CHAPTER VI- DISCUSSION AND CONCLUSION
Physico-chemical properties of water

Analysis of physico-chemical properties of water is essential and it has a great bearing on the explanation and metabolism of the aquatic ecosystems (Kumar, 2002). This is the first scientific study on the diversity of aquatic insects in lentic (Keibul Lamjao National Park) and lotic (River Nambol, River Moirang and River Nambul) systems of Manipur in relation to physico-chemical properties of water. The study revealed that mean DO values in both the years in all the sites were below standard limits (5 mg/l) of WHO (2004). Lowest DO recorded in the sites of Keibul Lamjao National Park may be due to stagnant conditions that prevent mixing. High natural organic levels will often cause a depletion of dissolved oxygen. Exposure to less than 2 mg/l of oxygen for one to four days may kill most of the aquatic life in a system. Prolonged exposure to low dissolved oxygen levels (less than 5 to 6 mg/l oxygen) may not directly kill an organism, but will increase its susceptibility to other environmental stresses (KDHE, 2010).

Comparison of the yearly mean values of different parameters of all the sites revealed that in both the years, mean pH (6.5 – 8.5), Cl\(^-\) (250 mg/l), NO\(_3\)\(^-\) (45 mg/l), TDS - (500 mg/l) in all the sites were within the permissible limits of WHO (2004). The mean Conductivity (340±95.5 μS/cm) recorded in the first year was beyond the WHO (2004) limits of 300 μS/cm. In both the years mean Fe, Pb and Hg in the different sites were beyond the permissible limits of 0.3 mg/l, 0.1 mg/l & 0.001 mg/l, respectively (WHO, 2004). (Table: 43 & 44).

Among all the sites, in the first year (2009-2010) highest conductivity (340±95.5 μS/cm), B.O.D (7.7±5.2 mg/l), TA (121.2±26.6 mg/l), TDS (107.5±35.4 mg/l), pH (7.3±0.97), Cl\(^-\) (32.5±7.5 mg/l), Salinity (58.7±0.25 mg/l), NO\(_3\)\(^-\) (0.55±0.26 mg/l), PO\(_4\)\(^3-\) (0.40±0.31 mg/l), Na (14.2±4.8 mg/l), K (6.6±1.4 mg/l), Fe (0.64±0.19 mg/l), Pb (0.48±0.40 mg/l), Hg (0.07±0.21 mg/l) were recorded in S8 (Table 43). In the second year, (2010-2011) also highest conductivity (340±95.5 μS-1 cm), TDS - (95.8±54 mg/l), pH (7.3±3.8), B.O.D (5.3±3 mg/l), TA (128.9±72 mg/l), Cl\(^-\) (36.7±20.2 mg/l), Salinity (95.9±1.8 mg/l), NO\(_3\)\(^-\) (0.22±0.12 mg/l), PO\(_4\)\(^3-\) (0.17±0.09 mg/l) Na (9.5±5.4
mg/l), K (5.2±3 mg/l), Pb (0.03±0.02 mg/l), Hg (0.002±0 mg/l) were recorded in S8. (Table 44). Further in S8 the highest recorded values of all the parameters were higher in the first year than that of second year.

A significant positive correlation of CI with Na, K, BOD in both the years in all the sites is supported by the findings of several workers (Venkatesharaju et al., 2010; Sharma et al., 2012; Thirupathaiah et al., 2013). Positive correlation observed between pH and sodium in all the sites except in S3 and S8 in first and second year is supported by the findings of Lena et al., (2012) in different ecosystems of Yercaud Hills, Eastern Ghats, South India. A positive correlation of air temperature with water temperature during both the years in all the sites indicated that air temperature plays an important role in the heat budget of the study sites. It is supported by the findings of Amaal and Abdel (2005) in the main channel of the River Nile and by Livingstone and Lotter (1998) in lakes of the Swiss plateau. PO₄³⁻ showed significant positive relationship with total dissolved solids (TDS) in all the sites in both the years which was in confirmation with the findings of Shinde et al., (2011) in Kham river, Aurangabad District (MS, India) and Pattusamy et al., (2013) in Bellandur Lake, Urban Bangalore, Karnataka, India.

A one-way ANOVA test revealed a statistically significant difference on physico-chemical parameters of water between different sites F=9.541, p=.000 (Table 108 and 109). This may be due to different habitat type and physico-chemical composition of the selected study sites as shown by Hamilton IV et al., (2012) in Temporary Surface Waters of Northern Stark County, Ohio.

**Monthly variation in different sites**

Monthly variations of different parameters in eight study sites are shown in Table (1) to Table (40) during first year (2009-2010) and second year (2010-2011).

S1 (KLN)
not undergo drastic changes in a year in lacustrine environments (Egborge, 1970; Gupta and Gupta, 2006; Akinyemi and Nwankwo, 2006) as compared to fluviatile environments. Water temperature is of enormous significance, as it regulates various physico-chemical and biological activities (Raney and Menzel, 1969). In the present study water temperature and air temperature were found to have similar trend in both the years. The water temperature (14.96± 0.51°C to 32± 0. °C) recorded in the first year is very much comparable with the findings of Meetei (2005) in Loktak Lake, Manipur (16.10 ± 3.8°C to 32.67 ± 0. °C). From these observations it could be understood that the surface water temperature is governed by atmospheric temperature (Puthiya et al., 2009).

Secchi transparency was maximum during September and minimum during June in both the years. The Secchi disc transparency is essentially a function of the reflection of light from its surface and is therefore influenced by the absorption characteristics of both the water and its dissolved particulate matter (Stepanek, 1959; Elster and Stepanek, 1967; Sczepanski, 1968) especially in productive water. The lowest transparency value observed during June could be attributed to the presence of large amounts of suspended particles such as clay silt and organic matters that were brought during monsoon. Variation in the lowest depth of water in the two years was prominent. While it was minimum during December in the first year due to absence of rainfall in December, it was minimum during May in the second year.

The highest values of conductivity were recorded during May and September in the subsequent years while lowest in June in both the years. Conductivity is a good and rapid method to measure the total dissolved ions and is directly related to total solids. Higher the values of dissolved solids, greater the amount of ions in water (Bhatt et al., 1999). In Chini Lake in Pahang, Malaysia TDS values were recorded maximum in rainy season (Islam et al., 2012). Measurement of pH gives the intensity of acidic or basic nature of water. pH value was recorded minimum in November (6.23± 0.01) and maximum in June (7.88± 0.08) in the first year. Fluctuation of pH was very less during second year, minimum in December (7.2± 0.01) and maximum in September (7.3±0.03). Changes in the pH of water may be the result of various biological activities (Gupta et al., 1996). The factors
like photosynthetic activity, respiratory activity, exposure to air, temperature and disposal of sewage etc. bring about changes in pH (Saxena, 1987).

The maximum concentration of free carbon dioxide ($5.46 \pm 0.05 \text{ mg l}^{-1}$) recorded during first year was within the tolerable limit i.e. $10 \text{ mg l}^{-1}$ for fish production (APHA, 2005).

The maximum free CO$_2$ value recorded during winter is supported by the findings of Manjare et al., (2010) in Tamdalge Tank in Kolhapur District, Maharashtra. Very high concentration of free carbon dioxide ($58.2 \pm 0.2 \text{ mg l}^{-1}$) during dry season in the second year agreed with the observation of Renn (1968) who said that CO$_2$ is released at high levels during low oxygen production. The mean range of CO$_2$ was found above the tolerable limit for fish production (APHA, 2005). Dissolved oxygen concentration were recorded maximum ($7.54\pm0.05$) and minimum ($1.44\pm0.05$) in the first year while maximum ($9.02\pm0.02$) and minimum value ($0.9\pm0.3$) in the second year. The minimum value recorded was much much below $5 \text{ mg} l^{-1}$. It is known that $5 \text{ mg} l^{-1}$ of DO for at least 16 hours of the day is the minimum requirement for maintenance of aquatic life in any water body (Abegaz, 2005). BOD was recorded minimum during January and maximum during August in the first year while minimum in February and maximum in December in the second year. When BOD levels are high, dissolved oxygen (DO) levels decrease. Maximum BOD recorded in winter season during second year is supported by the findings of Hardikar and Acharya, (2013) in Fresh Water Bodies Of Ahmedabad City, Gujarat. The low value of B.O.D in February may be due to the less rainfall recorded in this month during second year. The lowest value recorded ($1.54 \text{ mg l}^{-1}$) during winter season is similar with the findings of Anyanwu (2012) in Ogba River, Benin City, Nigeria.

Total alkalinity was recorded minimum in September ($9.6 \pm 0.57$) and maximum in April ($130 \pm 10$) in first year and minimum in February and maximum in August in second year. The minimum value recorded ($61.7\pm2.9$) in February in second year is supported by the findings of Khan et al.,(2012) in Triveni lake of Amravati district of Maharashtra. Freshwater having a total alkalinity of $40 \text{ mg l}^{-1}$ or more are productive (Moyle, 1945) and alkalinity below $20 \text{ mg l}^{-1}$ is definitely indicative of low production. So the site may be assumed as productive in the
second year. The maximum values of chloride recorded during summer season (24.08 ± 0.07 mg/l) in the first year is supported by the findings of Arafat et al. (2008) in Ullal lake in Bangalore. The concentration of salinity was minimum in September in both the years while maximum was recorded during April to June in the first year. In the second year maximum was recorded in August. The maximum salinity values recorded during rainy season in the second year is supported by the findings of Nambirajan et al., (2012) in lower Anicut reservoir Thiruvvidaimaruthur taluk in Tanjore District, Tamil Nadu, India. Salinity acts as a limiting factor in distribution of flora and fauna. Minimum Sodium during October and maximum in November in the first year and minimum during November and maximum in July in the second year was recorded in this site. Potassium (K) content was found maximum in July in both the years. It was due to surface water run off of decomposed plant materials from surrounding area of the site during monsoon which increased the concentration of potassium in the water. High values recorded during rainy season in the present study is supported by the findings of Garg et al.,(2008) in Ramsagar reservoir, Datia, Madhya Pradesh. During second year of the study period, lower potassium content was recorded in winter season. Sedimentation and utilization of potassium by biota caused decrease in its content during winter season (Garg et al., 2006 a,b).

The maximum concentration of Phosphate was recorded during winter (0.98± 0.01 mg/l), in first year and (0.04±0.002 mg/l) during post-monsoon in second year. Nitrate content was recorded minimum in November and maximum in January in the first year while minimum value was recorded in April and maximum in August in the second year. In both the years values were much below the standard limit of 45 mg/l of WHO (1984). The maximum value recorded during August in second year is supported by the findings of Patil et al., (2011) at Lotus lake in Maharashtra State of India which they have attributed to agitation of water during monsoon. The significant source of nitrates are chemical fertilizers from cultivated lands, drainage from livestocks feeds as well as from domestic sources.

The highest concentration of Iron (0.8mg/l) exceeded the standard limit (0.3mg/l) of dissolved iron prescribed by WHO (1984). The maximum value of
Lead (0.51 mg/l) in the present study exceeded the recommended MCL 0.0015 mg/l value for Pb (USEPA, 2010). The United States Environmental Protection Agency has classified Pb as being potentially hazardous and toxic to most forms of life (USEPA, 1986). Mercury (0.01 ± 0 mg/l) was recorded only during September and October in the first year while it was nil in the second year. High concentration of Hg could pose an ecological hazard, leading to contamination of plants, aquatic resources and bioaccumulation in the food chain.

When mercury-based compounds are used as catalysts in dye manufacturing, there is a possibility of its presence as trace residue. As a result of extensive use of dyes and pigments throughout the world, toxic metals associated with the dyes and pigments inevitably reach to aquatic environments, and pose serious treats to aquatic lives and the system unless textile effluent is treated properly. (Waranusantigul et al., 2003). Women of Manipur practiced dyeing yarns and fabrics using natural dyes. However this traditional process is no longer in use. As reported by local dyers vat and napthol dyes for cotton and sulphur dyes are used since they added variety of shades and hues. Vat and napthol dyes were used to dye expensive cotton yarn and direct dyes to dye low grade cotton yarns. Silk was dyed with acid dyes (Pandya and Thoudam, 2010). Textile dye effluents are complexes, containing a wide variety of dyes, natural impurities extracted from the fibers and other products such as acids, alkalis, salts and sometimes heavy metals (Laing, 1991). The weavers recently started dyeing threads by themselves with the easily available chemical dyes (Ningombam et al., 2012). These may be also one be the reason for the high levels of Mercury recorded in the study sites. Heavy metals like Mercury and Lead are constituents of some dyes and pigments. Mercury is also emitted in aqueous waste of research laboratories and even hospitals.

Mercury sulfide has been incorporated into organic pigments used to make paints and inks. The mercury is primary found in the red (vermilion) color family. The use of vermilion with a powder called sindoor in religious temples in Manipur may also contribute to the addition of Mercury in aquatic systems. Mercury is present in coal and petroleum products and is released into the atmosphere by burning of fossil fuels, such as gasoline, coal, and oil. The use of Mercury in gold
plating in jewellery stores in Manipur is also one of the anthropogenic sources of Mercury and may contribute to the detection of high Mercury in the study site.

According to the Pearson Correlation Coefficient analysis AT showed significant positive correlation with DO in both the years which is supported by the findings of Islam et al., (2012) in Chini Lake, Pahang, Malaysia (Table 92 &93). DO showed significant negative correlation with Conductivity and TDS in the first year which is in agreement with the finding of Patra et al., (2010) in Santragachi and Joypur Jheel, W.B., India. The transparency was found to show negative significant correlation with TA and Chloride in the first year (Table 92).

**Site 2 (S2) (KLNP)**

Air and water temperature recorded is similar to site 1(S1). High transparency values 63.10 ±0.10 cm and 133.3 ± 1.1 cm were obtained during September in both the years consequently. Lowest transparency values 27.16 ±0.28 cm and 38±0.3 cm were recorded during February and August in first and second year, respectively. The findings are higher than the values reported by Vashisht (1968) in Sukhna lake, Chandigrah (15 to 68 cm). Transparency values between 14 to 100 cm were also obtained in the various lagoons of Ghana (Frempmong, 1995). Maximum TDS value was recorded during April and minimum during January in the first year while maximum (86.7±5.8mg/l) during August and minimum (43.3±5.8mg/l) during February in the second year. The high values during rainy season in the second year indicated allochthonous origin of dissolved materials through in-coming flood water.

Minimum DO (2.05 ± 0 mg/l) was recorded during August and maximum (5.14 ± 0.05 mg/l) was recorded during April in the first year while in the second year it was minimum (1.2±0.01 mg/l) in October and maximum (3±0.02 mg/l) in June. The lowest value of DO in August in the first year corresponded with the highest BOD in the same month in the same year indicating input of organic load etc. in the system with surface runoff. This is supported by Das and Pandey (1980) in Nainital lake, Kumaun (U.P. presently Uttaranchal). Another reason might be decreased light penetration due to silt loading of inflowing water.
thereby reducing photosynthesis. Such observations are supported by the findings of Singh (1981) from Naukuchiyatal Lake in Kumaun, Himalaya.

Minimum Chloride value was recorded during September and maximum in June in the first year while minimum value was recorded during October and maximum in September in the second year. The present finding is very much comparable with the findings of Unni (1984) in Badatal reservoir (13 to 26mg/l) in second year. Higher values of Potassium in both the years during rainy season might be due to allochthonous origin brought by flood water. The values recorded in second year (1.7± 0.6 to 4.3±0.6) were in close similarity with the findings of Okram et al.,(2003) in Ikop lake of Manipur, nearer to Loktak lake in which the range was 1.9-4.2mg/l. The concentration of nitrate recorded in both the years was found to be below the WHO (2004) maximum permissible limit and maximum contamination limit of 10 mg l⁻¹ as laid down by USEPA (USEPA,1998). The concentration of phosphate recorded in both the years was found to be maximum during post-monsoon is supported by the findings of Manikannan et al., (2011) in Great Vedaranyam Swamp of the Point Calimere Wildlife Sanctuary, South-east coast of Tamil Nadu, India.

Like site 1 Fe concentration exceeded the standard limit (0.3 mg/l) of dissolved iron prescribed by WHO(1984). The study is also supported by the findings of Singh et al., (2013) in Loktak lake. It is essential for the nutrition of both plants and animals, but it is undesirable in domestic water supplies as it causes unpleasant tastes, deposits on food during cooking, stains and discolours laundry and plumbing fixtures. Iron in natural water usually exists in ferrous; however it is readily oxidized to ferric form and ferric salts are precipitated as rust colour deposits. The iron content is attributed to the solubilization of different compounds in the rocks draining of such water in addition to the industrial effluents of different rivers into the lake. The maximum values of Lead (0.50± 0.1 mg/l and 0.025± 0.01mg/l) in both the years exceeded the WHO maximum permissible limit of 0.01 mg l⁻¹ (WHO, 2004). Similarly Mercury value also exceeded WHO limit in few months as observed in site 1. The occurrence of metals in water may be due to draining of industrial effluents into the rivers, which drain into Loktak lake, dumping of unused compact fluorescence lamp in
surrounding water and use of insecticides, pesticides, mercurials fungicides such as Ceresan dry Phenyl Mercurate-dust 1%, Agrosan G.N., Hexason (Phenylmercuric acetate plus ethyl mercury-dust %), Agallol Tillex (Mercury chloride 36%) by the farmers living at the periphery of the lake. Another factor may be partly due to the inorganic and aryl mercury compounds generated by the action of micro organisms in the sediments of the water body.

In this site air temperature significantly correlated positively with DO and phosphate; pH showed significant positive correlation with B.O.D. DO significantly correlated positively with phosphate in both the years. All these correlations are supported by the studies of Tidame and Shinde (2012) in Temple pond of Nashik District (M.S.), India. (Table 94 & 95). T.D.S showed significant positive correlation with B.O.D in both the years which is supported by the findings of Pramod et al.,(2011) in Wetlands of Hebbe Range in Bhadra Wildlife Sanctuary, Mid Westernghat Region, India. The significant positive correlation of BOD with Phosphate in the first year conformed to the findings of Garg et al., (2009) in Ramsagar reservoir, India. TA showed significant positive correlation with Na which is supported by the findings of Irshad et al., (2012) at Anchar lake, in Kashmir.

Site 3(S3) (KLNMP)
Water temperature recorded 22.9 ± 0.15°C to 32.93 ± 0.10°C in the first year and 23.5± 3.5 to 34.7± 0.6 in the second year and did not show much variation in the two years. The range of transparency (50.93 ± 0.11 cm) to (114.18 ± 0.31 cm) obtained during first year in the present study is found to agree with the values reported from Pichhola lake, Udaipur, India (Billore and Vyas. 1982) . Higher values of TDS recorded in both the years during summer might be due to high evaporation during summer (Hutchinson, 1957). The high value of Free CO2 in the second year during summer season suggests active decomposition of organic matter. High CO2 content is indicative of high organic pollution (Cole, 1979). Higher values of DO (6.63± 0.05 mg/l) recorded during rainy season in the first year is supported by the findings of Yadava et al., (1982) in Dighali Beel Guawahati Assam. The main sources of dissolved oxygen in freshwater lakes are
photosynthetic oxygen release from ambient atmosphere, denitrification process of bacteria, wind action and addition of cold water (Ellis et al., 1946). High BOD values during rainy season in the first year, might be accounted to organic loads in the inflowing flood water. This is supported by Khalil (2000) in his study in lake Mariut, Egypt.

Chloride in water is mainly due to organic waste and generally increases with degree of eutrophication (Trivedy and Goel, 1984). The range of chloride (11.28 ±0.08 to 22.74 ± 0.05) to (13.7±0.8 to 29.3±3.6) during first and second year in the finding is very much comparable with the studies of Devi (1995) in Utrapat Lake, Manipur. The higher value of salinity (52.93 mg/l) obtained during rainy season in the present study is supported by the findings of Nambirajan et al., (2012) in lower Anicut reservoir (Anaikarai), Tamilnadu, India. Salinity acts as a limiting factor in distribution of flora and fauna. Lower phosphate content during winter season in the first year might be due to rapid utilization by growing macrophytes (Wetzel, 1996). Highest concentration of nitrate during monsoon in first year could be due to surface run-offs as well as the decomposition of organic matter. This is in agreement with the studies of Ibrahim et al.,(2009) in reservoir in Kontagora, Nigeria.

The highest value of Fe obtained(0.94 ± 0.1 mg/l) in first year is above the standard limit (0.3 mg/l) while the value (0.11± 0.01 mg/l) in second year was recorded below the standard limit of WHO(1984). The highest concentration of Pb obtained in both the years is higher than the WHO limit of 0.01 mg/l and maximum contaminant level (MCL) of 0.015 mg/l for drinking water WHO(1984).

Air temperature significantly correlated positively with water temperature and water temperature significantly correlated positively with pH in both the years which is in conformity with the findings of Atobatele et al., (2008) in Aiba Reservoir, Iwo, Osun, Nigeria (Table 96 & 97). pH showed significant negative correlation with free FCO₂ in the second year which was in confirmation with the findings of Okram et al., (2003) in a lake (Waithou Lake) nearer to Loktak. pH was found positively correlated with DO in the second year which is in conformity of the findings of Araoje, (2009) in Asa lake Ilorin, Nigeria.
Significant positive co-relationship of potassium with AT, WT, T.D.S in both the years is in confirmation with the study of Meitei (2005) in Loktak lake, Manipur.

Site 4 (S4) (KLNPK)

Water temperature recorded was similar with S3 in both the years. The higher value of transparency was recorded in monsoon in first year and post-monsoon in second year.

The present range of conductivity (100 ± 10μScm⁻¹) to (263.33 ± 5.77 μScm⁻¹) and (80± 20μScm⁻¹) to (216.7± 11.5μScm⁻¹) in first and second year respectively is very much comparable with the studies of Zutshi and Vass (1977) in Mansabal lake (152-300μScm⁻¹). The values of pH obtained 6.23 ± 0.01 to 7.88± 0.08 in first year is in close similarity with the studies of Antwi and Ofori-Danson (1993) in Kpong reservoir Ghana (6.4 to 7.3). Higher values of pH during summer season in first year might be due to increased rate of photosynthesis where CO₂ is utilized (Raven, 1970; Goldman, 1972). This is confirmed by the lower level of free CO₂ during post monsoon and summer months in the first year. Yousuf et al., (1996) also attributed that low free CO₂ in his study might be due to the increased photosynthetic activity. Highest value of DO (4.87 ± 0.06mg/l⁻¹) recorded in the present study site is very much low for the survival of the aquatic fauna. Similar value of DO was recorded by Venugopalan et al., (1998) in the Kokilimedu lake in Chennai Maximum total alkalinity was observed during May and the minimum in September in the first year while maximum was recorded during August and the minimum in February in the second year. The alkalinity of water is due to presence of mineral salt present in it. It is primarily caused by the carbonate and bicarbonate ions (Sverdrap et al., 1942).

The maximum value of lead (0.38 ± 0.01mg/l⁻¹) in October and (0.004±0.00101mg/l⁻¹) in June recorded in first and second year respectively exceeded the WHO maximum permissible limit of 0.01 mg/l⁻¹ (WHO,2004). The range of Hg in the present study exceeded the WHO maximum permissible limit of 0.001 mg l⁻¹ (WHO,2004).
Conductivity showed significant positive correlation with TDS only in the second year, pH had a significant positive relationship with temperature and DO in both the years which conformed to the findings of Islam et al., (2012) in Chini Lake, Pahang, Malaysia (Table 98 & 99). B.O.D showed positive relationship with water temperature and chloride in both the years and with total alkalinity, conductivity, and phosphate in the second year which is in confirmation with the findings of Patra et al., (2010) in Santragachi and Joypur Jheel, W.B., India. Phosphate showed significant positive relationship with TDS in both the years which was in confirmation with the findings of Shinde et al., (2011) in Kham river, Aurangabad District (MS, India). It also showed positive relationship with Chloride in both the years. This is supported by the findings of Pramod et al., (2011) in Wetlands of Hebbe Range in Bhadra Wildlife Sanctuary, Mid Western Ghat Region, India.

**Site 5 (S5) (KLNP)**

The water temperature values of this site (23.83±0.25- 32 ± 0) and (18.8±9.7-33.7±0) recorded during first and second year are very much comparable with the values of Triveni Lake of Amravati District In (MS) India by Khan et al., (2012). The temperature ranged between (3.5-30 °C) in Zarivar Lake Kurdistan Province-Iran (Sharifinia et al., 2013).

Maximum conductivity was recorded during April and minimum during September in the first year. In the second year it was highest during July and minimum in October. Water conductivity is mainly attributed to the dissolved ions liberated from the decomposed plant matter (Sarwar and Majid, 1997) and input of organic and inorganic waste (Wright, 1982). Like site S2 higher values of TDS (196.7±20 mg/l) were obtained during rainy season in the second year. In this site maximum pH values were found during June in both the years. During rainy season in both the years level of free CO₂ was higher which may be attributed to influx of free CO₂ through rainwater in the form of carbonic acid. Such observations were made by Chakraborty et al., (1959) and Mansoori et al., (1995). The relatively high dissolved oxygen content during summer season (4.13
± 0.05mg/l) in the first year is largely attributed to increase in temperature and increase in transparency. Increase in transparency and temperature has a greater activity of aquatic plants for photosynthesis in the freshwater bodies (Nasar and Dattamunshi, 1974 and Kumar, 1993).

The maximum concentration of Iron recorded (1.02±0.002) during second year are beyond the permissible limits of 0.3mg/l (WHO, 2004). The maximum concentration of Lead recorded (0.62 ± 0.01) during first year are beyond the permissible limits of 0.1mg/l (WHO, 2004). The maximum concentration of Mercury recorded (0.01± 0.005) and (0.1±0.0006) in both the years are beyond the permissible limits of 0.001mg/l (WHO, 2004).

WT showed significant positive correlation with pH, TDS, chloride in the second year and with BOD in both the years. The transparency has been found to show positive correlation with chloride in both the years (Table 100 & 101). The significant positive correlation of BOD with Chloride in both the years is in conformation to the findings of Thirupathaiah et al., (2013) in lower Manair reservoir of Karimnagar district, Andhra Pradesh. Again significant positive correlation of transparency with BOD and potassium in the second year is in confirmation with the findings of Garg et al., (2010) in Ramsagar reservoir, a small inland reservoir located in Datia district, Madhya Pradesh. Dissolved oxygen showed significant positive correlation with pH in both the years and with conductivity and air temperature in the second year. These are in conformity with the findings of Atobatele et al.,(2008).

**Site 6 (S6) (Nambol River)**

The trend of water temperature (19.9 ±0.46°C) to (28.96 ± 0.46°C) and (18.7±0.6°C) to (26.7±0.6°C) during first and second year in the present investigation is very much comparable with the values (17±0.5 °C) to (33.90 ± 0.58) obtained in water of River Ganga (Yadav and Srivastava, 2011). The values of transparency (8±0cm to 84± 0.6cm) is very much comparable with the findings of Costa and De Silva (1995) observed as 20 to 151 cm in various reservoirs in Sri Lanka. Maximum depth was recorded during August and a
minimum depth during November in the first year while in the second year maximum depth was recorded during June and a minimum depth during May. The highest rainfall value recorded during June second year may be the reason for the maximum depth during June. However lowest depth did not show any such pattern in the second year. In the first year lowest depth in November coincided with lowest rainfall recorded in November.

Maximum conductivity value recorded during November in the first year and in September in the second is in contrast with the findings of Vijayalakshmi et al.,(2013) where higher values of conductivity were recorded between the months of March and June in Cauvery river water in the Pallipalayam region of Tamilnadu, India. Maximum values of FCO2 recorded during June in the second year may be due to the low photosynthetic activities of the aquatic macrophytes. Decomposition is also regarded to be one of the attributing factors (Talling, 1957). Maximum Dissolved oxygen value recorded during January in the present study in the first year may be that , with the progression of winter, dissolved oxygen tends to increase gradually due to low temperature in winter (Hannan,1979). Highest BOD in the first year during August is supported by Das and Pandey (1980) who reported maximum value of BOD during rainy season in Nainital lake. Total alkalinity recorded maximum during May and minimum in September in the first year while maximum value was recorded during September and minimum in April in the second year. The maximum value obtained 31.7±4.3mg/l in the present study during the second year is very much comparable with the studies of Mahesh Kumar and Prabhahar,(2012) where the total alkalinity of Palar river water at Vaniyambadi segment ranged from 23.5 – 28.73 mg l⁻¹. Minimum Salinity was recorded in July (15.30 ± 0.10 mg/l) and maximum in August (43.50 ± 0.12 mg/l) in first year while in second year minimum (1.80±1.44 mg/l) was in January and maximum in July (57.26±7.76 mg/l). In the second year variation in salinity is very high. The values of Sodium recorded in both the years are below the maximum admissible limit of 100 mg/l of the guideline of WHO(2004). The higher values of potassium obtained could be due to washing cloths utensils and bathing using soaps and detergents directly
with river water Nambol river. However, the values of potassium recorded in both the years are less than the standard limits (<20 mg/L) of WHO (2004). Lower phosphate content during winter season in the second year might be due to rapid utilization by growing macrophytes (Wetzel, 1966). In this site concentration of nitrate was found to be within maximum limit of 10 mg L⁻¹ in all the months as laid down by USEPA (1998) for any tributary discharging to a lake (Trivedi and Goel, 1986). Similar observation was also reported by Royer et al. (2004).

The highest concentration of Iron (0.27 mg/L) obtained is within the limits set by WHO (0.3 mg/L). The maximum concentration of Mercury recorded (0.01 ± 0.005 mg/L) in this site is above the limits of 0.001 mg/L set by WHO. Among the most prominent symptoms of the exposure to Mercury are tremor (particularly of the hands) and emotional instability characterized by shyness, insomnia, depression, and irritability. These symptoms are probably the result of damage to the blood-brain barrier. This barrier regulates the transfer of metabolic, such as amino acids, to and from the brain. The effects of mercury probably disturb brain metabolic processes. The kidney is the primary target organ of mercury (II). Chronic exposure to inorganic mercury (II) compounds causes proteinuria. In case of mercury poisoning of any type, the kidney is the organ with the highest bioaccumulation of mercury (Roa et al., 2012).

A positive correlation of air temperature with water temperature during both the years indicated that air temperature plays an important role in the heat budget of Nambol river. It is supported by the findings of Amaal and Abdel (2005) in the main channel of the River Nile (Table 102 & 103). EC showed significant positive correlation with TDS, chlorides in both the years and with phosphates, nitrates in the second year. Again Chlorides had significant positive correlation with sodium and potassium in both the years. This is supported by the findings of Venkatesharaju et al., (2010) in Cauvery River of Kollegal stretch in Karnataka. Positive correlation observed between pH and sodium in the second year is supported by the findings of Lena et al., (2012) in different ecosystems of Yercaud Hills, Eastern Ghats, South India.
Site 7 (S7)(Moirang)

The values of water temperature obtained in the present study is very much comparable with the studies of Kosygen et al., (2006) where the value range from 17.2 °C to 29.1 °C in Moirang River. In general, depth variation in the small rivers was found to be not much, thus light availability in these streams might not be the limiting factors. However, in extremely turbid rivers such as the Missouri and the lower Mississippi (Ellis, 1936), light is reduced so rapidly with increasing depth that the latter must become a sharply limiting factor for small benthic organisms. The maximum value of depth recorded in rainy season in first year is supported by the findings of Singh et al., (2010) in Iril River, in Manipur. Maximum conductivity and TDS during rainy season in the second year might be due to allochthonous input of dissolved materials through incoming flood water (Bhatt et al., 1999). Higher values of pH during summer season in the first year might be due to increased rate of Photosynthesis (Raven, 1970; Goldman, 1972).

The values of Free Carbon dioxide were 1.65 ± 0.05 mg l\(^{-1}\) to 5.53 ± 0.05 mg l\(^{-1}\) and 4.33 ± 0.06 mg l\(^{-1}\) to 35.2 ± 5.2 mg l\(^{-1}\) in the two consecutive years. Devi (1993) in Waithou lake, Manipur recorded 10-35 ppm of Free Carbon dioxide. DO has been extensively used as a parameter delineating water quality and to evaluate the degree of freshness of a river (Fakayode, 2005). Maximum value of DO in the first year was recorded during rainy season (7.36 ± 0.05 mg l\(^{-1}\)). This is supported by the findings of Sujitha et al., (2012) in Karamana River Kerala, India. In the second year maximum DO was recorded during April. Swarnalatha (1994) reported significant increase in dissolved oxygen during summer. The values of pH, dissolved oxygen and chlorides are generally high in summer and low during the rainy season (Singh and Singh, 1995). Such varied observations are mainly due to differences in the climatic and edaphic conditions as well as physico-chemical characteristics of the physiographic factors in the different regions of India.

The maximum value of BOD (7.2 mg l\(^{-1}\)) recorded in the second year exceeded the value 6 mg l\(^{-1}\), the recommended limit for BOD in drinking water (WHO, 1971). Alkalinity of water is a measure of weak acid present in it and of the cations
balanced against them (Sverdrap et al., 1942). Minimum TA value was recorded during September and maximum in June in the first year while minimum value was noted during April and maximum in September in the second year.

The maximum value recorded in the second year is supported by the findings of Imnatoshi and Ahmed (2012) in Doyang River, Nagaland.

Chloride in natural waters can be attributed to discharge of effluents or sewage disposal resulting in low contamination of river water. Domestic sewage contains more chloride. Chloride is generally considered as a major factor to equalize cation and anion balance of the aquatic system. The present findings of Chloride are very much comparable with those reported by Devi (1995) in Utrapat Lake, Manipur and Singh et al., (2010) in Imphal river, Manipur. For Sodium no specific pattern could be discerned in the two years while for potassium minimum value was recorded in winter in both the years and maximum values during late premonsoon and early postmonsoon (May and September in the first and second year).

The high concentration of phosphate (0.15 ± 0.01 mg/l) during wet season in first year may be due to water run-off which carries fertilizer and pesticides applied in the agricultural fields by the host communities since majority of people are predominantly farmers. Murdoch et al., (2001) reported that high levels of both phosphates and nitrates can lead to eutrophication, which increases algal growth and ultimately reduces dissolved oxygen in the water. The highest concentration of Pb obtained for this river (0.62 mg/l) is higher than the WHO( 2004) limit of 0.01 mg/l and maximum contaminant level (MCL) of 0.015 mg/l for drinking water (Nkono and Asubiojo, 1997). The positive relationship of T.D.S with Na, K during the second year and the, positive correlation of DO with pH in both the years (Table 104& 105) are supported by the findings of Amaal and Abdel (2005) in river Nile from Idfo to Cairo.

**Site 8 (S8) (Nambul River)**

Water temperature recorded in both the years were similar with the values recorded in S7.
The minimum transparency recorded during rainy season in the first year is supported by the findings of Singh et al., (2010) in Irl river, Manipur and Chhetry and Pal (2011) in seepage stream, embankment of Sapta Koshi river in Nepal. This may be due to erosion of soil carried by run off from the catchment areas. Highest depth recorded in this site during rainy season is supported by the findings of Singh et al., (2010) in Irl river, Manipur.

In the present study, lowest conductivity value obtained in the rainy season during second year is supported by the findings of Venkatesharaju et al., (2010) in the River Cauvery of Kollegal stretch in Karnataka which may be due to dilution with rain. In this site highest value was recorded during winter in the first year.

Higher levels of Free CO2 observed during rainy season in both the years is supported by the findings of Chakraborty et al., (1959) in river Yamuna. Dissolved oxygen content is one of the most important factors in stream health. DO values also show lateral, spatial and seasonal changes depending on industrial, human and thermal activity. DO levels of 5 to 6 ppm are usually required for most of the fish population. In this site recorded lowest DO (1.85±0.05 mg/l) and highest DO (6.22 ± 0.06 mg/l) in the first year and lowest DO (2.0±0.01mg/l) and highest DO (5.1±0mg/l) in the second year do not indicate good health of the stream. Particularly the lowest values recorded in both the years are below the average values of DO values given by APHA (2005) which indicates the low quality of river water. BOD is a measure of the oxygen in the water that is required by the aerobic organisms. The biodegradation of organic materials exerts oxygen tension in the water and increases the biochemical oxygen demand (Abida, 2008). Unpolluted, natural waters will have a BOD of 5 mg/l or less. BOD directly affects the amount of dissolved oxygen in rivers and streams. The greater the BOD, the more rapidly oxygen is depleted in the stream. The consequences of high BOD are the same as those for low dissolved oxygen: aquatic organisms become stressed, suffocate, and die. Sources of BOD include leaves and woody debris; dead plants and animals; animal manure; effluents from pulp and paper mills, wastewater treatment plants, feedlots, and food-processing plants; failing septic systems; and urban storm water runoff (USEPA, 1997). Maximum values of BOD (15.24 ± 0.05) and
(10.15±0.99) during rainy season in both the years might be due to high organic loads along with the rain runoff from the catchment area of the river. This conformed to the findings of Das and Pandey (1980) in the lake Nainital, Kumaun (U.P).

The alkalinity of natural waters is due primarily to the salts of weak acids, although weak or strong bases may also contribute. Bicarbonate represents the major form of alkalinity, with that carbonate and hydroxide alkalinity also.

Higher values of Chlorides recorded during rainy season in both the years may be due to droppings of faecal matters by the grazing animals and decomposition of organic matter at higher temperature (Hutchinson, 1975). High concentration of chlorides is considered to be the indicators of pollution due to organic wastes of animal or industrial origin. Higher values of Chloride is harmful to aquatic life (Rajkumar, et al., 2004). Higher values of Chlorides recorded were within the standard limit of Indian Standard specifications for drinking water. Maximum value (170±4.3 mg/l) recorded in this site in the second year during August is supported by the findings of Patra et al., (2010) in Bada kuda area of Southern sector of Chilika Lake.

Sodium fluctuated from a minimum during September to a maximum during January in first year while it fluctuated from a minimum during August to a maximum during July during second year. Potassium is required for all cells principally as an enzyme activator and stored in the plant tissues than in surrounding medium (Hornes and Goldman, 1983). The maximum value of potassium recorded during rainy season in the second year is supported by the findings of Singh et al., (2010) in Thoubal river. The minimum value was recorded during post-monsoon and maximum in summer in the first year. The maximum value recorded (44 ± 0.01 mg/l) and (170±4.3 mg/l) in both the years is above the standard limits (<20 mg/l) of WHO (2004). Phosphate was recorded highest in winter in first year while in monsoon in second year. The higher values recorded in monsoon in second year is supported by the findings of Kumar et al., (2012) in Sabarmati River and Kharicut Canal, Ahmedabad, Gujarat.
The maximum value of Iron (Fe) (0.94 mg/l) observed in this site exceeded the standard (WHO, 2004). This might be attributed to municipal waste and discharge of wastewater from the Wangoi area. The maximum value of Lead (1.21 mg/l) in the first year recorded in this site exceeded the WHO maximum permissible limit of 0.01 mg/l (WHO, 2004). This is also supported by the findings of Takhelmayum et al., (2013) in Moirang river, Manipur. The highest values of Mercury (0.76 mg/l) and (0.1) recorded in the site 8 during first and second year were much beyond the maximum permissible limit of 0.001 mg/l (WHO, 2004).

Water temperature showed a positive correlation with air temperature during both the years (Table 106&107). In both the years, positive correlation of DO with pH in S8 are supported by the findings of Amaal and Abdel (2005) in river Nile from Idfo to Cairo.

Atobatele and Ugumba (2008) reported that Hydrogen ion concentration (pH) in Aiba Reservoir showed a strong positive correlation with dissolved oxygen. Increasing levels of dissolved oxygen in aquatic systems are usually associated with eutrophic and productive water bodies (Egborge, 1994). B.O.D showed significant positive correlation with PO4^-2 in all the sites which was in confirmation with the findings of Garg et al., 2009 in Ramsagar reservoir, India. TA showed significant positive correlation with Na which is supported by the findings of Irshad et al., (2012) of Anchar lake, in Kashmir.

**Aquatic Insects**

**Diversity and density**

Most aquatic habitats, particularly free-flowing water streams and waters with acceptable water quality and substrate conditions, support diverse macroinvertebrate communities in which there is a reasonably balanced distribution of species among the total number of individuals present. Such communities respond to changing habitats and water quality by variations in community structure (Sharma et al., 2004).
Spatial variation of collected insects in the two years revealed that highest number of insects was collected from S5 and S4 in the first year and second year, respectively while lowest in S6 during both the years. This showed that S4 and S5 being two sites of National Park area are rich in total insect population compared to other sites. Lowest insect population during both the years in S6 might be due to the fact that S6 (Nambol river) is a perennial river which arises from Kangchup hills and finally falls into Loktak Lake near Ishok. The river while traversing through hills, before reaching plain, maintain unpolluted water quality due to less human activities, but human population growth, urbanization, and associated land use changes have led to water quality deterioration in the downstream of the river. The study revealed that in the lentic systems (site S1, S2, S3, S4) collected number of insects were higher in the second year while in first year it was higher in (S5, S7 and S8).

However S5 being lentic system was exception. Here a clear demarcation in lotic and lentic systems were found. This could be due to habitat diversity and other physico-chemical factors (Stewart et al., 2008). The physicochemical profile directly affects the biological composition of streams and rivers since it provides the template upon which the ecological organization and dynamics of flowing ecosystems are observed (Minshall 1988, Resh et al., 1988; Poff and Ward 1989, Townsend and Hildrew 1994) and alteration of these habitats can have dramatic and persistent impacts on community assemblages (Niemi et al., 1990). Food availability is another important factor affecting abundance of benthic invertebrates (Arimoro et al., 2007). Substrate, suspended sediment, gradient, water temperature, stream order and width were observed to have significant influence over biomass and diversity of macroinvertebrates (Newlon and Rabe 1977).

This study revealed occurrence of three orders of aquatic insects Hemiptera, Odonata and Coleoptra in all the sites in both the years. Hemiptera was found to be the most dominant order. Hemipterans could survive in that environment because of the presence of elytra/hemi elytra in their body and alternate mode of respiration. Several studies also reported that aquatic bug Diplonychus is found to be less susceptible to temperature and salinity variations (Wollmann, 2001.
Venkatesan, 2004). Among all the sites highest number of families (9) were found in site S1, S3, S6, S7 and S8 and did not show much variation from others during first year. During second year highest number of families (8) was recorded in S5 and S6.

Total number of aquatic insect species encountered in the study is thirty two. *Leucorrhinia* sp. is the newly recorded species from India. *Leucorrhinia* sp. is recorded from S4 of Keibul Lamjao National Park and Moirang river only in first year.

Highest number of species was recorded in S7 in both the years, 18 in first year and 12 in second year. Lowest number of species (11 in first year and 9 in second year) was recorded in S3.

The number of species (18) in lotic systems (S6, S7, S8) was recorded higher in the first year while in the second year the same trend was not recorded. In this study highest number of species was recorded from the family Libellulidae. Libellulidae species have high distribution capacity and one of the largest odonate families in the world (Kalkman et al., 2008). Many studies revealed that family Libellulidae is widely represented in surveys locally and globally (Newbury, 1984; Che Salmah, 1996; Che Salmah et al., 2004). Previous study on the Takmu area of Loktak lake, Manipur also revealed highest number of species from the family Libellulidae (Takhelmayum and Gupta, 2011b).

Aquatic vegetation is crucial to Odonate population for reproduction since they are endophytic egg-layers. In addition, Odonates as juveniles use aquatic plants for anchorage, concealment, foraging, and site defense. (Buchwald, 1992).

Although odonates occur in almost all types of aquatic ecosystems, microhabitat with high heterogeneity of vegetation is believed to be the factor primarily responsible in determining their diversity and distribution (Watanabe et al., 2004). Highest no of species (7) of Libellulidae were recorded from S7, followed by S5, S6 and S8 in first year.

Highest no of species (5) of Libellulidae were recorded from S1 and S7 in second year.

The family Calopterigidae of the order Odonata have lowest no. of species. Stenotopic species of Odonata under the family Calopterigidae are restricted to
specific habitats, limited to a single habitat (Orr, 2003; Watanabe et al., 2004). They are highly sensitive to factors such as the amount of sunlight and water movement and are very abundant in primary forest especially in mixed dipterocarp and freshwater swamp (Chovanec & Raab, 1997).

According to Engelmann Scale (1978) Diplonychus rusticus (Fabricius) was the only species found Eudominant in S8 during second year. No other species was found eudominant in other sites during this study period. The dominant species those found in different sites were Diplonychus rusticus (Fabricius), Sympetrum sp. (Newman), Laccophilus sp., Hydrophilus sp., Rhodothemis sp. (Fraser), Crocothemis servilia servilia (Drury), Ischnura sp. (Charpentier), Pseudagrion sp. (Selys), Neurobasis chinensis chinensis (Linnaeus), Lestes sp. (Leach), were found only in the lentic systems i.e Keibul Lamjao National Park, while Ophiogomphus sp. (Selys), and Stylogomphus sp. (Fraser), were found only in the lotic system, Nambol River (S6).

Density of aquatic insects showed positive correlation with lead in S1 and S7 during first and second year respectively. The reason may be that highest number of species were recorded from order Odonata in S1 and S7 and Odonate larvae are known to sequester metals within the exoskeleton by adsorption or accumulation of metal indicating that odonates are tolerant to metal exposures (Tollett et al., 2009). There is considerable documentation that odonates and other aquatic insect larvae sequester high levels of metals, particularly Pb, in the cuticle (Hare 1992; Meyer et al., 1986).

One way analysis of Variance (ANOVA) revealed a statistically significant difference in insect abundance between the different sites. This is may be due to different habitat type and composition of the selected study sites.

**Biotic Indices and Scores**

Several biotic indices have been developed to assess water quality in the field (Depauw and Vanhooren, 1983; Washington, 1984; Metcalfe, 1989). Mason (2002) reviewed the ecology and responses of many aquatic organisms in water quality assessment. Shannon diversity index (Shannon H') was recorded lower than 1 in all the sites. This explained that systems were under stress. Wilhm and Dorris (1968) had set the diversity index of less than 1 for highly polluted, 1-3 for
moderately polluted, and greater than 4 for unpolluted water bodies. So all the study sites fell under highly polluted category. Among all the sites highest diversity index (Shannon H) was recorded in Nambol river (S6) in the month of March'10 during first year and in S5 in April during second year. This is confirmed by the highest evenness index and lowest Berger Parker Dominance index in S6 in March in first year. It can be said that diversity was high in premonsoon more or less in the dry season. Similar result was recorded in a study on Macae river basin (Buss et al., 2006). Minimum value was obtained in the month of September in S8 during first year and in S5 (Keibul Lamjao National Park) in July during second year. This is also supported by highest Berger Parker Dominance index in September in S8 in first year and in S5 in July in second year.

Margalef Diversity Index has no limit value and it shows a variation depending upon the number of species. Thus, it’s used for comparison of the sites (Kocatas, 1992). The values of Margalef Diversity Index were between 3.769 – 23.055. Margaleff M index was highest in S2,S3,S4 in January and in S7 in December in first year and in S7 in December in second year. Lowest Margaleff M index was in S5 in November in first year and in S3 in October in second year.

SIGNAL (Stream Invertebrate Grade Number-Average Level) was calculated for all the sites. It is a family-level water pollution index based on the known tolerances of aquatic macro-invertebrate families to various pollutants. A low grade number means that the macro invertebrate is tolerant of a range of environmental conditions, including common forms of water pollution. The index has a gradient from 1 to 10 (ranging from a pollution tolerant to a pollution sensitive community) (Chessman, 1995). The signal score also can be used for wetland studies where scores will be a bit lower (Chessman, 2003). On that basis among the different sites highest score (3.1) was recorded in S2 in the second year (Table 8) and lowest signal score was recorded in S3 (2.03) during first year (Table 88). This indicated that S2 has species who are relatively less tolerant. The lower SIGNAL scores indicate that the sites are likely to have higher levels of salinity or nutrients. These levels may be high either naturally, because of local geology and soil types, or as a result of human activities (Chessman, 2003).
The Biological Monitoring Working Party and Average Score Per Taxon scoring system (BMWP/ASPT) data in the first year showed that the water quality was moderate in S1, S3, S6, S7 and S8 and S2, S4 and S5 showed poor water quality. In the second year, all the sites showed poor water quality. (Table 90&91).

**Canonical correspondence analysis (CCA)**

Canonical correspondence analysis (CCA) was computed taking data of twenty one variables and species to find out possible correspondence between them. The CCA is a constrained ordination, and the water variables are directly projected on taxon and site coordinates (Chorng-Bin Hsu and Ping-Shih Yang, 2005). The CCA diagram revealed that during 2009-10 the sites are placed in four groups, group 1 (site 6 and 7) are placed in the positive side of axis 1 and axis 2, group 2 (site 2, 3 and 5) are placed in the negative side of both axis 1 and 2. Group 3 (Site 1 and 4) is in the negative side of axis 1 and positive site of axis 2. Group 4 (Site 8) is in the positive side of axis 1 and negative side of axis 2. This corresponded to the types of ecosystems as sites of group 1 and 4 are rivers and sites of group 2 and group 3 are lentic water system (KLN). (Fig:68)

*Ophiogomphus* sp., *Stylogomphus* sp. placed in group 1 were found positively correlated with DO. In general, Ophiogomphid larvae prefer clear, swift flowing rivers (Steffens and Smith, 1999). Depth was found to be the driving factor in the distribution of the species *Ranatra varipes* in Group 1. *Gerris* sp. in site 8 corresponded positively with total alkalinity, and chloride. Balachandran et al., (2012) also showed positive correlation of *Gerris* sp with total alkalinity, and chloride in the lakes of Bangalore.

Insect taxa *Pseudagrion* sp. and *Ischnura* sp. of group 2 were found positively correlated with Fe, Pb and Hg. This is supported by the findings of Girgin et al., (2010) where *Ischnura* sp. were positively correlated with Pb. Hence this can be said that they were able to survive despite high Pb concentration in water of KLN. *Ischnura* sp. were positively correlated with salinity. This is supported by Solimini (1997) and Askew (1988) who claimed that certain species of the larvae of *Ischnura* sp. have high tolerance for high salinity and low oxygen concentration. *Pseudagrion ruhriceps* and *Ischnura senegalensis* were also found
positively correlated with B.O.D. This is supported by Che Salmah et al., (1998) who stated that *Pseudagrion rubriceps* is a tolerant Dragonfly larvae. Insect taxa *Lestes* sp., *Rhodothermis* sp., *Sympetrum* sp., are major taxa of group 3 where Water temperature and Transparency were found to be the driving factor in the distribution of these species. In the group 4 FCO2 was found to be the driving factor in the distribution of *Crocothemis servilia servilia*. *Potomarcha* sp. and *Anax* sp.

In the second year, the CCA diagram (Fig:69) revealed that the sites are placed in four groups, group 1 (site 8) is placed in the positive side of axis 1 and axis 2, group 2 (site 6 and 7) is placed in positive side of axis 1 and negative side of axis 2, group 3 (site 1 and 4) is placed in negative side of axis 1 and axis 2, and group 4 (site 2, 3, and 5) is placed in negative side of axis 1 and positive side of axis 2. Like first year in the second year also grouping corresponded to the habitat type. Insect taxa *Corixa* sp. and *Anisops* sp. of group 1 showed relationship with physico-chemical parameters such as Pb, Fe, T.D.S, Salinity and Conductivity. *Ranatra varipes* and *Hydaticus* sp. of group 4 are the major group where WT, TRNS, AT and FCO2 are the driving factor in the distribution of these species.

Association of site 8 with all the environmental variables can be explained by the fact that the river Nambul while passing through the heart of Imphal city carried waste load of the whole city along with the agricultural waste on its way to its mouth ie lake Loktak, the largest fresh water lake in north east region of India. Population of 0.28 million living within Nambul river catchments generates 31,207 cubic metre of sewage daily. With rapid urbanization, industrialization and increasing population of the city the river gets polluted day by day leading to the increase of pollution levels of Loktak lake (Singh and Singh 2010). This may be the reason of high physico-chemical parameters viz. B.O.D, Chloride, Salinity, Lead, Iron and Mercury recorded in site 8 in both the years and this is further confirmed by the result of CCA. Because in CCA ordination diagram this site was positioned singly or isolated in both the years.

In site 8, during first year the BMWP total score (41.2) and ASPT score (12.1) indicated that the water quality of the site is moderately impacted while in
second year BMWP total score (25.9) and ASPT score(9.2) categorized it under poor water quality. According to (Gooderum and Tsyrlin, 2002) SIGNAL 2 Score Greater than 6 indicate Healthy habitat quality, Between 5 and 6 indicate Mild pollution, Between 4 and 5 indicate Moderate pollution, Less than 4 indicate Severe pollution. According to the SIGNAL 2 scores in the first year (2.9) and second year (2.4) the study sites fell under the category of severe pollution.

**Temporal variation of aquatic insects in different sites**

**S1 (KLNP)**

Variation of collected insects in the two years revealed that higher number of insects was collected in the second year than the first year. The higher number of families (9), genus (18) and species (18) were recorded in first year compared to 8 families, 12 genus and 12 species in second year which was much lower. Nepidae, Belostomatidae, Libellulidae, Coenagrionidae and Hydrophilidae were present in both the years (Fig:5 and Fig:8). Nepidae was present in all the months in the first year. Occurrence of these families was possible because of their high tolerance viz Libellulidae, Coenagrionidae (Tolerance value 9); Nepidae and Hydrophilidae (tolerance value 5) to anthropogenic impact (Mandaville, 2002). Relative abundance of Hemiptera and Coleoptera showed same seasonal pattern of variation in both the years while Odonata showed fluctuations in the pattern of variation in the two years (Fig:4 and Fig:7). In both the years insect density was highest in pre-monsoon (March and April) and lowest in postmonsoon (October and November). This is in contrast with the findings of Martin et al., (2000) in Tamiraparani river in South India and Scheibler and Debandi (2008) in Andean streams, Mendoza, Argentina where highest density was recorded in postmonsoon. Relative abundance of Hemiptera was recorded highest in November in first year and August in second year which is in contrast to the findings of Edward and Ugwumba, 2011 in Egbe Reservoir, Ekiti State, Nigeria.
where Hemiptera was higher in dry season. Highest relative abundance of Hemiptera in August is supported by the findings of Das and Gupta (2012) in temple pond of Cachar District, Assam, northeastern India.

The order Hemiptera was found in all the months in both the years and highest relative abundance was recorded in November in the first year and in August in the second year. Dominance of Hemiptera in spite of low DO (2.45 ± 0.07 to 4.67 ± 0.05) in the first year and (0.9 ± 0.3 to 5.2 ± 0.02) in the second year and slightly acidic pH (6.24 ± 0.01 to 7.88 ± 0.08) in first year and 7.1 ± 0.03 to 7.3 ± 0.1 in second year is due to their adaptations in semi-aquatic and aquatic life such as possession of siphon, plastron, physical gills etc. by which they get oxygen from air and need not depend on DO of water entirely. They have a competitive advantage over other group of insects those cannot survive in such hostile condition. Similar occurrence of Hemiptera in very low DO has been recorded in a study made in Loktak lake of Manipur, North East India (Takhelmayum and Gupta, 2011). Relative abundance of Odonata and particularly Libellulidae was found highest in January in the first year (Fig: 5) where Sodium and Potassium were recorded highest (Table: 27 and 29). The probable reason may be that some species of Odonata are salt tolerant compared to other aquatic macroinvertebrates (Kefford et al., 2004), although considerable variation in tolerance exists within the order (Gooderham and Tsyrlin, 2002; Chessman, 2003; and Morris et al., 2009). The tolerance score reflects the pollution tolerance of the respective macroinvertebrate taxon. For the most pollution tolerant taxa, Libellulidae, the tolerance score is as high as 9 (Hilsenhoff, 1988), which may be the probable reason for their highest relative abundance despite the presence of high Sodium and Potassium concentration in the first year.

The lowest relative abundance of family Calopterigidae could be explained by the fact that stenotopic species of Odonata under the family Calopterigidae are restricted to specific habitats (Orr, 2003; Watanabe et al., 2004). They are highly sensitive to factors such as the amount of sunlight and water movement (Chovanec and Raab, 1997). These may be the reason that in the present study relative abundance of Calopterigidae and Neurobasis chinensis chinensis was lowest and present only during the first year in this site.
Relative abundance of *Ranatra varipes*, *Laccotrephes rubber* and *Diplonychus rusticus* was recorded highest in all the months in first year and *Ranatra varipes*. *Gerris* sp., *Diplonychus rusticus* was recorded highest in the second year. The abundance of Hemiptera and *Diplonychus rusticus* is supported by the findings of Majumder *et al.*, (2013) where highest abundance of Hemiptera species and *Diplonychus rusticus* was reported in freshwater lakes of Tripura, northeast India. In the second year *Tramea* sp. was found. *Tramea* naiads are predatory engulpers that may be found sprawled among aquatic macrophytes in lentic and lotic habitats (Merritt and Cummins 1996). They may also be found crawling through trash and silt near shorelines of warm quiet ponds and lakes (Usinger 1968).

Shannon H' values for insects were highest in June in both the years (Table 47). According to Engelmann's scale (Table :55 ) *Diplonychus rusticus* was found dominant in monsoon and post-monsoon during both the years. Signal score was higher in first year as compared to second year (Table: 88). The Biological Monitoring Working Party and Average Score Per Taxon, score scoring system (BMWP/ASPT ) data in the first year showed that the water quality was moderate but poor in the second year.(Table: 90 and 91). Pearson’s correlation coefficient (r) (Table: 92 ) analysis showed significant positive correlation between lead and density of aquatic insects in the first year which is in agreement with the study conducted in Ankara Stream in Turkey where Odonate, and other species showed a positive correlation with lead ( Girgin et al., 2010). In the next year, density of aquatic insects showed positive correlation with Conductivity and with TA (Table: 93 ).This coincided with the study conducted in the Azul-Quemquemtreu river basin, Patagonia, Argentina where macroinvertebrate density correlated positively with conductivity and alkalinity. It is likely that inputs of nutrients to the study sites enhanced primary productivity, which in turn increased in density of aquatic insects( Miserendino and Pizzolon, 2003).

Pearson’s correlation coefficient (r) (Table : 93) analysis showed significant positive correlation of density of aquatic insects with free Carbon dioxide in second year. This coincided with the findings of Dhakal (2006) in Balkhu Khola in Kathmandu Valley, Central Nepal. It also showed significant positive
correlation of density of aquatic insects with TA in second year. This coincided with the study conducted in the Azul-Quemquemtreu river basin, Patagonia, Argentina where macro-invertebrate density was correlated positively with conductivity and alkalinity. It is likely that inputs of nutrients to the study sites enhanced primary productivity, which was reflected by an increase in density of aquatic insects (Miserendino and Pizzolon, 2003).

The insect density was highest in March and July during first and second year, respectively. This is supported by the findings of Silva and Henry, (2013) in marginal lentic ecosystems (São Paulo, Brazil). Lowest density was recorded in the month of October and April during first and second year, respectively (Fig 54 and 55). No seasonal pattern was observed in this site. In the first year relative abundance of Odonata was found hundred percent in September while in October it was replaced by Hemiptera. In other months it was shared by either two or three orders. In the second year it was shared by two or three orders in all the months.

In the first year Belostomatidae was recorded in the 6 months of the year while Libellulidae was found in 8 months of the year. Only in the months of June and August both the families were recorded simultaneously in the system. In rest of the months either of them was present. Relative abundance of family Belostomatidae was recorded highest in July in both the years and Libellulidae was highest during April and November during first year and second year, respectively. In the second year from September to March relative abundance of family Libellulidae was found highest while in May, June and July it was replaced by Belostomatidae. These facts very clearly stated that dry periods were preferred by family Libellulidae and wet periods were preferred by Belostomatidae. This is further confirmed by the dominance of Diplonychus rusticus (Belostomatidae) in the wet period and Sympetrum sp. (Libellulidae) in dry period in the second year of study.
According to Engelmann’s scale (Table: 57 and 58) \textit{Laccophilus} sp. was dominant in monsoon during first year. In the second year \textit{Sympetrum} sp. was found dominant in postmonsoon and winter while \textit{Diplonychus rusticus} was dominant in monsoon. The studies of Sarma and Baruah, (2013) reported that \textit{Sympetrum} sp. was found recedent in Bahini River of Guwahati city.

Shannon H' value for insects was highest in June in first year while in September in second year. Signal score was higher in first year as compared to second year. (Table : 88). The Biological Monitoring Working Party and Average Score Per Taxon, score scoring system (BMWP/ASPT) data showed that the water quality was poor in both the years. (Table: 90 and 91)

Pearson's correlation coefficient (r) (Table 90) analysis showed significant positive correlation between pH with Insect density and diversity in first year. This is supported by the studies of Clenaghan \textit{et al.}, (1998) who reported that taxa richness, density of invertebrates and diversity increased along a river continuum with increases in pH, hardness and nutrients.

\textbf{S3 (KLNP)}

In the first year, although total number of insects collected was lower compared to second year the number of families and species was higher. Highest insect density in the dry season in both the years conformed to the findings of Sharma \textit{et al.}, (2004) in the Dhauliganga in Nanda Devi Biosphere Reserve, India. Unlike S1 and S2 in this site relative abundance of Hemiptera was high in both the years and Odonata was very low in first year where Belostomatidae was the most dominant one (Fig: 16 and 19). In the second year dominant families were Libellulidae and Belostomatidae (Fig: 20). Shannon H' value for insects was highest in October in second year (Fig 59) is in contrast with the findings of Latha and Thanga, (2010) where it was lowest in October in Veli and Kadinamkulam lakes, South Kerala, India. In the present investigation, species diversity index was always less than one. Staub \textit{et al.}, (1970) proposed that H value $< 1$ indicates heavy pollution of water. The negative correlation of water temperature with diversity of aquatic insects during first year is in contrast to the
findings of Kholin and Nilsson (1998) who found increased temperature linked to
the increased richness in aquatic insects in temporary ponds at opposite east-west
ends of the Palearctic.

According to Engelmann’s scale of dominance (Table: 59 and 60). *Laccophilus*
sp. was dominant species in the winter and *Diplonychus rusticus* in monsoon and
post-monsoon, in the first year. In the second year *Sympetrum* sp. was dominant
in winter and premonsoon. The distribution of macro-invertebrates are likely to
be influenced by the distribution of their food (Thurnheer and Reyer.2000).
Signal score was higher in first year as compared to second year. (Table: 88)
The Biological Monitoring Working Party and Average Score PerTaxon, score
scoring system (BMWP/ASPT ) data in the first year showed that the water
quality was moderate but poor in the second year.(Table: 90 and 91)

**S4 (KLNP)**

Like site S3 in the first year, total number of insects collected was lower
compared to second year while the number of families, genus and species was
higher (Fig: 2and Fig: 3).
The insect density was highest in February & March during first and second year
respectively while lowest density was recorded in post monsoon in first year and
in winter in second year (Fig: 58 and 59). Lowest density in winter could be
attributed to the decreased water level as aquatic insects have strong relationship
with water surface fluctuations (Das and Gupta, 2010; 2012). The study is in
contrast with the findings of (Sayed *et al* 2003) lowest density was recorded in
summer in Khor Lake Nasser, Egypt.

Relative abundance of Belostomatidae, Libellulidae were highest among all other
families in both the years (Fig :23 and 26). Inspite of the low DO, in this site,
Libellulidae was recorded highest. The probable reason may be that Libellulidae
are very adaptable and tolerant of low dissolved oxygen concentration or highly
eutrophic in habitats (McCafferty, 1983). Lestidae was recorded lowest in
August in the first year. Lestidae larvae commonly inhabit vegetation in
permanent and temporary ponds and marshes, and occasionally may be found among vegetation in slow streams (Hilsenhoff 1991). *Lestes* sp. was present only in the first year during the two years of study period. This may be supported with Margolis et al., (2001) who claim that, changes in the benthic macro invertebrate assemblages are not determined by changes in the type and availability of food, but differences in the ability of resident genera to tolerate the environment around it despite the environment determining the type of food available (Matthaei et al., 2000).

Many studies have shown that submerged aquatic vegetation beds can essentially create a local community and food web entirely unlike what would be present in an open unvegetated state (Engel 1985; Dibble et al., 1996; Strayer et al., 2003). Members of the genus, *Lestes*, are climbers and swimmers as juveniles. They may be found in lentic and lotic habitats on aquatic plants (Merritt and Cummins 1996).

Shannon H' values for insect were highest in May in first year and in June in second year (Table 46). This is similar to Site 1. Ravera (2001) and Sandin & Johnson (2000) were of the view that diversity and biotic indices may be influenced by any stresses, including pollution. The evenness index J value was highest in May, and Berger Parker Dominance index was highest in January during first year is supported by the findings of Das and Gupta (2012) in a temple pond of Cachar District, Assam, Northeastern India.

Ward and Stanford (1979) also suggested that temperature pattern influences the life cycle phenomenon of insects such as emergence, which leads to increase in density. A significant difference in the diversity of aquatic insects may be attributed to the fluctuations in water temperature, high values of dissolved oxygen, pH and alkalinity in addition to the natural and anthropogenic disturbances.

According to Engelmann’s scale of dominance (Table 61: and 62) *Sympetrum* sp., *Rhodothemis* sp. and *Crocothemis servilia servilia* were dominant in winter in the first year. *Diplonychus rusticus* was dominant in monsoon in the second year while *Sympetrum* sp was dominant in pre-monsoon in second year. Signal score was higher in second year as compared to first year unlike S1, S2 S3
The Biological Monitoring Working Party and Average Score PerTaxon, score scoring system (BMWP/ASPT) data showed that the water quality was poor in both the years (Table : 88 and 90 and 91 ). Pearson’s correlation coefficient (r) (Table : 98) analysis showed significant positive correlation of air temperature with insect diversity in first year. Increased temperature has been linked to increased richness in aquatic insects (Kholin and Nilsson, 1998).

**S5 ((KLNP)**

Unlike sites 1,2,3,4, in this site number of collected aquatic insect was higher in first year (09-10) than next year (10-11)( Fig:1). While the number of families recorded similar in both the years, the number of genus and species were higher in first year as compared to second year.

The insect density was highest in November & December during first and second year, respectively (Fig: 60 and 61). Lowest population was recorded in September and February during first and second year, respectively. Highest density during winter was possibly due to a higher habitat stability and availability. The substrates during this season are less affected by water flow, allowing a greater period for colonization and processing of benthic organic matter by aquatic Hemiptera (Batista et al., 2001). Relative abundance of Belostomatidae was highest among all other families in both the years except in September and August in first year and in April and December in second year (Fig: 29 and 32). Diplonychus rusticus was found highest during post-monsoon in the first year and during monsoon in the second year.(Fig : 30 and Fig : 33 ).

Shannon H' value for insects was lowest in October during second year is supported by the finding of Bass and Potts,( 2001) in Boehler Lake,Atoka County, Oklahoma.

Highest Shannon H' value in the two subsequent years were found in June and April during first and second year, respectively (Table : 51). This can be explained by the fact that with the onset of pre-monsoon and monsoon, the dry and live plants of phumdis were rejuvenated with fresh flow of water. This might
have attracted more insects in the month of April and June. Based on Engelmann’s scale (Table : 63 and Table : 64 ) it has been found that Diplonychus rusticus was dominant in post-monsoon in both the years while in the second year it was dominant in moonson also. This might be due to the fact that after monsoon rainfall aquatic hydrophytes settle permanently in the system which is the habitat for them. Signal score was higher in first year as compared to second year. (Table: 88 ). The Biological Monitoring Working Party and Average Score Per Taxon, score scoring system (BMWP/ASPT ) data showed that the water quality was poor in both the years. (Table: 90 and 91). Pearson’s correlation coefficient (r) (Table: 100 and 101 ) analysis showed significant negative correlation of insect diversity with pH . This conformed to the findings Venkateswaraju, (1969).

S6 (Nambol River)

The total aquatic insect population was much higher in the first year (305) than that of second year (155) (Fig :1). This is unlike in site 1, 2, 3,4. The no. of families (8), genus, (18), species (18) was higher in first year than in second year. (Fig: 2 andFig : 3).

The insect density was highest in June & July during first and second year, respectively. Lowest population was recorded in October & January during first and second year, respectively. This is in agreement with the findings of Williams et al., (2003) in Ouachita Mountain headwater streams (central Arkansas, USA) and Moretti1 and Callisto1, (2005) in the middle Doce River watershed (MG, Brazil).

Relative abundance of Coenagriidae was highest among all other families followed by Belostomatidae in both the years. Despite the high salinities recorded in the site , (Table:25,26) Coenagriidae was highest among all other families (Fig :35 and 38) . The possible reason may be that Odonata (e.g. Coenagriidae) is among the most tolerant taxa to high salinities (Berenzina, 2002; Kefford et al., 2004b, 2006a; Dunlop et al., 2008). The tolerance value of Coenagriidae is 9. This statement is supported by the significant positive correlation of Density
and Diversity of insects with salinity in first year. (Table: 98). Relative abundance of *Pseudagrion* sp. was highest among all other species in both the years while *Ophiogomphus* sp. of the family Gomphidae was lowest among all other species and present only in the first year. Most Gomphidae prefer cooler and cleaner habitat of moderate to fast flowing water. In a hilly Bongor stream in Gerik, Perak, *Ophiogomphus* sp. constituted 41.6% of dragonfly community (Shamsul, 1998). Although Nambol river originates from Kangchup hills and finally falls into the Loktak Lake near Ishok, the sampling site was at lower reaches thus this may be the reason of less number of Gomphidae recorded from the site. *Anax* sp. was lowest in the second year. Aeshnidae species have a wide range of tolerances (Illinois EPA 1985; Hilsenhoff 1987). *Anax* naiads climb on vascular hydrophytes and stalk their prey. These are found in lentic habitats and are notoriously cannibalistic (Usinger, 1968). *Tholymis tillagra* of the family Libellulidae was present only in the second year during premonsoon. The distribution and composition of aquatic insects particularly Odonata always change from time to time following change in environment (Lenat 1993; Chesalmah et al., 1999). Their assemblage is too dependent on the composition and structure of vegetation in and around their microhabitats (Hawking and New 1996; Smith and Pritchard, 1956).

*Diplonychus rusticus* was recorded in minimum number in the monsoon during second year (Fig: 39) might be due to the fact that Belostomatidae uses high rainfall response behavior and shifts to the nearby safe places (Lytle and Smith, 2004).

According to Engelmann’s scale of dominance (Table: 61 and 62) *Ischnura* sp. and *Pseudagrion* sp. was dominant in pre-monsoon and monsoon in first and second year, respectively. Maximum H' (0.851) was obtained in the month of March during second year (Table 48).

The highest Evenness and Margalef indices (0.992), (18.863) recorded are higher than the values (0.7772 and 4.662) recorded from the studies of Balachandran et al (2012) in Aghanashini River of Central Western Ghats, India. The low values
may also indicate stress which is further confirmed by the low evenness ($J$) values and Shannon $H'$ value of the sampled site.

Signal score was higher in first year as compared to second year. (Table: 84). The Biological Monitoring Working Party and Average Score Per Taxon score (BMWP/ASPT ) data showed that the water quality was moderate in first year but poor in second year. (Table: 90 and 91).

Pearson’s correlation coefficient ($r$) (Table: 102) analysis showed significant positive correlation of diversity and density of aquatic insects with salinity in the first year. While some insect species are relatively tolerant to salinity, others are able to avoid saline conditions. Insect species are highly mobile (winged adults) and may occupy wetlands until conditions (e.g. salinity) become unfavourable, at which time they move to another wetland. (Nielsen et al., 2003). Density of aquatic insects showed positive correlation with lead in the second year. Odonate larvae are known to sequester metals within the exoskeleton by adsorption or accumulation of metal indicating that odonates are tolerant to metal exposures (Tollett et al., 2009).

A positive correlation was found between insect diversity and dissolved oxygen in second year (Table: 103). This coincided with the findings of the study conducted in Chandra river (Sharma et al., 2008). Dissolved oxygen is considered one of the most important limnological variables, both for the characterization of aquatic ecosystems and for the maintenance of aquatic life. Many organisms, specially the indicators of good environmental quality require high concentrations of dissolved oxygen for their survival (Bispo et al., 2006).

**S7(Moirang River)**

Like S5, S6 in this site also total aquatic insect population was higher in the first year (398) compared to second year (247) (Fig: 1). The no. of families (9), genus, (17) and species (18) was higher in first year than no. of families (6) genus, (12) and species (12) in second year (Fig.2&Fig.3). The insect density was highest in June & December during first and second year, respectively. No definite pattern was observed in this site in the two years (Fig: 64 and 65). The high density in
the monsoon could be due to high temperature, as the temperature plays a crucial role in physic-chemical and biological behaviour of aquatic ecosystems (Dwivedi and Pandey, 2002). Maringa (2012) observed that abundance of aquatic insects increased in the wet seasons when resource availability is higher.

Relative abundance of Coenagrionidae was highest among all other families followed by Belostomatidae in both the years (Fig: 41 and 44). However among the species relative abundance of Diplonychus rusticus was highest among all other species in both the years, relative abundance of Zyxomma petiolatum and Gerris sp. was lowest in first and second year, respectively (Fig: 42 and 45). According to Engelmann’s scale of dominance (Table: 63 and 64) Diplonychus rusticus was dominant in pre-monsoon and monsoon in first year and pre-monsoon and post-monsoon in the second year.

Shannon diversity index H' values revealed highest diversity in September (Table: 53). Diversity and biotic indices are influenced by different stresses, including pollution (Sandin Johnson 2000)) Since H' value<1 indicates heavy pollution of water (Staub et al., 1970) in the present study site Shannon H' values <1 throughout the year further confirmed perturbation of the system. This might be due to the fact that Moirang river originating from the western hills of Moirang travels towards its mouth carrying agricultural wastes from the surrounding agricultural fields, municipal sewage and solid wastes from Moirang town, a tourist area in Bishnupur district of Manipur and finally discharges into Loktak lake (Kosygin et al., 2007). Hence the river water has detrimental impact on the health of Loktak lake, the lifeline of the people of Manipur. Signal score was higher in first year as compared to second year (Table: 88). The Biological Monitoring Working Party and Average Score PerTaxon, score (BMWP/ASPT) data showed that the water quality was moderate in first year but poor in second year (Table: 90 and 91). Diversity and Density of aquatic insects showed positive correlation with salinity in second year (Table: 105). The possible reason may be that some insect species are relatively tolerant to salinity (Nielsen et al., 2003).
Like S5, S6, S7 in this site also the total aquatic insect population was higher in the year first year (500) compared to second year (238) (Fig: 1). The number of families (9), genus, (15) and species (18) was higher in first year than number of families (6) genus, (9) and species (9) in second year (Fig :2 and Fig: 3). The insect density was highest in September and December during first and second year, respectively and lowest in March and January during first and second year, respectively (Fig: 66 and 67). No definite pattern could be discerned. Relative abundance of Coenagriidae was highest among all other families during postmonsoon and winter and Corixidae was recorded highest in pre- monsoon and some months of monsoon in the first year. Belostomatidae was highest only in August in the first year (Fig: 47 and 50). In the second year no definite pattern was found and highest abundance was shared by mainly Belostomatidae and Nepidae. The abundance of Coenagriidae (Zygoptera) in the present study might be due to their shorter life cycle and widespread distribution (Norma-Rashid et al., 2001) and tolerance to wide range of habitats (Gentry et al., 1975; Samways 1989). The heteropteran families differ considerably in morphology and ecological preferences from one another and many species display specific habitat preferences and their presence may be due to their high tolerance level and capacity of withstanding a wide range of environmental conditions. It has been suggested that these taxa might also use terrestrial refugia to escape floods (Williams and Hynes, 1976; Gray,1981). Relative abundance of Ischnura sp. a relatively tolerant species usually found in rice fields (Nakao et al., 1976) was highest among all other species followed by Pseudagrion sp. and Corixa sp. in first year. Damselflies, especially Ischnura, can generally tolerate a wide range of chemical conditions, including high organic loading (Roback, 1974). Diplonychus rusticus was highest among all other species followed by Anisops sp. in second year (Fig:51)

According to Engelmann’s scale of dominance (Table: 69 and 70 ) Diplonychus rusticus was sub-dominant in pre-monsoon and monsoon in first year and eudominant in pre-monsoon and dominant in post-monsoon in the second year.
According to Arrington et al. (2005) distribution of insects in the tropical river is influenced by both the distribution of habitats on the landscape and physical habitat characteristics. *Diplonyxus rusticus* was present in all the months. In the second year one Tramea sp. was recorded in second year in S1.

Shannon diversity index $H'$ values was highest in November in the first year (Table: 50) is supported by the findings of Mohd Rasdi et al. (2012) in Keniam River, National Park, Pahang, Malaysia where it recorded highest in November. But Evenness ($J''$) index was recorded highest in July in this site which is in contrast in Keniam River, where Evenness ($J''$) index was recorded lowest in July. Signal score was higher in first year as compared to second year. (Table: 88). The Biological Monitoring Working Party and Average Score Per Taxon, scoring system (BMWP/ASPT) data showed that the water quality was moderate in first year but poor in second year. (Table: 90 and 91)

Diversity of aquatic insects showed positive correlation with Nitrate in second year (Table: 107). This coincided with the findings of Popoola and Otalekor (2011) in Awba reservoir, Nigeria. Diversity of aquatic insects showed positive correlation with iron in second year. The direct and indirect impacts of Fe contamination decrease the species diversity of periphyton, benthic macroinvertebrates and fishes (Vuori, 1995).

This is the first scientific study on the diversity of aquatic insects in lentic (Keibul Lamjao National Park) and lotic (Nambol River, Moirang River and Nambul River) systems of Manipur in relation to physico-chemical properties of water. Biodiversity within inland water ecosystems in the Eastern Himalaya region is highly diverse. One of the main reasons cited for inadequate representation of biodiversity is lack of readily available information on the status and distribution of inland water taxa (Allen et al., 2010). The investigation spanning two years (2009-2010 & 2010-2011) recorded a total of thirty two species of aquatic insects. The study revealed that mean DO values in both the years in all the sites were below standard limits (5 mg/l) of WHO (2004). In first year the mean Iron, Lead and Mercury were beyond the permissible limits of
WHO (2004) in the sites S2, S5, S7 and S8; in S3, S4, S5, S6, S7 and S8 respectively. In second year, the mean Iron, Lead and Mercury were beyond the permissible limits of WHO (2004) in the sites in S8; in S4, S5 and S8 while Lead was below the limits in all the sites in second year. All these facts are ominous sign for survival of any aquatic fauna in any fresh water system. Inspite of that record of 32 aquatic insect species justifies its position in the Indo-Burma biodiversity hotspot. This study recorded *Leucorrhinia* sp. belonging to the order Odonata for the first time in India. Plethora of factors such as very low DO, high concentration of heavy metals (Iron, Lead and Mercury) presence of only three predator groups, absence of sensitive groups EPT (particularly Ephemeroptera in the case of wetlands), preponderance of pollution tolerant families like Libellulidae and Belostomatidae indicated perturbation of the system. This is further confirmed by low diversity index (<1), low SIGNAL score (2.3-3.2) and low BMWP/ASPT score of the different study sites. Among all the sites, site 8 (River Nambul) was found to be the most polluted site. Ordination diagram (CCA) also confirmed the fact. Low SIGNAL score indicated that the sites are likely to have higher levels of salinity or nutrients. These levels may be high either naturally, because of local geology and soil types, or as a result of human activities which indicate that the study area is suffering from one or more forms of human impact, (Chessman, 2003). It can be said that beside several factors, discharge of all the pollution load of the three rivers (Nambol, Moirang, Nambul) into the Loktak Lake effected the water quality of KLNP in a large way. Deforestation within the catchment, agricultural pollution leading to nutrient enrichment as well as encroachment around the Loktak Lake margin have all increased in recent years (LDA and WISA, 1998; ERM, 2003). A detailed land use study indicated that western catchment area directly draining into the lake has 342 sq km under agriculture, 133 sq km under habitation, 262 sq km under forests, 22 sq. km under waterlogged and 287 sq. km being the lake area itself. (WISA and LDA 2004). Rapid urbanization in the Loktak catchment has led to severe stresses on the civic amenities especially safe drinking water and sanitation. So national park area though protected is under stress as it is a part of the lake. This is a matter of great concern because this
national park is the only home of *Rucervus eldii eldii*. This study found that although protected areas are meant for protecting biodiversity, in the freshwater systems management of outside protected area particularly catchment area should be given a priority for minimizing land use disturbance, altered hydrology and other related factors. Sources of direct pollution should be stopped. There should be thorough biomonitoring surveys which should be supplemented by experimental research on toxic effects of different pollutants. Conservation of this unique habitat and the species depends on the management and the people of the area. However effective conservation depends on close communication between scientists and others interested in freshwater resources (Dudgeon, 1999).