	2.37	8.42	11.20	5.00	0.19	0.002	4.62	40.16	5.40	0.7	11.26
Sep.	28.5	5.26	68	142	2.5	30.5	10.42	0.008	1.92	9.26	11.26	3.82	0.16	0.001	3.16	41.26	3.34	0.5	14.30
Oct.	27.5	6.15	78	135	1.6	33.5	18.30	0.010	1.63	11.25	10.30	4.20	0.25	0.001	2.15	42.32	9.20	0.6	5.30
Nov.	27.0	6.94	78	154	2.0	38.0	17.75	0.050	2.94	12.42	12.00	2.80	0.20	0.003	2.68	42.16	6.07	0.6	11.60
Dec.	28.0	6.37	68	134	9.2	40.0	17.75	0.160	3.80	10.42	10.90	2.60	0.80	0.002	3.89	42.15	4.02	0.6	7.63
Jan. '11	28.0	7.26	70	126	2.8	40.0	17.75	0.078	5.70	12.42	11.20	5.80	0.19	0.002	2.43	41.16	9.23	0.6	13.60
Feb.	28.5	7.10	66	130	0.6	36.0	15.25	0.032	4.60	11.30	10.00	4.60	0.25	0.002	2.16	41.20	7.26	0.7	11.30
Mar.	28.5	5.87	63	137	2.6	32.0	12.43	0.100	3.51	12.02	12.20	4.30	0.17	0.008	1.95	38.15	9.02	0.5	10.26
Apr.	29.0	5.80	70	142	2.6	35.0	11.80	0.009	2.60	11.20	10.30	3.60	0.12	0.002	3.16	38.60	8.36	0.5	12.90
May.	29.5	6.53	75	150	6.8	31.0	17.75	0.150	3.51	10.82	15.90	5.60	0.06	0.008	1.95	35.23	9.20	0.6	11.62
Jun.	28.0	7.03	80	145	1.8	39.0	14.20	0.240	5.89	11.22	8.00	6.10	0.06	0.009	3.16	41.16	10.20	0.5	11.09
Jul.	27.5	6.41	74	135	1.2	40.0	15.98	0.040	3.51	12.42	11.00	5.10	0.06	0.005	2.68	42.13	7.50	0.6	10.25
Aug.	27.0	6.21	75	140	1.2	32.0	15.25	0.060	4.32	10.20	10.30	4.60	0.06	0.008	2.60	33.00	9.30	0.5	11.26
Sep.	27.0	5.90	68	130	2.3	35.0	21.30	0.020	4.75	12.42	11.30	3.60	0.06	0.010	2.19	40.13	4.08	0.7	11.85
Oct.	27.2	6.21	72	140	2.0	32.0	20.00	0.062	5.26	10.20	11.20	2.90	0.06	0.009	3.26	39.20	8.30	0.7	9.36
Nov.	27.5	5.78	65	112	1.2	36.0	12.43	0.015	3.80	12.02	11.20	4.20	0.06	0.004	2.92	42.13	7.62	0.5	11.25

Table. 1.1.1. Physico-chemical parameters of Site-1 during Dec.2009 – Nov. 2011.

Site-2 Months	Temp. ˚C	pH	TDS mg/L	EC µS/cm	Turb. NTU	Alkalinity mg/L	Chloride mg/L	Phosphate mg/L	Sulfate mg/L	Calcium mg/L	Sodium mg/L	Potassium mg/L	Nitrate mg/L	Nitrites mg/L	mg mg/L	TH mg/L	DO mg/L	BOD mg/L	COD mg/L
Dec.'09	28.0	5.40	70	109	10.0	31.0	19.53	0.030	3.52	10.82	10.10	1.50	0.19	0.002	1.46	33.07	8.40	0.7	12.80
Jan. '10	28.5	6.52	55	116	8.0	31.0	23.08	0.080	2.96	8.42	12.20	1.60	0.52	0.010	1.95	29.14	9.13	0.6	5.60
Feb.	28.5	6.45	65	118	4.3	32.0	19.52	0.024	3.33	8.81	11.10	1.70	0.67	0.000	4.60	41.16	10.13	0.5	14.40
Mar.	30.0	6.38	69	144	14.0	42.0	23.08	0.008	5.46	8.82	11.80	2.20	0.45	0.002	6.32	48.16	8.39	0.5	8.00
Apr.	30.0	6.20	68	118	7.1	32.0	26.63	0.060	2.53	4.81	11.30	5.20	0.16	0.002	3.40	26.20	6.30	0.7	8.00
May.	28.5	6.81	75	116	2.6	40.5	10.65	0.040	2.83	10.82	10.30	1.80	0.18	0.013	2.92	39.18	4.67	0.5	8.00
Jun.	27.5	6.96	67	116	10.4	44.0	14.20	0.008	2.02	11.62	11.60	2.20	0.12	0.008	1.70	36.31	6.40	0.7	12.30
Jul.	28.0	6.39	59	95	5.8	45.0	14.26	0.016	1.80	9.20	10.20	2.90	0.25	0.002	1.60	38.92	7.20	0.6	13.30
Aug.	27.5	5.89	59	95	2.1	28.0	19.53	0.030	1.80	8.82	10.30	4.60	0.26	0.009	3.89	38.16	3.60	0.6	15.60
Sep.	27.5	6.25	52	95	3.2	26.5	7.65	0.002	2.16	8.24	10.83	2.60	0.14	0.005	2.32	38.36	3.65	0.6	8.90
Oct.	28.5	6.24	53	97	0.2	28.0	17.40	0.040	1.99	10.42	6.98	3.25	0.15	0.003	2.72	36.34	9.00	0.4	8.30
Nov.	27.5	6.11	55	112	1.3	26.0	14.20	0.030	2.28	8.02	11.30	2.20	0.21	0.070	2.92	32.18	3.40	0.6	9.20
Dec.	28.5	6.10	51	102	2.1	41.0	8.88	0.030	2.37	9.62	11.00	2.00	0.52	0.008	1.70	31.10	3.42	0.7	8.25
Jan. '11	28.5	7.12	49	91	3.1	41.0	15.98	0.004	2.37	12.02	11.20	2.90	0.18	0.009	1.95	38.18	8.35	0.5	12.80
Feb.	29.0	7.13	48	95	1.2	40.0	14.63	0.005	3.10	11.20	11.10	2.00	0.20	0.006	1.25	38.60	8.50	0.5	10.35
Mar.	29.5	6.21	57	113	4.9	30.0	8.83	0.080	1.99	10.02	10.10	5.00	0.20	0.011	2.68	36.16	8.76	0.7	11.60
Apr.	30.0	6.30	63	119	0.9	31.0	8.00	0.020	1.86	11.22	10.90	1.20	0.24	0.001	2.40	41.16	7.20	0.6	13.60
May.	29.5	6.36	59	118	2.1	30.0	14.20	0.180	1.71	9.62	13.40	2.30	0.09	0.005	2.07	32.65	8.40	0.5	10.85
Jun.	28.0	5.25	48	100	1.9	25.0	12.43	0.230	3.80	10.02	10.50	2.70	0.21	0.011	3.16	38.15	7.90	0.6	12.09
Jul.	27.5	5.81	53	98	0.5	26.0	14.20	0.100	2.37	8.42	10.10	3.00	0.23	0.009	2.19	30.16	8.90	0.6	11.30
Aug.	26.5	5.62	59	93	1.6	45.0	12.63	0.090	3.62	9.60	11.30	3.00	0.24	0.015	2.40	45.80	7.45	0.7	14.30
Sep.	27.0	5.58	52	95	2.1	30.0	14.20	0.117	3.13	6.81	11.20	4.30	0.21	0.007	5.35	39.07	8.20	0.6	12.63
Oct.	28.3	5.92	50	98	1.2	31.0	12.20	0.140	2.89	8.63	10.30	4.00	0.24	0.006	2.40	34.60	7.53	0.5	11.36
Nov.	28.2	5.66	53	95	0.8	28.0	12.43	0.039	2.37	8.02	11.40	4.00	0.23	0.005	4.62	39.15	8.52	0.6	10.62

Table. 1.1.2. Physico-chemical parameters of Site-2 during Dec.2009 – Nov. 2011.

Site-3 Months	Temp. ˚C	pH	TDS mg/L	EC µS/cm	Turb. NTU	Alkalinity mg/L	Chloride mg/L	Phosphate mg/L	Sulfate mg/L	Calcium mg/L	Sodium mg/L	Potassium mg/L	Nitrate mg/L	Nitrites mg/L	mg mg/L	TH mg/L	DO mg/L	BOD mg/L	COD mg/L
Dec.'09	28.0	5.16	68	96	0.9	21.0	26.63	0.040	4.44	7.01	12.23	2.90	0.32	0.002	2.07	26.02	5.46	0.7	11.20
Jan. '10	28.0	6.43	49	100	5.6	20.5	19.53	0.120	4.81	4.41	13.20	3.00	0.80	0.000	4.26	28.79	6.07	0.5	4.80
Feb.	28.5	6.36	48	88	2.1	35.0	19.52	0.016	3.70	7.62	12.00	2.80	0.92	0.034	1.95	27.18	6.07	0.7	11.20
Mar.	29.0	6.03	48	101	1.5	19.0	21.30	0.036	3.24	4.81	12.20	3.30	0.93	0.000	3.40	26.28	6.38	0.7	9.60
Apr.	29.5	5.95	56	96	2.0	23.0	23.08	0.040	1.82	4.41	10.60	3.60	0.09	0.003	3.64	26.22	4.63	0.6	9.60
May.	28.5	6.40	71	107	3.8	29.0	15.98	0.050	3.13	5.21	12.90	3.00	0.59	0.008	4.13	30.19	4.27	0.7	6.40
Jun.	28.5	6.62	60	100	4.0	28.0	17.75	0.012	3.74	6.01	15.20	3.90	0.67	0.011	3.40	29.15	4.13	0.5	6.30
Jul.	28.5	6.53	63	112	9.3	35.0	14.20	0.009	4.26	5.30	9.60	8.00	0.42	0.016	2.10	30.10	9.10	0.5	9.80
Aug.	27.0	5.62	63	110	1.5	29.0	17.75	0.060	6.17	6.81	11.30	2.90	0.48	0.010	3.65	32.10	5.78	0.5	9.14
Sep.	28.0	5.95	68	111	1.6	28.0	11.60	0.010	3.25	6.16	11.60	3.80	0.09	0.006	2.92	29.30	2.30	0.4	11.60
Oct.	28.0	5.90	69	112	2.6	30.0	18.60	0.060	3.26	6.25	6.42	3.40	0.25	0.002	2.10	29.25	5.30	0.5	9.60
Nov.	28.0	5.73	55	108	0.8	23.0	14.20	0.060	5.98	7.21	12.60	4.00	0.48	0.013	2.92	30.16	2.62	0.5	10.20
Dec.	29.0	5.90	47	91	1.8	26.0	10.65	0.070	3.99	5.61	11.90	3.80	0.98	0.020	2.43	24.16	5.70	0.6	9.92
Jan. '11	27.5	6.98	48	85	4.8	29.0	15.98	0.031	2.85	6.41	15.20	3.10	0.12	0.005	2.55	26.20	9.02	0.4	10.26
Feb.	29.0	6.85	45	89	1.4	26.0	15.12	0.013	3.20	4.92	12.20	3.30	0.13	0.005	2.00	30.20	5.10	0.6	9.06
Mar.	29.0	6.01	45	101	0.5	10.0	8.83	0.040	1.80	4.80	8.60	3.00	0.12	0.010	4.26	29.64	8.35	0.5	9.26
Apr.	29.5	6.09	48	108	0.5	18.0	6.98	0.030	2.60	12.02	7.20	3.80	0.14	0.003	2.43	36.60	6.30	0.6	12.60
May.	30.0	6.06	48	105	0.8	15.0	14.20	0.020	2.37	7.21	13.30	3.70	0.66	0.008	1.46	24.16	5.98	0.7	11.98
Jun.	28.5	6.30	79	136	6.3	23.0	14.20	0.040	4.08	7.62	6.90	6.90	0.41	0.016	2.92	31.10	8.30	0.7	9.36
Jul.	28.0	5.68	72	130	0.9	24.0	15.98	0.010	2.94	7.21	8.30	3.10	0.47	0.010	3.40	32.10	8.63	0.7	14.60
Aug.	27.0	5.92	79	135	0.8	29.0	14.25	0.060	3.10	5.60	9.30	2.60	0.33	0.016	3.86	26.90	6.80	0.6	15.25
Sep.	27.5	5.82	75	128	4.0	23.0	10.65	0.043	5.79	7.21	10.60	5.60	0.31	0.010	1.95	26.20	7.36	0.5	8.95
Oct.	28.0	5.82	73	125	2.1	21.0	10.25	0.062	6.30	5.41	10.20	4.80	0.62	0.016	4.11	35.30	7.00	0.6	12.10
Nov.	28.6	5.45	48	91	1.5	12.0	10.65	0.078	3.04	4.81	10.60	2.40	0.13	0.016	3.40	26.14	8.20	0.5	10.85

Table. 1.1.3. Physico-chemical parameters of Site-3 during Dec.2009 – Nov. 2011.

Site-4 Months	Temp. ˚C	pH	TDS mg/L	EC µS/cm	Turb. NTU	Alkalinity mg/L	Chloride mg/L	Phosphate mg/L	Sulfate mg/L	Calcium mg/L	Sodium mg/L	Potassium mg/L	Nitrate mg/L	Nitrites mg/L	mg mg/L	TH mg/L	DO mg/L	BOD mg/L	COD mg/L
Dec.'09	27.0	5.25	78	113	3.0	33.5	26.63	0.060	4.81	8.40	13.10	2.80	0.13	0.000	3.53	35.55	6.07	0.6	14.40
Jan. '10	27.0	6.35	62	123	1.1	33.5	21.30	0.100	5.65	9.22	14.80	3.20	0.08	0.002	2.07	31.79	9.97	0.8	6.40
Feb.	27.0	6.25	61	110	8.0	34.0	30.18	0.091	4.17	6.81	13.90	3.10	0.14	0.004	3.40	31.10	10.97	0.6	16.00
Mar.	29.0	6.02	58	121	3.9	29.0	28.40	0.036	3.61	6.41	13.10	3.40	0.42	0.110	7.05	35.23	8.61	0.8	12.80
Apr.	30.0	6.30	65	112	5.3	34.0	28.40	0.050	3.03	6.01	14.20	4.20	0.08	0.002	3.40	29.14	8.71	0.5	6.40
May.	29.0	6.53	90	129	0.8	33.5	15.98	0.070	2.53	6.81	14.60	2.90	0.16	0.003	5.12	38.16	8.71	0.7	6.40
Jun.	29.0	6.60	71	113	11.7	34.0	15.98	0.020	3.23	8.42	15.20	3.90	0.09	0.001	3.65	36.14	7.20	0.7	11.20
Jul.	28.5	6.75	62	115	10.3	36.0	18.20	0.020	3.80	7.24	10.10	3.60	0.10	0.009	3.20	32.90	4.63	0.7	8.90
Aug.	27.0	5.72	65	111	0.9	34.0	19.53	0.060	3.70	8.02	10.60	4.60	0.18	0.002	4.38	38.19	8.61	0.7	8.92
Sep.	28.0	5.90	72	115	1.0	36.0	10.25	0.010	2.88	7.10	9.80	3.10	0.08	0.003	3.40	31.63	4.45	0.6	20.00
Oct.	27.5	5.97	65	118	3.2	39.0	12.50	0.030	2.99	8.63	10.32	5.20	0.41	0.012	3.20	39.20	8.10	0.6	8.20
Nov.	27.5	5.58	68	119	4.1	33.0	10.65	0.040	4.27	12.02	8.90	5.20	0.16	0.002	1.95	38.22	5.70	0.7	12.20
Dec.	28.0	6.45	58	103	2.9	30.0	14.20	0.100	3.32	9.62	9.20	4.60	0.14	0.002	1.95	32.10	2.44	0.8	16.25
Jan. '11	27.0	6.60	75	116	4.0	30.0	14.20	0.047	2.37	10.42	16.20	4.60	0.20	0.003	1.34	31.10	9.36	0.6	14.60
Feb.	27.5	6.35	73	119	3.6	27.5	13.30	0.062	3.40	8.92	13.60	4.00	0.40	0.003	3.00	31.60	5.63	0.7	11.36
Mar.	28.5	5.90	55	119	0.9	29.0	10.65	0.100	5.79	8.42	12.00	4.90	0.08	0.005	2.65	36.16	10.02	0.7	10.50
Apr.	29.0	6.20	59	125	3.2	29.0	10.05	0.080	4.86	9.42	11.30	3.92	0.02	0.010	1.95	36.16	9.07	0.4	9.26
May.	29.5	5.89	53	113	4.6	26.0	15.98	0.220	4.08	8.22	14.40	3.90	0.08	0.003	3.16	33.65	6.45	0.6	12.36
Jun.	28.5	6.90	81	140	6.8	36.0	10.65	0.100	7.60	10.02	10.10	3.60	0.28	0.025	2.68	36.16	9.36	0.6	10.29
Jul.	28.0	5.61	75	135	1.1	30.0	12.43	0.020	4.75	9.62	11.00	2.90	0.14	0.016	3.65	39.18	8.00	0.8	10.98
Aug.	27.5	5.85	76	140	1.5	36.0	11.32	0.080	4.65	6.99	12.40	2.80	0.26	0.021	4.10	33.80	9.25	0.7	11.39
Sep.	27.5	5.98	63	10	3.8	30.0	12.43	0.066	2.37	8.02	14.20	4.90	0.13	0.016	3.90	36.16	9.02	0.6	8.00
Oct.	27.9	6.20	60	115	3.2	28.0	12.25	0.075	3.19	7.25	12.60	4.90	0.24	0.032	4.26	32.92	8.63	0.6	8.93
Nov.	26.9	5.63	55	98	2.0	30.0	8.88	0.039	3.99	5.21	13.00	4.90	0.17	0.006	5.84	37.16	7.55	0.6	11.90

Table. 1.1. 4. Physico-chemical parameters of Site-4 during Dec.2009 – Nov. 2011.

Site-5 Months	Temp. ˚C	pH	TDS mg/L	EC µS/cm	Turb. NTU	Alkalinity mg/L	Chloride mg/L	Phosphate mg/L	Sulfate mg/L	Calcium mg/L	Sodium mg/L	Potassium mg/L	Nitrate mg/L	Nitrites mg/L	mg mg/L	TH mg/L	DO mg/L	BOD mg/L	COD mg/L
Dec.'09	27.0	5.57	180	264	8.0	80.5	33.73	0.060	8.24	25.85	21.90	10.00	0.40	0.008	4.01	81.14	10.10	0.8	9.60
Jan. '10	27.0	6.38	140	284	4.6	87.0	28.40	0.110	10.56	23.25	24.30	11.00	0.20	0.010	6.93	86.84	6.07	1.2	12.80
Feb.	27.0	6.08	146	266	9.2	88.0	33.73	0.028	6.48	26.45	23.20	11.30	0.38	0.073	5.11	87.20	6.07	0.9	22.40
Mar.	29.0	6.30	144	299	10.7	86.0	35.50	0.051	6.85	20.84	25.30	13.20	0.44	0.020	8.27	86.32	6.43	1.0	14.40
Apr.	30.0	6.75	163	289	6.3	90.0	39.05	0.100	4.14	20.84	25.60	14.10	0.17	0.002	7.54	83.18	7.20	0.9	12.80
May.	28.0	6.24	200	309	5.3	100.5	33.73	0.140	7.17	23.25	24.30	12.60	0.33	0.095	6.81	86.24	6.40	0.9	14.40
Jun.	28.0	6.67	202	343	7.0	102.0	46.15	0.030	5.66	24.05	25.80	15.40	0.26	0.120	6.08	85.33	3.72	1.2	15.20
Jul.	28.0	6.40	131	243	12.6	55.0	39.00	0.030	4.46	25.62	12.00	5.00	0.26	0.003	5.00	83.20	6.30	0.9	14.60
Aug.	28.0	5.90	130	240	2.5	71.0	28.40	0.140	7.60	20.84	25.30	11.60	0.48	0.010	9.00	89.20	6.38	0.8	7.29
Sep.	27.0	5.75	142	242	1.5	68.0	21.98	0.006	8.36	16.30	18.80	10.60	1.36	0.041	6.26	81.50	1.62	0.7	25.30
Oct.	28.0	5.95	139	242	4.0	80.0	30.30	0.008	7.32	20.15	18.60	13.80	0.51	0.080	5.38	83.30	8.90	0.8	12.60
Nov.	28.0	5.98	120	247	6.3	71.0	24.85	0.150	7.69	26.05	29.00	11.30	0.32	0.050	3.65	80.32	1.80	0.8	13.60
Dec.	27.5	6.04	119	231	2.8	76.0	42.60	0.360	8.64	22.04	25.60	10.00	0.66	0.139	6.32	81.33	3.20	1.2	20.30
Jan. '11	26.5	6.10	250	380	2.0	112.0	56.80	0.078	7.69	26.05	29.30	20.00	0.19	0.136	5.96	89.83	8.32	0.9	28.80
Feb.	27.0	6.00	240	360	2.1	85.5	50.30	0.080	10.20	20.15	25.20	16.00	0.53	0.210	4.01	82.30	10.12	1.0	15.60
Mar.	28.0	6.25	134	298	3.9	61.0	42.60	0.200	7.60	26.45	21.30	13.60	0.20	0.070	4.13	83.18	6.62	0.8	13.40
Apr.	29.0	6.50	141	305	3.0	65.0	36.00	0.190	7.92	20.01	21.00	10.20	0.08	0.010	4.13	85.13	5.78	0.9	24.20
May.	29.0	6.70	135	300	2.1	63.0	28.40	0.050	6.17	24.65	25.50	15.40	0.14	0.068	5.11	82.69	7.25	1.2	13.85
Jun.	28.0	5.98	145	280	0.3	52.0	31.95	0.390	9.02	20.44	12.00	4.80	0.38	0.003	3.16	64.15	10.00	0.9	12.38
Jul.	27.5	5.91	130	250	0.9	51.0	28.40	0.360	5.98	20.84	16.20	4.00	0.58	0.025	2.68	63.31	9.30	1.4	17.30
Aug.	27.0	6.21	145	260	0.6	98.0	29.30	0.530	7.32	20.90	13.60	6.90	0.69	0.039	5.92	89.60	9.80	0.9	16.80
Sep.	27.0	6.15	175	250	4.3	40.0	28.40	0.313	8.83	22.44	20.10	11.30	0.36	0.027	3.40	70.18	5.02	0.9	16.26
Oct.	28.2	6.25	180	260	4.2	39.0	26.30	0.316	9.63	25.30	20.20	10.30	0.49	0.042	6.30	86.20	9.80	0.8	13.98
Nov.	27.0	6.01	149	255	3.6	63.0	39.76	0.352	8.55	19.64	24.00	6.90	0.54	0.023	10.46	92.19	9.24	0.8	15.61

Table. 1.1.5. Physico-chemical parameters of Site-5 during Dec.2009 – Nov. 2011.

Site-6 Months	Temp. °C	pH	TDS mg/L	EC µS/cm	Turb. NTU	Alkalinity mg/L	Chloride mg/L	Phosphate mg/L	Sulfate mg/L	Calcium mg/L	Sodium mg/L	Potassium mg/L	Nitrate mg/L	Nitrites mg/L	mg mg/L	TH mg/L	DO mg/L	BOD mg/L	COD mg/L
Dec.'09	27.0	5.75	101	149	4.2	39.5	24.85	0.030	5.83	12.02	15.50	3.90	0.45	0.005	2.19	39.07	10.00	0.6	12.80
Jan. '10	27.0	6.48	70	143	3.3	34.5	23.08	0.100	6.67	8.42	16.60	4.60	0.24	0.004	2.68	32.15	9.16	0.7	8.00
Feb.	26.5	6.29	73	132	6.9	34.0	26.63	0.004	4.72	10.82	14.90	4.40	0.66	0.234	2.80	38.69	10.16	0.6	19.20
Mar.	29.0	6.51	72	151	7.7	31.0	24.85	0.048	5.46	4.81	15.40	5.10	0.59	0.001	4.86	32.13	9.17	0.6	11.20
Apr.	30.0	7.00	80	142	8.7	30.0	23.08	0.080	3.54	7.21	17.60	5.50	0.10	0.007	2.92	30.16	5.78	0.7	9.60
May.	29.0	6.63	130	194	4.2	38.0	14.20	0.110	5.25	8.02	16.30	5.90	0.69	0.004	4.62	39.13	7.20	0.6	12.80
Jun.	28.0	6.84	105	180	11.0	45.0	19.53	0.020	3.94	10.02	18.40	6.20	0.83	0.005	3.40	39.29	4.60	0.7	9.20
Jul.	28.0	6.81	75	129	10.8	21.0	18.20	0.030	3.90	6.98	9.00	2.90	0.16	0.008	2.60	42.01	8.40	0.6	9.20
Aug.	27.0	5.92	75	130	1.8	32.0	17.75	0.040	2.37	7.62	13.30	6.80	0.74	0.005	4.13	36.16	8.21	0.5	13.20
Sep.	28.5	6.25	78	131	2.9	35.0	11.62	0.005	2.96	7.80	10.10	8.80	0.08	0.002	1.93	33.00	2.44	0.7	14.20
Oct.	28.5	6.26	80	130	1.6	32.0	15.20	0.060	2.63	11.24	11.30	4.60	0.09	0.002	1.63	41.25	10.00	0.7	13.20
Nov.	28.0	5.78	70	141	1.2	28.0	8.88	0.040	3.32	8.02	16.30	5.80	0.46	0.011	2.94	31.18	4.63	0.6	7.82
Dec.	28.0	6.22	60	116	4.1	42.0	19.53	0.200	5.60	8.02	16.00	4.20	0.67	0.007	2.92	32.10	4.27	0.7	12.60
Jan. '11	27.0	6.20	108	195	2.1	40.0	15.98	0.063	1.99	11.22	16.30	6.90	0.72	0.016	1.34	33.77	7.60	0.8	25.60
Feb.	26.5	6.16	106	155	2.0	29.5	12.60	0.009	2.60	10.60	10.10	2.90	0.65	0.020	1.26	31.60	8.00	0.7	9.30
Mar.	27.0	5.80	66	141	3.0	28.0	21.30	0.080	2.47	10.42	12.80	3.20	0.12	0.007	3.16	39.07	9.36	0.6	12.46
Apr.	28.0	5.92	72	142	0.4	28.0	18.30	0.100	3.25	8.42	10.30	4.80	0.16	0.006	1.95	39.70	9.26	0.7	14.60
May.	28.5	6.66	78	159	3.2	30.0	12.43	0.040	2.37	10.22	15.50	5.80	0.26	0.006	2.92	37.65	8.80	0.8	10.90
Jun.	27.5	6.10	83	145	0.4	30.0	21.30	0.160	2.94	12.83	5.90	3.20	0.47	0.012	2.43	42.17	8.00	0.7	10.49
Jul.	27.0	6.01	78	145	1.6	21.0	17.75	0.150	1.99	12.42	8.60	2.10	0.45	0.009	2.43	41.16	8.50	0.9	9.60
Aug.	26.5	6.24	90	140	1.2	42.0	16.24	0.240	2.10	9.00	8.90	3.20	0.52	0.002	3.25	40.30	10.30	0.7	12.30
Sep.	27.0	6.31	75	140	2.0	16.0	17.75	0.098	3.89	6.41	12.60	8.30	0.23	0.018	3.16	29.14	7.32	0.6	10.25
Oct.	27.0	6.42	72	135	3.4	14.0	16.25	0.091	4.62	9.86	11.80	8.60	0.21	0.020	2.98	38.80	10.60	0.6	9.92
Nov.	27.2	5.80	65	121	2.1	29.0	14.20	0.023	2.37	8.42	17.00	2.00	0.26	0.005	2.43	31.16	8.45	0.6	8.92

Table. 1.1.6. Physico-chemical parameters of Site-6 during Dec.2009 – Nov. 2011.

Sites	Site-1				Site-2				Site-3			
Months	**Copepoda**	**Rotifera**	**Cladocera**	**Total zoo.**	**Copepoda**	**Rotifera**	**Cladocera**	**Total zoo.**	**Copepoda**	**Rotifera**	**Cladocera**	**Total zoo.**
Dec.'09	9.15	0.6	9.8	19.55	211.5	42.7	54	308.2	0.6	0.15	0.05	0.8
Jan. '10	101	97.35	0.2	198.55	66.6	16.2	9.9	92.7	0.5	0	0.05	0.55
Feb.	68.85	44	2.95	115.8	84.85	1.45	6.25	92.55	4.95	0.15	0	5.1
Mar.	56.2	7.5	11.8	75.5	74.1	2.8	14.5	91.4	2.15	0.6	0.55	3.3
Apr.	120	0.55	0.55	121.1	27.8	5.4	6.4	39.6	0.75	0.05	0.7	1.5
May.	16.4	1.05	0.9	18.35	60.9	3.65	4.4	68.95	3.85	0.1	0	3.95
Jun.	2.3	0.05	0.05	2.4	1	0	0.4	1.4	0.1	0	0	0.1
Jul.	30.8	0.9	0.35	32.05	6.15	0	0	6.15	0.15	0	0.4	0.55
Aug.	3.4	0.6	0	4	0.75	0	0	0.75	0	0	0.2	0.2
Sep.	0.15	0	0	0.15	4.75	0	0	4.75	0	0	0	0
Oct.	1.5	0	0	1.5	55.8	0	0.2	56	0.25	0	0	0.25
Nov.	23	4	0	27	44.7	0	0	44.7	0.3	0	0	0.3
Dec.	14	3.8	1.8	19.6	32	0	0	32	0.15	0	0	0.15
Jan. '11	34.3	15.05	1.4	50.75	114.4	0.4	4	118.8	0.9	0	0.15	1.05
Feb.	32.2	7.8	2.2	42.2	95.2	0	11.5	106.7	1.85	0.2	0	2.05
Mar.	51.6	3	0.6	55.2	54.5	0	9.25	63.75	0.4	0.1	0.1	0.6
Apr.	70.4	2.2	0	72.6	16.9	0.25	2.8	19.95	2.5	0	0.25	2.75
May.	53.65	1.3	8.15	63.1	105.3	3.6	7.2	116.1	1.8	0	0.8	2.6
Jun.	8.9	0.35	0	9.25	6.9	0	0.8	7.7	0.85	0	0	0.85
Jul.	1.2	0	0.05	1.25	4.15	0	0	4.15	0.1	0	0.65	0.75
Aug.	7.55	0.85	0	8.4	7.95	0.15	0	8.1	1.35	0	0.2	1.55
Sep.	17.05	0	0.55	17.6	3.15	0	0	3.15	6.5	0	0.4	6.9
Oct.	60.3	4.2	2.4	66.9	56	24.3	1.15	81.45	9.3	0.95	0	10.25
Nov.	172.15	10.8	11.4	194.35	149.85	89.55	0.9	240.3	0.9	0	0	0.9
Average	39.84	8.58	2.30	50.71	53.55	7.94	5.57	67.05	1.68	0.10	0.19	1.96

Table. 1.2.1. Zooplankton abundance (Ind/L) from Site-1, Site-2 and Site-3 during Dec. 2009 – Nov. 2011.

Sites	Site-4				Site-5				Site-6			
Months	**Copepoda**	**Rotifera**	**Cladocera**	**Total zoo.**	**Copepoda**	**Rotifera**	**Cladocera**	**Total zoo.**	**Copepoda**	**Rotifera**	**Cladocera**	**Total zoo.**
Dec.'09	1.05	0.6	0.45	2.1	133.65	1	20.15	154.8	17.55	20.6	0.2	38.35
Jan. '10	9.45	3.5	11.55	24.5	20.9	0.6	3.75	25.25	17.3	2.85	1.05	21.2
Feb.	22.8	15.6	13.05	51.45	66.1	0.65	7.3	74.05	23.1	5.5	0.75	29.35
Mar.	7.2	7.8	0.35	15.35	91.8	21.6	60.15	173.55	29.7	0.75	0.5	30.95
Apr.	9.75	21.65	1.15	32.55	91.5	2.4	33.65	127.55	16.1	14.95	1.5	32.55
May.	48.95	1.8	1.75	52.5	82.05	10.6	2.7	95.35	85.75	1.25	0.15	87.15
Jun.	9	61.5	13	83.5	15.8	0	50.2	66	16.7	4.4	9	30.1
Jul.	2.2	0.5	4.15	6.85	103.7	0.35	0	104.05	32.4	6.1	2.8	41.3
Aug.	2.05	2.1	6	10.15	15.47	1.25	0	16.72	17.85	12	1.25	31.1
Sep.	3.4	1.15	0.25	4.8	5.85	1.5	0.45	7.8	5.25	33.25	1.25	39.75
Oct.	4.9	0.9	0.2	6	25.5	24.75	1	51.25	3.7	0.65	0.15	4.5
Nov.	9.75	1.6	0.65	12	34.9	11.5	6.25	52.65	20.55	33	1.8	55.35
Dec.	5.9	0.4	0.5	6.8	52.2	6	13.8	72	37.5	107	3.5	148
Jan. '11	7.45	1.75	9.3	18.5	15.7	0.25	11.75	27.7	24.3	11	2.8	38.1
Feb.	2.15	4.3	9	15.45	44.25	11.9	39	95.15	19.2	4.15	3.35	26.7
Mar.	1.75	24	0.25	26	69.5	40.5	16.75	126.75	20.25	1	5	26.25
Apr.	7.4	3	0.15	10.55	25.5	2.4	4.2	32.1	21.5	0.8	1.6	23.9
May.	1.4	1.15	0.15	2.7	52.75	39.75	16	108.5	45.3	0	8.1	53.4
Jun.	9.1	11.5	3.35	23.95	32.8	11	27.8	71.6	12	2.8	2.1	16.9
Jul.	1.05	1.05	1.3	3.4	4.65	0	0.75	5.4	5.7	11.2	0.25	17.15
Aug.	3.3	0	3.6	6.9	34.7	0.45	0	35.15	13.5	2.8	0	16.3
Sep.	3.2	0	0	3.2	48.3	0.7	0.7	49.7	1.3	0.3	0	1.6
Oct.	5.15	1.3	1.1	7.55	46.5	11	12.35	69.85	6.1	1.6	0.3	8
Nov.	2.15	1.65	2.8	6.6	152.1	3.15	48.6	203.85	21.9	1.5	2.05	25.45
Average	7.52	7.03	3.50	18.06	52.76	8.47	15.72	76.95	21.44	11.64	2.06	35.14

Table. 1.2.2. Zooplankton abundance (Ind/L) from Site-4, Site-5 and Site-6 during Dec. 2009 – Nov. 2011.

Parameters	**Normal and / or Max. limit**	**Site-1**	**Site-2**	**Site-3**	**Site-4**	**Site-5**	**Site-6**
Temp. ˚C *	-----	27.90±0.74	28.35±0.95	28.38±0.76	28.01±0.90	27.78±0.85	27.65±0.92
pH	6.0 - 9.0	6.40±0.53	6.19±0.50	6.07±0.43	6.12±0.41	6.17±0.29	6.27±0.35
TDS mg/L **	500-1500	77.23±10.79	57.89±7.72	59.39±11.86	66.67±9.33	157.52±35.21	81.75±16.69
EC μs/cms **	1000 – 4770	141.79±12.96	106.17±12.89	106.88±14.88	113.83±24.31	279.04±39.57	145.25±19.96
Turbidity NTU	10	3.77±2.79	3.81±3.63	2.55±2.18	3.79±2.90	4.49±3.20	3.74±3.06
Alkalinity mg/L**	200-600	36.13±3.40	33.50±6.73	24.02±6.37	32.13±3.33	74.35±19.54	31.23±7.88
Chloride mg/L**	250 -1000	18.29±5.43	14.93±4.94	15.33±4.69	16.01±6.46	34.82±8.44	17.98±4.56
Phosphate mg/L**	0.02-0.20	0.07±0.06	0.06±0.06	0.04±0.03	0.07±0.04	0.17±0.15	0.08±0.06
Sulphate mg/L**	200 – 450	4.35±1.61	2.68±0.86	3.74±1.29	3.96±1.22	7.59±1.60	3.62±1.37
Calcium mg/L**	75	11.28±1.66	9.33±1.62	6.25±1.62	8.22±1.55	22.60±2.76	9.20±2.03
Potassium mg/L**	-------	4.46±0.94	2.84±1.14	3.78±1.34	3.96±0.82	11.22±3.82	4.99±1.95
Sodium mg/L**	200	12.51±2.75	10.85±1.13	11.01±2.37	12.44±2.08	22.00±4.83	13.35±3.43
Nitrates mg/L**	45	0.27±0.32	0.25±0.14	0.44±0.28	0.17±0.11	0.41±0.26	0.41±0.24
Nitrites mg/L	-------	0.005±0.004	0.009±0.014	0.010±0.008	0.012±0.022	0.054±0.054	0.017±0.046
Magnesium mg/L**	30	2.88±0.70	2.83±1.29	2.97±0.85	3.45±1.29	5.65±1.92	2.79±0.90
TH mg/L**	300-600	40.68±4.06	36.75±5.05	28.89±3.16	34.73±2.90	82.66±7.25	36.29±4.28
DO mg/L	3 and above	7.34±2.09	7.23±2.02	6.20±1.86	7.77±2.06	6.89±2.55	7.93±2.15
BOD mg/L**	3	0.56±0.09	0.59±0.09	0.58±0.10	0.65±0.10	0.94±0.17	0.67±0.09
COD mg/L**	250	10.33±2.39	11.01±2.53	10.15±2.35	11.15±3.38	15.98±4.98	11.97±3.86
MPN(Coli./100ml)	10	1050±777	26.5±4.94	910±975	920±961	885±1011	1250±494
Zooplk. Ind/L	--------	50.71±56.61	67.05±76.07	1.96±2.48	18.06±19.75	76.95±52.56	35.14±30.03

Key: * $P < 0.05$, ** $P < 0.01$

Table. 1.2.3. Average physico-chemical and biological parameters throughout study period in different sites.

Table. 1.3.1: Pearson's bivariate correlation for physico-chemical factors and zooplankton abundance in Site-1.

Site-1	Temp	pH	TDS	EC	Turb.	Alkal.	Cl	Po_4	So_4	Ca	Na	K	No_3	No_2	Mg	TH	DO	BOD	COD
Copepoda	0.16	-0.17	-0.08	0.01	0.07	0.03	0.25	-0.06	0.18	-0.07	0.39	0.04	0.19	0.23	-0.13	-0.23	0.20	-0.38	-0.17
Rotifera	-0.11	0.20	0.09	0.34	-0.01	0.09	0.33	0.09	.566**	0.22	0.37	0.14	.677**	.569**	-0.24	0.11	-0.06	-0.28	-0.22
Cladocera	-0.14	-0.21	0.10	0.02	0.31	-0.06	0.18	-0.11	0.30	0.40	0.30	0.13	0.23	-0.08	-0.29	0.18	0.26	0.11	-0.15
Total zoo.	0.07	-0.07	-0.03	0.13	0.07	0.06	0.33	-0.02	0.37	0.06	.457*	0.09	.409*	0.38	-0.21	-0.12	0.15	-0.39	-0.22

*. Correlation is significant at the 0.05 level (2-tailed). **. Correlation is significant at the 0.01 level (2-tailed).

Table. 1.3.2: Pearson's bivariate correlation for physico-chemical factors and zooplankton abundance in Site-2.

Site-2	Temp	pH	TDS	EC	Turb.	Alkal.	Cl	Po_4	So_4	Ca	Na	K	No_3	No_2	Mg	TH	DO	BOD	COD
Copepoda	0.28	0.05	0.15	0.14	0.20	-0.03	0.24	-0.15	0.21	0.24	0.10	-0.24	0.05	-0.12	-0.04	-0.06	0.40	-0.23	-0.09
Rotifera	-0.02	-0.34	0.00	-0.11	0.02	-0.22	0.05	-0.02	0.06	-0.14	0.07	0.11	-0.03	-0.13	0.15	-0.06	0.21	0.04	-0.06
Cladocera	0.20	-0.14	0.40	0.28	.518**	0.00	0.34	-0.13	0.36	0.20	0.01	-0.30	0.03	-0.18	-0.15	-0.10	0.28	0.10	0.01
Total zoo.	0.22	-0.08	0.17	0.11	0.22	-0.08	0.23	-0.13	0.22	0.16	0.09	-0.18	0.03	-0.14	-0.01	-0.07	0.38	-0.14	-0.08

*. Correlation is significant at the 0.05 level (2-tailed). **. Correlation is significant at the 0.01 level (2-tailed).

Table. 1.3.3: Pearson's bivariate correlation for physico-chemical factors and zooplankton abundance in Site-3.

Site-3	Temp	pH	TDS	EC	Turb.	Alkal.	Cl	Po_4	So_4	Ca	Na	K	No_3	No_2	Mg	TH	DO	BOD	COD
Copepoda	-0.02	0.00	0.21	0.19	-0.03	-0.01	-0.18	-0.01	0.33	0.08	0.03	0.13	0.20	0.29	-0.02	0.19	0.09	0.25	0.09
Rotifera	0.05	-0.10	0.03	0.13	-0.11	-0.19	0.03	0.08	0.25	-0.22	0.03	0.06	0.37	-0.08	0.28	0.19	0.08	0.36	0.09
Cladocera	.450*	-0.14	-0.13	0.03	-0.26	-0.27	0.32	-0.27	-.409*	-0.10	0.02	-0.12	0.16	-0.28	0.00	-0.25	0.05	0.30	0.25
Total zoo.	0.02	-0.01	0.20	0.25	-0.03	-0.08	-0.21	-0.01	0.28	0.07	-0.03	0.16	0.19	0.23	0.03	0.20	0.17	0.29	0.14

*. Correlation is significant at the 0.05 level (2-tailed). **. Correlation is significant at the 0.01 level (2-tailed).

Table. 1.3.4: Pearson's bivariate correlation for physico-chemical factors and zooplankton abundance in Site-4.

Site-4	Temp	pH	TDS	EC	Turb.	Alkal.	Cl	Po_4	So_4	Ca	Na	K	No_3	No_2	Mg	TH	DO	BOD	COD
Copepoda	0.20	0.36	.452*	0.18	0.01	0.19	0.22	0.03	-0.18	-0.15	0.28	-0.29	-0.05	-0.07	0.16	0.07	0.27	0.02	-0.21
Rotifera	0.38	0.30	0.00	-0.08	.581**	0.11	0.18	-0.13	0.06	-0.07	0.32	0.01	-0.20	-0.07	0.01	-0.04	0.18	0.00	-0.05
Cladocera	-0.34	.411*	0.13	-0.04	.408*	0.15	0.27	-0.06	0.02	0.05	.482*	-0.20	-0.01	-0.25	-0.17	-0.32	0.28	0.20	0.01
Total zoo.	0.30	.488*	0.25	0.02	.501*	0.20	0.29	-0.08	-0.05	-0.12	.461*	-0.18	-0.17	-0.13	0.04	-0.07	0.31	0.05	-0.14

*. Correlation is significant at the 0.05 level (2-tailed). **. Correlation is significant at the 0.01 level (2-tailed).

Table. 1.3.5: Pearson's bivariate correlation for physico-chemical factors and zooplankton abundance in Site-5.

Site-5	Temp	pH	TDS	EC	Turb.	Alkal.	Cl	Po_4	So_4	Ca	Na	K	No_3	No_2	Mg	TH	DO	BOD	COD
Copepoda	0.11	0.01	-0.01	-0.11	.546**	-0.03	0.18	-0.04	-0.18	0.21	0.04	-0.16	-0.18	-0.22	0.32	0.25	0.25	-0.27	-0.30
Rotifera	0.39	0.20	-0.19	0.13	-0.06	-0.16	-0.04	-0.17	-0.01	0.18	0.11	0.33	-0.20	0.18	-0.12	-0.01	0.08	-0.01	-0.28
Cladocera	0.25	0.24	0.29	.439*	0.23	0.21	.479*	-0.10	-0.05	-0.11	0.33	0.24	-0.13	0.18	0.35	0.14	0.16	0.13	-0.17
Total zoo.	0.26	0.13	0.05	0.09	.475*	0.01	0.29	-0.10	-0.15	0.16	0.17	0.04	-0.23	-0.07	0.34	0.24	0.26	-0.17	-0.34

*. Correlation is significant at the 0.05 level (2-tailed). **. Correlation is significant at the 0.01 level (2-tailed).

Table. 1.3.6: Pearson's bivariate correlation for physico-chemical factors and zooplankton abundance in Site-6.

Site-6	Temp	pH	TDS	EC	Turb.	Alkal.	Cl	Po_4	So_4	Ca	Na	K	No_3	No_2	Mg	TH	DO	BOD	COD
Copepoda	0.37	0.27	0.421*	0.461*	0.21	0.32	-0.10	0.03	0.29	-0.21	0.37	-0.08	0.35	-0.01	0.453*	0.07	-0.07	-0.12	0.10
Rotifera	0.13	-0.13	-0.26	-0.33	0.00	0.33	-0.04	0.27	0.26	-0.13	0.19	0.03	0.19	-0.06	-0.06	-0.30	-.576**	0.07	0.05
Cladocera	0.13	0.27	0.04	0.27	0.34	0.27	-0.12	-0.22	-0.19	0.14	0.30	-0.04	0.15	-0.09	-0.05	0.05	-0.32	0.25	-0.07
Total zoo.	0.33	0.09	0.06	0.05	0.15	0.443*	-0.10	0.20	0.34	-0.21	0.37	-0.01	0.35	-0.06	0.21	-0.19	-.501*	0.00	0.09

*. Correlation is significant at the 0.05 level (2-tailed). **. Correlation is significant at the 0.01 level (2-tailed).

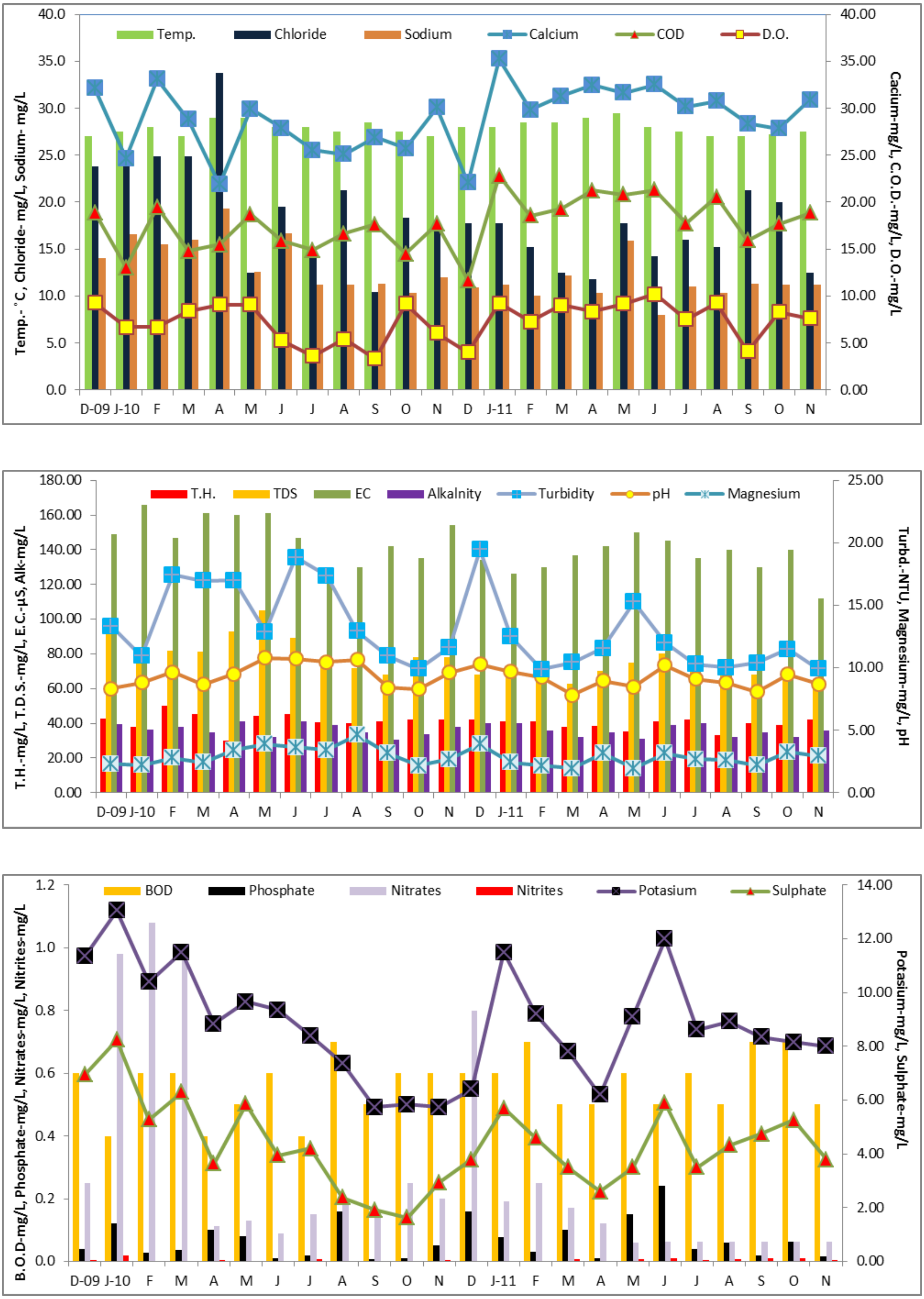


Fig. 1.1.1.Physico-chemical parameters of Site-1 (Shri Shantadurga Temple tank – Kavalem).

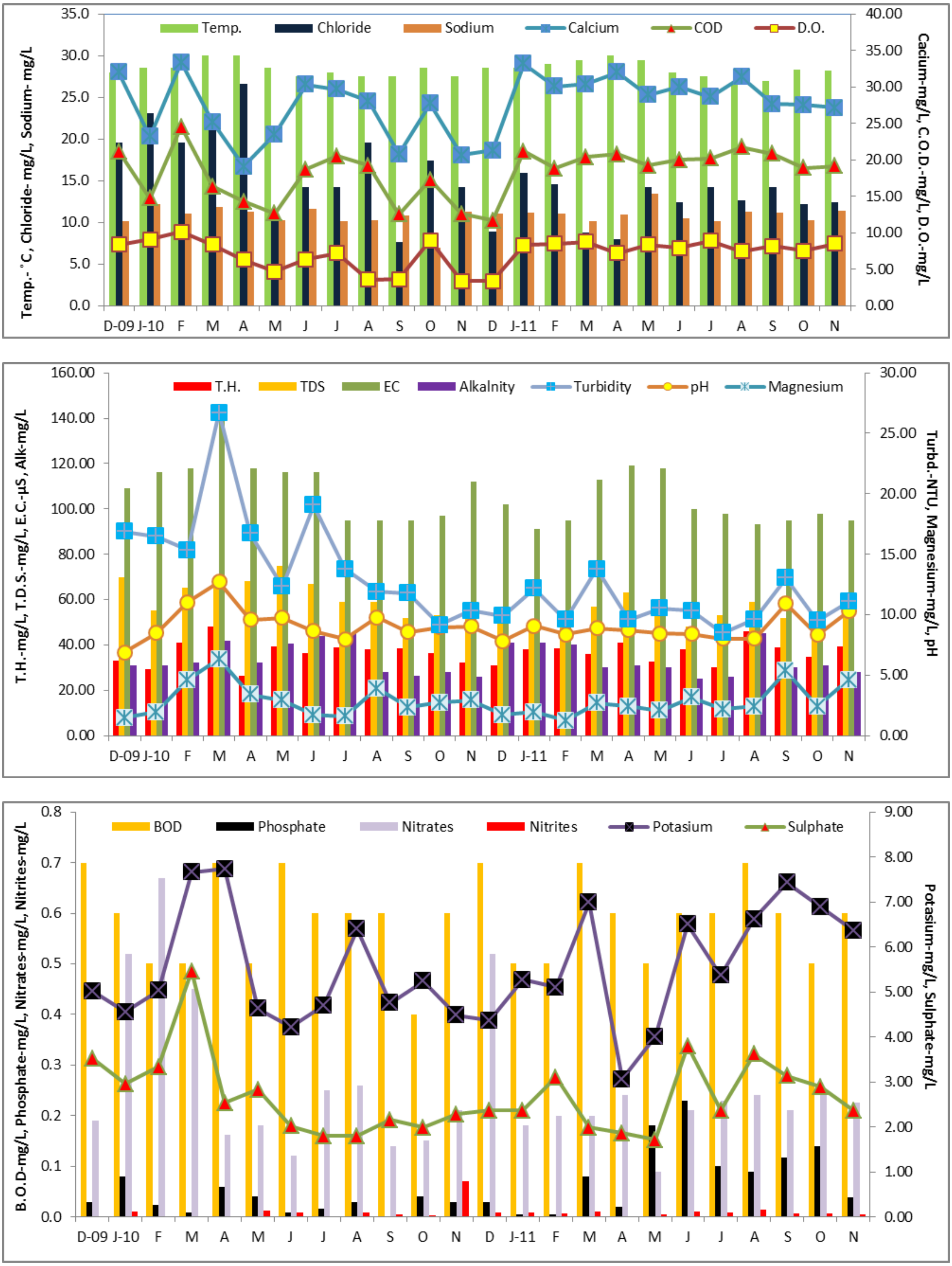


Fig. 1.1.2. Physico-chemical parameters of Site-2 (Shri Ramnath Temple tank – Ramnathi).

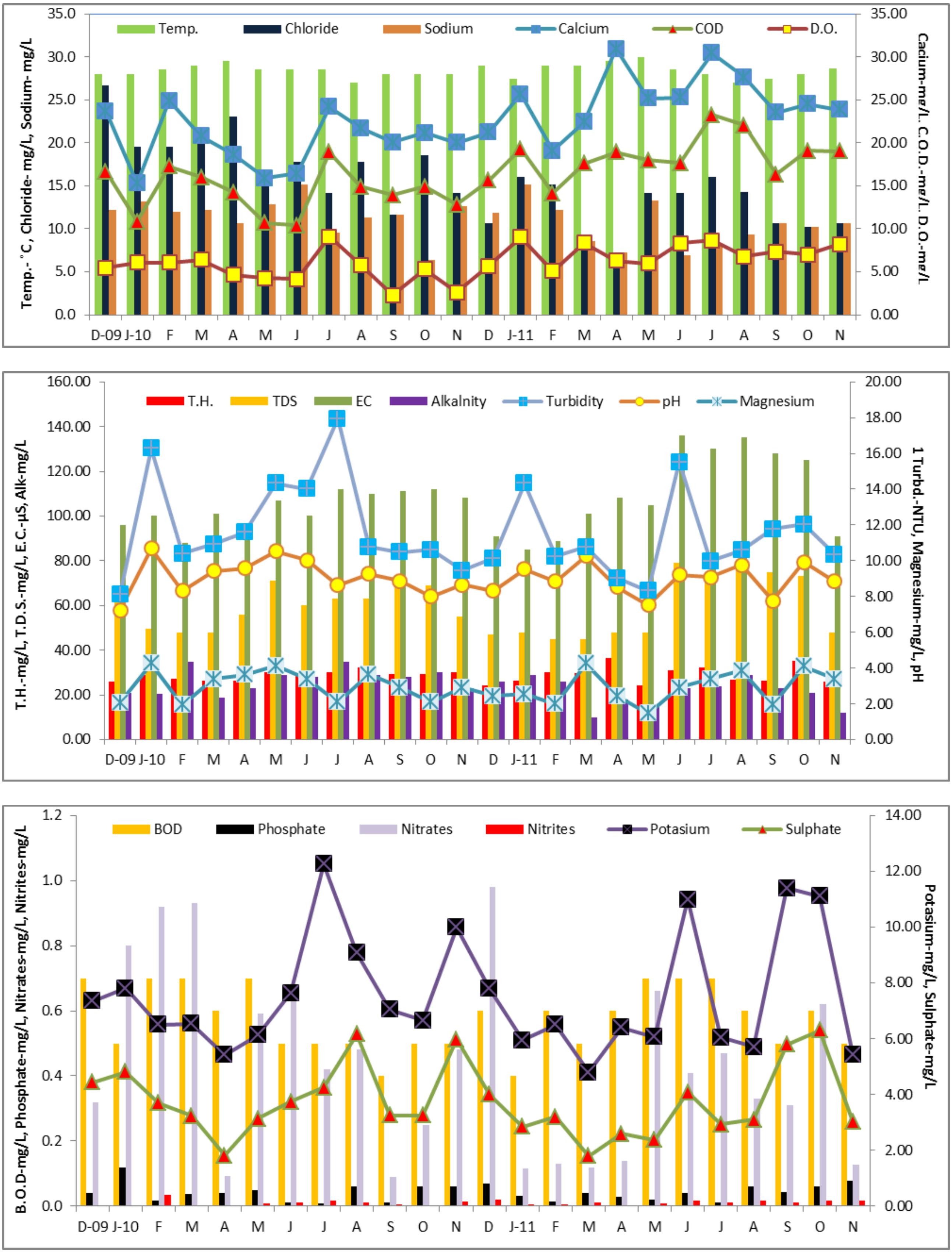


Fig. 1.1.3. Physico-chemical parameters of Site-3 (Shri Naguesh Temple tank – Nagueshim).

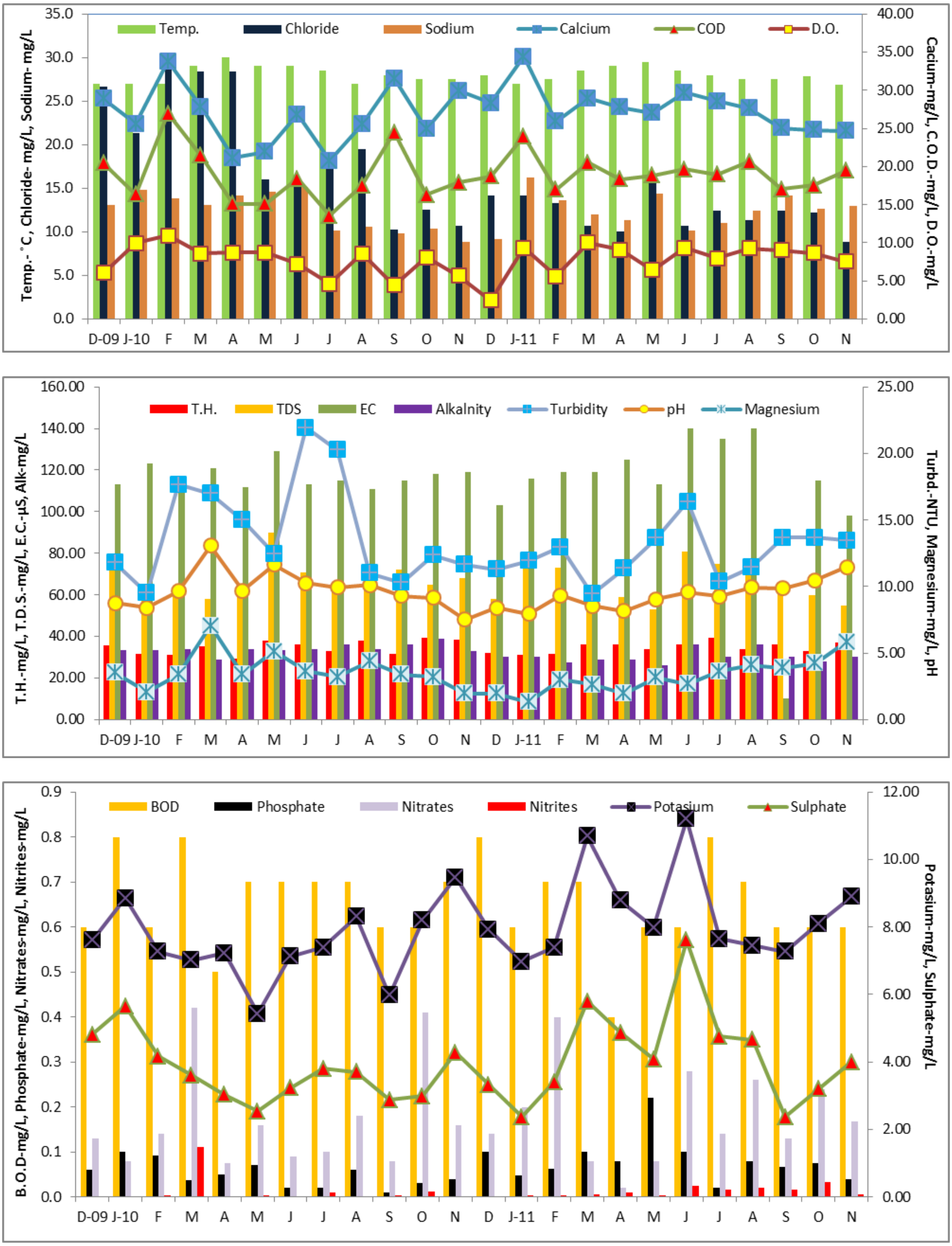


Fig. 1.1.4. Physico-chemical parameters of Site-4 (Shri Mahalaxmi Temple tank – Bandora).

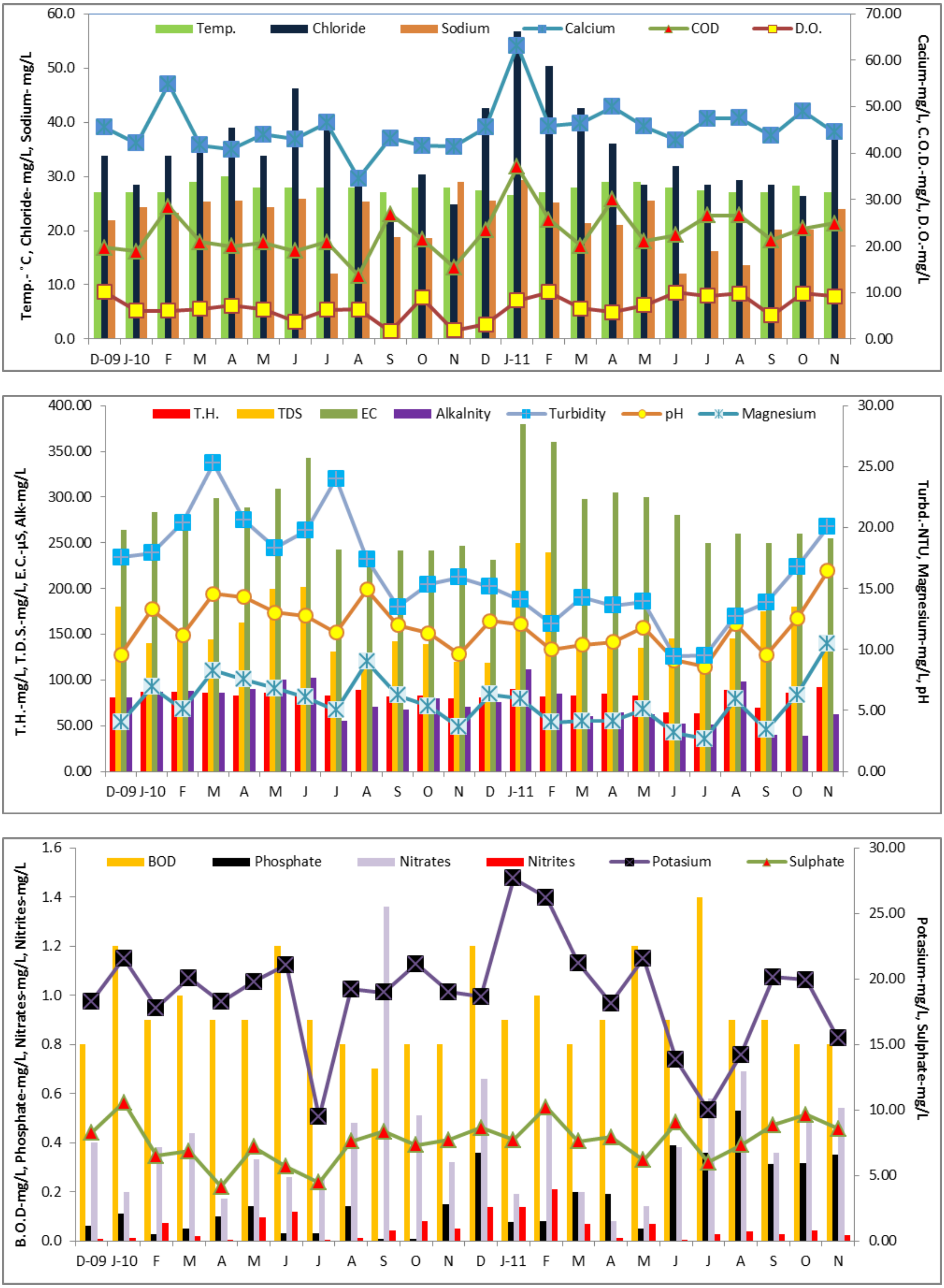


Fig. 1.1.5. Physico-chemical parameters of Site-5 (Shri Mahalsa Temple tank – Mardol).

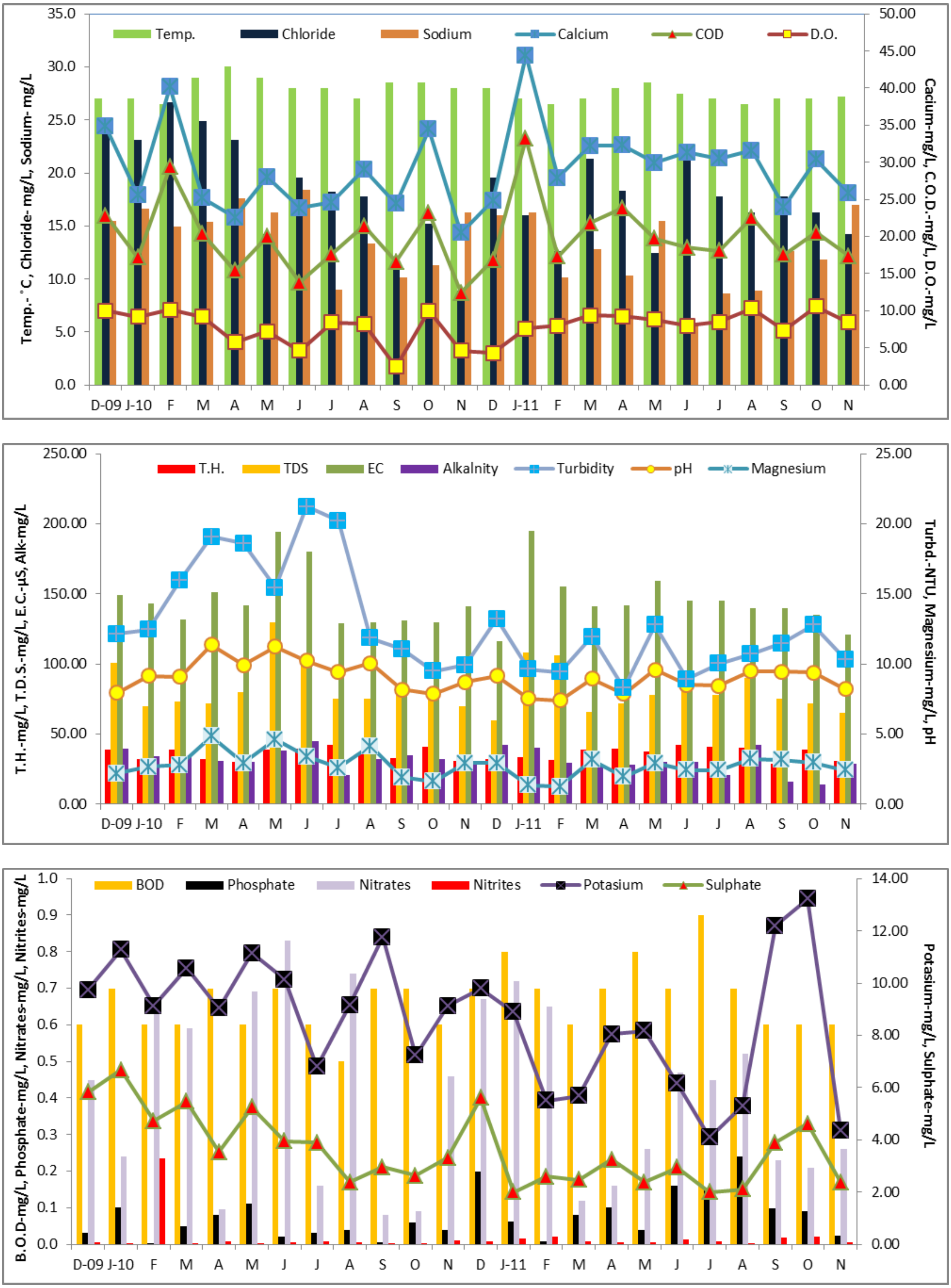


Fig. 1.1.6.Physico-chemical parameters of Site-6 (Shri Manguesh Temple tank–Mangueshim)

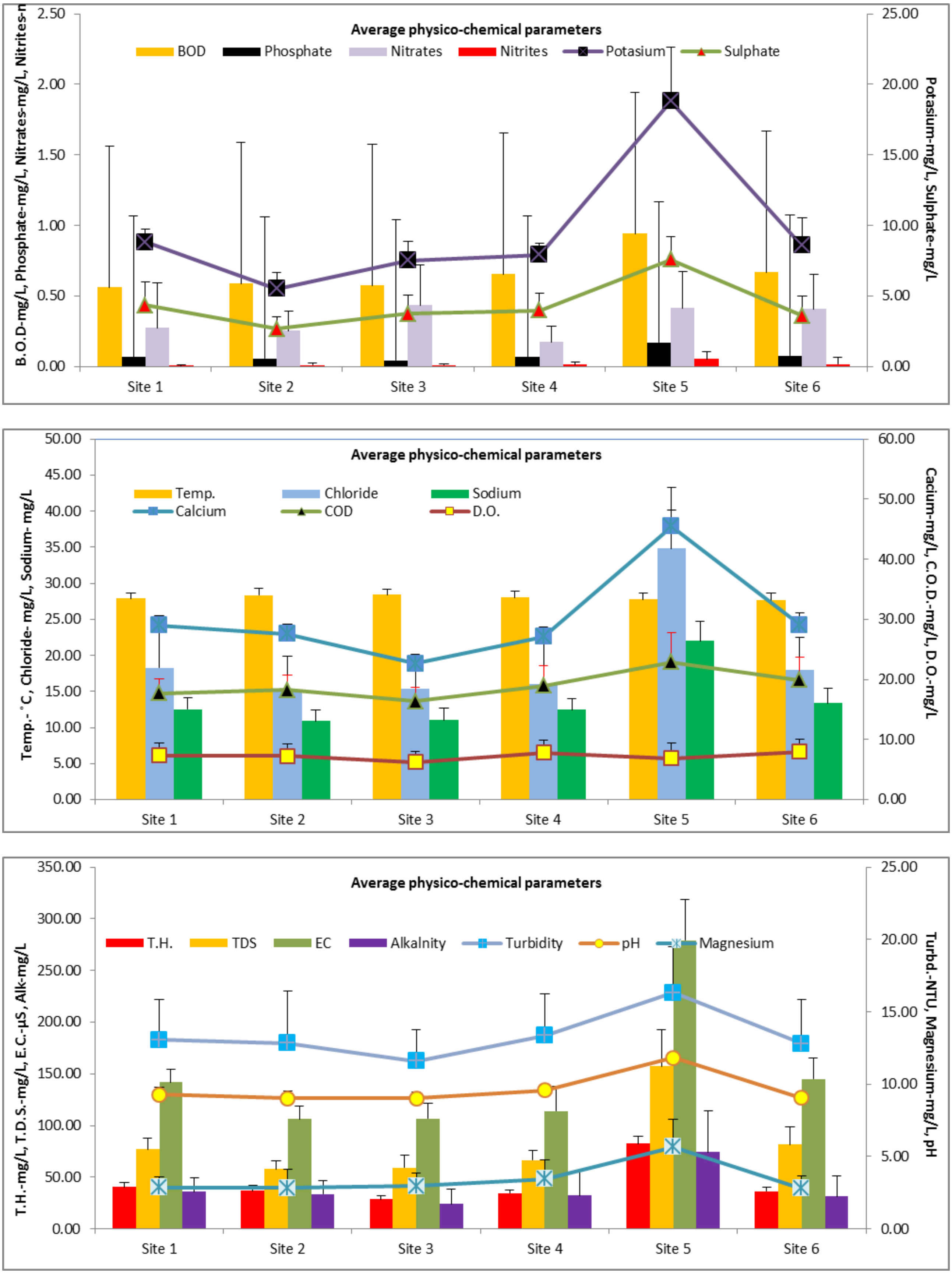


Fig. 1.1.7. Average physico-chemical parameters of all sites during Dec. 2009 – Nov. 2011.

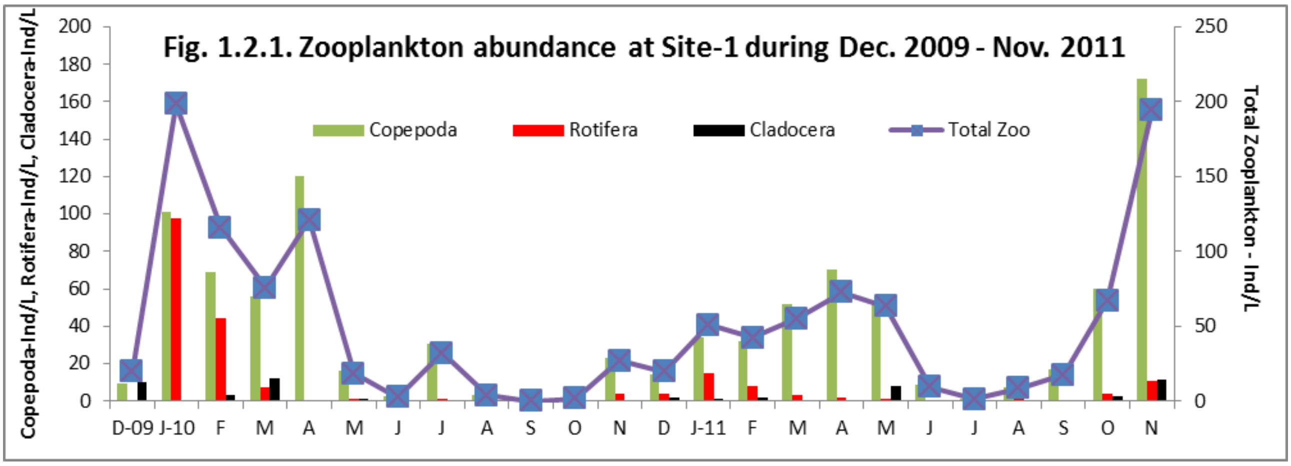


Fig. 1.2.1. Zooplankton abundance at Site-1 during Dec. 2009 - Nov. 2011
Copepoda
Rotifera
Cladocera
Total Zoo
Copepoda-Ind/L, Rotifera-Ind/L, Cladocera-Ind/L
Total Zooplankton - Ind/L
D-09 J-10 F M A M J J A S O N D J-11 F M A M J J A S O N

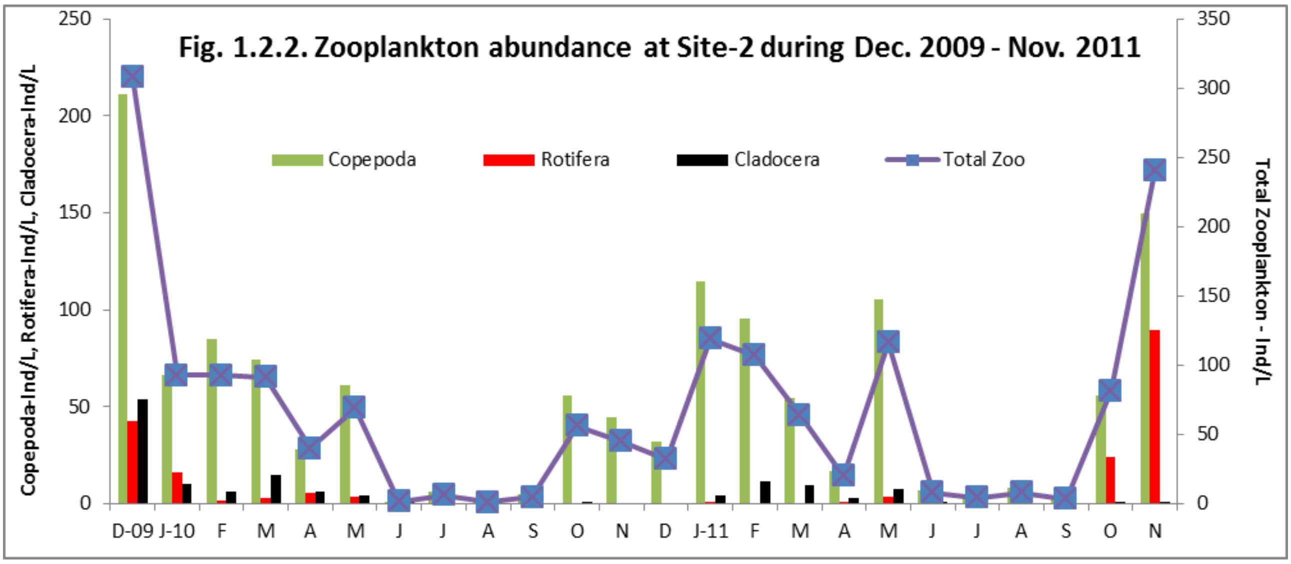


Fig. 1.2.2. Zooplankton abundance at Site-2 during Dec. 2009 - Nov. 2011
Copepoda
Rotifera
Cladocera
Total Zoo
Copepoda-Ind/L, Rotifera-Ind/L, Cladocera-Ind/L
Total Zooplankton - Ind/L
D-09 J-10 F M A M J J A S O N D J-11 F M A M J J A S O N

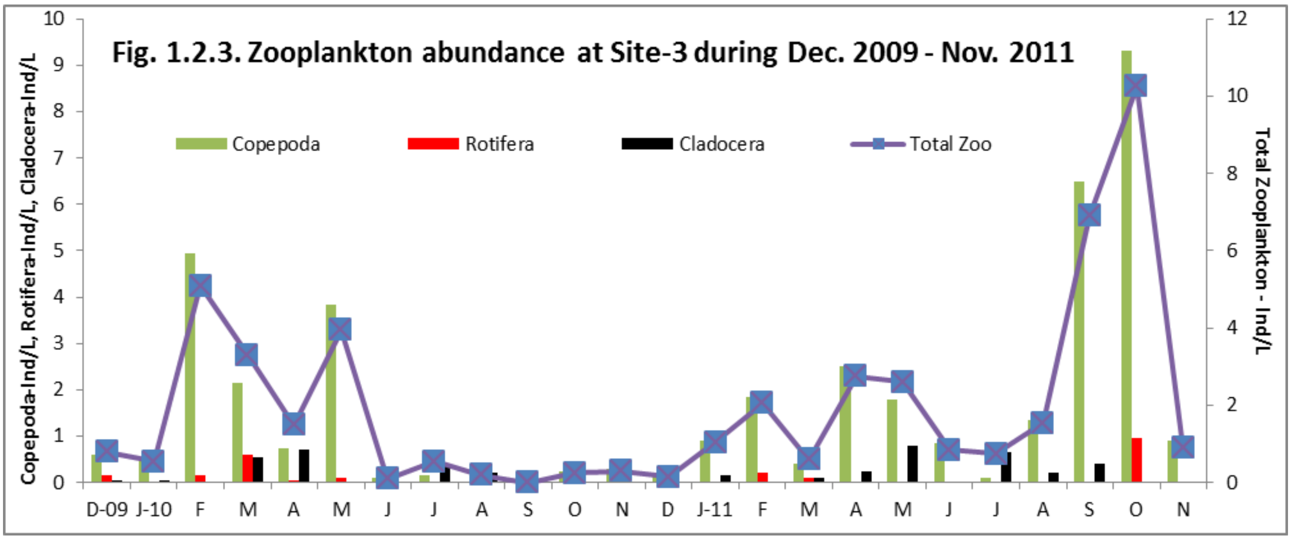


Fig. 1.2.3. Zooplankton abundance at Site-3 during Dec. 2009 - Nov. 2011
Copepoda
Rotifera
Cladocera
Total Zoo
Copepoda-Ind/L, Rotifera-Ind/L, Cladocera-Ind/L
Total Zooplankton - Ind/L
D-09 J-10 F M A M J J A S O N D J-11 F M A M J J A S O N

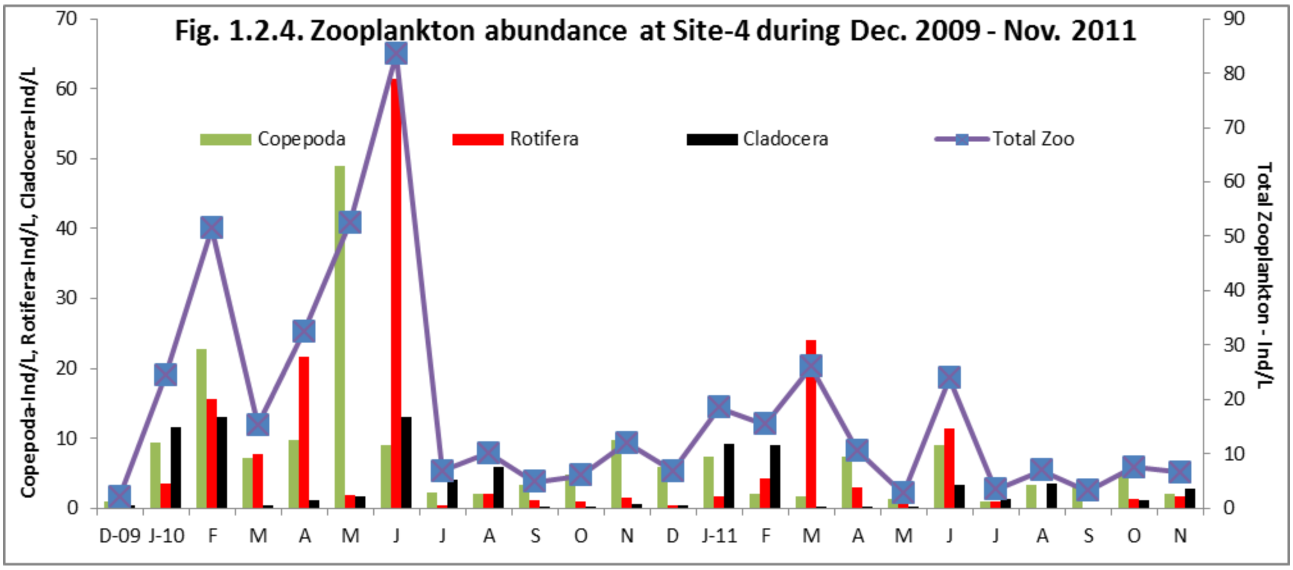


Fig. 1.2.4. Zooplankton abundance at Site-4 during Dec. 2009 - Nov. 2011

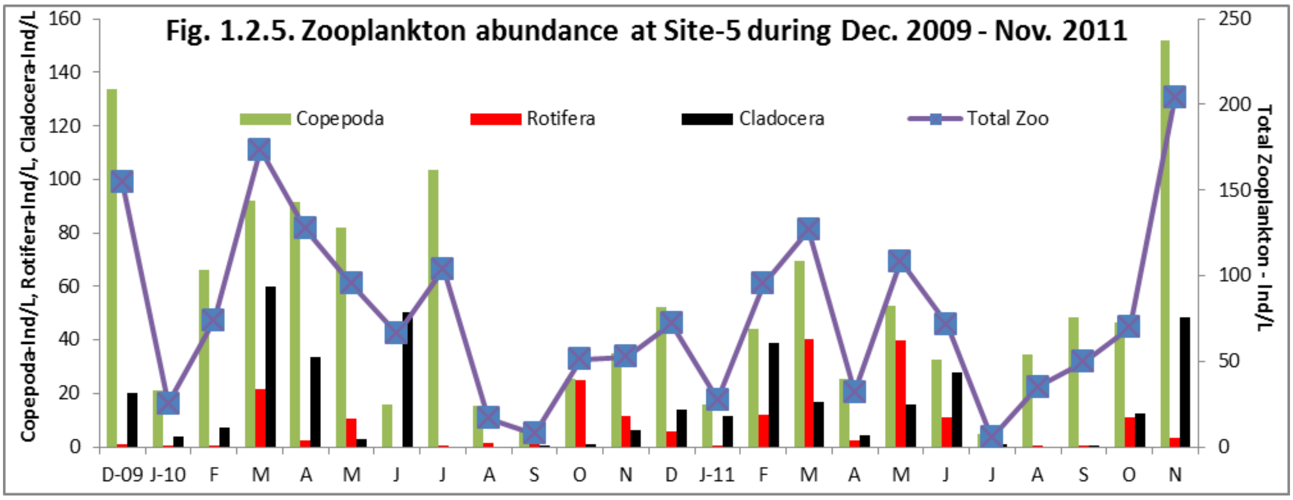


Fig. 1.2.5. Zooplankton abundance at Site-5 during Dec. 2009 - Nov. 2011

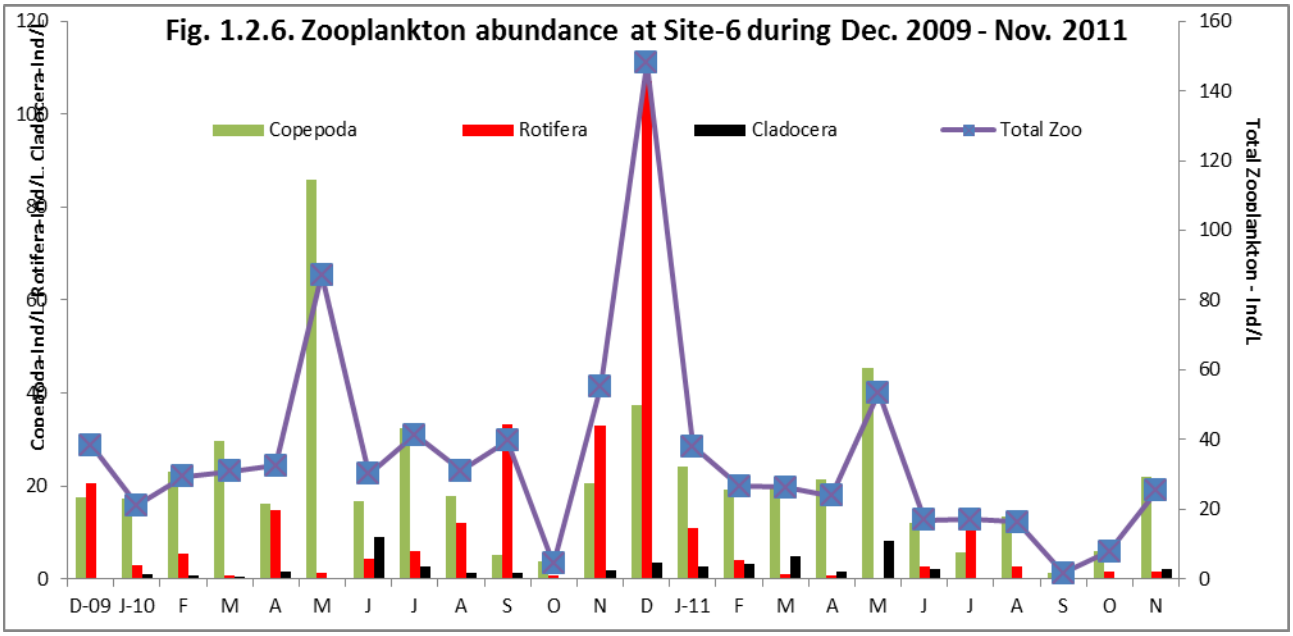


Fig. 1.2.6. Zooplankton abundance at Site-6 during Dec. 2009 - Nov. 2011

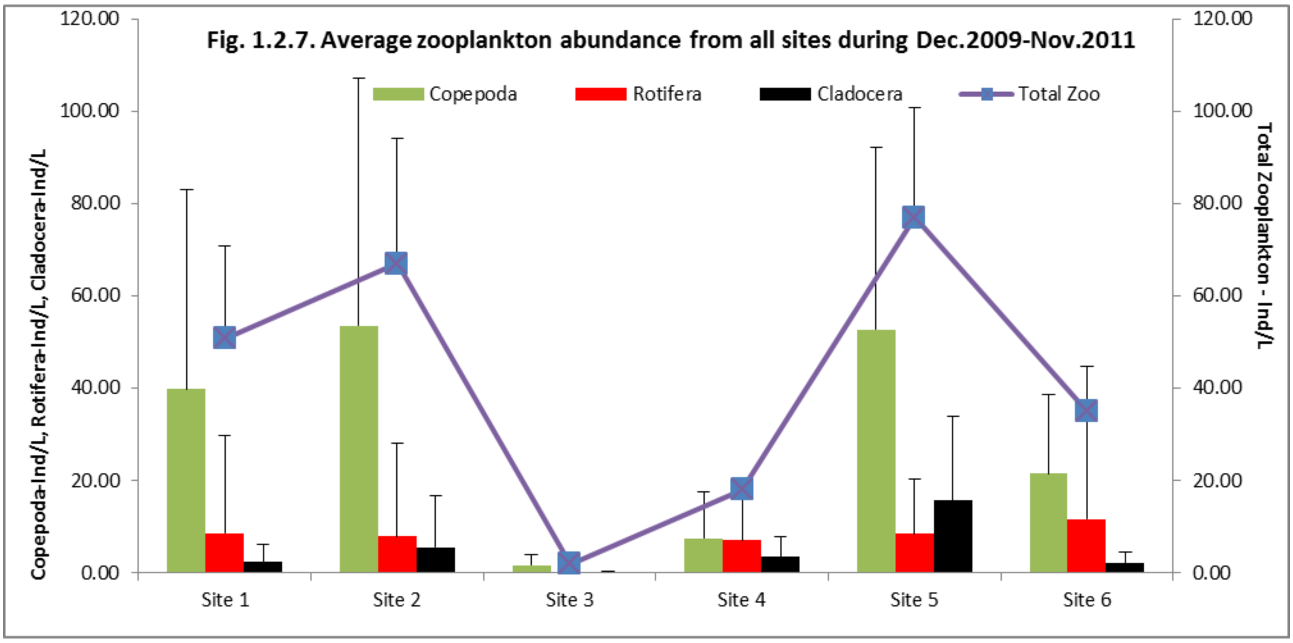


Fig. 1.2.7. Average zooplankton abundance from all sites during Dec.2009-Nov.2011
Copepoda
Rotifera
Cladocera
Total Zoo
Copepoda-Ind/L, Rotifera-Ind/L, Cladocera-Ind/L
Total Zooplankton - Ind/L
120.00
100.00
80.00
60.00
40.00
20.00
0.00
Site 1
Site 2
Site 3
Site 4
Site 5
Site 6

CHAPTER II

In the recent past, biological studies have been increasingly employed in monitoring water quality of water bodies in general and lakes in particular. Phytoplankton, zooplankton, macrophytic plants and fishes were used considerably in biomonitoring of lake ecosystems. zooplankton are one of the most important biotic components, influencing all the functional aspects of an aquatic ecosystem such as food chains, food webs, energy flow and cycling of matter (Dadhick and Sexena, 1999). Therefore, for better understanding of life processes in any lentic or lotic water body, adequate knowledge of zooplankton communities and their population dynamics is major requirement (Tyor *et. al*., 2014).

The zooplankton studies of aquatic ecosystems reveal, different groups of zooplankton have their own peak periods of density, which is also affected by local environmental conditions prevailing at the time. Zooplankton by their heterotrophic activity plays a key role in the cycling of organic materials in aquatic ecosystems and used as bioindicators (Sitre and Thakare, 2013). They have been widely used in assessment of aquatic pollution because of their sensitivity to small changes in environment, short generation time, parthenogenic mode of reproduction etc. The group appears to prolifer more in ponds, lakes and reservoirs (Balakrishna *et. al*., 2013). The bioindicators are evaluated through presence/absence, condition, relative abundance, reproductive success, community structure (i.e. composition and diversity), community function (i.e. trophic structure), or any combination thereof (Kodarkar, 1994).

COPEPODA: Copepods are also known as significant chitin producers in planktonic and benthic ecosystems. Cyclops constitutes major food items for many freshwater fishes like Indian major carps (Pai, 2002). Copepods are primary and secondary consumers in aquatic food chains and can make organic material available to higher trophic levels, thus saving the foraging energy of their predators (Ansari and Khan, 2014). The living copepods constitute an essential link in the aquatic food chain. Though they are not as important element in fish diet as the Cladoceran Species however they are in intermediate trophic level among bacteria, algae and protozoa on one hand and small and large plankton predators on the other (Sharma *et. al*., 2010).

CALANOIDA:

Family: Diaptomidae

1. *Heliodiaptomus vidus* (Gurney, 1916)
2. *H. cinctus* (Gurney, 1907)
3. *Phyllodiaptomus annae* (Apstein, 1907)
4. *Paradiaptomus greeni* (Gurney, 1906)
5. *Diaptomus judayi* (Marsh, 1907)
6. *D. saltillinus* (Brewer, 1898)
7. *D. gracillus* (Sars, 1863)
8. *D. floridanus* (Marsh, 1926)
9. *D. trybomi* (Lillijeborg, 1889)
10. *Eurytemora* sps.

CYCLOPOIDA:

Family: Cyclopidae

1. *Eucyclops agilis* (Koch, 1838)
2. *Paracyclops fimbriatus* (Fischer, 1853)
3. *P. affinis* (Sars, 1863)
4. *P. poppei* (Rehberg, 1880)
5. *Cyclops viridis* (Jurine, 1820)

6. *Mesocyclops dybowskii* (Lande, 1890)
7. *M. hyalinus* (Rehberg, 1880)
8. *Haliocyclops christiansis* (Norman, 1936)

Of the 18 Copepod species identified, eight were cyclopoida and ten belonged to calanoida.

Site-1 harboured seven species of copepods during study period. Among the calanoids, *Diaptomus saltillinus, D. judayi* and *D. trybomi* were present, while cyclopoids such as *Paracyclops poppei, P.affinis, Haliocyclops christiansis* and *Mesocyclops dybowskii* were present.

A total of five species were detected from Site-2. The calanoids were *Diaptomus saltillinus* and *Heliodiaptomus cinctus*. The cyclopoids recorded from Site-2 were *Paracyclops poppei*, *Mesocyclops dybowskii* and *Mesocyclops hyalinus*.

The Copepoda species of Site-3 were represented by three species *Paradiaptomus greeni*, *Diaptomus gracilus* and *Cyclops viridis*.

The composition of copepoda species of Site-4 were *Paradiaptomus greeni, Phyllodiaptomus annae* , *Mesocyclops hyalinus* and *Paracyclops fimbriatus*.

The highest number of copepoda species i.e., seven were identified from Site-5 as that of Site-1. Calanoids identified from Site-5 were *Heliodiaptomus cinctus, H. vidus, Phyllodiaptomus annae* and *Diaptomus gracilus*. While the cyclopoids such as *Haliocyclops christiansis*, *Cyclops viridis* and *Eucyclops agilis*.

Copepoda population of Site-6 were represented by five calanoids such as *Paradiaptomus greeni, Heliodiaptomus vidus, Diaptomus saltillinus, D. floridanus* and *Eurytemora* sps., while cyclopoid namely *Mesocyclops hyalinus.*

ROTIFERA: Freshwater rotifers play an important role in the conversion of plant origin food to animal food and serve as prey to other smaller predatory fauna (Hulyal and Kaliwal, 2008). These are the most important soft bodied metazoans invertebrates having very short life cycle among the plankton. They increase in large quantity rapidly under favorable environments conditions. The list of Rotifera taxa recorded during the study period is as follows:

Family: Brachionidae

1. *Brachionus angularis* (Gosse, 1851)
2. *B. budapestitensis* (Daday, 1885)
3. *B. calyciflorus f. amphiceros* (Ehrenberg, 1838)
4. *B. caudatus apsteini* (Fadeev, 1925)
5. *B. falcatus* (Zacharias, 1898)
6. *B. forficula* (Wierzejski, 1891)
7. *Keratella procurva* (Thorpe, 1891)
8. *Keratella tropica* (Apstein, 1907)

Family: Asplanchnidae

1. *Asplanchna brightwelli* (Gosse, 1850)
2. *A. intermedia* (Hudson, 1886)

Family: Filinidae

1. *Filinia opoliensis* (Zacharias, 1898)

The identified rotifers belonged to three families of which, family Brachionidae species were more in numbers i.e. eight.

Keratella tropica was detected in all water bodies while *Brachionus calyciflorus, B. budapestitensis, B. falcatus and B. angularis* were also most frequently encountered.

The total number of rotifer species identified from Site-1 was four. The most populous rotifer species in site was *Keratella tropica* followed by *Brachionus calyciflorus, B. caudatus* and *B. forficula.*

Rotifer population comprised of five species in Site-2. *Brachionus calyciflorus* was the most populous followed by *B. budapestitensis*. Other members are *B. angularis, B. forficula* and *Keratella tropica*

Keratella tropica and *Filinia opoliensis* are rotifers recorded from Site-3 with maximum rotifer population of 12 individuals /L in March 2010.

The rotifer population of Site-4 represented by seven species viz. *Brachionus calyciflorus, B. falcatus, B. budapestitensis, B. forficula, Filinia opoliensis, Keratella tropica* and *K. procurva*. *Keratella tropica* was most abundant followed by *B. falcatus.*

Site-5, recorded the eight rotifer species. The rotifer species identified were *Brachionus calyciflorus B. falcatus, B. budapestitensis, B. angularis, Keratella tropica, Asplanchna brightwelli, A. intermedia* and *Filinia opoliensis. Brachionus calyciflorus* was most populous specie followed by *Keratella tropica.*

Site-6 had abundance of *Keratella tropica* followed by *Brachionus falcatus* species and showed the presence of following four species *Brachionus falcatus, Brachionus angularis, Asplanchna brightwelli* and *Keratella tropica*.

CLADOCERA: The cladoceran fauna of India appears to be reasonably rich and diversified. They serve as major prey item for many species of invertebrates and vertebrates and invariably comprise food of fry, fingerlings and adults of many economically important and culturable species of fishes. In addition to providing an important food source for planktivorous fish and invertebrates, they are important grazers on algae and detritus (Mondal *et. al*., 2013) and can play an important role in the recycling of nutrients in aquatic ecosystems The littoral and limnetic cladocerans constitute significantly to biological productivity and energy flow in freshwater environments because of their rapid turnover rates, metabolism and capability to build up substantial population in short intervals of time (Ansari and Khan, 2014). List of Cladocera taxa recorded during the study period is as follows:

Family: Sididae

1. *Diaphanosoma excisum* (Sars, 1885)

2. *Ceriodaphnia cornuta* (Sars, 1885)

Family: Moinidae

1. *Moina brachiata* (Jurine, 1820)
2. *Moina micrura* (Kurz, 1874)

3. *Moinodaphnia macleayi* (King, 1853)

Family: Bosminidae

1. *Bosminopsis deitersi* (Richard, 1895)

2. *Bosmina longirostris* (Muller, 1776)

Family: Macrothricidae

1. *Macrothrix laticornis* (Fisher, 1851)

2. *Llyocryptus spinifer* (Herrick, 1882)

The nine cladoceran species were found present in the water bodies of Goa. These species belonged to four families. The frequently encountered cladoceran species in the water bodies of Goa were *Moina micrura, Diaphanosoma excisum* and *Bosmina* species.

Site-1 had three species of cladocerans, which were identified as *Macrothrix laticornis*, *Llyocryptus spinifer* and *Moinodaphnia macleayi*.

Five species found in Site-2 were *Moinodaphnia macleayi*, *Moina micrura, Diaphanosoma excisum*, *Ceriodaphnia cornuta,* and *Bosminopsis deitersi*. *Diaphanosoma excisum* was most abundant followed by *Moinodaphnia macleayi.*

Site-3 and Site-4 had one and two species of cladocerans respectively. The species encountered in Site-3 was *Moina micrura*. In Site-4 cladoceran species were *Bosminopsis deitersi* and *Bosmina longirostris*.

Cladoceran species found in Site-5 were *Bosmina longirostris, Ceriodaphnia cornuta, Moina micrura* and *Diaphanosoma excisum*. *Diaphanosoma excisum* was most abundant followed by *C. cornuta.*

Moina brachiata, Moina micrura, Bosminopsis deitersi and *Moinodaphnia macleayi* were found in Site-6. *Moinodaphnia macleayi* was most abundant.

DISCUSSION

The two year study of zooplankton fauna of freshwater bodies in Goa was carried out. The limnological study of six temple tanks of Goa shows that the Copepod group was most abundant with the species of families *Diaptomidae* and *Cyclopidae*.

During the present study, copepoda species were found to be in higher densities during summer. Calanoids have longer life cycles than the cyclopoids, which show two cycles; a period of growth and a period of retarded growth. Retardation is caused due to decrease in water temperature, photoperiod, reduced food availability, anoxia and increased predation (Wetzel, 2001; Jack and Thorp, 2002). Scarcity or absence of calanoids is usually observed in tropical water bodies, which are in the process of eutrophication (Zago, 1976). In the present investigations, naupliar stages were observed throughout the period of investigations. Only slight differences were observed in the number of nauplii in the tanks. This shows that reproduction in copepods is carried out throughout the year. Pennak (1978) has also reported that reproduction in some species of copepods is carried out throughout the year having three or more generations (Ansari and Khan, 2014).

Species diversity of copepods was highest in Site-5 along with Site-1. Among all the six temple tanks analysed, Site-3 and Site-5 had the least and most number of copepoda species, respectively. Site-3 was the least nutrient rich, hence lowering the calanoida counts. The species that were commonly encountered were *Heliodiaptomus* sps., *Diaptomus* sps., and *Mesocyclops* sps. *Mesocyclops* sps, which was suggested as pollution indicator species by several workers (Pennak, 1968; Sharma *et al*., 2007 and Mondal *et. al*., 2013) encountered at Site-1, Site-2, Site-4 and Site-6 during present study. Copepoda species are regarded as pollution sensitive zooplankton as they disappear from polluted water (Verma *et. al*., 1984). Contrary to this observation is the finding that Cyclops sp. are pollution tolerant, found abundant in nutrient rich environment and thus can be considered as eutrophication indicators (Adholia and Vyas, 1992). However in present study, calanoids were found in high numbers along with absence of Cyclops sp. for most of the months during study period in all sites. Thus it can be concluded that, water bodies studied are not in the process of eutrophication. Copepods dominated during dry seasons in all sites and least abundance was recorded in rainy season. At all sites highest abundance was observed in summer season except at Site-1, where highest abundance was seen in winter season. Higher abundance in dry season may be attributed to low water levels during dry seasons.

Rotifers have often been used to indicate trophic status of a water body (Sharma *et. al*., 2010). The presence of least number of rotifer species indicative of the fact that Site-3 is less nutrient rich or oligotrophic in nature as compared to the other water bodies, which had a higher species diversity. A rotifer *Keratella tropica* was found in all the sites during study period. Similar findings have also been reported by Berde, 2004. *Keratella tropica* is present mostly in polluted water and is considered as pollution indicator and pollution tolerant species (Rao and Chandramohan, 1977; Sampath *et. al*., 1978; Kulshrestha *et. al.,* 1991; Bahura *et.al.,* 1993; Bhatt and Singh, 1998; Mishra and Saksena, 1998). *K. tropica* was most abundant in Site-1 and Site-6 as compared to other sites. However, these species are also common inhabitants of tropical waters.

The second dominant rotifer *Brachionus* sps., was found in almost all the water bodies analysed except for Site-3. *Brachonidae* family dominated over other rotifer groups. Common occurrence of this family has been reported earlier by Sharma and Michael (1980) and this is attributed to the ability of the species of this family to survive in different habitats. The species of this family commonly encountered *i.e. Brachionus calciflorus* and *keratella tropica*, are cosmotropical in nature. Occurrence of *Keratella* sps., with *Brachionus* sps., indicate nutrient rich status of water body (Berzins and Pejler, 1989).

Overall among all the six temple tanks surveyed during the study period, Site-3 had the lowest number of rotifer species along with density while the Site-5 had the highest rotifer species diversity (eight sps.) and Site-6 had highest density. The various species of *Brachionus* and *Filinia* are greater in polluted waters (Karuthapandi *et. al*., 2013). Nogueira, 2001 considered the abundance of *B. angularis* and *B. calyciflorus* as a biological indicator of eutrophic water. All the above mentioned rotifer species were found in Site-5 indicating gradual eutrophication of water body. Least abundance of rotifers was recorded at all sites in rainy season except Site-4 and Site-6, which can be attributed to dilution due to rain water. Site-4 and Site-6 showed least abundance in winter and summer season respectively, may be due to predation by other zooplankton. Larger copepods and cladocerans are planktivorous and effective in causing significant mortalities of smaller zooplankton species (Murtaugh, 1981; Lehman, 1991). Also predation of larger zooplankton by fish results in dominance of rotifers, which are smaller plankters.

As stated earlier, nine cladoceran species belonging to five families were identified from the temple tanks of Goa. Rajashekhar *et. al*., (2009) reported that *Diaphanosoma excisum* is more abundant in high organic content water bodies. In present study, *Diaphanosoma excisum* was most abundant among all sites during study period at Site-5, can also be considered as an indication of increased organic content in the water body. The study of cladoceran communities revealed that Site-2 followed by Site-5 had the higher species diversity of cladocerans, while the Site-3 showed least number of species among the temple tanks of Goa. In present study higher density of cladocera was observed in summer and winter at Site-1, Site-2 and Site-5. At Site-3 and Site-6 cladoceran population was lowest in winter season and in Site-4 lowest abundance was recorded in summer season. Highest summer abundance was observed at Site-2, Site-3, Site-5 and Site-6. According to Padate *et.*

al., (2014), rising temperature and increasing food supply from algae, detritus and bacteria in summer, favour increase in cladoceran populations.

In shallow waters, no thermal stratification is observed and distribution of zooplankton is highly variable. *Bosmina sp., Ceriodaphnia sp.* and cyclopoid copepods are more abundant in littoral than in pelagic areas. Thus, during the present study, nineteen copepods (including harpacticoid), eleven rotifers, nine cladocerans and two ostracods were recorded from the littoral zones of the temple tanks of Goa.

However presence of species such as *Brachionus calcyflorus, B. falcatus, Keratella tropica, Moina* sps., *Cyclops* sps., *Diaptomus* sps., in the waters of Site-5 shows that, it is nutrient rich. All these species have been reported by various workers as indicator of pollution (Verma and Dalela, 1975; Saksena and Sharma, 1982; Verma *et. al.,* 1984).

During the present study only two members of Ostracods viz., *Cypris* sps., and *Prinocypris* sps., were encountered. One or two individuals of *Cypris* sps., per 20 litres was found once or twice during study period from Site-1 to Site-5. *Prinocypris* was encountered only once in Site-1. Most of the freshwater ostracods are bottom dwellers, although some appear occasionally in plankton samples (Ansari and Khan 2014).

The order of species diversity in the temple tanks of Goa under study was Site-5 > Site-2 > Site-1 > Site-6 > Site-4 > Site-3.

Heavy predation from juvenile and adult fish as well as by larger zooplankton, may greatly simplify the zooplankton community, resulting in scarcity of some species (Jack and Thorp, 2002). Larger copepods and cladocerans are planktivorous and effective in causing significant mortalities of smaller zooplankton species (Murtaugh, 1981; Lehman, 1991). Diurnal patterns of habitat selection of fish, eutrophication, acidic rains etc., influence the tropical lakes and its plankton community.

Fewer species diversity as well as low zooplankton density being recorded at Site-3 may be due to less nutrient richness in the water body. While the other sites showed higher diversity and density of zooplankton. Nevertheless, their zooplankton as a whole has a typical tropical, limnetic, species composition.

Abundance of zooplankton groups as recorded during the study period in all sites is as follows Copepoda > Rotifera > Cladocera except at Site-5 which shows Copepoda > Cladocera > Rotifera.

Season wise abundance at all sites shows similar pattern wherein copepod dominated all seasons followed by rotifers and then cladocera.

Total zooplankton abundance, at all sites, throughout study period, shows highest zooplankton abundance along with diversity at Site-5 followed by Site-2 and lowest at Site-3. It was observed that, seasonal occurrence and distribution of zooplankton diversity at different sites is influenced by various physico-chemical characteristics. The occurrence and abundance of zooplankton may be regarded as, a major indicator of the entire environmental status of any water body.

Fig.2.1.1. Average abundance of zooplankton groups throughout the study period at different sites

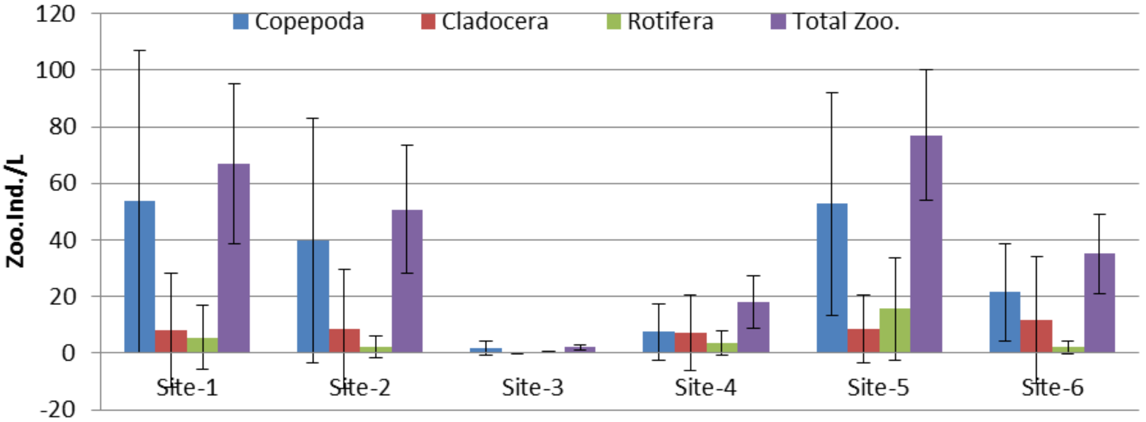


Fig.2.1.2. Seasonwise average abundance of different zooplankton groups from all sites during study period.

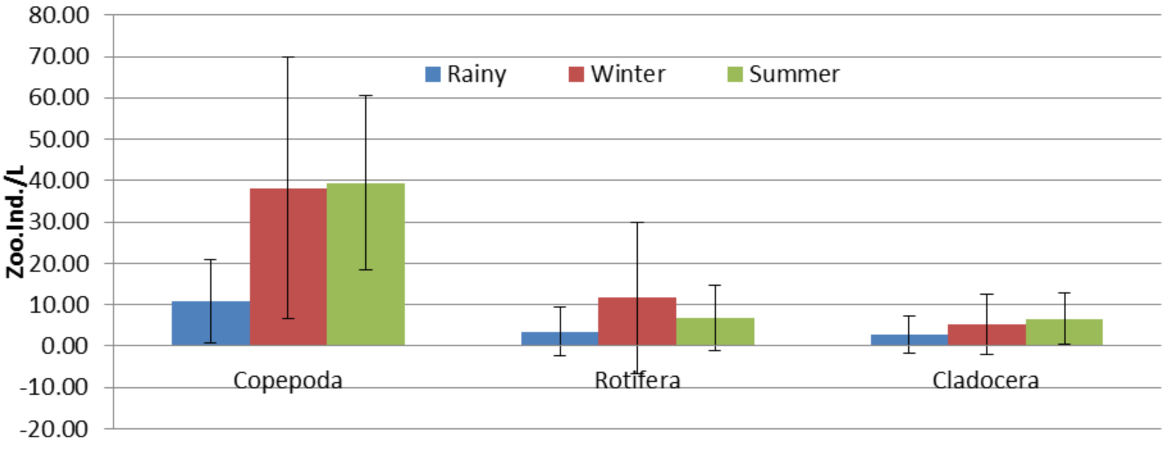
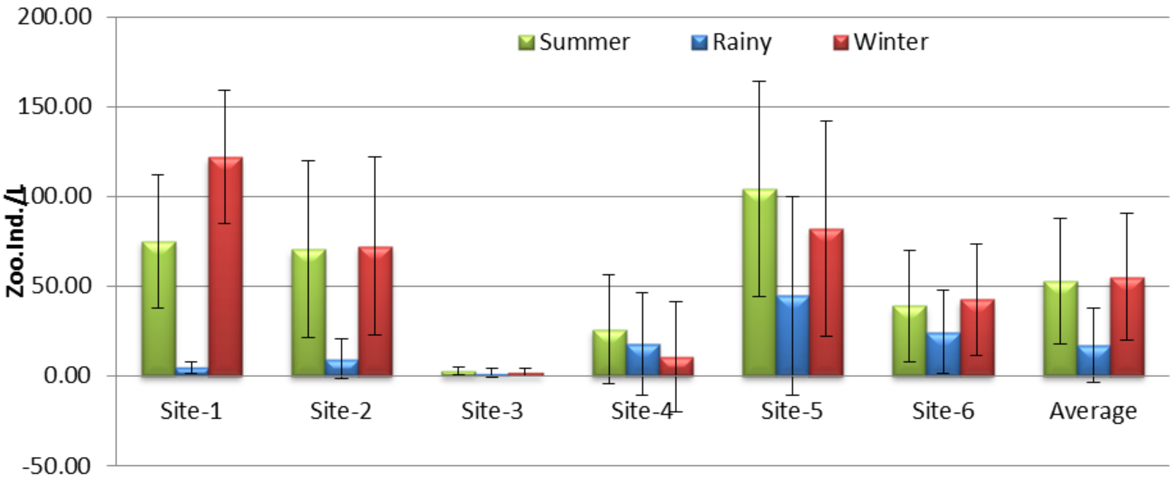


Fig.2.1.3. Seasonwise average comparative zooplankton abundance in different sites



Sites	zooplankton group	Winter	Summer	Rainy	Average
	Copepoda	91.36+62.35	64.94+31.25	4.35+2.63	53.55+53.54
	Rotifera	21.64+31.51	2.14+2.02	0.02+0.05	7.94+20.05
Site-1	Cladocera	8.77+18.58	7.79+3.82	0.15+0.30	5.57+11.18
	Copepoda	51.93+58.42	58.66+30.64	8.92+10.40	39.84+43.17
	Rotifera	16.98+32.87	8.43+14.65	0.34+0.39	8.58+21.03
Site-2	Cladocera	3.38+4.57	3.39+4.29	0.13+0.21	2.30+3.80
	Copepoda	1.61+3.12	2.28+1.51	1.13+2.22	1.68+2.32
	Rotifera	0.14+0.33	0.15+0.19	0.00+0.00	0.10+0.22
Site-3	Cladocera	0.03+0.05	0.30+0.33	0.23+0.24	0.19+0.26
	Copepoda	5.73+3.13	12.68+16.22	4.16+3.12	7.52+10.02
	Rotifera	1.46+0.96	9.91+9.22	9.73+21.26	7.03+13.41
Site-4	Cladocera	3.32+4.50	3.74+2.75	3.96+4.19	3.50+4.37
	Copepoda	60.18+52.73	65.43+23.52	32.66+32.47	52.76+39.38
	Rotifera	7.28+8.36	16.23+16.24	1.91+3.71	8.47+11,92
Site-5	Cladocera	14.71+14.99	22.47+20.17	9.99+18.88	15.72+18.12
	Copepoda	18.61+10.59	32.61+23.34	13.09+9.75	21.44+17.30
	Rotifera	22.28+36.11	3.55+4.98	9.11+10.58	11.64+22.42
Site-6	Cladocera	1.48+1.27	2.62+2.74	2.08+2.97	2.06+2.38
All sites	**Average zooplankton**	18.38+24.26	17.60+21.91	5.66+7.74	13.88+16.64

Table. 2.1.1. **Average season-wise zooplankton abundance (Ind/L) from different sites during December 2009 – November 2011.**

CHAPTER III

The data obtained on physico-chemical parameters and zooplankton abundance for the six temple tanks of Goa was calculated for various indices, as provided in materials and method section. Further, zooplankton abundance was subjected to single linkage hierarchical clustering. The results of same are presented below.

The indices calculated for zooplankton abundance in Site-1 during study period are given in Table 3.1. Dominance ranged between 0.16 (Mar. `10) to `1` (Aug. to Oct. `10 and Jul. `11). Simpsons diversity index (1-D) was between `0` (Aug. to Oct. `10 and Jul. `11) to 0.84 (Mar. `10). Shannon's index (H) ranged between `0` (Aug. to Oct. `10 and Jul. `11) and 1.91 (Mar. `10). Evenness was between 0.47 (Nov. `11) to `1` (Dec. `09, May, Jun. `10, Aug. to Dec. `10, Jun. to Aug. `11). Lowest value `0` of Brillouin index was seen in Aug. to Oct. `10 and Jul. `11. While highest value of 1.47 was seen in Jan. `10. The range of Menhinick's index was from 0.76 (Oct. `11) to 2.48 (Mar. `10). Margalef's richness index ranged between `0` (Aug. to Oct. `10 and Jul. `11) to 2.89 (Mar. `10). Equitability `J` was between 0.57 (Nov. `11) to `1` (Dec. `09, May, Jun. `10 and Jul., Aug. `11). Fisher alpha diversity ranged between `0` (Dec. `09, May, Jun. `10, Aug. to Dec. `10 and Jun. to Aug. `11) to 26.78 (Mar. `10). Berger-Parker dominance was between 0.25 (Jan. and Mar. `10) and `1` (Aug. to Oct. `10 and Jul. `11). Chao species richness ranged between `1` (Aug. to Oct. `10 and Jul. `11) and 16 (Nov. `11). The total number of species in this temple tank during the study period were in the range of `1` (Aug. to Oct. `10 and Jul. `11) to `7` (Jan, Mar., Apr., `10).

The single linkage hierarchical clustering for zooplankton abundance of Shri Shantadurga Temple tank (Site-1) was constructed using the *Past 3.01 software*. As seen from dendrogram (Fig 3.1.2), highest number of similarity was seen between `9` (Aug. `10), 11(Oct. `10) and 20 (Jul. `11) at level 1.00. This formed a cluster at 0.68 level with group formed by linkage of `7` (Jun. `10) and 19 (Jun. `11) at level 0.80. Also `4` (Mar. `10), `8`

(Jul. `11) and 21 (Aug. `11) were linked to this cluster at 0.68 level. Another close cluster was formed at level of 1.00 between `6` (May `10) and 13 (Dec. `10) and their link with 14 (Jan. `11) at 0.75. These together were linked with 12 (Nov. `10) and 15 (Feb. `11) at 0.68 level.

The indices calculated for zooplankton abundance in Site-2 during study period are given in Table 3.2. Dominance ranged between 0.12 (Dec. `09) to `1` (Jun. to Sep. `10 and Jul. `11). Simpsons diversity index (1-D) was between `0` (Jun. to Sep. `10 and Jul. `11) to 0.88 (Dec. `09). Shannon's index (H) ranged between `0` (Jun. to Sep. `10 and Jul. `11) and 2.31 (Dec. `09). Evenness was between 0.0.80 (Feb. `11) to `1` (Apr. `10, Jun. `10 to Sep. `10, Apr. to Sep. `11). Lowest value `0` of Brillouin index was seen in Jun. to Sep. `10 and Jul. `11. While highest value of 1.84 was seen in Dec. `09. The range of Menhinick's index was from 0.71 (Jul., Sep. `10) to 2.31 (Dec. `09). Margalef's richness index ranged between `0` (Jul., Sep. `10) to 3.34 (Dec. `09). Equitability `J` was between 0.84 (Feb. `11) to `1` (Apr. `10, Apr. `11, Jun. and Sep. `11). Fisher alpha diversity ranged between `0` (Apr., Jun., Aug `10, Apr. to Jul. `11 and Sep. `11) to 8.28 (Dec. `09). Berger-Parker dominance was between 0.20 (Apr. `10) and `1` (Jun. to Sep. `10 and Jul. `11). Chao species richness ranged between `1` (Jun. to Sep. `10 and Jul. `11) and 15 (Apr. `10). The total number of species in this temple tank during the study period were in the range of `1` (Jun. to Sep. `10 and Jul. `11) to 12 (Dec. `09).

Single linkage hierarchical clustering for zooplankton abundance in Site-2 showed two main Clusters (Fig. 3.2.2). Highest level of linkage was at `1` level between `7` (Jun. `10), `9 ` (Aug. `10), 20 (Jul. `11) and 22 (Sep. `11). Second cluster was formed by linkage of `8` (Jul. `10), 10 (Sep. `10) and 13 (Dec. `10) at level 1.00. Similarly `3` (Feb. ` 10) was linked to 16 (Mar. `11) at 0.89 and this was linked with 11 (Oct. `10) at 0.74 to form a cluster with 12 (Nov. `10) and 18 (May `11) at 0.80 level and with 14 (Jan. `11), which was linked to 12 (Nov. `11) and 18 (May `11) at 0.76 level.

The indices calculated for zooplankton abundance in Site-3 during study period are given in Table 3.3. Dominance ranged between `0` (Jun. `10, Aug., Sep., Nov., Dec. `10, Mar. and Sep. `11) to `1` (Dec.`09, Jan., Mar., Apr., Jul., Oct. `10, May to Aug. `11 and Nov. `11). Simpsons diversity index (1-D), Shannon's index (H), Brillouin index and Margalef's richness index was `0` for most of the months except Feb., May. `10, Apr. `11 and Oct. `11. While was highest during Oct. `11 as 0.75, 1.39, 0.79 and 2.16 respectively. Evenness was `0` and `1` during different months. Menhinick's index was highest of `2` (Oct. `11). Equitability `J` was also `0` and `1`. Berger-Parker dominance was between `0` and `1`. Chao species richness was highest during Oct. `11 (10). The total number of species in this temple tank during the study period was highest in the month of Oct. `11(`4` Sps.).

Five main clusters were identified from the dendrogram (Fig. 3.2.3) for zooplankton abundance of Site-3. The biggest cluster with highest similarity was formed by `7` (Jun. `10), `9` (Aug. `10), 10 (Sep. `10), 12 (Nov. `10), 13 (Dec. `10), 16 (Mar. `10) and 22 (Sep. `11) at `1` level. The second highest similarity cluster at `1` level was formed by linkage between 15 (Feb. `11), 18 (May `10), 19 (Jun. `11) and 24 (Nov. `11). Other three clusters were formed by linkage at level `1` between `8` (Jul. `10) and 21 (Aug. `11), `5` (Apr. `10) and 11 (Oct. `10), `1` (Dec. `09) and 14 (Jan. `11).

The indices calculated for zooplankton abundance in Site-4 during study period are given in table 3.4. Dominance ranged between 0.18 (Feb. `10) to `1` (Dec. `09, Sep. `10, Jul. `11 and Sep. `11). Simpson's diversity index (1-D) was between `0` (Dec. `09, Sep. `10, Jul. `11 and Sep. `11) to 0.82 (Feb. `10). Shannon's index (H) ranged between `0` (Dec. `09, Sep. `10, Jul. `11 and Sep. `11) and 1.75 (Feb. `10). Evenness and equitability was lowest during

May `10 with 0.79 values for both. Lowest value `0` of Brillouin index was seen in Dec. `09, Sep. `10, Jul. `11 and Sep. `11. While highest value of 1.12 was seen in Feb. `10. The range of Menhinick's index was from `0` (Dec. `09, Sep. `10, Jul. `11 and Sep. `11) to 2.27 (Feb. `10). Margalef's richness index ranged between `0` (Dec. `09, Sep. `10, Jul. `11 and Sep. `11) to 2.57 (Feb. `10). Fisher alpha diversity was highest of 19.95 (Feb. `10). Berger-Parker dominance was between 0.25 (Nov. `10) and `1` (Dec. `09, Sep. `10, Jul. `11 and Sep. `11). Chao species richness ranged between `1` (Dec. `09, Sep. `10, Jul. `11 and Sep. `11) and 11 (Feb. `10). The total number of species in this temple tank during the study period were in the range of `1` (Dec. `09, Sep. `10, Jul. `11 and Sep. `11) to `6` (Feb. `10).

Single linkage cluster analysis for zooplankton abundance at Site-4 resulted in dendrogram shown in Fig. 3.2.4. Linkage between 18 (May `11) and 23 (Oct. `11) at 0.80 level which in turn forms cluster with `4` (Mar.` 10), 17 (Apr. `11), 13 (Dec. `10), `2` (Jan. `10), `9` (Aug. `10), 10 (Sep. `10), `6` (May `10) and `1` (Dec. `09) at 0.66 level.

The indices calculated for zooplankton abundance in Site-5 during study period are given in Table 3.5. Dominance ranged between 0.12 (Dec. `09) to 0.5 (Sep. `10 and Jul. `11). Simpson's diversity index (1-D) was between 0.5 (Sep. `10 and Jul. `11) to 0.8 (Dec. `09). Shannon's index (H) ranged between 0.69 (Sep. `10 and Jul. `11) and 2.21 (Dec. `09). Evenness and equitability was lowest during Jul. `10 with 0.73 and 0.80 value respectively. Lowest value 0.35 of Brillouin index was seen in Sep. `10 and Jul. `11. While highest value of 1.64 was seen in Mar. `10. The range of Menhinick's index was from 1.41 (Sep. `10 and Jul. `11) to 2.58 (Dec. `09). Margalefs richness index ranged between 1.44 (Sep. `10, Apr. `11, Jul., and Aug. `11) to 3.32 (Dec. `09). Fisher alpha diversity was highest of 26.78 (Oct. `11). Berger-Parker dominance was between 0.15 (Mar. `11) and 0.55 (Jul. `10). Chao species richness ranged between `3` (Sep. `10 and Jul. `11) and 21 (Nov. `10). The total number of species in this temple tank during the study period were in the range of `2` (Sep. `10 and Jul. `11) to 10 (Dec. `09, Mar. `10, and Nov. `11).

Site-5 zooplankton fauna was subjected to single linkage cluster analysis. The resulting dendrogram (Fig. 3.2.5.) showed very few clusters. Cluster of highest similarity level was formed between 17 (Apr. `11) and 22 (Sep. `11) at 0.80 level, which in turn is linked to 11 (Oct. `10) at 0.66 and to `6` (May `10) at 0.60 to form a cluster.

The indices calculated for zooplankton abundance in Site-6 during study period are given in table 3.6. Dominance ranged between 0.14 (May `10) to `1` (Sep. `11). Simpsons diversity index (1-D) was between `0` (Sep. `11) to 0.86 (May `10). Shannon's index (H) ranged between `0` (Sep. `11) and 2.02 (May `10). Evenness and equitability was lowest during Dec `10 and Jul. `10 with value of 0.87 and 0.81 respectively. Lowest value `0` of Brillouin index was seen in Sep. `11. While highest value of 1.37 was seen in May `10. The range of Menhinick's index was from `1` (Jul. `10 and Sep. `11) to 2.53 (May. `10). Margalef's richness index ranged between `0` (Sep. `11) to 3.04 (May `10). Fisher alpha diversity was highest of 18.57 (May `10). Berger-Parker dominance was between 0.20 (May `10, Sep. `10 and Jan. `11) and `1` (Sep. `11). Chao species richness ranged between `1` (Sep. `11) and 15 (Sep. `10 and Jan. `11). The total number of species in this temple tank during the study period were in the range of `1` (Sep. `11) to `8` (May `10).

The zooplankton abundance of Site-6 was used for constructing dendrogram seen in Fig. 3.2.6. Highest similarity was seen between `3` (Feb. `10), 19 (Jun. `11), 15 (Feb. `11) and 21 (Aug. `11) at 0.86 level, which in turn was linked to 16 (Mar. `11) at 0.74 level completing one cluster. Second cluster was formed between `2` (Jan. `10) and 24 (Nov. `11) at 0.85 level, which were linked with 14 (Jan. `11) at 0.65 and 17 (Apr. `11) at 0.57 level. A third cluster was observed between `8` (Jul. `10), `9` (Aug. `10) and `1` (Dec. `09) at 0.74, followed by its linkage with 12 (Nov. `11) at 0.72 level.

DISCUSSION

Diversity indices can be used to characterise species abundance relationships in communities. The two aspects are dealt with, when studying the species diversity of zooplankton, species richness and evenness. Since both the components are incorporated into a, single numerical value, interpretation and correct usage are much debated and confusing. Interpretation of data obtained is the biggest obstacle. In spite of these problems, ecologists continue use of diversity indices (Ludwig and Reynolds, 1988).

In the present study, various diversity, evenness and richness indices have been calculated and zooplankton diversities are compared with the help of availed data. A diversity index as proposed by Simpson (1949), is to describe the probability that, a second individual drawn from a population should be of the same species as the first. Magurran (2004) (cf. Seaby and Henderson, 2006) states that"the Simpson index is one of the most meaningful and robust diversity measures available. In essence, it captures the variance of the species abundance distribution". As the Simpson (1-D) index value increases, diversity also increases. Simpson index was lower for all sites during rainy season indicating low species diversity. Highest value of Simpson's index was found in Site-5 during December 2009, indicating highest diversity among different sites throughout study period.

The value of the Shannon-Wiener index usually lies between 1.5 and 3.5 for ecological data and rarely exceeds 4.0 (Seaby and Henderson, 2006). Index affected by both number of species and evenness of their population. Diversity increases as both increases. Shanon-Wiener index was maximum during winter months in most of the sites (Site-2, 3, 4, 5), indicating higher number of species and evenness of their population in winter. Diversity is maximum when all species are equally abundant.

The Brillouin index measures the diversity of a collection, as opposed to the Shannon index which measures a sample. Pielou (1975) recommends Brillouin index in all situations where a collection is made, sampling was non-random or the full composition of the community is known. The value obtained rarely exceeds 4.5 and both the Brillouin and Shannon Indices tend to give similar comparative measures (Seaby and Henderson, 2006). The Brillouin index gives similar trends to that of Shannon index.

Equitability or evenness refers to the pattern of distribution of the individuals between the species. Evenness will vary between `1` and `0`. The closer to `1` the more even the populations that form the community. Equitability and evenness values were always closer to 1 indicating even distribution of species at all sites.

Berger-Parker Dominance index was considered by May (1975) to be one of the best. It is simple measure of the numerical importance of the most abundant species (Seaby and Henderson, 2006). Berger-Parker Dominance was lowest in the months of dry season when the diversity was highest, indicating more evenness of species.

Hayek and Buzas (1997) believe Fisher's alpha to be a useful index provided the ratio of the total number of individuals to the species number (N/S) exceeds 1.44 (Seaby and Henderson, 2006). Fisher’s alpha diversity was highest during months of dry season coinciding with Shannon index for all sites except Site-5. Site-5 shows highest Shannon diversity index in December `09 and Fisher’s alpha diversity in October `11 (26.78), which was highest of all sites throughout study period.

Margalef’s, Menhinick’s and Chao species richness values were higher in the months of dry season similar to other diversity indices. Margalef’s and Menhinick’s richness values were coinciding with each other at all sites with highest at Site-5 in December `09. Chao species richness show little different trend and was also highest at Site-5 (November `10) as compared to other sites throughout study period.

In present study all the diversity indices were higher at all the sites during the months of dry season and lower during wet season. This was because of lower zooplankton population due to dilution of water at different sites during monsoon and concentration of nutrients during dry seasons due to evaporation leading to higher zooplankton population.

Also the diversity indices were highest in Site-5 as compared to other sites, indicating nutrient richness of the water body. Similarly, Site-3 showed, the lowest diversity indices as compared to other sites indicating least nutrient richness of the water body.

Single linkage cluster analysis for zooplankton abundance, show intra and inter seasonal relationships in the different sites. In Site-1 two kinds of similarities were observed. Similarity with the months of wet seasons of both years seen in first cluster, similarly in second cluster similarity in the months of dry seasons of both years was observed. Similar kinds of trends were observed in all the sites, where the months of wet season show similarity within the same year as well as the next year forming a cluster. Also months of dry season formed cluster within same year and the next year. Such clustering indicates that, the similarity in zooplankton populations depends upon the prevailing conditions. As the prevailing conditions are similar in the same season and year after year it shows similarity.

Months	Taxa	Individuals	Dominance	Simpson	Shannon_H	Evenness	Brillouin	Menhinick	Margalef	Equitability	Fisher_ alpha	Berger-Parker	Chao-1
Dec-09	3.00	3.00	0.33	0.67	1.10	1.00	0.60	1.73	1.82	1.00	0.00	0.33	6.00
Jan-10	7.00	20.00	0.17	0.83	1.85	0.91	1.47	1.57	2.00	0.95	3.83	0.25	7.00
Feb-10	6.00	12.00	0.22	0.78	1.63	0.85	1.19	1.73	2.01	0.91	4.78	0.33	7.50
Mar-10	7.00	8.00	0.16	0.84	1.91	0.96	1.24	2.48	2.89	0.98	26.78	0.25	14.50
Apr-10	7.00	13.00	0.27	0.73	1.63	0.73	1.18	1.94	2.34	0.84	6.18	0.46	12.00
May-10	3.00	3.00	0.33	0.67	1.10	1.00	0.60	1.73	1.82	1.00	0.00	0.33	6.00
Jun-10	3.00	3.00	0.33	0.67	1.10	1.00	0.60	1.73	1.82	1.00	0.00	0.33	6.00
Jul-10	3.00	4.00	0.38	0.63	1.04	0.94	0.62	1.50	1.44	0.95	5.45	0.50	3.50
Aug-10	1.00	1.00	1.00	0.00	0.00	1.00	0.00	1.00	0.00	-----	0.00	1.00	1.00
Sep-10	1.00	1.00	1.00	0.00	0.00	1.00	0.00	1.00	0.00	-----	0.00	1.00	1.00
Oct-10	1.00	1.00	1.00	0.00	0.00	1.00	0.00	1.00	0.00	-----	0.00	1.00	1.00
Nov-10	3.00	3.00	0.33	0.67	1.10	1.00	0.60	1.73	1.82	1.00	0.00	0.33	6.00
Dec-10	3.00	3.00	0.33	0.67	1.10	1.00	0.60	1.73	1.82	1.00	0.00	0.33	6.00
Jan-11	4.00	5.00	0.28	0.72	1.33	0.95	0.82	1.79	1.86	0.96	9.28	0.40	5.50
Feb-11	3.00	4.00	0.38	0.63	1.04	0.94	0.62	1.50	1.44	0.95	5.45	0.50	3.50
Mar-11	5.00	7.00	0.27	0.73	1.48	0.87	0.96	1.89	2.06	0.92	7.82	0.43	11.00
Apr-11	6.00	8.00	0.19	0.81	1.73	0.94	1.15	2.12	2.40	0.97	10.91	0.25	8.00
May-11	4.00	6.00	0.33	0.67	1.24	0.87	0.80	1.63	1.67	0.90	5.25	0.50	7.00
Jun-11	2.00	2.00	0.50	0.50	0.69	1.00	0.35	1.41	1.44	1.00	0.00	0.50	3.00
Jul-11	1.00	1.00	1.00	0.00	0.00	1.00	0.00	1.00	0.00	-----	0.00	1.00	1.00
Aug-11	2.00	2.00	1	0.50	0.69	1.00	0.35	1.41	1.44	1.00	0.00	0.50	3.00
Sep-11	2.00	3.00	0.56	0.44	0.64	0.94	0.37	1.16	0.91	0.92	2.62	0.67	2.00
Oct-11	2.00	7.00	0.76	0.24	0.41	0.75	0.28	0.76	0.51	0.59	0.94	0.86	2.00
Nov-11	6.00	18.00	0.54	0.46	1.04	0.47	0.77	1.41	1.73	0.58	3.15	0.72	16.00

Table 3.1. Indices for zooplankton abundance in Site-1 (Shri Shantadurga Temple tank - Kavalem) during study period.

Months	Taxa	Individuals	Dominance	Simpson	Shannon_H	Evenness	Brillouin	Menhinick	Margalef	Equitability	Fisher_ alpha	Berger-Parker	Chao-1
Dec-09	12.00	27.00	0.12	0.88	2.31	0.84	1.84	2.31	3.34	0.93	8.28	0.22	13.00
Jan-10	5.00	9.00	0.28	0.72	1.43	0.83	0.99	1.67	1.82	0.89	4.63	0.44	6.50
Feb-10	6.00	10.00	0.20	0.80	1.70	0.91	1.19	1.90	2.17	0.95	6.33	0.30	7.00
Mar-10	6.00	9.00	0.19	0.81	1.74	0.94	1.19	2.00	2.28	0.97	7.87	0.22	6.75
Apr-10	5.00	5.00	0.20	0.80	1.61	1.00	0.96	2.24	2.49	1.00	0.00	0.20	15.00
May-10	5.00	8.00	0.25	0.75	1.49	0.89	1.02	1.77	1.92	0.93	5.71	0.38	6.50
Jun-10	1.00	1.00	1.00	0.00	0.00	1.00	0.00	1.00	0.00	-----	0.00	1.00	1.00
Jul-10	1.00	2.00	1.00	0.00	0.00	1.00	0.00	0.71	0.00	-----	0.80	1.00	1.00
Aug-10	1.00	1.00	1.00	0.00	0.00	1.00	0.00	1.00	0.00	-----	0.00	1.00	1.00
Sep-10	1.00	2.00	1.00	0.00	0.00	1.00	0.00	0.71	0.00	-----	0.80	1.00	1.00
Oct-10	3.00	5.00	0.44	0.56	0.95	0.86	0.60	1.34	1.24	0.87	3.17	0.60	4.00
Nov-10	2.00	6.00	0.56	0.44	0.64	0.94	0.45	0.82	0.56	0.92	1.05	0.67	2.00
Dec-10	2.00	3.00	0.56	0.44	0.64	0.94	0.37	1.16	0.91	0.92	2.62	0.67	2.00
Jan-11	6.00	11.00	0.22	0.78	1.64	0.86	1.18	1.81	2.09	0.92	5.40	0.36	7.00
Feb-11	4.00	16.00	0.38	0.62	1.16	0.80	0.92	1.00	1.08	0.83	1.71	0.56	4.00
Mar-11	3.00	6.00	0.39	0.61	1.01	0.92	0.68	1.23	1.12	0.92	2.39	0.50	3.00
Apr-11	4.00	4.00	0.25	0.75	1.39	1.00	0.79	2.00	2.16	1.00	0.00	0.25	10.00
May-11	6.00	10.00	0.24	0.76	1.61	0.83	1.12	1.90	2.17	0.90	6.33	0.40	9.00
Jun-11	2.00	2.00	0.50	0.50	0.69	1.00	0.35	1.41	1.44	1.00	0.00	0.50	3.00
Jul-11	1.00	1.00	1.00	0.00	0.00	1.00	0.00	1.00	0.00	-----	0.00	1.00	1.00
Aug-11	3.00	4.00	0.38	0.63	1.04	0.94	0.62	1.50	1.44	0.95	5.45	0.50	3.50
Sep-11	2.00	2.00	0.50	0.50	0.69	1.00	0.35	1.41	1.44	1.00	0.00	0.50	3.00
Oct-11	5.00	9.00	0.23	0.77	1.52	0.92	1.07	1.67	1.82	0.95	4.63	0.33	5.33
Nov-11	9.00	25.00	0.15	0.85	2.04	0.86	1.64	1.80	2.49	0.93	5.04	0.28	9.00

Table 3.2. Indices for zooplankton abundance in Site-2 (Shri Ramnath Temple tank - Ramnathi) during study period.

Months	Taxa	Individuals	Dominance	Simpson	Shannon_H	Evenness	Brillouin	Menhinick	Margalef	Equitability	Fisher_ alpha	Berger-Parker	Chao-1
Dec-09	1.00	1.00	1.00	0.00	0.00	1.00	0.00	1.00	0.00	-----	0.00	1.00	1.00
Jan-10	1.00	1.00	1.00	0.00	0.00	1.00	0.00	1.00	0.00	-----	0.00	1.00	1.00
Feb-10	2.00	2.00	0.50	0.50	0.69	1.00	0.35	1.41	1.44	1.00	0.00	0.50	3.00
Mar-10	1.00	1.00	1.00	0.00	0.00	1.00	0.00	1.00	0.00	-----	0.00	1.00	1.00
Apr-10	1.00	1.00	1.00	0.00	0.00	1.00	0.00	1.00	0.00	-----	0.00	1.00	1.00
May-10	2.00	2.00	0.50	0.50	0.69	1.00	0.35	1.41	1.44	1.00	0.00	0.50	3.00
Jun-10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Jul-10	1.00	1.00	1.00	0.00	0.00	1.00	0.00	1.00	0.00	-----	0.00	1.00	1.00
Aug-10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sep-10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Oct-10	1.00	1.00	1.00	0.00	0.00	1.00	0.00	1.00	0.00	-----	0.00	1.00	1.00
Nov-10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Dec-10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Jan-11	1.00	1.00	1.00	0.00	0.00	1.00	0.00	1.00	0.00	-----	0.00	1.00	1.00
Feb-11	1.00	1.00	1.00	0.00	0.00	1.00	0.00	1.00	0.00	-----	0.00	1.00	1.00
Mar-11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Apr-11	2.00	2.00	0.50	0.50	0.69	1.00	0.35	1.41	1.44	1.00	0.00	0.50	3.00
May-11	1.00	1.00	1.00	0.00	0.00	1.00	0.00	1.00	0.00	-----	0.00	1.00	1.00
Jun-11	1.00	1.00	1.00	0.00	0.00	1.00	0.00	1.00	0.00	-----	0.00	1.00	1.00
Jul-11	1.00	1.00	1.00	0.00	0.00	1.00	0.00	1.00	0.00	-----	0.00	1.00	1.00
Aug-11	1.00	1.00	1.00	0.00	0.00	1.00	0.00	1.00	0.00	-----	0.00	1.00	1.00
Sep-11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Oct-11	4.00	4.00	0.25	0.75	1.39	1.00	0.79	2.00	2.16	1.00	0.00	0.25	10.00
Nov-11	1.00	1.00	1.00	0.00	0.00	1.00	0.00	1.00	0.00	-----	0.00	1.00	1.00

Table 3.3. Indices for zooplankton abundance in Site-3 (Shri Naguesh Temple tank - Nagueshim) during study period.

Months	Taxa	Individuals	Dominance	Simpson	Shannon_H	Evenness	Brillouin	Menhinick	Margalef	Equitability	Fisher_ alpha	Berger-Parker	Chao-1
Dec-09	1.00	1.00	1.00	0.00	0.00	1.00	0.00	1.00	0.00	-----	0.00	1.00	1.00
Jan-10	3.00	4.00	0.38	0.63	1.04	0.94	0.62	1.50	1.44	0.95	5.45	0.50	3.50
Feb-10	6.00	7.00	0.18	0.82	1.75	0.96	1.12	2.27	2.57	0.98	19.95	0.29	11.00
Mar-10	2.00	3.00	0.56	0.44	0.64	0.94	0.37	1.16	0.91	0.92	2.62	0.67	2.00
Apr-10	4.00	5.00	0.28	0.72	1.33	0.95	0.82	1.79	1.86	0.96	9.28	0.40	5.50
May-10	3.00	6.00	0.50	0.50	0.87	0.79	0.57	1.23	1.12	0.79	2.39	0.67	4.00
Jun-10	5.00	9.00	0.23	0.77	1.52	0.92	1.07	1.67	1.82	0.95	4.63	0.33	5.33
Jul-10	2.00	2.00	0.50	0.50	0.69	1.00	0.35	1.41	1.44	1.00	0.00	0.50	3.00
Aug-10	2.00	2.00	0.50	0.50	0.69	1.00	0.35	1.41	1.44	1.00	0.00	0.50	3.00
Sep-10	1.00	1.00	1.00	0.00	0.00	1.00	0.00	1.00	0.00	-----	0.00	1.00	1.00
Oct-10	2.00	3.00	0.56	0.44	0.64	0.94	0.37	1.16	0.91	0.92	2.62	0.67	2.00
Nov-10	4.00	4.00	0.25	0.75	1.39	1.00	0.79	2.00	2.16	1.00	0.00	0.25	10.00
Dec-10	3.00	3.00	0.33	0.67	1.10	1.00	0.60	1.73	1.82	1.00	0.00	0.33	6.00
Jan-11	3.00	4.00	0.38	0.63	1.04	0.94	0.62	1.50	1.44	0.95	5.45	0.50	3.50
Feb-11	3.00	3.00	0.33	0.67	1.10	1.00	0.60	1.73	1.82	1.00	0.00	0.33	6.00
Mar-11	5.00	7.00	0.22	0.78	1.55	0.94	1.02	1.89	2.06	0.96	7.82	0.29	6.00
Apr-11	3.00	3.00	0.33	0.67	1.10	1.00	0.60	1.73	1.82	1.00	0.00	0.33	6.00
May-11	2.00	2.00	0.50	0.50	0.69	1.00	0.35	1.41	1.44	1.00	0.00	0.50	3.00
Jun-11	5.00	7.00	0.22	0.78	1.55	0.94	1.02	1.89	2.06	0.96	7.82	0.29	6.00
Jul-11	1.00	1.00	1.00	0.00	0.00	1.00	0.00	1.00	0.00	-----	0.00	1.00	1.00
Aug-11	2.00	2.00	0.50	0.50	0.69	1.00	0.35	1.41	1.44	1.00	0.00	0.50	3.00
Sep-11	1.00	1.00	1.00	0.00	0.00	1.00	0.00	1.00	0.00	-----	0.00	1.00	1.00
Oct-11	3.00	3.00	0.33	0.67	1.10	1.00	0.60	1.73	1.82	1.00	0.00	0.33	6.00
Nov-11	3.00	3.00	0.33	0.67	1.10	1.00	0.60	1.73	1.82	1.00	0.00	0.33	6.00

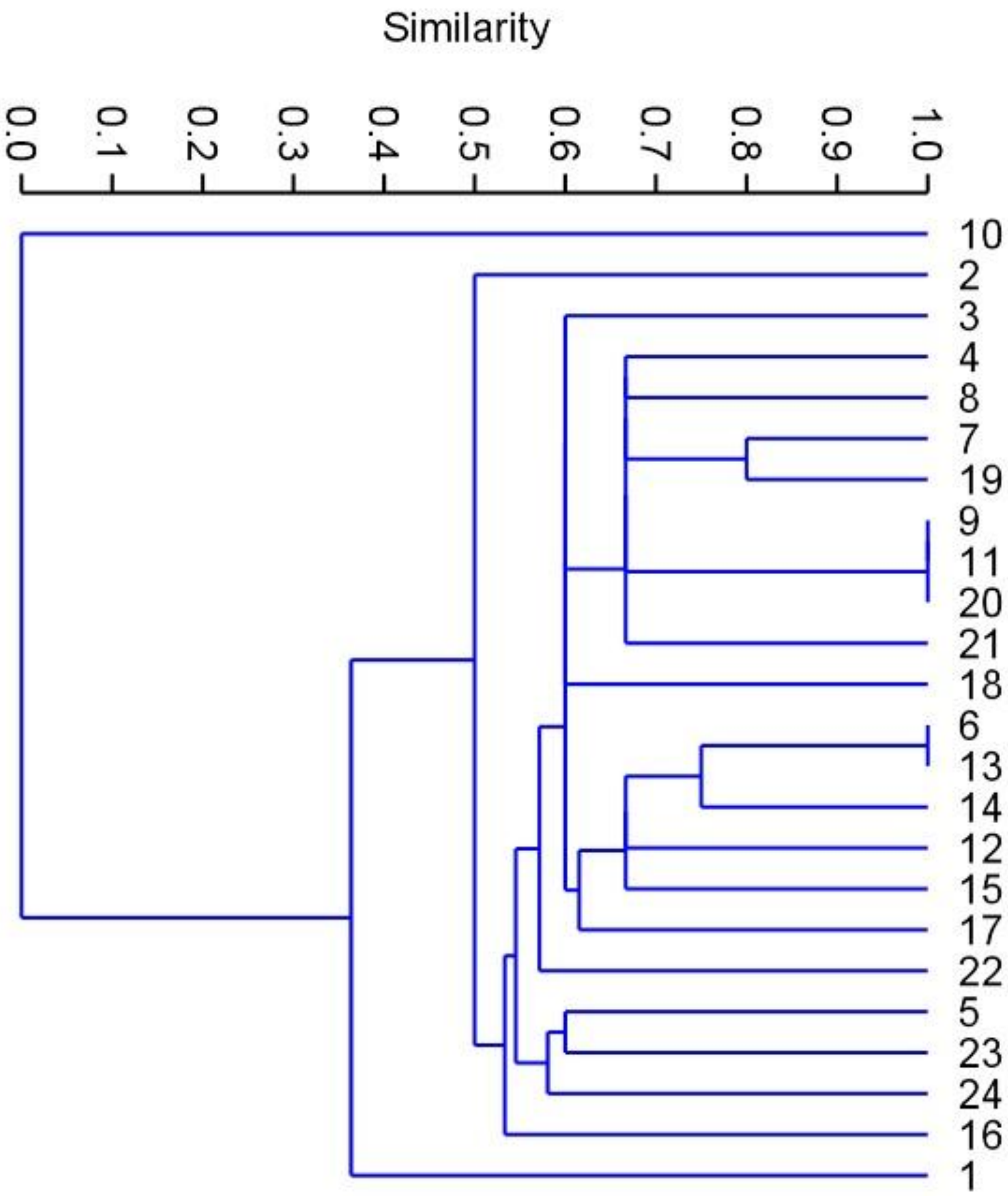
Table 3.4. Indices for zooplankton abundance in Site-4 (Shri Mahalaxmi Temple tank - Bandora) during study period.

Months	Taxa	Individuals	Dominance	Simpson	Shannon_H	Evenness	Brillouin	Menhinick	Margalef	Equitability	Fisher_ alpha	Berger-Parker	Chao-1
Dec-09	10.00	15.00	0.12	0.88	2.21	0.91	1.60	2.58	3.32	0.96	13.11	0.20	13.75
Jan-10	3.00	3.00	0.33	0.67	1.10	1.00	0.60	1.73	1.82	1.00	0.00	0.33	6.00
Feb-10	5.00	7.00	0.22	0.78	1.55	0.94	1.02	1.89	2.06	0.96	7.82	0.29	6.00
Mar-10	10.00	17.00	0.12	0.88	2.20	0.90	1.64	2.43	3.18	0.96	10.19	0.18	12.50
Apr-10	8.00	12.00	0.15	0.85	1.98	0.90	1.40	2.31	2.82	0.95	10.49	0.25	11.33
May-10	6.00	10.00	0.24	0.76	1.61	0.83	1.12	1.90	2.17	0.90	6.33	0.40	9.00
Jun-10	5.00	7.00	0.22	0.78	1.55	0.94	1.02	1.89	2.06	0.96	7.82	0.29	6.00
Jul-10	5.00	11.00	0.36	0.64	1.30	0.73	0.93	1.51	1.67	0.80	3.54	0.55	6.50
Aug-10	4.00	5.00	0.28	0.72	1.33	0.95	0.82	1.79	1.86	0.96	9.28	0.40	5.50
Sep-10	2.00	2.00	0.50	0.50	0.69	1.00	0.35	1.41	1.44	1.00	0.00	0.50	3.00
Oct-10	4.00	6.00	0.33	0.67	1.24	0.87	0.80	1.63	1.67	0.90	5.25	0.50	7.00
Nov-10	6.00	6.00	0.17	0.83	1.79	1.00	1.10	2.45	2.79	1.00	0.00	0.17	21.00
Dec-10	6.00	8.00	0.19	0.81	1.73	0.94	1.15	2.12	2.40	0.97	10.91	0.25	8.00
Jan-11	4.00	4.00	0.25	0.75	1.39	1.00	0.79	2.00	2.16	1.00	0.00	0.25	10.00
Feb-11	7.00	11.00	0.17	0.83	1.85	0.91	1.30	2.11	2.50	0.95	8.29	0.27	9.00
Mar-11	8.00	13.00	0.14	0.86	2.03	0.95	1.47	2.22	2.73	0.98	8.86	0.15	8.50
Apr-11	3.00	4.00	0.38	0.63	1.04	0.94	0.62	1.50	1.44	0.95	5.45	0.50	3.50
May-11	7.00	11.00	0.17	0.83	1.85	0.91	1.30	2.11	2.50	0.95	8.29	0.27	9.00
Jun-11	5.00	8.00	0.25	0.75	1.49	0.89	1.02	1.77	1.92	0.93	5.71	0.38	6.50
Jul-11	2.00	2.00	0.50	0.50	0.69	1.00	0.35	1.41	1.44	1.00	0.00	0.50	3.00
Aug-11	3.00	4.00	0.38	0.63	1.04	0.94	0.62	1.50	1.44	0.95	5.45	0.50	3.50
Sep-11	4.00	6.00	0.33	0.67	1.24	0.87	0.80	1.63	1.67	0.90	5.25	0.50	7.00
Oct-11	7.00	8.00	0.16	0.84	1.91	0.96	1.24	2.48	2.89	0.98	26.78	0.25	14.50
Nov-11	10.00	20.00	0.14	0.86	2.13	0.84	1.63	2.24	3.00	0.92	7.96	0.25	13.33

Table 3.5. Indices for zooplankton abundance in Site-5 (Shri Mahalsa Temple tank - Mardol) during study period.

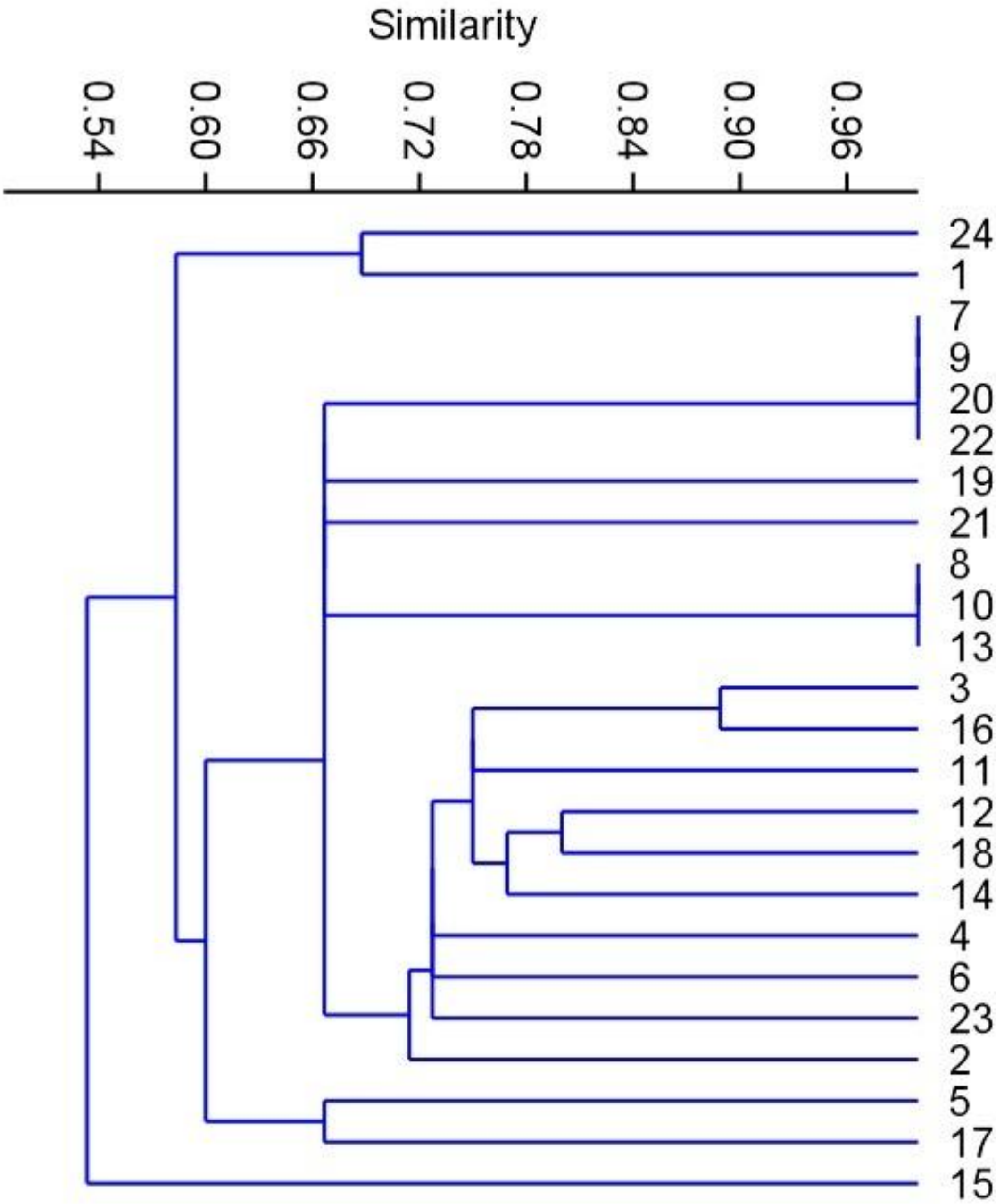
Site-6	Taxa	Individuals	Dominance	Simpson	Shannon_H	Evenness	Brillouin	Menhinick	Margalef	Equitability	Fisher_ alpha	Berger-Parker	Chao-1
Dec-09	4.00	4.00	0.25	0.75	1.39	1.00	0.79	2.00	2.16	1.00	0.00	0.25	10.00
Jan-10	3.00	3.00	0.33	0.67	1.10	1.00	0.60	1.73	1.82	1.00	0.00	0.33	6.00
Feb-10	3.00	4.00	0.38	0.63	1.04	0.94	0.62	1.50	1.44	0.95	5.45	0.50	3.50
Mar-10	4.00	4.00	0.25	0.75	1.39	1.00	0.79	2.00	2.16	1.00	0.00	0.25	10.00
Apr-10	4.00	4.00	0.25	0.75	1.39	1.00	0.79	2.00	2.16	1.00	0.00	0.25	10.00
May-10	8.00	10.00	0.14	0.86	2.03	0.95	1.37	2.53	3.04	0.97	18.57	0.20	13.00
Jun-10	4.00	4.00	0.25	0.75	1.39	1.00	0.79	2.00	2.16	1.00	0.00	0.25	10.00
Jul-10	2.00	4.00	0.63	0.38	0.56	0.88	0.35	1.00	0.72	0.81	1.59	0.75	2.00
Aug-10	3.00	4.00	0.38	0.63	1.04	0.94	0.62	1.50	1.44	0.95	5.45	0.50	3.50
Sep-10	5.00	5.00	0.20	0.80	1.61	1.00	0.96	2.24	2.49	1.00	0.00	0.20	15.00
Oct-10	2.00	2.00	0.50	0.50	0.69	1.00	0.35	1.41	1.44	1.00	0.00	0.50	3.00
Nov-10	5.00	7.00	0.22	0.78	1.55	0.94	1.02	1.89	2.06	0.96	7.82	0.29	6.00
Dec-10	7.00	15.00	0.18	0.82	1.81	0.87	1.36	1.81	2.22	0.93	5.11	0.27	8.50
Jan-11	5.00	5.00	0.20	0.80	1.61	1.00	0.96	2.24	2.49	1.00	0.00	0.20	15.00
Feb-11	3.00	4.00	0.38	0.63	1.04	0.94	0.62	1.50	1.44	0.95	5.45	0.50	3.50
Mar-11	3.00	4.00	0.38	0.63	1.04	0.94	0.62	1.50	1.44	0.95	5.45	0.50	3.50
Apr-11	3.00	4.00	0.38	0.63	1.04	0.94	0.62	1.50	1.44	0.95	5.45	0.50	3.50
May-11	4.00	6.00	0.28	0.72	1.33	0.94	0.87	1.63	1.67	0.96	5.25	0.33	4.33
Jun-11	3.00	3.00	0.33	0.67	1.10	1.00	0.60	1.73	1.82	1.00	0.00	0.33	6.00
Jul-11	2.00	2.00	0.50	0.50	0.69	1.00	0.35	1.41	1.44	1.00	0.00	0.50	3.00
Aug-11	2.00	3.00	0.56	0.44	0.64	0.94	0.37	1.16	0.91	0.92	2.62	0.67	2.00
Sep-11	1.00	1.00	1.00	0.00	0.00	1.00	0.00	1.00	0.00	-----	0.00	1.00	1.00
Oct-11	3.00	3.00	0.33	0.67	1.10	1.00	0.60	1.73	1.82	1.00	0.00	0.33	6.00
Nov-11	4.00	4.00	0.25	0.75	1.39	1.00	0.79	2.00	2.16	1.00	0.00	0.25	10.00

Table 3.6. Indices for zooplankton abundance in Site-6 (Shri Manguesh Temple tank - Mangueshim) during study period.



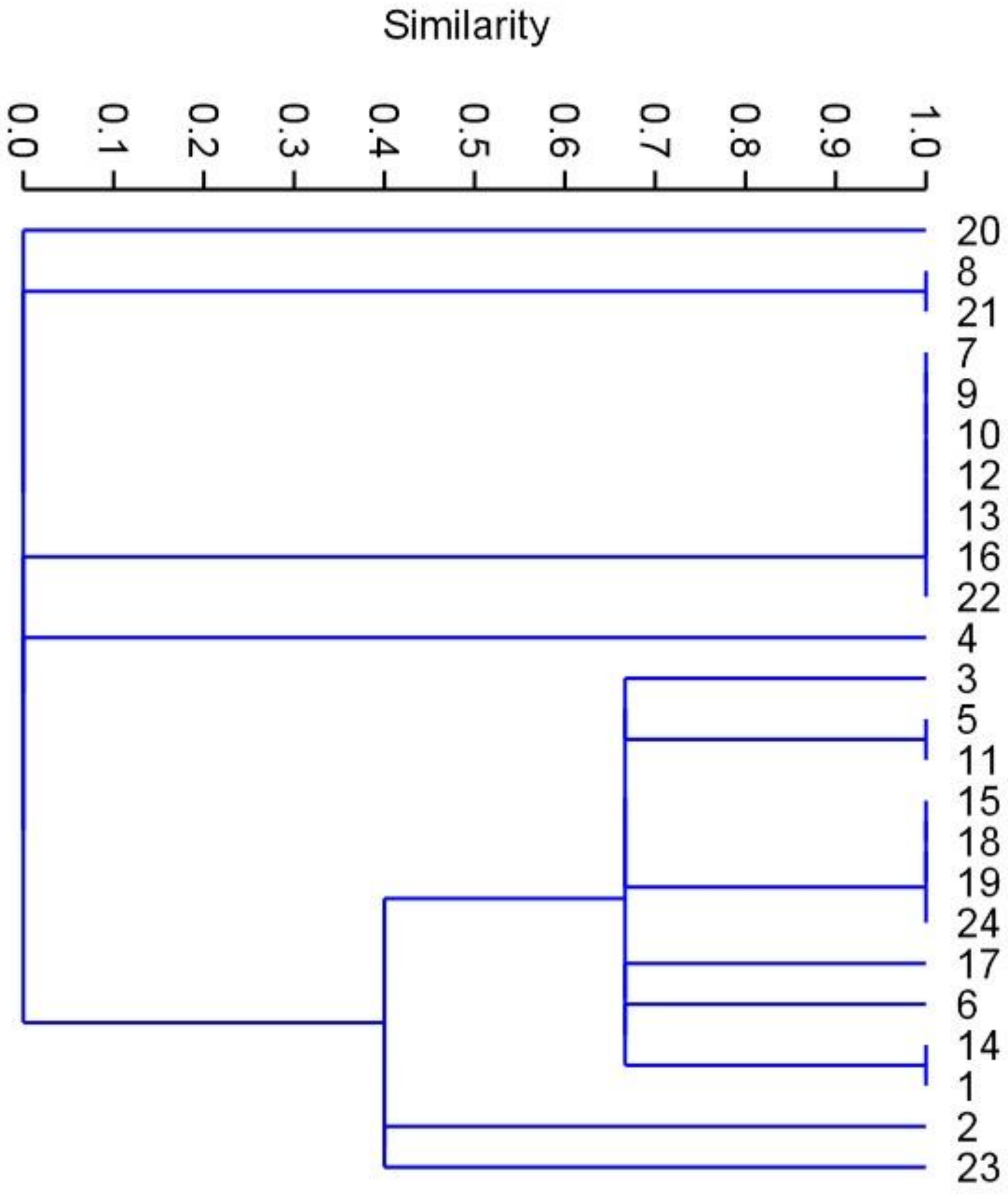
Key: 1-24, December 2009 – November 2011

Fig. 3.2.1. Single linkage cluster analysis for Site-1 during study period.



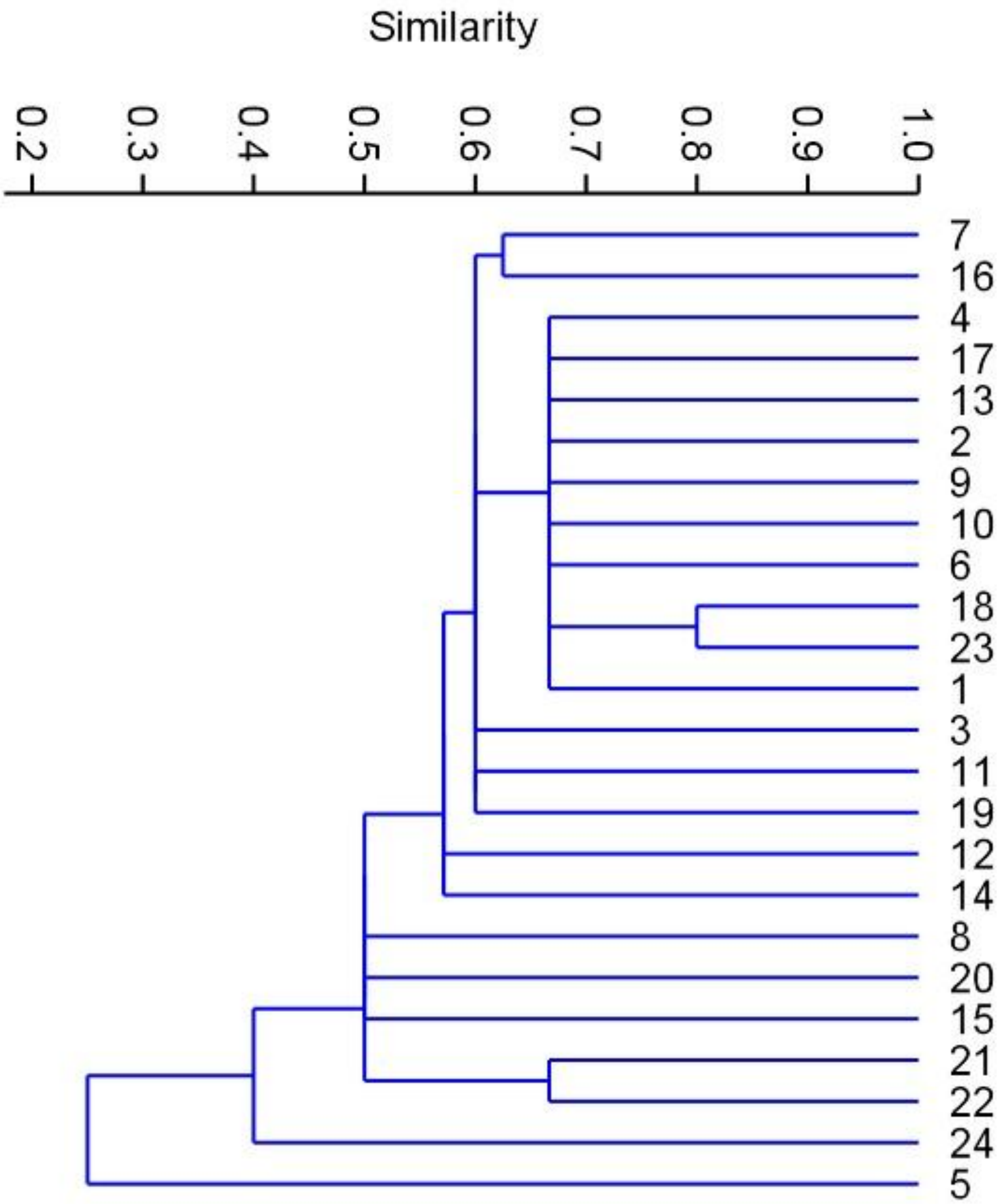
Key: 1-24, December 2009 – November 2011

Fig. 3.2.2. Single linkage cluster analysis for Site-2 during study period.



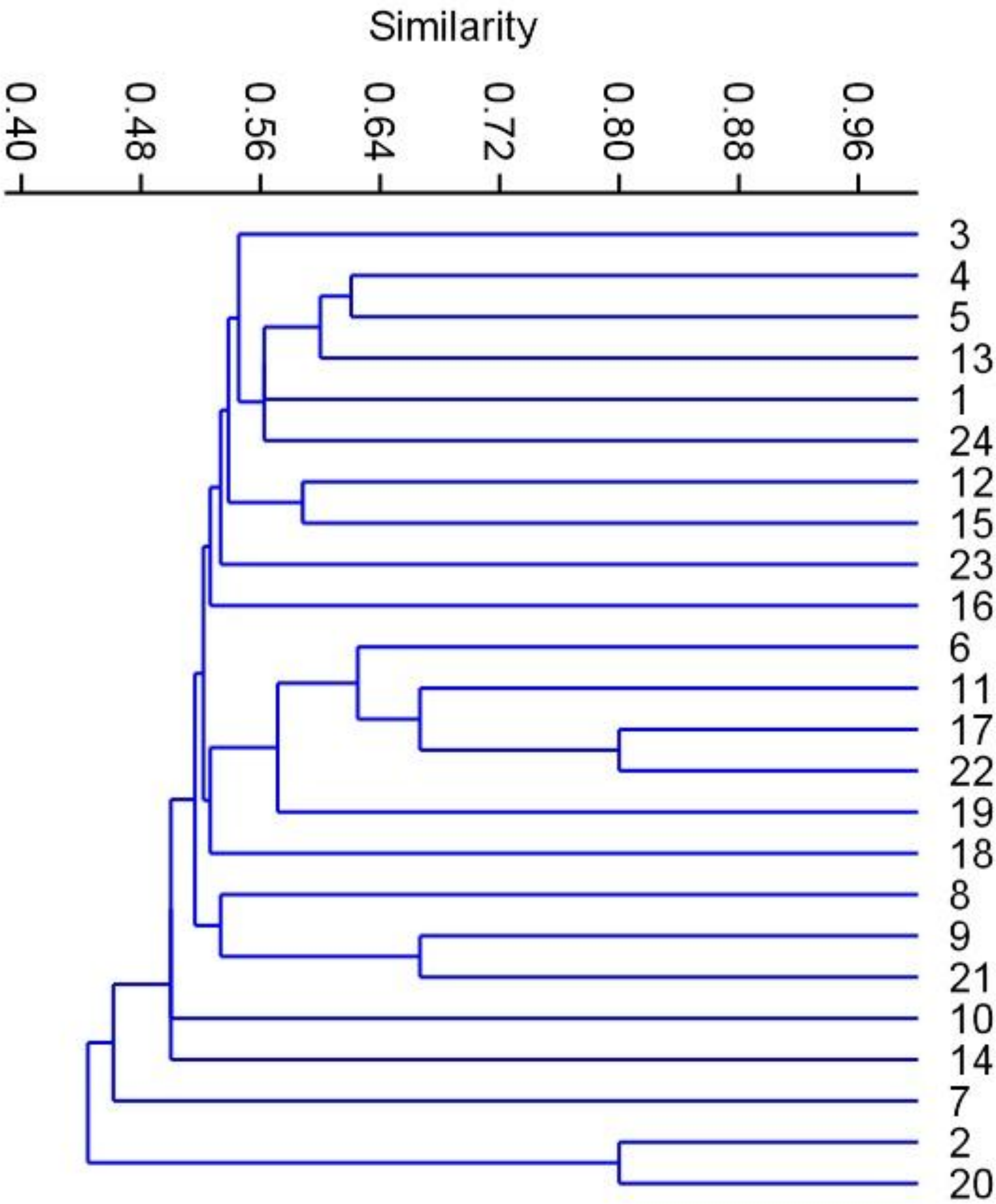
Key: 1-24, December 2009 – November 2011

Fig. 3.2.3. Single linkage cluster analysis for Site-3 during study period.



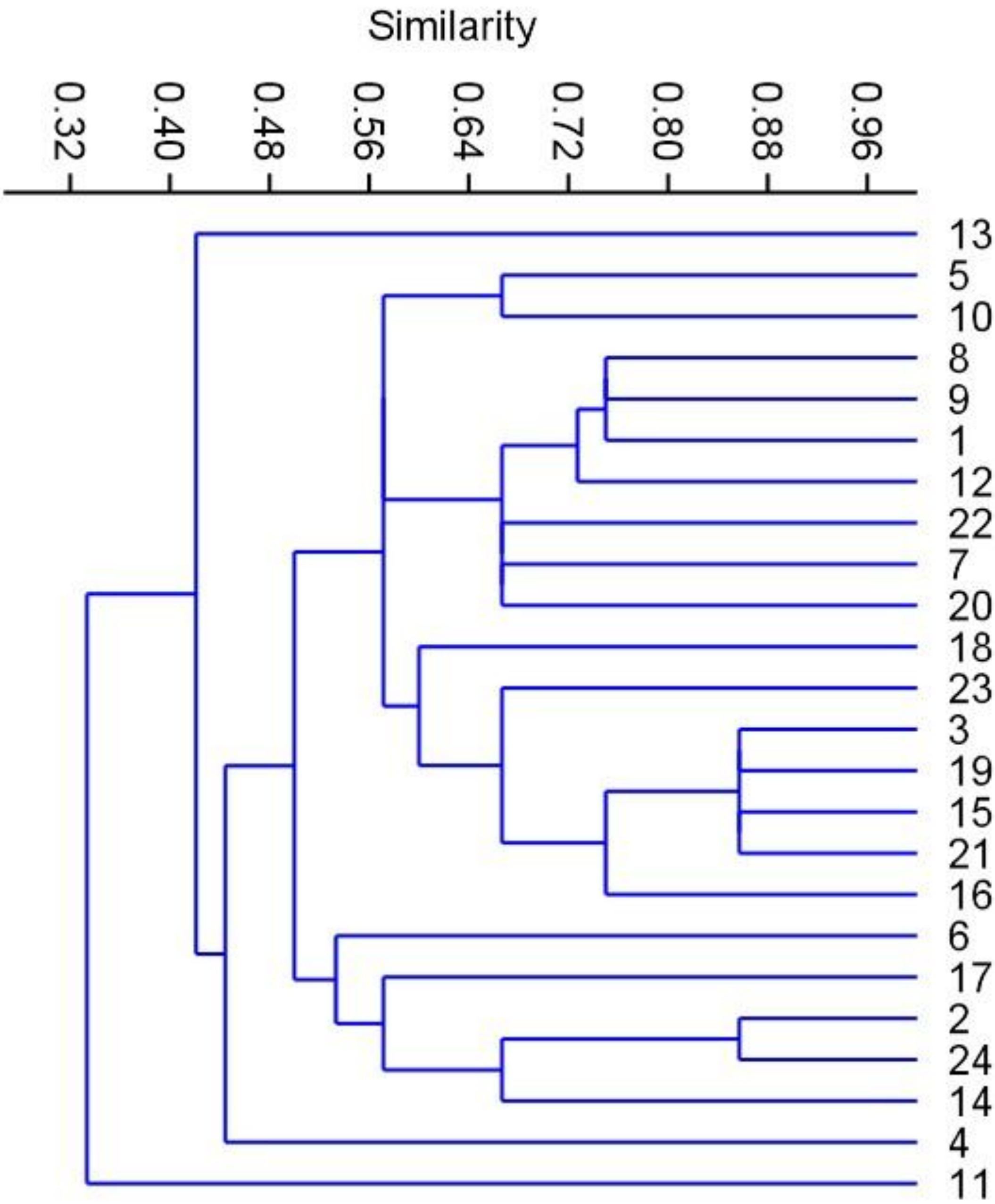
Key: 1-24, December 2009 – November 2011

Fig. 3.2.4. Single linkage cluster analysis for Site-4 during study period.



Key: 1-24, December 2009 – November 2011

Fig. 3.2.5. Single linkage cluster analysis for Site-5 during study period.



Key: 1-24, December 2009 – November 2011

Fig. 3.2.6. Single linkage cluster analysis for Site-6 during study period.

SUMMARY AND CONCLUSION

- Probably, for the first time a comprehensive study on temple tanks of Ponda taluka of Goa state was undertaken.
- The project was almost complete and comprehensive as the studies included analysis of physical, chemical and biological parameters.
- The present investigation led us to conclude that, quality of water from all the sites under study was within the permissible limits for majority of physicochemical parameters, except for bacteriological standards are concerned, where the water needs to be treated before using it in domestic purposes.
- During rainy season, a rise in phosphate content was observed in all water bodies under study, which can be accounted for runoffs from nearby area of Kulagarhs (surrounding areca nut / coconut and other agricultural fields), which are sprayed with fertilisers.
- All water bodies studied, showed seasonal bimodal peaks with higher zooplankton density during summer, followed by winter, which may be due to congenial environment for its luxuriant growth of the biological materials due to presence of nutrients. Apart from the above, during rainy season, the water body gets more quantity of water, diluting the density of zooplankton.
- Copepods were found to be dominant in all water bodies studied followed by rotifers and cladocerans in all water bodies studied except Site-5, which showed cladocerans dominance followed by rotifers
- From this study, it can be inferred that, the copepod group adapts well to the changes occurring throughout the year, in the water bodies and thus found during all seasons.
- Rotifers were the second most abundant zooplankton group in all water bodies, which may be due to their small size, sturdiness and capacity for adaptation to varied agro-climatic conditions.

- Harpacticoids and ostracods were present in very low numbers may be due to their poor adaptability.
- Site-3 (Shri Naguesh Temple tank) had the least zooplankton abundance among the temple tanks studied and Site-5 (Shri Mahalasa Temple tank), had the highest zooplankton abundance as the Site-3 has least nutrients and Site-5 shows gradual change towards eutrophication.
- Among rotifers, species of Brachionidae were found in maximum numbers. Among these, *Keratella tropica* was the most predominant species present in all sites.
- In the present faunistic survey of zooplankton 38 species of zooplankton recorded.
- Site-5 (Shri Mahalasa Temple tank) had the highest species diversity of zooplankton, while Site-3 (Shri Naguesh Temple tank) had the least number of species among the temple tanks studied.
- The trends in zooplankton abundance in this study indicated that, it was more in abundance, during the months of the dry season and less during the months of the wet season.
- Larval stages of copepods showed regular appearance throughout the year.
- Similarity in zooplankton population depends upon the prevailing climatic conditions.
- Pearson’s correlation between physico-chemical parameters and zooplankton from different sites has revealed mostly insignificant results of coefficient of correlation (r). This indicates that no single factor is strong determinant for zooplanktonic abundance and a sum total of a number of factors are responsible for their diversity and density.
- Study has determined that, abundance of zooplankton has been governed by the cumulative effect of physico-chemical and biological variables.

- All the temple tanks studied are oligotrophic in nature, though the Site-5 (Shri Mahalasa Temple tank) showed an inclination towards enrichment of nutrients and hence is in the process of eutrophication.

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1) Priolkar, K. and I. K. Pai (2010). Water quality assessment of a few sacred temple tanks of Goa. *Columban J. of life science*, 11(1&2): 63-66.

2) Priolkar, K. and I. K. Pai (2013). Seasonal variations of zooplankton community in two sacred temple tanks of Ponda, Goa, India. *Biojournal*, 8(1): 44-52.

3) Priolkar, K. and I. K. Pai (2013). Diversity and seasonal abundance of zooplankton communities in two sacred temple tanks of Ponda taluka, Goa. *J. Appl. Biosci.*, 39(1): 30-34.

4) Priolkar, K. and I. K. Pai (2013). A survey of diversity and seasonal abundance of zooplankton communities in temple tanks of Ponda taluka, Goa. *Biojournal*, 8(2): 80-90.

Paper Presented:

1) Priolkar, K. and I. K. Pai (2010). Hydrobiological studies of a few sacred temple tanks of Goa. *Intl. Conf. on Envtl. Poll. Water Conserv. & Health.*, Jul. 29-31, Bangalore.

PLATE 4

Diaptomus gracillus

Heliodiaptomus cinctus

Heliodiaptomus cinctus

Diaptomus floridanus

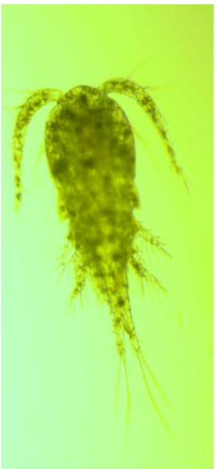
Paradiaptomus greeni

Diaptomus floridanus

PLATE 5

Eucyclops agilis

Haliocyclops christiansis



Mesocyclops dybowskii

Paracyclops poppei

Bryocamptus sps

Tanypodinae Larva

PLATE 6

Ceriodaphnia cornuta

Moinodaphnia macleayi

Moina brachiata

Macrothrix laticornis

Moina micrura

Cypris

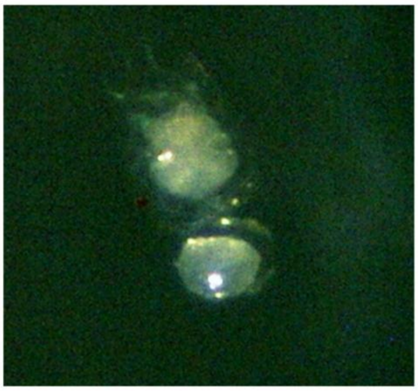
PLATE 7

Asplanchna intermedia

Keratella procurva

Brachionus falcatus

Brachionus caudatus



Brachionus calciflorus

Brachionus calciflorus