Chapter - 6

DISCUSSION
DISCUSSION

During present study different desert water ponds (Kolayat, Gajner and Kodemdesar) were explored to determine the relationships among the principal cations, anions and various other limnological parameters and plankton community. The main objective was to elucidate the effect of relative ionic composition on the diversity and density of plankton populations. The limnological parameters studied included Temperature, Depth, Transparency, Turbidity, pH, EC, DO, Free CO₂, Hardness, Alkalinity, Salinity, cations including Sodium, Potassium, Calcium, Magnesium and anions including Carbonates, Bicarbonates, Chlorides and Sulphates, besides the important plant nutrients Phosphates, Nitrates and Silicates. In addition, both phytoplankton and zooplankton community of the ponds were investigated.

6.1 PHYSICAL-CHEMICAL VARIABLES

TEMPERATURE

Temperature was found to be more important as a co-variate with other factors than as an individual factor. Heat transfer influenced the water temperature in the ponds as the ponds were directly exposed to sun and absorption from the surround air. The atmospheric temperature was higher than the temperature of surface and bottom water. The high temperature recorded during summer at all the three ponds was due to high solar radiation. Low temperatures observed during monsoon and early postmonsoon season may be attributed to the monsoonal rain, cloudy sky and cold weather. Extreme seasonal temperature variation was due to differential amount of light
incidence over the water surface in different seasons, which is an important factor in arid and semiarid regions (Vyas 1968; Kumar 1996).

The extreme summer temperature (38°C) led to decline in water column due to evaporative loss and resultant increase in concentration of electrolytes as evident from high EC. Mittal (1996) has also documented some influence in hot desert water. Harding (1997) states that small water bodies are typically shallow and subject to continuous mixing. Therefore, the general pattern of the temperature profiles in the ponds was of a well mixing water body due to the small temperature ranges in the water column and the shallow nature of the ponds. Statistical analysis showed a positive correlation between air and surface water temperature of all the study areas.

**HYDROGEN ION CONCENTRATION (pH)**

The pH of the studied ponds was found to be alkaline in nature and varied between 7 to 9.5. The maximum pH was recorded in the month of February at Gajner pond and minimum in the month of October at Kolayat pond. The present observation of this parameter was in conformity with the work of (Muraleedharan et al., 2010) in Tamilnadu. Nile water in Egypt showed pH ranges of 7.4 to 8.4 (Ahmed et al., 1986 a). Very high pH 9.7 was recorded in the small stream of New Zealand (Marshall & Winterbourn, 1979). Similarly, in the river Padma, the water maintained relatively higher value of pH in winter season, when the phytoplankton was generally high (Ashfaque & Alfasane, 2004).

The earlier studies show that the range of pH of a majority of lakes and reservoirs lies between 6 and 9. This is in
accordance with earlier reports by Wetzel (1975) who reported that the value of pH ranges from 8 to 9 units in Indian waters. The alkaline nature of waters in the arid region is a common feature (Misra et al., 1978; Bugalia, 1990; Mittal, 1996; Chadha, 1999). Concentration of hydrogen ion is relatively stable and high in desert waters (Cole, 1968) and rise and fall in pH seems directly linked with concentration and dilution of alkali ions, particularly carbonates (Mittal, 1996). Sharma (2003) reviewed physical-chemical limnology of desert waters around Bikaner and also recorded alkaline nature of all the waters with a pH ranging from 7.1 (a temple tank) to 10.9 (a canal). He found that annual mean of pH among these waters ranged from 8.4 to 10.4. When different types of water were compared, he found that ponds, in general, were least alkaline and canal the most. The least annual fluctuations in pH (0.9) were found in canal and maximum (3.6) in tanks. The least fluctuation in canal water are because of its riverine source, where as in other waters the dilution and concentration of salts is pronounced and therefore, such waters present wide chemical variation over the annual cycle.

**ELECTRICAL CONDUCTANCE (EC)**

Conductivity of water depends upon the concentration of ions and its nutrient status and the variation in dissolved solid content. Higher the value of dissolved solids, greater the amount of ions in water (Bhatt et al., 1999).

The electrical conductance of pond waters ranged from 0.072 to 1.780 mmhos/cm. It was low during postmonsoon and winter season while there was a constant increase during summer. EC having a direct dependence upon various ions,
displayed positive correlation with calcium, nitrate, silica (P<0.1) and potassium (P<0.01) in Kodemdesar pond while with calcium, magnesium and alkalinity (P<0.01) in Gajner pond. Only Kolayat pond showed negative correlation of EC with sodium (P<0.1).

Sharma (2003) in his observations pointed out that desert waters around Bikaner held an EC ranging from 0.057 to 1.850 mmhos/cm and both minimum and maximum values were presented by village ponds. In the Indian desert surface waters are noted to hold, in general, relatively high EC (from 0.05 to 1.850 mmhos/cm) as shown in the studies of various workers (Lubana, 1991; Sharma, 1992; Sharan, 1993; Chadha, 1999 and Kiradoo, 2001).

TRANSPARENCY AND TURBIDITY

The intensity of light required to saturate algal photosynthesis varies with the transparency of the water, which is governed by the concentration of dissolved and particulate organic matter and abiotic turbidity (Wetzel, 2001) together with the Secchi depth. During present study the low Secchi depth values were observed in monsoon and postmonsoon seasons and it was due to increased turbidity of the water and low intensity of solar radiation. The transparency of the water varied from minimum (10 cm) during rainy season to maximum (195 cm) in winter season. Similar has been reported by (Singh et al., 2010) in Manipur river system.

The reduction of light penetration during monsoon season has been noted by (Chishty, 2002) in Udaipur waters. Qasim (1978) reported that the light penetration in water depends upon the clarity of water, the depth of the water column and the nature of the sediment. Turbidity of ponds varied from 0 J.T.U.
to 100 J.T.U. Kodemdesar pond showed maximum turbidity throughout the study period, while as Kolayat pond and Gajner pond were turbid only during monsoon season while during rest of the period there was 0 J.T.U. turbidity.

**DISSOLVED OXYGEN**

Dissolved Oxygen has been extensively used as a parameter delineating water quality and to evaluate the degree of freshness of a river (Fakayode, 2005). It is also an important limnological parameter indicating level of water quality and organic pollution in the water body (Wetzel & Lines, 2006). The maximum dissolved oxygen concentration occurred in the surface water of the ponds.

In present study DO content varied from 0.8 mg/l to 11.3 mg/l. Higher amount of DO was found in December at Gajner pond. The recommended DO concentration for healthy and productive water body is 8 mg/l (Wetzel, 1973). Variation of oxygen in water depends upon the temperature of water, which influences oxygen solubility (Zutshi & Vass, 1978).

In the desert waters, shallow pond water was found to be well aerated and is the review by Sharma (2003), the DO ranged from 0.89 mg/l (a temple tank) to 12.6 mg/l (a village pond). When different categories of water were compared, it was found that reservoir and canal were better oxygenated while ponds, tanks and lakes were almost at par.

The high oxygen in reservoir and canal may be correlated with the greater agitation in water leading to better oxygenation through air water interface. The period of high temperature nearly coincided with those of low oxygen found in Gajner pond, a feature also observed by (Neel, 1951).
In present study the fall in the level of DO from April to September, were followed by gradual rise in temperature. The hypersaturation of DO occurred during the month of December, February and March. During these months, phytoplankton density was higher and their higher photosynthetic rate might be the reason of hypersaturation. A strong correlation was also observed between pH and DO in Gajner pond. The value of DO was depleted during summer because at high temperature the oxygen holding capacity of water decreases. Present observations are in agreement with similar ones made by (Shastri & Pendse, 2001; Shanthi & Lakshmanaperumalsamy, 2002) who studied the Dahikhura Reservoir and Singanalluar Lake respectively.

FREE CO₂

The pond waters exhibit maximum carbon dioxide as 88 mg/1 (October) at Kodemdesar pond and minimum was 6 mg/1 (August) at Gajner pond. But Gajner pond presented higher amount of CO₂ in summer, might be due to deoxygenation to some extent, a feature also observed by (Talling, 1957). The rise in temperature in the water could be correlated with increased in CO₂ levels (Talling, 1957), but when the water level increased with commencement of the monsoon, its concentration decreased sharply. A strong positive correlation was observed between free CO₂ and water temperature in Gajner pond. Cole (1975) noted that free CO₂ supply rarely limits the growth of phytoplankton.

ALKALINITY

Alkalinity of water is a measure of weak acid present in it and of the cations balanced against them (Sverdrap et al., 1942).
Total alkalinity of water is due to presence of mineral salts present in it. It is primarily caused by the carbonate and bicarbonate ions. Alkalinity was high during summer season (164 mg/l) at Kolayat pond followed by steep fall in monsoon and postmonsoon periods (50 mg/l and 46 mg/l). The low alkalinity during monsoon is due to dilution. Bishop (1973) reported similar findings in their study on Malayan rivers and the Halali reservoir.

A strong positive correlation was observed between alkalinity and hardness in Kolayat pond and with calcium, magnesium and sodium in another two ponds.

**TOTAL HARDNESS**

It is the parameter which determines suitability of water for domestic, industrial and drinking purpose and attributed to the presence of bicarbonates, sulphates, chlorides and nitrates of calcium and magnesium (Taylor, 1949).

Kannan (1991) has classified water on the basis of hardness values in the following manner 0-60 mg/l (soft), 61-120 mg/l (moderately hard), 120-160 mg/l (hard) and greater than 180 mg/l (very hard). Using these criteria, the water of Kolayat pond was found of very hard nature due to its higher value as 220 mg/l (January). It is perhaps due to use of soaps, washing and bathing by people at various ghats of pond. Gajner pond presented higher value 12 mg/l in the month of May which may be due to evaporation of water and addition of calcium and magnesium salts. The value of this pond showed the soft nature of water and Kodemdesar pond presented moderately hard category of water with a value 88 mg/l. Our observations about
alkalinity and hardness were in conformity with the work of Singh et al. (2010) in Thoubal river.

**SALINITY**

Among the hydrochemical factors studied, salinity seems to be the most fluctuating parameter with wide range of variations and it also acts as a limiting factor in the distribution of living organisms, and its variation caused by dilution and evaporation is most likely to influence the fauna in the intertidal zone (Gibson, 1982).

In present study, salinity ranged from minimum 64.95 mg/l (July) to maximum 409.6 mg/l (January). The minimum salinity was presumably due to the influence of heavy rain fall and the resultant run off which is a regular annual event during monsoon. This is evident by the negative correlation between salinity and rainfall. Salinity showed strong positive correlation with calcium, potassium (P<0.1) and chloride ions (P<0.001) at all study sites. So the variations in salinity at all study areas were mainly influenced by rainfall and entry of fresh water.

**6.2 IONIC COMPOSITION**

It is generally accepted that no natural aquatic body is pure in true sense but it always contains certain amount of salts dissolved in it. The common salts include carbonates, bicarbonates, chlorides, phosphates, sulphates and nitrates of calcium, magnesium, potassium, sodium, manganese and iron. After dissociation, these salts yield both cations and anions. The significant cations are sodium, potassium, calcium and magnesium while anions are carbonates, bicarbonates, chlorides and sulphates.
Main characteristic of desert water is high ionic concentration and higher rate of evaporation is noted as one of the major factors responsible for it (Cole, 1968). Indian desert waters are, in general, more rich in electrolytes as compared to those of central India and other parts (Patil et al., 1985; Unni, 1985, Singh & Rai, 1988; Kaushik & Saksena, 1995). Similar findings have also been made by (Saxena, 1998) who summarized the physical-chemical conditions of surface waters in the Indian desert.

Many factors contribute and affect the chemical composition of desert waters, which obviously, include the interrelationships of temperature, precipitation, evaporation, basin sediments, nature of influent water and biotic effect. William (1964) has reported the following relative ion abundance Cl>CO₃>SO₄ and Na>Mg>Ca>K. A precisely similar abundance trend of ion was reported by Jakher et al. (1990) in closed basin Didwana lake of Rajasthan and somewhat similar trend by Olsen & Sommerfeld (1977) in a desert lake in Arizona (Cl>HCO₃>SO₄; Na>Mg>Ca>K).

During present study, a general trend of cations was recorded as Mg>Ca>K>Na in Gajner and Kodemdesar ponds but in Kolayat it was found as Ca>K>Na>Mg depicting that calcium and magnesium were the major cation (annual mean, 71, 74, 86 mg/l), while sodium was minor anion (annual mean 4-13 mg/l) in Gajner and Kodemdesar ponds. Magnesium was found as the least cation in Kolayat pond.

Most of the studies on desert waters reveal calcium in excess of sodium (Wetzel, 1975; Haan & Voerman, 1988; Kaushik & Saksena, 1995, Mittal, 1996; and Chadha, 1999), while in some of studies sodium is reported in excess of calcium.
Present findings show that with the slight difference in annual average, the concentration of calcium and magnesium ions was almost at par. Calcium was found higher both in summer and winter seasons. Munawar (1970) also noticed higher values of this parameter in these two seasons. Magnesium values are rich in two ponds but poor in Kolayat pond. Calcium and magnesium play an important role in antagonizing the toxic effects of various ions and in neutralizing excess acid produced (Munawar, 1970). Potassium is required for all the cells principally as an enzyme activator and stored in the plant tissue than in surrounding medium (Hornes & Goldman, 1983).

Among anions, the trend was recorded as Cl>HC0₃>SO₄>CO₃, which is somewhat contrary with the observations of Mittal (1996) and Chadha (1999) from the same arid region of Rajasthan while accounting for major and minor anions on annual mean basis, it was found that chlorides and bicarbonates were major anion (98,112,119mg/l) and carbonates and sulphates were minor anions (15, 27, 64 mg/l). Chadha (1999) also recorded bicarbonates as major anions, however in her study chlorides too were not less. The value of sulphate presented high natural abundance in Kolayat pond during winter season and same range of abundance was recorded by Siddiqi (2008) in extreme hyperalkaline, saline habitat.

Chloride content of waters in the present study was considerably high during March and minimum during monsoon. In the river Moosi, the chloride reached its maximum during summer, when the water level was low and reached minimum
during monsoon and winter season with comparatively high water levels (Venkateswarlu, 1969).

Herbst & Bromley (1984) worked on aquatic habitats in southern desert of Israel and found Na⁺ and Cl⁻ were dominant ions in springs and wells, while Ca²⁺, Mg²⁺ and HCO₃⁻ were dominant in rock pools. In the southern desert water of Israel, they found that relative ionic composition may also influence community structure (e.g. SO₄²⁻ dominated waters, Cl⁻ dominated waters). Others have suggested that relative ionic composition affects species abundance and richness. The magnesium: calcium or magnesium: sodium ratios are thought to be extremely important (Cole, 1968).

Pearsall's (1922) cationic ratio (Na⁺K)/(Mg+Ca) was selected for a subjective attempt to incorporate information on the major cations into the concept of trophic state without adding each cation as an individual indicator. Shannon & Brezonik (1972) felt that this ratio should be inversely related to increasing eutrophy as many workers have found a general correlation between high productivity and Ca and Mg concentration. Shannon & Brezonik (1972) found the cationic ratio to be a reasonably good trophic indicator with high values of inverse ratio (1/CR) indicative of eutrophic condition in Florida lakes.

During present study the Pearsall's cationic ratio was calculated as 0.4987 in Kolayat pond, 0.2714 in Gajner pond and 0.3018 in Kodemdesar pond. Inverse cationic ratio (1/CR) was found as 2.0052, 3.684, 3.3134 in respective ponds. Saxena & Chadha (2002) applied the Pearsall's cationic ratio as an index of trophy in some desert waters. They found the 1/CR to range from 2.887 to 3.732 in order of increasing trophy. In this light
the present ratio indicates higher trophy at all the three ponds studied.

6.3 PLANT NUTRIENTS

Nutrients are chemical elements and the level of plant nutrients in aquatic ecosystem is an important consideration in view of assessment of their trophic status. The three plant nutrients studied included phosphorous (inorganic phosphates), nitrates and silica. Nitrates and phosphorus are important to aquatic life, but in high concentration they can be contaminate water. Both of these are affected by chemical and biological processes that can change their form and can transfer them to or from water, soil, biological organisms, and the atmosphere (MuUer & Helsel, 1996).

In the present study, the concentration of inorganic phosphorus ranged from 0.000 to 0.009mg/l, of silica from 0.8413 to 4.8103 mg/l and of nitrates from 0.019 to 2.319 mg/l. It is evident that of the three plant nutrients studied, phosphates were present in the least concentration. Usually a major part of total phosphorus is present in organic form; only inorganic phosphorus plays a dynamic role in an aquatic ecosystem (Welch, 1948). The concentration of inorganic phosphorus was moderate and comparable with the other records from the region (i.e. from 0.002 to 0.008 mg/l, Bohra, 1976; Alam, 1980; Khatri, 1980; Saxena, 1982; Gupta, 1983; Arora, 1994). Even in saline lake Didwana in the same region Jakher et al. (1990) noted phosphate in a range from 0.0009 to 0.0103 mg/l. From the above ranges of phosphorus it is observed that the waters of the Indian desert including the closed basin are poor in this nutrient. Olsen & Sommerfeld (1977) recorded inorganic
phosphorus to range from 0.2 to 0.3 mg/l from Canyon lakes of the Central Arizona desert. Phosphorus is the first limiting nutrient for plants in fresh water (Stickney, 2005) which regulate the phytoplankton production in presence of nitrogen. Schindler et al. (1971) also concluded from nutrient studies on smaller lakes that phosphorus is a limiting factor in inland waters. The standard value of phosphate is 0.2 mg/l for surface inland water.

The second principal nutrient nitrate was although moderate throughout the study period at all the three ponds varying between 0.019 to 2.319 mg/l. The nitrate is considered to be highest oxidized form of nitrogen in water and waste water (Metcalf & Eddy, 1979). The standard value of nitrate for inland surface water is 0.1 mg/l (NEERI, 1988). This is an important parameter in view of its role in increased productivity rate of ecosystem. Jakher et al. (1990) in a saline lake and Olsen & Sommerfeld (1977) in a desert lake noted maximum nitrate content upto 0.119 mg/l and 1.5 mg/l respectively. Observation from semi-arid region of Rajasthan and from the non-arid parts of the country revealed the concentration of nitrate from 0.002 to 0.36 mg/l (Bohra, 1976; Sarkar et al., 1977; Khatri, 1980; Saxena, 1982; Habib and Pandey, 1989; Kaushik and Saksena, 1995). Golterman (1975) presented the mean nitrate content as only 0.012 mg/l from Asian waters. In arid region Bikaner, the surface waters are, in general, found to hold high nitrate - nitrogen (Gupta, 1993; Sharma, 1995; Mittal, 1996).

The dissolved silica was also within moderate range but it greatly fluctuated through the study period and it ranged from 0.8413 to 4.41721 mg/l. The minimum was recorded in the month of July and maximum in the month of February but in
the month of May it touched a peek of 4.8103 mg/l. It was lower than the values reported by Jeelani (2004; 29-39 mg/l) and Yousuf & Shah (1988; 8.3 - 18 mg/l). Hutchinson (1957) pointed out that the waters of arid regions, in general, have higher silica contents than do the waters of humid temperate regions, but not more than those of humid tropical regions. Cole et al. (1967) could rarely demonstrate silica in the concentrated salt ponds. This fact is also demonstrated in some Indian studies. Jakher et al. (1990) in a closed basin lake recorded only from 0.3 to 5.0 mg/l silica while the same is noted in a range from 6.83 to 16.35 mg/l and from 42.0 to 55.0 mg/l in open waters in the humid region of the country by Kaushik & Saksena (1995) and Habib & Pandey (1989) respectively. In Indian desert, Mittal (1996) recorded upto 7.559 mg/l silica in a temple tank and upto 27.622 mg/l in a canal water.

6.4 PHYTOPLANKTON AND THEIR RELATION WITH IONIC REGIME

In present study, the following groups of planktonic algae were reported in order of abundance: Chlorophyceae (greens) > Bacillariophyceae (diatoms) > Cyanophyceae (blue greens). The total phytoplankton crop ranged from 148 unit x 10^3/l (June) to 464 unit x 10^3/l (December) in Kolayat pond, from 228 unit x 10^3/l (July) to 448 unit x 10^3/l (December) in Gajner pond and from 173 unit X 10^3/l (June) to 402 unit X 10^3 (December) in Kodemdesar. Greater algal diversity and density was observed in pond I followed by pond II and III. Ezra & Nwankwo (2001) reported that plankton abundance and distribution are affected by seasonal variation of some physico-chemical parameters.
The seasonal abundance of phytoplankton at all the three ponds was very high during period from (January to April). This could be due to prolonged availability of light in the postmonsoon period and significantly high inflow of nutrients during the monsoon. Jepachandramohan et al. (2009) observed similar results in Pechiparai reservoir in Tamil Nadu.

The phytoplankton population were considerably low during period of high precipitation; this could be due to high turbid nature of ponds which in turn brings about the decline in intensity of light on the upper region (Sugunan, 1980). A direct relationship between monsoon flow and plankton density has been reported in Richand reservoir. Similar observations have been made by Rana (1991, 1996) and Pundhir & Rana (2002).

The major algal group Chlorophyceae (greens) constituted the most dominant group of phytoplankton in all the three ponds, which was represented by 38 genera. The population density of Chlorophyceae at Kolayat pond varied from minimum 84 unit $\times 10^3/1$ (June) to maximum 344 unit $\times 10^3/1$ (April). While in Gajner pond it varied from 80 unit $\times 10^3/1$ (June) to 224 unit $\times 10^3/1$ (January) and in Kodemdesar pond from 120 unit $\times 10^3/1$ (June) to 293 unit $\times 10^3/1$ (December). Chlorophyceae depicted unimodal spring peak in Kolayat pond. Kant & Kachroo (1977) also reported a single chlorophycean peak in summer at Dal Lake, Kashmir. Spring peak in present investigation can be attributed to increased temperature in addition to increased nitrate concentration. These findings were contrary with the work of Ganai et al. (2010).

Class Chlorophyceae qualitatively and quantitatively dominated at all the study sites when compared to others. It might be due to high DO, pH, alkalinity and total hardness.
Singh & Nayak (1990) and Bajpai & Agarkar (1997) have also observed that green algae prefer water with high concentration of dissolved oxygen. The observed dominant genera in all the three ponds were *Scenedesmus, Closterium, Selenastrum, Costeriopsis* and *Protococcus*. Some of them are perennial too. The possible reason for this observation might be its resilient ability to withstand the varied environmental factors. Among these genera *Spirogyra* and *Closterium* indicated the eutrophic nature of water bodies (Bajpai & Agarkar, 1997; Adesalu & Nwankwo, 2008). Chellapa et al. (2008) pointed out that *Closterium* sp. and *Scenedesmus* sp. are found in mesotrophic water bodies.

Greens were positively correlated with the depth of water, EC (P<0.1), carbonates (P<0.001) and bicarbonates (P<0.01), but calcium (P<0.01) and nitrate (P<0.1) presented a negative influence. In Kolayat pond *Chlamydomonas*, *Dispora*, *Closteriopsis, Tetraedron* and *Volvox* were positively correlated with nitrates and *Coelastrum, Crucigenia* with phosphates. In Gajner pond *Selenastrum, Cosmarium, Hormidium, Staurastrum, Spirotaenia* and *Diachros* were found to be sensitive genera, positively influenced by salinity, chlorides and silica and some of were negatively influenced by hardness and silica. In Kodemdesar pond most of these genera were favoured by potassium and silica. *Scenedesmus* was found to be the most hardy green genus, not affected by most of the chemical variables but it was found to be thermophilic favoured by temperature while *Volvox* and *Ankistrodesmus* were negatively correlated with temperature.

*Bacillariophyceae* formed the second most dominant group of phytoplankton and it constituted most important group of algae even though most species are sessile and associated with
littoral substrate (Wetzel, 1983). Diatoms preferred food that are used by many grazers and organisms in the upper trophic level and thus, form the basis of productive fisheries (Ryther, 1969). The population density of diatoms at the Kolayat pond varied from 28 to 96 unit x $10^3/1$ and in Gajner pond from 87 to 97 unit x $10^3/1$ while Kodemdesar pond showed minimum 27 unit x $10^3/1$ and maximum 102 unit x $10^3/1$. It was minimum in the months of May, June and October, while maximum in the month of January and March.

The most abundant species of Bacillariophyceae in terms of population density were Coscinodiscus (68 unit x $10^3/1$) and Navicula (62 unit x $10^3/1$) in Gajner pond and Frustulia (19 unit x $10^3/1$) at Kodemdesar pond. Navicula and Coscinodisus were perennial too at all the study sites. On seasonal basis, highest population density of diatoms was observed in winter which could be attributed to their ability to grow under the condition of weak light and low temperature. These findings were in full agreement with the work of Ganai et al. (2010); Chadha (1999) and Sharan (2006) also recorded the dominance of diatoms in respect of diversity and density and the presence of some algal genera like Navicula and Nitzschia were indicative of nitrate rich desert waters.

Among different ions magnesium, potassium, carbonates and silica were found to have most pronounced effect on different diatoms. Turbidity is major factor which affected negatively on Synedra, Gyrosigma and Campylodiscus in Kodemdesar pond.

Cyanophyceae have world wide distribution and majority of species are cosmopolitan. They are good photosynthesizer and replenish the water with oxygen. Certain species of this group in
fresh water fix atmospheric nitrogen to supplement nitrogen requirement viz., *Nostoc* and *Anabaena* and thus have potential value as biofertilizer (Kapoor & Arora, 2000). This least algal group in present study was represented by six genera among all three sites. The most abundant species in terms of population density was *Anacystis* (26 unit x 10^3/l). The phytoplankton density of class *Cyanophyceae* varied from a minimum of 8 unit x 10^3/l in the month of May and March to a maximum of 108 unit x 10^3/l in the month of January at three three water bodies. *Cyanophyceae* presented unimodal winter peak, thereby indicating influence of temperature on this group. However, increased phosphate and calcium ion concentration can also be related to dominant winter peak.

During present study *Nostoc, Anacystis* and *Merismopedia* presented positive correlation with pH, calcium and potassium in Kolayat pond while with potassium, carbonates, silica and sulphates in Kodemdesar pond. Among plant nutrients silica was found to be the most significantly correlated nutrient with various algal genera while nitrates had moderate bearing and phosphates the least.

From the above discussion, it may be pointed out that the total phytoplankton population was found to be higher at Kolayat pond in the month of December. This is due to high nutrient content of water. Similar findings were made by (Muraledharan et al., 2010). Temperature is also a major driver of this successional pattern, both through its direct effect on phytoplankton population growth and its indirect effect through changes in water column stability and predator population growth (Karentz & Samayda, 1984).
6.5 ZOOPLANKTON AND THEIR RELATION WITH IONIC REGIME

In natural aquatic ecosystems, zooplankton organism by their heterotrophic activity initially handles and manages the biogenic organic materials of primary and secondary production to a considerable extent. Gannon & Stemberger (1978) in a comprehensive review on the subject very rightly remarked that our present knowledge of zooplankton as indicators of trophic conditions has been accrued almost entirely from investigation on lakes in cold temperate region. There is comparatively lack of such information from warm temperate. The warm temperate, sub-tropical and tropical water bodies have received very little attention is still true, despite some studies in Africa (Adeniji, 1978) and South East Asia (Arora, 1961, 1966; Mahajan & Singh, 1973; Baqi & Siddiqui 1974; Juneja, 1979). Mahajan (1981) listed the use of zooplankton as bioindicators.

The microscopic taxonomical study of zooplankton revealed that sixty three genera belonging to major groups of zooplankton (Protozoa, Rotifera, Crustacea, Turbellaria, Oligochaeta, Hirudinea, Insecta and Acari) inhabited the all studied water bodies. The total zooplankton ranged from 13 No./l (June) to 80 No./l (February) in Kolayat pond but peak value of zooplankton at this pond was observed 130 No./l in the months of August. In Gajner pond it ranged from 4No./l (June) to 130 No./l (January) while in Kodemdesar pond it ranged from 7 No./l (July) to 99 No./l (February). This showed a sharp decline in summer but increased in monsoon and post monsoon months. This observation is in conformity with the work of Muraleedharan et al. (2010).
Normally the monsoon season, is associated with low zooplankton densities due to its dilution effect and decreased photosynthetic activity by primary producers. Similar results have been shown by Bais & Agrawal (1993).

Sarkar & Chowdhury, (1999) observed that the fluctuation of abiotic factors, like concentration of DO, temperature, total alkalinity, total nitrogen, phosphate and pH can influence the growth of zooplankton. Sampaio et al. (2002) studied relationship between trophic state of reservoir and diversity of zooplankton communities of 7 reservoirs of Brazil. A positive correlation has been found between trophic state of reservoir and diversity of zooplankton population.

The present limnobiotic status of all the three ponds revealed that the distribution and population density of zooplankton species depend upon the physical-chemical factors of the environment. Statistical analysis showed that there exist significant correlations between the biological and non biological factors. Similar findings were observed by Hulyal & Kaliwal (2008).

In present study Protozoa was the most dominant group of the zooplankton. The protozoan population was high in the studied ponds. Kolayat pond showed density from 13 No./l (June) to 130 No./l (August). The observed dominant taxa at all three ponds were Ophryoglena flava, Metopus es, Stentor coeruleus, Paramecium caudatum, Glaucoma pyriformis; out of which Ophryoglena flava was present throughout the study period, except the month of February. In Kolayat pond Metopus es appeared with the onset of rains in July as 12 No./l and maintained up to the month of November. It showed positive correlation with depth and turbidity and negative with
magnesium and Silica. *Ophryoglena flava* showed positive correlation with DO, sodium and alkalinity at Kodemdesar pond. Rao et al. (1982) studied zooplankton diversity of four village ponds in Bangalore and they found Protozoa to be richer in variety whereas some of the rotifers were found to be high in number at all ponds. Dutta et al. (1990) studied the ecology of protozoans from some pools present along the side of river Tawsi, in Jammu and they collected 21 species of protozoans and also showed their seasonal prevalence.

Among the rotifers *Brachionus* was the most abundant genus with four species (*B. havaensis, B. calyciflorus, B. quadridentata* and *B. bidenta*) and to lesser extent *Keratella cochlearis, K. valga, K. quadrata, Lecane loricca, Monostyla, Platymias polycanthus, P. platulus* and *Filinia longiseta* were present at the study sites. They presented positive correlation with calcium, potassium, silica, chloride and sulphate and showed negative correlation with nitrates, bicarbontes, calcium and sulphates. Twelve genera were identified in this group and its population ranged from minimum 1 No./l (May) to maximum 45 No./l (March) among the study areas. It was greater in postmonsoon and winter and lowest in summer.

Various studies indicated that several abiotic features exert a considerable influence on the zooplankton abundance. Sampath et al. (1979), Vermal et al. (1984) and Mishra & Saksena (1990) reported *Brachionus* species are widely distributed plankton froms. Filinia was considered as sensitive form by Palharya & Malviya (1988) during their study on Narmada River. In present study Filinia was absent in Gajner pond and present in other two ponds. Among rotifers, higher population density was noted of *Platyias polycanthus* (3 No./l) in
Kolayat pond. Arora & Mehra (2003) observed richness and dominance of rotifers in Yamuna River. Most diverse genera reported by them were Lecane, Trichocerca and Lepadella; however Lecane lorica was poorly present in water bodies studied during present study. Halvorson (2004) and Vasisht (1968) observed that B. calyciflours and Keratella tropica were dominant in alkaline waters.

Present study showed that Turbellarian appeared only for 3 months (March to May) during the study and after a long lapse they abruptly appeared in the month of January, 2010. It showed positive correlation only with potassium (P<0.001).

Various genera of Oligochaeta were seen in Gajner and Kodemdesar ponds. Three Oligochaetes were identified out of which Aeolosoma hemprichi was higher in population density (0.93 No./l). Various ions like chloride, sodium (P<0.001) and phosphate showed positive correlation while potassium, calcium, and nitrates presented negative correlation with Oligochaetes.

Like Turbellarian, Hirudinea were represented by single genus and it presented positive correlation with potassium, silica (P<0.01) and carbonates (P<0.1). It appeared with the onset of winter and spring seasons and was absent in rest of the study period.

Among Crustaceans Gajner pond showed maximum population and diversity. Cyclops scutifer, Cyclocypris and Nauplius larva were important at all the three ponds. In Kolayat pond crustacean population showed positive correlation with calcium, potassium, magnesium, silica and DO but in Gajner pond its relation was with phosphates, carbonates, bicarbonates, silica, potassium, pH, salinity and it was also favoured by the depth of water column. In Kodemdesar pond bicarbonates,
chlorides, phosphates, silica, DO, pH and hardness of water showed positive correlation with various crustaceans. The population of all genera was higher in winter and spring seasons.

Arcifa et al. (1992) studied the composition and fluctuations of the zooplankton in a tropical Brazilian reservoir and found that the fluctuations in population were more due to food and predation rather than other factors. Akpan (1995) also observed this fact and attributed the low zooplankton taxa to the effect of municipal effluents, predation and low food availability in a tropical freshwater pond in Nigeria. Herbst & Bromley (1984), however, noted in a study on relationship between habitat stability, ionic composition and distribution of aquatic invertebrates in desert regions of Israel, that the dominant factor determining the community structure over a wide range of salinities is habitat stability. They found that in the intermediate range of salinity the relative ionic composition was less important than habitat stability in determining community structure.

Jha & Bharat (2003) carried out a qualitative analysis of zooplankton in Lake Mirik in Himalayas. The lake was polluted and in this condition Moina, Daphnia, Bosmina, Cyclops and Phylldiaptomus were found and these species served as bioindicator to determine the health of this aquatic body.

Among zooplanktons various insects larvae were found at studied ponds. Concentration of potassium, chloride, sulphates as well as salinity and chloride ions of water has pronounced effect on the insect population of Gajner pond. This pond also has boured higher population diversity. Concentration of silica, calcium, pH and depth of water column had little bearing on that
insect population of other two ponds. Caddisfly larva, Mayfly nymphs and Rat tailed maggot were the most common forms found in the three ponds.

Cole (1968) while reviewing the desert limnology mentioned that in most instances the invertebrates found in the highest salinities are euryhaline, occurring through a wide range of salinities.

Water mites in group Acari were found at all the three study sites. These flourished only during postmonsoon and winter months. Water mites showed positive correlation with transparency of water in Kolayat pond while with potassium and bicarbonates at Kodemdesar pond.

Conclusively, it is evident that most of the zooplanktons were favoured by DO, transparency, pH, salinity and depth of water column and among ions potassium, silica, chloride, carbonates, bicarbonates and phosphates favoured them. But these were negatively influenced by temperature, hardness, free CO₂, calcium potassium, magnesium and nitrates.