A. PHYTOSOCIOLOGY:

a. QUALITATIVE CHARACTERS:

i. Floristic composition:

In the Laisoi pat lake 43 macrophytic plant species were recorded during the study period. The plants were grouped into 5 different categories viz., submerged (3 species), rooted submerged (4 species), rooted with floating leaves (5 species), free floating (6 species) and emergent (25 species). The present findings are in conformity with the findings by many authors viz., Kaul et al., (1978) in the water bodies of Kashmir where out of 43 species, 28 were found belonging to the emergent, 7 in the rooted with floating leaves and 8 in the submerged groups, Shah and Abbas (1979) in river Ganga at Bhagalpur with 22 species as emergent species, 4 submerged species and 2 floating species. Kumar and Pandit (2005) in the Hokersar Lake in Kashmir, (30 species emergent, 7 rooted floating species, 2 free floating, 7 submerged species). Devi, L. G. and Sharma (2007) recorded 36 macrophytic plant species in Awangsoipat lake, Manipur (8 submerged species, 4 rooted with floating
leaved species, 4 free floating and 20 emergent species). Devi, Th. M. and Sharma (2007) in Yenapat lake, Manipur recorded 26 species (4 species submerged, 2 species rooted with floating leaves, 3 free floating and 17 emergent species. Devi, S. U. (2008) recorded 40 species in Oksoipat lake, Manipur (7 submerged species, 7 rooted with floating leaves, 4 free floating, 13 emergent species and 9 semi-terrestrial species). Comparatively higher number of species was recorded in Loktak lake, Manipur (a Ramsar site) by Devi, N. B. (1993) where she reported 86 species of which 73 species were emergent which were recorded in the phumdi zone (Floating mats) and 13 species were recorded in the non-phumdi (Clear water) zone (6 submerged species, 4 free floating and 3 rooted with floating leaved species). Devi, O. I. (1993) in Waithou lake reported 35 species of which 18 were emergent, 5 free floating, 6 rooted with free floating leaves and 6 submerged species. In Utrapat lake, Devi, K. I. (1998) recorded 26 species comprising 11 emergent species, 6 submerged, 3 species each of rooted with floating leaves and free floating species.

In the freshwater ponds of Canchipur Devi, Ch. U. (2000) recorded 50 macrophytic species of which 8 species belonged to submerged group, 6 rooted floating leaved species, 4 free floating species and 32 emergent species. Devi, Kh. U. (2002) in Poiroupat lake reported 30 macrophytic species comprising 3 submerged species, 5 rooted with floating leaved species, 6 free floating species and 16 submerged species. Devi, N. P. and Sharma (2007) in Hidenkompat lake, Manipur reported 20 emergent species, 3 rooted with
floating leaved species, 5 free floating species and 4 submerged species. In the present study, the abundance of emergent species indicates the eutrophic nature of the lake.

The macrophytic plant communities in the lake under present study are found occurring in intermixed mats. Hence, it may be inferred that, there is no clearcut zonation of floating, emergent and submerged species and hence all the communities exhibit a heterogenous composition of mixed stand of aquatic vegetation. In Kolleru lake, Seshavatharam et al., (1982) reported intermixed mats of macrophytic species of emergent, submerged and free floating groups. Swindale and Curtis (1957) and Schmid (1965) also reported heterogenous composition in the submerged vegetations of U.S.A. Crowder et al., (1977) also reported heterogenous composition of submerged vegetation in lake Opinicon, Canada.

The variation in the distribution of the macrophytes in the different groups in the present study might have been influenced by a number of factors mainly the physico-chemical characteristics of water as well as morphometric and bathymetric characters of the lake. Influence of hydrological factors and the nature of the substratum on the growth of the macrophytes were also reported earlier by Sculthrote (1967) and Gopal et al. (1978).

ii. Life form:

During the study period, the 43 macrophytic plant species were found belonging to 6 different life forms viz., Therophytes with 15 species
constituting the maximum species percentage of 34.88 %, Errant Vascular Hydrophytes with 11 species (25.58 %), Geophytes with 9 species (20.93 %), Hemicryptophytes with 6 species (13.95 %), Chamaephytes and Lianas with 1 species (2.33 %) each. Raunkiaer’s classification (1934) of 5 life forms have been expanded into 23 major life forms. The life form spectra of the different regions of India were compiled by Meher-Homji (1981) where the author laid emphasis on the climatic characteristics like the annual rainfall, length of the dry season and mean temperature of the coldest month of the year. Puri et al. (1990) differentiated 10 types of phytoclimates for the Indian vegetations based on Raunkiaer’s life form classes. Occurrence of maximum number of species in Therophytes have also been recorded earlier from a number of lakes and wetlands in Manipur (Table 9) by several authors.

iii. Biological spectrum:

In the present study, the highest percentage to the biological spectrum was contributed by Therophytes (34.88 %) which was approximately 2.70 times the percentage value of Therophytes (13 %) in the ‘Normal spectrum’ of Raunkiaer. It was followed by Errant Vascular Hydrophytes. Based on the various life form classes, the Laisoipat lake under the present study may be assigned to the “Thero-Erant Vascular Hydrophytic” types of Phytoclimate. The predominance of Therophytes in the present study is indicative of a warm climate which is in conformity with the bioclimatic diagram of Dansereau (1957). Similar types of phytoclimate have also been reported earlier in a

iv. Growth form:

In the present study, 13 growth form categories have been reported in Laisoipat lake. Similar number of growth forms (13 growth forms) were recorded by Devi, O. I. (1993) in Waithou lake, Manipur and Bebika (2001) in Sanapat Lake, Manipur. Lower number of growth form categories were reported by many authors viz., Devi, N. B. (1993) in Loktak lake, Manipur with

Higher number of growth forms i.e., 14 forms were recorded by Devi, Ch. U. (2000) in the freshwater ecosystems of Canchipur, Devi, S. U. (2008) in Oksoipat lake, Manipur and Singh, K. K. (2010) in Kharungpat lake, Manipur. The highest number of growth forms (16 forms) were recorded from Ikop lake, Manipur by Devi, Ch. N. (2002).

b. QUANTITATIVE CHARACTERS:

i. Frequency:

In the present study, the main dominant species recorded were *Alternanthera philoxeroides*, *Atylosia scarabaeoides*, *Echinochloa stagnina*, *Eichhornia crassipes*, *Pennisetum glaucum*, *Salvinia cucullata* etc. The maximum values of frequency observed in *Eichhornia crassipes* was 30 % to 100 % and 10 % to 100 % in *Salvinia cucullata*. The maximum frequency value of *Eichhornia crassipes* (100%) was observed during June to November in different study sites. For *Salvinia cucullata* the maximum frequency value (100%) was observed during January to July in the different study sites. The maximum frequency value was successively followed by *Potamogeton crispus* (5 – 95 %), *Alternanthera philoxeroides* (10 – 90 %), *Echinochloa stagnina* (5 – 85 %), *Kyllinga triceps* (5 – 85 %), *Azolla pinnata* (10 – 75 %), *Pennisetum glaucum* (10 – 75 %), *Enhydra fluctuans* (5–65 %), *Brachiaria mutica* (5 – 60 %),
Hydrilla verticillata (5 – 60 %). The minimum frequency value of 5 % was shown by Diplazium porrectum, Nymphaea pubescence and Riccia natans.

The present findings are in conformity with the findings reported by Devi, N. B. (1993) in Loktak lake, Manipur for Salvinia cucullata (33.20 – 100.00 %), Potamogeton crispus (6.67 – 100.00 %) and Echinochloa stagnina (66.67 – 100.00 %). Devi, K. I. (1998) in Utrapat lake, Manipur also reported comparable ranges in Hydrilla verticillata (13.33 – 80.00 %), Jussiaea repens (20.00 – 60.00 %), while Devi, Ch. N. (2002) in Ikop lake reported comparable values in Alternanthera philoxeroides (33.33 – 66.67 %), Azolla pinnata (13.33 – 46.67 %), Enhydra fluctuans (26.67 – 60.00 %) and Salvinia natans (13.33 – 46.67 %). Devi S.U. (2008) reported comparable values of frequency in Alternanthera philoxeroides (3.50 – 70.00 %) and Hydrilla verticillata (35.00 – 65.00 %) from Oksoipat lake, Manipur.

Higher values as compared to the present findings were also reported by Devi Ch. U. (2000) for Azolla pinnata (6.66 – 100.00 %), Hydrilla verticillata (6.66 – 100.00 %) and Potamogeton crispus (6.66 – 100.00 %) in the freshwater ecosystems of Canchipur, Manipur.

The macrophytes showing minimum frequency were occurring only once or twice in the entire period of study. The maximum values of frequency in the main dominant specie were observed during the rainy season which is attributed to the warm temperature and humid climate of the season. Hogeweg and Brenkert (1969) also opined that the warm temperature during rainy season
in the tropics favours the rich growth of the aquatic macrophytes. Rai and Munshi (1982) also viewed the rainy season to be the most favourable season for the germination of the buried seeds of the perennial emergents (*Cyperus* sp.) and mud growing species such as *Enhydra, Ipomoea* etc. Shah and Abbas (1979) reported that monsoon period has been found to be most favourable for the optimum growth of submerged hydrophytes whereas winter season has been found most favourable for the free floating forms like *Salvinia cucullata*.

The ranges of frequency in the present findings are in conformity with the findings reported by Devi, Ch. B. (2001) in Sanapat lake, Manipur, for *Eichhornia crassipes* (40.00 – 93.33 %). Shah and Abbas (1979) also reported maximum frequency for *Hydrilla verticillata* (80.00 %), and *Eichhornia crassipes* (80.00 %) in the river Ganga. Ambasht (1970) and Misra (1989) also reported higher percentages for the macrophytes like *Azolla* (100.00 %), *Trapa, Utricularia* and *Spirodella* (65.00 – 80.00 %) and *Hydrilla* (55.00 %) from the freshwater ponds of Banaras Hindu University, Varanasi. The present findings are found to be higher when compared with the findings of Devi, K. I. (1998) in Utrapat lake, Manipur for *Eichhornia crassipes* (13.33 – 26.67 %), *Azolla pinnata* (13.33 – 40.00 %), *Echinochloa stagnina* (13.33 – 26.67 %) and *Enhydra fluctuans* (20.00 – 26.67 %), Devi, S. U. (2008) in Oksoipat lake for *Eichhornia crassipes* (55.00 %), *Potamogeton crispus* (30.00 %) and *Salvinia cucullata* (45.00 – 65.00 %).
The value shown by *Nymphoides cristatum* (5.00 – 30.00 %) is higher than the findings of Devi, Ch. N. (2002) in Ikop lake, Manipur for *Nymphoides cristatum* (6.66 %). The present value is significantly lower when compared with findings reported by Devi, K. I. (1998) in Uttrapat lake, Manipur (73.33 %) and Devi, S. U. (2008) in Oksoipat lake, Manipur (20.00 – 65.00 %). The present values of frequency for *Nymphaea pubescence* (5.00 %) is found to be much lower when compared with the values reported by Devi, Ch. B. (2001) in Sanapat lake, Manipur (20.00 – 80 %).

**ii. Density:**

During the study period the maximum values of density were recorded in *Salvinia cucullata* with values ranging from 6.30 – 1004.00 plants m\(^{-2}\). The values of density recorded in *Salvinia cucullata* was maximum in all the different study sites which was followed by *Potamogeton crispus* (0.80 – 608.80 plants m\(^{-2}\)), *Hydrilla verticillata* (1.60 – 457.00 plants m\(^{-2}\)), *Potamogeton natans* (2.40 – 197.60 plants m\(^{-2}\)), *Kyllinga triceps* (1.60 – 183.20 plants m\(^{-2}\)), *Pennisetum glaucum* (1.60 – 157.00 plants m\(^{-2}\)). The minimum value was exhibited by *Nymphaea pubescence* (0.80 plants m\(^{-2}\)).

The maximum value of density for *Salvinia cucullata* is found much higher than the values reported by a number of authors viz., Devi, Ch. U. (2000) in the fresh water ecosystems of Canchipur (190.40 plants m\(^{-2}\)), Devi, Ch. B. (2001) in Sanapat lake, Manipur (2.08 – 61.78 plats m\(^{-2}\)), Devi, Ch. N. (2002) in the Ikop lake, Manipur (0.96 – 116.16 plants m\(^{-2}\)), Devi, Kh. U. (2002)
in Poiroupat lake, Manipur (1.60 – 36.80 plants m\(^{-2}\)) and Devi, S. U. (2008) in Oksoipat lake, Manipur (14.40 – 152.96 plants m\(^{-2}\)).

The present findings for *Echinochloa stagnina* (2.40 – 85.60 plants m\(^{-2}\)) are found to be comparable with the values reported by Handoo and Kaul (1982) at Hoakarsar (48.00 plants m\(^{-2}\)), Shalbagh (137.00 plants m\(^{-2}\)) and Kranchu (116.00 plants m\(^{-2}\)) in Kashmir but they are lower than the values reported by Devi, N. B. (1993) in Loktak lake, Manipur (108 – 618 plants m\(^{-2}\)) and Devi, S. U. (2008) in Oksoipat lake, Manipur (370.40 plants m\(^{-2}\)). The present findings for *Ludwigia adscendens* (1.60 – 46.40 plants m\(^{-2}\)) is comparable to the findings made by Devi, Ch. B. (2001) in Sanapat lake, Manipur (2.08 – 44.80 plants m\(^{-2}\)) and Devi, Kh. U. (2002) in Ikop lake, Manipur (11.20 – 38.40 m\(^{-2}\)).

The present findings for *Hydrilla verticillata* (1.60 – 457.00 plants m\(^{-2}\)) are higher than the values reported by Devi, O. I. (1993) in Waithou lake, Manipur (0.03 – 35.47 plants m\(^{-2}\)). Devi, K. I. (1998) in Utrapat lake (16.00 – 73.12 plants m\(^{-2}\)), Devi, Ch. N. (2002) in Ikop lake, Manipur (0.96 – 180.16 plants m\(^{-2}\)), Devi, Kh. U. (2002) in Poiroupat lake, Manipur (8.00 – 40.00 plants m\(^{-2}\)) and Devi, S. U. (2008) in Oksoipat lake, Manipur (60.00 – 158.40 plants m\(^{-2}\)). Shah and Abbas (1979) had earlier reported density of 19.00 – 22.00 plants m\(^{-2}\) for *Hydrilla verticillata* in the mid rainy season and 8.50 – 10.80 plants m\(^{-2}\) for *Eichhornia crassipes* during January – February and 8.89 plants m\(^{-2}\) for *Ceratophyllum demersum* during summer. The present findings
of *Ceratophyllum demersum* (1.60 – 28.00 plants m\(^{-2}\)) are lower than the values reported by Devi, K. I. (1998) in Utrapat lake, Manipur (48.28 – 154.72 plants m\(^{-2}\)), Devi, S. U. (2008) in Oksoipat lake, Manipur (264 – plants m\(^{-2}\)) but they are higher than the values reported by Devi, O. I. (1993) in Waithou lake, Manipur (0.04 – 0.65 plants m\(^{-2}\)). The present values observed for *Azolla pinnata* (4.00 – 152.00 plants m\(^{-2}\)) are lower than the values reported earlier by Ambasht (1970) and Misra (1989) in the freshwater ponds of Varanasi (3445.00 plants m\(^{-2}\)). The density values for *Alternanthera philoxeroides* and *Eichhornia crassipes* observed in the present study are found higher than those reported by a number of authors viz., Devi, Ch. N. (2002) in Ikop lake, Manipur for *Alternanthera philoxeroides* (0.96 – 22.40 plants m\(^{-2}\)) and *Eichhornia crassipes* (0.96 – 36.16 plants m\(^{-2}\), Devi, S.U. (2008) in Oksoipat lake, Manipur (*Alternanthera philoxeroides* 11.20 – 319.20 plants m\(^{-2}\), *Eichhornia crassipes* 3.20 – 28.80 plants m\(^{-2}\), Devi, K.I. (1998) in Utrapat lake, Manipur (*Alternanthera philoxeroides* 6.48 – 29.37 plants m\(^{-2}\), *Eichhornia crassipes* 4.34 – 16.85 plants m\(^{-2}\)).

### iii. Abundance:

In the present study, the maximum values for abundance were shown by *Salvinia cucullata* (48.00 – 1004.00 plants m\(^{-2}\)) followed by *Hydrilla verticillata* (16.00 – 915.20 plants m\(^{-2}\), *Potamogeton crispus* (16.00 – 716.20 plants m\(^{-2}\), *Azolla pinnata* (16.00 – 608.00 plant m\(^{-2}\), *Pennisetum glaucum* (16.00 – 406.40 plants m\(^{-2}\), *Potamogeton natans* (32.00 – 395.00 plants m\(^{-2}\),
*Ceratophyllum demersum* (16.00 – 280.00 plants m$^{-2}$), *Kyllinga triceps* (16.00 – 242.46 plants m$^{-2}$). The minimum value (16.00 plants m$^{-2}$) was shown by *Nymphaea pubescence*.

The highest values for *Salvinia cucullata* and *Hydrilla verticillata* in the present study are higher than the values reported by a number of authors viz., Devi, N. B. (1993) and Sharma, B. M. and Devi, N. B. (2002) in the non-phumdi sites of Loktak lake, Manipur for *Salvinia cucullata* (16.00 – 149.28 plants m$^{-2}$) and *Hydrilla verticillata* (19.00 – 98.08 plants m$^{-2}$), Devi, K. I. (1998) in Utrapat lake, Manipur for *Hydrilla verticillata* (16.00 – 73.12 plants m$^{-2}$), Devi, Kh. U. (2002) in Poiroupat lake, Manipur for *Hydrilla verticillata* (9.60 – 80.00 plants m$^{-2}$), Devi, S. U. (2008) in Oksoipat lake, Manipur for *Hydrilla verticillata* (129.44 – 363.43 plants m$^{-2}$), *Salvinia cucullata* (57.60 – 230.67 plants m$^{-2}$). High values of abundance were also reported for phumdi species of Loktak lake, Manipur viz., *Cryptococcus* (136.00 – 992.00 plants m$^{-2}$), *Echinochloa* (168.00 – 618.72 plant m$^{-2}$) by Devi, N. B. (1993) and Sharma, B. M. and Devi, N. B. (2002).

The present findings are highly comparable to the values reported by Devi, Ch. N. (2002) in Ikop lake, Manipur for *Azolla pinnata* (16 – 633.60 plants m$^{-2}$) and *Ceratophyllum demersum* (16 – 288 plants m$^{-2}$). The present values observed in the present study are found higher than those reported for *Azolla* (215.30 plants m$^{-2}$) by Ambasht (1970) and Misra (1989) in the freshwater ponds of Varanasi whereas very low values (1.00 – 6.50 plants m$^{-2}$)
were also recorded in species like *Trapa, Utricularia, Vallisneria* and *Potamogeton*. The values from the present investigation for *Ceratophyllum demersum* is found to be lower than the values observed by Devi, S. U. (2008) in Oksoipat lake, Manipur (190.72 – 422.67 plants m$^{-2}$) but higher than the values observed by Devi, K. I. (1998) in Utrapat lake, Manipur (48.96 – 154.70 plants m$^{-2}$) and Devi, Kh.U. (2002) in Poiroupat lake, Manipur (32.00 – 96.00 plants m$^{-2}$).

The present findings have been found to be in conformity with the findings of Devi, K. I. (1998) in Utrapat lake, Manipur where the values of abundance ranged from 40.00 – 54.40 plants m$^{-2}$ for *Atylosia scarabaeoides*, *Enhydra fluctuans* (16.00 – 60.00 plants m$^{-2}$), *Euryale ferox* (16.00 – 29.28 plants m$^{-2}$).

**iv. Abundance/Frequency (A/F) Ratio:**

According to Curtis (1959) if the A/F ratios of the different species are less than 0.025, the species are found distributed homogeneously, while the ratios within 0.025 – 0.05 indicate random distribution. When the ratios are higher than 0.05 the same indicates the aggregate nature of distribution of the species.

In the present study, the abundance/frequency ratios of different species varied from 0.01 – 1.75. The maximum values of abundance/frequency ratio were exhibited by *Ceratophyllum demersum* (0.07 – 1.75), *Kyllinga triceps* (0.03 – 1.60), *Chara zeylanica* (0.15 – 1.56), *Utricularia aurea* (0.05 – 1.55).
Azolla pinnata (0.03 – 1.52), Pennisetum glaucum (0.06 – 1.51), Fagopyrum dibotrys (0.05 – 1.40), Hydrilla verticillata (0.05 – 1.39), Salvinia cucullata (0.01 – 1.17), Utricularia exoleta (0.05 – 1.15), Carex cruciata (0.07 – 1.00), respectively.

A large number of interacting physico-chemical characters of water may be attributed to the successful growth and distribution of important macrophytic species which are distributed regularly throughout the year. Of the multiple factors affecting the distribution of submerged macrophytes, water depth (Swindale and Curtis, 1957, Spence, 1967) and turbidity (Ruttner, 1963, Sculthrope, 1967) have been given main importance. In the present study maximum abundance/frequency ratio was shown by Ceratophyllum demersum. Wilson (1941) and Vander Valk and Bliss (1971) could observe that Ceratophyllum demersum could tolerate very low light intensities. Similar observations were also made by Kaul et al. (1978) in the macrophytes of the lakes in Kashmir.

In the present study, the different species were found distributed generally in the aggregate manner since the abundance/frequency ratios of the various macrophytes in the lake exceeds 0.05 (Curtis, 1959). The aggregate nature of the distribution of the species is found to be comparable to the nature of distribution reported earlier in the various freshwater ecosystems of Manipur viz., ponds and streams of Canchipur, Manipur (Devi, L. G., 1993, Devi, Ch. U., 2000), Loktak lake, Manipur (Devi, N. B., 1993), Waithou lake, Manipur

**v. Importance Value Index (IVI):**

In the present investigation, the maximum values of IVI were exhibited by *Salvinia cucullata* (10.62 – 151.93) followed by *Potamogeton crispus* (3.89 – 105.42), *Hydrlila verticillata* (3.93 – 91.73), *Kyllinga triceps* (4.74 – 77.21), *Pennisetum glaucum* (3.70 – 73.51), *Eichhornia crassipes* (11.27 – 55.68), *Azolla pinnata* (4.55 – 49.15) *etc*. The minimum IVI value were shown by *Vimphaea pubescence* (1.79). The ranges of IVI in the present investigation are found to be in conformity with the findings of Billore and Vyas (1982) in Pichhola lake, Udaipur for *Eichhornia crassipes* (24.40 – 51.50) *Hydrlila verticillata* (8.10 – 138.6) and *Potamogeton crispus* (8.70 – 42.30). The present findings for *Alternanthera philoxeroides* (5.71 – 42.91), *Atylosia scarabaeoides* (1.84 – 18.23) and *Azolla pinnata* (4.55 – 49.15) are much comparable to the findings made earlier by Devi, K.I. (1998) in Utrapat lake, Manipur where the IVI values ranged from 6.48 – 23.37 for these species. The present reported IVI values of *Alternanthera philoxeroides* and *Echinochloa stagnina* are found to be in conformity with values reported earlier by Sankhla and Vyas (1982) in Baghela tank, Udaipur (7.40 – 138.70) and Devi, S.U.

The highest values of IVI observed in the present investigation for *Salvinia cucullata* are comparable to the values reported by Devi, Ch. U. (2000) in the freshwater ecosystems of Canchipur (8.50 – 168.98) and Devi, Ch. N. (2002) in Ilkop lake, Manipur (6.19 – 123.12). However, the present values are higher than the values reported by Devi, Kh. U. (2002) in Poiroupat lake, Manipur which ranged from 6.20 to 14.60. The present findings are found to be lower when compared with the findings of Devi, Ch. B. (2001) in Sanapat lake, Manipur.

Comparable values to those in the present investigation were also reported by Devi, Ch. N. (2002) for *Potamogeton crispus* (3.83 – 148.13) and *Hydrilla verticillata* (2.82 – 148.81) in Ilkop lake, Manipur.

In the present investigation, *Salvinia cucullata*, *Potamogeton crispus* and *Hydrilla verticillata* exhibited the highest IVI values and their luxuriant growth may be attributed to the favourable climatic conditions prevailing in the lake. The physico-chemical characteristics of water like the pH also influence the growth of aquatic macrophytes, besides the climatic factors (Gopal *et al.*, 1978). Low pH is found to limit the successful growth of some macrophytes like *Pistia stratiotes* and *Nymphoides* as reported by Mitra (1955, 1966). But Das (1968) reported that *Spirodea polyrhiza* is distributed in water having pH between 6.20 and 8.60. The establishment of floating leaf species with the
increase in the water depth in Hoaksar lake (Kashmir) was observed by Kaul et al. (1978). Spence (1967) had quite earlier observed that the submerged aquatic plants exhibit better growth on organic matter rich soils. The abundance of individual species responded only to prevailing environmental conditions (Hagen, 1992). Thus, the occurrence and characteristics of the different macrophytes are determined by a large number of environmental factors as discussed.

B. BIOMASS DYNAMICS:

In the present study of two consecutive years, the biomass dynamics of eighteen (18) macrophytic plant species has been studied. The maximum ranges of biomass were recorded in *Eichhornia crassipes*, *Salvinia cucullata*, *Alternanthera philoxeroides*, *Echinochloa stagnina*, *Kyllinga triceps*, *Hydrilla verticillata* etc. *Salvinia cucullata* recorded the maximum biomass in the first two sites viz., Site I and Site II. *Alternanthera philoxeroides* and *Eichhornia crassipes* had maximum values of biomass in Site III and Site IV respectively.

The biomass of *Eichhornia crassipes* varied 31.34 gm⁻² to 140.84 gm⁻² and 25.59 gm⁻² to 168.44 gm⁻² in the first year and second year respectively. The present findings are highly comparable to the values reported by Saha (1986) in Mukhra and Tiwari ponds, Bhagalpur (188.90 gm⁻²); Shah and Abbas (1979) in the river Ganges, Bhagalpur (Bihar) 250.40 gm⁻² to 375.60 gm⁻²; Devi, L. G. (2007) in Awangsoipat lake, Manipur (27.46 gm⁻² to 148.23 gm⁻²).
The present reported values are higher than the values reported by Billore and Vyas (1982) recording the lowest value (5.00 gm\(^{-2}\)) during summer season and the highest value (25.00 gm\(^{-2}\)) in winter season; Bebika and Sharma (2002) in Sanapat lake, Manipur (1.82 – 39.79 gm\(^{-2}\)); Devi, Kh. U. (2002) in Poiroupat lake, Manipur (6.92 – 26.54 gm\(^{-2}\)); Devi S.U. (2008) in Oksoipat lake, Manipur (17.76 – 64.96 gm\(^{-2}\)).

Higher biomass values when compared to the present study were also reported by Da Silva and Esteves (1993) in the semi-humid tropical freshwater ponds, Mato Grosso (Brazil); Devi, O.I. (1993) in Waithou lake, Manipur (946.66 gm\(^{-2}\)); Sahai and Sinha (1970) in Ramgarh lake, Gorakhpur (720 gm\(^{-2}\)); Gopal et al. (1978) in some fresh water ecosystems, Jaipur (2067 gm\(^{-2}\)) and Singh (1983) in the Surha tal lake, Ballia (908.43 gm\(^{-2}\)).

The biomass of *Salvinia cucullata* varied from 31.57 to 166.70 gm\(^{-2}\) and 33.64 – 141.47 gm\(^{-2}\) in the first year and second year respectively. The present estimated values of are very much comparable to the values reported by Devi, N. B. (1993) in Loktak lake, Manipur (3.16 – 204.15 gm\(^{-2}\)); Devi, Ch. U. (2002) in freshwater ecosystems of Canchipur (185.51 gm\(^{-2}\) for the first year and 168.42 gm\(^{-2}\) for the second year); Devi, L. G. (2007) in Awangsoipat lake, Manipur (9.52 – 185.24 gm\(^{-2}\)). Higher values when compared to the present study were also reported by Kaul et al. (1972); Zutshi and Vass (1971) and Kaul and Bakaya (1976) in Kashmir (266.00 – 355.00 gm\(^{-2}\)); Babalonas and Papastergiadou (1989) in lake Kerkini (112.60 – 238.79 gm\(^{-2}\)). The present
reported values are higher than the values reported by Devi, Ch. N. (2002) in Ikop lake, Manipur (0.99 – 22.02 gm\(^2\) for the shoot and 0.06 – 11.25 gm\(^2\) for the root); Devi, Kh. U. (2002) in Poiroupat lake, Manipur (31.93 – 34.12 gm\(^2\)); Devi, S. U. (2008) in Oksoipat lake, Manipur (9.17 – 67.51 gm\(^2\)).

The biomass of *Alternanthera philoxeroides* varied from 34.05 – 145.01 gm\(^2\) in the first year and 32.03 – 142.54 gm\(^2\) in the second year. The present estimated values are comparable to values reported by Devi, Kh. U. (2002) in the Poiroupat lake, Manipur (64.32 – 139.77 gm\(^2\)); Devi, L. G. and Sharma (2002) in some fresh water ponds of Canchipur, Manipur (34.52 – 104.93 gm\(^2\)); Devi, L. G. (2007) in Awangsoipat lake, Manipur (22.50 – 153.66 gm\(^2\)); Devi, S.U. (2008) in Oksoipat lake, Manipur (19.94 – 139.41 gm\(^2\)). Lower values when compared to the present ranges have been observed by Devi, O. I. (1993) in Waithou lake, Manipur (53.70 gm\(^2\) in the first year and 50.30 gm\(^2\) in the second year); Devi, K. I. (1998) in Utrapat lake, Manipur (57.12 – 93.01 gm\(^2\)); Devi, Ch. N. (2002) in Ikop lake, Manipur (1.09 – 8.43 gm\(^2\) for the shoot and 0.48 – 2.98 gm\(^2\) for the root). In Sanapat lake Bebika (2001) and Bebika and Sharma (2002) reported lower values ranging from 1.19 – 84.94 gm\(^2\) for shoot and 0.06 – 28.54 gm\(^2\) for root during the two years of study. Higher values when compared to the present ranges were also reported by Devi, N. B. (1993) and Sharma and Devi, N. B. (2002) in Loktak lake, Manipur (8.64 – 206.15 gm\(^2\) for shoot and 0.25 – 21.70 gm\(^2\) for the root) and Kaul *et al.* (1978)
where the biomass for the different low growing emergent plants ranged from 12.00 – 580.00 gm$^2$ for the shoot and 4.00 – 379.00 gm$^2$ for the root.

The biomass of *Echinochloa stagnina* ranged from 37.49 – 112.41 gm$^2$ in the first year and 40.79 – 118.39 gm$^2$ second year. The present findings are in conformity with the values reported by Devi, Ch. U (2000) in some freshwater ecosystems of Canchipur (151.64 gm$^2$ and 157.65 gm$^2$); Devi, L. G. (2007) in Awangsoipat lake, Manipur (147.05 gm$^2$ in the first year and 164.60 gm$^2$ in the second year); Devi, S. U. (2008) in Oksoipat lake, Manipur (13.82 – 110.46 gm$^2$ in the first year and 23.57 – 142.14 gm$^2$ in the second year). The present values are much higher when compared with the values reported by Devi, O. I. (1993) in Waithou lake, Manipur (13.13 – 39.07 gm$^2$); Devi, Ch. N. (2002) and Nivanonee and Sharma (2006) for *Echinochloa colomum* (1.89 – 43.45 gm$^2$) in Ikop lake, Manipur. The present ranges are found to be lower when compared to the values observed by Devi, N. B. (1993) in Luktak lake, Manipur (46.12 – 266.68 gm$^2$ for the shoot and 73.74 gm$^2$ for the root).

The biomass values of *Kyllinga triceps* varied from 4.37 – 89.64 gm$^2$ in the first year and 4.65 – 37.61 gm$^2$ in the second year. The present values of biomass are found to be lower than the values reported by Devi, L. G. (2007) in Awangsoipat lake, Manipur for *Kyllinga triceps* (15.01 – 190.57 gm$^2$ for shoot and 1.28 – 31.40 gm$^2$ for root in the two years of study. Kaul et al. (1978) also reported high values in some water bodies of Kashmir viz., 12.00 – 291.00 gm$^2$. 
(root) part in some emergent species like *Scirpus palustris*, *Cyperus aerotinus*, *Echinochloa crus-gali* etc.

The total biomass of *Hydrilla verticillata* ranged from 2.63 – 74.67 gm⁻² during the whole period of study. The present findings are comparable with the values reported by Harlan *et al.* (1985) in big lake, North Carolina (52.00 – 64.00 gm⁻²); Devi, K. I. (1998) in Utrapat lake, Manipur (12.70 – 61.60 gm⁻²); Devi, Kh. U. (2002) in Poiroupat lake, Manipur (16.09 – 65.22 gm⁻² for the first year and 22.23 – 67.00 gm⁻² for the second year). Lower values as compared to the present observation have also been reported by Devi, O. I. (1993) in Waithou lake, Manipur (10.47 – 32.09 gm⁻²). Higher values of biomass were recorded by many workers from different wetlands *viz.*, Sinha and Sahai (1973) in Gorakhpur (533.00 gm⁻²); Singhal and Singh (1978) and Purohit and Singh (1978) in Nainital lake (40.00 – 243.00 gm⁻² and 2.00 – 354.00 gm⁻²); Gopal *et al.* (1978) in Kashmir (104 – 387 gm⁻²); Durani and Rout (1982) in Nandan Kanan lake, Orissa (324.50 gm⁻²); Anand (1986) in Gadigarh stream, Jammu (206.29 gm⁻²); Devi, N. B. (1993) in Loktak lake, Manipur (4.28 – 433.83 gm⁻² for shoot and 0.16 gm⁻² for the root); Hudon *et al.* (2000) in St. Lawrence river and Ottawa river, Canada (296.00 – 631.60 gm⁻²). Higher values were also reported by Devi, L. G. (2007) in Awangsoipat lake, Manipur (10.44 – 117.44 gm⁻²) and Devi, S. U. (2008) in Oksoipat lake, Manipur (22.29 – 130.99 gm⁻²).
The total biomass of *Potamogeton crispus* varied from 1.70 – 75.61 gm². The present findings are in conformity with the values observed by Billore and Vyas (1982) in Udaipur (10.00 – 66.00 gm²) and Devi, N. B. (1993) in Loktak lake, Manipur (0.34 – 72.21 gm²); Devi, L. G. (2007) in Awangsoipat lake, Manipur (2.53 – 73.65 gm²). Higher values when compared to the present study were reported by Kaul *et al.* (1978) in some water bodies of Kashmir (220.00 – 276.00 gm²) and Devi, Ch. U. (2000) in some freshwater ecosystems of Canchipur, Manipur (10.05 – 175.98 gm²). Lower values of biomass have been reported by Jupp and Spence (1977) in Loch Leven, Carden Bay for *Potamogeton pectinatus* (97.20 gm²) and Shardendu and Ambasht (1991) in a tropical wetland (26.0 gm²).

The total biomass of *Ludwigia adscendens* varied from 10.06 – 60.04 gm² during the study period of two years. The observed values of biomass in the present study are comparable with the values reported by Devi, O. I. (1993) in Waithou lake, Manipur (1.91 – 45.70 gm²); Devi, K. I. (1998) in Utrapat lake, Manipur (11.12 – 55.56 gm²); Bebika (2001) and Bebika and Sharma (2002) in Sanapat lake, Manipur (3.31 – 49.56 gm²); Devi, Kh. U. (2002) in Poiroupat lake, Manipur (14.09 – 89.32 gm²); Devi, L. G. (2007) in Awangsoipat lake, Manipur (10.04 – 66.86 gm²) and Devi, S. U. (2008) in Oksoipat lake, Manipur (16.64 – 57.76 gm²). Devi Ch. U. (2000) also reported comparable values in the freshwater ecosystems of Canchipur 1.63 – 109.37 gm² in the first year and 2.73 to 56.56 gm² in the second year. Low values
were reported by Devi, L. G. and Sharma (2002) in the freshwater ponds of Canchipur, Manipur which ranged from 1.57 – 17.72 gm⁻² Devi, Ch. N. (2002) in Ikop lake, Manipur (1.04 – 29.70 gm⁻² for shoot and 0.01 – 10.24 gm⁻² for root).

The total biomass of *Trapa natans* varied from 7.26 – 51.12 gm⁻² during the whole period of study. The present values are comparable to the values reported by Devi, Ch. N. (2002) in Ikop lake, Manipur (20.88 gm⁻² in the first year and 3.71 gm⁻² in the second year). The present reported values are found to be much lower when compared to the values observed by Ambasht (1971) in Varanasi (570 gm⁻²); Kvet and Hussak (1978) in Southern Bohemia (107 gm⁻²) for *Trapa natans*; Kaul et al. (1978) in Kashmir (22 – 545 gm⁻²); Handoo and Kaul (1982) in Badatal reservoir of Chindwara (436 – 994 gm⁻²).

The total biomass of *Enhydroa fluctuans* varied from 2.67 – 41.15 gm⁻² in the first year and 3.17 – 22.99 gm⁻² in the second year. The present estimated values are found to be in conformity with the values reported by Devi, O. I. (1993) in Waithou lake, Manipur (1.50 – 38.56 gm⁻²); Devi, Ch. N. (2002) in Ikop lake, Manipur (1.01 – 40.99 gm⁻² for shoot and 0.32 – 5.60 gm⁻² for root).

The total biomass of *Azolla pinnata* varied from 1.28 – 14.21 gm⁻² during the whole period of study. The present estimated values are found to be very low in comparison to the values reported by Devi, Ch. N. (2002) in Ikop lake, Manipur (0.58 – 110.38 gm⁻²); Devi, O. I. (1993) in Waithou lake, Manipur (25.72 gm⁻²). Higher values were reported by many workers viz.,
Gopal (1967) and Ambasht (1971) from Varanasi (278.00 – 400.00 gm²); Saha (1986) in the Mukhra and Tiwari ponds of Bhagalpur (30.50 – 69.21 gm²).

Low biomass values were observed in emergent species like *Atylosia scarabaeoides, Ipomoea aquatica* and *Oenanthe javanica* with values ranging from 1.25 – 24.78 gm². In conformity with the present study, Billore and Vyas (1982) reported low biomass for the emergent species in the Pichhola lake, Udaipur (10.00 – 35.80 gm²). Comparable values were also reported by Devi, L. G. (2007) in Awangsoipat lake, Manipur for *Ipomoea aquatica, Oenanthe javanica* and *Atylosia scarabaeoides* for which the values ranged from 1.78 – 36.09 gm². Comparable values for *Ipomoea aquatica* were also reported by Devi, Ch. B. (2001) in Sanapat lake, Manipur (4.87 – 26.93 gm²). Nivanonee and Sharma (2006) also reported comparable biomass values for *Ipomoea aquatica* (4.87 – 26.93 gm²).

The total biomass values of “other species” varied from 1.64 – 44.03 gm². The present findings are very much comparable to the values reported by Devi, K. I. (1998) in Utrapat lake, Manipur (12.47 – 32.87 gm²); Devi, Kh. U. (2002) in Poiroupat lake, Manipur (8.48 – 91.92 gm²); Devi, L. G. (2007) in Awangsoipat lake, Manipur (0.17 – 44.28 gm²).

In the present study, the total biomass of all species (combined) varied from 271.45 – 617.46 gm². The present observed values are in high conformity with the values observed by Odum (1957) in the Silver Springs of Florida. Comparable values were also reported by many authors viz., Jha (1968) in
Varanasi for a semi-permanent fish pond (554.70 gm\(^2\)); Wassink (1975) in Malaysia (370.00 – 520.00 gm\(^2\)). Pieczynska and Ozimek (1976), reported biomass values of 540.00 gm\(^2\) and 180.00 gm\(^2\) for the emergent and submerged macrophytes respectively in Masurian lake in Poland. Misra (1989) reported the maximum biomass of 554.60 gm\(^2\) in a shallow pond in Varanasi. Freedman (1989) also reported comparable values for macrophytes in some eutrophic ponds in Michigan. The present findings are also comparable to the values reported by various workers viz., Devi, N. B. (1993) in Loktak lake, Manipur (29.13 – 455.97 gm\(^2\)) for the non-plumdi species; Devi, K. I. (1998) in Utrapat lake, Manipur (139.18 – 579.85 gm\(^3\)); Devi, Ch. U (2000) in the freshwater ecosystems of Canchipur (36.09 – 408.40 gm\(^2\)); Devi, Kh. U. (2002) in Poiropolat lake, Manipur (130.07 – 512.28 gm\(^2\)) and Devi, S. U. (2008) in Oksoipat lake, Manipur (150.87 – 588.05 gm\(^2\))

The estimated values of total biomass found in the present study are comparatively lower as compared with the values reported by a numbers of workers viz., Bellamy (1967) for swamp vegetations of Assam (850.00 gm\(^{-2}\)); Ambasht (1971) in a fish pond of Varanasi for above ground biomass of the emergent species (1250.00 gm\(^{-2}\)); Mitchell, (1974) (800.00 gm\(^{-2}\)); Crowder et al. (1977) in lake Opinicon (1154.00 gm\(^{-2}\)); Singh (1983) in the Littoral zone (1340.47 gm\(^{-2}\)) and in the Pelagic zone (1403.91 gm\(^{-2}\)) in Surha Tal lake, Ballia. Howard-Williams et al. (1986) in lake Waikaremona, New Zealand (1106.00 gm\(^{-2}\)); Vyas et al., (1989) in five lakes of Udaipur (537.60 – 1884.09 gm\(^{-2}\)) and Devi, O. I. (1993) in Waithou lake, Manipur (422.97 – 1173.01 gm\(^{-2}\)). Billore et al. (1998) reported maximum biomass values of 1.70 – 2.70 kg m\(^{-2}\) for macrophytic species. Kaul et al. (1978) also reported the highest biomass values in the tall growing emergents (812.00 – 6197.00 gm\(^{-2}\)), successively followed by the low growing emergents (20.00 – 965.00 gm\(^{-2}\)) and submerged species (23.00 – 480.00 gm\(^{-2}\)). Singh, K. K. (2010) recently reported 313.36 to 989.95 gm\(^{-2}\) of macrophytic biomass in Kharungpat lake, Manipur (Table 20).

Sculthrope (1967) has given the biomass data for lakes in different parts of the world in which the biomass values varied from 0.07 – 680.00 gm\(^{-2}\) in temperate lakes, 50.00 – 1000.00 gm\(^{-2}\) in New Zealand lakes and 630.00 – 4640.00 gm\(^{-2}\) in reed swamps of Minnesota (U.S.A.). The biomass values of the present study are fall within the range recorded from temperate lakes. From the present biomass data, the present study lake fall within the average global
biomass values for the lakes and streams of the world which varied from 0.02 – 0.10 kg m\(^{-2}\) (Lieth, 1973; Whittaker and Likens, 1973).

In the present study, the maximum values of biomass was contributed by free floating species and emergent species. The free floating species like *Eichhornia crassipes* and *Salvinia cucullata* produced maximum biomass during the winter season. Kaul *et al.* (1978) also reported optimum growth of aquatic plants during July – September. The peak biomass of submerged species like *Hydrilla verticillata* was obtained during the summer and the rainy seasons. Thus, the different macrophytic species exhibited peak biomass in different seasons. Handoo (1978), Kaul and Handoo (1989) and Vyas *et al.* (1989) reported that emergent species recorded maximum productivity in shallow depths and on the other hand, floating and rooted floating leaved species reported higher values in deeper regions. Shah and Abbas (1979) also reported that during the winter months the light intensity is lower resulting to the retardation in the photosynthetic activity of the submerged macrophytes. But, the free floating species may not be influenced by this factor as the free floating plants which are exposed to the sunlight got moderate temperature and full sunlight which are favourable for the photosynthetic activity of the aquatic plants. Thus in the present study maximum biomass was produced by free floating species like *Eichhornia crassipes* and *Salvinia cucullata* during the winter season.
From the present findings, it is evident that physico-chemical nature and the depth of the water bodies influence the production rate of the macrophytes. The variation in the floristic composition and its distribution were also influenced by the depth of water. The luxuriant growth of macrophytic plant species and their high values of biomass indicate that the lake under study is found to be Eutrophic in nature.

C. NET PRIMARY PRODUCTIVITY:

i) Daily Net Primary Productivity:

In the present study of two consecutive years, the maximum daily net primary productivity was contributed by many dominant macrophytic plant species in the different study sites. *Salvinia cucullata* exhibited maximum daily NPP in site I and site II while in site III and site IV, maximum daily NPP was recorded by *Eichhornia crassipes*.

The peak daily net primary production was observed in *Salvinia cucullata* in which the values varied from 0.01 – 3.04 gm$^{-2}$day$^{-1}$ in the first year and 0.01 – 1.80 gm$^{-2}$day$^{-1}$ in the second year. The values observed in the present study are in highly conformity with values reported by Devi, N. B. (1993) in the non-phumdi zone of Loktak lake, Manipur (0.07 – 2.51 gm$^{-2}$day$^{-1}$). Comparable values with the present ranges have been reported by many workers *viz.*., Devi, Ch. U. (2000) in freshwater ecosystems of Canchipur, Manipur (0.16 – 0.55 gm$^{-2}$day$^{-1}$); Devi, Ch. B. (2001) in Sanapat lake, Manipur.
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(0.01 – 0.34 gm$^{-2}$day$^{-1}$). Lower values as compared to the present study were also reported by Devi, L. G. and Sharma, B. M. (2002) in some ponds of Canchipur, Manipur (0.01 to 0.54 gm$^{-2}$day$^{-1}$); Devi, Ch. N. (2002) in Ikop lake, Manipur (0.00 to 0.44 gm$^{-2}$day$^{-1}$ in the first year and 0.02 to 0.63 gm$^{-2}$ day$^{-1}$ in the second year); Devi, Kh. U. (2002) in Poiroupat lake, Manipur (0.01 to 0.18 gm$^{-2}$day$^{-1}$ in the first year and 0.03 to 0.32 gm$^{-2}$ day$^{-1}$ in the second year). The values reported by Devi, L.G. (2007) in Awangsoipat lake, Manipur (0.02 to 1.28 gm$^{-2}$day$^{-1}$) is comparable with the present findings of first year. Kaul and Bakaya (1976) in Kashmir reported comparable values (0.75 to 1.19 gm$^{-2}$ day$^{-1}$) for Salvinia natans.

*Potamogeton crispus* recorded the daily net primary production ranging from 0.01 – 1.92 gm$^{-2}$day$^{-1}$ during the second year of the present study. The presence of *Potamogeton crispus* in the first year was insignificant. The present estimated values are found to be comparable with the values reported by Devi, N. B. (1993) in the non-phumdi zone of Loktak lake, Manipur (0.03 – 1.47 gm$^{-2}$day$^{-1}$). The present estimated values are higher than the values reported by Devi, L. G. and Sharma (2002) in the freshwater ponds of Canchipur, Manipur (0.02 – 0.68 gm$^{-2}$day$^{-1}$); Nivanonee and Sharma (2006) in Ikop lake, Manipur (0.01 – 0.80 gm$^{-2}$day$^{-1}$); Devi, L. G. (2007) in Awangsoipat lake, Manipur (0.02 – 1.06 gm$^{-2}$day$^{-1}$); Billore and Vyas (1982) in Pichhola lake, Udaipur (0.16 – 0.66 gm$^{-2}$day$^{-1}$). Very low values have also been observed by Ingle and
Dhargalkar (1998) in the freshwater Priyadarshini lake, Schirmachar Oasis, East Antarctica (0.0013 – 0.014 gm²·day⁻¹).

The daily net primary production of *Alternanthera philoxeroides* varied from 0.08 gm²·day⁻¹ to 1.42 gm²·day⁻¹ in the first year and 0.02 gm²·day⁻¹ to 1.71 gm²·day⁻¹ in the second year. The present values of the daily net primary productivity are found to be highly in conformity with the values reported by Devi, L.G. (2007) in Awangsoipat lake, Manipur (0.07 gm²·day⁻¹ to 1.22 gm²·day⁻¹ in the first year and 0.36 gm²·day⁻¹ to 1.82 gm²·day⁻¹ in the second year). The present values are found higher in comparison with the values reported by Devi, O. I. (1993) in Waithou lake, Manipur (0.09 to 0.91 gm²·day⁻¹); Devi, K. I. (1998) in Ultrapat lake, Manipur (0.11 to 0.79 gm²·day⁻¹); Devi, Ch. N. (2002) in Ikop lake, Manipur (0.01 to 0.28 gm²·day⁻¹) and Devi, Kh. U. (2002) in Poiroupat lake, Manipur (0.03 to 0.89 gm²·day⁻¹). The present values of the daily net primary productivity are found lower in comparison with the values observed by Devi, N. B. (1993) in the phumdi zone of Loktak lake, Manipur (0.02 to 3.54 gm²·day⁻¹); Devi, L. G. and Sharma (2002) in the different freshwater bodies of Canchipur, Manipur (0.04 to 2.32 gm²·day⁻¹); Devi, Ch. B. and Sharma (2002) in Sanapat lake, Manipur (0.01 to 2.27 gm²·day⁻¹) and Devi, S. U. (2008) in Oksoipat lake, Manipur (0.02 – 2.38 gm²·day⁻¹).

The estimated values of daily net primary productivity of *Eichhornia crassipes* varied from 0.01 – 1.59 gm²·day⁻¹ in the first year and 0.02 – 2.09 gm²·day⁻¹ in the second year. The present values are found comparable with the
values reported by Devi, Ch. N. (2002) in Ikop lake, Manipur (0.00 – 2.48 gm\(^{-2}\)\(\text{day}^{-1}\) and 0.06 – 0.77 gm\(^{-2}\)\(\text{day}^{-1}\) in the first and second year respectively) and De Busk et al. (1981) in central region of Florida (2.29 gm\(^{-2}\)\(\text{day}^{-1}\)). Comparable values were also reported by Daost and Childers (1999) in the macrophytes of the wet prairie community in freshwater Everglades, Florida (0.17 – 1.61 gm\(^{-2}\)\(\text{day}^{-1}\)); Singh (1983) in Surhatal lake (1.22 gm\(^{-2}\)\(\text{day}^{-1}\)), Shah and Abbas (1979) also reported the peak value (1.70 gm\(^{-2}\)\(\text{day}^{-1}\)) for *Eichhornia crassipes* during the late winter season. The present estimated values were found to be higher than the values reported by Billore and Vyas (1981) in Pichhola lake, Udaipur (0.10 gm\(^{-2}\)\(\text{day}^{-1}\)); Saha (1986) 0.30 gm\(^{-2}\)\(\text{day}^{-1}\) in Mukhara and Tiwari pond Bhagalpur (0.30 gm\(^{-2}\)\(\text{day}^{-1}\)); Bebika and Sharma (2002) in the Sanapat lake, Manipur (0.81 gm\(^{-2}\)\(\text{day}^{-1}\)); Devi, Kh. U. (2002) in Poiroupat lake, Manipur (0.04 – 0.28 gm\(^{-2}\)\(\text{day}^{-1}\)) and Devi, L. G. (2007) in Awangsoipat lake, Manipur (0.002 – 0.93 gm\(^{-2}\)\(\text{day}^{-1}\)). The present values were found to be lower than the values reported by Westlake (1963) in New Orleans (22.00 gm\(^{-2}\)\(\text{day}^{-1}\)) and Devi, O. I. (1993) in Waithou lake, Manipur (1.96 – 10.93 gm\(^{-2}\)\(\text{day}^{-1}\)).

The daily net primary production of *Hydrilla verticillata* varied from 0.04 to 1.51 gm\(^{-2}\)\(\text{day}^{-1}\). The values are in conformity with the values reported by Devi, L. G. (2007) in Awangsoipat lake, Manipur (0.10 – 1.10 gm\(^{-2}\)\(\text{day}^{-1}\) in the first year and 0.20 – 1.13 gm\(^{-2}\)\(\text{day}^{-1}\) in the second year) and Devi, S. U. (2008) in Oksoipat lake, Manipur (0.02 – 1.78 gm\(^{-2}\)\(\text{day}^{-1}\) in the first year and 0.03 – 1.70 gm\(^{-2}\)\(\text{day}^{-1}\) in the second year). Higher values were reported by Devi,
N. B. (1993) in Loktak lake, Manipur (0.02 – 6.58 gm$^{-2}$day$^{-1}$). Higher values were also reported by Sinha and Sahai (1973) in Gorakhpur (39.60 gm$^{-2}$day$^{-1}$); Kaul et al. (1978) in Kashmir (0.18 – 2.30 gm$^{-2}$day$^{-1}$). Lower values as compared to the present estimated values were also reported by many workers *viz.*, Billore and Vyas (1981) from Udaipur (0.35 gm$^{-2}$day$^{-1}$); Singh (1983) from Ballia (0.97 gm$^{-2}$day$^{-1}$); Saha (1986) from Bhagalpur (0.30 gm$^{-2}$day$^{-1}$) and Shardendu and Ambasht (1991) with 0.31 gm$^{-2}$day$^{-1}$ from Varanasi. Lower values of daily productivity were also reported from the wetlands of Manipur by Devi, O. I. (1993) in Waithou lake with the values of (0.01 – 0.42 gm$^{-2}$day$^{-1}$); Devi, K. I. (1998) in freshwater ecosystems of Canchipur (0.002 – 0.13 gm$^{-2}$day$^{-1}$); Devi, Kh. U. (2002) in Poiroupat lake (0.06 – 0.78 gm$^{-2}$day$^{-1}$) and Devi, Ch. N. (2002) in Ikop lake (0.01 – 0.27 gm$^{-2}$day$^{-1}$).

The daily net primary productivity of *Trapa natans* varied from 0.57 to 1.10 gm$^{-2}$day$^{-1}$ and the species was present only in the second year of study. The present reported values are found to be lower as compared with values reported by Kaul et al. (1978) in Anchar lake, Kashmir (2.96 – 3.78 gm$^{-2}$day$^{-1}$). The present estimated values are higher than the values reported by Devi, N. B. (0.05 – 0.60 gm$^{-2}$day$^{-1}$) in Loktak lake, Manipur; Devi, K. I. (1998) in Utrapat lake, Manipur (0.004 – 0.66 gm$^{-2}$day$^{-1}$) and Devi, Ch. N. (2002) in Ikop lake, Manipur (0.16 – 0.99 gm$^{-2}$day$^{-1}$). The daily net primary productivity of *Azolla pinnata* varied from 0.01 to 0.21 gm$^{-2}$day$^{-1}$ and 0.01 – 0.22 gm$^{-2}$day$^{-1}$ in the first year and second year respectively. The present reported values are comparable.
to the values observed by Devi, O. I. (1993) in Waithou lake, Manipur, with values of $0.02 - 0.40 \, \text{gm}^{-2} \cdot \text{day}^{-1}$. The present estimated values are found higher than the values recorded by Saha (1986) $0.11 \, \text{gm}^{-2} \cdot \text{day}^{-1}$ in Bhagalpur ($0.11 \, \text{gm}^{-2} \cdot \text{day}^{-1}$), but they are lower than the values reported by Devi, Ch. N. (2002) in Ikop lake, Manipur ($0.02 - 3.21 \, \text{gm}^{-2} \cdot \text{day}^{-1}$) and Gopal (1967) in Varanasi ($1.80 - 4.70 \, \text{gm}^{-2} \cdot \text{day}^{-1}$).

The daily net primary productivity of *Echinochloa stagnina* varied from $0.03$ to $0.90 \, \text{gm}^{-2} \cdot \text{day}^{-1}$ and $0.04$ to $0.94 \, \text{gm}^{-2} \cdot \text{day}^{-1}$ in the first and second year respectively. Comparable values with the present study were reported earlier by Devi, O. I. (1993) with values of $0.08 - 0.81 \, \text{gm}^{-2} \cdot \text{day}^{-1}$ from Waithou lake, Manipur; Devi, L. G. (2007) with $0.10 - 0.91 \, \text{gm}^{-2} \cdot \text{day}^{-1}$ from Awangsoipat lake, Manipur. Higher values as compared to the present study were reported by Devi, N. B. (1993), in the phumdi areas of Loktak lake, Manipur ($0.02 - 5.22 \, \text{gm}^{-2} \cdot \text{day}^{-1}$); Devi, Ch. N. (2002) in Ikop lake, Manipur with values ranging from $0.01 - 0.23 \, \text{gm}^{-2} \cdot \text{day}^{-1}$ in the first year and $0.02 - 0.40 \, \text{gm}^{-2} \cdot \text{day}^{-1}$ in the second year and Devi, S. U. (2008) in Oksoipat lake, Manipur ($0.02 - 1.54 \, \text{gm}^{-2} \cdot \text{day}^{-1}$). Lower values were earlier reported by Devi, Ch. U. (2000) from the freshwater ecosystems of Canchipur ($0.008 - 0.57 \, \text{gm}^{-2} \cdot \text{day}^{-1}$).

*Enhydra fluctuans* recorded daily net primary productivity values ranging from $0.01$ to $0.53 \, \text{gm}^{-2} \cdot \text{day}^{-1}$ and $0.01$ to $0.38 \, \text{gm}^{-2} \cdot \text{day}^{-1}$ in first and second year respectively. The values found in present study are comparable with the values reported by Devi, O. I. (1993) in Waithou lake, Manipur ($0.002$
0.52 gm$^2$day$^{-1}$) but the present values are lower than the values reported by Devi, Ch. N. (2002) in Ikop lake, Manipur (0.05 – 1.50 gm$^2$day$^{-1}$).

*Kyllinga triceps* recorded daily net primary productivity values ranging from 0.04 to 0.52 gm$^2$day$^{-1}$ and 0.01 to 0.33 gm$^2$day$^{-1}$ in first and second year respectively. The present estimated values are found lower as compared to the values reported by Devi, L. G. (2007) in Awangsoipat lake, Manipur (0.03 – 1.44 gm$^2$day$^{-1}$).

The daily net primary production of *Ludwigia adscendens* varied from 0.19 to 0.56 gm$^2$day$^{-1}$ in the first year and 0.17 to 0.35 gm$^2$day$^{-1}$ in the second year. Comparable values were reported earlier by many worker from various wetlands of Manipur viz., Devi, Ch. U. (2000) in the fresh water ecosystems of Canchipur (0.09 – 0.91 gm$^2$day$^{-1}$, first year and 0.01 – 0.64 gm$^2$day$^{-1}$, second year); Devi, Ch. B. (2001) in Sanapat lake, Manipur (0.01 – 0.95 gm$^2$day$^{-1}$); Devi, Ch. N. (2002) in Ikop lake, Manipur (0.01 – 0.97 gm$^2$day$^{-1}$); Devi, Kh. U. (2002) in Poiroupant lake, Manipur (0.02 – 0.67 gm$^2$day$^{-1}$); Devi, O. I. (1993) in Waithou lake, Manipur (0.09 – 0.91 gm$^2$day$^{-1}$ in the first year and 0.01 – 0.64 gm$^2$day$^{-1}$ in the second year); Devi, L. G. (2007) in Awangsoipat lake, Manipur (0.16 – 0.78 gm$^2$day$^{-1}$) and Devi, S. U. (2008) in Oksoipat lake, Manipur (0.06 – 0.72 gm$^2$day$^{-1}$ in the first year and 0.03 – 0.66 gm$^2$day$^{-1}$ in the second year). Higher values as compared to the present values were observed by Nivanonee and Sharma (2006) in Ikop lake, Manipur (0.01 – 1.24 gm$^2$day$^{-1}$).
The daily net primary production of all species (combined) varied from 0.17 gm$^2$day$^{-1}$ (December) to 4.32 gm$^2$day$^{-1}$ (September) in the first year and 0.08 gm$^2$day$^{-1}$ (November) to 4.30 gm$^2$day$^{-1}$ (August) in the second year. The minimum value was observed in November and the maximum value was observed in September. The present findings are very much agreeable with the values reported by many authors viz. Nasar and Munshi (1971) in the pond ecosystems of Bhagalpur (4.30 gm$^2$day$^{-1}$); Misra (1974) in freshwater pond in Vanarasi (4.50 gm$^2$day$^{-1}$); Devi. Ch. U. (2000) in the freshwater ecosystems of Canchipur (0.07 – 4.38 gm$^2$day$^{-1}$); Devi. Ch. N. (2002) and Nivanonee and Sharma (2006) in Lkop lake, Manipur (0.06 – 4.93 gm$^2$day$^{-1}$) and Kumar et al. (2001) in the different wetlands of Jharkhand. Comparable values were also reported by Devi. N. B. (1993) in the non-phumdi zone of Loktak lake. Manipur (0.01 – 5.04 gm$^2$day$^{-1}$). Likens (1975) also reported comparable values of net primary production (1.0 – 5.40 gm$^2$day$^{-1}$) for the submerged macrophytes. The values reported by Likens (1975) in the tropical lakes (0.68 – 6.49 gm$^2$day$^{-1}$) and subtropical lakes and rivers (0.246 – 5.51 gm$^2$day$^{-1}$) are comparable with the values obtained in the present study. The maximum daily net production during the rainy season (July-Oct.) in the present investigation are similar with the findings reported by many authors. Sinha and Sahai (1973) recorded maximum production (39.60 gm$^2$day$^{-1}$) of the macrophytes during July to August and the minimum (1.30 gm$^2$day$^{-1}$) during January. Verma et al.
(1982) in Gujar lake observed maximum daily net production of 31.90 gm\(^2\) day\(^{-1}\) during August.

Lower values when compared to the present investigation were reported by Shardendu and Ambasht (1991) in the Tropical wetlands of Vanarasi (0.5 gm\(^2\) day\(^{-1}\)); Devi. K. I. (1998) in Utrapat lake, Manipur (0.004 – 2.00 gm\(^2\) day\(^{-1}\)); Ingole and Dhargalkar (1998) in lake Priyadarshini in Seirmachar Oasis, East Antarctica (0.0013 – 0.014 gm\(^2\) day\(^{-1}\)); Bebika and Sharma (2002) in Sanapat lake, Manipur (3.22 gm\(^2\) day\(^{-1}\)); Devi. I. G. and Sharma (2002) in the freshwater pond ecosystems of Canchipur, Manipur (2.81 gm\(^2\) day\(^{-1}\)); Devi. Kh. U. (2002) in Poiroupatek lake, Manipur (0.01 – 2.86 gm\(^2\) day\(^{-1}\)) and Devi. S. U. (2008) in Oksoipat lake, Manipur (0.01 – 2.38 gm\(^2\) day\(^{-1}\)).

Higher values of daily productivity as compared to the present findings were reported by Likens (1975) in Tropical lakes (0.20 – 15.20 gm\(^2\) day\(^{-1}\)); Westlake (1975) in the submerged macrophytes (2.00 – 10.00 gm\(^2\) day\(^{-1}\)); Devi. O. I. (1993) in Waithouh lake (0.48 – 12.95 gm\(^2\) day\(^{-1}\)); Devi. N. B. (1993) from the phumdi zone of Loktak lake, Manipur (0.03 – 9.79 gm\(^2\) day\(^{-1}\)) and Devi. L. G. (2007) in Awangsoipat lake, Manipur (0.02 – 5.21 gm\(^2\) day\(^{-1}\)). In the Oksoipat lake, Manipur, Devi. S. U. (2008) reported daily biomass of all species ranging from 0.08 to 5.21 gm\(^2\) day\(^{-1}\). Comparatively higher values of daily productivity of the macrophytes has recently been reported as ranging from 0.03 to 8.42 gm\(^2\) day\(^{-1}\) by Singh, K. K. (2010) in Kharungpat lake, Manipur (Table22).
ii). Annual Net Production:

The annual net primary production of all species (combined) ranged from 393.40 to 580.99 gm$^2$year$^{-1}$ in the first year and 483.01 to 631.71 gm$^2$year$^{-1}$ in the second year. The estimated values of present study are found to be in conformity with those by Billore and Vyas (1982) in Pichhola lake, Udaipur (691.00 gm$^2$year$^{-1}$) and Devi, Ch. U. (2000) in Freshwater ecosystems of Canchipur, Manipur (354.57 – 678.16 gm$^2$year$^{-1}$) in the first year and (288.68 – 620.08 gm$^2$year$^{-1}$) in the second year.

Higher values when compared with the present study were also observed by Bellamy (1967) in Swamp vegetations. Assam (850.00 gm$^2$year$^{-1}$); Sankhia (1981) in Baghela tank, Udaipur (748.31 gm$^2$year$^{-1}$) Singh et al. (1982) in Nakuchiaatal lake, Kumaun (1226 gm$^2$year$^{-1}$); Zutshi and Vass (1982) in Dal Lake, Kashmir (4100.00 gm$^2$year$^{-1}$); Paliwal (1984) in Fateh Sagar tank, Udaipur (719.23 gm$^2$year$^{-1}$); Vyas et al. (1989) in Udaipur (788.67 gm$^2$year$^{-1}$); Devi, N. B. (1993) in phumdi areas of Loktak lake, Manipur (737.64 – 1240.64 gm$^2$year$^{-1}$); Devi, O. I. (1993) in Waithou lake, Manipur (1350 – 1601.04 gm$^2$year$^{-1}$); Devi, L. G. (2007) in Awangsoipat lake, Manipur (486.59 – 850.00 gm$^2$year$^{-1}$) and Devi, S. U. (2008) in Oksoipat lake, Manipur (196.85 – 756.33 gm$^2$year$^{-1}$). Singh, K. K. (2010) has recently reported annual productivity
macrophytes ranging from 682.64 to 891.13 gm²/year⁻¹ in Kharungpat lake, Manipur (Table 23).

Lower values when compared to the present findings were reported earlier by Jha (1968) and Ambasht (1974) in the ponds of Varanasi (350.00 – 353 gm²/year⁻¹); Schalles and Shure (1989) in the Dystrophic Carolina Bay wetlands (140.00 gm²/year⁻¹); Ambasht (1971) in Ramgarh lake, Varanasi (350.00 gm²/year⁻¹); Shardendu and Ambasht (1991) in the tropical wetlands (179.00 gm²/year⁻¹); Hillbricht Illkowska (1993) in Mikolajkie lake, Poland (130.66 gm²/year⁻¹); Devi, K. I. (1998) in the Utrapat lake, Manipur (2.97 – 265.46 gm²/year⁻¹); Devi, Ch. B. (2001) in Sanapat lake, Manipur (242.64 – 316.88 gm²/year⁻¹); Kumari and Arvindkumar (2002) in the different ponds of Jharkhand (4.52 – 54.11 gm²/year⁻¹); Devi, Ch. N. (2002) in Ikop lake, Manipur (2.07 – 137.13 gm²/year⁻¹); Devi, Kh. U. (2002) in Poiroupat lake, Manipur (214.47 – 384.02 gm²/year⁻¹) and Devi, L. G. and Sharma (2002) in the freshwater ecosystems of Canchipur, Manipur (2.23 – 104.26 gm²/year⁻¹).

Various ecologists have designated the freshwater lakes into different trophic levels based on the values of net primary productivity. According to Wetzel (1975) and Likens (1975) the lakes are designated as oligotrophic lakes when the production rate varies from 50.00 to 300.00 mg Cm⁻²·day⁻¹, mesotrophic lakes when the net primary productivity value varies from 250.00 – 1000.00 mg Cm⁻²·day⁻¹ and eutrophic lakes when the daily net primary productivity values reach 600.00 – 8000.00 mg Cm⁻²·day⁻¹. Rodhe (1969)
opined that the lakes having gross productivity over 75.00 gm$\text{Cm}^2\text{year}^{-1}$ are found to be naturally Eutrophic while the lakes having a gross productivity over 350.00 gm$\text{Cm}^2\text{year}^{-1}$ are culturally Eutrophic and highly polluted. The degree of cultural eutrophication has close relationship with high production rates as the cultural eutrophication is mainly caused by additional input of sewage borne phosphates and run-off nitrates from the catchment areas. Dodds (2002) also used the levels of productivity to signify different trophic status of lakes viz., Oligotrophic having productivity upto 300.00 mg $\text{Cm}^2\text{day}^{-1}$, Mesotrophic 300.00 – 600.00 mg $\text{Cm}^2\text{day}^{-1}$ and Eutrophic with productivity over 600.00 mg $\text{Cm}^2\text{year}^{-1}$. Likens (1973) opined that cultural eutrophication also sets in when the rate of net primary production exceeds 150.00 gm$\text{Cm}^2\text{year}^{-1}$ (equivalent to 300 gm dry matter m$^2$year$^{-1}$). Woodwell et al. (1978) also analysed the magnitudes of net primary productivity of major habitats of the biosphere where the lakes and streams recorded 200.00 gm$\text{Cm}^2\text{year}^{-1}$ while the swamps and marshes recorded 1350.00 gm$\text{Cm}^2\text{year}^{-1}$. From the above observations made by different authors, the Laisoipat lake in the present study having annual net primary productivity of 393.40 gm$^2\text{year}^{-1}$ to 631.71gm$^2\text{year}^{-1}$ may be regarded as culturally eutrophic lake which is highly polluted. The highly eutrophic nature of the lake is attributed to a number of factors such as human encroachment for paddy cultivation, overuse and misuse of chemical fertilizers, insecticides, pesticides and weedicides in the paddy cultivated areas. The practice of fish farming in and
around the lake where artificial feeds are used also increases the concentration of nutrients in the lakes. The occurrence of high magnitudes of productivity along with physico-chemicals characters of water as well as physiographic and morphometric characteristics reveal the Eutrophic nature of the Laisoipat lake under present investigation. To save and protect further deterioration of the Laisoipat lake, immediate remedial measures are required before further degradation and eutrophication takes place in the lake.

D. PHYSICO-CHEMICAL CHARACTERISTICS:

i. Surface water temperature:

The overall range of temperature varied from $12.67 \pm 0.58^\circ C$ to $31.33 \pm 0.29^\circ C$ during the tenure of two years. The maximum temperature were recorded during May to August and minimum temperature during January. The same trend of water temperature were also recorded by Vashisht (1968) in Sukhna lake, Chandigarh ($13.00^\circ C$ December – January to $32.00^\circ C$, June – July); Singh and Sahai (1986) in Gorakhpur ($14.40^\circ C$ in January to $33.33^\circ C$ in June); Shardendu and Ambasht (1988) in rural and urban tropical aquatic ecosystems, ($14.20^\circ C$ in winter to $29.30^\circ C$ in summer in rural and $14.90^\circ C$ in winter to $30.80^\circ C$ in summer in urban pond); Vyas (1968) in Pichhola lake, Udaipur ($17.80^\circ C$ January to $33.35^\circ C$ June); Yadava et al. (1987) in Dighali Beel, Assam ($18.00^\circ C$ January to $30.00^\circ C$ August – September); Papasteregiadou and Babalonas (1992) recorded the surface water temperature
ranging from 9.00°C (March) to 29.70°C (July) in the lake Kerkini, Greece. More or less similar ranges of temperature (27.10°C to 31.80°C) were also noticed by Singh (1983) in Surhatal lake, Varanasi; 23.00 – 30.00°C by Frempong (1995) in Bosumtwi lakes in Ghana, Venugopalan et al. (1998) in Kokilimedu lake (31.80°C) in Chennai. Antwi and Ofori – Danson (1993) recorded the surface water temperature ranging from 27.40°C to 32.00°C in Kpong reservoir in Ghana. Devi, N. B. (1993) recorded surface water temperature ranging from 15.00 ± 0.81°C to 29.00 ± 0.81°C in Loktak lake, Manipur; while Devi, O. I. (1993) recorded 11.00 to 28.00°C in Waithou lake, Manipur. Devi, K. I. (1998) recorded 15.50°C (January) to 30.30°C (July and September) in Utrapat lake while Devi, Ch. B. (2001) recorded 14.00 ± 0.28°C to 32.10 ± 0.14°C in Sanapat lake, Manipur.

ii. pH:

In the present study, the values of pH varied from 6.60 to 8.30 in the different study sites. Comparable values of pH have also been recorded in various fresh water bodies as reported by a number of authors viz., Vyas (1968) in Pichhola lake, Udaipur (7.40 to 8.30); Misra and Singh (1968) in the temporary pond of Varanasi (7.00 to 8.50); Maulood et al. (1979) in Arab (7.70 to 8.50); Billore and Vyas (1982) in Pichhola lake, Udaipur (7.46 to 8.64); Durani and Rout (1982) in Nandankanan lake (6.60 to 8.40); Verma et al. (1982) in Gujar lake (7.20 to 8.40); Singh and Sahai (1986) in Jalwania pond, Gorakhpur 97.00 to 8.60; Devi, O. I. (1993) in Waithou lake, Manipur (7.40 to
8.30); Devi, N. B. (1993) in Loktak lake, Manipur (6.00 to 9.30); Das and Sinha (1994) in river Ganga at Patna (7.00 to 8.60); Nazneen (1995) in lakes of Pakistan (6.50 to 8.00); Unni and Naik (1997) in the tropical river Narmada (6.20 to 8.30). Comparable values were also reported by many authors viz., Devi, K. I. (1998) in Utrapat lake, Manipur (6.28 to 8.88); Gupta and Singh (2003) in Varuna river (7.10 to 8.30); Ramasubramanian et al. (2004) in ground water around Sivakasi town (7.20 to 8.50); Narayana et al. (2005) in Basavanahole tank (7.10 to 8.30); Majumdar et al. (2006) in Lentic freshwater of North Cachar Hills, Assam (6.50 to 8.30).

Lower values were recorded by a number of authors viz., Yadava et al. (1987) in Dighali Beel, Assam (6.50 to 7.50); Banik and Chakraborti (1998) in the river Gomoti, Tripura (6.40 to 6.90); Thiebaut et al. (1998) in weakly mineralized streams in the Northern Vosges mountain, North East France (6.00 to 6.90); Thiebaut et al. (1998) in France (4.33 to 7.32); Devi, Kh. U. (2002) in Poiroupat lake, Manipur (5.00 ± 0.03 to 7.40 ± 0.05); Singh and Gupta (2004) in the river Yamuna, Mathura (6.90 to 7.60).

Higher values as compared to those in the present investigation were also reported by various workers viz., Serrano and Toja (1995) in Spain (4.00 to 10.60); Rajput et al. (2004) in Hatnur reservoir of Jalgaon (8.10 to 9.10); Kanungo et al. (2006) in Doodhadahri pond of Raipur, Chhattisgarh (8.60 to 9.60).
In the present investigation, the maximum values were recorded during April, 2007. This is in accordance with the other findings in the wetlands of other regions of India. Kaul and Handoo (1982) reported higher values of 8.20 to 9.20 during summer. Higher values of 8.10 were observed during summer by Kumar (1995) in May. The occurrence of maximum pH values may be due to the abundance of buffer substances in the rain water which is drained into the lakes from the adjoining areas during the rainy months.

iii. Secchi Transparency (Turbidity Index):

During the present investigation, the Secchi transparency varied from 11.00 ± 0.90 (April) to 105.66 ± 0.26 (January) cm in the first year and 10.93 ± 0.06 (May) to 144 ± 0.40 (November) cm in the second year. The overall values varied from 10.93 ± 0.06 to 144.40 ± 0.40 cm. In the first year, the highest transparency values were observed during January in all the study sites. This may be due to the significant decrease of phytoplankton populations in winter and the occurrence of suspended particles in this season and organic matter content were also substantially low in this season. In the second year, the highest transparency values were observed during November. The lowest transparency values were observed during April except in site I in the first year. During the second year, the minimum values were observed during May and July except in site III. The low transparency observed during late summer to mid rainy season may be attributed mainly to the luxuriant growth of the algal blooms. This is also substantiated by the occurrence of higher amounts of
suspended particles such as clay, silt and organic matters which get accumulated in the water through rainfall.

The values in the present study are found to be comparable with the values reported by various authors from different wetlands viz., Devi, K. I. and Sharma (2002) in Utrapat lake, Manipur (36.23 ± 0.25 to 107.93 ± 0.30 cm); Devi, Kh. U. (2002) in Poiroupat lake, Manipur (32.50 ± 0.76 to 142.30 ± 0.73 cm); Ara et al. (2003) in Dal lake, Kashmir (13.00 to 100.00 cm); Singh and Gupta (2004) in the river Yamuna in Mathura (103.00 to 185.00 cm). Lower values were reported by Devi, O.I. (1993) in Waithou lake, Manipur (15.00 to 45.00 cm); Devi, Ch. U. (2000) in fresh water ecosystems of Canchipur, Manipur (3.72 to 86.04 cm); Bebika (2001) in Sanapat lake, Manipur (12.25 to 77.50 cm); Devi, Ch. N. (2002) in Ilkop lake, Manipur (25.50 to 79.25 cm); Gupta and Singh (2003) in Varuna river, Varanasi (17.30 to 51.20 cm); Saxena et al. (2005) in river Sengar, Uttar Pradesh (17.50 to 50.50 cm); Devi, S.U. (2008) in Oksoipat lake, Manipur (19.00 ± 1.00 to 54.67 ± 0.76 cm). Higher values were reported earlier by various authors viz., Zutshi and Vass (1982) in Dal lake, Kashmir (30 to 500 cm); Billore and Vyas (1982) in Pichhola lake, Udaipur (520 to 1190 cm); Zutshi (1989) in Sivalik lake, Kashmir (275 to 500 cm); Costa and De Silva (1995) in Tissa Wewa reservoir in the dry zones of Srilanka (100 to 300 cm).

The present lake under study with the Secchi transparency ranging from 10.93 to 144 cm may be assigned to the Eutrophic category gradually
approaching towards Hypertrophic status (OECD, 1982; Nürnberg, 1996 and Dodds, 2002).

iv. Total Solute Content:

In the present investigation, the values of total solute content ranged from 40 to 600 mg/l (April, 2007). The occurrence of the maximum values of solute content may be due to the presence of large suspended particulates and dissolved solids which were brought down along with the heavy rainfall during April. The values observed in the present study are comparable with those of Sah et al. (2000) in the Narayani river in Nepal (273.07 to 420.50 mg/l); Devi, Ch. N. (2002) in Ikop lake, Manipur (40 to 600 mg/l); Bebika (2001) in Sanapat lake (70 to 790 mg/l); Devi, S. U. (2008) in Oksoipat lake (40 to 360 mg/l); Goel et al. (1980) in Shiv Doongri (300 to 600 mg/l). Higher concentrations as compared to those in the present study have been recorded by many authors viz., Sohani et al. (2001) in ground water of Nandurbar, Maharashtra (620 – 3420 mg/l); Khare (2002) in Satri Tank, Chhatarpus, Madhya Pradesh (408 to 1010 mg/l); Pandey et al. (2002) in Hamor pond of Kishangarh, Ajmer (948 to 4703 mg/l); Khanna and Bhutiani (2003) in Sitapur pond at Hardwar (402.73 ± 10.76 to 800.63 ± 13.20 mg/l); Aruchelvan et al. (2004) in wastewater from Bakelite industry, Tamil Nadu (2530 to 4120 mg/l).

Comparatively lower values of total solute contents were recorded by different workers viz., Ambasht (1970) in freshwater ecosystems of Varanasi (24 to 46 mg/l); Antwi and Ofori – Danson (1993) in the Pong reservoir in
Ghana (30.60 to 39.9 mg/l); Rao et al. (1996) in Narsingi pond (2.00 to 16.0 mg/l); Banik and Chakrabati (1998) in Gomoti river, Tripura (3.20 to 13.97 mg/l); Gupta and Singh (2003) in Varuna river, Varanasi (56 to 141 mg/l).

v. Electrical conductivity:

The values of electrical conductively in the present study ranged from 40 to 90 μ Scm⁻¹ in the different study sites. The present values of conductivity are very much comparable with those of Yadava et al. (1987) in Dighali Beel, Assam (53.80 to 97.00 μ Scm⁻¹); Thiebaut and Muller (1998) in streams in the Northern Vosges mountains North East, France (44 to 80 μ Scm⁻¹); Robach et al. (1996) in running waters, France (49 to 80 μ Scm⁻¹); Bebika (2001) in Sanapat lake, Manipur (40 to 180 μ Scm⁻¹); Devi, K. I. (2002) in Utrapat lake, Manipur (20 to 120 μScm⁻¹); Majumdar et al. (2006) in freshwater systems of North Cachar hills, Assam (4.80 to 78.10 μ Scm⁻¹).

The present observed values are lower as compared with those of Muli et al., (2000) in lake Victoria in Kenya (103.70 to 156.50 μ Scm⁻¹); Kulshrestha et al. (1989) in the river Kshipra (410 to 2200 μ Scm⁻¹); Venugopalan et al. (1998) from the Eutrophic Kokilemedu lake (3040 μ Scm⁻¹); Devi, Ch. N. (2002) in Ikop lake, Manipur (70 to 380 μ Scm⁻¹); Devi, Kh. U. (2002) in Poiroupat lake, Manipur (40 to 400 μScm⁻¹). Exceptionally low values as compared to the present findings were also reported by Suvarna and
Somashekar (1997) in the river Cauvery and its tributaries (0.21 to 2.10 m mol cm\(^{-1}\)); Matsuno and Hock (2000) in Embilikala lagoon, Sri Lanka (2.09 \(\mu\) Scm\(^{-1}\)).

vi. Free Carbon dioxide:

During the present study, the concentrations of dissolved free carbon dioxide ranged from 5.70 ± 0.06 mg l\(^{-1}\) (March, 2007) to 28.30 ± 0.15 mg l\(^{-1}\) (April, 2008). The findings in the present study are comparable with the data recorded by various workers viz., Devi, Ch. N. (2002) in Ikop lake, Manipur (0.20 to 23.00 mg l\(^{-1}\); Devi et al. (2005) in Nambol river (7.90 to 20.10 mg l\(^{-1}\); Yadava et al. (1987) in Dighali Beel, Assam (3.30 to 23.40 ppm).

In the present study, the maximum concentrations of CO\(_2\) were recorded during April, where the heavy rainfall were also occurred. It may be primarily due to the diffusion of atmospheric carbon dioxide into the rain water producing carbonic acid (Chakrabarty et al., 1959; Mathew, 1978; Moss, 1989 and Mansoori., 1995). It may also be due to the low photosynthetic activities of the aquatic macrophytes. Deoxygenation is also regarded to be one of the attributing factors (Talling, 1957). The occurrence of the high concentration of CO\(_2\) especially during the rainy season may indicate the overall Eutrophic nature of the lake. Increase in transparency and temperature in water is also found to correspond with the increase in CO\(_2\) concentration (Vyas, 1968).

The minimum concentrations of dissolved free CO\(_2\) were recorded during February and March during the present study. Shardendu and Ambasht (1988) also reported the same trend where the maximum value occurred in the
rainy season and the minimum during February and March. Devi, K. I. (1998) reported the minimum value (4.33 ± 0.58 mg/l) during January; Devi, O. I. (1993) also reported the minimum value (10.00 ppm) during December in Waithou lake, Manipur.

The present findings for dissolved free CO₂ were found to be lower as compared to those by a number of authors viz., Vyas (1968) in Pichhola lake, Udaipur (39.20 to 76.40 ppm); Sharma et al. (1978) in polluted freshwaters (0.00 – 51.00 mg/l) in Jaipur; Singh (1983) in Surha Tal lake, Varanasi (51.40 to 98.90 ppm); Unni (1984) in Badatal lake (0.00 to 88.00 ppm); Rao et al. (1982) in high altitude lake (0.00 to 36.00 mg/l) in Nainital; Devi, N. B. (1993) in Loktak lake, Manipur (1.00 to 39.33 mg/l); Shoukat Ara et al. (2003) in Dal lake, Kashmir (46.00 to 85.00 mg/l); Majumdar et al. (2006) in Lentic freshwater systems of North Cachar hills, Assam (0.90 to 66.00 mg/l); Devi, S. U. (2008) in Oksoipat lake, Manipur (6.67 ± 0.58 to 39.00 ± 1.00 mg/l).

The present findings are found higher when compared with those recorded by various workers viz., Billore and Vyas (1982) in Pichhola lake, Udaipur (0.00 to 7.80 mg/l); Kumar (1995) in tropical wetland of south Bihar (1.80 to 7.90 mg/l); Mihsra and Prasad (1997) in Goga Beel lake, Bihar (1.46 to 6.43 mg/l); Banik and Chakrabarti (1998) in river Gomoti, Tripura (7.50 to 10.90 mg/l); Devi, Ch. U. (2000) in freshwater ecosystems of Canchipur, Manipur (0.17 to 8.26 mg/l); Bebika (2001) in Sanapat lake, Manipur (0.17 to 8.26 mg/l); Pandey et al. (2002) in Hamor pond of Kishangarh, Ajmer (8.80 to
13.40 mg\textsuperscript{l}^{-1}); Khanna and Bhutiani (2003) in Sitapur pond at Hardwar, Uttaranchal (2003  ±  0.38 to 5.88  ±  0.35 mg\textsuperscript{l}^{-1}); Narayana et al. (2005) in Basavanahole tank, Karnataka (4.40 to 13.20 mg\textsuperscript{l}^{-1}); Saxena et al. (2005) in Sengar river, Uttar Pradesh (8.30 to 14.10 mg\textsuperscript{l}^{-1}).

vii. Dissolved Free Oxygen:

In the present study, the concentration of dissolved oxygen ranged from 1.40 ± 0.00 mg\textsuperscript{l}^{-1} (July 2008) to 9.60 ± 0.10 mg\textsuperscript{l}^{-1} (February, 2008). The findings in the present study are comparable with the data recorded from various freshwater bodies by various workers viz., Devi, O. I. (1993) in Waithou lake, Manipur (2.20 to 7.40 ppm) Devi, K. I. (1998) in Utrapat lake, Manipur (1.76 ± 0.05 to 8.98 ± 0.07 mg\textsuperscript{l}^{-1}); Bebika (2001) in Sanapat lake, Manipur (0.70 to 10.10 mg\textsuperscript{l}^{-1}); Devi, Ch. N. (2002) in Ikop lake, Manipur (1.10 ± 0.14 to 10.33 ± 0.14 mg\textsuperscript{l}^{-1}); Sah, et al. (2000) in Narayani river of Nepal (9.80 to 10.69 mg\textsuperscript{l}^{-1}); Gautam et al. (2000) in Ganga water at Rishikesh (8.00 to 10.00 mg\textsuperscript{l}^{-1}); Sohani et al. (2001) in Nandurbar, Maharastra (6.33 to 10.76 mg\textsuperscript{l}^{-1}); Rao et al. (2003) in Subansiri river, Assam (7.00 to 9.00 mg\textsuperscript{l}^{-1}).

In the present study, the maximum concentrations of dissolved oxygen were recorded during winter season while the minimum values were observed during the summer season. Similar trends were also observed by Verghese et al. (1992) in a polluted tropical pond where the maximum concentration of dissolved oxygen occurred during February and the minimum during August. Kumar (1995) reported maximum dissolved oxygen concentration during January (7.50 mg\textsuperscript{l}^{-1})
and the minimum (4.40 mg/l) during September in tropical wetlands of south Bihar. Kumar et al. (1996) also reported maximum values of dissolved oxygen during December (8.50 mg/l) while the minimum (3.75 mg/l) was recorded during July.

The occurrence of high concentrations of dissolved oxygen during winter season are largely attributed to low temperature rather than the photosynthetic activity of the phytoplankton because low temperature has a greater capacity to hold dissolved oxygen than warm water (Welch, 1951 and Vass and Langer. 1990). With the progression of winter, dissolved oxygen tends to increase gradually attaining its highest peak value during the winter. This may be due to the circulation by cooling resulting in the accumulation of dissolved oxygen in winter (Hannan, 1979). The decrease in water temperature during winter season probably results to a lower rate of respiration and hence the same produces maximum dissolved oxygen in this season (Gupta and Mehrotra, 1986). The low values in summer may be consequential of a number of processes such as high uptake of oxygen by bacteria, a faster decomposition of organic matter and the rapid rate of respiration of the micro-organisms (Golterman, 1993). The concentration of dissolved oxygen tends to decrease as summer progresses due to high temperature (Agarwal et al., 1976; Hannan, 1979). The decomposition of organic matter is an important factor in the warm weather (Morrissette and Mavini, 1976).
The present values of dissolved free oxygen are found to be higher than those recorded by Venugopalan et al. (1998) in Kokilimedu lake, Chennai (5.00 mg l\(^{-1}\)); Gupta and Singh (2003) in Varuna river, Varanasi (2.10 to 6.00 mg l\(^{-1}\)); Singh and Gupta (2004) in river Yamuna, Mathura (3.50 to 5.90 mg l\(^{-1}\)); Babu and Puttaiah (2005) in Tarkikere Taluk, Karnataka (3.55 to 6.05 mg l\(^{-1}\)); Kanungo et al. (2006) in Doodhadahri pond, Raipur, Chhatisgarh (3.10 to 6.80 mg l\(^{-1}\)).

The present findings were found lower when compared with those recorded by various workers viz., Devi, Ch. U. (2000) in freshwater ecosystems of Canchipur, Manipur (0.18 to 14.54 mg l\(^{-1}\)). Khare (2002) in Satri Tank, Chhatarpur (0.45 to 14.60 mg l\(^{-1}\)) and Khabade et al. (2002) in Lodhe water reservoir, Maharashatra (5.70 to 13.80 mg l\(^{-1}\)); Narayana et al. (2005) in Basavanahole tank, Karnataka (2.36 to 15.40 mg l\(^{-1}\)); Devi, S. U. (2008) in Oksoipat lake, Manipur (0.87 ± 0.12 to 11.53 ± 0.12 mg l\(^{-1}\)).

viii. Total Alkalinity:

During the present study the values for total alkalinity varied from 17.30 ± 0.06 mg l\(^{-1}\) (November, 2008) to 57.70 ± 0.06 mg l\(^{-1}\) (May, 2008). The findings in the present study are comparable with the values recorded by many authors viz., Devi, K. I. and Sharma (2002) in Utrapat lake, Manipur (19.73 ± 0.23 to 55.20 ± 0.34 mg l\(^{-1}\)); Narayana et al. (2005) in Basavanahole tank, Karnataka (10.00 60.00 mg l\(^{-1}\)); Ofori-Danson and Antwi (1994) in Volta lake (40.20 mg l\(^{-1}\)). Moyle (1945) designated the lakes as soft lake having alkalinity
value up to 40 mg\text{\textperthousand} l^{-1}; medium lake having alkalinity up to 90 mg\text{\textperthousand} l^{-1} and hard lake exhibiting over 90 mg\text{\textperthousand} l^{-1} of alkalinity. According to this scheme of classification the lake in the present study may be designated as medium lake category.

The values reported in the present study are found lower as compared to the values reported by a number of authors \textit{viz.}, Billore and Vyas (1982) in Pichhola lake (257.40 to 429.00 mg\text{\textperthousand} l^{-1}); Unni (1984) in Badatal reservoir (40.00 to 68.00); Kulshrestha \textit{et al.} (1989b) in Mansarover reservoir (121.50 to 256.00 mg\text{\textperthousand} l^{-1}); in Nandurbar, Khabade \textit{et al.} (2002) in Lodhe water reservoir, Maharastra (215.00 to 500.00 mg\text{\textperthousand} l^{-1}); Khanna and Bhutiani (2003) in Sitapur pond at Hardwar (215.70 ± 1.69 to 367.30 ± 5.32 mg\text{\textperthousand} l^{-1}); Rajput \textit{et al.} (2004) in Hatnur reservoir of Jalgaon, Maharastra (161.00 to 278.40 mg\text{\textperthousand} l^{-1}); Babu and Puttaiah (2005) in Tarikere Taluk, Karnataka (14.70 to 913.00 mg\text{\textperthousand} l^{-1}); Kanungo \textit{et al.} (2006) in Doodhadahri pond of Raipur, Chhattisgarh (233.20 to 297.00 mg\text{\textperthousand} l^{-1}); Devi, S. U. (2008) in Oksoipat lake, Manipur (10.67 ± 1.15 mg\text{\textperthousand} l^{-1} to 101.33 ± 0.58 mg\text{\textperthousand} l^{-1}).

\textbf{ix. Total Hardness:}

The values for total hardness of water varied from 17.40 ± 0.06 (September, 2008) to 110.00 ± 0.10 mg\text{\textperthousand} l^{-1} (October, 2008) in all the study sites. The findings in the present study are comparable with the values recorded by many authors \textit{viz.}, Nandan and Galankan (2000) in Unapdeo thermal spring, Maharastra (40 to 120 mg\text{\textperthousand} l^{-1}); Negi \textit{et al.} (2001) in some aquifers in Himalaya
(34.00 to 140.00 mg/l$^{-1}$); Baruah and Baruah (2003) in Subangiri river (35.00 to 100.00 mg/l$^{-1}$); Devi, S. U. (2008) in Oksoipat lake, Manipur (22.00 ± 0.00 to 116.00 ± 4.00 mg/l$^{-1}$).

The values in the present study are found to be comparatively higher than those reported by various authors from different wetlands viz., Devi, K. I. and Sharma (2002) in Utrapat lake, Manipur (8.70 to 37.93 mg/l$^{-1}$); Unni (1984) in Badatal reservoir (40.00 to 68.00 ppm); Abbasi et al. (1996) in Kuttiadi lake (5.00 to 18.00 ppm); Thiebaut et al. (1998) in running waters of France (0.30 to 0.60 mg/l$^{-1}$); Narayana et al. (2005) in Basavanahole tank (20.00 to 44.00 mg/l$^{-1}$).

The values in the present study are found lower when compared with the values reported by various workers viz., Devi, Kh. U. (2002) in Poirupat lake, Manipur (30.00 ± 0.23 to 974.00 ± 0.60 mg/l$^{-1}$); Sohani et al. (2001) in the water samples of Nandurbar, Maharastra (344 to 1388 mg/l$^{-1}$); Khabade et al. (2002) in Lodhe reservoir in Maharastra (94 to 260 mg/l$^{-1}$); Mishra and Patel (2002) in Hamor pond of Kishangarh, Ajmir (1092 to 2100 mg/l$^{-1}$); Rao et al. (2003) in Kolleru lake (175 to 495 ppm); Sharma and Verma (2003) in Hamirpur springs, Himalayas (100 to 340 mg/l$^{-1}$); Khanna and Bhutiani (2003) in Sitapur pond at Hardwar (239.61 ± 0.51 to 293.67 ± 1.66 mg/l$^{-1}$); Singh and Gupta (2004) in river Jamuna at Mathura (516 to 600 mg/l$^{-1}$); Mathivanan et al. (2004) in river Cauvery (122 to 232 mg/l$^{-1}$); Kumar and King (2004) in groundwater at Visakhapatnam (100 to 998.01 mg/l$^{-1}$); Babu and Puttaiah (2005) in Tarikere Taluk water, Karnataka (85 to 1775 mg/l$^{-1}$); Kanungo et al. (2006) in
Doodhadahri pond of Raipur, Chhattisgarh (168.40 to 246.20 mg/l); Harikumar et al. (2006) in Kol wetland (16 to 1120 mg/l).

x. Chloride:

During the present investigations the chloride contents of the water ranged from 10.93 ± 0.06 (May, 2008) to 75.69 ± 0.06 mg/l (October, 2008). The findings in the present study are comparable with the values recorded by many workers viz., Rajput et al. (2004) in Hatnur reservoir of Jalgaon, Maharashtra (24.20 to 90.20 mg/l); Kulshretha et al. (1989b) in Mansarover reservoir, Bhopal (49.60 to 99.40 mg/l); Devi, Kh.U. (2002) in Poiroupat lake, Manipur (12.80 ± 0.10 to 75.20 ± 0.14 mg/l).

The values of chloride contents in the present study are found higher than those reported by various authors in the different wetlands viz., Devi, K. I. (1998); Devi, K. I. and Sharma (2002) in Utrapat lake, Manipur (5.96 to 28.59 mg/l); Antwi and Otóri-Danson (1993) in Kpong reservoir, Ghana (4.61 to 14.46 mg/l); Abbasi et al. (1996) in Kuttiadi lake (4.50 to 11.80 ppm); Thiebaut et al. (1998) in stream water, France (2.96 to 5.02 mg/l); Negi et al. (2001) in aquifers of Himalaya (3.00 to 25.00 mg/l); Baruah and Baruah (2003) in Subansiri river (5.00 to 7.00 mg/l); Nayarana et al. (2005) in Basavanahole tank, Karnataka (8.00 to 18.43 mg/l). Higher values of chloride concentrations were reported by Rana and Nirmal Kumar (1992) in Tarapur pond (85 to 315 mg/l); Sharma et al. (2001) in wetlands of Birbhum district, West Bengal (22.70 to 285.80 mg/l); Sohani et al. (2001) in Nandurbar,
Macrophyte Ecology of Laisoipat lake

Maharastra (93.72 to 438.78 mg l\(^{-1}\)); Pandey \textit{et al.} (2002) in Hamor pond, Ajmer (330.15 to 442.63 mg l\(^{-1}\)); Rao \textit{et al.} (2003) in Kolleru lake (7.10 to 27.69 mg l\(^{-1}\)); Ramasubramanian \textit{et al.} (2004) in Ground water of Sivakasi town, Tamil Nadu (900 to 1276 mg l\(^{-1}\)); Prasana and King (2004) in Ground water of Visakhapatnam (107.12 to 714.97 mg l\(^{-1}\)); Babu and Puttaiah (2005) in Tarikere Taluk water, Karnataka (25.65 to 750 mg l\(^{-1}\)); Harikumar \textit{et al.} (2006) in Kol wetland, Kerala (18.00 to 6500 mg l\(^{-1}\)); Devi, S. U. (2008) in Oksoipat lake, Manipur (9.94 ± 1.42 to 100.35 ± 2.17 mg l\(^{-1}\)).

E. CO-RELATIONSHIPS:

The possible statistical relationships have been worked out among the various data of the physico-chemical parameters of water and biomass and productivity of the macrophytes of the lake.

\textbf{a) Relationships amongst the physico-chemical parameters of water:}

The possible relationships among the various parameters \textit{viz.}, Dissolved O\(_2\) vs Alkalinity, Free CO\(_2\) vs Chloride, Temperature vs Conductivity, pH vs Conductivity, pH vs Hardness and Turbidity vs TDS were assessed through correlation and regression analysis.

Positive relationships were evident between Dissolved oxygen and Free Carbondioxide, Temperature and Dissolved O\(_2\) in all the study sites. Both Turbidity and TDS and Free CO\(_2\) and Chloride showed negative relationship in
all sites except in site I. the values of ‘r’ and allometric equations have been
furnished in Table 25 and Fig. 6(a – e).

b) Relationships amongst Biomass and the various parameters of water:

Positive and negative relationships were evident amongst the biomass
and the various parameters of water. Positive correlations were observed
between Biomass and Depth in all the study sites. Biomass and Free Carbon
Dioxide showed positive relationship except in site IV. Negative cor-
relations were evident between Biomass and Dissolved oxygen while
Biomass and Temperature showed positive relationship in two sites (site II and
Site IV). The value of ‘r’ have been set in Table 26.

c) Relationships amongst net primary productivity and the various
parameters of water:

In all the study sites, positive relationship was observed between Net
Primary Productivity and Temperature. Biomass and pH showed negative
relationship in all sites except site IV. Negative relationship between NPP and
Turbidity index was observed in all sites except site III. The values of ‘r’ and
allometric equations have been furnished in Table 27 and Fig. 7(a – c).

Similar significant relationships among the various physico-chemical
characters of water as well as biomass and net primary productivity and various
parameters of water have been recorded earlier by many authors in Loktak lake,
Table 25: Relationship amongst the various parameters of water (Figures in parenthesis indicate levels of significance)

<table>
<thead>
<tr>
<th>Variables</th>
<th>Sites</th>
<th>Correlation Coefficient</th>
<th>Allometric Equations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dissolved Oxygen</td>
<td>I</td>
<td>r = 0.072</td>
<td></td>
</tr>
<tr>
<td>VS</td>
<td>II</td>
<td>r = 0.124</td>
<td></td>
</tr>
<tr>
<td>Total Alkalinity</td>
<td>III</td>
<td>r = 0.154</td>
<td></td>
</tr>
<tr>
<td>IV</td>
<td>r = 0.139</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Free Carbon dioxide</td>
<td>I</td>
<td>r = 0.086</td>
<td></td>
</tr>
<tr>
<td>VS</td>
<td>II</td>
<td>r = -0.029</td>
<td></td>
</tr>
<tr>
<td>Chloride</td>
<td>III</td>
<td>r = -0.159</td>
<td></td>
</tr>
<tr>
<td>IV</td>
<td>r = -0.163</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Temperature</td>
<td>I</td>
<td>r = 0.248</td>
<td></td>
</tr>
<tr>
<td>VS</td>
<td>II</td>
<td>r = 0.219</td>
<td></td>
</tr>
<tr>
<td>Conductivity</td>
<td>III</td>
<td>r = 0.367</td>
<td></td>
</tr>
<tr>
<td>IV</td>
<td>r = 0.289</td>
<td></td>
<td></td>
</tr>
<tr>
<td>pH</td>
<td>I</td>
<td>r = 0.228</td>
<td></td>
</tr>
<tr>
<td>VS</td>
<td>II</td>
<td>r = 0.089</td>
<td></td>
</tr>
<tr>
<td>Conductivity</td>
<td>III</td>
<td>r = 0.108</td>
<td></td>
</tr>
<tr>
<td>IV</td>
<td>r = 0.124</td>
<td></td>
<td></td>
</tr>
<tr>
<td>pH</td>
<td>I</td>
<td>r = 0.437 (0.05)</td>
<td>Y = -176.98 + 30.844 X</td>
</tr>
<tr>
<td>VS</td>
<td>II</td>
<td>r = 0.005</td>
<td></td>
</tr>
<tr>
<td>Hardness</td>
<td>III</td>
<td>r = 0.211</td>
<td></td>
</tr>
<tr>
<td>IV</td>
<td>r = 0.243</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dissolved Oxygen</td>
<td>I</td>
<td>r = -0.234</td>
<td></td>
</tr>
<tr>
<td>VS</td>
<td>II</td>
<td>r = -0.366</td>
<td></td>
</tr>
<tr>
<td>Free Carbon dioxide</td>
<td>III</td>
<td>r = -0.233</td>
<td></td>
</tr>
<tr>
<td>IV</td>
<td>r = -0.293</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Temperature</td>
<td>I</td>
<td>r = -0.457 (0.05)</td>
<td>Y = 9.1568 − 0.2185 X</td>
</tr>
<tr>
<td>VS</td>
<td>II</td>
<td>r = -0.499 (0.01)</td>
<td>Y = 8.1017 − 0.1773 X</td>
</tr>
<tr>
<td>Dissolved Oxygen</td>
<td>III</td>
<td>r = -0.436 (0.05)</td>
<td>Y = 7.0534 − 0.1276 X</td>
</tr>
<tr>
<td>IV</td>
<td>r = 0.349</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Turbidity</td>
<td>I</td>
<td>r = 0.4260 (0.05)</td>
<td>Y = 60.639 + 2.0444 X</td>
</tr>
<tr>
<td>VS</td>
<td>II</td>
<td>r = -0.138</td>
<td></td>
</tr>
<tr>
<td>TDS</td>
<td>III</td>
<td>r = -0.061</td>
<td></td>
</tr>
<tr>
<td>IV</td>
<td>r = -0.109</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table 26: Relationship between Biomass and the various parameters of water (Figures in parenthesis indicate levels of significance)

<table>
<thead>
<tr>
<th>Variables</th>
<th>Sites</th>
<th>Correlation Coefficient</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biomass Vs Depth</td>
<td>I</td>
<td>r = 0.254</td>
</tr>
<tr>
<td></td>
<td>II</td>
<td>r = 0.251</td>
</tr>
<tr>
<td></td>
<td>III</td>
<td>r = 0.345</td>
</tr>
<tr>
<td></td>
<td>IV</td>
<td>r = 0.199</td>
</tr>
<tr>
<td>Biomass Vs Free Carbondioxide</td>
<td>I</td>
<td>r = 0.073</td>
</tr>
<tr>
<td></td>
<td>II</td>
<td>r = 0.163</td>
</tr>
<tr>
<td></td>
<td>III</td>
<td>r = 0.139</td>
</tr>
<tr>
<td></td>
<td>IV</td>
<td>r = -0.193</td>
</tr>
<tr>
<td>Biomass Vs Dissolved Oxygen</td>
<td>I</td>
<td>r = -0.220</td>
</tr>
<tr>
<td></td>
<td>II</td>
<td>r = -0.348</td>
</tr>
<tr>
<td></td>
<td>III</td>
<td>r = -0.059</td>
</tr>
<tr>
<td></td>
<td>IV</td>
<td>r = -0.077</td>
</tr>
<tr>
<td>Biomass Vs Temperature</td>
<td>I</td>
<td>r = -0.062</td>
</tr>
<tr>
<td></td>
<td>II</td>
<td>r = 0.027</td>
</tr>
<tr>
<td></td>
<td>III</td>
<td>r = -0.336</td>
</tr>
<tr>
<td></td>
<td>IV</td>
<td>r = 0.058</td>
</tr>
</tbody>
</table>

Table 27: Relationship between Net Primary Productivity and Physico-Chemical parameters of water. (Figures in parenthesis indicate levels of significance)

<table>
<thead>
<tr>
<th>Variables</th>
<th>Sites</th>
<th>Correlation Coefficient</th>
<th>Allometric Equations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Net Primary</td>
<td>I</td>
<td>r = 0.476 (0.05)</td>
<td>Y = 19.759 + 1.8508 X</td>
</tr>
<tr>
<td>productivity Vs</td>
<td>II</td>
<td>r = 0.646 (0.01)</td>
<td>Y = 19.043 + 2.3887 X</td>
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<tr>
<td>Temperature</td>
<td>III</td>
<td>r = 0.277</td>
<td></td>
</tr>
<tr>
<td></td>
<td>IV</td>
<td>r = 0.314</td>
<td></td>
</tr>
<tr>
<td>Net Primary</td>
<td>I</td>
<td>r = -0.259</td>
<td></td>
</tr>
<tr>
<td>productivity Vs</td>
<td>II</td>
<td>r = -0.272</td>
<td></td>
</tr>
<tr>
<td></td>
<td>III</td>
<td>r = -0.343</td>
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</tr>
<tr>
<td></td>
<td>IV</td>
<td>r = 0.045</td>
<td></td>
</tr>
<tr>
<td>Net Primary</td>
<td>I</td>
<td>r = -0.505 (0.01)</td>
<td>Y = 48.439 - 9.2985 X</td>
</tr>
<tr>
<td>productivity Vs</td>
<td>II</td>
<td>r = -0.354</td>
<td></td>
</tr>
<tr>
<td></td>
<td>III</td>
<td>r = 0.266</td>
<td></td>
</tr>
<tr>
<td>Turbidity</td>
<td>IV</td>
<td>r = -0.206</td>
<td></td>
</tr>
</tbody>
</table>
Fig. 6a: Relationship between pH and Hardness (mg/l)

\[ Y = -176.98 + 30.844x \]
\[ r = 0.437 \]
Fig. 6b-d: Relationship Temperature (°C) and Dissolved O₂ (mg/l)
Fig. 6e: Relationship between Turbidity (cm) and TDS (mg/l)

\[ y = 60.639 + 2.0444x \]
\[ r = 0.426 \]
Fig. 7a and b: Relationship between NPP (gm$^{-2}$) and Temperature (°C)
Fig. 7c: Relationship between NPP (gm$^{-2}$) and Turbidity (cm)

\[ Y = 48.874 - 9.4381x \]

\[ r = 0.505 \]