CHAPTER - V

DISCUSSION
Diverse kind of planktonic fauna and flora are present in Sagar lake and are conditioned to seasonal environmental and biological factors. Though the biota present is of a natural one, yet at times it appears that the outside factors like waste water from hospital, domestic sewage, wallowing of cattles, washing and bathing, culture of fish and cultivation of some hydrophytes like Trapa, Nelambo species have changed the natural conditions of the habitat which have succeeded the survival of a biota different from the original one. Due to lack of previous records it is not possible to make a comparison for this assumption. Though in previous years, characeae, a grass geen algae, were in abundance in Sagar lake, yet they are not common today. Similarly Notopterus which were in abundance in early years are now going to extinct from Sagar lake. This shows that the physico-chemical properties have been changed and are thus, altering the biological conditions in the direction of eutrophication.

Physico-chemical Factors:
Temperature:

The physico-chemical, metabolic and physiological behaviour of aquatic system are governed by the temperature of air and water. Temperature varies from place to place, from time to time, in a day and from season to season in a year. Verma (1969) recorded maximum water temperature 32°C in July and minimum 19°C in December and January in Tekanpur reservoir.
Ghosh et al. (1974) noted maximum water temperature 31.5°C in the month of June and July and minimum 22.0°C in February at Khardah fish pond. Mathew (1975) observed, in Govindgarh lake the highest water temperature 30.44°C during June and lowest 18.12°C in January. Singh and Rai (1984) worked on Engineering College Lake of Jabalpur and noted highest water temperature 32°C and lowest 19°C. In the present study the maximum water temperature has been recorded as 29°C in April and minimum 17.5°C in January.

Hussainy (1967) recorded short time fluctuations in temperature in Vihar lake Bombay. According to him homothermal condition of lake was probably due to flood condition of Vihar lake. During the present study author has also reported that the Sagar lake is a homothermal lake as there is no permanent thermocline. The water temperature increased gradually from March onward and it reached maximum in summer in the month of June, then subsequently decreased to minimum in winter in the month of January. Water temperature always remained less than air temperature.

Wyas (1968) viewed that the higher water temperature in summer was due to the low water level, clear atmosphere and greater isolation from the sun, and lower temperature was due to the frequent clouds, high percentage of humidity, high current velocity and higher water level. In the present study the higher water temperature in summer may be due to the same climatic factors as reported by Wyas (1968) and lower water temperature may be due to the high percentage of humidity and frequent clouds.
Goldman et al. (1968) in Maggiore lake of Italy recorded positive correlation between pH and water temperature. Singh (1975), Zutshi and Khan (1977), Zutshi and Vass (1978) in different Himalayan lakes and Purohit and Singh (1981) in Nainital lake noticed positive relationship between pH and water temperature. In the present investigation author also noticed the same relationships between these two parameters as reported by above authors (Figs. 39, 40).

Hussainy (1967), Awatramani (1980) and Gupta (1984) reported the inverse correlation between water temperature and transparency. Present author also observed the similar relationship between water temperature and transparency.

Ghosh et al. (1974) and Jhingran (1977) recorded negative correlation between water temperature and dissolved oxygen. During the present investigation also the oxygen contents present in water was low in summer but high in winter season. It indicates a negative correlation between water temperature and dissolved oxygen (Figs. 39, 40). Kaul (1977), Purohit and Singh (1981), Sharma and Bhatt (1985) noticed a positive relationship between water temperature and dissolved oxygen in certain water bodies of India located in places with severe winter.

Kaul (1977), Khan and Zutshi (1979) suggested that the positive correlation between water temperature and dissolved oxygen may be due to the fact that during summer the higher temperature stimulates photosynthesis resulting in the
increased amount of dissolved oxygen, and low temperature in winter constitutes limiting factors for photosynthesis at high altitudes thus causing decrease in the oxygen contents in water. This shows positive correlation between water temperature and dissolved oxygen. According to present investigations it is suggested that when the temperature was high during summer the photosynthesis and water temperature was a major limiting factor for the biotic component of lake and aquatic inhibitors. Thus, they modified their life activity such as feeding, growth and reproduction. Singh and Rai (1984) reported that the biota inhabiting the lake shows a wide range of temperature tolerance.

Secchi Transparency:

In 1865 Secchi of Italy used Secchi disc for transparency but later on it was modified by Wipple dividing the disc into 4 quadrants in black and white alternate. Transparency is inversely proportional to the turbidity of water. According to Tyler (1968), the secchi transparency represent 1% to 15% of light transmission in euphotic zone. Mishra and Yadav (1978) stated that the transparency of water is directly influenced by the quantity of total solids present in water and by the plankton population.

noted that the secchi transparency was minimum in May. In the present observation the minimum value of transparency was also recorded in June.

Sreenivasan (1968) in Stanley reservoir, Zutshi and Khan (1977) in two subtropical lake of Kashmir, Vass et al. (1977) in Kashmir lake and Yadav (1986) in Sagar lake observed low transparency during summer. During the present investigation the low value of transparency during summer may be due to the higher temperature, low water levels and decay macrophytes suspended themselves in water which in turn reduce the light penetration causing a minimum secchi transparency, this view is also supported by Awatramani (1980). Saha et al. (1971) recorded low value of transparency in July and August in fresh water pond at Cuttack mainly due to the planktonic organisms suspended in the water and also due to the silt, clay and organic matter present in the pond. Singh (1975) noted high range of transparency between 210 - 945 cm. in Naukuchiatal lake. Purohit and Singh (1981) reported low value of transparency in Nainital lake ranged between 65 cm.-205 cm. Singh (1975) suggested that the higher transparency in Naukuchiatal lake should be due to the little tourism and other biotic interference as compared to that of Nainital lake.

during rainy season. In the present observation, the highest transparency was noted in the month of September and October i.e. in late rainy season (Fig. 10). The maximum value of transparency in late rainy season may be due to the flood condition, dilution of water, presence of metallic road all round the lake and due to stony fencing wall, protect the entry of slits into the lake, which is also supported by Singhal (1980).

Unmi (1971), Biswas (1972) and Gupta (1984) noted low transparency in littoral zone as compared to the limnetic zone, due to the thick growth of macrophytes in shallow water. In the present study too, author noted low transparency during her study period at littoral zone, due to the same reason as stated by above authors.

Forel (1901) recorded negative relation between secchi transparency and water temperature. He explained that the particles floating in water absorb heat more rapidly than water and this heat was radiated by particles to the surrounding water. Hussainy (1967), Singhal (1980) and Yatheesh (1990) noted inverse correlation between secchi transparency and water temperature. The present observation also showed negative relationship between water temperature and secchi transparency (Figs. 39, 40).

Welch (1935) recorded that the secchi transparency is negatively correlated with pH and Chloride. In the present study secchi transparency also shows negative correlation with pH and chloride (Figs. 39, 40, 45, 46).
\[ \text{pH} : \]

In natural water the extreme pH value may reach between 3 and 12. In most of the Indian lake pH value ranged between 6 and 9. Saha et al. (1971) reported that in perennial fresh water pond at Cuttack water pH fluctuated from 7.2 to 8.5. Ghosh et al. (1974) observed pH between 7.30 to 8.90 in sewage fed ponds, Khardah. Zutshi and Khan (1977) noted that the surface water of subtropical Surinsar and Mansar lakes were slightly alkaline with maximum value 8.0 and minimum 7.1. Mishra and Yadava (1978) observed alkaline nature of river and lake water in Central India ranging between 8.0 to 8.8. Farrell et al. (1979) reported that the pH of Moondarra lake is slightly alkaline ranging between 7.5 to 8.2. The slight alkaline nature of water in Queensland lake was also recorded by Bayly and Williamson (1972). Chandra Prakash (1983) observed that the pH of water ranged from 8.6 to 9.6 in Keetham lake. Saha and Pandit (1985) noted that the pond water of Bhagalpur remained alkaline ranging from 7.1 to 7.5 whereas riverine water was slightly acidic during the month of July and August and noted as 6.9. Adoni and Yadav (1985) in Sagar lake observed pH of water between 6.8 to 10.5. Ahmad and Krishnamurthy (1990) recorded alkaline range of water in Wohar reservoir, ranged from 7.0 to 8.0.

The present observations showed alkaline nature of lake water, pH ranged from 7.5 to 9.4. Alkaline nature of Indian water bodies was also reported by a number of workers.
Adoni (1975), Zutshi and Khan (1978), Chandra Prakash (1983), Thakur and Bais (1986), Joshi (1987), and Qayoom et al. (1989). The alkaline nature of Sagar lake may be due to the high buffering capacity of system. This view is supported by Ganapati (1960), Vyas (1968), Wetzel (1972) and Awatramani (1980).

Hutchinson (1932) recorded both acidic and alkaline water in tropical African lakes, pH ranged from 3.7 to 8.9. Bayly (1964), Bayly and Williams (1972) noted acidic nature of water in fresh water coastal lake.

Verma (1969) in Tekanpur reservoir observed maximum pH value in May and July, and minimum was in the month of February. Ghosh et al. (1974) recorded pH value between 7.3 and 8.9 in a private fish pond at Khardah, the maximum pH was in the month of January and minimum in March and April. Zutshi and Khan (1977) noted maximum value of pH 8.0 in November in Surinsar and Mansar lakes. Awatramani (1980) noted maximum value of pH 9.3 in April and minimum 7.0 in January in Sagar lake. Bagde and Verma (1985) worked on J.N.U. lake, New Delhi and noted maximum pH 8.6 in June and minimum of 7.5 in August. In the present observation the maximum pH was recorded 9.4 in April and minimum of 7.5 in February. The increased value of pH was generally found from March to June.

Adoni (1975) recorded high pH value during summer months and lower pH in winter months. Singh and Sahai (1978) noted maximum pH value in summer and minimum was in rainy season in Jalwania pond. Chaudhary et al. (1979) reported
low pH value in winter at Hirakund dam, whereas Chandra Prakash (1983) in Keetham lake noted that the pH was higher in rainy and winter season and lower in summer season. Prasad et al. (1985) in some ponds of Lucknow recorded highest pH value during summer and in early winters and lower during the monsoon period. Adoni and Vaishya (1985) noted slightly higher pH value in rainy and summer seasons in comparison to winter season in a central Indian reservoir. Yadav (1986) recorded maximum pH value in summer and minimum in winter season in Sagar lake. The present author also recorded high pH value in summer and low pH value in winter season (Table 9; Fig.10). The highest pH value in summer season and lowest in winter season were also recorded by Singh (1960) in inland water of Uttar Pradesh and Zutshi and Vass (1978) in Dalsagar lake of Kashmir.

Pearsall (1930) and Zafar (1966) observed that the pH of water appears to be dependent upon the relative quantities of calcium, carbonates and bicarbonates. According to them the water tends to be more alkaline when it possesses carbonates and it is much less alkaline when it possesses larger quantities of bicarbonates, carbon-dioxide and calcium. Feviser and Fernando (1960) stated that the differences of pH among lakes, probably result from shifts in major buffering system. Throughout the period of present study the water of Sagar lake remained alkaline. This can be attributed due to the presence of more buffering substance and so the lake is placed in category of alkaline water according to the classification of Wehrle (1927), Zutshi and Vass (1978), and Bagde and Verma (1985).
suggested that the high pH values during summer are probably due to the higher photosynthetic activity and low pH value in winter may be due to the low photosynthetic activity during these months. Bagde and Varma (1985) stated that the pH decreased in monsoon may be attributed to rain water drained into the lake water. Present observation showed that the fluctuation in pH seem to be indicated by photosynthetic activity which was higher in summer causes corresponding increase in pH. It was also associated with low secchi transparency due to higher planktonic biomass and decreasing in water volume due to evaporation. This view was also supported by Adoni (1975). Congdom and Mc. Comb (1976) in lake Joondalup in Western Australia reported that the pH decreases during wet season. Farrell et al. (1979) showed that pH gradually increases during dry season and decreases in wet season.

George (1961), Verma (1969), Awatramani (1980) and Yatheesh (1990) reported that the pH of water positively correlated with water temperature and also noted that pH increases in day time and decreases during night hours. Mishra and Yadav (1978) found no definite correlation between pH and temperature. Present author also showed positive relation between water temperature and pH (Figs. 39, 40).

Datta et al. (1985) and Joshi (1987) recorded negative relationship between pH and secchi transparency. Present observation also showed similar relationship between pH and secchi transparency as reported by above authors (Figs. 39, 40).
Zafar (1966) and Prasad et al. (1985) found a positive relationship between pH and carbonate. Goldman et al. (1968), and Awatramani (1980) showed negative relationship between pH and bicarbonate. Singh (1981) observed negative correlation between pH and bicarbonate, as in deeper layer the pH was usually 7 and the bicarbonate alkalinity was maximum. Sharma & Bhatt (1985) showed positive correlation between pH and total alkalinity in Ñágirúthí river. A negative relationship between pH and bicarbonate and positive relationship between pH and carbonate was observed during the present study.

Saxena and Adoni (1973) did now show any relationship between pH and dissolved oxygen, whereas Awatramani (1980) found positive correlation between pH and dissolved oxygen. Present author did not find any relationship between these two parameters.

Das (1961) correlated higher pH with denser phytoplankton and lesser zooplankton. Unni (1984) showed that the zooplankton density was higher at low pH. Gupta (1984) showed low degree of inverse correlation between pH and zooplankton. On the other hand Lakshminarayan (1965) found a direct relationship between high pH and high plankton production. Ramalingam and Jayaraman (1985) observed that the plankton survived most at pH 8 and 7. Present observation also showed negative relation between pH and zooplankton (Figs. 39,40).
Specific Conductivity:

An atom which has lost or gained electrons to become electrically neutral is called as an ion. The conductivity of a solution depends on the electrolytes which are anions or cations of acids, bases or salts. There are two types of electrolytes; first is weak electrolyte and second is strong electrolyte. Substances which are less soluble in water are called as weak electrolytes, showing low conductivity, and substances which have high solubility are called strong electrolytes and showing high conductivity. Conductivity is an index of electrolyte content which is proportional to total dissolved solids.

Vollenweider and Frel (1953) used specific conductivity as an indicator for assessing trophic status of a lake. Olsen (1950) classified lakes having conductivity values between 200-250 us as mesotrophic and having less than 200 us as oligomesotrophic. Thus the Sagar lake falls under the category of mesotrophic having conductivity values between 224-630 m mhos/cm. Conductivity of water varies differently in different water systems. Zutshi and Khan (1977) observed specific conductivity in two sub-tropical lakes in Kashmir. In Surinsar lake specific conductivity varies from 182 us to 420 us and which of Mansar lake ranges from 153-374 us. Kelly et al. (1978) recorded conductivity in the water of Texas pond varies from 460 u mhos cm\(^{-1}\) to 585 u mhos/cm\(^{-1}\). Gupta (1984) recorded specific conductivity in Sagar lake ranged from 289.87 micro mhos/cm in August and February to 777.70 micro mhos/cm in the
month of June. Raina (1985) noted that the Gadsar and Zumsar lake of Kashmir are unproductive, having a very low specific conductivity as 40 us to 75 us. Kundangar and Zutshi (1985) noted that the conductivity in Ahansar lake ranged between 217 us and 338 us and in Waskur lake ranged from 239 to 320 us at 25°C. Rao and Durve (1989) observed high value of electrical conductivity on an annual average of 0.516 mhos/cm in lake Rang Sagar Udaipur. During the present investigation the specific conductivity was recorded as 224 m.mhos/cm in November and 630 m.mhos/cm in July.

Singh et al. (1979), Gupta (1984) and Bagde and Verma (1985) reported highest value of specific conductivity during summer season. In the present observation also, highest value of specific conductivity was recorded in summer and lowest during winter season (Table 9, Fig.11).

Higher specific conductivity in summer at surface water was recorded due to the high temperature, high photosynthetic activity, high mineralization and low water level of the lake. This view is also supported by Adoni (1975). Hutchinson (1957) reported that at the bottom of lake libration of ions takes place due to the consumption of oxygen which increases the conductivity of the industrial water in the mud.

Atkins and Harris (1924) found inverse relationship between pH and conductivity, Gupta (1984) showed a moderate degree of negative correlation between pH and conductivity. Bagde and Verma (1985) noted that the electrical conductivity
ran more or less parallel to pH of water in pattern and periodicity. In the present investigation specific conductivity did not show any distinct relation with pH. It showed positive relation with water temperature, total dissolved solids and chloride and negative relation with dissolved oxygen. Similar results were recorded by Yatheesh (1990) also (Figs. 47,48).

**Total Dissolved Solids:**

Conway (1942) reported that the value of average total dissolved solids in world fresh water is 124 mg/l. Farrell *et al.* (1979) observed mean value for total dissolved solids in the main body of the lake Moondarra was 177 mg/l and maximum value was recorded as 300 mg/l. Saha and Pandit (1985) in pond water of Bhagalpur noted the total dissolved solids ranging between 200 ppm to 780 ppm in July and April respectively. Rao and Durve (1989) in the lake of Rangasagar found an annual average value of total dissolved solids as 184.66 mg/l. In the present study the value of total dissolved solids obtained between 116.2 mg/l and 403.2 mg/l in September and July respectively.

Chandra Prakash (1983); and Ahmad and Krishnamurthy (1990) observed the maximum value of total dissolved solids in rainy season, whereas Verma *et al.* (1977) recorded maximum total dissolved solids during summer. During the present investigation the high value of total dissolved solids was observed during summer and low in winter season (Table 9, Fig.11).
Alkalinity:

According to Hutchinson (1957) and Golterman (1975), bicarbonate and some time carbonates are present in appreciable amounts in natural waters. Their paramount importance in aquatic bodies are due to its active role in the primary production and of its buffering capacity. Their salts hydrolysed in solution and release hydroxyl ions increase the pH of water.

Bicarbonate alkalinity, carbonate alkalinity and total carbon-dioxide shows inter-relationships. Generally total carbon-dioxide and bicarbonate alkalinity showed positive relation, whereas bicarbonate alkalinity and carbonate alkalinity showed inverse relation.

The free carbon-dioxide was altogether absent throughout the study period and it may be either due to its complete consumption in carbon assimilation by autotrophs or its complete utilization in the formation of carbonic acid which ultimately converted into stable carbonate and bicarbonates. The absence of free carbon-dioxide in surface water was also conformed by Saha and Pandit (1985) in water bodies of Bhagalpur town.

Patil et al. (1985) observed that presence of free carbon-dioxide in bottom water might be due to the decay of organic matter, decomposition of bottom deposit and photosynthetic activity. Chourasia and Adoni (1985) reported that its presence in bottom water may perhaps be owing to less trophogenic activity.
Carbonate Alkalinity:

Verma (1969) in Tekanpur reservoir, Patil et al. (1985) in fresh water tank of Jabalpur noted that the carbonate alkalinity was absent during the study period.

Dubey and Verma (1966) observed that carbonate was recorded only in the month of May and January in Budhwari tank. Purohit and Singh (1981) in Nainital lake, noted that carbonate alkalinity fluctuated from 18 mg/l to 64 mg/l. Saha and Pandit (1985) in Kuppa ghat of river Ganga, the carbonate alkalinity was observed only in June, whereas in Babu pond of Bhagalpur it was present only in the month of March, April and June as 14 ppm, 18 ppm and 20 ppm respectively. Adoni and Yadav (1985) in Sagar lake observed that carbonate alkalinity in surface water was maximum 72 ppm in March and April. During the present study it fluctuated between 12 mg/l to 48 mg/l. The minimum carbonate alkalinity was observed in October and maximum in April.

Zafar (1966) found higher quantities of carbonate during summer. Chaurasia (1985) recorded low carbonate in rainy season and higher in summer. In the present study its lower value was observed in rainy season as studied by Chaurasia and higher in summer and winter season, whereas Awatramani (1980) and Gupta (1984) observed lower value of carbonate in winter months. The presence of low value of carbonate in rainy season is also supported by the observation of Goldman and Wetzel (1963) and Sreenivasan (1966).
Maximum value of carbonate in summer was due to the low water level and rise in water temperature which is also reported by Rao and Govind (1964).

Sarkar and Rai (1964) correlated high values of carbonate with oxygen supersaturation, high pH and photosynthetic activity. Prasad et al. (1985) showed negative relationship between carbonate and total alkalinity whereas Singh (1979) found positive correlation between carbonate and total alkalinity. Yatheesh (1990) noted that the carbonate alkalinity is negatively correlated with bicarbonate and total carbon dioxide. The author in her study found negative relationship between carbonate and bicarbonate alkalinity, and positive relationship between carbonate alkalinity and water temperature.

**Bicarbonate Alkalinity**:

Morton et al. (1972) suggested the view that phytoplankton and macrophytes used bicarbonates as a alternative source of carbon-dioxide. Ruttner (1953) and Munawar (1970) stated that the presence of bicarbonate throughout the year may be due to the presence of free carbon-dioxide in water.

Dubey and Verma (1966) in Budhvari tank showed that bicarbonate fluctuated from 162.0 ppm in July to 222.0 ppm in February. Farrell et al. (1979) reported that in Moondarra lake bicarbonate value ranged between 79.4 mg/l and 88.0 mg/l. Purohit and Singh (1981) in Nainital lake observed the maximum bicarbonate 228 mg/l in March and minimum 76 mg/l in September.
Patil et al. (1985) in tropical fresh water tank of Jabalpur found that bicarbonate alkalinity detected throughout the year ranged from 50 mg/l$^{-1}$ in July and 120 mg/l$^{-1}$ in February. Prasad et al. (1985) in different pond of Lucknow recorded that bicarbonate alkalinity varied from a minimum of 109.80 mg/l to a maximum of 793.00 mg/l. Rao and Durve (1989) in Rangasar lake noted annual average value of bicarbonate 120.66 mg/l$^{-1}$. In the present study the bicarbonate alkalinity fluctuated from 44 mg/l$^{-1}$ in November to 138 mg/l$^{-1}$ in July.

Zutshi and Vass (1978) recorded in Dal lake the high values of alkalinity during spring and low in summer. Chaudhary et al. (1979) in Hirakund dam, Chaurasia and Adoni (1985), and Joshi (1987) in Sagar lake observed that bicarbonate alkalinity was high in rainy season than in winter and summer. Present observation also showed same condition as recorded by above authors. Singhal (1980) observed higher value of bicarbonate during winter season and lower in summer season. Prasad et al. (1985) found higher value of bicarbonate in the late winter and early summer.

Welch (1952) and Rao and Govind (1964) recorded that the maximum value of bicarbonate contents in winter might be due to the presence of free carbon-dioxide and less evaporation. Mishra and Yadav (1978) noted higher bicarbonate value in river in comparison to lake water. They observed higher value of bicarbonate in Bewas river at the time of ill illumination, whereas in Sagar lake the condition is so different that its low
value thought to be due to the more consumption of carbon-dioxide in photosynthesis in lake is owing to a larger photosynthetic population. This is suggested by Saxena and Adoni (1973) also. According to Choudhury et al. (1979) the higher value of bicarbonate in rainy season may be due to the inflow of mineral salt along with water from river. Present author suggested that the higher value of bicarbonate in rainy season might be due to the less evaporation, ill illumination, and less photosynthetic activity during rainy season.

During the present investigations carbonate alkalinity, bicarbonate alkalinity and total carbon-dioxide shows inter-relationships, bicarbonate alkalinity and total carbon-dioxide were found to have a positive relation, whereas bicarbonate and carbonate alkalinity showed inverse relation with each other during all the three seasons (Figs. 41,42). The lowest value of carbonate alkalinity was observed during rainy season and maximum in winter season, whereas bicarbonate alkalinity was highest in rainy and lowest in winter season. Total carbon-dioxide was observed maximum in rainy season and minimum in winter season as trend shows for bicarbonate alkalinity (Table 9, Fig.11). Negative relationship between carbonate and bicarbonate was also observed by Zafar (1964), Adoni (1975), Adoni and Vaishya (1985) and Joshi (1987).

Goldman et al. (1968) found negative correlation between bicarbonate and pH in Maggiore lake, Italy. Similar relationships were also reported by Awatramani (1980) and Gupta (1984)
and Thakur and Bais (1986) in Sagar lake. In the present observation author also noted negative relationship between pH and bicarbonate and positive relationship between pH and carbonate.

**Chloride:**

Chlorides are generally present in low concentration in natural water in the form of chlorine ions. Their higher concentrations in water considered to be the indicators of pollution which is either due to organic wastes of human origin or industrial effluents. Free chlorine is commonly used as disinfectant for drinking waters but in the form of chlorides it becomes toxic to aquatic inhabitants. According to Wetzel (1975) chloride is widely distributed in nature but it is not essential for metabolic activities and therefore spatial and temporal fluctuations are only due to hydrographic factors (Ruttner, 1963). The world mean value of chloride is 7.8 mg l⁻¹ (Wetzel, 1975).

Verma (1969) recorded minimum chloride contents 22.0 ppm in September and maximum of 56.0 ppm in April in Tekanpur reservoir. Lakshmanan et al. (1971) worked on four ponds at Killa fish farm, Cuttack during 1965 to 1968. They noted chloride concentration in these ponds between 7.7 ppm and 38.0 ppm. Ghosh et al. (1974) in a private sewage fish pond Khardah reported that the chloride content in this pond fluctuated from 115 ppm in September to 245.5 ppm in June. Leath et al. (1980) noted that the chloride concentration in a hyper-
eutrophic lake ranges between 44 mg\textsuperscript{l-1} and 130 mg\textsuperscript{l-1}. Unni (1984) observed that chloride concentration in a sewage polluted pond of Chhindwara varies from 69.5 mg\textsuperscript{l-1} to 117 mg\textsuperscript{l-1}. Singh and Rai (1984) recorded the maximum chloride value in Engineering College lake of Jabalpur as 93 mg/litre. Prasad et al. (1985) observed the chloride concentration in some ponds of Lucknow varies from minimum of 32.00 mg/l to a maximum of 180.00 mg/l. Verma and Sahu (1985) recorded chloride concentration in Sagar lake ranged from the lowest value 27 mg\textsuperscript{l-1} in September to the highest value 108 mg\textsuperscript{l-1} in July. Patil et al. (1986) reported that the chloride contents in a polluted stream near Jabalpur ranged from 70 mg/l to 113.5 mg/l. In the present investigation the minimum chloride contents were 24.0 mg\textsuperscript{l-1} in the month of September and maximum 53.0 mg\textsuperscript{l-1} in May.

Zutshi and Khan (1977) in Surinsar and Mansar lake, Gadri and Yousuf (1979) in Bheemana spring and Raina (1985) in Gadsar and Zumsar lake of Kashmir reported that chloride concentration in these lakes and streams remain in a very low amount ranged from 6 mg/l to 9 mg/l.

Lakshmanan et al. (1971) in Kilsafish farm Cuttack, and Chandra Prakash (1983) in Keetham lake observed that the maximum chloride contents were found in summer and minimum in rainy season, whereas Chourasia (1985) noted that the chloride contents increased in rainy season and decreased in winter season and again increased in summer season. Higher value of chloride during summer was also recorded by George (1966), Bhatnagar (1984).
and Prasad et al. (1985). In the present investigation too the chloride concentration was observed maximum in summer and minimum in rainy season (Table 9, Fig.13).

Hutchinson (1957), Aboo and Manual (1967) supported the view that the maximum chloride concentration during summer was due to the highly decomposition of organic matter and high rate of evaporation. Saha et al. (1971) opinion was that the chloride concentration fluctuated inversly with water level, when water depth was lowest and show highest chloride concentration and vice versa. Lakshmanan et al. (1971); and Mishra and Yadav (1978) suggested that the higher chloride concentration in summer was due to the lower water level and higher concentration of salts. During the present investigation it was observed that the minimum value of chloride concentration during post-rainy season and pre-winter season, followed a gradual increase and reaching maximum during summer. Generally in post-rainy season chloride contents remained constant from August to October. Similar behaviour of chlorides in their studies was also recorded by Prasad et al. (1985). The higher concentration of chloride during summer season was probably due to the reduction in water level, high rate of decomposition of organic matter, supported the view of Joshi (1987). Low value of chloride concentration during rainy season have been related to dilution of water in that season which was supported by Rao and Govind (1964), Sreenivasan (1965), Verma (1969), Awatramani (1980) and Gupta (1984). Chourasia (1985) reported that the higher value of chloride in rainy season may be due to the incoming of organic
wastes from human origin with rain water in the lake and higher value of chloride in summer due to the evaporation and evapotranspiration. Shashikant and Raina (1990) recorded maximum value of chloride during the rainy season was probably due to the heavy rainfall which might be supplemented its source from the catchment area.

Sreenivasan (1965), Singh and Rai (1984), Patil et al. (1986), Rao and Durve (1989) ascribed that the water contained higher percentage of chloride contents indicating organic pollution derived from animal origin. The pollution of Sagar lake is due to washing down of organic matter of animal origin from catchment area, washing of clothes and sewage from hospital which bring chloride salts as such.

Sahai and Sinha (1969), Gupta (1984) showed positive relationship between chloride and temperature. Chourasia and Adoni (1985) reported that chloride showed positive relation with temperature and bicarbonate alkalinity. In the present observation chloride showed positive relationship with temperature, total hardness and total dissolved solids (Figs. 45, 46, 47, 48). Similar observations were also made by Verma and Shukla (1970) and Singhal (1980), whereas Qadri and Yousuf (1979) reported that chloride inversely correlated with total hardness in Beehama spring.

Mishra and Yadav (1978), Yatheesh (1990) reported positive correlation between chloride and specific conductivity. Similar relationship was also observed during the present study in these two parameters (Figs. 47, 48).
Verma and Shukla (1970) and Chourasia and Adoni (1985) correlated the maximum growth of phytoplankton and zooplankton with the chloride. In the present study chloride did not show distinct relationship with zooplankton population (Figs. 45, 46).

**Hardness:**

The quality of water is determined through hardness and is governed by the contents of calcium and magnesium salts. Hardness of water due to bicarbonates of calcium and magnesium is called temporary hardness, while hardness due to the sulphate and chloride of calcium and magnesium is called permanent hardness.

**Calcium Hardness:**

Calcium is an essential element of all organisms because it is an important constituent of cell wall. It also regulates various physiological functions of animals.

Singhal (1980) recorded the value of calcium hardness from 16.0 ppm to 39.6 ppm in Sagar lake. Patil et al. (1985) observed in Jabalpur tank calcium hardness ranging from 18 mg/l to 56 mg/l the maximum was noted in February and minimum in July. Saha and Pandit (1985) worked on Davi Babu pond and on Ganga river of Bhagalpur. They observed that the calcium hardness value was minimum in June as 4 ppm and maximum in January as 108 ppm in pond and river water respectively. During the present investigation calcium hardness was recorded minimum of 23.2 mg/l in April and maximum of 46.5 mg/l in January.
During the present study low value and calcium hardness was observed during summer season than those of winter and rainy season (Table 9, Fig.12). The low value of calcium hardness in summer was also recorded by Sharma (1983) and Joshi (1987). Low value of calcium hardness during summer season may be attributed due to the high photosynthetic activities of autotrophs. They absorb carbon-dioxide and bicarbonate more rapidly, resulting in excessive release of carbonate, which in turn precipitate as calcium carbonate, so that the calcium is taken away from the dynamic site of the system. This view is supported by Wetzel (1975), whereas other workers Munnawar(1970), Daborn (1976) and Bagde and Verma (1985) reported high value of calcium hardness during summer and winter and lower in rainy season. They suggested that the high value of calcium hardness during summer may be attributed to the steady state of hardening of water due to evaporation and addition of calcium and magnesium salts from detergents and soap used for washing and bathing. On the other hand, low value of calcium hardness during rainy season was due to excessive dilution by heavy rains.

**Total Hardness**:

Qasim et al. (1966) in the polluted river Kali recorded total hardness from 154 mg/l to 448 mg/l. Hugh (1978) found in Canadian Brown water stream minimum total hardness 95 mg/l and maximum of 95 mg/l. Qadri and Yousuf (1979) recorded in the water of Bihama spring total hardness ranged from 136.0 mg/l to 168.0 mg/l, highest in April and lowest in March. Singh and
Rai (1984) noted minimum total hardness 44 mg/l and maximum of 108 mg/l in Engineering College lake of Jabalpur. Unni (1984) observed total hardness in a sewage polluted tank in Central India, the minimum of 68 ppm and maximum of 132 ppm. Patil et al. (1985) in Jabalpur tank recorded total hardness varied from 52 mg/l to 95 mg/l in July and March respectively. Patil and Panda (1986) in fresh water tank of Patan, Andhra Pradesh, observed minimum total hardness 84 mg/l and highest 114 mg/l. During present study the value of total hardness was minimum 98.0 mgl⁻¹ in November and maximum of 146 mgl⁻¹ in June.

Chandra Prakash (1983) in Ketham lake recorded maximum total hardness in summer as 150.0 ppm and minimum in rainy season as 61.00 ppm. In the present investigation maximum total hardness was higher as 124.5 mgl⁻¹ in summer than that of rainy and winter season as 111.5 mgl⁻¹ and 115.2 mgl⁻¹ respectively (Table 9, Fig.12). The higher value of total hardness during summer season was also reported by Hussainy (1967), Singhal (1980) and Prasad et al. (1985), whereas Saha and Pandit (1985) observed low value of total hardness during summer season in pond and river at Bhagalpur. The higher value of total hardness in summer may increase with the increased eutrophication and evaporation of water during summer.

Total hardness showed positive relation with chloride (Figs. 47, 48). Similar relationship was also made by Singhal (1980). Qadri and Yousuf and Yatheesh (1990) however, showed inverse correlation between chloride and total hardness. Gupta (1984) noted low degree of negative correlation between
total hardness and chloride.

Singh (1979) and Prasad et al. (1985) observed positive correlation between total hardness and calcium hardness. Joshi (1987) reported that total hardness showed almost similar trend as that of calcium hardness. Present investigation showed that the calcium hardness and total hardness positively correlated with total carbon-dioxide and negatively correlated with water temperature (Figs. 43, 44).

According to Barrett (1953) hard water is more productive than soft water. Swingle (1967) recorded the total hardness of 50 ppm act as a separation point between soft and hard water. Thus the water of Sagar lake comes under the category of hard water as having more than 50 ppm total hardness.

**Dissolved Oxygen**:

Oxygen is of paramount importance to all living organisms, as it is essential for the metabolism of organism that possess aerobic respiration. Severe restriction on the distribution of animals caused by shortage of oxygen, is much common in fresh water because the decomposable organic materials are much more concentrated either naturally or because of pollution. The lower content of water is a serious limiting factors.

The atmosphere contains 1/5 part of oxygen and 4/5 part of nitrogen. In water the occurrence of dissolved oxygen may be attributed by two distinct phenomenon, direct diffusion from the air and photosynthetic activity of autotrophs. The first
one is a physical process and depends on the solubility of oxygen, whereas second is a biological process and depends on the availability of light and the rate of metabolic process. Oxygen is more soluble in water than nitrogen. The solubility of oxygen in water is two times more than that of nitrogen which is under the influence of temperature, salinity and water movement. Colder waters have more solubility of oxygen. That is why they have more fish fauna as compared to tropical water. Hutchinson (1957) are of the opinion that solubility of oxygen in water is further influenced by altitudinal changes of atmospheric pressure. Eutrophic lake have wide range of dissolved oxygen and showed clinograde curve, whereas oligotrophic lake have narrow range of dissolved oxygen and show ortho-grade oxygen curve.

Dubey and Verma (1966) noted that the dissolved oxygen in Budhwar tank ranged from 4.8 ppm in April to 8.2 ppm in August. Saha et al. (1971) reported that dissolved oxygen in perennial fresh water pond varied from 2.02 ppm to 12.1 ppm, the higher value was noted on surface water which gradually decline with depth. Tandon and Singh (1972) observed higher value of dissolved oxygen in May and June and lower in October. Ghosh et al. (1974) noted dissolved oxygen in a fish pond at Khardah West Bengal varied from 2.0 ppm to 5.7 ppm. In Volta lake Asamoah (1977) observed that the oxygen concentration ranged between 1.2 mg/l and 7.7 mg/l. Zutshi and Khan (1977) recorded dissolved oxygen contents in the surface of water of Surinsar lake and Mansar lake of Kashmir and found that the oxygen
concentration in Surinsar lake was (3.3 mg/l to 10.4 mg/l) higher than that of Mansar lake (7.6 mg/l to 8.4 mg/l), its maximum value was obtained in February in both the lake. Qadri and Yousuf (1979) observed that the dissolved oxygen in Beehama spring ranged between 4.0 mg/l and 10.4 mg/l. Awatramani (1980) noted dissolved oxygen concentration in surface water of Sagar lake ranged from 4.53 ppm to 13.2 ppm. Purohit and Singh (1981) found maximum value of dissolved oxygen as 14.4 ppm and minimum of 4 ppm in surface water of Nainital lake. Singh and Rai (1984) in Engineering College lake of Jabalpur noted maximum dissolved oxygen 8.1 mg/l and minimum of 4 mg/l. Bagde and Verma (1985) recorded dissolved oxygen in the water of J.N.U. lake, New Delhi that ranged between 3.6 mg/l and 9.6 mg/l. Patil and Panda (1986) observed oxygen concentration in freshwater tank of Patan ranging from 2.8 mg/l to 6.4 mg/l. George (1986) worked on some Dune pond in North Carolina. He noted that the value of oxygen concentration varied from 3.6 mg/l to 8.3 mg/l. Datta et al. (1987) observed that the oxygen concentration in fresh water pond at Calcutta varied from 1.5 mg/l to 12.0 mg/l. Qayoom et al. (1989) recorded wide range of dissolved oxygen in Dal lake Kashmir ranged from 0.80 mg/l to 13.2 mg/l. In the present study the concentration of dissolved oxygen ranged from 4.4 mg/l to 14.2 mg/l, maximum value was obtained in January and minimum in May.

Bagde and Verma (1985) in J.N.U. lake, New Delhi noted that the higher value of dissolved oxygen was found in winter and lower in summer season. In the present observation the
increased value of dissolved oxygen was recorded after summer months, reaching maximum in January i.e. in winter season and decreased trend was found after winter months, became lowest in May. The higher value of dissolved oxygen in winter and lower in summer was also recorded by Hussainy (1967), Zutshi and Vass (1978), Sharma (1983), Yadav (1986) and Joshi (1987).

The concentration of dissolved oxygen in water is influenced by the temperature, photo synthesis, respiration, decomposition and oxidation of dissolved organic compound. APHA (1976) and Zutshi and Vass (1978) stated that the seasonal variation in dissolved oxygen depends upon the temperature of water which influences oxygen solubility. Hannan (1979) reported that depletion of dissolved oxygen during summer developed due to high temperature whereas Ganapati (1964) and Nasar and Datta Munshi (1974) did not find temperature to be a controlling factor for dissolved oxygen concentration.

Yentsh and Ryther (1957) recorded low value of dissolved oxygen in summer. According to them in summer photo-oxidation of pigments takes place under increased light which decline the chlorophyll contents in plant cell. Golterman (1975) viewed that the degree of oxygen depletion is dependent upon the total amount of oxygen percentage, which varies with depth, and amount of sinking dead materials. Morriissette and Mavinic (1978) opined that decomposition of organic matter was the main factor in consumption of dissolved oxygen, which was more vigorous in warm weather. Chourasia and Adoni (1985) viewed that the lower
value of dissolved oxygen during summer was due to the higher catabolic rate of aquatic organisms, accelerated decomposition and decrease in oxygen solubility at higher temperature. In the present study the low value of dissolved oxygen during summer might be due to the high water temperature, low water level and low transparency, which prevent photosynthesis and as a result oxygen did not liberate through autotrophs and high water temperature decreases the oxygen solubility. This view is also supported by Sreenivasan (1969). On the other hand, Unni (1984) reported that in sewage polluted tank at Chhindwara the highest value of dissolved oxygen in surface water coincided with the highest temperature in the month of May.

Hannan (1979) reported that higher value of dissolved oxygen during monsoon, because of the oxygenation of water caused due to circulation and mixing by inflow after monsoon rains. Hannan again noted that the highest value of oxygen during winter may be attributed due to the circulation by cooling and draw down of dissolved oxygen in water. This pattern of dissolved oxygen succession was noted by Gordon and Nicholas (1970) also. Singh (1983) reported that higher values of dissolved oxygen in monsoon may be due to the enormous growth of plankton and in winter due to low water temperature and luxurient growth of macrophytes. During present observation the higher value of dissolved oxygen in winter season may be attributed due to the higher solubility of oxygen at low water temperature. An apparent inverse relation between dissolved oxygen and temperature was noticed in the present study (Figs. 39, 40).
Similar conclusions have been drawn by Sreenivasan (1968), Mathew (1975), Mishra and Yadav (1978), Bagde and Verma (1985) and Sen (1988).

Some workers showed positive relation between dissolved oxygen and temperature. Purohit and Singh (1981) in Nainital lake found positive relation between temperature and dissolved oxygen at surface water and observed that low temperature in winter may constitute one of the major limiting factor for photosynthesis at high altitudes, thus causing a decreased in oxygen contents of water, and high temperature during summer stimulate photosynthesis resulting in increased amount of dissolved oxygen. Similar relationship between oxygen and temperature was also recorded in other sub-tropical water bodies by Singh (1975), Kaul (1977), Zutshi and Khan (1977), Zutshi and Vass (1978) and Tilak and Baloni (1985).

Dissolved oxygen showed positive relationship with transparency (Figs. 45, 46). Similar relationship was also recorded by Biswas (1972) for Volta lake and Yadav (1986) for Sagar lake. On the other hand Tandon and Singh (1972) observed that dissolved oxygen value increased with increase in turbidity in the month of May and June.

Qadri and Yousuf (1979) and Yathoesh (1990) recorded inverse relationship between dissolved oxygen and chloride. Similar relationship between these two parameters was also noted during the present study.
**Percentage Oxygen Saturation:**

The percentage oxygen saturation showed similar seasonal fluctuation as that of dissolved oxygen. Sreenivasan (1964) in Bhawansagar reservoir recorded high oxygen super saturation in December and January. Verma (1969) observed oxygen saturation in Tekanpur reservoir varied from 55.20% in June to 104.84% in August. Zutshi and Khan (1978) recorded oxygen saturation in Dal lake, Kashmir varied from 115% to 174%. The higher value was observed during winter season and minimum in summer season. Qadri and Yousuf (1979) in Beehama spring found maximum oxygen saturation 134.5% in March and minimum 50.08% in November. Saha and Pandi (1985) observed maximum oxygen saturation as 92% in July and minimum as 31% in August in Devi Babu pond at Bhagalpur. Adoni and Yadav (1985) in Sagar lake observed that the maximum oxygen saturation 225.3% was recorded in August and minimum 63% in September. During present investigation the oxygen saturation varied from 50.34% to 147.52%, maximum value were observed in December and minimum in May. The maximum oxygen saturation during winter and minimum in summer were also recorded by Chourasia and Adoni (1985), and Yateesh (1990).

Similar factors were responsible for the variation of oxygen saturation as that of dissolved oxygen. According to Ignjatovic (1968) oxygen supersaturation was caused due to change in temperature, pressure, vertical mixing of stratified water, vertical diffusion and evaporation. Yadav (1986) viewed
**Fig. 39** Inter-relationships of pH (Unit), Dissolved Oxygen (m<sup>3</sup>l<sup>-1</sup>), Water Temperature (°C), Secchi Transparency (cm), and Zooplankton (Organisms l<sup>-1</sup>) at Station A.
FIG: 40. INTER-RELATIONSHIP OF pH (Unit), DISSOLVED OXYGEN (mg l⁻¹), WATER TEMPERATURE (°C), SECCHI TRANSPARANCY (cm) & ZOOPLANKTON (Organisms l⁻¹) AT STATION B.
FIG: 41. INTER-RELATIONSHIPS OF CHLORIDE, CARBONATE ALKALINITY, BICARBONATE ALKALINITY, TOTAL CARBONDIOXIDE (mg l⁻¹) AND ZOOPLANKTON (Organisms l⁻¹) AT STATION A.
FIG. 42. INTER-RELATIONSHIPS OF CHLORIDE, CARBONATE ALKALINITY, BICARBONATE ALKALINITY, TOTAL CARBON DI OXIDE (mg\textsuperscript{l}^{-1}) AND ZOOPLANKTON (organism \textsuperscript{l}^{-1}) AT STATION B.
FIG. 43. INTER-RELATIONSHIPS OF TOTAL CARBONDIOXIDE, CALCIUM HARDNESS, TOTAL HARDNESS (mg l⁻¹), SECCHI TRANSPARANCY (Cm), WATER TEMPRATURE (°C) & ZOOPLANKTON (ORGANISMS l⁻¹) AT STATION A.
FIG. 44. INTER-RELATIONSHIPS OF TOTAL CARBON DIOXIDE, CALCIUM HARDNESS, TOTAL HARDNESS (mg/l), SECCHI TRANSPARENCY (cm), WATER TEMP (°C) & ZOOPLANKTON (Organisms l⁻¹) AT STATION B.
FIG: 45. INTER RELATIONSHIPS OF CHLORIDE, DISSOLVED OXYGEN (mg/l), SECCHI TRANSPARENCY (cm), WATER TEMPERATURE (°C), AND ZOOPLANKTON (organism l⁻¹) AT STATION A.
Fig: 46. Interrelationships of chloride, dissolved oxygen (mg/l), Secchi transparency (cm), water temperature (°C), and zooplankton (organisms l⁻¹) at station B.
**Fig. 47.** Inter-relationships of specific conductivity (m·mhos/cm), total dissolved solids, total hardness, total carbon dioxide, chloride (mg/l) and zooplankton (organisms l⁻¹) at station A.
FIG: 48. INTER-RELATIONSHIPS OF SPECIFIC CONDUCTIVITY (mhos/cm)
TOTAL DISSOLVED SOLIDS, TOTAL HARDNESS, TOTAL CARBON DIOXIDE, CHLORIDE (mg/l) & ZOOPLANKTON (Organisms/l)
AT STATION B.
that the oxygen super saturation in surface and bottom water in August may be attributed due to the mixing of water. Author agrees with the view of Ignjatovic.

Zooplankton:

The term plankton was coined by Victor Henson in 1887 to designate the heterogenous assemblage of suspended finely divided materials and minute organisms in water which wander at the mercy of winds and water current. However, the term plankton has been confined only to the microscopic, free floating organisms (Welch, 1935). Naturally planktons are divided into two groups, i.e. phytoplankton and zooplankton. Seasonal qualitative and quantitative fluctuations usually occur in planktonic population. Certain planktonic forms disappear at specified periods and reappear during others.

Welch (1952) expressed that the planktonic productivity shows a bimodel pattern of fluctuation. Bimodel pattern of planktonic production have also been reported by Das and Shrivastava (1956a). Bhowmik (1968) reported that the winter peak of plankton was dominated by zooplankton, particularly the rotifers in Kalyani fish pond. Michael (1969) recorded that single prolonged peak period lasted from January to April in a fresh water pond at Barrackpore. This peak period was composed of protozoans, crustaceans, rotifers phytoplanktons. Saha et al. (1971) in fish pond at Cuttack (1959 to 1961) observed that zooplanktons exhibited four peaks i.e. in March, July, October and in January during the first year
and only one peak was observed during the second year in the month of November. Tandon and Singh (1972) recorded three peaks of zooplankton in Nagal lake, primary peak from September to November and two secondary peaks, one in March and the other in May. Patnaik (1973) in Chilka lake noted two zooplanktonic peaks first in May and second in November. Ghosh et al. (1974) in fish pond at Khardah exhibited three zooplanktonic peaks viz. in August, November and February and main peak was obtained in February. Chakraborthy (1980) recorded maximum planktonic production in Monsoon and winter. Chandra Prakash (1983) observed only one peak of zooplankton from Keetham lake in summer season. Chourasia (1985) in Sagar lake exhibited three peaks of zooplankton viz. in July, October and in March and the main peak was observed in March due to the rotifers. During present observations zooplankton showed three peaks i.e. in November, February and July, and the main peak was noted in July at both the stations.

Jana (1973), and Khan and Siddiqui (1974) noted that generally zooplankton periodicity depends on the phytoplankton periodicity. Zooplankton density increased with the decline of phytoplankton density and vicer verca. According to grazing theory, zooplankton consume phytoplankton resulting the less number of phytoplankton, and when the zooplankton are less, phytoplankton multiply resulting into bloom, which is stated by Anderson et al. (1955), Wright (1965), Jana (1973) and Kundangar and Zutshi (1985).
It was thought earlier that small to medium size lake contained only 3-7 species of rotifers, 2-4 species of cladocerans and 1-3 species of copepods. Sewell (1934) recorded 10 species of rotifers, 15 species of cladocerans, 10 species of copepods, 1 species of ostracods and 3 species of polyzoans from the fresh water pond of Calcutta. Chacko and Krishnamurthy (1954) reported only two groups of zooplankton, copepoda and cladocera from the different pond of South India. Alikunhi et al. (1955) from the water of nursery pond at Cuttack observed 11 species of rotifers, 2 species of copepods, 3 species of cladocerans and some ostracods. George (1966) worked on five fresh water tank of Delhi and he observed 31 species of rotifers, 7 species of copepods, 11 species of cladocerans, 4 species of ostracods, 2 species of oligochaets and few protozoans. Shastry et al. (1970) obtained 9 species of rotifers, and 14 species of protozoans from the upper lake of Bhopal. Saha et al. (1971) observed in the perennial pond at Cuttack, 11 species of rotifers, 4 species of copepods, 1 species of cladocerans and some species of protozoans. Moitra and Mukherji (1972) from the fish pond of Kalyani recorded 7 species of rotifer, 3 species of copepod and 7 species of cladocera. In the water of Keetham lake Chandra-prakash (1983) noted 14 species of rotifera, 11 genera of protozoa, 6 genera of crustacea, 10 genera of insects and 3 molluscan genera. Jain and Rao (1984) recorded that zooplankton fauna in the water of Ujjain area consisted of 15 species of cladocera and 6 species of copepoda. Patil et al. (1985) observed zooplankton from the fresh water tank of
Jabalpur 22 species of rotifera, 14 species of cladocera, 3 species of copepoda and 4 species of ostracoda. Kundangar and Zutshi (1985) recorded 15 species of rotifers, 3 species of copepods and 4 species of cladocerans from the Ahansar and Waskur lake of Shrinagar. During the present observations the zooplankton fauna was noted as 4 species of protozoa, 26 species of rotifera, 7 species of cladocera, 2 species of copepoda, and Nauplii larvae.

In the present study in Sagar lake, zooplankton fauna showed numerical dominance of rotifers over cladocerans and copepods, it has also been observed by Zutshi et al. (1980) in Jammu and Kashmir lakes, Kundangar and Zutshi (1985) in Ahansar and Waskur lake of Himalaya and Chourasia and Adoni (1987) in Sagar lake. On the other hand Chacko and Krishnamurthy (1954) and Mills et al. (1981) observed that the dominant zooplanktons were either cladocerans or copepods and not the rotifers. Patil et al. (1985) found that the cladoceran population was more than rotifers in fresh water tank of Jabalpur.

During present investigation protozoan population in Sagar lake constituted a negligible percentage 1.25% at Station A and 1.34% at Station B in the total zooplankton population and were represented only by Arcella, Difflugia and Centrop vxis. Chourasia (1985) worked on three water bodies around the Sagar city i.e. Sagar lake, Bila reservoir and Chitora reservoir. He observed very less number of protozoans in Sagar lake in comparison to Chitora and Bila reservoir. The fewer number of protozoans in Sagar lake may be suggested
that the older water bodies harbour less protozoans due to competition and may be due to the result of their predation. Very less number of protozoans from a old perennial pond at Cuttack was also reported by Saha et al. (1971).

It is a well known fact that rotifers are wide spread cosmopolitons. The presence of rotifer species in a particular pond are dependent on the chemical condition and plant inhibiting in that pond. Sharma and Michael (1980) noted that near about 245 species of rotifers are recorded from India. During the present study only 26 species of rotifers were observed in Sagar lake.

The percentage composition of rotifers in total zooplankton was recorded by Saha et al. (1971) in a perennial pond at Cuttack for 2 years period as 73.87% and 82.30% respectively. Patil et al. (1985) in Jabalpur tank recorded 34.07% rotifers in total zooplankton population. During the present investigations the percentage composition of rotifers in total zooplankton at both the stations A and B were recorded as 52.74% and 47.71% respectively. (Tables 37,38; Figs. 51,52).

Das and Shrivastava (1956a) recorded the maximum rotifer population in June in a fresh water pond at Lucknow. George (1966) in fish tank of Delhi observed measured population of rotifers in April. Patnaik (1973) in Chilka lake recorded maximum rotifers in February. Singh and Sahai (1978) observed maximum density of rotifers in February and minimum in July and August. Gupta (1984) observed in Sagar lake two peaks of
rotifers one in February and other in May. Kundangar and Zutshi (1985) in Ahansar lake found rotifer peak in September contributing 65.6% of the total zooplankton density. Patil et al. (1985) recorded two peaks of rotifers first in July and second in December in a fresh water tank of Jabalpur. Chourasia and Adoni (1987) in Sagar lake recorded the main peak of rotifers in March. During present investigations two peaks of rotifers were observed, first in July and second in February. The main peak of rotifers at both the stations was recorded in July as 1230 organisms/litre at station A and 1580 organisms/litre at station B (Figs. 49,50).

Michael (1969), Awatramani (1980), Sharma (1983) and Rao and Durve (1989) recorded higher density of rotifers in summer season. In contrast to above, Patil (1976) and Jha (1979) could not attributed the summer maxima. Sharma and Rai (1980) in Makhana and D.M.C.H. Swamp observed rotifer peak in late summer and in early monsoon. Awatramani (1980) found two peaks of rotifers, one in summer and other in winter. Chourasia and Adoni (1985) recorded maximum density of rotifers in summer and minimum in rainy season. They viewed that the optimal thermal and nutrient conditions were generally responsible for the outburst of rotifers population in summer. During the present investigations the higher density of rotifers was observed in winter season (Table 18; Fig. 21).

Rotifers were represented by a maximum number of species and genera. Certain forms of rotifers such as Brachionus, Keratella and Anuraeopsis were generally recorded throughout
the period of investigations, while other rotifers e.g. *Monostyla*,
*Filinia*, *Polyarthra* were occasionally found, whereas *Notholca*,
*Hordaella*, *Lepadella*, *Lecane*, and *Rotatoria* were incidentally
observed. Among rotifers the *Brachionus* was very commonly
encountered. Common occurrence of *Brachionus* in many tropical
water bodies was also reported by Green (1972). The occurrence
of *Brachionus* in higher number have been considered to be the
indication of eutrophication. This view was also supported by
Singh *et al.* (1985), Chourasia and Adoni (1987) and Rao and

The cladoceran population was scanty in comparison to
rotifers and copepods as 5.43% at station A and 4.79% at
station B in total zooplankton (Tables 37,38). It is mainly
represented by three genera e.g. *Daphnia*, *Moina* and *Bosmina*.
Das and Shrivastava (1956a) noted that the cladoceran peak was
observed in December and January in the water of Lucknow ponds.
Tandon and Singh (1972) recorded cladoceran peak in March in
Nagal lake. Das and Pathani (1978) in Nainital lake observed
October and November as the main peak of Cladocerans. Chourasia
and Adoni (1985) reported that the main peak of cladocerans was
observed in October and smaller peak in April in Sagar lake.
During the present investigations the two peaks of cladocera
were observed, main peak in July and other in November (Figs.49,50).

Wright (1965) noted that the density of cladocerans is
primarily determined by the food supply. Gulati (1978) stated
that if food supply is high cladocerans usually build up high
number and biomass, but due to high grazing pressure subsequent
decrease in food concentration results in a near collapse of cladoceran population. Patil et al. (1985) reported that the dominance of cladoceran over other zooplankton might be due to the presence of low population of predators. Chourasia (1985) suggested that the decline in the number of cladocerans in the presence of sufficient food may be due to fish predation and moreover, the competition between cladocerans and other zooplanktonic groups for food. Present investigations agree with the view of Chourasia.

The group copepoda mainly consisted of cyclops and Nauplii larvae. Diaptomus was found occasionally. Pillai et al. (1973) noted that the copepods constitute the predominant portion of zooplankton. Saha et al. (1971) observed the copepods form 15.33% to 29.88% in total zooplankton during 1959 and 1961 respectively. Mills et al. (1981) reported that the cyclopoid copepods contributed 80% in the total biomass of zooplankton. Patil et al. (1985) recorded that the percentage of copepods in total zooplankton population was 20.34%. During present investigations the contribution of copepod in total zooplankton was usually next to the rotifers. The copepods contributed 40.58% and 46.46% in total zooplankton at station A and B respectively. (Tables 37,38; Figs. 51,52).

Goswami and Kumar (1977) observed bimodal pattern of copepods in Goa, and the major peak was noticed in October and November and the second peak in March and April. Govinda (1978) worked on Tungabhadra reservoir and observed two peaks of copepods, one from February to April and other from November
to December. Das and Pathani (1978) found the main peak of copepods during August and September from Nainital lake of Kashmir. Singh (1980) in Suraha lake recorded three peaks of copepods viz. December, April and September. Kohli and Singh (1981) noted maximum number of copepods during March in Govind Sagar reservoir. Sharma and Saksena (1983) in Janaktal lake, Gwalior observed bimodal pattern of copepods and noticed cyclopoids peak during March and Calanoids peak in March and September. Gupta (1984) recorded three peaks of copepods from Sagar lake i.e. October, March and May. During the present study, the main peak of copepods was observed in July and second other peak in October and November (Figs. 49,50).

On the seasonal basis Chapman (1972) recorded two peaks of copepods one in summer and other in winter months. Patnaik (1973) in Chilka lake observed maximum number of copepods during winter and minimum in monsoon months. Sharma and Rai (1980) recorded the peak of copepods during late summer and early monsoon in char swamp of Durbhanga. Chourasia and Adoni (1985) noted that the copepods were higher in rainy months and lower in summer months. Present observations showed that the population of copepods was higher in rainy season (Table 18,Fig.22).

Patil et al. (1985) noted that the nauplii larvae in a fresh water fish tank of Jabalpur showed definite peaks in March, August and December. In the present study nauplii larvae were seen throughout the year, two peaks of nauplii were observed one in July and other in November (Figs. 49,50).
Number of biotic and abiotic factors affects the zooplankton communities. Among the physico-chemical factors, the temperature proved to be the main factor that regulates the densities of plankton. Davis (1954) remarked that the biotic and abiotic circumstances act simultaneously must be taken into consideration in understanding the fluctuation of plankton population. Byars (1960) noted that the periodicity of rotifers influenced by temperature. Botterell (1975) reported that in laboratory conditions the densities of plankton depends on temperature which has been demonstrated within certain limits, so far as the birth rate of cladocerans and rotifers is concerned. Jha (1979) stated that the temperature played a vital role in the distribution of zooplankton. On the other hand Pejler (1957) observed that the temperature is not a limiting factor for rotifers population, but it is only a set of environmental condition. Verma and Shukla (1970) do not find any relation between plankton and temperature. During the present observations it was noted that the optimal thermal and nutrient conditions were generally responsible for the active production of zooplankton in June, July and November.

pH and zooplankton whereas Clarke (1964) observed that certain species prefer low alkaline medium while others have high alkaline medium. From the present study it was observed that the population of zooplankton increased at low pH, thus zooplankton showed inverse relation with pH (Figs. 39, 40).

Welch (1952) and Tandon and Singh (1972) stated that during monsoon, high turbidity values result in the death of plankton. Tilak and Baloni (1985) noted that during winter months, production of phytoplankton, zooplankton, insect larvae was maximum due to the low turbidity.

Awatramani (1980) reported inverse relation between chloride and zooplankton. Chourasia and Adoni (1985) noted that the chloride showed positive relation with zooplankton. Shrivastava (1988) observed that zooplanktons were directly and linearly related with oxygen and chloride. During the present study zooplankton showed somewhat positive relation with transparency and oxygen, whereas chloride did not show any distinct relation with zooplankton density (Figs. 45, 46).
FIG: 49. MONTHLY VARIATION IN DIFFERENT ZOOPLANKTON GROUPS AT STATION A OF SAGAR LAKE.
FIG: 50. MONTHLY VARIATION IN DIFFERENT ZOOPLANKTON GROUPS AT STATION B OF SAGAR LAKE.

<table>
<thead>
<tr>
<th>MONTHS</th>
<th>ZOOPLANKTON GROUPS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>PHOTONOA</td>
</tr>
<tr>
<td>November</td>
<td>-</td>
</tr>
<tr>
<td>December</td>
<td>2.39</td>
</tr>
<tr>
<td>January</td>
<td>4.24</td>
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<tr>
<td>February</td>
<td>0.50</td>
</tr>
<tr>
<td>March</td>
<td>-</td>
</tr>
<tr>
<td>April</td>
<td>-</td>
</tr>
<tr>
<td>May</td>
<td>2.29</td>
</tr>
<tr>
<td>June</td>
<td>2.20</td>
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<tr>
<td>July</td>
<td>0.78</td>
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<tr>
<td>August</td>
<td>0.47</td>
</tr>
<tr>
<td>September</td>
<td>0.74</td>
</tr>
<tr>
<td>October</td>
<td>1.20</td>
</tr>
</tbody>
</table>

Annual Mean 1.25 52.74 05.43 40.58
Fig. 51. Monthly percentage composition of different zooplankton groups in total zooplankton at station A.
Table - 38  Monthly Percentage Composition of Different Zooplankton Groups in Total Zooplankton Population at Station B of Sagar lake during November 1981 - October 1982.

<table>
<thead>
<tr>
<th>MONTHS</th>
<th>PROTOZOA</th>
<th>ROTIFERA</th>
<th>CLADOCERA</th>
<th>COPEPODA</th>
</tr>
</thead>
<tbody>
<tr>
<td>November</td>
<td>-</td>
<td>39.56</td>
<td>10.09</td>
<td>50.35</td>
</tr>
<tr>
<td>December</td>
<td>1.76</td>
<td>47.78</td>
<td>1.78</td>
<td>48.68</td>
</tr>
<tr>
<td>January</td>
<td>3.0</td>
<td>74.0</td>
<td>2.0</td>
<td>21.0</td>
</tr>
<tr>
<td>February</td>
<td>2.45</td>
<td>80.39</td>
<td>7.36</td>
<td>9.80</td>
</tr>
<tr>
<td>March</td>
<td>-</td>
<td>29.78</td>
<td>4.26</td>
<td>65.96</td>
</tr>
<tr>
<td>April</td>
<td>-</td>
<td>34.09</td>
<td>2.28</td>
<td>63.63</td>
</tr>
<tr>
<td>May</td>
<td>1.35</td>
<td>28.37</td>
<td>2.70</td>
<td>67.58</td>
</tr>
<tr>
<td>June</td>
<td>2.61</td>
<td>52.28</td>
<td>5.25</td>
<td>39.86</td>
</tr>
<tr>
<td>July</td>
<td>0.81</td>
<td>51.57</td>
<td>2.93</td>
<td>44.69</td>
</tr>
<tr>
<td>August</td>
<td>-</td>
<td>44.06</td>
<td>6.78</td>
<td>49.16</td>
</tr>
<tr>
<td>September</td>
<td>1.88</td>
<td>45.28</td>
<td>7.56</td>
<td>45.28</td>
</tr>
<tr>
<td>October</td>
<td>2.33</td>
<td>41.86</td>
<td>4.65</td>
<td>51.16</td>
</tr>
<tr>
<td>Annual Mean</td>
<td>1.34</td>
<td>47.41</td>
<td>4.79</td>
<td>46.46</td>
</tr>
</tbody>
</table>
FIG. 52. MONTHLY PERCENTAGE COMPOSITION OF DIFFERENT ZOOPLANKTON GROUPS IN TOTAL ZOOPLANKTON AT STATION B.
Fish Ecology:

Fresh water environment whether it is lotic or lentic, the biotic potential of any water body, depends upon its standing crop of organisms. These organisms are phytoplankton, bottom flora, bottom fauna, zooplankton and fishes. The first two constitute a producing cycle and the other three form a consuming cycle (Welch, 1952). These features establish a complex inter-relationship in the form of a nutritional chain in water (Darnell, 1961).

There are number of larvivorous fishes in Indian water which are used as mosquito control measures for e.g. Gambusia affinis, Aplocheilus lineatus, Macropodus cupanus, Aphanius dispar, Carassius auratus, Fundulus confluentus, Cyprinus carpio, Orizias latipes, Poecilia reticulata, Tilapia mossambica, Rasbora daniconius, Danio malabaricus, Esoxus danricus, Ambassis ranga, A. nama, Notopterus notopterus, Puntius ticto, Channa punctatus, Glassogobius giuris, Chela bacaila, Colisa fasciata, Badis badis, Anabas testudinosis etc. In Sagar lake most common larvivorous fishes are Rasbora daniconius, Danio malabaricus, Ambassis ranga and Channa punctatus. Though Rasbora daniconius, Danio malabaricus and Ambassis ranga are not a commercially important species, they are larvivorous fishes in ponds competing with major carps for food. Rasbora daniconius and Danio malabaricus are commonly occurring cyprinoid forage fish in the fresh water of India (Day, 1878). They prefer clear water with rich vegetation.
but they can also be found in turbid water. They have slightly compressed body with rounded abdomen. *Rasbora daniconius* has a black lateral strip, whereas *Danio malabaricus* has three strips passes from eye to the base of caudal fin on both sides of the body. These are small fishes. *Rasbora daniconius* do not exceed 12.5 cm in length and *Danio malabaricus* attain the length not more than 12.0 cm. The local name of *Rasbora daniconius* is Anjara, and of *Danio malabaricus* is Palaiya. *Ambassis ranga* have attractive and delicate forms distributed in rivers, pools, stag non-tstreams with abundant emergent vegetation. These are little fishes, not exceeding 11.0 cm in length, having glassy transparent compressed body. The local name of the fish is Jhanjhra. *Ghanna punctatus* (Bloch) is the common fresh water murrel of India and has an widely geographical distribution. It has also been recorded from brakish water having slightly purple colour (Raj, 1916). These are air breathing fishes which can survive in fairly large numbers in all kinds of seasonal and perennial ponds. When seasonal ponds get dried up in summer the fish burries itself in soil and aestivates. These fishes have excellent commercial values as the flesh is tasty. The body is cylindrical anteriorly and somewhat compressed posteriorly, predatory in habits; only the young ones (3.0 – 9.3 cm) are larvivorous.

**Environmental conditions suitable for survival of these larvivorous fishes are like those of the major carps. Water temperature, Secchi transparency, light, pH, alkalinity, oxygen and chloride are the important physico-chemical parameters**
which influence the growth and other activities of the fish.

Water temperature plays an important role in various vital activities of the fish such as feeding, reproduction, growth and movement. Cold water fishes can tolerate the great variability in temperature. Sehgal (1973), Baloni and Tilak (1983) observed that the fish *Schizothorax richardsoni* in Northern India can tolerate the temperature ranged from 8.0°C - 22.0°C and 6.0 - 24.5°C respectively. Jhingran (1977) noted that temperature between 18.3°C and 37.8°C are most suitable for the Indian major carps. He further stated that temperature below 16.7°C and above 39.5°C is fatal to them. Abbas and Haq (1982) reported that the temperature between 10°C and 32°C is suitable for *Channa punctatus* in derelict water ecosystem. They pointed out that the population density of *G. punctatus* was low during summer due to the rise in temperature as the fish seem to migrate in deeper region and aestivate. Das (1945) attributed that the upper lethal temperature limit of *Channa punctatus*, *Anabas testudineus*, *Puntius ticto*, *Rasbora daniconius* and *Glassogobius giuris* is between 39°C - 41°C. During the present investigation it has been observed that all the four larvivorous fishes thrive well between the temperature 17.5°C and 29.0°C. The fish feeds actively and attains the final stage of maturity when temperature becomes favourable.

Schneberger and Jewel (1928) reported that the high fish production is associated with low turbidity. Jhingran (1977) suggested that the major Indian carps tolerated the high range of turbidity. Gupta (1984) noted that the population of
_Labeo rohita_ (Him.Buch) was higher during winter season, which might be due to the high transparency. Present investigations shows that low transparency effect the feeding activity of larvivorous fish as the fish is unable to detect the food. As a result fish growth is checked.

Alikunhi et al. (1955) recorded high pH value during high fish yield. Das and Shrivastava (1956b), Das (1961, 1967) and Sreenivasan (1963) stated that the alkaline water is favourable for the growth of plankton which indirectly supports the high fish population as the planktons are used for fish food. Das (1961) reported that in Eutrophic lake pH of water is an important factor for high fish production. Hora and Pillay(1962) stated that pH 8 is suitable for fish growth and culture. According to Banerjea (1967) a neutral pH 6.5 to 7.5 is most favourable for production of fish. pH below 6.5 and above 8.5 are unproductive and pH between 7.5 and 8.5 may be favourable for average production. Swingle (1967) stated that the pH between 6.5 - 9.0 considered as most suitable for fish culture and fish dies at about pH 11. He further reported that acid waters reduce the appetite of fish, their growth and tolerance to toxic material. Pathani (1979) in Bhimtal lake attributed that the pH range 7.8 to 8.4 is suitable for fish production. Baloni and Tilak (1983) in the river and streams of Garhwal Himalaya recorded pH between 7.0 and 8.3, they have not observed adverse effect on the fish within this range of pH. Singh and Rai (1984) stated the the pH between 6.4 and 8.3 is favourable for fish growth. During the present investigation
it has been observed that the pH between 7.8 and 8.5 is favourable for the average fish growth.

Alikunhi (1957) noted that the alkalinity of water ought to be over 100 ppm as highly productive water. Banerjea (1967) reported that the total alkalinity below 20 ppm is responsible for the poor fish production.

The fish and aquatic fauna depend totally on oxygen. Mortality in fishes takes place mostly due to severe oxygen deficiency. On cloudy days the photosynthesis reduces and sometimes continuous cloudy days cause a peril to fish life due to severe lack of oxygen. Qasim et al. (1966) reported that in river Kali, mortality of fish occur surely by the complete depletion of oxygen. Similarly fish mortality in Rewalsar lake in Himachal Pradesh, in summer was caused due to the change in water temperature and depletion in dissolved oxygen content as 1.36 mg/l (Singh et al. 1985). During the present investigation in Sagar lake the mortality of larvivorous fishes Rasbora daniconius, Danio malabaricus and Ambasis ranga in June caused due to the depletion of dissolved oxygen as 1.6 mg/l.

Banerjea (1967) noted that the dissolved oxygen below 5 ppm may be considered as unfavourable for the fish production and above 7 ppm is suitable for the fish production. Mathur (1967) reported that Rasbora daniconius survive in low oxygen in tropical temperature. Mills (1971) stated that 5.0 ppm to 5.5 ppm dissolved oxygen is essential for survival of trout. Baloni and Tilak (1983) reported that Schizothorax richardsoni
abundently occurred where the concentration of dissolved oxygen ranged from 8.2 ppm to 24.6 ppm. They attributed that the high concentration of dissolved oxygen in hill streams is associated with the rapid flow of water due to clarity of water, the sun rays penetrate the water and are utilized by the macrophytes and phytoplankton in the processes of photosynthesis. According to present investigation, the larvivorous fishes survive between 4.4 ml\(^{-1}\) and 14.2 ml\(^{-1}\). Tolerance of *Rasbora daniconius*, *Danio malabaricus* and *Ambassis ranga* are as such that they can live in tropical water in low oxygen condition while *Channa punctatus* having accessory respiratory organs, often engulf atmospheric air in anaerobic conditions. In the lake water the high value of dissolved oxygen were recorded during winter season, associated with the high yield of larvivorous fishes. These observations are supported by Gupta (1984) for *Labeo rohita*. 
Food and Feeding

In the ecological and biological study of fishes the food and feeding habits have a special significance. Menon and Chacko (1955) classified the fishes according to their feeding habits. Under the group surface feeders come those fishes which feed on plankton (zooplankton and phytoplankton) and insect and their larvae. The fishes Barbus ticto, B. amphibius, B. filamentosus, B. sophore and B. chola are phytoplanktonic surface feeders and so they are herbivorous in nature, whereas Ambasis ranga, A. nama, Chela clupeoides, C. bacaila, Rasbora daniconius, Danio aequipinnatus, D. malabaricus, Anabas scandens, Barilius bakeri, Gambusia affinis and Aplocheilus lineatus feed on zooplanktons, insects, and their larvae; so they are carnivorous surface feeder in nature. Menon and Chacko (1955) noted that the main food items of Ambasis nama and A. ranga were copepods with percentage composition of 45.8% and 46.9% respectively. While main food items of Danio aequipinnatus and Rasbora daniconius were Insects as 45.6% and 40.0% respectively. According to Das and Moitra (1955) fishes feeding on diatoms, plankton algae, plankton rotifers, plankton crustaceans and their larvae, aquatic insects and their larvae are to be placed under the group surface feeders. They include the fish Ambasis ranga and Ambasis nama under this group because the main food items of these fishes were observed as insects and crustaceans. The percentage of insects and crustaceans in Ambasis ranga were noted as 76.4% and 10.3%.
respectively, whereas in *Ambasis nama* the percentage of insects was recorded 26.7% and of crustaceans 59.9%. Natraj an *et al.* (1975) in Konar reservoir noted that the food of *Ambasis ranga* constituted copepods, prawn and insects. The main food item was copepods with 73.75% and the main food item of *Ambasis nama* in Konar reservoir was copepods as 16.57% and in Tilaya reservoir was insects as 35.0%.

From the foregoing account, it was observed that *Hasbora daniconius*, *Danio malabaricus* and *Ambasis ranga* consume a sizeable amount of zooplankton as 35.12%, 36.0% and 12.6%; crustaceans as 8.75%, 10.83% and 24.27%; Insects and their larvae as 36.28%, 34.6% and 47.05% respectively (Tables 39, 40; Figs. 53, 54). This indicates that these fishes are to be placed under the group of surface feeders as suggested by Menon and Chacko (1955). Although these fishes showed preferential larvivorous feeding habits by taking mainly the insects larvae such as Chironomous, Ephemeropteran, Dipterian and Odonata larvae, but some fishery biologists have preferred to call *Hasbora daniconius* and *Danio malabaricus* as omnivorous due to the presence of phytoplanktons and algae in their gut contents. During the present observation the gut of these fishes contained some phytoplankton and aquatic plant material, suggested that the presence of very small quantities of vegetable food in their gut may be possibly to balance the diet, supported the view of Kyle (1926).
The fishes *Rasbora daniconius*, *Danio malabaricus* and *Ambassis ranga* have upturned mouth, which may be correlated with the surface and larvivorous feeding habit of these fishes. Mookerjee and Ganguly (1951) and Das (1971) correlated the upturned mouth in *Esoxus danrica* with surface feeding habit. Sewell and Chaudhury (1912), however, described *E. danrica* as larvicidal fish.

Menon and Chacko (1955) stated that fishes feeding on filamentous algae, molluscs and whose gut contains sand grains are placed under the group of bottom feeders. According to them the main constituents of food of *Ophioccephalus punctatus* were recorded as insects 25%, molluscs 20%, worms 30% and mud and sand 20%. Qayyum and Qasim (1964 a) observed that the immature *Channa punctatus* feed on insects, crustaceans, rotifers and molluscs in fair quantity, whereas the older fishes are predatory in habit and consume forage fishes, insects, gastropods, prawns and algae. Thus it shows that the smaller fishes of *C. punctatus* are surface feeders, whereas older fishes are bottom feeders. The bottom feeding habit of *C. striatus* was recorded by Das and Moitra (1955). Abbas and Haq (1982) reported that the important food items of *C. punctatus* in the derilict water were insect larvae, annelids and molluscs etc. According to them the dipteran larvae constituted the bulk of the food of *C. punctatus*; they formed 56% of the total food consumed by the fish and the fishes were found to feed on insect larvae around the year. Insect eggs, rotifers, cyclops and other crustaceans were consumed mainly by smaller fishes.
Present observation indicates that the main food items of *Channa punctatus* were insects and their larvae constituted 35.70%, crustaceans 25.52%, miscellaneous 12.40%, fish and their larvae 4.25%, whereas smaller sized fish consumed crustaceans, copepods, cladocerans and insect larvae. Chironomid larvae were also recorded from the gut contents of older fishes (Table 40; Fig. 54). From the examination of the food intake correlated at various size groups, it was observed that small sized fish consume smaller organisms like rotifers, diaptomus, copepods, insect eggs, larvae and pupae, whereas larger fishes of the same species consume large sized food items such as fish, crabs, prawns etc. Alikunhi (1952) recorded that carps of smaller size have distinct preference for zooplankton. Shyam Sunder (1985) indicated that larger fishes browsed more actively on the bottom of the lake while the smaller group consumed more zooplankton than other groups. This variation in the diet of smaller and older fishes of the same species have been recorded in some other fishes also, such as *Gasterosteus aculeatus* (Hynes, 1950), *Clarias senegalensis* (Thomas, 1966), *Cyprinus carpio* Specularis Linnaeus (Shyam Sunder et al. 1984).

The feeding rhythm in all the four species varied from season to season. The quality and quantity of the food consumed was influenced by physical factor like temperature and rainfall and biological factors gonads maturity and spawning. Almost a close similarity between the gut contents of all the species and the food items available in the aquatic environment was
noticed during various seasons of the year. Zooplanktons were maximum in guts during late summer and early rainy season when they were abundant and insects and their larvae were recorded maximum during late winter and early summer. Chironomid larvae in *Channa punctatus* were noted generally from December to April and oligochaete worms were found from July to September and forage fishes were noted from July onwards when they were found in larval stages or in small size. This indicates that fish feed on those organisms which are easily available in the environment. This view is supported by Haq *et al.* (1980), Arvindran (1980), Gupta (1981) and Sinha (1984). Shyam Sunder *et al.* (1984) also recorded that the feeding activity of *Cyprinus carpio* remained low from October to April due to various environmental and physiological factor such as the approach of winter season.

The relationship between feeding and spawning in different fishes deserve special mention. Qayyum and Qasim (1964a) reported that the intensive feeding in *Ophiocephalus punctatus* has been recorded after the spawning period from October to November and low feeding was noted during the spawning period i.e. in July and August. Rita Kumari and Nair (1979) attributed that the intensive feeding in *Noemacheilus triangularis* (Day) occurred in April and May i.e. after the spawning. Feeding was minimal from January to March which coincided with the spawning period of species. Shyam Sunder *et al.* (1984) noted that the fish *Cyprinus carpio* fed actively during the summer months i.e. from June to September while lower feeding was recorded in winter season i.e. from October to February and moderate
feeding was observed from March to May during the spawning months. According to them the low and moderate feeding activity from October to May was recorded due to various environmental and physiological factors such as approach of winter season, development of gonads and spawning season.

During the present study in Rasbora daniconius and Danio malabaricus two periods of intensive feeding were observed in a year. The first was from February to May, required for the building up of gonads, and second from September to November, this may be because of the post-spawning season of the fish. The minimum feeding activity has been recorded from June to mid September, these being the spawning months. The marked reduction in feeding is probably due to the peak maturity and spawning. Moderate feeding was recorded during December and January. In Ambassis ranga there was also two intensive feeding period first from April to June (preparatory period) and next in October and November i.e. during the post-spawning period, whereas the poor feeding was observed during the first and second spawning period i.e. in February and March, and from July to September. Moderate feeding was recorded during the pre-spawning period i.e. in December and January. In Channa punctatus the intensive feeding occurred first in June and July i.e. after first spawning and second from November to February (post-spawning period) and the lower feeding was recorded during the first and second spawning period i.e. from mid April to May and from August to October respectively (Tables 24-27; Figs. 27-30).
Abbas and Haq (1982) has recorded low feeding activity in *Channa punctatus* from April to June, which appears to be because of the high temperature and low oxygen concentration in derilict water in these months. In addition, this may also be correlated with the aestivation behaviour of the fish in summer.

As regards feeding intensity in present observation the intensive feeding during post-spawning period, i.e. after spawning, may be suggested due to the recruitments of the food expected to increase for the recovery of the fish weight from the spawning. During the pre-spawning period the intensive feeding presumably required for the building up of gonads to reach the final stage of maturity, whereas the minimum feeding during the spawning period is probably due to the peak maturity and spawning. It was observed that when the oocytes are fully mature and largest in size, the ovary becomes considerably large and dilated, it is probable that this increase in volume of the ovary exerts pressure on the alimentary canal, thereby preventing the passage of food through the alimentary canal. This may result in the low rate of feeding. Poor and moderate feeding in winter months i.e. from December to January may be attributed that fish may be less active at low temperature for hunting its prey.

Such a slackness in feeding prior to spawning associated with the development of the gonad has been the subject of discussion from earlier. Homans and Vladykov (1954) have observed that *Melanogrammus aegilinus* cease to take food during the spawning season, but feed voraciously after termination
of the spawning season, trying to recover the weight loss due to spawning. Karekar and Bal (1958) have correlated the feeding intensity with the maturity stages in *Polynemus indicus*. Qayyum and Qasim (1964 a,c) in *Barbus stigma* and *Callichthys bimaculatus*; Thomas (1969) in goat fishes; Bhatt (1968, 1970) in *Heteropneustes fossilis* and *Mystus seenghala* observed the same phenomenon as placed above. Malhotra (1967) in *Botia bimaculatus* has recorded a pre-spawning fasting. Later the intensive feeding during post-spawning period and poor feeding in spawning period were reported by different workers in different fishes, such as Unnitham (1978) in *Labeo gonius*, Abbas and Haq (1982) in *Channa punctatus*, Baloni and Tilak (1983) in *Schizothorax richardsoni* (Gray), Sinha (1984) in *Plectrosus canius* (Hamilton). Shyam Sunder (1985) in *Puntius conchonius* (Hamilton). In contrast to above view Joty and Malhotra (1975) found continuous voracious feeding in *Noemacheilus kashmirensis* during spawning season.
Table - 39  Percentage Composition of Annual Food Items of *Rasbora daniconius* and *Danio malabaricus*.

<table>
<thead>
<tr>
<th>Food Items</th>
<th><em>Rasbora daniconius</em></th>
<th><em>Danio malabaricus</em></th>
</tr>
</thead>
<tbody>
<tr>
<td>Phytoplankton</td>
<td>8.87</td>
<td>7.05</td>
</tr>
<tr>
<td>Higher aquatic plants</td>
<td>3.38</td>
<td>4.85</td>
</tr>
<tr>
<td>Zooplankton</td>
<td>35.12</td>
<td>36.00</td>
</tr>
<tr>
<td>Other crustaceans</td>
<td>8.75</td>
<td>10.83</td>
</tr>
<tr>
<td>Insects and their larvae</td>
<td>36.28</td>
<td>34.60</td>
</tr>
<tr>
<td>Fish, fish eggs and larvae</td>
<td>0.44</td>
<td>0.36</td>
</tr>
<tr>
<td>Chironomid larvae</td>
<td>0.41</td>
<td>0.40</td>
</tr>
<tr>
<td>Miscellaneous</td>
<td>6.75</td>
<td>5.91</td>
</tr>
</tbody>
</table>
FIG. 53. PERCENTAGE COMPOSITION OF ANNUAL FOOD ITEMS OF RASBORA DANICONIUS AND DANIO MALABARICUS.
Table - 40 Percentage Composition of Annual Food Items of *Ambasis ranga* and *Channa punctatus*.

<table>
<thead>
<tr>
<th>Food Items</th>
<th>Ambasis ranga</th>
<th>Channa punctatus</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phytoplankton</td>
<td>1.23</td>
<td>1.12</td>
</tr>
<tr>
<td>Higher aquatic plants</td>
<td>2.86</td>
<td>2.74</td>
</tr>
<tr>
<td>Zooplankton</td>
<td>12.60</td>
<td>15.77</td>
</tr>
<tr>
<td>Other crustaceans</td>
<td>24.27</td>
<td>25.52</td>
</tr>
<tr>
<td>Insects and their larvae</td>
<td>47.05</td>
<td>35.70</td>
</tr>
<tr>
<td>Fish, fish eggs and larvae</td>
<td>1.11</td>
<td>4.25</td>
</tr>
<tr>
<td>Chironomid larvae</td>
<td>0.92</td>
<td>2.50</td>
</tr>
<tr>
<td>Miscellaneous</td>
<td>9.96</td>
<td>12.40</td>
</tr>
</tbody>
</table>
FIG. 54. PERCENTAGE COMPOSITION OF ANNUAL FOOD ITEMS
OF AMBASIS RANGA AND CHANNA-PUNCTATUS.
Breeding:

From the foregoing account it has been observed that the sex ratio in different months in different species of larvivorous fishes, *Rasbora daniconius*, *Danio malabaricus*, *Ambassis ranga* and *Channa punctatus* showed dominance of one sex—the females. The highest values of female in all the above said species were recorded during their spawning season, at that time females become heavy due to the bulkier ovaries so that they get trapped easily, in addition to this the female become lethargic and hence get caught more easily than the males. Mallars and Fowler (1970) stated that in other larvivorous fish Gambusia affinis more females are encountered in the environment. Relative abundance of females in comparison to males during spawning season has also been reported for *Labeo fimbriatus* (Bhatnagar, 1972) and for Rasbora daniconius (Nagendran et al., 1981) whereas Tandon (1961) found that the male and female of *Selaroides leptolepis* may be counted in almost equal number. Same condition is also reported for *Macropodus cupanus* (Jacob and Nair, 1983). The minimum size at the first maturity for *Rasbora daniconius* is found to be between 7.5 and 8.4 cm, for *Danio malabaricus* 7.0 and 8.2 cm, for *Ambassis ranga* 7.0 and 7.8 cm and for *Channa punctatus* between 11.0 and 12.0 cm. These larvivorous fishes attain maturity within a year like other minor carps.

Alikunhi (1953), Qasim and Qayyum (1961), and Parameswaran et al. (1970) reported that the maturity cycle and spawning season in fishes depend on the prevailing climatic conditions of the region, mainly water temperature and rain fall. According to
Hickling (1962) and Alikunhi (1966) the carp is a seasonal spawner in temperate water and a perennial spawner in tropical water. Alikunhi (1966) stated that the fish may spawn two or three times in ponds, while in the wild condition it may spawn only once. Parmeswaran et al. (1970) reported that although carp breed throughout the year in India, generally there are two peaks of spawning season first from late January to March, when the water temperature goes up after the extreme winter months and second from late June to August when the water temperature become low after the summer months, with the beginning of monsoon.

Spawning periodicity in different larvivorous fishes were recorded by different workers. Jones (1940) stated that the larvivorous fish *Macropodus cupanus* breeds in January and February, and from September to November. Padmanabhan (1955) reported that this fish is a perennial spawner with a peak spawning during the monsoon months. Jacob and Nair (1983) indicate that *Macropodus cupanus* exhibits proteted spawning from April to September and then a shorter one in January and February.

Menon (1977) reported that the indigenous larvivorous fish *Alocheilus panchax* and *A. lineatus* are prolific perennial breeder with maximum spawning from June to August, and the breeding period of *A. blochi* a small fish, is said to be during January and February. Other genera *Oryzias melastigma* is also a perennial breeder with maximum spawning during monsoon months.
Joseph et al. (1979) noted that *Puntius ticto* has two active spawning seasons in the month of August and November. However, the species appear to spawn in most of the months of the year.

Muddanna (1971) and Nagendran et al. (1981) stated that the cyprinid forage fish *Rasbora daniconius* breed during the monsoon seasons from July to August. Nagendran and Katre (1977) and Nagendran et al. (1981) observed variations in the size of ova within each ovary of *Rasbora daniconius*. Perhaps this indicates that the fish spawns more than once during a breeding season. Thakre and Bapat (1980) studied the maturation and spawning of *Rasbora daniconius* and noted that the spawning season extend from early June to late October. They observed in ova diameter distribution a wide range of mature and immature ova in a ovary indicating a prolonged breeding season of the species (Prabhu, 1956). Raizada (1971), Pathak (1986) reported that the spawning season of *Rasbora daniconius* extends for a long period from April to August.

During the present investigation the ova diameter frequency in different months and collected gravid specimens have given important indications on the spawning of larvivorous fishes *Rasbora daniconius*, *Danio malabaricus*, *Ambassis ranga* and *Channa punctatus*. Presence of gravid ovaries in most of the collected specimen from April to September and maximum number of mature ova in these months concluded that the spawning season in *Rasbora daniconius* extended from April to September and the spawning occurred from June to September which exhibited
a prolonged spawning periodicity in a single spawning season. *Danio malabaricus* showed similar maturing condition like *Rasbora daniconius* except that the spawning period in this fish extends up to August and spawning takes place during June to August (Tables 32, 33; Figs. 35, 36). *Ambassis ranga* spawns twice a year. Presence of gravid females in collected specimen and the presence of mature ova during February and March, and from July to September indicate that there were two spawning seasons, first from February to March and second from July to September and presence of spent specimen in the subsequent months showed that fish spawn twice a year. Presence of immature ova from October to January indicates that spawning did not occur during these months (Table 34; Fig. 37).

In some other fishes like *Puntius sarana*, Qasim and Qayyum (1961) and Sinha (1975) reported that ovary of this fish contain only one batch of maturing ova, clearly demarcated from immature stock indicating that the spawning is strictly periodic, restricted to a definite short period and each individual spawns only once in a year. Similar conditions have also been reported in *Cirrhinus mrigala* by Qasim and Qayyum (1961), in *Catla catla* by Natarajan and Jhingran (1963), in *Notopterus notopterus* by Parameswaran and Sinha (1966), in *Labeo gonius* by Parameswaran et al. (1974), in *Mystus gilio* by Kaliyamurthy (1981-82). On the other hand Qasim and Qayyum (1961) in *Barbus puntitora* observed several batches of eggs maturing simultaneously indicate that the species may spawn several times during a prolonged breeding season. Varghese (1961) noted that the
presence of successive batches of developing eggs in mature ovaries of *Coilia horaneensis* suggested repeated spawning by an individual fish during protracted breeding season. Similar conditions were also observed by Somvanshi (1980) in *Garra mullya* and prolonged breeding season extends from June to November. He noted that the number of smaller ova decreased in proportion to the number of bigger ones as the breeding season increased, indicating that the fish is a fractional spawner having a series of spawning bursts during the breeding season. Recently similar spawning behaviour was also recorded by Babikar (1986) in *Tilapia nilotica*, Hyslop (1987) in *Hemichromis bimaculatus* and Khan (1990) in *Notopterus notopterus*.

In *Channa punctatus* spawning period showed controversy in different part of the country. Raj (1916) at Madras reported that the *Ophiocephalus punctatus* breed twice a year first in January–February and second time in July–August. Mookerjee (1945a) in Bengal noted that the breeding season in Indian carps seems to last from June to August. Husaini and Rahimullah (1946) observed that *Q. punctatus* breed throughout the year in Hyderabad. Qayyum and Qasim (1964a) stated that the breeding season of *Q. punctatus* in Aligarh lasts from June to October. They noted that during breeding season ripe ovaries of each female contain more than one group of ova. This indicates that each individual may spawn more than once during the breeding season. The continued occurrence of ripening stage exhibits the predominant spawning season of the fish, suggesting a repeated spawning of each individual, Parmeswaran
and Murugesan (1976) reported that in *Channa punctatus* and *C. orientalis* spawning season extend from April to August with peak spawning in June and July, whereas *C. marulius* and *C. striatus* breed throughout the year in Karnataka except the winter months of December and January.

During the present investigation, the percentage frequency of ova diameter have indicated that the ovaries of *C. punctatus* contain two well defined groups of mature ova, first from April to May and then from July to October. Presence of large number of ripe fish during these months concluded that there were two spawning seasons in *C. punctatus* and the presence of spent ovaries, during subsequent months, indicate that this fish spawns twice a year first in pre-monsoon and second time in post-monsoon months, and total absence of mature ova from December to March indicate that fishes have not spawned during these months (Table 35; Fig. 38).

Alikunhi (1957) reported that in South India all the four species of murrels — *C. marulius*, *C. striatus*, *C. punctatus* and *C. orientalis* breed throughout the year, whereas in northern India these species breed during June to August (Qasim and Qayyum, 1961). According to Qasim and Qayyum in South India the moderate climate and abundant rainfall provide favourable conditions for breeding of murrels throughout the year. But in northern India such conditions are prevalent only in the monsoon and post-monsoon months.
Maturation of Gonads and Spawning in Relation to the Environment:

During the present investigation it was observed that generally in all the four larvivorous species the maturity of gonads advanced successively from April to September and spawning occurs from monsoon to post-monsoon i.e. from June to October. The maturity of gonads was influenced by some environmental factors such as light, temperature, rain-fall, secchi transparency, pH, dissolved oxygen and total alkalinity.

Hazard and Eddy (1951) reported that both the light and the temperature are considered as important factors for controlling the maturation of gonads in fishes. Variation in duration of light and temperature may influence the rate of gonadal development. Harrington (1959) in Fundulus confluentus and Yoshioka (1963) in Oryzias latipes reported that the early maturation and spawning of these fishes were influenced as a result of enhanced photoperiodic regime. In contrast to these observations Shiraishi and Fukuda (1966) stated that Salvelinus fontinalis, Salmo gauderii and Oncorhynchus rhodurus in northern latitudes attain early maturity under short light period and delayed maturation under long light period. Varghese (1968) attributed that the Indian Cirrhinus reba attain early maturity when subjected to artificial day length longer than natural day even at the low temperature of winter months. de Valming (1972) reported that photoperiod and temperature are important factors regulating the gonad development in Cyprinid fishes. Jhingran (1988) suggested that the requirements of light for activation
of reproductive cycle vary from species to species and from place to place, as the day length and temperature differ depending on the latitude of the place concerned.

Chaudhuri (1960a), Ahsan (1966) and Ibrahim et al. (1968) studied the role of environmental temperature on the sexual maturation and breeding of fish. According to them there are optimum temperature range for induced breeding of cultivated fishes, below or above this limit fish will not reproduce.

Morosova (1957) stated that the low temperature prevents the sexual maturity and spawning in Perca fluviatilis. Harrington (1959) in Fundulus confluentus observed that the low temperature accelerates the earlier phase of maturity but suppresses the later phases. Cridland (1962) noted that the low temperature delays the sexual maturity in Tilapia species. Ahsan (1966) reported that the low temperature retards the rate of post-spawning regression in Fundulus. Further he stated that in number of fishes warm temperature plays a primary role to stimulate the maturation of gonads and increases the spermiation. The influence of temperature on the maturity of gonads has also been pointed out by Raizada (1971), Bais (1977), Saxena (1980), Peter (1981), Saini (1984) and Pathak (1986).

Sharma et al. (1974) noted that the common carp Cyprinus carpio in Anjana fish farm, West Bengal, starts breeding from December and continued till April, at the temperature ranging from 18°C - 25°C. Shrestha and Khanna (1979) reported that during breeding season of carp Schizothorax plagiostomus water
temperature ranged from 20.6°C to 21.5°C and pH 6.5 to 7.2. Baloni and Tilak (1983) reported that in Garhwal Himalaya the breeding season of carp *Schizothorax richardsonii* falls from July to October, during this period mean water temperature ranged between 18.5°C and 22.5°C and pH 7.1 to 7.5.

Present observation investigates that the increasing of water temperature accelerates the maturity of gonads. It increased from February to April and then show minor fluctuation from April to September as the maturation proceeds. pH showed decreasing trend with the advanced maturity stages of gonads, it decreased from April 9.0 to September 7.8. pH was minimum in July at the peak maturity of gonads. High value of secchi transparency is observed to accelerate the spawning phases of maturity. Maturation of gonads increased from June to September with the increasing of secchi transparency. Dissolved oxygen showed wide range of fluctuation with the gonad maturation from April to October. High value of dissolved oxygen were recorded during the pre-spawning season with peak in January and low value in spawning season. High value of total alkalinity coincided with the increasing tendency of maturation of gonads in June and July (Figs. 31-34).

In so far as the onset of maturation and synchronization of spawning are concerned, although considerable literature is available to show that endogenous factors are most important (Liley, 1969), in tropical waters, as stated by Qasim (1973) and Peter (1981), climatic changes associated with the monsoon rain may also stimulate spawning.
Khan (1945), Mookerji (1945a), Khanna (1958) and Ray et al. (1969) stated that the factors responsible for the breeding of major carps in river, pond, lake have been considered as fresh rain water, flood water, water current, shallow inundated grounds and physico-chemical conditions of water such as turbidity temperature, pH, dissolved oxygen contents, carbonate, bicarbonate, chloride etc. as an important ecological inducements for natural spawning of Indian major carps. Alikunhi and Rao (1951), Alikunhi (1956) noted that the breeding requirements of minor carps are similar to those of the major carps.

Selvaraj et al. (1971), Karamchandani et al. (1979) and Nautiyal (1984) attributed that the fresh rain water, flooded condition and lowering of atmospheric and water temperature are the primary factors responsible for providing the stimulus for spawning. During the present investigation it was observed that the larvivorous fishes spawn in shallow, confined and flooded rain water having abundance macrovegetation. Rasbora daniconius and Danio malabaricus were spawned at the first flood of season, whereas Ambassis ranga and Channa punctatus spawn in subsequent floods. In addition to this A. ranga was also spawned in February-March and C. punctatus in May-June at the suitable environmental conditions.

Ganapati and Chacko (1954) observed that the flooding in the early phase of south-west monsoon is necessary and fish do not spawn if the rains are delayed. They further stated that the rise in the level of water, which may be caused
artificially or naturally, is responsible to bring about the spawning. Majority of the workers reported that generally spawning occur in still water.

Chaudhuri (1960a) noted that the Indian major carps breed within the range of temperature 24°C to 31°C, beyond this limit, as the temperature rises, fish do not spawn. David (1953) reported that water temperature ranged from 22°C - 28°C in cold months highly influenced the breeding of Mahandi mahseer. Dubey and Tuli (1961) observed that the water temperature on the breeding ground of major carp in Madhya Pradesh ranged between 26°C-33°C. Alikunhi et al. (1963b) noted that the Chinese grass and silver carp successively bred at the temperature between 28.2°C to 34°C, whereas Chaudhury et al. (1966) found that breeding was very poor above 30°C. Desai (1973) considered the range of water temperature between 19.9°C-28.4°C to be the optimum temperature for breeding of Narmada mahseer Tor tor. Benerji (1974) observed that the fish C. punctatus was spawn below the temperature 29°C in laboratory conditions. Karamchandani et al. (1979) recorded that water temperature on the breeding day was 27.7°C for major carps in dry bundh of Uttar Pradesh. Nautiyal (1984) observed the temperature range from 21°C-25°C during the spawning of Garhwal Himalayan mahseer. During the present investigation the water temperature at the spawning of larvivorous fishes was observed from 23.5°C to 26.8°C.
In Japan Inaba *et al.* (1957) noted that the Chinese grass and silver carp are observed to breed in river tone at the temperature between 17.6°C and 22°C. In South Africa Cambray (1984) reported the fish *B. anoplus* spawn after the period of steady rain fall in the water of Lake leHoux, the first spawning occurred when water temperature were near about 20°C and the second at 22°C.

Ganapati *et al.* (1951) observed that the spawning of carp in river Cauvery occurred almost in summer condition owing to failure of monsoon rain and absence of floods with clear water, they further stated that the dissolved oxygen contents and the percentage of oxygen saturation in water were not higher and other physico-chemical factors like, pH, free carbon-dioxide, carbonate and bicarbonate did not show any significant variation during the spawning. They conclude that only the shallow spawning ground with shallow depth of water appear to be the most important factor for inducing spawning. Saha *et al.* (1957) reported that the spawning in Indian major carp in breeding bundh West Bengal was influenced by cloudy days accompanied by rains and neutral water with low alkalinity, whereas temperature and dissolved oxygen did not influence the spawning. Khanna (1958) has noted that the flood water with water current of moderate intensity are prerequisite for spawning of major carp at the fish farm in Panjab. High dissolved oxygen and increased pH value are not required for fish breeding. He has also noticed that the chemical properties of water does not show any appreciable change during the fish breeding. Dubey and Tuli (1961)
noted that the carp breed during the south-west monsoon in Madhya Pradesh, at the spawning time, pH recorded between 7.2 and 8.2 and oxygen contents ranging from 4.2 to 6.8 ppm and the fish spawn in standing waters with wave action. Selvaraj et al. (1971) stated that the *Labro boggut* in Panna, Madhya Pradesh spawn after the onset of monsoon, during this period turbidity, free carbon-dioxide and dissolved oxygen contents of water increased, whereas water temperature, pH, alkalinity and chloride value decreased. Karamchandani et al. (1979) recorded physico-chemical condition of water at the spawning time of major carps in dry bundh, Uttar Pradesh as pH 7.6, dissolved oxygen 5.6 ppm - 7.6 ppm, total alkalinity 28 ppm - 32 ppm and free carbon-dioxide 12 ppm. During the present investigation the physico-chemical condition of lake water at spawning time of larvivorous fish recorded as water temperature 23.5°C-26.8°C, pH 7.6-8.0, secchi transparency 20.5 cm - 42.3 cm and dissolved oxygen 6.4 mg/l - 8.2 mg/l.

From the present observation it is concluded that the low temperature and low pH were conducive to the natural spawning of larvivorous fish. This is also supported by Khan (1945), Ganapati and Chacko (1954), Saha et al. (1957), Khanna (1958), Selvaraj et al. (1971) and Karamchandani et al. (1979) and the increased value of dissolved oxygen and secchi transparency provide a congenial atmosphere to these fishes. Increased value of dissolved oxygen during the spawning was recorded by Selvaraj et al. (1971) and Nautiyal (1984). In
contrast to above view Ganapati et al. (1951) and Khamma (1958) suggest that the lower value of dissolved oxygen contents are required for the breeding of fishes. Slightly decreased value of chloride and total alkalinity were obtained during the spawning time than before the spawning suggest that the fluctuation in alkalinity and chloride contents did not show specific influence on the spawning of these fishes.