Distribution, Production and Biochemical Status of Dominant Macrophytes in Wular Lake, a Ramsar Site in Kashmir Himalaya

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Certificate

This is to certify that the Ph.D thesis entitled "**Distribution, Production and Biochemical Status of Dominant Macrophytes in Wular Lake, a Ramsar Site in Kashmir Himalaya"** is an original work of **Mr. Naseer Ahmad Dar** submitted for the award of the degree of **Doctor of Philosophy (Ph.D)** in **Environmental Science** from **University of Kashmir**. This study has been carried out under our supervision and the same or any part of this thesis has not been submitted for this or any other degree so far. The candidate worked under our supervision for the period required under statutes and he has put in the required attendance in the department.

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Wetlands are considered as transitional areas between land and water. These ecosystems represent the transition between the two extreme diversifications, sustaining both amphibious as well as purely aquatic taxa, harbour a very complex taxonomic makeup of the macrophytic community (Smith, 1980; Banerjee and Venu, 1994). Wetlands are recognized for their high species diversity and productivity (Williams, 1990; Mitsch and Gosselink, 2000). They maintain ecological balance by performing four fundamental functions *viz.* hydrological, physico-chemical, biological and socioeconomic (Williams, 1990).

Wetlands are often described as "*nature's kidneys*" for their ability to filter waste and pollutants, as well as "*nature's supermarket*" for their high productivity and ability to act as a source of food to many organisms (Mitsch and Gosselink, 2000, 2007). The ecological significant services provided by the wetlands include climate regulation, turnover of organic matter, biomass accumulation, as well as substrate for phytophilous organisms and a source of food for aquatic as well as terrestrial organisms (Winter, 1989; Gorham, 1991; Cox, 1993). These ecological services are often considered in anthropocentric terms, because of their ability to ameliorate floods, stabilize shoreline, prevent erosion, as well as removal of contaminants from the water (Cox, 1993). Wetlands also play significant role in the biogeochemical cycling of nutrients by acting as nutrient source, as well as sink of nutrients (Schlesinger, 1991).

Wetlands, representing the last stage of lake succession, are heavily infested with macrophytes particularly emergents acting as nutrient pumps (Pandit, 1984; Cronk and Fennessy, 2001). Macrophytic infestation in aquatic ecosystems, like littorals and shorelines of lakes, marshes etc., determines the structure and functioning of these ecosystems in terms of their community architecture and distribution (Pandit, 1984). It has been emphasized that the aquatic plants occupy great diversity of niches and display morphological plasticity. At the same they also occur in considerably wide range of forms and size though not as great as seen among the terrestrial plants (Pandit, 1984, 2008). It is true for our all aquatic ecosystems and more so for wetlands that all the three macrophyte types, representing different tiers: (a) submerged, floating leaf-types and free floating species, (b) low growing emergents and (c) tall emergents, are present influencing their physico-chemical environment as they form the basis of detritus food chains after their decay (Pandit, 1984, 2008).

Macrophytes, as a component of fresh water ecosystems, have diverse roles to play in the functioning of these ecosystems (Pandit, 1984; Wetzel, 2001). They are directly involved in modifying the nutrient chemistry within the water by acting as nutrient sinks as well as source of nutrients. (Carignan and Kalff, 1980; Pandit, 1984; Cronk and Fennessy, 2001). Besides, controlling the level of oxygen, macrophytes are also able to perform pivotal role in the biotic interactions of the littoral zone of shallow lakes and wetlands (Raspopov *et al*., 2002). The structural design of macrophytes within wetlands offers refuge for macroinvertebrate communities and periphyton (Pandit, 1984; Carpenter and Lodge, 1986; Cyr and Downing, 1988; Beckett *et al*., 1992). Herbivorous invertebrates such as crayfish obtain their food directly from aquatic plants (Lorman and Magnuson, 1978; Price *et al*., 1980; Rozas and Odum, 1988; Chambers *et al*., 1990; Hanson *et al*., 1990), and some fish (Pandit, 1984; Carpenter and Lodge, 1986). Macrophytes provide an efficient method for removing contaminants from the water, which has resulted in the successful implementation of treatment wetlands (Maine *et al*., 2006). Macrophytes offer significant regulating services through the stabilization of shoreline and at the same time prevent erosion with the help of root structure. Amelioration of flood effects by slowing incoming water flow, thereby acting as a sponge is also among the significant ecosystem services provided by macrophytes (Croft, 2007).

Macrophytes have pronounced impact on their abiotic environment (Kaul *et al*., 1980; Pandit, 1980; Makela *et al*., 2004). They slow down currents and thereby increase sedimentation (Spence, 1982; Carpenter and Lodge, 1986; James and Barko, 1990). The composition of the sediments beneath macrophyte beds differs considerably from other sediments. Sediments beneath the macrophytes are rich in nitrogen, phosphorus, calcium and organic compounds (James and Barko, 1990). The sediments below macrophytes also have increased proportion of decaying material from the plant bed (Carpenter and Lodge, 1986). Macrophytes alter the quantity and quality of light under them. The reduction in the amount of light causes the water under the macrophytes to be cooler than the surrounding water (Carpenter and Lodge, 1986). Macrophytes are having profound influence on chemical characteristics of wetland waters. Respiration and photosynthesis processes carried out by macrophytes influence the oxygen and carbon dioxide levels in littorals than the limnetic zone. Organic and inorganic carbon levels in the water are increased by macrophytes while inorganic nutrient levels are generally reduced (Carpenter and Lodge, 1986). Recent studies also suggest that macrophytes play a central role in shallow lakes which can have two possible stable equilibria: (i) a clear-water state that is dominated by aquatic macrophytes, and (ii) a turbid-water state that is dominated by phytoplankton (Scheffer *et al*., 1993; Moss *et al.*, 1994; Hakanson and Boulion, 2002). In addition to these ecosystem services, macrophytes acts as potential source of food and fodder for humans and bovine population, besides serving as a base of aquatic foodchain (Pandit, 1984; Tardío *et al*., 2005; Rahman *et al*., 2007; Hasan and Chakrabarti, 2009; Smith, 2011; Swapna *et al*., 2011).This realization of multiple ecological and socio-economical importance of macrophytes has generated a great interest towards better understanding of their diversity and role in natural ecosystems, thus paving a way for scientific management of macrophytes dominated ecosystems-the wetlands (Pandit, 1999).

The shape of some macrophytes determines the environment that they may inhabit (Duarte and Roff, 1991). The aquatic macrophytes in the littoral zone of lakes are arranged in specific zones (Spence, 1982; Wetzel, 1983). Emergent macrophytes occur nearest the shore, the floating macrophytes occupy the intermediate zone, and the submersed macrophytes are farthest from shore towards the limnetic zone. The occurrence, density, distribution and growth of aquatic macrophytes depends on myriad of abiotic factors such as pH, water depth, transparency, bicarbonate alkalinity, dissolved organic matter, nitrate-nitrogen, phosphate etc. (Pip, 1979; Madsen *et al*., 2006; Vis *et al*., 2007; Dar *et al*., 2014). Composition and properties of sediments also seem to have considerable effect on the diversity and distribution of certain macrophytic species (Dawson and Krysztof, 1999; Heegard *et al.*, 2001; Makela *et al*., 2004; Tamire and Mengistou, 2012; Sossey-Alaoui and Rosillon, 2013). In addition to these factors the growth of macrophytes also depends on the number of growing days in the season (Wetzel,1988) and accordingly different macrophyte species may exhibit seasonally variable growth patterns (Wetzel, 2001). Macrophytes act as important bioindicators of environmental conditions and long-term ecological changes in water quality (Pandit, 1984, 92; Solimini *et al*., 2006; Beck *et al*., 2010; Sondergaard *et al*., 2010). Because of their high rate of biomass production, macrophytes act as an important primary food resource for aquatic organisms (Pandit, 1980, 84). The complex tropic dynamics and primary productivity of wetlands is greatly influenced by the higher diversity and biomass of macrophytes (Kumar and Singh, 1987).

Phytoplankton and emergent, floating and submerged macrophytes which differ in terms of their productivity, consumption of different sources of nutrients and energy, are principal primary producers in shallow lakes and wetlands (Horne and Goldman, 1994; Nikolic *et al*., 2009). The abundance and productivity of macrophytes can vary within two orders of magnitude among lakes of different trophic levels. It has been well documented that maximum productivity of the biosphere occurs in the zone of emergent aquatic macrophytes and declines rapidly in case of submerged macrophytes (Westlake, 1963; Wetzel, 1990). Among macrophytes, emergents and rooted floating-leaf type are the most abundant and productive than submerged aquatic macrophytes and that are herbaceous perennial plants, developing highly dissected foliage and are not the rapidly growing surface canopy forming species under eutrophic conditions. The continuous turnover of organic matter with production of relatively resistant particulate organic matter in senescent tissues is mainly caused due to the continuous growth of perennial plants. However, annual plants do not exhibit such continuous growth and biomass turnover (Wetzel and Sondergaard, 1998). The productivity of perennials with thin, finely divided, reticulated foliage that increases surface area, enhances gas exchange and light harvesting is very much higher compared to productivity of rosette perennials such as the isoetids and of most annual submerged plants (Sculthorpe, 1971). The higher productivity of aquatic macrophytes may hasten the process of eutrophication at the time of their decomposition (Nikolic *et al*., 2007, 2009; Dar *et al*., 2012). Therefore, for protecting the ecological balance in freshwater ecosystems, it becomes imperative to monitor these ecosystems for growth and development of macrophytes with high biomass rates (Coops *et al*., 2002; Nikolic *et al*., 2009).

For the assessment of nutritional value and evaluation of food potential of aquatic plants, the knowledge of their ecological significance and chemical composition is essential (Chapman and Chapman, 1980; Hawkins and Hartnoll, 1983; Pandit, 1984, 1993; Pandit and Qadri, 1986; Abbott 1988). It is well known that seasonal variations in certain abiotic factors such as light, temperature, sediment composition and water chemistry can influence photosynthetic rates and biochemical composition of macrophytes (Koskimies and Nyberg, 1987; Roslin, 2001; Ordsuna-Rojas *et al*., 2002; Rajasulochana *et al*., 2002), thus necessitating the determination of their biochemical composition.

The biogeochemistry and trophic dynamics of wetlands is largely controlled by the distribution patterns of macrophytes and therefore, it becomes imperative to view wetlands as complex mosaic of habitats with distinct structural and functional attributies (Rose and Crompton, 1996).Considerable efforts have gone into the field studies to correlate the spatial distribution pattern of aquatic plants with major physico-chemical environment of their habitat. In India the studies on wetland ecosystems have attracted the attention of quite a few investigators in the last few decades (Gopal, 1968; Das and Gopal, 1969; Verma, 1979; Verma *et al.*, 1982; Paliwal, 1984; Shardendu and Ambasht, 1991; Usha, 2002; Singh and Sharma, 2012) to mention a few, but most of them deal mainly with floristics composition, production and zonation in relation to water depth. There are only few reports regarding the distribution patterns and community characteristics of macrophytes including the studies pertaining to physiognomy of wetland vegetation in Kashmir (Handoo, 1978; Kak, 1978, 1981, 1990; Kumar and Pandit, 2005, 2008; Rather and Pandit, 2006; Mir, 2007; Mir and Pandit, 2008; Pandit, 2008; Kumar, 2009; Rather, 2009). Further, very little but preliminary published literature is available on Wular lake (Mir, 2007; Mir and Pandit, 2008) particularly on the very aspect of macrophytes. It is only very recently some work, yet to be published, has been conducted on the production and nutrient dynamics of macrophytes in Hokersar wetland (Kumar, 2009) which as such has remained untouched as far as the distribution patterns and biochemical composition of macrophytes is concerned. In this backdrop the present study on “Distribution, production and biochemical status of dominant macrophytes in Wular lake, a Ramsar Site in Kashmir Himalaya” has been undertaken to work out a generalized relation between water and macro- vegetation distribution, production and biochemical composition. This study can latter on in future help in determining the pattern in which distribution, production and biochemical composition of macrophytes change as the water quality deteriorates. The present study thus aims at fulfilling the following objectives:

1. To study the community features of macrophytes.
2. To assess the complex physiognomy of macrophytes in terms of species composition and various diversity indices.
3. To work out the primary productivity of dominant macrophytes.
4. To prepare vegetation map depicting the zonation and current status of the macrophytic community in respect of the diversity and distribution.
5. To assess the seasonal variations in the biochemical status of dominant macrophytes (carbohydrate, lipid, protein and chlorophyll (a, b and total) contents).
6. To study the seasonal variations in the physico-chemical characteristics of lake waters.
7. To study the relationship between macrophytes and physico-chemical characteristics of lake waters for determining the ecological distribution of macrophytes.

Limnological studies of freshwater ecosystems are essential to understand their trophic dynamics and biological diversity and productivity. The literature pertaining to limnology of lakes and wetlands is quite vast and voluminous and dates back to the beginning of nineteenth century. Forel’s (1901) monographic work on Lac Leman (Lake Geneva) is considered as a landmark limnological contribution. Different workers have made noteworthy contributions in the proposed field of lakes and wetlands. Some of them include works on different lakes like Lake Suraha (Swarup and Singh, 1979), Great Bear lake (Moore, 1980), Swiss lakes (Lachavanne, 1985), Jastericie lake (Hudee *et al*., 1995), Great Lakes (Lougheed *et al*., 2001), Lake Edku (Okbah and El-Gohary, 2002), Danish lakes (Sondergaard *et al*., 2003b), Lake Hiidenvesi (Nurminen, 2003), Manchhar lake (Mahar, 2003), Moro lake (Mustapha and Omotosho, 2005), Yarseli lake (Tepe *et al*., 2005), Mansar lake (Zuber, 2007) and Lake Ziway (Beneberu and Mengistou, 2010).

The pioneering work on limnology of Kashmir lakes with regard to general ecology, lake succession and morphometery dates back to Mukherjee (1932,34) besides, there are some ecologically important early research works (Edmondson and Hutchinson, 1934; Zutshi *et al*., 1972, 1980; Zutshi and Vass, 1978; Zutshi and Wangneo, 1989; Kaul, 1977; Kaul *et al*., 1978; Kaul and Handoo, 1980; Pandit, 1980, 1992, 1993, 1998; Qadri and Yousuf, 1980; Pandit and Kaul, 1982; Trisal, 1987; Kundangar and Sarwar, 1997; Kundangar and Abubakar, 2004; Zutshi and Yousuf, 2004) that could be used as the baseline for the current and future limnological research. However, due to availability of voluminous literature on various limnological aspects of lakes and wetlands, it is quite impossible to incorporate them all in the present thesis. Hence every effort has been made to include all the important and relevant references from the last three to four decades in the present work under various headings.

2.1. General limnology and physico-chemical charactersistics of water

Physico-chemical parameters and quantity of nutrients in water play significant role in the distributional patterns and species composition of aquatic organisms (Mahar, 2003). In aquatic habitats, the environmental factors include various physical properties of water such as light penetration, temperature, density and solubility of gases and solids. The chemical factors such as pH, hardness, phosphates and nitrates are very essential for growth and development of aquatic organisms such as macrophytes, phytoplankton and zooplankton. The term "Water quality" refers for the physical, chemical and biological setup of water and all these characteristics directly or indirectly influences the growth and survival of aquatic species (Boyd, 1998).) The human factors are responsible for changing the physico-chemical and biological environment of the freshwater ecosystems (Yousuf, 1995). As water quality is an index of water pollution, assessing water quality parameters is baseline information for monitoring freshwater environments. Besides, having a profound impact on the distribution patterns and population density of both animals and plants (Odum, 1984), physico-chemical characteristics of water also regulate the productivity of lakes and wetlands (Mahboob *et al.*, 1988).

Depth of a water body is determined by the hydrological factors like the amount of water brought in and sent out (Steward and Kantrud, 1971).There is no certain boundary for classification of lakes based on depth. According to Goldman and Horn (1983), lakes with a depth of more than 100 m are relatively deep and reasonably large with an area of more than 40-80 ha. Buraschi *et al*. (2005) characterized the lake levels as very shallow (mean depth < 3 m); shallow (mean depth 3-15 m) and deep (mean depth >15 m). Lower values of mean depth have been used as an important criterion to establish the trophic status of lakes (Hayes, 1957; Pandit, 2002). Depth and water volume are relative factors that influences temperature of a water body (Atobatele and Ugumba, 2008). According to Hutchinson (1957), thermal structure of a lake is dependent upon geographical position and depth.

The light in water is of paramount importance for its role in the photosynthetic processes of all chlorophyll bearing aquatic plants and thus for the primary production (Mahar, 2003). The extent to which light can penetrate depends on the transparency of standing water column. In water, different wavelengths of light are differently absorbed depending upon the roughness of the water surface and the angle of the radiation (Mahar, 2003). Secchi disc transparency, being a function of the amount of light reflected from the surface of water, is influenced by the absorption characteristics of water and the amount of dissolved and particulate matter contained in the water (Wetzel and Likens, 2000). Natural waters are not pure and contain many substances, which further interfere with light penetration. It is often a limiting factor in the distribution of organisms in water particularly the plankton. Further, transparency of water is inversely proportional to turbidity, created by suspended inorganic and organic matter (Saxsena, 1987). The transparency of water is affected in various seasons due to algal blooms and suspended sediments (Horn and Goldman, 1994). In most of the studies, mean depth and transparency have been used as an important criterion to establish the trophic status of any waterbody. Margalef (1958), on the other hand, related depth and transparency to biotic factors rather than trophic basis. Mustapha and Omotosho (2005) reported that absence of high water velocity, run-offs and sedimentation were responsible for greater transparency in winter season.

Temperature plays an important role in rates of biological and chemical processes in shallow lakes and wetlands. It influences the oxygen contents of water quantity and quality of autotrophs, while affecting the rate of photosynthesis and also indirectly affecting the quantity and quality of heterotrophs (Barnabe, 1994). Studies have revealed that temperature in freshwater aquatic systems varies locally and over short time scales and water temperature of an aquatic body follows closely the air temperature (Joshi, 1996). Animals are stressed when temperature changes rapidly, because there is no enough time for physiological adaptation (Boyd, 1998). Mahboob and Sheri (2001) stated that temperature is significantly affected by the intensity of light and has corresponding effect on the primary productivity. All organisms including fish, possess limits of temperature tolerance. The seasonal fluctuation of temperature influences the feeding habits of the fish. All biological activities like ingestive variation, reproduction, movement, distribution and growth patterns of aquatic organisms are greatly influenced by water temperature (Baqai and Rehana, 1973; Iqbal *et al.*, 1990). Decrease in temperature is also directly related to increase in dissolved oxygen (Boyd, 1998). Mahboob and Sheri (2001) stated that temperature is significantly affected by the intensity of light and has corresponding effect on the primary productivity. High temperature intensifies the effect of toxic substances and speed up biological degradation process. A temperature of about 35ºC is generally considered as maximum for survival of aquatic life (Mahar, 2003).

Conductance, being principally a function of ions and being an indicative of total salt concentration, can be used for assessing the trophic status of any water body (Berg *et al*., 1958). Rainfall patterns, incoming waters, evaporation rates, drainage type and nutrient status are the major factors that influence conductivity of a lake (Kinnear and Garnett, 1999).The level of conductivity in water gives a good indication of the amount of charged ions dissolved in it, such as phosphate, nitrate and nitrites (Mahar, 2003). Different ions vary in their ability to conduct the electricity. But generally conductivity of the natural water is directly proportional to the concentration of ions. According to Rhode (1949) the specific conductance of the common bicarbonate-type lake water is closely proportional to the concentrations of the major ions. Distilled water has a conductivity of about 1µmhos/cm, while natural water normally has conductivity of 20-1500 µS/cm (Boyd, 1998) .The conductivity of solutions depends upon the quantity of dissolved salts present (Boyd, 1998). Kumar and Pandit (2007), while studying the physico-chemical features of water in Hokersar wetland in Kashmir Himalaya, placed the wetland in β- mesotrophic type of Olson (1950) on the basis of specific conductance (200-250 μScm^{-1}). Otsuki and Wetzel (1974), observed strong correlation between Ca^{2+} and HCO^{-}_{3} with conductivity. Pandit (1999) attributed the winter high and summer low in the conductivity values to the uptake of ions by plants during the growing season. Similar observation has been reported by Mustapha and Omotosho (2005).

Total dissolved solids (TDS) indicate organic and inorganic matter in the sample. Total dissolved solids are very useful parameters describing chemical constituents of the water and can be, in general, related to the edaphic factor that contributes to the productivity within the water body (Goher, 2002). A high concentration of dissolved solids increases the density of water affecting osmoregulation of fresh water organisms, besides reducing solubility of gases and utility of water for drinking, irrigational and industrial purposes (Boyd, 1998). It has been considered that the growth and primary production of phytoplankton is influenced by the amount of dissolved solids in water. The presence of dissolved solids in water affects the amount of light available for the primary productivity thereby influencing distribution and photosynthetic activity of aquatic organisms (Danilov and Ekelund, 2001). Shinde (2011) observed significant positive relationship between total dissolved solids and conductivity. Brion (1973) registered low dissolved solids in winter season while maximum value was obtained in monsoon due to the addition of solids from surface run-off. Khaliq (2012), on the other hand, registered maximum seasonal amounts of total dissolved solids during winter as against the minimum being recorded during summer.

The concentration of carbon dioxide is an important property of aquatic ecosystems reflecting both internal carbon dynamics and external biogeochemical processes in the terrestrial ecosystems (Richey *et al.*, 1990). The high value of the free carbon dioxide content is an indication of high degree of pollution (Todda, 1970; Cole, 1979). An inverse relation of free carbon dioxide with pH is well documented (Zafar, 1964; Swarup and Singh, 1979 and Jhingran, 1982).Free carbon dioxide influences the concentration of carbonates, bicarbonates, pH and total hardness (Wetzel, 1973; Qadri and Yousuf, 1978).Water rich in CO_2 in the cooler months is generally less alkaline having smaller bicarbonates and hardness and no or very little carbonates, whereas water poor in this gas in warmer months is more alkaline having smaller bicarbonate and hadrness content and high carbonate content (Munawar, 1970; Qadri and Yousuf, 1978).Wetzel (1973) and Nassar and Dutta-Munshi (1975) held the direct influence of photosynthetic action of phytoplankton and macrophytes on free carbon dioxide responsible for comparatively higher pH during the summer. Similar observations were made by Kumar and Pandit (2007) in Hokersar wetland, Kashmir.

Dissolved oxygen (DO) is essential to all forms of aquatic life (Edmondson, 1959; Makhlough, 2008). Sources of dissolved oxygen in the aquatic environment include the atmospheric and photosynthesis and depend on its solubility while losses of oxygen include respiration, decay of aerobic bacteria and decomposition of dead decaying sediments (Gupta and Gupta, 2006). The quantity of dissolved salts and temperature greatly affects the ability of water to hold oxygen. The solubility of oxygen increases with decrease in temperature (Singh, 1990). Low dissolved oxygen retaining capacity of water due to increased organismal respiratory demand at high temperature may also cause these low values of dissolved oxygen (Rao, 1986). Increasing levels of dissolved oxygen in aquatic systems are usually associated with eutrophic and productive water bodies (Egborge, 1994). Inverse relationship of dissolved oxygen and free carbon dioxide is well known (Bosserman, 1983; Horn and Goldman, 1994). Although there is usually inverse relationship between temperature and dissolved oxygen exceptions do exist (Oben, 2000). Lewis (2000) opined that oxygen conservation is an important management principle for tropical lakes. Vass *et al*. (1977) and Qadri *et al*. (1981) advocated that high dissolved oxygen concentration during winter can be attributed to low biological activity.

pH is principally a function of amounts of calcium, magnesium, carbonates and carbon dioxide in the water (Wetzel, 2001) . The interaction of both the H^+ generated by dissociation of H_2CO_3 and OH^- produced during the hydrolysis of HCO_3^- governs the pH of natural waters to a large extent (Wetzel, 2001). Optimal pH range for sustainable aquatic life is pH 6.5 - 8.2 (Boyd, 1998; Wetzel, 2000). Acidic pH (<6.5) is usually a feature of oligotrophic lakes, while as the neutral (6.5-7.5) and alkaline pH (>7.5) is mainly exhibited by eutrophic lakes (Whitemore, 1984). Large pH changes of one unit or more have been reported under a combination of low to moderate alkalinity and high algal or submerged macrophyte biomass resulting in large daytime CO_2 and HCO_3^- withdrawal (depletion), thereby increasing pH (Boyd, 1990). Wetzel (1973) and Nassar and Dutta-Munshi (1975) held photosynthetic action of phytoplankton and macrophytes responsible for comparatively higher pH values during summer months. On the other hand, pH declines in winter season due to increased decomposition under least water depth.

Chloride is one of the major inorganic anions in natural water. In potable water, the salty taste is produced by chloride ions. Its concentration is variable and dependent on the chemical composition of water. According to Chapman and Kimstach (1992) in pristine conditions chloride concentration of fresh water are often lower than 10 mg/L. Metabolic utilization of chloride does not cause significant variations in spatial and seasonal variations within a water body (Pandit, 1999). Bhat *et al*. (2001) opined that the high chloride content, an indicator of organic pollution, owes its origin to the sewage wastes carrying detergents and sewage from human settlement. While Munawar (1970) related high chloride content to high nitrate and ammonia levels, Thresh *et al*. (1944) and Kumar (2009) associated high chloride content of water to the organic pollution of animal origin. Kumar and Pandit (2007), while studying the physico-chemical features of water in Hokersar wetland in

Kashmir Himalaya reported that heavy rains and subsequent run-off from the catchment area were responsible for the higher levels of the chloride ion during spring season.

Hard water contains high concentrations of alkaline earth metals while soft water has low concentrations. Hardness usually includes only Ca^{2+} and Mg^{2+} ions expressed in the terms of equivalent $CaCO_3$ (Abbasi, 1998). Total hardness of 15 ppm or above are satisfactory for the growth of fish and do not require liming but water having hardness values less than 11 ppm require liming for higher production of fish. Water having hardness less than 5 ppm $CaCO_3$ equivalent cause low growth, distress and eventually death of fish (Rath, 1993). The type of minerals in the soil and watershed bedrock, and the amount of lake water coming into contact with these minerals are the major factors that influence hardness of a lake (Tepe *et al*., 2005). Calcium is generally considered to be the dominant cation in Kashmir lakes on account of the predominance of lime rich bed rock in the catchment area (Zutshi *et al*., 1980; Pandit, 1993). The changes in ionic (Ca^{2+} and Mg^{2+}**)** ratios in water, with Ca^{2+} values being higher than Mg^{2+}, may result from base exchange or the replacement of Ca^{2+} by Na^+, K^+ and Mg^{2+} (Wetzel, 2001).

Alkalinity is mainly due to the presence of carbonates, bicarbonates and hydroxides of calcium and magnesium with calcium ions being the dominant cation (Das and Dhiman, 2003; Dallas and Day, 2004). In fresh water bodies there is predominance of bicarbonates and calcium over chloride and magnesium (Rodhe, 1949). Zutshi *et al*. (1980) reported that calcium is generally the dominant cation in Kashmir lakes on account of predominance of lime rich bed rock in the catchment area. In their study on Wular lake, Qadri *et al.* (1981) observed that two inlet streams of Wular lake, Erin and Madhumati, are alkaline due to carbonates and bicarbonates of calcium and magnesium.Weathering in the watershed is considered the primary process regulating the concentration of alkalinity, calcium and magnesium (Panday *et al*., 1999; Mosello *et al*., 2004). Alkalinity declines in winter season due to decomposition of organic matter (Parashar *et al*., 2006). On the other hand, summer fall in the alkalinity has been associated with relatively higher pH and temperature (Wetzel, 1973). Vass *et al*. (1977) opined that total alkalinity value of 60 mg/l or more indicates hard water. Reyaz and Yousuf (2005) while studying the ecology of macrozoobenthic community in the Wular lake observed high values of bicarbonates of calcium and magnesium, total inorganic nitrogen and total phosphorus, thus giving it the status of typical hard water type. Tepe *et al.* (2005) while studying physicochemical characteristics of Yarseli lake, Hatay (Turkey) opined that groundwater from aquifers containing limestone minerals such as calcite ($CaCO_3$) and dolomite ($CaMgCO_3$) resulted in higher alkalinity and hardness values.

2.2. Nutrients and trophic status

Nutrients are essential elements for the primary productivity of any aquatic ecosystem and include mainly nitrogen and phosphorus (Wetzel, 1983). The nutrient dynamics are influenced by different factors such as the weather, geology and soil type, drainage pattern and weathering processes. Nutrients occur in various sources and forms. Within the aquatic ecosystems, phosphorus and nitrogen roles can vary (McCarthy, 1981; Howarth 1980). Nitrogen occurs in numerous forms such as dissolved molecular nitrogen and a large number of organic compounds such as amino acids, amines, proteins, nitrates, nitrite and ammonium (Wetzel, 1983). Sources of nitrogen include precipitation falling directly from onto the lake surface, nitrogen fixation in the water and sediments, input from the surface and ground water recharge. Nitrogen inversely fluctuates with water temperature (Munawar, 1970). It well known that plants prefentially take up the reduced NH_4^+ rather than oxidized NO_3^- , so that lower levels of ammonia occur in water (Kalff, 2002). Xie *et al.* (2004), Shilla *et al*. (2006) and Bhat (2010) reported that the decrease in the concentration of ammonical and nitrate nitrogen during the vegetation period is related to uptake by autotrophs i.e., phytoplankton and macrophytes. On the other hand, relatively higher levels of ammonical nitrogen in winter may be due to low microbial activity which converts ammonia into nitrites and nitrates (Shah and Pandit, 2013). Nandan and Patel (1992) stated that due to blooms of *Microcystis* in summer months, the values of nitrogen and nitrates were low in comparison to those of other seasons.

Phosphorus is a least abundant element and often-limiting factor for the biological productivity (phosphorus promotes excessive aquatic plant growth). In freshwater systems total phosphorus levels have often shown the strongest correlations with levels of chlorophyll *a* (Pridmore and McBride 1984). It occurs in organic and inorganic (polyphosphate, orthophosphate) forms. Only phosphate-phosphorus (PO_4^{-3}-P) can be used by phytoplankton and macrophyte for growth. The dissolved inorganic phosphate phosphorus values are in generally low as compared to total phosphate phosphorus (Khan and Zutshi, 1980; Kundagar *et al*., 1996; Shah and Pandit, 2012). Phosphorus load in Dal lake (Kashmir) as observed by Ishaq and Kaul (1989) revealed that 99% of the total phosphorus is locked up within the sediments whereas remaining 1% is distributed in and is being utilized by aquatic organisms. The release of orthophosphate usually takes place when the concentration of nitrate is low, but when the concentration of nitrogen becomes highest the concentration of phosphates begins to decline (Anderson, 1982). Phosphate ion is reported to co-precipitate with carbonate under the influence of increased pH associated with high temperature and higher alkalinity (Otsuki and Wetzel, 1972; Kaul *et al*., 1978; Pandit, 1999). Thornton and Nduku (1982) suggested the values of dissolved inorganic phosphorus >30µg/L as indicative of eutrophic status in temperate lakes. Kaul *et al*. (1985) obtained a positive correlation between flushing rate of water and phosphorus loading and negative correlation between flushing rate and retention coefficient of phosphorus indicating high flushing rate to be a great check on nutrient accumulation in the lake ecosystems in general and wetlands in particular. While Dittrich *et al*. (2004) reported lower concentration of total phosphorus in lake waters in summer, Mahar (2003) and Kumar and Pandit (2007) reported that the uptake and turnover rate of phosphorus are extremely rapid in summer.

Nutrient enrichment from anthropogenic sources is one of the major stresses affecting aquatic ecosystems (Bishop *et al*., 2006) and total inorganic nitrogen and total phosphorus are the primary macro-nutrients that enrich freshwaters (Pandit and Yousuf 2002). Nitrogen plays an important role in the eutrophication of water along with phosphates (Singh *et al.,* 1990). While Harris (1986) observed that the constant addition of even low levels of nitrogen and phosphorus to an aquatic environment could greatly stimulate algal growth, Wetzel (1975) observed that inorganic phosphate and soluble orthophosphate plays dynamic role in aquatic ecosystems even in small quantity.

Silicon is an essential nutrient for diatoms which form important component of the phytoplankton community in most of the water bodies of the world (Hutchinson, 1967; Okbah and El-Gohary, 2002). Silicon occurs in two major forms: silicon dioxide and silica (Wetzel, 1983). The major source of dissolved silica is from the degradation of the aluminum silicate minerals (Mustapha and Omotosho, 2005). Talling and Talling (1965) documented that in African lakes the river input plays a big role in silica supply and concentration in lakes. Silicate solubility is known to increase at higher pH values and higher temperatures (Willen, 1991). Willen (1991) showed that small, shallow water bodies tend to experience higher epilimnetic silica concentrations than deep, large lakes worldwide. Mwaitega (2003), reported that the increase of nitrogen and phosphorus accompanied with decrease of silica can result into change of the whole algae community of these lakes. Further, Wetzel (1983) reported that the changes in silica concentration could have strong influence on the overall pattern of algal succession and the productivity of a lake. Werner and Roth (1983) opined that the availability of silicate is important for the control of the diatom population.

Iron is an important micronutrient of microflora, plants and animals as it plays an important role in many enzymatic transformations. The quantity of total iron in oxygenated surface waters of neutral or alkaline lakes ranges from about 50-200 µg/L and much higher levels may occur in certain alkaline and closed lakes rich in organic matter. Iron along with other cations such as manganese is known to affect the hardness of water (Mahar, 2003). Mwaitega (2003) observed that once living organisms die, they sink to the bottom and the phosphorus becomes unavailable as it combine with iron or other locking element changes to insoluble forms ($Fe_3PO_4^{-3}$). Kumar and Pandit (2007), while studying the physico-chemical features of water in Hokersar wetland in Kashmir Himalaya, reported higher concentration of total iron content in wetland waters during winter season. Similar observations were made by Ramesh and Selvanayagam (2013) in Kolavoi lake, India. Akram (1992) related higher iron content in lake waters to agricultural activities and increased diffusion of ferrous ion from the sediment at lower oxygen concentration near the sediment surface.

2.3. Distribution of macrophytes

Macrophytes play significant role in the structure and functioning of shallow lakes and wetlands (Pandit, 1984, 1992; Tamire and Mengistou, 2012; Sossey-Alaoui and Rosillon, 2013). The function of macrophytes in these ecosystems is related to their structural attributes like species composition, distribution, abundance and diversity which in turn relies on various environmental factors such as light, water temperature, substrate composition, epiphyte loading, fluctuations in water level, quality of the lake water, sediment nutrients and competitive interactions, (Kaul *et* *al*., 1978; Pandit, 1984, 1992; Barko and Smart, 1986; Duarte *et al*., 1986; Cronk and Fennessey, 2001; Wetzel, 2001; Pankhurst, 2005; Jaikumar *et al*., 2011; Siraj *et al*., 2011; Feldmann, 2012; Tamire and Mengistou, 2012). In addition to these factors composition and properties of sediments also have significant effect on the presence of certain macrophytic species in aquatic environments (Dawson and Krysztof, 1999; Heegard *et al*., 2001; Makela *et al*., 2004; Madsen *et al*., 2006). Some aquatic macrophytes become cosmopolitan in distribution due to their efficient reproduction strategies and good dispersal capabilities (Sculthorpe, 1967; Barrat-Segretain, 1996; Santamaria, 2002). Vegetative and clonal reproduction is considered to be the most important mechanism involved in the growth and dispersal of macrophytes because sexual reproduction and genetic recombination are often considered as subordinate strategies (Wetzel, 2001).

The distribution pattern of macrophytes is largely controlled by water clarity and the amount of light that reaches the plant. A number of studies have found these to be the most significant factors governing the abundance, composition and distribution of macrophytes (Bini *et al*., 1999; Lougheed *et al*., 2001; Pandit *et al*., 2002). It is well documented that underwater light plays a significant role in determining the depth distribution of different life-form classes of macrophytes (Sculthorpe, 1971; Chambers and Kalff, 1985; Hrivnak *et al*., 2006). It has been emphasized that water level is closely related to light transmission, with deeper water hindering the processes of scattering and absorption (Wetzel, 1988; Sand-Jensen and Borum, 1991). A number of studies indicate that certain species of aquatic macrophytes mostly submerged ones usually extend into the depths in order to maximize their absorption of the light and CO_2 needed for photosynthesis; for example, *Hydrilla* sp. is very effective in elongating its shoots (Barko and Smart, 1981; Maberly and Madsen, 2002). Chambers and Kalff (1985) noted that submerged macrophytes grow to a depth of two to three times the Secchi depth. Chambers and Kalff (1985) and Dennison *et al.* (1993) obtained a positive relationship between secchi depth and rhizophytes. They found that this relationship is probably related to light availability-dependent habitat heterogeneity for submerged species. On the other hand, Duarte and Kalff (l987) found that climatic differences associated with geographic latitude seems to have a strong impact on the relationship between transparency and depth distribution of submerged plants.

Lot of research has been done from time to time to evaluate the effects of water quality, sediment characteristics and geological formations on aquatic macrophyte distribution (Kaul, 1971; Chambers, 1987; Gopal, 1987; Barko *et al*., 1991; Lougheed *et al*., 2001; Mir *et al*., 2009; Alahuhta, 2011; Gecheva *et al*., 2011; Tamire and Mengistou, 2012; Sossey-Alaoui and Rosillon, 2013). Sediment related factors affecting the distribution of macrophytes are the high organic matter content that may have a toxic influence on macrophytes due to the accumulation of phytotoxins, poor oxygen availability that may disturb the metabolic processes in roots, nutrient limitation due to complex formation and granulometric composition (Drew and Lynch, 1980; Sikora and Keeney, 1983; Lachavanne, 1985; Barko and Smart, 1986; James and Barko, 1990; Barko *et al*., 1991; Sand-Jensen, 1998; Armstrong *et al*., 1999; Boedeltje *et al*., 2001).

The distribution and growth of aquatic macrophytes is associated with nutrient rich environments particularly nitrate and phosphate which have been noted to favour macrophytes growth (Frankouich *et al*., 2006). Several studies have established that the nutrient enrichment can cause significant changes in the density and species richness of vegetation in lakes (Lougheed *et al*., 2001; Rosset *et al*., 2010; Alahuhta 2011). Nutrient enrichment of waters due to clay soils seems to have positive influence on the relationship between helophyte vegetation distribution and finer grained soils and less acidic bedrocks. In boreal catchments, clay soils can promote littoral overgrowth both at the lake and habitat levels (Partanen *et al*., 2009). Recently, Shah and Reshi (2014) linked the distribution of invasive aquatic flora in different aquatic ecosystems of Kashmir Himalaya to their trophic status.

Riis *et al.* (2000) while examining the relationship between environmental factors such as water depth, soil type, light attenuation, water velocity and land use and aquatic plant composition in Danish streams found that alkalinity was the most important factor in predicting plant distribution. On the other hand, Day *et al*. (1988) found that water depth, the effects of spring flooding in removing litter and the fertility gradient produced by flowing water are the three main factors affecting the distribution patterns of aquatic plants. Sossey-Alaoui and Rosillon (2013) linked the distribution of macrophytes in some selected natural and impacted water-courses in Belgium to the nature of the geological formations and to the degree and nature of the pressure exerted on these environments.

Hydrologic and hydrodynamic conditions affect the distribution patterns of macrophytes mainly in two ways: (i) by fluctuating water level (Spence, 1982; Coops *et al*., 1996; Schwarz and Hawes, 1997; Fernández-Aláez *et al*., 1999; Kors *et al*., 2012), and (ii) by mechanical stress caused by waves and water flow (Spence, 1982; Idestam-Almquist and Kautsky, 1995; Rea *et al*., 1998).Several studies have found that the variations in water depth leads to variations in species zonation, distribution, biomass and richness (Khedr, 1997; Fernandez-Alaez, 1999; Arts, 2002; Lacoul and Freedman 2006). The turbidity of water also determines the extent of colonization of submerged aquatic plants (Kaul *et al*., 1978; Kaul, 1982; Pandit, 1992, 2008; Scheffer *et al*., 1992). The higher turbidity and fluctuations in water level limits the distribution of macrophytes to mainly turbidity tolerant species, for example rooted floating-leaf types and emergents (Nurminen, 2003). Low water levels may have a greater impact on the submerged vegetation in comparison to the lower lakes, due to the steeper shorelines (Pankhurst, 2005). Kumar and Pandit (2008) investigated effect of water level fluctuations on distribution of emergent vegetation in Hokersar wetland (Kashmir) and reported that water depth play significant role in the distribution and diversity of the emergent species.

The exposure to wind and waves largely influences the distribution of aquatic plants in shallow waters (Chambers, 1987; Vermaat and De Bruyne, 1993; Pankhurst, 2005). Hudon (2000) found that the biomass and distribution of submerged macrophytes to be influenced by site exposure and differences in species distribution attributable to growth form. Sand-Jensen (1989) held decrease in water depth responsible for increase in the wave-induced turbulent forces on the bottom. The helophyte zone and, especially, the zone of floating-leaved plants decrease with the increasing lake area due to wind stress related to the height and strength of waves (Spence, 1982). There exists a greater correlation between species diversity and lake area (Capers *et al*., 2010). A few studies have indicated that this relationship may be due to the habitat heterogeneity, as larger lakes encompass more microhabitats more species are able to find a suitable habitat with increasing area (Roslett, 1991; Jones *et al*., 2003; Heegaard, 2004; Capers *et al*., 2010).

Competitive interactions among wetland species may also influence aquatic macrophyte distribution and abundance. Several studies have found that competitive interactions between naturally occurring species may play a larger role in shaping macrophyte distribution and community structure (Chambers and Prepas, 1990; Pankhurst, 2005; Kors *et al.*, 2012). The temporal changes in macrophytes distribution are mainly temperature-driven (Heikkinen *et al.*, 2009; Alahuhta, 2011; Kors *et al.*, 2012). Recent studies have indicated that the temperature driven distribution patterns of macrophytes can be influenced by the increased nutrient concentrations (Jylha *et al.*, 2004; Rosset *et al.*, 2010).

Apart from these, factors such as latitudinal and altitudinal pattern, dispersal, soil, bedrock and land use and land cover (LULC) are known to play an important role in the distribution of macrophytes and richness between lake catchments (Sand-Jensen *et al.*, 2000; Jones *et al.*, 2003; Heegaard, 2004; Edvardsen and Okland, 2006; Partanen *et al.*, 2009; Capers *et al.*, 2010). Further, Luoto *et al.* (2007), Heino and Toivonen (2008) and Alahuhta (2011) reported that land use patterns generally have a strong influence on the distribution of macrophytes at finer extents.

2.4. Productivity of macrophytes

Macrophytes, the photosynthetic organisms, play essential role in the structure and functioning of shallow lakes and wetlands, the most basic being primary production (Wetzel, 2001; Peters and Lodge, 2009; Nikolic *et al.*, 2009; Jones *et al.*, 2010). Phytoplankton and emergent, floating and submerged macrophytes which differ in terms of their productivity, consumption of different sources of nutrients and energy, are principal primary producers in shallow lakes and wetlands (Horne and Goldman, 1994; Nikolic *et al.*, 2009). The abundance and productivity of macrophytes can vary within two orders of magnitude among lakes of different trophic levels (Nikolic *et al.*, 2009).

Primary productivity can be estimated by the summation of positive increments in biomass (Milner and Hyges, 1968; Purohit and Singh, 1987). A few studies have indicated that the productivity in terms of annual biomass in wetlands is about 3.5 times more than that of terrestrial ecosystems (Turner, 1982; Larson and Golet, 1982). The ratio of Below Ground (BG) and Above Ground (AB) biomass could be used for the estimation of BG biomass assuming that the ratio does not change considerably and a fixed production of total organic matter by plants is always invested in the below-ground tissues (Westlake, 1965). The below-ground organs contribute only 30-40% and 41% of the total standing crop for *Phragmites australis* and *Sparganium ramosum* respectively (Westlake, 1975; Handoo and Kaul, 1982).

While for *Typha* species this value was estimated at about 50-60% by Dykyjova (1971) and Kvet (1971).

Primary productivity is closely related with the mineral cycling of plant communities (Mark and Graham, 1976). Khan and Shah (2010) obtained direct correlation between nutrient concentration and biomass changes in macrophytes. Pandit (1999) while estimating the primary production rates and standing crop (biomass) of various macrophytes in different aquatic ecosystems of Kashmir, observed that among various nutrients locked up by the macrophytes in Dal lake (Kashmir), the maximum quantity was that of N followed by Ca, K, Mg, Na and P and emergents locked up maximum nutrients. Rien and Hannie (1994) studied nitrogen use efficiency of *Carex* species in relation to nitrogen supply. The authors recognised that among the three species differing in maximum growth rates, *Carex acutiformis* was recorded to be dominant in more productive eutrophic fens, where as *Carex diandra* and *Carex rostrata* were dominant in less productive mesotrophic fens.

There is evidence that seasonal variations in the productivity of macrophytes in tropical ecosystems are strongly associated with water level fluctuations, light levels, temperature and nutrient availability (Froend and McComb, 1994, Neue *et al*., 1997; Penha *et al*., 1999, Santos and Esteves, 2004; Gustavo *et al*., 2012). However, the variations in the seasonal productivity of macrophytes are very apparent in temperate ecosystems (Kaul, 1971; Fernández-Alaez *et al*., 2002, Fox *et al*., 2008). The variations in the productivity of emergent aquatic macrophytes are related to the amount of maximum mineral content in their above-ground tissues (Hwang *et al*., 1996). Net primary productivity of macrophytes depends on the life-form of the macrophytes and on the trophic status of their habitats (Kvet *et al*., 2008). Moreover, relatively higher carbon fixation occurs in emergent and semi-emergent macrophytes in eutrophic biotopes and in floating-leaved rooted and submerged macrophytes in mesotrophic biotopes. Ambasht (1971), while working on the total community production in wetland habitats, reported that *Eleocharis* sp. dominated the emergent plant community with the highest biomass production. Whittaker and Likens (1973) gave a comprehensive account of mean net primary productivity of wetlands and other ecosystems. Ravinder *et al*. (2007), while studying the primary productivity of macrophytes in Hokersar wetland, a Ramsar Site in Kashmir Himalaya, reported that plant habitat, shoot density, spatial leaf arrangement, the growing season and plant height are the major factors affecting the standing crop of macrophytes.

It has been well documented that maximum productivity of the biosphere occurs in the zone of emergent aquatic macrophytes and declines rapidly in case of submerged macrophytes (Westlake, 1963; Wetzel, 1990).Among macrophytes, emergents and rooted floating-leaf type are the most abundant and productive than submerged aquatic macrophytes and that are herbaceous perennial plants, developing highly dissected foliage and are not the rapidly growing surface canopy forming species under eutrophic conditions. Emergent macrophytes occupy lesser areas as compared to rooted- floating leaf types and submergeds; they are unique in utilizing the available space and light with maximum efficiency and great economy because they are capable of regulating spatial patterns, particularly in leaf density and leaf inclinations (Wetzel, 2001). Besides, emergent macrophytes contain structural tissue whose cell walls are heavily thickened with cellulose, which is relatively refractory to rapid microbial decomposition (Atkinson and Cairns, 2001). Standing crop of emergents like *Typha angustata* in pure stands is very much higher compared to the standing crop in mixed stands (Sharma and Pradhan, 1983).

The productivity of perennials with thin, finely divided, reticulated foliage that increases surface area, enhances gas exchange and light harvesting is very much higher compared to productivity of rosette perennials such as the Isoetids and of most annual submerged plants (Sculthorpe, 1971). Rooted floating-leaf type plants like *Nelumbo* accumulated the most photosynthetic biomass in the tissues lying over the water surface but in other rooted floating-leaf type species like *Vallisneria*, most photosynthetic biomass remained in the lowest stratum. (Ambasht and Ram, 1976). In shallow lakes, submerged aquatic macrophytes contribute significantly to the overall primary productivity (Margalef, 1983).The productivity as well as species composition of submerged macrophytes is largely influenced by the availability of light and temperature (Barko *et al*., 1986; Chambers, 1982; Hopson and Zimba, 2003; Nekrasova *et al*., 2003; Ronzhina *et al*., 2004). Kual (1982) and Pandit (2008) held low water depth, high water turbidity and thick cover of floating leaf species of macrophytes responsible for the poor growth and low productivity of submerged macrophytes in shallow lakes and wetlands of Kashmir, Himalaya. The standing crop estimates for *Lemna* and *Salvinia* was worked out by Kaul and Bakaya (1976) while working on the interspecific competition affecting the distribution of aquatic macrophytes. The Kaul and Handoo (1993), while investigating various wetlands of Kashmir in terms of species diversity recorded an annual increment of 502 g m^{-2} primary production in general.

The loss of biomass production and species diversity can have significant impact on biogeochemical cycles, faunal habitats and food webs (Carpenter and Lodge, 1986). Certain studies indicate that severe eutrophication is responsible for the marked decline in the area occupied by and the biomass of submerged macrophytes in temperate aquatic ecosystems (Bini *et al*., 1999; Magee *et al*., 1999). Stanley *et al*. (2000) reported that species richness showed a significant quadratic response to increased annual primary productivity (^{14}C estimate, g $C \cdot m^{-2} \cdot yr^{-1}$) when lake area is taken into account. Lindholm *et al*. (2008) pointed out that high productivity of certain aquatic plants such as *Myriophyllum sibiricum* can modify the sediment texture. The higher productivity of aquatic macrophytes may hasten the process of eutrophication at the time of their decomposition (Nikolic *et al*., 2007, 2009; Dar *et al*., 2012). Therefore, for protecting the ecological balance in freshwater ecosystems, it becomes imperative to monitor these ecosystems for growth and development of macrophytes with high biomass rates (Coops *et al*., 2002; Nikolic *et al*., 2009).

2.5. Biochemical composition of macrophytes

Aquatic macrophytes, photosynthetic organisms of freshwater habitats, play significant role in the structure and functioning of these ecosystems (Wetzel, 2001; Jones *et al.*, 2010). Macrophytes also act as important bioindicators of environmental conditions and long-term ecological changes in water quality (Lacoul and Freedman, 2006). Macrophytes act as potential source of food and fodder for humans and bovine population, besides serving as a base of aquatic food chain (Smith *et al*., 2011; Swapna *et al*., 2011). For the assessment of nutritional value and evaluation of food potential of aquatic plants, the knowledge of their ecological significance and chemical composition is essential. (Chapman and Chapman, 1980; Hawkins and Hartnoll, 1983; Pandit, 1984; Pandit and Qadri, 1986; Abbott, 1988; Pandit, 1993). It is well known that seasonal variations in certain abiotic factors such as light, temperature, sediment composition and water chemistry can influence photosynthetic rates and biochemical composition of macrophytes (Koskimies and Nyberg, 1987;

Roslin, 2001; Ordsuna-Rojas *et al*., 2002; Rajasulochana *et al*., 2002), thus necessitating the determination of their biochemical composition.

The chemical composition of the macrophytes serves as a base and an effective tool to define the most profitable use of their biomass (Rabemanolontsoa, and Saka, 2012). Numerous authors have emphasized that the various biochemical constituents of macrophytes are primarily influenced by the environmental factors such as temperature, light available for photosynthesis, nutrient concentration in the ambient waters as well as the development stage of the macrophytes (Haroon *et al*., 2000; Kalesh, 2003; Ortiz *et al*., 2006). Chemical and textural nature of the sediments can also have a major influence on the biochemical composition of aquatic plants (Prasannakumari, 2006).

2.5.1. Protein content of macrophytes

Proteins are considered to be the major biochemical components of aquatic plants (Brown and Jeffrey, 1992; Wikfors *et al*., 1992). Certain studies indicate that rapidly growing cells are characterized by high protein content (Henderson and Sargent, 1989; Zhu *et al*., 1997). Gangadevi (1997) and Prasannakumari and Gangadevi (2012) attributed the presence of large number of meristematic tissues during the juvenile and growing stage to the higher concentration of proteins in aquatic plants. The differential nutrient uptake potential of macrophytes especially that of nitrogen which in turn is influenced by various environmental and biological factors such as the type of tissue, the age of the plant part, its nutrient past history, interplant variability etc. is responsible for the interclass and interspecies variations in the protein content of macrophytes (Lobban and Harrison, 1997; Kalesh, 2003). Prasannakumari and Gangadevi (2012) opined that the differential potential in the protein accumulation patterns of different aquatic plants may be due to variation in the accumulation efficiency in terms of their phenology.

Numerous studies indicate that free floating-type macrophytes such as *Azolla* sp., *Lemna minor* and *Salvinia natans* contained more amounts of protein than other life-form classes (NAS, 1984; Meyers, 1977; Edwards, 1980; Pandit, 1984; Pandit and Qadri, 1986; Banerjee and Matai, 1990; Dewanji *et al*., 1997). Due to the presence of higher protein to energy (P/E) ratio, certain species of aquatic plants such as *Ipomoea reptans* and *Lemna minor* can prove as a potential source of supplementary feed in commercial fish feed (Kalita *et al*., 2007). The recommended concentration of leaf protein for human consumption is 55-65% (Bray, 1977), while for animal feeding, the value is reported to be 55% (Fiorentini, and Galloppini, 1983). Dewanji *et al*. (1997) reported that the concentration of leaf protein was more than 50% in 06 species of aquatic plants with *Allmania nodiflora* having the highest concentration (62.7%). The authors further reported that leaf proteins of the eight aquatic plant species had a digestibility above 54% with *Allmania nodiflora* and *Pistia stratiotes* having the highest. Shah *et al.* (2010) On the other hand, reported that rooted floating-leaf type macrophytes such as *Nymphaea* and *Nymphoides* contained crude protein contents of 20% higher than those in Berseem hay. The accumulation and subsequent conversion of nitrogen into protein building in the mature tissues during the metabolic process is at its maximum during the peak growth of macrophytes, thus resulting in higher concentration of proteins (Sahyun, 2008; Ahmad *et al*., 2011). Authors like Lapointe (1981), Dawes (1998) and Banerjee *et al*. (2009) also reported the concentration of proteins in aquatic plants depends upon the availability of nitrogen. Jayasankar (1999), on the other hand, reported lower concentration of proteins in certain plants of south-eastern coast of India during summer. Edwards (1980) advocated that the protein content increases as the nutrient content of the water in which the plant is grown increases.

2.5.2. Carbohydrate content of macrophytes

The patterns of carbohydrate allocation differ considerably among different species of aquatic plants, which reflects the differences in their adaptation strategies (Hwang *et al*., 1996). Variations that occur in carbohydrate content among different groups of macrophytes are influenced by the accumulation efficiency of macrophytes in terms of their phenology. A number of studies have found this to be the most significant factor governing the carbohydrate content of macrophytes (Mini, 2003; Arathy, 2004; Prasannakumari and Gangadevi, 2012). Brown and Jeffrey (1992) reported that the changes in carbohydrate content in aquatic plants are influenced by the differences in growth medium, especially nutrient levels. Macrophytes exhibit distinct seasonality in their carbohydrate content. The nature of synthetic efficiency as well as the certain environmental factors such as temperature, nutrients etc. influence the seasonal carbohydrate dynamics of macrophytes (Kalesh, 2003; Prasannakumari and Gangadevi, 2012). It is believed that the vegetative growth as well as development also influence the fluctuations in the carbohydrate concentration of macrophytes (Prasannakumari and Gangadevi, 2012). Jayasankar (1999) attributed the summer high and winter low values of carbohydrate in macrophytes to the increase in the growth rate of macrophytes resulting from the favourable environmental conditions. The positive impact of temperature on the carbohydrate metabolism of aquatic plants has been supported by various authors (Rosenberg and Ramus, 1982; Rotem *et al*., 1986; Banerjee *et al*., 2009). There exists a positive correlation of carbohydrate concentration with biomass and growth of certain aquatic plants (Jayasankar, 1999). Banerjee *et al*. (2009) observed significant positive relationship between carbohydrate synthesis and surface water temperature,

The state of physiological stress in a plant can be well judged by the ratio of energy content to that of soluble sugars (Sauter and Kloth, 1987; Larcher and Thomaser-Thin, 1988). In aquatic plants physiological stresses have been used as control points to suppress growth and eradicate target aquatic weeds (Luu and Getsinger, 1990).The stems of submerged macrophytes are characterized by higher concentration of soluble carbohydrates than in roots and leaves (El-Sarraf, 1995). Hwang *et al*. (1996) reported that the below-ground tissues of certain emergent macrophytes contain variable carbohydrate content depending on the seasons, ranging from 10-45%. The authors further opined that the higher proportion of carbohydrate content in the below-ground tissues relative to above-ground tissues after the peak growth season of macrophytes suggests an allocation of metabolites from above-ground to below-ground tissues for the growth of new stems in the next season. In aquatic plants, during the periods of low photosynthetic production, the growth and development of other plant parts is supported by the stored carbon content of below-ground tissues (Dawes and Lawrence, 1980; Durako and Moffler, 1985; Dawes and Guiry, 1992). While deriving estimates of whole plant carbon balance, it becomes imperative to consider the stored carbon content of belowground parts (Fourqurean and Zieman, 1991; Kraemer and Alberte, 1993). Several studies pointed out that the rooted floating-leaf type macrophytes contained higher levels of carbohydrates (Wikfort *et al*., 1992). An earlier study on the biochemical composition of aquatic plants of Dal lake in Kashmir Himalaya revealed carbohydrates including fibre making 46.41 – 85.74% on dry weight basis (Pandit and Qadri, 1986).

2.5.3. Lipid content of macrophytes

Lipids, which constitute a major source of energy in the aquatic environment with a high recycling rate, are utilized by many aquatic organisms for their growth and development (Stable, 1977). There is evidence for temporal variability in the lipid characteristics of aquatic plants, including seasonal differences in the lipid content of macrophytes under the influence of variable environmental conditions (Cherepanov, 1981; Koskimies and Nyberg, 1987; Stefanov, 1988; Roslin, 2001; Nelson *et al*., 2002; Rajasulochana *et al*., 2002). While studies indicated that the variability in the lipid content of macrophytes depends upon the differences in the species, season and location (Annon, 1984). Prasannakumari and Gangadevi (2012) reported that fluctuations in the concentration of lipid in different genera may be due to the changes in the environmental factors that might have influenced the vegetative growth and development including availability of nutrients, allochthonous materials as well as variation in the efficiency of lipid accumulation among the plants. Macrophytes are reported to contain higher levels of lipids in their tissues during their peak growth season (Esteves and Suzuki, 2010; Dar *et al*., 2013). As lipids are the end products of metabolic reactions in mature and aged tissues, they are naturally higher at this stage (Akingbade *et al*., 2001; Sahyun, 2008; Ahmad *et al*., 2011).The variations that occur in the lipid content of macrophytes indicate an acceleration of productive metabolic activity during their peak growth period and/ or higher consumption of this organic compound during other seasons (Dar *et al*., 2013). The significant increases in the lipid content (about 5 times) have been reported for C*eratophyllum demersum* in the rainy season (Esteves and Suzuki, 2010). The authors attributed increase in the total lipid content of submerged macrophytes in rainy season to the decrease in conductivity values and alkalinity as a consequence of the largest inflow and accumulation of fresh water from catchment. The authors also suggested that the tendency to accumulate higher concentration of total lipids in the tissues of submerged macrophytes presents better conditions to the development of these macrophytes. Haroon *et al*. (2000) and Nelson *et al*. (2002) stated that due to the reduction in the levels of proteins and carbohydrates in rainy season, the concentration of lipids was higher in aquatic plants compared to those of other seasons. Mini (2003) and Arathy (2004) also registered significant differences in the lipid content of various aquatic as well as riparian vegetations with a distinct pattern between the seasons. Physico-chemical parameters of water are known to have profound influence on the lipid content of aquatic plants (Banerjee *et al*., 2009).

According to the reported values in the literature, most aquatic plants contained lipid content in the range of 1.18 to 5.42% (Boyd, 1968). An earlier study on the biochemical composition of aquatic plants of Dal lake in Kashmir Himalaya revealed higher concentration of lipids in *Trapa natans* on dry weight basis (Pandit and Qadri, 1986). Banerjee and Matai (1990) and Rozentsvet *et al*. (1995), on the other hand, reported higher lipid content in emergent aquatic plants. Goncharova (2004), while studying the impact of seasonal variations in temperature on the lipid content of aquatic plants revealed some peculiarities of their functional role and the capacity of these aquatic plants to adapt to the environmental changes.

2.5.4. Chlorophyll content of macrophytes

Macrophytes and their parts are vertically stratified in different positions in the water body. The productive structures i.e. parts rich in chlorophyll in different plants are concentrated at different levels. The chlorophyll content per unit weight of plant parts is higher in leaf lamina than other green parts. Increased chlorophyll concentration acts as an indicator of enhanced photosynthetic capacity (Keeley and Sandquist, 1991). Light and temperature act together in affecting growth, morphology, photosynthesis, chlorophyll composition and reproduction of macrophytes (Barko *et al*., 1982, 1986: Chambers, 1982; Nekrasova *et al*., 2003; Ronzhina *et al*., 2004; Robledo and Freile-pelegrin, 2005). Barko *et al*. (1986) advocated that within individual plants, total chlorophyll can vary significantly in response to light, with greatest chlorophyll concentration at the basal (darkest) portion of the plant. Temperature is considered to be the single environmental variable profoundly influencing the photosynthetic rates of aquatic plants over the whole range of their occurrence (Gorham, 1974; Pilon and Santamaria, 2002). The positive impact of temperature on the photosynthetic rates of macrophytes has been supported by various authors (Hopson and Zimba, 1993; Vis *et al*., 2007; Shilla and Dativa, 2008). A number of reports indicate that under high-temperature regimes, the activity of certain enzymes such as 5- aminolevulinate dehydratase (ALAD) involved in the mechanism of chlorophyll biosynthesis decreases, thus resulting in the inhibition of chlorophyll biosynthesis (Mohanty *et al*., 2006; Dutta *et al*., 2009; Reda and Mandoura, 2011; Ashraf and Harris, 2013).The biological functions such as photosynthesis, physiology, etc. in macrophytes are dependent on chlorophyll a (chl a), a key photosynthetic pigment. Consequently, changes in chl a can indicate plant growth (Raven *et al*., 1992) or disturbances from stressors (Blackburn, 2007). The value of chlorophyll-decreases when the light transmission increases (Atici and Alas, 2012). In contrast to this under low light transmission, the concentration of Chlorophyll-b is favourable for growth based on the fact that Chlorophyll-b absorbs shortwave light more efficiently than Chlorophyll-a (Yokohama, 1983; Robledo and Freile-Pelegrin, 2005). It is believed that the adaptation of macrophytes to light conditions in water stratum is ensured by the distinct variation in pigment content as well as specific features of their pigment complex (Terrados and Ros, 1992; Ronzhina *et al*., 2004; Robledo and Freile-pelegrin, 2005).

It has been emphasiszed that macrophytes, as a whole, are characterized by low chlorophyll pigment content (on % fresh weight basis) in comparison to the terrestrial plants (Popova *et al*., 1984; Ronzhina *et al*., 2004). It is well known that different groups of macrophytes with different degree of leaf submergence (emergent, rooted floating, free floating and submerged) exhibit appreciable variations with distinct profile in their seasonal pigment content (Ronzhina *et al*., 2004; Dar *et al*., 2013). The highly productive emergent and rooted floating-leaf type macrophytes contain lower chlorophyll pigment compared to other life-form classes (Dar *et al*., 2013). Vertical orientation of leaves and presence of special features in the pigment complex enable submerged macrophytes to accumulate higher chlorophyll pigment levels (Ronzhina *et al*., 2004). Nikolic *et al*. (2009) also reported that submerged aquatic plants contain higher concentration of chlorophyll pigment.

3.1. General Description of Study Area

3.1.1. Study Area

Kashmir valley, an intermonate, oval shaped basin about 135 km long and 45 km wide and being the northern most State of India, is an all round interesting geomorphic entity. It is a longitudinal depression in the great northwestern complex of the Himalayan ranges and constitutes an important relief feature of geographic significance. Carved tectonically, the valley has a strong relationship with the Himalayan complex, which exercises an all pervading influence on its geographic personality (Raza *et al*., 1978). Originally formed as a tectonic valley and subsequently filled with a lake which was gradually drained out during the last interglacial epochs. This event as well as the glacial and fluviatile activity, which it has undergone, has added a complex character to the landscape ecology of the valley. It is bound by an almost unbroken ring of mountains which give it the character of an enclosed Vale. The Pir Panjal range bounds it on the south and west separating it from Jammu region and the Greater Himalayan range (Zanaskar range) encloses it on the east-northeast and north-northwest. By its geomorphic characteristics, Kashmir valley is almost unique in the entire Himalayan region. Valley spreads over a latitudinal extent of approximately 33^0 25′ N to 34^0 45′ N and a longitudinal extent of approximately 73^0 55′ E to 75^0 35′ E. It comprises an area of about 12,450 square kilometers and ranges in elevation from 1577 metres (lank in the Wular lake) to about 5423 meters (Kolahoi peak) in the Pahalgam area.

The valley of Kashmir abounds in numerous lovely lakes, swamps, springs and streams. The valley is drained by River Jhelum which originates from Verinag spring and in its course is joined by about 18 tributaries. Among the fresh water bodies of the valley Wular lake enjoys special status of being the largest freshwater body within

Indian sub-continent and plays a significant role in the hydrological regime of the Kashmir valley by acting as a huge absorption basin for floodwaters of Jhelum floodplain. Wular lake and its associated wetlands act as an important habitat for migratory water birds within Central Asian Flyway and supports rich biodiversity. Besides, generating revenue to the state government through fisheries and auctioning of *Trapa natans*, fodder and other economically important species, it also supports a large population living along its fringes owing to its huge fishery potential.The catchment of the lake is comprised of slopping hills of the Zanaskar ranges of the western Himalaya on the north eastern side and arable land around used for agriculture purposes. Recognizing the importance of the wetland for its biodiversity and socio economic values, the Wular lake was designated as Ramsar Site under Ramsar Convention in 1990.

Geographically the lake is situated at an altitude of 1580 m (a.m.s.l) lying between $34^{o}16'24.67''$ - 34^{o} $20'26.26''$ N latitudes and 74^{o} $33'41.42''$ - 74^{o} $44'02.90''$E longitudes of Kashmir Valley. The ox- bow type lake is mono- basined, elliptical in shape and is of fluviatile in origin, formed by the meandering of River Jhelum. Its depth on average is 3.6 m throughout length, reaching 5.8 m at its deepest point (Pandit, 2002). The average area has been estimated as 48-54 km^2 which declines to 18-24 km^2 during the lean period and increases 75 km^2 during summer months. Bandipora district and Sopore Town are the two main townships situated on the banks of the lake. Various rivers and streams which drain into the Wular lake are River Jhelum, Erin Nallah, Madhumati Nallah, Ferozepur Nallah, Sukhnag Nallah, Ningal Nallah, Ajus Nallah, etc. and the only exit (outlet) of the lake is River Jhelum.

The Directory of Wetlands of India (MoEF, 1990) indicates the area of the lake to be only 189 sq km. On the other hand, Stein (1961) reported that the lake during ancient part was about 202 km^2, which has got reduced to 24 km^2 of open water area at present. According to the recent revenue records the lake area has been described as 130 km^2 of which 3.70 km^2 are under paddy cultivation and other dry crops, 0.15 km^2 under human habitation and 60.5 km^2 under plantation. The main reasons for the shrinking of the lake area are siltation, human settlements and huge willow plantation. The weed infestation and large scale encroachment have threatened the very existence of this wetland which offers a permanent winter habitat for the water fowl species besides sustenance to thousands of people living around the lake

The macrophyte dominant lake has a well developed littoral zone. Extended littorals in general, are dominated by (i) emergents like *Phragmites australis, Typha angustata* and *Sparganium ramosum,* (ii) rooted floating-leaf types like *Nymphoides peltatum*, *Trapa natans* and *Nymphaea mexicana*, and (iii) free-floating types dominated by *Salvinia natans, Azolla* sp. and *Lemna minor*, all growing together intermixed and forming a complex physiognomy. The slightly deeper zone has abundant growth of submergeds like *Ceratophyllum demersum, Potamogeton crispus* and *Potamogeton lucens* forming meadows at various places. The littorals towards the north-eastern side are densely populated with *Salix* plantation which is eating the vitals of the lake. The location map of the study area is depicted in figure 3.1.1.

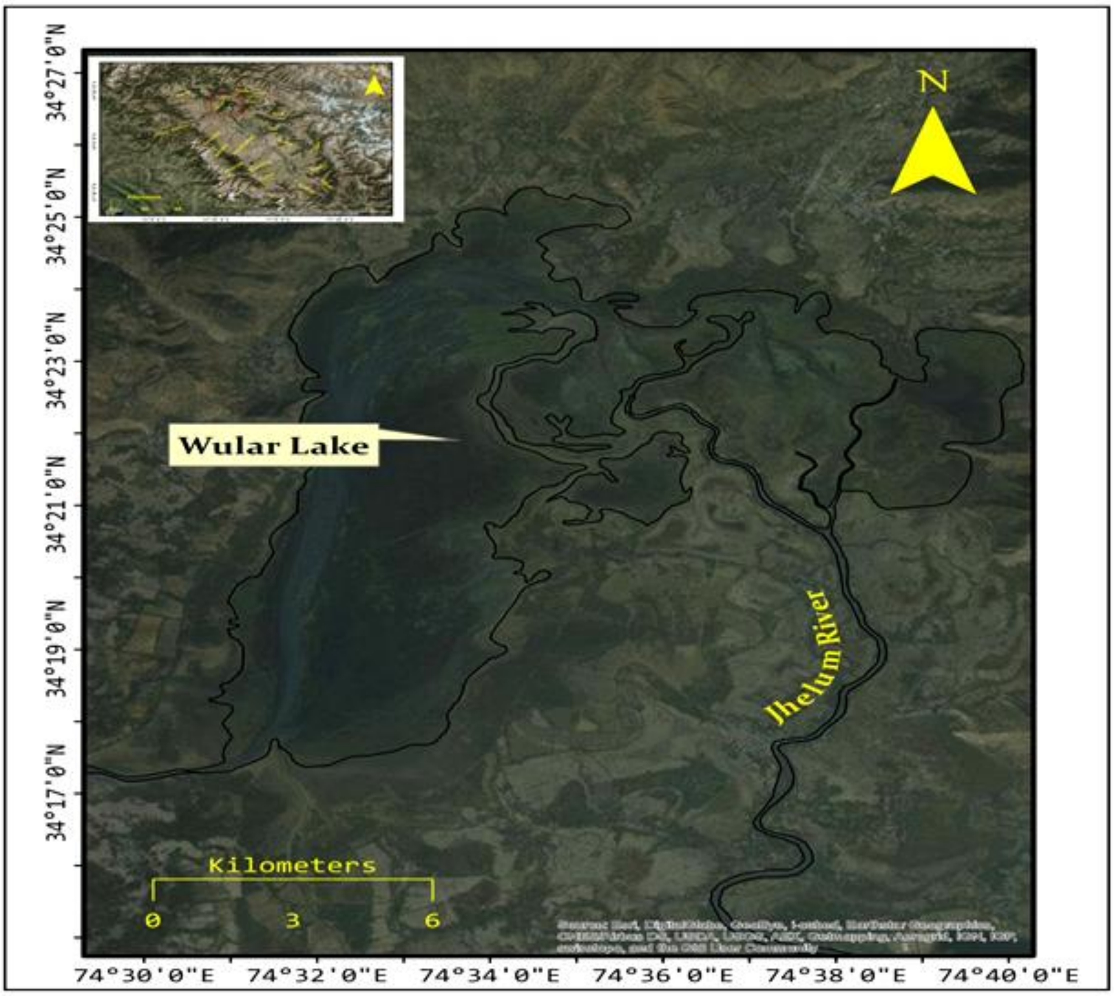


Fig. 3.1.1. Location map of the study area

3.1.2 Study Sites

For the present study, nine sampling sites were selected on the basis of location, water depth, vegetation, and other related characteristics (Fig. 3.1.2).The location and description of nine sampling sites is given as under.

Site I: This site is situated towards the eastern side of the lake near the village Saderkote. It lies between geographical coordinates of 34^0 39′ 19″ N latitude and 74^0 47′ 8.8″ E longitude. Agriculture land under paddy cultivation and washing of clothes by the local people are the main activities in the close catchment of this site. This site is heavily infested with emergent macrophytes among which *Phragmites australis, Typha angustata, Myriophyllum verticillatum and Sparganium ramosum* are the dominant ones.The maximum water depth at this site 0.9 m was recorded in spring against the minimum 0.3 m in winter.

Site II: It is located towards the eastern side of the lake at the foot of Vintage Park in district Bandipora, between geographical coordinates of 34^0 21′ 56.9″ N latitude and 74^0 39′ 42.0″ E longitude. This site is under the direct influence of human settlements.The vegetation here is dominated by rooted floating, followed by emergents and submergeds. *Nymphoides peltatum, Trapa natans, Hydrocharis dubia, Typha angustata* and *Ceratophyllum demersum* are the dominant macrophytes of this site. *Salix* plantation is also found along the margins, contributing litter to the lake periphery.The average water depth at this site ranges from 0.8 m in winter to 3 m in summer.

Site III: The site is located near village Kulhama opposite to site I at the entry of Erin nallah between geographical coordinates of 34^0 22′ 53.1″ N and 74^0 39′ 11.5″ E. This site is characterized by dense growth of rooted floating type macrophytes such as *Nymphoides peltatum, Trapa natans, Nymphaea alba* and *Hydrocharis dubia* and also sparse growth of emergents such as *Typha angustata* and *Phragmites australis* along its periphery. Here the average water depth ranges between 0.7 m in winter and about 2.6 m in summer.

Site IV: Geographically this site lies between 34^0 23' 47.4" N and 74^0 35' 9.1" E near Laharwalpora in District Bandipora .The site is under the direct influence of sand extraction, being carried by local people .There is sparse growth of macrophytes such as *Marselia quadrifolia, Trapa natans, Salvinia natans, Azolla* sp., *Hydrilla verticillata* and *Potamogetan crispus* .The maximum water depth at this site (1.9 m) was recorded during spring and summer seasons against the minimum (0.4 m) in winter months.

Site V: located near Ashtung village (latitude 34^0 24′ 14.8″ N and longitude 74^0 32′ 34.9″ E) on the north western side of the lake, and is characterized by having abundant growth of macrophytes such as *Trapa natans, Nymphoides peltatum, Salvinia natans, Azolla* sp., Lemnids, *Ceratophyllum demersum* and *Potamogetan natans* towards the limnetic zone and sparse growth of *Myriophyllum verticillatum, Polygonum hydropiper, Polygonum amphibium, Marselia quadrifolia, Typha angustata, Phragmites australis* and *Nelumbo nucifera* along its periphery. This site can be called the open water site. Here the average depth ranges between 0.8 m in winter and about 3.1 m in summer.

Site VI: It is located adjacent to site V between geographical coordinates of 34^0 23′ 0.3″ N and 74^0 32′ 0.8″ E on the north western side of the Wular lake. The site is heavily infested with emergent and rooted floating leaf type macrophytes such as *Typha angustata*, *Phragmites australis*, *Polygonum hydropiper*, *Polygonum amphibium*, *Myriophyllum verticillatum*, *Trapa natans*, *Nymphaea* mexicana, and *Potamogetan natans* along the periphery and the growth of submerged macrophytes such *Ceratophyllum demersum* is sparse .This site is under the direct influence of agriculture land .The average water depth ranges from 0.4 m in winter to 1.2 m in spring.

Site VII: Located near the Watlab Ghat at the foothills of shrine of Baba Shukruddin^{RA} (latitude 34^0 11′ 29.4″ N and longitude 74^0 31′ 48.2″ E) on the western side of the lake, has profuse growth of macrophytes such as *Nymphoides peltatum*, *Trapa natans*, *Myriophyllum verticillatum*, *Hydrocharis dubia*, *Ceratophyllum demersum*, *Potamogetan crispus*, *Polygonum hydropiper* and *Salvinia natans*. This is the deepest point of the lake and here the average water depth ranges between 2 m in winter and about 4.5 m in spring.

Site VIII: This site is located near the outlet channel (Ningal) towards Sopore town (latitude 34^0 17′ 74.31″ N and longitude 74^0 31′ 29.8″ E). Along the periphery of this site there is sparse growth of free floating and submerged macrophytes such as *Ceratophyllum demersum*, *Potamogetan crispus*, *Salvinia natans* and *Azolla* sp. Its depth ranges from 1.6 m in winter to 3.9 m in spring.

Site IX: It is located towards the north- eastern side of the lake near the inlet River Jehlum falling in the lake between geographical coordinates of 34^0 20′ 39. 2″ N and 74^0 34′ 52.2″ E. This site is dominated by emergents, rooted floating leaf type and free floating macrophytes such as *Phragmites australis*, *Typha angustata*, *Myriophyllum verticillatum*, *Nymphoides peltatum*, *Trapa natans*, *Salvinia natans* and *Azolla* sp. towads the littorals besides the sparse growth of submergeds such as *Ceratophyllum demersum* and *Potamogetan crispus* towards the limnetic zone .The maximum water depth at this site (1.3 m) was recorded in spring and summer seasons against the minimum (0.5 m) in winter months.

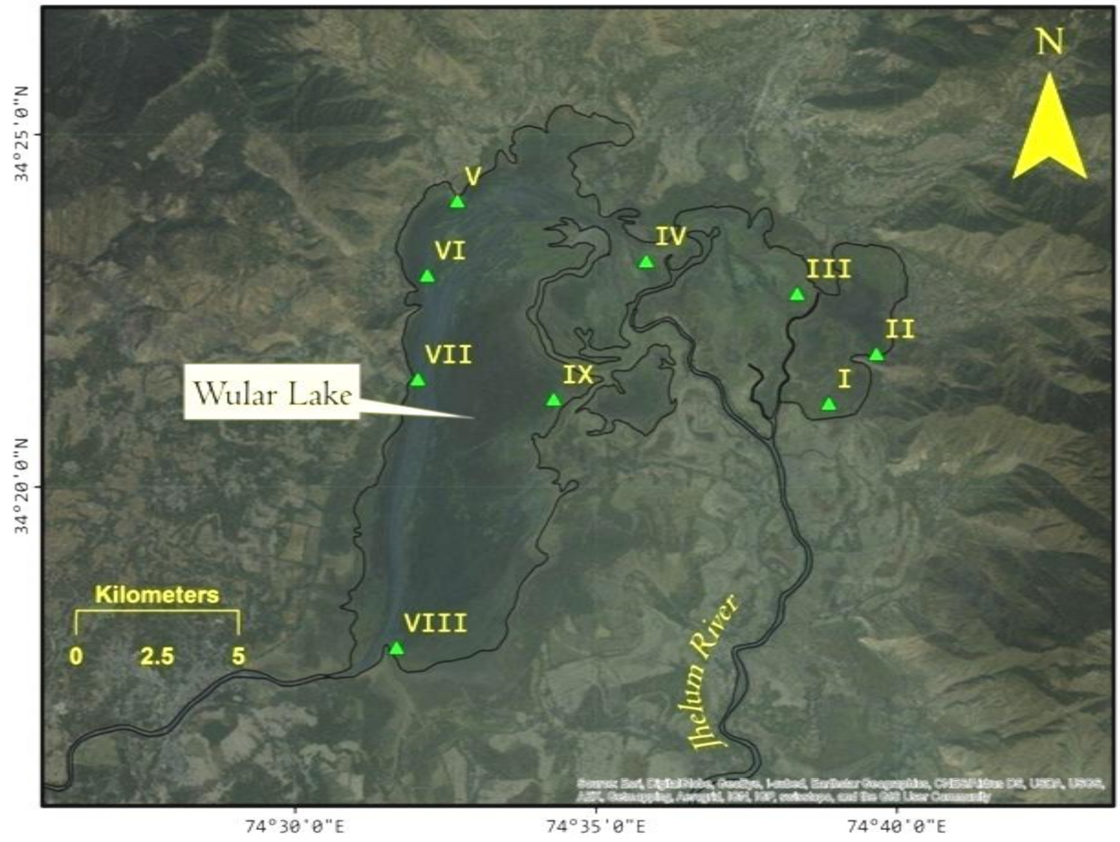


Fig. 3.1.2. Location map of the study area with sampling sites

Table 3.1. General geographical features of nine sampling sites.

Site	Code	Latitude	Longitude
Saderkote	I	34^{0} 39′ 19″ N	74^{0} 47′ 8.8″ E
Vintage	II	34^{0} 21′ 56.9″ N	74^{0} 39′ 42.0″ E
Kulhama	III	34^{0} 22′ 53.0″ N	74^{0} 39′ 11.5″ E
Laherwalpora	IV	34^{0} 23′ 47.4″ N	74^{0} 35′ 9.1″ E
Ashtung	V	34^{0} 24′ 3.8″ N	74^{0} 32′ 41.7″ E
Kuinus	VI	34^{0} 23′ 0.3″ N	74^{0} 32′ 0.8″ N
Watlab	VII	34^{0} 21′ 29.4″ N	74^{0} 31′ 48.2″ N
Ningal	VIII	34^{0} 17′ 74.31″ N	74^{0} 31′ 29.8″N
Makhdomyari	IX	34^{0} 20′ 39. 2″N	74^{0} 34′ 52.2 ″N

3.1.3. Climate

Climate of a particular place is the net result of the combination of several factors like latitude, altitude, terrain, distance from the sea and prevailing winds. Latitudinally the Kashmir valley lies in the sub-tropics (33°22′ N to 34°43′ N) but in reality it experiences a different type of climate which is almost temperate, the modification being introduced primarily by altitude which is of the order of 1577-5425 metres above mean sea level.

Terrain is important as it with mountain ring which girdles Kashmir valley acts as a climatic barrier. It checks the onward movement of moisture laden winds from Arabian Sea. The Pir Panjal range is the first high barrier, particularly with regard to south-west monsoon. It prevents the monsoon winds from entering the valley of Kashmir. The great Himalayan range forms the second high barrier. However, it is very favourable climatic barrier for Kashmir valley as it does not allow the "Western Disturbance" in winter to cross over easily. As a result, the valley of Kashmir gets substantial precipitation during winter from western disturbances which are extra-tropical disturbances having their origin near about the Mediterranean. These disturbances travel from west to east and enter India through Iran, Afghanistan and Pakistan. The great Himalayan range also shields the Kashmir valley from the frost bitten winds of the north.

Kashmir valley lies far away from the sea in the interior of the continent. It is characterized by extremes of temperature (continentality). Mean temperature of the hottest month that is July is 24.6°C and that of the coldest month that is January it is 1°C (Kaul, 1987). The daily range of temperature is also high. Kashmir valley has thus continental type of climate, characterized by marked seasonality. In general the valley has a fairly long winter. For five months a year (i.e., from November to March) the mean monthly temperature in Srinagar is below 10°C. Sub-zero temperature is common in winter which results in frost.

The Kashmir valley receives precipitation both in the form of rain and snow. It has been noted that the rainfall pattern exhibit peculiar distribution patterns throughout the year, being greatly concentrated in the winter and spring months across the valley. The share of the winter and spring rainfall is, however, only about one- third of the total annual rainfall in the central and south eastern parts, while it is more than three – fourth in the North- western region of the valley. The Annual rainfall recorded in the Vale is about 750 mm. It shows a regular increasing trend in all directions from Budgam and Srinagar and fluctuates over a wide range, recording its minima of 579 mm at Budgam to maxima of 1195 mm at Dooru. The most notable feature of the rainfall in Kashmir valley is its low intensity per rainy day. A perusal of data on the rainfall intensity of the valley over a period of fifty years (1950 – 2001) revealed that the average rainfall intensity varies from a minimum of 5.08 mm to a maximum of 26.27 mm (Ahmed and Ahmed, 2013). During monsoon period (June – August), a significant decrease in the intensity of sunlight occurs over the whole India except Jammu and Kashmir where the maximum insolation occurs in the months of June and July respectively, and minimum in January due to its particular geographical location. In the state of Jammu and Kashmir, humidity values fluctuates over a narrow range recording its minimum value of 71% in the month of May and maximum value of 80%, being recorded in the month of December (Raina, 2002).

On meso level the year in Kashmir is divisible into four seasons. There is one hot and one cold season and in between these, are two warm seasons. The winter season is of four months i.e., from mid-November to mid-March. The summer also lasts for four months i.e., from mid-May to mid-September. There is one transitional season (spring) of two months between winter and summer and another transitional season (autumn) of two months between summer and winter. However, a common practice in Kashmir is to recognize six seasons in a year (two months each) (Hussain, 2000; Dar *et al*., 2002).

(i) Spring (*Sonth*) from mid-March to mid-May

(ii) Summer (*Grishm*) from mid-May to mid-July

(iii) Rainy season (*Wahrat*) from mid-July to mid-September

(iv) Autumn (*Harud*) from mid-September to mid-November

(v) Winter (*Wand*) from mid-November to mid-January

(vi) Severe winter (*Sheshur*) from mid-January to mid-March.

Site I - Saderkote

Site II – Vintage

Site III – Kulhama

PLATE - I

Site IV - Laharwalpora

Site V – Ashtung

Site VI- Kuinus

PLATE - II

Site VII- Watlab

Site VIII – Ningal

Site IX - Makhdomyari

PLATE - III

4.1. PHYSICO-CHEMICAL CHARACTERISTICS OF WATER

In order to assess the water quality of Wular lake, a detailed characterization of the physico–chemical characteristics of the water was carried out for a period of two years from March 2011 to February 2013 on monthly basis. The surface water samples were collected between 10.00 and 14.00 hours from each of the sampling sites in one litre polythene bottles and were brought to the laboratory for analysis. The parameters including depth, transparency, temperature, pH and conductivity were determined on spot, whereas the rest of the parameters were determined in the laboratory within 24 hours of sampling. The analysis was done as per standard methods given by APHA (1998) and Wetzel and Likens (2000).

4.1.1. Depth

Method: Standard Lead Weight

The water depth was recorded by sounding the wetland bottom, at all the sampling sites, with a standard lead weight (1 kg), tied to a marked rope and the results were expressed in meters.

4.1.2. Transparency

Method: Secchi Disc

Transparency or light penetration in water was measured with Secchi disc. It was dipped into the water on a calibrated line until it disappeared. The depth at which it disappeared and also the depth at which it reappeared when rose was recorded. The average of these two readings is called Secchi disc reading.

Calculation

$$\text{Secchi disc reading (cm)} = \frac{A+B}{2}$$

Where:

A = Depth at which Secchi disc disappears

B = Depth at which Secchi disc reappears

2 = Standard value of equation

4.1.3. Air temperature

Method: Mercury Thermometer

The air temperature was recorded by using graduated mercury Celsius thermometer. The thermometer was placed in shade for at least two minutes for obtaining the air temperature. The results were expressed in °C.

4.1.4. Water temperature

Method: Mercury Thermometer

The temperature of surface water was recorded by using graduated mercury Celsius thermometer. The bulb of the thermometer was dipped in water for at least two minutes for obtaining the water temperature. The results were expressed in °C.

4.1.5. Electrical conductivity

Method: Conductivity Cell Potentiometric

The conductivity of water samples was measured with the help of a digital conductivity meter. The conductivity meter was calibrated before use with standard potassium chloride solution (0.01M). The results were expressed in μScm^{-1} at 25°C.

4.1.6. Total dissolved solids (TDS)

Method: Gravimetric after Filtration

250 mL of filtered sample was evaporated to dryness in a pre-weighed evaporating dish in an Oven at $104^{o}C$ for at least 1 hour. The evaporating dish containing the dry residual sample was cooled and weighed again. The concentration of total dissolved solids was determined using the following formula:

$$\text{Total Solids (mg /L)} = \left(\frac{A - B}{\text{ml of sample}}\right) \text{x } 1000$$

Where:

A = weight of dish + residue, (mg)

B = weight of dish, (mg)

Conductivity measurements were converted to TDS values by factor 0.65 to check the accuracy of TDS measurements.

4.1.7. Free carbon dioxide

Method: Titrimetric

To 50 mL of water sample, two drops of phenolphthalein indicator were added and titrated against 0.02 N NaOH. The results obtained were expressed as mg/L.

$$CO_2\ mg/L= \left(\frac{\text{Titrant used (mL)}}{\text{Volume of sample}}\right)\ X\ 1000$$

Factors for calculating carbon dioxide concentrations in water with known pH, temperature and alkalinity measurements were used for accuracy (Tucker, 1984). Factors should be multiplied by total alkalinity (mg/L) to get carbon dioxide (mg/L).

4.1.8. Dissolved oxygen

Method: Iodometric Method

The dissolved oxygen content was determined by Iodometric method. The initial fixation of the dissolved oxygen was done on spot by collecting the liquid in the 300 mL BOD bottle, to which 1 ml of each alkali-iodide reagent and manganous sulphate was added. The bottle was tightly stoppered to exclude air bubbles and was inverted for few times to mix the reagents thoroughly. The floc formed was allowed to settle approximately half of the bottle. The precipitate was dissolved by addition of 2 ml of concentrated sulphuric acid by inverting it several times until dissolution was complete. 50 mL of the sample was then taken and titrated against 0.025N sodium thiosulphate using starch as indicator. The D.O. concentration was calculated from the given formula and the results were expressed in mg L^{-1}.

$$\text{Dissolved oxygen } (mgL^{-1}) = \left(\frac{V1 \text{ x } N \text{ x Eq.wt.}}{V2}\right)\ X\ 1000$$

V_1 = Volume of sodium thiosulphate used

V_2 = Volume of the sample taken for titration

N = Normality o f sodium thiosulphate

Eq. wt. = Equivalent weight of oxygen

4.1.9. pH

Method: Potentiometric

The pH of water samples was determined by means of a digital pH meter (Systronics-MKVI). Before measuring the pH of water samples, the pH meter was standardized against buffer solutions of pH 4.0, 7.0 and 9.2.

4.1.10. Chloride

Method: Argentometric Titration

100 mL of sample was titrated against 0.0141N silver nitrate solution using potassium chromate as indicator solution, till brick red colour end point was attained. Concentration in mg L^{-1} was determined by using the following formula:

$$\text{Chloride } (\text{mgL}^{-1}) = \left(\frac{V_1 - V_2 \text{ x N x Eq.wt.}}{V_3}\right) \text{x } 1000$$

V_1 = Volume of silver nitrate used for sample (mL)

V_2 = Volume of silver nitrate used for blank (mL)

V_3 = Volume of the sample taken for titration (mL)

N = Normality of silver nitrate solution.

Eq. wt. = Equivalent weight of chlorine

4.1.11. Total hardness

Method: EDTA Titrimetric

To 50 mL of water sample, 1-2 mL of buffer solution (NH_4- NH_4OH) and a pinch of EBT indicator was added and was then titrated against 0.01M EDTA within 5 minutes after buffer addition till wine red colour changed to blue. The concentration (mg L^{-1}) was determined by using the following formula:

$$\text{Total hardness as } CaCO_3 \ (\text{mgL}^{-1}) = \left(\frac{V_1 - V_2}{V_3}\right) X \ 1000$$

V_1 = Volume of EDTA used for the sample (mL)

V_2 = Volume of EDTA used for the blank (mL)

V_3 = Volume of the sample taken for titration (mL)

4.1.12. Calcium content (Ca^{2+})

Method: EDTA Titrimetric

To 50 mL of water sample, 2 mL of 1N sodium hydroxide and a pinch of murexide indicator was added and then titrated against 0.01N EDTA till colour changes from pink to purple. The concentration (mgL^{-1}) was determined by using the following formula:

$$\text{Calcium content } (\text{mgL}^{-1}) = \left(\frac{V_1 - V_2}{V_3}\right) \text{ x } 400 \text{ x} 1.05$$

V_1 = Volume of EDTA used for the sample (mL)

V_2 = Volume of EDTA used for the blank (mL)

V_3 = Volume of the sample taken for titration (mL)

4.1.13. Magnesium content (Mg^{2+})

Method: Calculation from total hardness and calcium content

Magnesium content was obtained from the total hardness and calcium content by using the following formula:

Magnesium content (mgL^{-1}) = {Total hardness (mgL^{-1}) – Calcium content (mgL^{-1})} × 0.243

4.1.14. Bicarbonate alkalinity

Method: Titrimetric (Methyl orange)

100 ml of water sample was titrated against 0.02N H_2SO_4 using methyl orange as indicator. The results were expressed in mg L^{-1} after using the following formula:

$$\text{Total alkalinity as } CaCO_3\ (mgL^{-1}) = \left(\frac{V_1 - V_2 \text{ x } N}{V_3}\right) \text{ X } 1000 \text{ X } 50$$

V_1 = Volume of titrant used for the sample

V_2 = Volume of titrant used for the blank (mL)

V_3 = Volume of the sample taken for titration (mL)

N = Normality of H_2SO_4

4.1.15. Dissolved silica

Method: Ammonium Molybdate

To 10 mL of water sample, 5 mL (0.25 N HCl), 5 mL (5%) ammonium molybedate and 5 mL (1%) disodium EDTA were added. After 5 minutes, 10 mL of 17% sodium sulphite was added and the sample allowed for 30 minutes for colour development. The absorbance of samples was then measured at 700 nm and the results obtained were expressed in mg/L. Standard was prepared from sodium silicate pentahydrate.

4.1.16. Ortho-phosphate phosphorus

Method: Stannous Chloride

The orthophosphate phosphorus concentration was estimated by molybdenum blue method. To 50 mL of water sample 4 mL of ammonium molybedate and 0.5 mL of stannous chloride was added. The intensity of blue colour developed was measured after 10 but before 20 minutes at 690 nm spectrophotometrically. Potassium dihydrogen phosphate was used for making various standards. The results were expressed in µg L^{-1}.

4.1.17. Total phosphorus

Method: Stannous Chloride Method

The total phosphorus concentration was estimated by stannous chloride method. 50 ml sample was digested with 1 ml sulphuric acid and 5 ml nitric acid on hot plate to a volume of 1ml.The sample was then cooled and diluted with 20ml distilled water. Then sample was titrated against 1N sodium hydroxide solution with phenolphthalein as indicator, till faint pink colour appeared. Strong acid solution was used to discharge the colour. The final volume was again raised to 50ml with distilled water. Then 4ml molybdate reagent and 10 drops of stannous chloride were added to sample with continuous stirring.. The intensity of blue colour developed was measured at 690 nm spectrophotomerically between 10-20 minutes. The various standards were made from potassium dihydrogen phosphate and the results were expressed in µgL^{-1}.

4.1.18. Ammonical-nitrogen

Method: Phenate Spectrophotometric

To 25 mL of water sample, 1 mL phenol, 1 mL sodium nitroprusside solution and 2.5 mL of oxidizing solution were added and kept at room temperature for about one hour till the colour develops fully and light exposure was suitably avoided. The intensity of colour developed was measured at 640nm. Ammonium chloride was used for making various standards. The results were expressed in µg L^{-1}.

4.1.19. Nitrate - nitrogen

Method: Salicylate Method

To 100 mL of water sample, 1 mL of sodium salicylate was added and evaporated to dryness on water bath. The residue was treated with 1 mL of concentrated sulphuric acid and after 5-10 minutes 6 mL of distilled water and 7 mL of 30% NaOH solution was added. After development of yellow colour, the intensity was measured at 410nm and the results were expressed in µgL^{-1}. Standards were prepared from potassium nitrate.

4.1.20. Total iron

Method: Phenanthroline Method

To 50 mL of sample 2 mL of conc. HCl and 1 mL NH_2OH. HCl solution was added. A few glass beads were added and heated to boiling till the volume is reduced to 15-20 mL, cooled, and transferred to a 50 mL volumetric flask. After cooling, 10 mL $NH_4C_2H_3O_2$ buffer solution and 4 mL phenanthroline solution were added, diluted to 50 ml with distilled water. Mixed and allowed to stand for 10-15 min. for colour development. Absorbance was measured at 510nm and the results were expressed in µgL^{-1}. Standards were prepared from ferrous ammonium sulphate.

4.2. VEGETATION

The community features of macrophytes were worked out on seasonal basis for a period of two years, using the Random Quadrat Method (Misra, 1968; Gupta, 1999). 5-10 Quadrats of 1 m^2 sizes were laid randomly at all the selected sites. The macrophytes falling in each quadrat were sorted species-wise and the numbers of individuals of each species were counted for working out various phytosociological features (Misra, 1968). Ekman dredge was used to collect the submerged species falling in each quadrat. The identification was carried using standard taxonomic works of Kak (1978), Cook (1996), Fasset (1998) and Kumar (2009). For *Nymphoides peltatum* three leaves were taken as one individual while for *Nymphaea mexicana* one leaf was taken as one individual. In case of *Ceratophyllum demersum* (submerged species) one meter length of the plant along with all its branches was taken as a unit to represent one individual.

4.2.1. Quantitative characteristics

The quantitative community characteristics of macrophytes like density, abundance, frequency and importance value index (IVI) were determined by the following formulae:

Density $= \dfrac{\text{Total no.of individuals of a species in all the sampling units}}{\text{Total no.of sampling units studied}}$

Relative density $= \dfrac{\text{Density of a species}}{\text{Total density of all the species}} \times 100$

Abundance $= \dfrac{\text{Total no.of individuals of a species in all the sampling units}}{\text{No.of sampling units in which species occurred}}$

Relative abundance $= \dfrac{\text{Abundance of a species}}{\text{Total abundance of all the species}} \times 100$

Frequency %age $= \dfrac{\text{No.of sampling units in which the species occurred}}{\text{Total no.of sampling units}} \times 100$

Relative frequency $= \dfrac{\text{Frequency of a species}}{\text{Total frequencies of all the species}} \times 100$

Importance Value Index (IVI) = Relative Density + Relative Frequency + Relative Abundance

Rank abundance was worked out by taking log10 values of IVI in the peak month of growth (in August) and then arranging these values in descending order.

4.2.2. Diversity Indices

Diversity indices were determined by the following formula:

(a) Shannon diversity index ($H^{/}$)

Species diversity was determined after Shannon (1949) as:

$$H^{/} = -\sum_{i=1}^{i=s}\left(\frac{ni}{N}\right)\log_e\left(\frac{ni}{N}\right)$$

$H^{/}$ = Index of species diversity

n_i = Density of one species

N = Density of all the species

e = Base of natural logarithm $\log_e\left(\frac{ni}{N}\right) = 2.303 \log_{10}\left(\frac{ni}{N}\right)$

$\sum_{i=1}^{i=s}$ = Addition of the expression for values of *i* from *i* = 1 to *i* =S

(b) Simpson's diversity index (D)

Diversity within the macrophytic community was described using the Simpson's diversity index ("D"), which was calculated as:

$$D = 1-\sum_{i=1}^{s}(pi)^2$$

Where, "pi" is the proportion of individuals in the "ith" taxon of the community and "s" is the total number of taxa in the community (Simpson, 1949).

(c) Similarity index

$$S = \frac{2C}{A+B} \times 100 \text{ (after Sorenson, 1948)}$$

Where A and B represent the number of species at sites A and B respectively, C is the number of species common to both the sites.

4.2.3. General Distribution Pattern

General vegetation map depicting distribution pattern of macrophytes was prepared based on field observations at the time of optimum growth of macrophytes i.e., July- September using Arc View-GIS 3.2a. Area occupied by different life-form classes of macrophytes was estimated based on a 4-degree scale (10-25% = sparse,

>25-50% = moderate, >50-75% = dense, >75-100% = very dense) according to EPA (2007).

4.2.4. Net Primary Productivity

An estimation of net primary productivity was done by harvesting the macrophytes at the selected sites on monthly basis from March 2011 to February 2013 using quadrat method (Misra, 1968; Gupta, 1999). Five quadrats of standard size ($1m^2$) were laid at each site. Macrophytes falling in each quadrat were collected, stored in separate plastic bags and taken to laboratory for analysis. Dry weight biomass was obtained by oven drying the samples at 105^0C for 24 hours (Misra, 1968; Gupta, 1999). For primary production, the measurements were made for each species according to the procedures described by Milner and Huges (1968) using the formula:

Total annual production in g $m^{-2} = \sum n \left(B_n-(B_{n-1})\right)$

Where:

B_n = Standing crop of nth sampling period

B_{n-1} = Standing crop of previous sampling period

Before drying, the plants of each species were counted to work out the production in plant, besides the values in g m^{-2}.

4.2.5. Biochemical Analysis of Macrophytes

The quantitative estimations of various biochemical constituents viz. chlorophyll content, total carbohydrates, total lipids and total proteins for dominant macrophytes were worked out on seasonal basis for a period of two years. After harvesting the macrophytes in the quadrats, they were placed in polybags and transported to the laboratory where they were incised to include only leaves and shoots. The plant material was then washed thoroughly to render free of mud, periphytic growth, encrustaceans, etc. and moisture was drained before being analysed for various biochemical parameters. The analysis was done as per standard methods given by Lowry *et al.* (1951), Dubious *et al.* (1956), Knight *et al.* (1972), Bames and Blackstock (1973), Strain *et al.* (1971) and Lichtentaler and Wellburn (1983).

4.2.5.1. Estimation of total proteins

Total protein content of macrophytes was determined colourimetrically by the method of Lowry *et al.* (1951) after the extraction of proteins with buffer solution of pH-7. 1 g fresh weight of plant material was homogenized by grinding with buffer solution of pH-7 using pestle mortar. 0.2 ml and 0.4 ml of the extract were pipetted into separate test tubes and the volume made 1 ml with distilled water followed by addition of 5 ml of freshly prepared alkaline copper tartrate reagent. The samples were then incubated for 10 minutes followed by addition of 1ml of IN Folin - Ciocalteu reagent. The contents of each test tube were immediately vortexed and subsequently incubated for 30 minutes at room temperature for colour development. The absorbance was then read at 700 nm against a reagent blank using visible spectrophotometer. Bovine serum albumin was used as standard and the amount of protein was calculated from the standard curve. The results were expressed as percentage of %age fresh weight of macrophytes.

4.2.5.2. Estimation of total carbohydrate

Total carbohydrate content of macrophytes was determined colourimetrically by phenol - H_2S0_4 method after extraction into buffer solution of pH-7(Dubois *et al.,* 1956). 1 g of fresh weight of plant material was homogenized with buffer solution of pH-7 using pestle mortar. 0.5 ml and 1 ml of the extract were pipetted into separate test tubes and the volume made 1ml with distilled water followed by rapid addition of 5 ml of concentrated sulphuric acid. The contents were shaken thoroughly and subsequently incubated for 40 minutes at room temperature for colour development. After incubation, 1ml of 5% phenol was added to the test sample. The absorbance was then measured at 490 nm against a reagent blank using visible spectrophotometer. Glucose was used as standard and the amount of carbohydrates was calculated from the standard curve. The results were expressed as percentage of fresh weight of macrophytes.

4.2.5.3. Estimation of total lipids

Total lipid content of macrophytes was determined colourimetrically by Sulphophosphovanillin method after extraction in buffer solution of pH-7 (Knight *et al*., 1972; Bames and Blackstock, 1973). 1 gm of fresh weight of plant material was homogenized with buffer solution of pH-7 using pestle mortar. 0.1 ml of the extract was pipetted in a separate test tube and digested with 2 ml of conc. H_2SO_4. After cooling the test tube, 5 ml of phosphovanillin reagent was added and the sample was subsequently incubated for 40 minutes at room temperature for colour development. The absorbance was then measured at 520 nm against a reagent blank using visible spectrophotometer. Olive oil was used as standard and the concentration of total lipids was calculated by using following formula.

$$(A_T-A_B)/(A_S-A_B) \times 500$$

Where:
A_T = Absorbance of test sample
A_B = Absorbance of blank
A_S = Absorbance of standard
The results were expressed as percentage of fresh weight of macrophytes.

4.2.5.4. Estimation of chlorophyll content

Chlorophyll content (Chl a, Chl b and Total Chlorophyll) was determined Spectrophoto-metrically, in acetone extracts prepared from fresh samples (Strain *et al.*, 1971; Lichtentaler and Wellburn, 1983). Acetone extract of the macrophytes was prepared by macerating 1 gm fresh weight of plant leaves with 80% aqueous acetone using a mortar and pestle. The decanted suspension was centrifuged for 3 minutes at 1320 rpm. After centrifugation, the upper green clear solution was decanted from the colorless residue and then made upto 10ml with 80% acetone in 10 ml test tubes. The solution was then subjected to centrifugation at 10000 rpm for 10 minutes. The absorbance of the solution was determined using a spectrophotometer at wavelengths of 665 and 649 nm respectively. The results were expressed as mg/g fresh wt. basis.

Chlorophyll ‘a’ (mg/g) = $11.63 (A_{665})-2.39 (A_{649})$
Chlorophyll ‘b’ (mg/g) = $20.11 (A_{649})-5.18 (A_{665})$
Total Chlorophyll (mg/g) = $6.45 (A_{665}) +17.72 (A_{649})$

4.3. STATISTICAL ANALYSIS

The statistical analysis was performed using SPSS package (10th version) and Minitab (11th version).

4.3.1. ANOVA and correlations

The data was analysed for correlations and analysis of variance (ANOVA).

4.3.2. Cluster Analysis

Cluster analysis is a powerful tool for analyzing data and classifies objects, so that each object is similar to others in the cluster with respect to a pre-determined selection criterion (Reeve *et al*., 1996). In clustering, the objects are grouped such that the similar objects fall into the same classes (Danielsson *et al*., 1999). In cluster analysis, a dendrogram (tree like diagram) is produced, which summarises the process of clustering. Similar cases are joined by links whose position in the diagram is determined by the level of similarity between these cases (Aldenderfer and Blashfield, 1984).

5.1. PHYSICO-CHEMICAL CHARACTERISTICS OF WATER

The ecological studies in fresh water involve a choice between two types of approaches, one connected with knowledge of the dynamics of aquatic species in a given area and the other relating to knowledge of water body and its physical and chemical characteristics.

In order to define a particular freshwater body, it is important to analyze accurately as many physical and chemical characteristics of water as possible before initiating the biological studies. The measurements of these characteristics provide valuable information about the aquatic environment. In this perspective some of the important physico-chemical characteristics of the Wular lake have been analyzed.

5.1.1. Depth

Wular lake, the ox- bow type lake, is mono- basined, elliptical in shape and is of fluviatile in origin, formed by the meandering of River Jhelum. Its mean maximum depth was 4.6 m (at Site VII) during spring 2011 as against the mean minimum depth of 0.3 m (at Site I), being recorded during winter 2012. Irrespective of the sites, the greatest depth was recorded during spring and the least during winter (Fig.5.1.1 and 5.1.2).

While analyzing the data on the basis of monthly values, it was noted that during the year 2011 the maximum depth of 5.8 m was recorded at Site VII in May compared to the minimum value of 0.3 m being recorded at Site I during January (Table 5.1.1).During 2012 the highest depth of 4.3 m was registered at Site VII during April as against the lowest of 0.2 m being recorded at Site VI during January (Table 5.1.2).Thus, Site VII, the open water site located towards the centre of the lake, was the deepest site and Site I was the shallowest site althrough the study period.

5.1.2. Transparency

During the entire study period, Wular waters were found to be least turbid for most of the time period. In general, the greater water transparency was recorded during winter, followed by autumn, summer and decreasing to the lowest during spring each year (Fig.5.1.3 and 5.1.4).The maximum seasonal mean transparency of 1.9m was recorded at Site VII during winter 2011 as against the minimum transparency of 0.1m being recorded at Site I during spring 2012.During 2011 the lowest seasonal mean transparency of 0.2±0.1 m was recorded at Site I in spring as against the highest seasonal mean record of 1.9±0.2 m at Site VII, being registered during winter (Table 5.1.3).During 2012 the minimum seasonal mean transparency of 0.1±0.1 m was again recorded at Site I during spring compared to the maximum of 1.7±0.1 m at Site VII during winter (Table 5.1.4). In general, significant temporal variations in water transparency, ranging between a high of 2.1m (Site VII) in December 2011 and a low of 0.1m (Site I) during May 2011 and April, May and January 2012 were recorded during both the years of study.

5.1.3. Air temperature

The air temperature fluctuated over a wide range, recording its lowest of 3.2 ^{0}C at Site V in January 2012 and a highest of 33.2 ^{0}C at Site IX in August, 2011.Seasonally, summer recorded the highest mean temperature while winter recorded the lowest mean air temperature at all the study sites. Seasonal mean temperatures, however, fluctuated between 32.3±0.6 ^{0}C at Site VI during summer 2011 and 5.1±1.2 ^{0}C at Site VIII during winter 2012.There was hardly any spatial variation in air temperature of the lake (Fig. 5.1.5 and 5.1.6) though slightly overall a decreasing trend in air temperature of two successive years was evinced. Thus, during 2011 maximum air temperature of 33.2 ^{0}C was recorded during August at Site IX as against the minimum of 3.9 ^{0}C, being recorded during January at the Site VII (Table 5.1.5). In the year 2012 slightly decreased values of air temperature were obtained and during this year the highest air temperature of 30.4 ^{0}C was recorded during July at Site VII as against the lowest temperature of 3.2 ^{0}C recorded at Site V during January (Table 5.1.6).

5.1.4. Water temperature

Water temperature in Wular lake was in accordance with the prevailing annual thermal cycle and was in close proximity with air temperature, recording its highest values during summers and lowest values during winters at all the sites. Seasonal mean temperatures, however, fluctuated between 26.4±0.4 ^{0}C at Site VI during summer 2011 and 4.2±1.2 ^{0}C at the Site VIII during winter 2012.There was hardly any spatial variation in water temperature of the lake (Fig. 5.1.7 and 5.1.8).During 2011 maximum water temperature of 26.7 ^{0}C was recorded during August at Site VI as against the minimum of 3.0 ^{0}C, being recorded during January at the Site VIII (Table 5.1.7). Despite 2012 being comparatively a colder year, a highest water temperature of 26.8 ^{0}C was recorded during July at Site V as against the lowest temperature of 2.6 ^{0}C being registered at Site IX during January (Table 5.1.8).

5.1.5. Specific conductivity

Specific conductivity, being the indirect estimate of total ions present in water, depicted greater spatial as well as temporal variations. Thus, the highest specific conductivity was registered during winter, followed by autumn, spring and summer (Tables 5.1.9 and 5.1.10).The maximum seasonal mean conductivity of 508.7±17.0 µScm^{-1} at 25 ^{0}C was maintained at Site I during winter 2011 as against the minimum conductivity of 115±10.0 µScm^{-1} at 25 ^{0}C at Site III during summer the same year.

While analyzing the data on the monthly basis, it was noted that during the year 2011 the maximum conductivity of 525µScm^{-1} was obtained at Site I in February compared to the minimum value of 90 µScm^{-1} being recorded at Site III during September (Fig. 5.1.9). Further, during 2012 the highest conductivity of 489 µScm^{-1} was registered at Site I during January as against the lowest of 100 µScm^{-1} recorded at Site V during May (Fig. 5.1.10).

5.1.6. Total dissolved solids

Total dissolved solids followed the same trend as that of specific conductivity, witnessing its peak amount during winter and then following a decline to reach the lowest value during summer where after an increasing trend was evinced towards the autumn (Fig.5.1.11 and 5.1.12).On seasonal basis, the maximum seasonal mean value of total dissolved solids (308.3±10.4 mg/L) was obtained during winter 2012 at Site I against the minimum seasonal mean value of 69.7±5.5 mg/L, being recorded during summer 2011 at Site III (Table 5.1.11 and 5.1.12).Monthly values, however, fluctuated between a high of 320 mg/L (Site I in January 2012) and a low of 64 mg/L (Site III in August 2011).

5.1.7. Free carbon dioxide

Wetland waters, during both the years of study, recorded very noticeable temporal variations in the amount of free carbon dioxide. A perusal of the data revealed that there was a summer fall in free carbon dioxide concentrations in Wular water (Table 5.1.13 and 5.1.14, Fig. 5.1.13 and 5.1.14).The spring and autumn season registered almost equal but modest amounts of free carbon dioxide and the values peaked during winter. Thus, the seasonal mean values of free carbon dioxide reached its high of 24.3±3.5 mg/L at Site VI during winter 2011 as against the low of 5.7±0.6 mg/L at Site IV during summer 2011. However, the monthly values fluctuated from a maximum of 28 mg/L in December 2011 at Site VI to a minimum of 5 mg/L in August 2011 at Site IV.

5.1.8. Dissolved oxygen

Dissolved oxygen, depicting an inverse relationship with the water temperature, recorded its highest during winters and lowest during summers at all the sites. Thus, the maximum seasonal mean amounts of dissolved oxygen (9.6± 0.2 mg/L) were registered during winter 2012 at Site VII as against the minimum of 6.7±0.4 mg/L, being recorded during summer 2011 at Site I (Table 5.1.15 and 5.1.16). During 2011 the highest amount of dissolved oxygen (9.8 mg/L) was noted at Site VIII during February while the lowest dissolved oxygen of 6.4 mg/L was evinced at Sites I, II and VI during July, August and September respectively (Fig.5.1.15). However, in the year 2012, the maximum amounts of dissolved oxygen (11 mg/L) was recorded at Site VIII during November as against the lowest of 6.6 mg/L, being registered at Site VI during July (Fig. 5.1.16).Overall, there were little variations in the dissolved oxygen values during the two years of study although the two year study showed comparatively elevated levels of dissolved oxygen during the first year (2011).

5.1.9. pH

The waters of Wular were alkaline throughout the study period although there were spatial as well as temporal variations in the pH values of the lake water, ranging between 7.1(December 2011 at Site VI and December, February 2012 at Site I) and 8.5 (June 2011 at Site VII).However, comparatively more spatial variations were recorded during the second year of study (Fig. 5.1.17 and 5.1.18).On seasonal basis, in general, more alkaline water was recorded during summer and least during winter.

During 2011 the lowest seasonal mean pH of 7.3± 0.0 was recorded at Site VIII in winter as against the highest seasonal mean of 8.3±0.0, being recorded at sites III and IV during summer (Table 5.1.17). During 2012 the minimum seasonal mean pH of 7.1± 0.1 was maintained at Site I during winter compared to the maximum of 8.2± 0.2 at Site IV during summer (Table 5.1.18).

5.1.10. Chloride

Lake waters, during both the years of study, recorded very noticeable seasonal trend in the amounts of chloride, registering its highest during spring and lowest during winter at all the sites. Seasonal mean values of chloride content, however, fluctuated between 22.7±4.2 mg/L at Site IX during spring 2011 and 7.3±1.5 mg/L at Site III during winter 2011 and Site IV during winter 2012 (Tables 5.1.19 and 5.1.20).There were, however, more monthly variations in chloride content in Wular waters and as such during 2011 maximum chloride content of 28.0 mg/L was recorded during April at Site V as against the minimum of 6.0 mg/L, being recorded during December at Site III (Fig.5.1.19). However, in the year 2012 slightly decreased levels of chloride content were obtained as evinced by a record of minimum chloride content (6.0 mg/L) at sites III and IV during February compared to its maximum amounts (26.5 mg/L) at Site VIII during April (Fig.5.1.20).

5.1.11. Total hardness

Wular waters, during both the years of study, recorded very noticeable temporal variations in the amount of total hardness. Greater amounts were recorded during winters and least during summers. In 2011 the highest seasonal mean amounts of total hardness (276.7±12.6 mg/L) were maintained during winter at Site I as against the lowest mean values of 61.7±7.6 mg/L at Site III during summer (Table 5.1.21). Further, in the year 2012 the maximum seasonal mean values of total hardness (251.7±17.6 mg/L) were again registered at Site I during winter against the minimum amounts (68.3±10.4 mg/L) being recorded at Site III during spring (Table 5.1.22).Overall, during the entire study period, the highest amount of total hardness (290 mg/L) was recorded in February 2011 at Site I as against the lowest of 55 mg/L being recorded at Site III during August and September and Site IV during September of the same year (Fig.5.1.21 and 5.1.22).

5.1.12. Calcium content

A perusal of data on calcium content in Wular waters reveals that winter and spring waters are comparatively harder as compared to summers, having lesser amounts of calcium, hence less hard.

A comparison of two year data shows that during 2011 the seasonal mean values of calcium content ranged between a high of 106.4±1.2 mg/L at Site I during winter and a low of 38.5±1.2 mg/L at Site III during summer while in the year 2012 the maximum seasonal mean of 93.5±8.6 mg/L was again registered at Site I during winter as against the minimum of 34.6±4.9 mg/L recorded at Site IV during summer (Fig.5.1.23 and 5.1.24). There were slight monthly but very marginal spatial variations in the calcium content in the lake. Thus, Site I recorded the highest amounts of calcium (107.1 mg/L) during January and February 2011 as against the lowest amounts of 37.6 mg/L, being recorded at Site III during July 2011 (Table 5.1.23).For the year 2012 the maximum calcium content (100.8 mg/L) was registered at Site I during December as against the minimum of 30.24 mg/L at Site IV during July (Table 5.1.24).

5.1.13. Magnesium content

Magnesium content almost followed the same trend as witnessed for calcium content, depicting its peak values in winter and the lowest values in summer months. On seasonal basis the maximum seasonal mean amount of magnesium (43.1±1.9 mg/L) was recorded at Site I during winter and the minimum seasonal amount of 5.9 ±1.4 mg/L) was obtained at Site III during summer in the year 2011 (Fig. 5.1.25). However, during 2012 the maximum seasonal mean magnesium content of 39.1±9.2 mg/L was noted at Site II during winter as against the lowest seasonal mean of 6.0±2.4 mg/L), being recorded at Site III in spring (Fig. 5.1.26).In general, there were significant monthly variations in magnesium content which ranged between a high of 47.0 mg/L (Site II) in February 2012 and a low of 4.6 mg/L at Site III during August 2011 (Table 5.1.25 and 5.1.26).

5.1.14. Bicarbonate alkalinity

In Wular, the alkalinity of water was absolutely due to bicarbonates only as the carbonates were not recorded at any of the sites throughout the study. During the first year of investigation (2011), the maximum seasonal mean bicarbonate alkalinity (218.3±27.5 mg/L) was obtained at Site VI during winter compared to the minimum seasonal amounts (63.3±2.9 mg/L) being recorded at Site III during summer (Fig.5.1.27). During 2012, the maximum bicarbonate alkalinity of 200± 20.0 mg/L was registered again at Site VI during winter as against the minimum of 61.7±7.6 mg/L, being registered again at Site III during summer (Fig. 5.1.28).Greater spatial variations in bicarbonate alkalinity were, however, witnessed during 2011 as compared 2012.Besides, significant temporal fluctuations were observed during both the years of study. Thus, the highest value of bicarbonate alkalinity (245 mg/L) was recorded at Site VI during January 2011 against the lowest value of 55 mg/L at Site III during August 2012 (Table 5.1.27 and 5.1.28).

5.1.15. Dissolved silica

Lake waters, during both the years of study, recorded noticeable temporal variations in the amount of dissolved silica. The amounts of dissolved silica were maximum during spring, followed by summer and autumn and decreased to the minimum during the winter. In 2011 the highest seasonal mean amounts of dissolved silica (16.6±1.1 mg/L) were registered during spring at Site VII as against the lowest seasonal mean values of 6.0±1.6 mg/L at Site II during winter (Fig. 5.1.29). In the year 2012 the maximum seasonal mean amounts of dissolved silica (16.5±1.8 mg/L) were again registered at Site VII during spring against the minimum amounts (6.3± 1.2 mg/L), being recorded at Site III during winter (Fig. 5.1.30).During the entire study period, the highest amount of dissolved silica (18.4 mg/L) was recorded in April 2012 at Site VII as against the lowest values of 3.8 mg/L, being recorded at Site VIII during January 2011 (Table 5.1.29 and 5.1.30).

5.1.16. Orthophosphate-phosphorus

A perusal of data shows that amounts of orthophosphate-phosphorus were low during summers which gradually rose to moderate levels in autumn and then peaked in winter; thereafter a decline in the concentrations of the ion followed (Fig. 5.1.31 and 5.1.32).The data further clearly reveals that the temporal variations in orthophosphate-phosphorus evinced a wide range with the greatest value (118 µg/L) being recorded at Site VI during January 2011 against the lowest (9 µg/L) being recorded at Site IV during June of the same year.

During 2011 the maximum seasonal mean orthophosphate-phosphorus concentration of 100.3± 19.1 µg/L was observed during winter at Site VI as against the minimum one (11.3±1.5 µg/L), being registered during spring at the Site VIII (Table 5.1.31). In

2012 the highest seasonal mean amounts of orthophosphate-phosphorus (89.0±5.0 µg/L) were recorded during winter at Site I as against the lowest mean values of 13.3 ± 3.1 µg/L at Site IV during summer (Table 5.1.32).

5.1.17. Total phosphorus

Total phosphorus followed the same trend as witnessed for orthophosphate phosphorus, depicting its peak values in winter and the lowest values in summer months. Very little fluctuations were observed in the amounts of total phosphorus in the lake waters although temporally the values fluctuated significantly (Table 5.1.33 and 5.1.34, Fig.5.1.33 and 5.1.34).The ranges of total phosphorus over the whole period of investigation were much wider and thus fluctuated from the lowest value (60 µg/L) at Site VIII during September 2011 to the highest values (393 µg/L) at Site V during February of the same year. However, the maximum seasonal mean value of 350.3± 35.9 µg/L was recorded at Site VI during winter 2011 as against the minimum value of 73.3± 10.4 µg/L, being registered at Site VIII during summer 2011.

5.1.18. Ammonical-nitrogen (NH_4-N)

Ammonical-nitrogen followed the same trend as that of total phosphorus, with its peak amounts recorded during winters and the least amounts during summers (Fig.5.1.35 and 5.1.36). Like that of phosphate phosphorus, ammonical-nitrogen also evinced a wide range with the greatest value (330 µg/L) being recorded at Sites VII and IX during December 2011 as against the lowest (35 µg/L), being recorded at Site VIII during September the same year. On seasonal basis, the highest seasonal mean value of 290.0± 20.0 µg/L was obtained during winter 2011 at Site I as against the lowest mean values of 48.5± 9.2 µg/L, being recorded at Site III during summer (Fig. 5.1.35). However, for the year 2012 the maximum seasonal mean of 268.0±14.7 µg/L was recorded at Site I during winter as against the minimum of 50.3±11.7 µg/L, being recorded at Site VIII during summer (Fig.5.1.36).In general, more temporal fluctuations were recorded during 2011 as compared to the year 2012 (Tables 5.1.35 and 5.1.36; Fig. 5.1.35 and 5.1.36).

5.1.19. Nitrate-nitrogen (NO_3-N)

Nitrate- nitrogen followed the same trend as that of ammonical-nitrogen, witnessing its peak amount during winter and then following a decline to reach the lowest value during summer where after an increasing trend was evinced towards the autumn (Fig. 5.1.37 and 5.1.38).On seasonal basis, the maximum seasonal mean value of nitrate- nitrogen (1416.7±336.1 µg/L) was obtained during winter 2011 at Site VI against the minimum seasonal mean value of 178.7±22.7 µg/L, being recorded during summer 2012 at Site VIII. Monthly values, however, fluctuated between a high of 1710 µg/L at Site VI in February 2011 and a low of 120 µg/L at Site IV in August 2012 (Table 5.1.37 and 5.1.38).

5.1.20. Total iron

A perusal of the data revealed that there was a summer fall in total iron content in the lake waters (Fig. 5.1.39 and 5.1.40).The autumn and spring season registered modest amounts of total iron and the values peaked during winter. Thus, the seasonal mean values reached its high of 389.0± 21.2 µg/L at Site VII during winter 2011 as against the low of 216.0±18.3 µg/L at Site VIII during summer 2012 (Fig.5.1.39 and 5.1.40).However, on monthly basis total iron also evinced a wide range with the greatest value (413 µg/L) being recorded at Site VII during February 2011 against the lowest (189 µg/L), being recorded at Site VIII during August of the same year (Table 5.1.39 and 5.1.40).

5.1.21. Correlations between various physico-chemical parameters of water in Wular lake

Correlation coefficients worked out for all the physico-chemical parameters of water depicted both significant and non-significant positive as well negative correlations between the various parameters (Table 5.1.41).

There was a strong positive correlation between air temperature and water temperature ($p<0.01$, $r = 0.896$) as was highlighted in the observations recording a fall in the values of both during winter. Highest values for air temperature as well as water temperature were also corresponding to each other. Water temperature was also found to be strongly correlated with dissolved oxygen ($p<0.05$, $r = -0.781$). pH showed negative correlation with almost all the parameters except total iron. The parameters depicting strong correlation with pH were total dissolved solids ($p<0.01$, $r = -0.875$), conductivity ($p<0.01$, $r = -0.858$), free carbon dioxide ($p<0.05$, $r = -0.754$), alkalinity ($p<0.01$, $r = -0.799$), total hardness ($p<0.01$, $r = -0.907$), calcium content ($p<0.01$, $r = -0.907$), magnesium content ($p<0.01$, $r = -0.888$) and total iron ($p<0.05$, $r = 0.697$). Water transparency did not show strong correlation with any of the parameters except dissolved oxygen ($p<0.05$, $r = 0.788$).

The strong inverse relationship between conductivity and pH was evident from the results which was proved statistically ($p<0.01$, $r = -0.858$).Conductivity also revealed highly significant positive correlation with free carbon dioxide ($p<0.01$, $r = 0.874$), alkalinity ($p<0.01$, $r = 0.953$), total hardness ($p<0.01$, $r = 0.978$), calcium content ($p<0.01$, $r = 0.964$), magnesium content ($p<0.01$, $r = 0.980$) and orthophosphate-phosphorus ($p<0.01$, $r = 0.857$).Conductivity, however, depicted highly significant perfect positive correlation with total dissolved solids ($p<0.01$, $r = 0.999$).All these parameters depicted a summer fall and winter peak in their concentrations in water. Chloride was the only exception which could not depict strong correlation with any of the parameters.

All those parameters which depicted significant positive correlations with conductivity were again positively and significantly correlated to total dissolved solids (free carbon dioxide: $p<0.01$, $r = 0.877$; alkalinity: $p<0.01$, $r = 0.953$; total hardness: $p<0.01$, $r = 0.981$; calcium content: $p<0.01$, $r = 0.969$; magnesium content: $p<0.01$, $r = 0.982$; orthophosphate phosphorus: $p<0.01$, $r = 0.848$). Total dissolved solids, however, showed highly significant negative correlation with pH ($p<0.01$, r = -0.875).

The most significant positive correlation of calcium content was recorded with total hardness ($p<0.01$, r = 0.991) and magnesium content ($p<0.01$, r = 0.975) and its most significant negative correlation ($p<0.01$, r = -0.907) was noted with pH. Magnesium content depicted strong positive correlations with alkalinity ($p<0.01$, r = 0.939) and orthophosphate-phosphorus ($p<0.01$, r = 0.807), besides total dissolved solids, conductivity, and free carbon dioxide discussed earlier. Alkalinity depicted a trend similar to that of magnesium content in terms of correlation co-efficient. However, alkalinity also depicted strong positive correlation with total phosphorus ($p<0.05$, r = 0.720) which was not revealed by magnesium content. Both magnesium content and alkalinity had significant negative correlations with pH ($p<0.01$, r = -0.888 for magnesium content and $p<0.01$, r = -0.799 for alkalinity respectively).

Dissolved silica maintained significant positive correlations with ammonical-nitrogen ($p<0.01$, r = 0.807) and nitrate-nitrogen ($p<0.05$, r = 0.726).Dissolved silica, however, did not show any significant negative correlations with any of the parameters.

In addition to all these, there were some more significant positive correlations (between orthophosphate phosphorus and total phosphorus: $p<0.05$, r = 0.792; orthophosphate-phosphorus and nitrate-nitrogen: $p<0.05$, r = 0.722; total phosphorus and ammonical-nitrogen: $p<0.01$, r = 0.893; total phosphorus and nitrate-nitrogen: $p<0.01$, r = 0.942 and free carbon dioxide and orthophosphate-phosphorus: $p<0.05$, r = 0.795).

5.1.22. Analysis of variance (ANOVA)

The balanced analysis of variance worked out between different physico-chemical parameters of water during the study period depicted highly significant spatial as well as temporal variations ($P <0.05$) for most of the parameters (Tables 5.1.42 and 5.1.43). However, calcium content and water transparency depicted slight insignificant variations.

Table 5.1.1 Monthly fluctuations (with seasonal mean±SD) in depth (m) of Wular lake from Mar. 2011 to Feb. 2012

Site	Mar	Apr	May	Mean±SD	Jun	Jul	Aug	Mean±SD	Sep	Oct	Nov	Mean±SD	Dec	Jan	Feb	Mean±SD
Site I	0.8	1	0.9	**0.9±0.1**	0.8	0.6	0.7	**0.7±0.1**	0.6	0.5	0.5	**0.5±0.1**	0.4	0.3	0.5	**0.4±0.1**
Site II	1.77	2.1	2.9	**2.3±0.6**	3.3	2.9	2.7	**3.0±0.3**	2.9	2.4	1.7	**2.3±0.6**	1.3	1	0.8	**1.0±0.3**
Site III	1.7	2.1	2.8	**2.2±0.6**	2.3	1.8	1.5	**1.9±0.4**	1.7	1.3	1.1	**1.4±0.3**	0.9	0.7	0.8	**0.8±0.1**
Site IV	1.4	1.8	2.4	**1.9±0.5**	2.1	1.7	1.3	**1.7±0.4**	1.5	1	0.8	**1.1±0.4**	0.6	0.5	0.5	**0.5±0.1**
Site V	1.8	2.3	3.1	**2.4±0.7**	4.1	3.3	2.9	**3.4±0.6**	3.1	2.6	1.9	**2.5±0.6**	1.7	1.2	0.8	**1.2±0.5**
Site VI	1.2	1.1	1.4	**1.2±0.2**	1.2	1	0.8	**1±0.2**	0.9	0.7	0.5	**0.7±0.2**	0.3	0.4	0.5	**0.4±0.1**
Site VII	3.6	4.4	5.8	**4.6±1.1**	5	4.2	3.8	**4.3±0.6**	4.2	3.9	3.2	**3.8±0.5**	2.4	2.1	1.8	**2.1±0.3**
Site VIII	3	3.9	4.9	**3.9±1.0**	4	3.4	3.6	**3.7±0.3**	4	3.6	3	**3.5±0.5**	2.1	1.4	1.6	**1.7±0.4**
Site IX	1	1.3	1.7	**1.3±0.4**	1.5	1.3	1.1	**1.3±0.2**	1.3	0.9	0.7	**1.0±0.3**	0.6	0.4	0.7	**0.6±0.2**

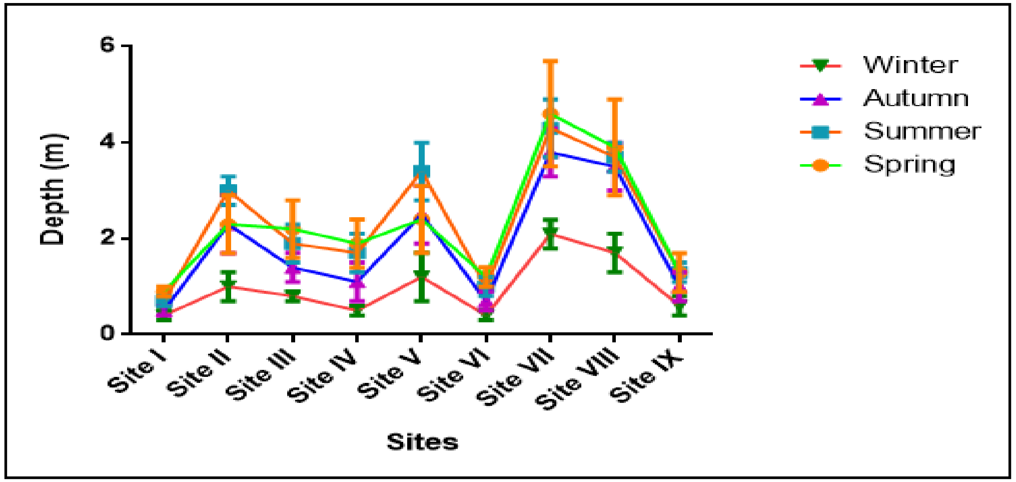


Fig. 5.1.1. Seasonal fluctuations (mean±SD) in depth (m) recorded in Wular lake from Mar. 2011 to Feb. 2012

Table 5.1.2. Monthly fluctuations (with seasonal mean±SD) in depth (m) of Wular lake from Mar. 2012 to Feb. 2013

Site	Mar	April	May	Mean±S.D	June	July	Aug	Mean±S.D	Sept.	Oct	Nov.	Mean±S.D	Dec.	Jan.	Feb.	Mean±S.D
Site I	0.6	0.7	0.5	**0.6±0.2**	0.6	0.8	0.7	**0.7±0.1**	0.4	0.4	0.3	**0.4±0.2**	0.3	0.4	0.5	**0.4±0.2**
Site II	3	2.4	2.2	**2.5±0.8**	1.7	1.9	2.1	**1.9±0.2**	1.8	1.6	1.5	**1.6±0.7**	1	0.8	0.6	**0.8±0.8**
Site III	2.2	2	1.8	**2.0±0.6**	1.4	1.5	2.2	**1.7±0.4**	1.6	1.3	1.2	**1.4±0.6**	0.9	0.7	0.6	**0.7±0.6**
Site IV	1.6	1.4	1	**1.3±0.5**	1.2	1.6	1.9	**1.6±0.3**	1.2	0.7	0.5	**0.8±0.5**	0.4	0.3	0.5	**0.4±0.5**
Site V	2.4	2.4	2.3	**2.4±0.7**	1.5	2.3	2.5	**2.1±0.4**	1.8	1.4	0.9	**1.4±0.7**	0.9	0.7	0.9	**0.8±0.7**
Site VI	1	0.9	0.7	**0.9±0.3**	1	1.2	1.1	**1.1±0.1**	0.8	0.6	0.5	**0.6±0.3**	0.4	0.2	0.3	**0.3±0.2**
Site VII	4	4.3	3.8	**4.0±1.2**	2.9	3.6	4.2	**3.6±0.5**	3.7	3	2.8	**3.2±1.1**	2.3	2	1.8	**2.0±1.1**
Site VIII	3.3	3.1	2.5	**3.0±0.9**	2.41	3.25	3.5	**3.1±0.5**	3.2	2.2	1.8	**2.4±0.9**	1.5	1.5	1.8	**1.6±0.9**
Site IX	1.3	1.4	0.9	**1.2±0.4**	0.9	1.6	1.4	**1.3±0.3**	1.6	0.9	0.6	**1.0±0.4**	0.5	0.4	0.6	**0.5±0.4**

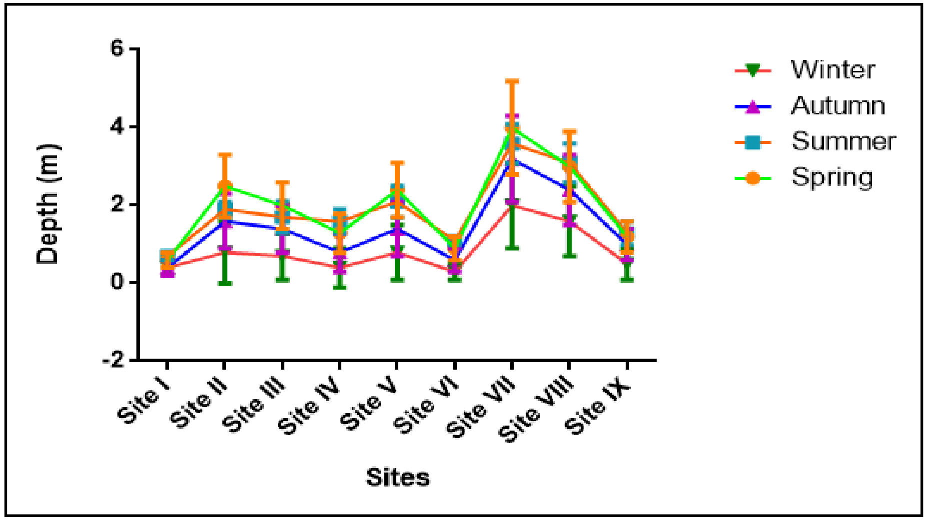


Fig. 5.1.2. Seasonal fluctuations (mean±SD) in depth (m) recorded in Wular lake from Mar. 2012 to Feb. 2013

Table 5.1.3. Monthly fluctuations (with seasonal mean±SD) in water transparency (m) of Wular lake from Mar. 2011 to Feb. 2012

Site	Mar	Apr	May	Mean±SD	Jun	Jul	Aug	Mean±SD	Sep	Oct	Nov	Mean±SD	Dec	Jan	Feb	Mean±SD
Site I	0.2	0.3	0.1	**0.2±0.1**	0.3	0.2	0.3	**0.3±0.1**	0.2	0.4	0.3	**0.3±0.1**	0.4	0.3	0.4	**0.4±0.1**
Site II	0.6	0.7	0.8	**0.7±0.1**	0.8	0.9	1.1	**0.9±0.2**	0.9	1.2	1.2	**1.1±0.2**	1.3	1	0.8	**1.0±0.3**
Site III	0.6	0.5	0.6	**0.6±0.1**	0.7	0.8	0.7	**0.7±0.1**	0.8	0.8	0.9	**0.8±0.1**	1.1	0.9	0.8	**0.9±0.2**
Site IV	0.3	0.4	0.3	**0.3±0.1**	0.5	0.6	0.5	**0.5±0.1**	0.6	0.5	0.6	**0.6±0.1**	0.5	0.4	0.5	**0.5±0.1**
Site V	0.5	0.7	0.6	**0.6±0.1**	0.6	0.9	1	**0.8±0.2**	0.9	1.2	1.2	**1.1±0.2**	1	1.2	0.8	**1.0±0.2**
Site VI	0.3	0.3	0.2	**0.3±0.1**	0.4	0.3	0.4	**0.4±0.1**	0.3	0.5	0.4	**0.4±0.1**	0.3	0.4	0.5	**0.4±0.1**
Site VII	1.1	0.6	1.2	**1.0±0.3**	1.2	1.4	1.5	**1.4±0.2**	1.5	1.9	1.8	**1.7±0.2**	2.1	2	1.7	**1.9±0.2**
Site VIII	0.8	0.4	0.8	**0.7±0.2**	0.9	1	1.1	**1.0±0.1**	1.2	1.3	1.6	**1.4±0.2**	1.8	1.4	1.4	**1.5±0.2**
Site IX	0.4	0.2	0.3	**0.3±0.1**	0.4	0.5	0.4	**0.4±0.1**	0.3	0.6	0.5	**0.5±0.2**	0.6	0.4	0.7	**0.6±0.2**

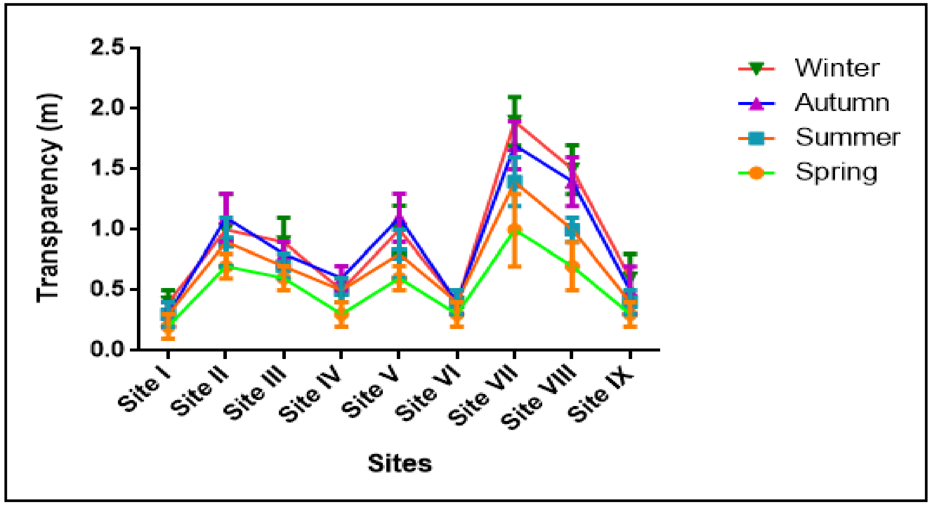


Fig. 5.1.3. Seasonal fluctuations (mean±SD) in water transparency (m) recorded in Wular lake from Mar. 2011 to Feb. 2012

Table 5.1.4. Monthly fluctuations (with seasonal mean±SD) in water transparency (m) of Wular lake from Mar. 2012 to Feb. 2013

Site	Mar	Apr	May	Mean±SD	Jun	Jul	Aug	Mean±SD	Sept	Oct	Nov	Mean±SD	Dec	Jan	Feb.	Mean±SD
Site I	0.2	0.1	0.1	**0.1±0.1**	0.2	0.2	0.2	**0.2±0.0**	0.3	0.2	0.3	**0.3±0.1**	0.3	0.1	0.4	**0.3±0.2**
Site II	0.3	0.2	0.2	**0.2±0.1**	0.3	0.3	0.4	**0.3±0.1**	0.9	0.5	0.4	**0.5±0.3**	0.6	0.7	0.6	**0.6±0.1**
Site III	0.3	0.4	0.3	**0.3±0.1**	0.5	0.5	0.4	**0.5±0.1**	0.5	0.5	0.7	**0.6±0.1**	0.8	0.6	0.6	**0.7±0.1**
Site IV	0.3	0.3	0.2	**0.3±0.1**	0.4	0.3	0.4	**0.4±0.1**	0.3	0.4	0.4	**0.4±0.1**	0.3	0.3	0.5	**0.4±0.1**
Site V	0.2	0.3	0.4	**0.3±0.1**	0.5	0.6	0.3	**0.5±0.2**	0.6	0.6	0.7	**0.6±0.1**	0.8	0.6	0.8	**0.7±0.1**
Site VI	0.3	0.3	0.2	**0.3±0.1**	0.4	0.3	0.3	**0.3±0.1**	0.3	0.5	0.4	**0.4±0.1**	0.3	0.4	0.5	**0.4±0.1**
Site VII	0.6	0.5	0.6	**0.6±0.1**	0.7	0.8	1.1	**0.9±0.2**	1.3	1.2	1.4	**1.6±0.1**	1.8	1.7	1.7	**1.7±0.1**
Site VIII	0.3	0.4	0.5	**0.4±0.1**	0.4	0.6	0.8	**0.6±0.2**	0.9	1	1.2	**1.0±0.2**	1.3	1.4	1.3	**1.3±0.1**
Site IX	0.3	0.2	0.2	**0.2±0.1**	0.4	0.2	0.3	**0.3±0.1**	0.3	0.3	0.5	**0.4±0.1**	0.5	0.4	0.6	**0.5±0.1**

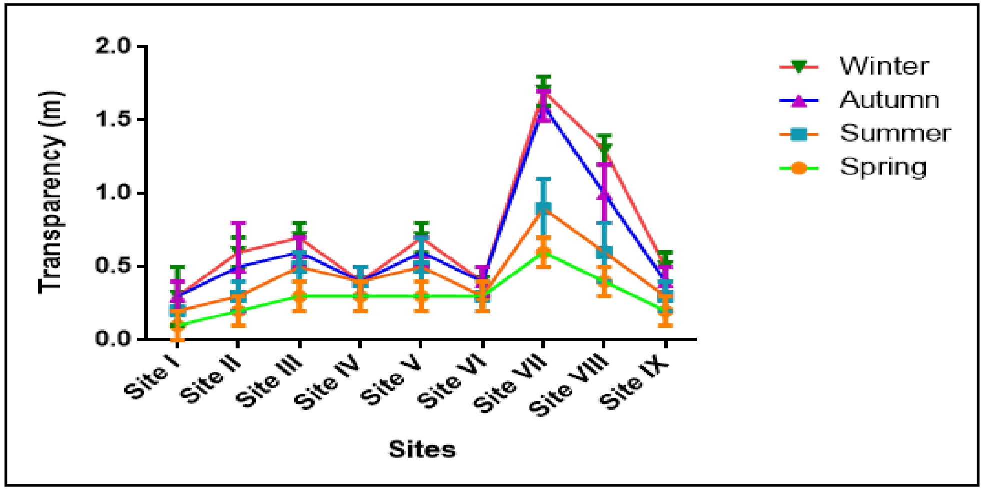


Fig. 5.1.4. Seasonal fluctuations (mean±SD) in water transparency (m) recorded in Wular lake from Mar. 2012 to Feb. 2013

Table 5.1.5. Monthly fluctuations (with seasonal mean±SD) in air temperature (^{0}C) of Wular lake from Mar. 2011 to Feb. 2012

Site	Mar	Apr	May	Mean±SD	Jun	Jul	Aug	Mean±SD	Sep	Oct	Nov	Mean±SD	Dec	Jan	Feb	Mean±SD
Site I	16	18.5	24	**20±4.1**	29.5	30.6	31.5	**30.5±1.0**	22	18	13	**17.7±4.5**	8	7.6	8	**7.9±0.2**
Site II	14	17	22.9	**18±4.5**	29	30	31	**30±1.0**	23	17	11	**17±6.0**	6	5.7	8.2	**6.6±1.4**
Site III	15.3	18	24	**19±4.5**	28	29	30.6	**29.2±1.3**	24	15	12.5	**17.2±6.0**	6.4	4.8	8.6	**6.6±1.9**
Site IV	15.5	19	25	**20±4.8**	27.5	29.3	31	**29.3±1.8**	26	16	10.9	**17.6±7.7**	5.4	4.9	7.4	**5.9±1.3**
Site V	16	17	25	**19±4.9**	30	32.1	33	**31.7±1.5**	25	18	15	**19.3±5.1**	4.7	4.3	7.5	**5.5±1.7**
Site VI	17	19	26	**21±4.7**	32	33	32	**32.3±0.6**	27	19	16	**20.7±5.7**	6.6	5	8	**6.5±1.5**
Site VII	15	16	25	**19±5.5**	29.5	31	32	**30.8±1.3**	24	15	12	**17.0±6.3**	6	3.9	7.6	**5.8±1.9**
Site VIII	13	13.5	22	**16±5.1**	27	29.3	31	**29.1±2.0**	21	12	9	**14±6.2**	5	4.6	7	**5.5±1.3**
Site IX	16	18	26	**20±5.3**	31	32	33.2	**32.0±1.1**	26	19	16.1	**20.3±5.1**	6.5	6.7	7.7	**7.0±0.6**

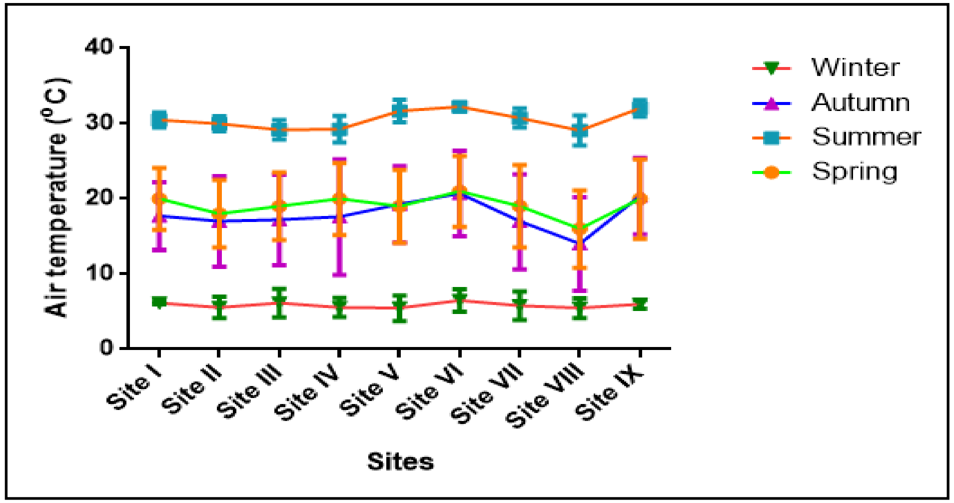


Fig. 5.1.5. Seasonal fluctuations (mean±SD) in air temperature (^{0}C) recorded in Wular lake from Mar. 2011 to Feb. 2012

Table 5.1.6. Monthly fluctuations (with seasonal mean±SD) in air temperature (^{0}C) of Wular lake from Mar. 2012 to Feb. 2013

	Mar	Apr	May	Mean±SD	Jun	Jul	Aug	Mean±SD	Sep	Oct	Nov	Mean±SD	Dec	Jan	Feb	Mean±SD
Site I	14	15.8	20.4	**16.7±3.3**	23.4	29.6	30.2	**27.7±3.8**	24.2	18.4	12.6	**18.4±5.8**	8.4	4.9	7.6	**7.0±1.8**
Site II	13	16.1	19.7	**16.3±3.4**	22.7	28.2	26.7	**25.9±2.8**	22.3	15.2	10.8	**16.1±5.8**	7.3	5.3	7.5	**6.7±1.2**
Site III	14.2	16.3	21.3	**17.3±3.6**	23.6	29.4	27.2	**26.7±2.9**	22.6	14.1	10.5	**15.7±6.2**	6.8	4.6	7.3	**6.2±1.4**
Site IV	13.4	16.5	22.2	**17.4±4.5**	23.8	30.2	28.6	**27.5±3.3**	23.8	13.4	10.3	**15.8±7.1**	5.9	4.5	6.8	**5.7±1.2**
Site V	14.3	15.8	19.8	**16.6±2.8**	22.9	27.9	26.5	**25.8±2.6**	24.3	13.8	11.8	**16.6±6.7**	5.4	3.2	6.9	**5.2±1.9**
Site VI	14.5	16.7	21.4	**17.5±3.5**	23.5	29.8	27.9	**27.1±3.2**	22.8	14.3	12.2	**16.4±5.6**	5.8	4	7.4	**5.7±1.7**
Site VII	13.9	14.7	21.9	**16.8±4.4**	24.8	30.4	28.3	**27.8±2.8**	25.6	14.7	11.4	**17.2±7.4**	5.5	4.1	7.2	**5.6±1.6**
Site VIII	12.6	13.2	18.6	**14.8±3.3**	21.7	28.7	26.7	**25.7±3.6**	23.4	13.8	9.5	**15.6±7.1**	5.2	3.9	6.2	**5.1±1.2**
Site IX	14.4	16.2	22.6	**17.7±4.3**	22.6	30.1	27.4	**26.7±3.8**	22.8	17.7	12.5	**17.7±5.2**	6.2	3.8	7.3	**5.8±1.8**

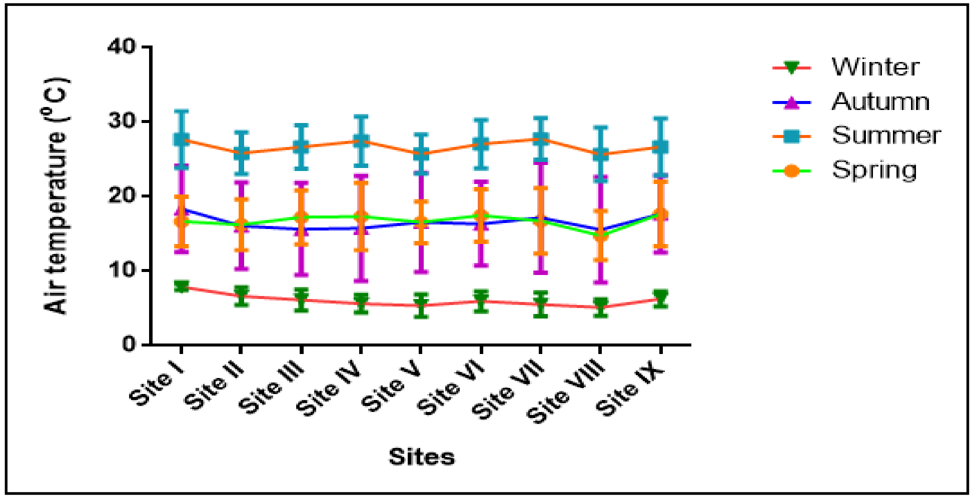


Fig. 5.1.6. Seasonal fluctuations (mean±SD) in air temperature (^{0}C) recorded in Wular lake from Mar. 2012 to Feb. 2013

Table 5.1.7. Monthly fluctuations (with seasonal mean±SD) in water temperature (^{0}C) of Wular lake from Mar. 2011 to Feb. 2012

	Mar	Apr	May	Mean±SD	Jun	Jul	Aug	Mean±SD	Sep	Oct	Nov	Mean±SD	Dec	Jan	Feb	Mean±SD
Site I	14	15.5	21.7	**17.1±4.1**	23.5	25.6	25.2	**24.8±1.1**	18	15	10.3	**14.4±3.9**	6	6.4	7.6	**6.7±0.8**
Site II	11	14.3	19	**14.8±4.0**	24	25.5	25.3	**24.9±0.8**	20	14	8	**14.0±6.0**	5.5	4	7.5	**5.7±1.8**
Site III	12	14.5	20.7	**15.7±4.5**	25	25.7	25.3	**25.3±0.4**	21	12	9.5	**14.0±5.8**	5.9	4.5	7	**5.8±1.3**
Site IV	12.5	15	21	**16.2±4.4**	25.4	26	26.3	**25.9±0.5**	23	13.2	9.4	**15.2±7.0**	5.2	4.3	6.9	**5.5±1.3**
Site V	12	14	20	**15.3±4.2**	25.8	26.3	26.6	**26.2±0.4**	22	12.9	10	**15.0±6.3**	4.2	3.4	6	**4.5±1.3**
Site VI	12.3	14.6	21	**16.0±4.5**	26	26.5	26.7	**26.4±0.4**	23	13.2	11	**15.7±6.4**	5	4.7	7.3	**5.7±1.4**
Site VII	11.6	12.5	21	**15.0±5.2**	24	26	24	**24.7±1.2**	22	12.3	9	**14.6±7.0**	5.1	3.5	6.7	**5.1±1.6**
Site VIII	8	8.9	17.8	**11.6±5.4**	24	25.1	25.2	**24.8±0.7**	19	10	8	**12.2±5.6**	4.7	3	5.5	**4.4±1.3**
Site IX	12.5	14.5	21.3	**16.1±4.6**	24.7	25.2	25.6	**25.2±0.5**	21	12.9	11	**15.0±5.3**	6	5.5	7	**6.2±0.8**

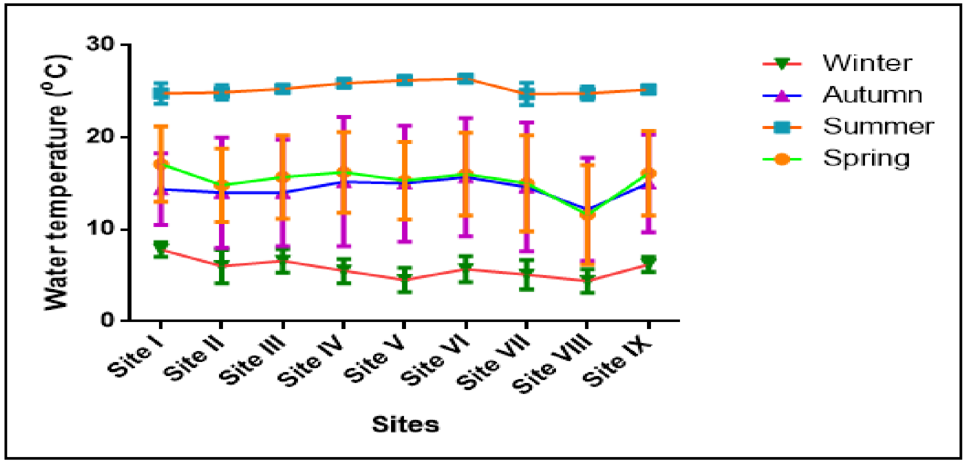


Fig. 5.1.7. Seasonal fluctuations (mean±SD) in water temperature (^{0}C) recorded in Wular lake from Mar. 2011 to Feb. 2012

Table 5.1.8. Monthly fluctuations (with seasonal mean±SD) in water temperature (^{0}C) of Wular lake from Mar. 2012 to Feb. 2013

	Mar	Apr	May	Mean±SD	Jun	Jul	Aug	Mean±SD	Sep	Oct	Nov	Mean±SD	Dec	Jan	Feb	Mean±SD
Site I	12.9	14.2	18.7	**15.3±3.0**	21.5	26.3	24.8	**24.2±2.5**	20.1	14.2	11	**15.1±4.6**	7.6	4.5	7.1	**6.4±1.7**
Site II	9	12.1	17.2	**12.8±4.1**	20.2	27.1	23.9	**23.7±3.5**	19.2	13.5	9	**13.9±5.1**	6.3	4.4	7.2	**6.0±1.4**
Site III	10	12.3	18.3	**13.5±4.3**	21.5	25.4	24	**23.6±2.0**	20.3	11	8.6	**13.3±6.2**	6	4	6.5	**5.5±1.3**
Site IV	11	12.7	19.5	**14.4±4.5**	22.6	26.7	24.6	**24.6±2.1**	21.4	11.3	7.9	**13.5±7.0**	5.1	4.1	5.9	**5.0±0.9**
Site V	10	11.5	17.9	**13.1±4.2**	20.8	26.8	24.8	**24.1±3.1**	22.1	11.5	8.8	**14.1±7.0**	4.5	2.7	6	**4.4±1.7**
Site VI	10.5	12.1	18.3	**13.6±4.1**	21.7	27.2	24.9	**24.6±2.8**	20.6	12.1	9.8	**14.2±5.7**	4.6	3.6	6.7	**5.0±1.6**
Site VII	9.8	10.8	18.8	**13.1±4.9**	22.1	27.4	25	**24.8±2.7**	22.5	11.6	7.9	**14.0±7.6**	4.8	2.9	6.5	**4.7±1.8**
Site VIII	8.5	10.3	15.4	**11.4±3.6**	18.6	25.8	24.1	**22.8±3.8**	20.1	9.8	8.1	**12.7±6.5**	4.5	2.8	5.2	**4.2±1.2**
Site IX	10.5	12.7	17.6	**13.6±3.6**	20.9	26.3	24	**23.7±2.7**	19.9	11.7	10.3	**14.0±5.2**	5.7	2.6	6.5	**4.9±2.1**

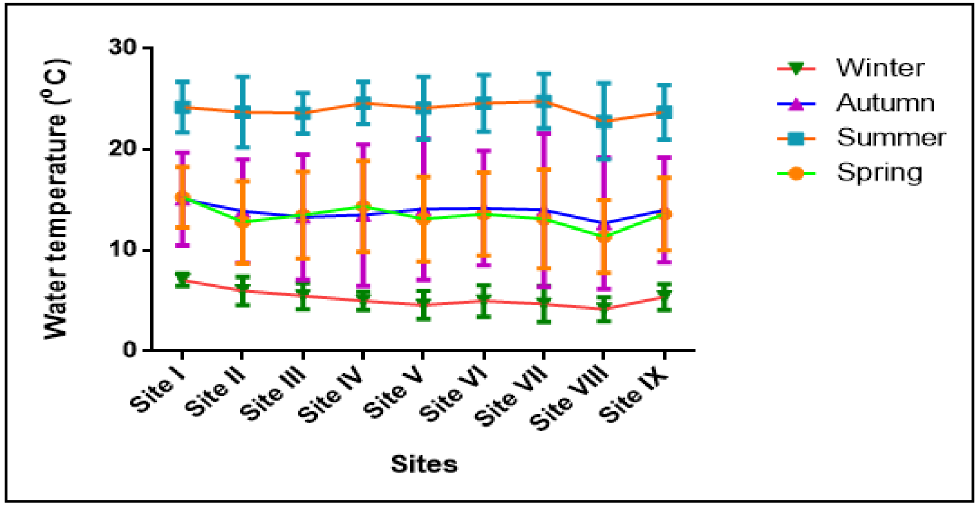


Fig. 5.1.8. Seasonal fluctuations (mean±SD) in water temperature (^{0}C) recorded in Wular lake from Mar. 2012 to Feb. 2013

Table 5.1.9. Monthly fluctuations (with seasonal mean±SD) in specific conductivity (µS /cm) at 25 ^{0}C of Wular lake from Mar. 2011 to Feb. 2012

	Mar	Apr	May	Mean±SD	Jun	Jul	Aug	Mean±SD	Sep	Oct	Nov	Mean±SD	Dec	Jan	Feb	Mean±SD
Site I	385	355	342	**360.7±22.1**	324	300	325	**316.3±14.2**	300	430	470	**400.0±88.9**	491	510	525	**508.7±17.0**
Site II	350	310	301	**320.3±26.1**	260	270	230	**253.3±20.8**	250	360	390	**333.3±73.7**	420	452	470	**447.3±25.3**
Site III	180	155	130	**155±25.0**	125	105	115	**115.0±10.0**	90	160	175	**141.7±45.4**	205	210	220	**211.7±7.6**
Site IV	209	180	165	**184.7±22.4**	150	130	118	**132.7±16.2**	95	170	200	**155.0±54.1**	215	240	255	**236.7±20.2**
Site V	215	182	170	**189±23.3**	115	130	150	**131.7±17.6**	100	170	210	**160.0±55.7**	245	270	284	**266.3±19.8**
Site VI	370	340	330	**346.7±20.8**	310	270	320	**300.0±26.5**	300	380	420	**366.7±61.1**	460	485	505	**483.3±22.5**
Site VII	280	242	230	**250.7±26.1**	180	170	200	**183.3±15.3**	160	250	264	**224.7±56.4**	290	325	310	**308.3±17.6**
Site VIII	325	292	260	**292.3±32.5**	237	212	180	**209.7±28.6**	150	210	265	**208.3±57.5**	295	320	310	**308.3±12.6**
Site IX	330	310	280	**306.7±25.2**	210	170	235	**205.0±32.8**	145	220	280	**215.0±67.6**	325	350	385	**353.3±30.1**

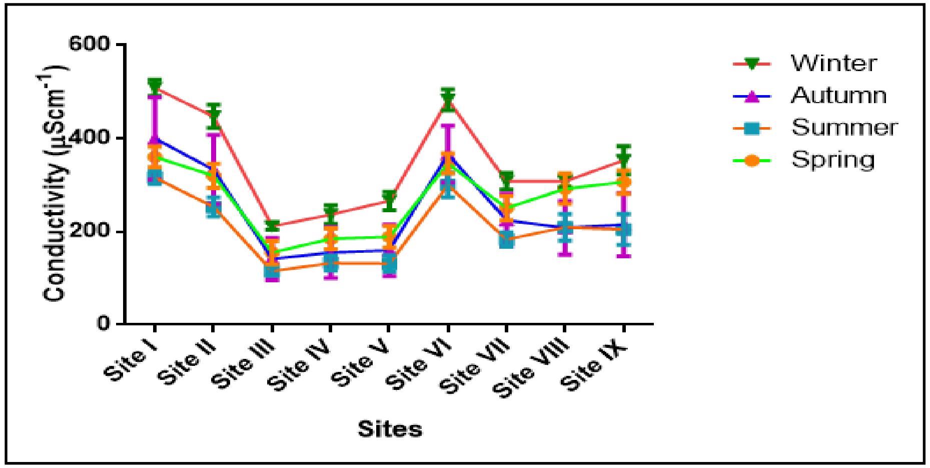


Fig. 5.1.9. Seasonal fluctuations (mean±SD) in specific conductivity (µS /cm) at 25 ^{0}C recorded in Wular lake from Mar. 2011 to Feb. 2012

Table 5.1.10. Monthly fluctuations (with seasonal mean±SD) in specific conductivity (µS /cm) at 25 ^{0}C of Wular lake from Mar. 2012 to Feb. 2013

	Mar	Apr	May	Mean±SD	Jun	Jul	Aug	Mean±SD	Sep	Oct	Nov	Mean±SD	Dec	Jan	Feb	Mean±SD
Site I	362	341	326	**343.0±18.1**	298	312	290	**300.0±11.1**	322	363	410	**365.0±44.0**	461	489	472	**474.0±14.1**
Site II	330	321	292	**314.3±19.9**	245	231	211	**229.0±17.1**	265	311	363	**313.0±49.0**	390	411	387	**396.0±13.1**
Site III	192	150	136	**159.3±29.1**	130	110	121	**120.3±10.0**	110	142	163	**138.3±26.7**	220	191	233	**214.7±21.5**
Site IV	210	190	183	**194.3±14.0**	135	120	139	**131.3±10.0**	110	160	220	**163.3±55.1**	210	251	240	**233.7±21.2**
Site V	256	221	100	**192.3±81.9**	137	205	226	**189.3±46.5**	277	235	350	**287.3±58.2**	289	356	361	**335.3±40.2**
Site VI	313	290	333	**312.0±21.5**	287	283	301	**290.3±9.5**	342	363	390	**365.0±24.1**	433	452	387	**424.0±33.4**
Site VII	292	234	211	**245.7±41.7**	154	197	204	**185.0±27.1**	281	234	360	**291.7±63.7**	308	311	257	**292.0±30.3**
Site VIII	278	265	197	**246.7±43.5**	167	210	214	**197.0±26.1**	267	210	345	**274.0±67.8**	297	351	307	**318.3±28.7**
Site IX	311	253	210	**258.0±50.7**	221	200	234	**218.3±17.2**	276	240	354	**290.0±58.3**	324	342	338	**334.7±9.5**

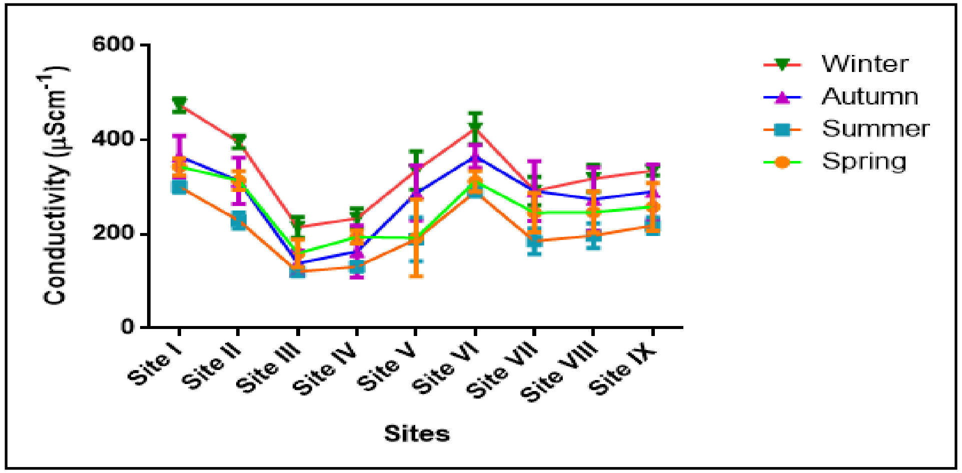


Fig. 5.1.10. Seasonal fluctuations (mean±SD) in specific conductivity (µS /cm) at 25 ^{0}C recorded in Wular lake from Mar. 2012 to Feb. 2013

Table 5.1.11. Monthly fluctuations (with seasonal mean±SD) in total dissolved solids (mg/L) of Wular lake from Mar. 2011 to Feb. 2012

	Mar	Apr	May	Mean±SD	Jun	Jul	Aug	Mean±SD	Sep	Oct	Nov	Mean±SD	Dec	Jan	Feb	Mean±SD
Site I	230	213	210	**217.7±10.8**	190	180	195	**188.3±7.6**	250	258	280	**262.7±15.5**	295	305	315	**305.0±10.0**
Site II	208	190	181	**193.0±13.7**	155	135	160	**150.0±13.2**	195	215	234	**214.7±19.5**	252	270	282	**268.0±15.1**
Site III	110	95	85	**96.7±12.6**	75	70	64	**69.7±5.5**	75	95	106	**92.0±15.7**	123	125	132	**126.7±4.7**
Site IV	126	110	100	**112.0±13.1**	90	78	70	**79.3±10.1**	75	100	118	**97.7±21.6**	130	145	154	**143.0±12.1**
Site V	130	110	104	**114.7±13.6**	90	77	68	**78.3±11.1**	96	115	125	**112.0±14.7**	147	162	170	**159.7±11.7**
Site VI	222	205	215	**214.0±8.5**	186	160	192	**179.3±17.0**	230	240	252	**240.7±11.0**	276	290	305	**290.3±14.5**
Site VII	168	145	135	**149.3±16.9**	120	102	107	**109.7±9.3**	125	151	159	**145.0±17.8**	174	195	187	**185.3±10.6**
Site VIII	195	175	156	**175.3±19.5**	142	125	108	**125.0±17.0**	125	140	172	**145.7±24.0**	190	217	220	**209.0±16.5**
Site IX	200	187	170	**185.7±15.0**	140	125	102	**122.3±19.1**	130	155	175	**153.3±22.5**	196	210	230	**212.0±17.1**

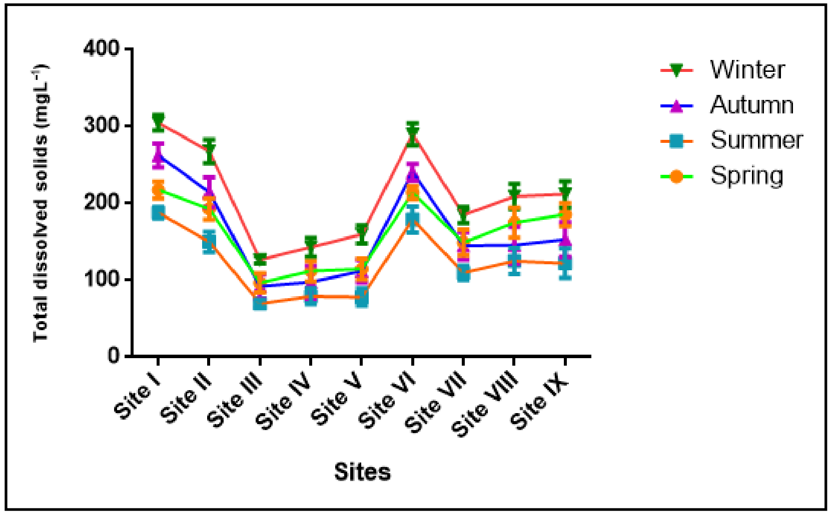


Fig. 5.1.11. Seasonal fluctuations (mean±SD) in total dissolved solids (mg/L) recorded in Wular lake from Mar. 2011 to Feb. 2012

Table 5.1.12. Monthly fluctuations (with seasonal mean±SD) in total dissolved solids (mg/L) of Wular lake from Mar. 2012 to Feb. 2013

	Mar	Apr	May	Mean±SD	Jun	Jul	Aug	Mean±SD	Sep	Oct	Nov	Mean±SD	Dec	Jan	Feb	Mean±SD
Site I	240	220	210	**223.3±15.3**	190	200	185	**191.7±7.6**	205	180	260	**215.0±40.9**	300	320	305	**308.3±10.4**
Site II	215	210	190	**205.0±13.2**	160	148	140	**149.3±10.1**	170	205	230	**201.7±30.1**	250	265	252	**255.7±8.1**
Site III	120	100	85	**101.7±17.6**	85	76	79	**80.0±4.6**	76	91	104	**90.3±14.0**	140	120	152	**137.3±16.2**
Site IV	135	125	119	**126.3±8.1**	88	78	89	**85.0±6.1**	72	105	141	**106.0±34.5**	137	164	155	**152.0±13.7**
Site V	165	144	71	**126.7±49.3**	92	130	147	**123.0±28.2**	173	151	222	**182.0±36.3**	189	230	237	**218.7±25.9**
Site VI	198	185	210	**197.7±12.5**	184	181	193	**186.0±6.2**	220	237	251	**236.0±15.5**	280	295	251	**275.3±22.4**
Site VII	191	153	135	**159.7±28.6**	100	125	134	**119.7±17.6**	180	150	235	**188.3±43.1**	197	203	168	**189.3±18.7**
Site VIII	175	170	126	**157.0±27.0**	111	137	141	**129.7±16.3**	174	137	220	**177.0±41.6**	194	230	201	**208.3±19.1**
Site IX	205	160	137	**167.3±34.6**	144	130	153	**142.3±11.6**	180	157	231	**189.3±37.9**	211	223	225	**219.7±7.6**

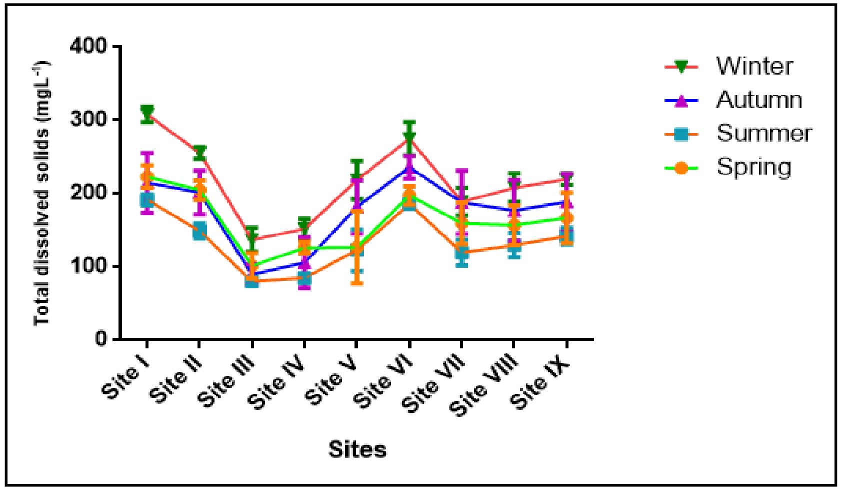


Fig. 5.1.12. Seasonal fluctuations (mean±SD) in total dissolved solids (mg/L) recorded in Wular lake from Mar. 2012 to Feb. 2013

Table 5.1.13. Monthly fluctuations (with seasonal mean±SD) in free carbon dioxide (mg/L) of Wular lake from Mar. 2011 to Feb. 2012

	Mar	**Apr**	**May**	**Mean±SD**	**Jun**	**Jul**	**Aug**	**Mean±SD**	**Sep**	**Oct**	**Nov**	**Mean±SD**	**Dec**	**Jan**	**Feb**	**Mean±SD**
Site I	21	17	12	**16.7**±4.5	11	10	8	**9.7**±1.5	9	18	21	**16.0**±6.2	26	22	19	**22.3**±3.5
Site II	18	16	11	**15**±3.6	10	12	11	**11.0**±1.0	10	15	20	**15.0**±5.0	24	21	18	**21.0**±3.0
Site III	13	13	8	**11.3**±2.9	7	6	6	**6.3**±0.6	7	12	15	**11.3**±4.0	18	17	13	**16.0**±2.6
Site IV	12	11	8	**10.3**±2.1	6	6	5	**5.7**±0.6	7	10	12	**9.7**±2.5	15	14	12	**13.7**±1.5
Site V	14	15	9	**12.7**±3.2	7	6	7	**6.7**±0.6	8	14	18	**13.3**±5.0	21	19	15	**18.3**±3.1
Site VI	22	19	14	**18.3**±4.0	13	11	10	**11.3**±1.5	12	20	23	**18.3**±5.7	28	24	21	**24.3**±3.5
Site VII	18	17	12	**15.7**±3.2	10	9	8	**9.0**±1.0	9	17	21	**15.7**±6.1	25	22	19	**22.0**±3.0
Site VIII	19	16	10	**15**±4.6	14	12	17	**14.3**±2.5	12	16	20	**16.0**±4.0	24	20	18	**20.7**±3.1
Site IX	14	12	11	**12.3**±1.5	10	8	7	**8.3**±1.5	9	19	21	**16.3**±6.4	20	17	16	**17.7**±2.1

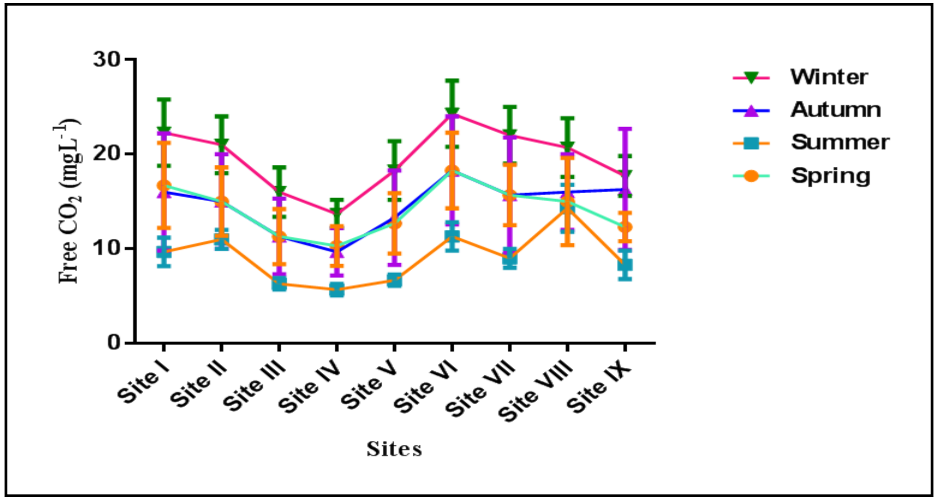


Fig. 5.1.13. Seasonal fluctuations (mean±SD) in free carbon dioxide (mg/L) recorded in Wular lake from Mar. 2011 to Feb. 2012

Table 5.1.14. Monthly fluctuations (with seasonal mean±SD) in free carbon dioxide (mg/L) of Wular lake from Mar. 2012 to Feb. 2013

	Mar	Apr	May	Mean±SD	Jun	Jul	Aug	Mean±SD	Sep	Oct	Nov	Mean±SD	Dec	Jan	Feb	Mean±SD
Site I	16.4	15.4	11.2	**14.3±2.8**	9	8.2	7.4	**8.2±0.8**	8.2	13	17.4	**12.9±4.6**	21	19.4	18.2	**19.5±1.4**
Site II	15	12.2	10.6	**12.6±2.2**	7.2	11	8.4	**8.9±1.9**	11	13.4	16	**13.5±2.5**	19.4	22.6	14.6	**18.9±4.0**
Site III	14	11	8.8	**11.3±2.6**	6.4	7.4	8.2	**7.3±0.9**	9.2	12.4	14	**11.9±2.4**	16.8	19	13	**16.3±3.0**
Site IV	9	7.8	7.2	**8.0±0.9**	6.8	8.6	7	**7.5±1.0**	8.6	11.6	13	**11.1±2.2**	15	14	12	**13.7±1.5**
Site V	13	8.9	8.4	**10.1±2.5**	6	9	7.2	**7.4±1.5**	6	9.6	10.2	**8.6±2.3**	13	10.4	11	**11.5±1.4**
Site VI	17	13	10	**13.3±3.5**	9.4	10	12	**10.5±1.4**	11	17	19	**15.7±4.2**	19.4	23	17.6	**20.0±2.7**
Site VII	11	9.9	9.3	**10.1±0.9**	8.4	5.8	6.6	**6.9±1.3**	7	10	11	**9.3±2.1**	13	11	14	**12.7±1.5**
Site VIII	16	9.5	9.2	**11.6±3.8**	8.9	8	8	**8.3±0.5**	9	12	14	**11.7±2.5**	10.8	17	12	**13.3±3.3**
Site IX	10	11.3	8.7	**10.0±1.3**	8.7	7.2	5.6	**7.2±1.6**	9.6	8.5	11.3	**9.8±1.4**	11	9.5	13.6	**11.4±2.1**

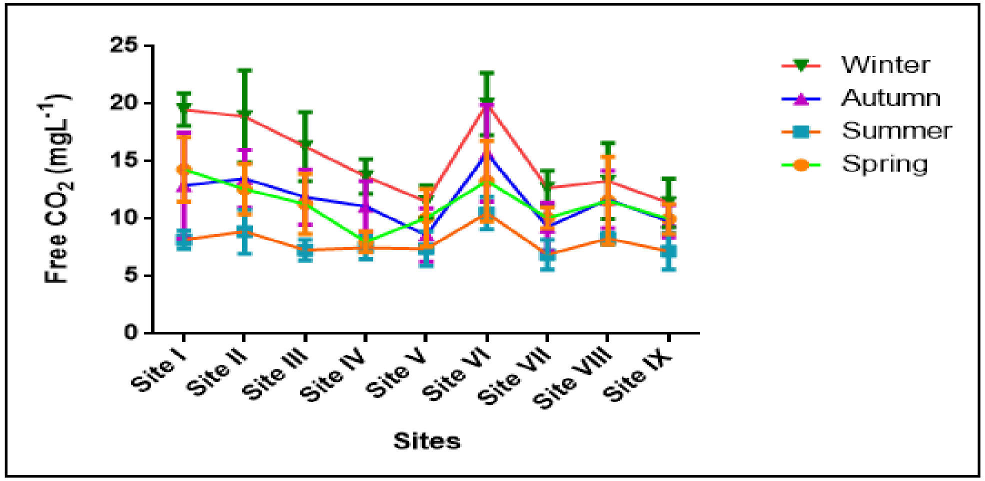


Fig. 5.1.14. Seasonal fluctuations (mean±SD) in free carbon dioxide (mg/L) recorded in Wular lake from Mar. 2012 to Feb. 2013

Table 5.1.15. Monthly fluctuations (with seasonal mean±SD) in dissolved oxygen (mg/L) of Wular lake from Mar. 2011 to Feb. 2012

	Mar	Apr	May	Mean±SD	Jun	Jul	Aug	Mean±SD	Sep	Oct	Nov	Mean±SD	Dec	Jan	Feb	Mean±SD
Site I	8	7.6	7.2	**7.6±0.4**	7.2	6.4	6.6	**6.7±0.4**	6.8	7.2	7.6	**7.2±0.4**	8	8.4	7.3	**7.9±0.6**
Site II	8.8	8.4	7.2	**8.1±0.8**	7.8	6.8	6.4	**7.0±0.7**	8.8	8.4	8.8	**8.7±0.2**	9.2	9.6	9.2	**9.3±0.2**
Site III	8.4	8	7.6	**8.0±0.4**	7.8	7.4	7	**7.4±0.4**	7.6	8	8.4	**8.0±0.4**	9.2	9.4	9.2	**9.3±0.1**
Site IV	8	7.6	7.2	**7.6±0.4**	7.2	7	6.6	**6.9±0.3**	7.2	7.6	8.2	**7.7±0.5**	8.6	9.2	9.6	**9.1±0.5**
Site V	8.8	8.8	8.2	**8.6±0.3**	8.2	7.8	7.6	**7.9±0.3**	7.6	8.4	8.8	**8.3±0.6**	8.8	9.2	8.4	**8.8±0.4**
Site VI	7.6	7.2	7.6	**7.5±0.2**	7.2	6.8	6.6	**6.9±0.3**	6.4	7.2	7.6	**7.1±0.6**	8.2	8.2	7.6	**8.0±0.3**
Site VII	9.5	8.8	7.6	**8.6±1.0**	7.4	6.8	6.6	**6.9±0.4**	7.6	8.2	8.4	**8.1±0.4**	8.6	9.2	9.4	**9.1±0.4**
Site VIII	9.2	7.6	7.6	**8.1±0.9**	7.2	7	7	**7.1±0.1**	7.6	9.2	9.6	**8.8±1.1**	9.2	9.4	9.8	**9.5±0.3**
Site IX	8	7.6	7.2	**7.6±0.4**	7.4	7	7.2	**7.2±0.2**	7.2	8.4	8.4	**8.0±0.7**	9.2	9.6	8.8	**9.2±0.4**

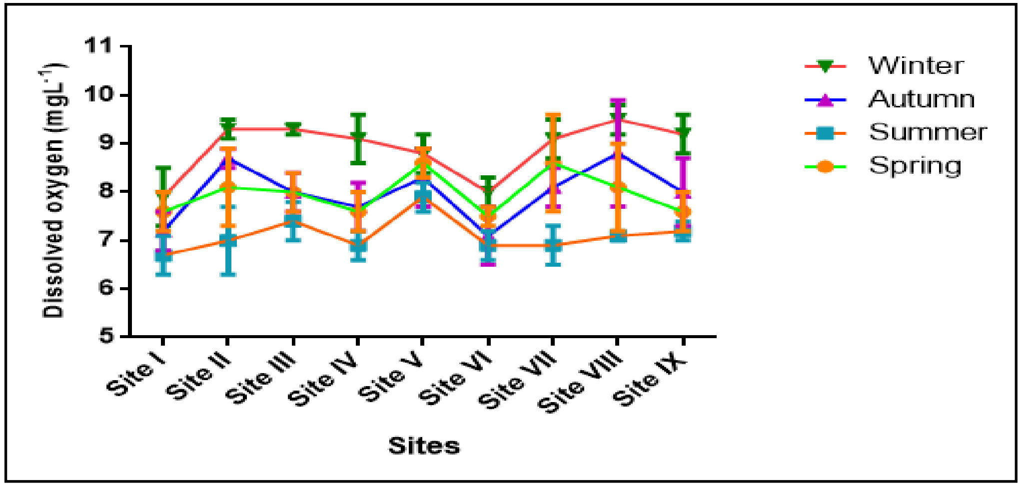


Fig. 5.1.15. Seasonal fluctuations (mean±SD) in dissolved oxygen (mg/L) recorded in Wular lake from Mar. 2011 to Feb. 2012

Table 5.1.16. Monthly fluctuations (with seasonal mean±SD) in dissolved oxygen (mg/L) of Wular lake from Mar. 2012 to Feb. 2013

	Mar	Apr	May	Mean±SD	Jun	Jul	Aug	Mean±SD	Sep	Oct	Nov	Mean±SD	Dec	Jan	Feb	Mean±SD
Site I	7.6	8.2	7.4	**7.7±0.4**	6.8	7	7.2	**7.0±0.2**	7.6	8	7.8	**7.8±0.2**	8.2	8.6	7.6	**8.1±0.5**
Site II	9	8.2	7.4	**8.2±0.8**	8.2	7.2	6.8	**7.4±0.7**	8.4	8.8	8.2	**8.5±0.3**	8.8	9.2	8.6	**8.9±0.3**
Site III	8	8.6	7.8	**8.1±0.4**	7.2	7.8	7.4	**7.5±0.3**	8	8.6	7.8	**8.1±0.4**	8.8	9	8.8	**8.9±0.1**
Site IV	8.4	7.8	8	**8.1±0.3**	7.6	7.4	7	**7.3±0.3**	7.6	7.8	8.4	**7.9±0.4**	9.2	8.6	8.2	**8.7±0.5**
Site V	9.4	9.2	9	**9.2±0.2**	8.4	7.3	7.5	**7.7±0.6**	7.9	8.2	8.8	**8.3±0.5**	9.2	8.8	9.6	**9.2±0.4**
Site VI	7	7.4	7.8	**7.4±0.4**	7.2	6.6	7	**6.9±0.3**	7.4	8	8.4	**7.9±0.5**	8.8	8.6	9	**8.8±0.2**
Site VII	9.8	8.7	9.8	**9.4±0.6**	8	7.6	7.3	**7.6±0.4**	7.6	8.3	9.6	**8.5±1.0**	9.4	9.8	9.6	**9.6±0.2**
Site VIII	8.9	8.6	8.3	**8.6±0.3**	8.1	7.9	8.2	**8.1±0.2**	8	8.8	11	**9.3±1.6**	9.7	9	9.8	**9.5±0.4**
Site IX	8.6	8	8.7	**8.4±0.4**	8.3	8.1	7	**7.8±0.7**	8.1	9.2	8.8	**8.7±0.6**	7.8	8.6	9	**8.5±0.6**

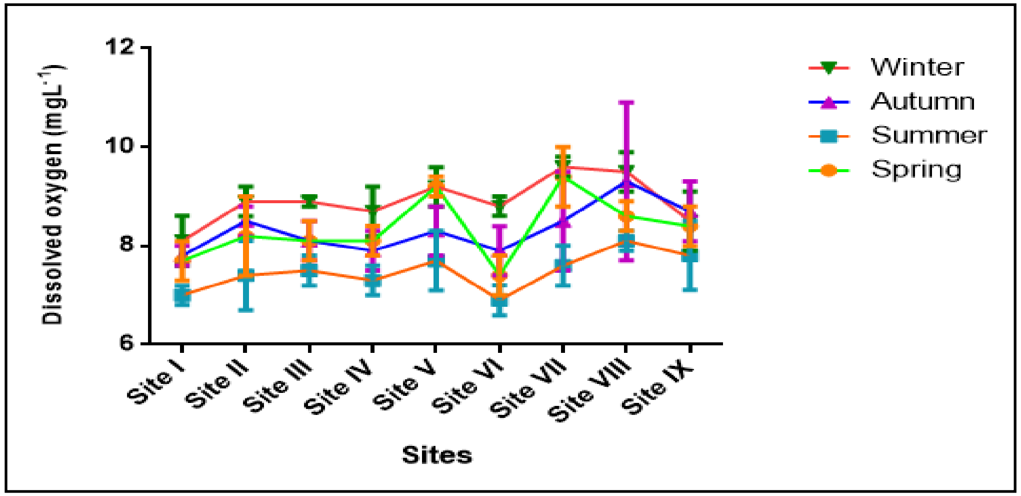


Fig. 5.1.16. Seasonal fluctuations (mean±SD) in dissolved oxygen (mg/L) recorded inWular lake from Mar. 2012 to Feb. 2013

Table 5.1.17. Monthly fluctuations (with seasonal mean±SD) in pH of Wular lake from Mar. 2011 to Feb. 2012

	Mar	Apr	May	Mean±SD	Jun	Jul	Aug	Mean±SD	Sep	Oct	Nov	Mean±SD	Dec	Jan	Feb	Mean±SD
Site I	7.8	8	8.1	**8.0±0.1**	7.8	8.0	8	**7.9±0.1**	8.1	7.4	7.3	**7.6±0.4**	7.2	7.4	7.6	**7.4±0.2**
Site II	7.4	7.8	8.1	**7.8±0.4**	8	8.0	7.9	**8.0±0.0**	8	7.8	7.4	**7.7±0.3**	7.2	7.4	7.8	**7.5±0.3**
Site III	8	8.1	8.2	**8.1±0.1**	8.3	8.2	8.3	**8.3±0.1**	8.3	7.9	7.7	**8.0±0.3**	7.6	7.5	7.3	**7.5±0.2**
Site IV	8.1	8.2	8.2	**8.2±0.1**	8.3	8.2	8.4	**8.3±0.1**	8.2	7.9	7.8	**8.0±0.2**	7.5	7.6	7.7	**7.6±0.1**
Site V	7.7	7.6	7.9	**7.7±0.2**	8.1	8.2	8.4	**8.2±0.1**	8.2	7.9	7.7	**7.9±0.2**	7.3	7.5	7.8	**7.5±0.3**
Site VI	7.7	7.8	7.9	**7.8±0.1**	7.6	7.9	8	**7.8±0.2**	8.1	7.6	7.5	**7.7±0.3**	7.1	7.6	7.7	**7.5±0.3**
Site VII	7.6	7.7	8	**7.8±0.2**	8.5	8.2	8.3	**8.1±0.2**	8.3	7.7	7.4	**7.8±0.5**	7.3	7.4	7.7	**7.5±0.2**
Site VIII	7.6	7.8	8.1	**7.8±0.3**	8	8.2	7.8	**8.0±0.2**	8.1	7.5	7.4	**7.7±0.4**	7.2	7.3	7.3	**7.3±0.0**
Site IX	7.8	7.9	7.9	**7.8±0.1**	8.	7.9	8	**8.0±0.0**	8	7.5	7.4	**7.6±0.3**	7.4	7.6	7.7	**7.6±0.2**

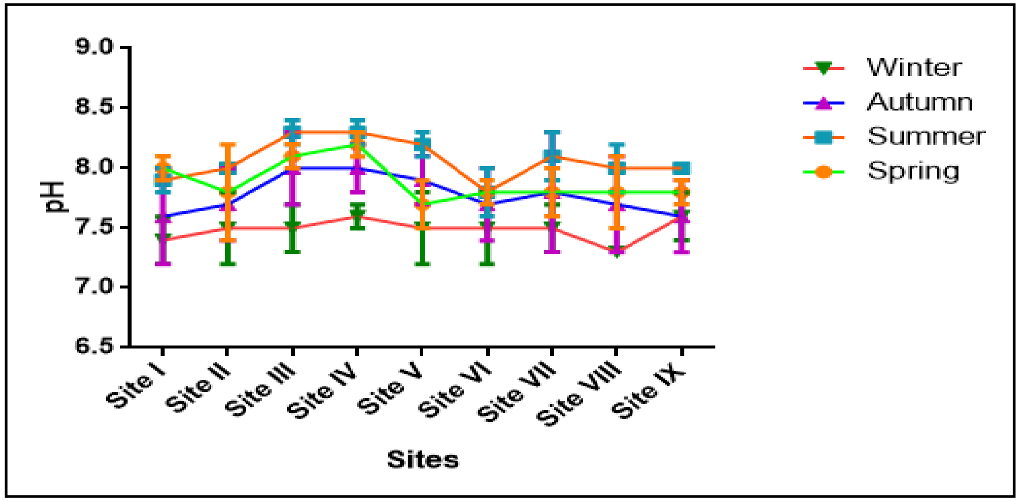


Fig. 5.1.17. Seasonal fluctuations (mean±SD) in pH recorded in Wular lake from Mar. 2011 to Feb. 2012

Table 5.1.18. Monthly fluctuations (with seasonal mean±SD) in pH of Wular lake from Mar. 2012 to Feb. 2013

	Mar	Apr	May	Mean±SD	Jun	Jul	Aug	Mean±SD	Sep	Oct	Nov	Mean±SD	Dec	Jan	Feb	Mean±SD
Site I	7.4	7.6	7.8	**7.6±0.2**	7.9	8.3	8.1	**8.1±0.2**	7.7	8.1	8.2	**8.0±0.3**	7.1	7.2	7.1	**7.1±0.1**
Site II	8.2	7.2	7.8	**7.7±0.5**	8	7.8	7.6	**7.8±0.2**	7.8	7.3	7.2	**7.4±0.3**	7.6	7.3	7.4	**7.4±0.2**
Site III	8.4	7.4	8	**7.9±0.5**	8.3	7.9	7.7	**8.0±0.3**	8.1	7.6	7.4	**7.7±0.4**	7.8	7.5	7.4	**7.6±0.2**
Site IV	7.9	8	7.8	**7.9±0.1**	8.3	8.2	8	**8.2±0.2**	7.7	7.5	7.6	**7.6±0.1**	7.3	7.2	7.5	**7.3±0.2**
Site V	8.3	7.3	8.1	**7.9±0.5**	7.5	8	7.5	**7.7±0.3**	8	7.5	7.6	**7.7±0.3**	7.7	7.35	8.5	**7.9±0.6**
Site VI	7.8	7.6	7.4	**7.6±0.2**	7.7	8.1	7.9	**7.9±0.2**	7.5	7.8	7.3	**7.5±0.3**	7.6	7.2	7.3	**7.4±0.2**
Site VII	7.2	7.6	7.8	**7.5±0.3**	7.8	8.1	7.8	**7.9±0.2**	7.8	7.5	8.1	**7.8±0.3**	7.6	7.33	8.7	**7.9±0.7**
Site VIII	7.8	7.2	8.2	**7.7±0.5**	8.1	7.6	7.9	**7.9±0.3**	7.8	7.6	7.7	**7.7±0.1**	7.5	7.5	7.36	**7.5±0.1**
Site IX	7.2	7.4	7.6	**7.4±0.2**	7.7	8.4	7.5	**7.9±0.5**	7.9	7.9	8.2	**8.0±0.2**	7.8	7.43	7.6	**7.6±0.2**

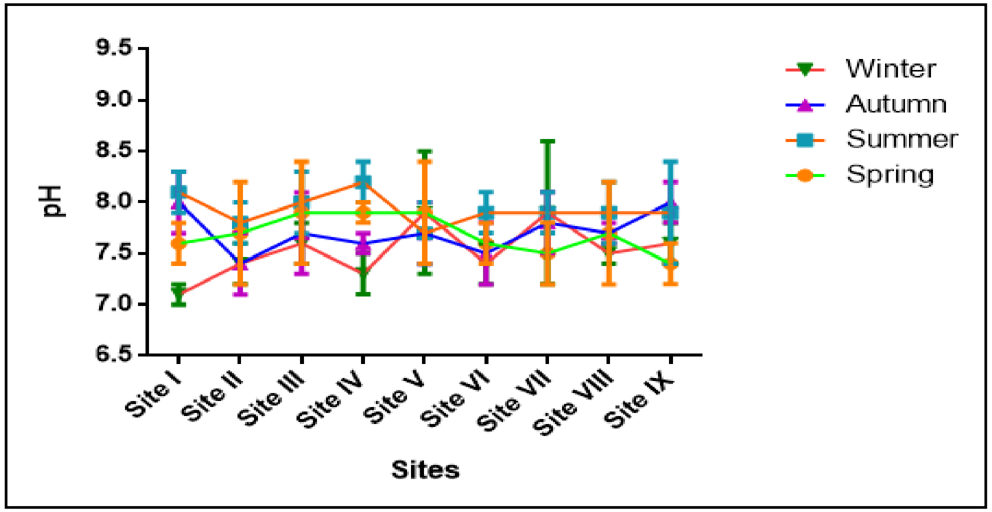


Fig. 5.1.18. Seasonal fluctuations (mean±SD) in pH recorded in Wular lake from Mar. 2012 to Feb. 2013

Table 5.1.19. Monthly fluctuations (with seasonal mean±SD) in chloride (mg/L) of Wular lake from Mar. 2011 to Feb. 2012

	Mar	Apr	May	Mean±SD	Jun	Jul	Aug	Mean±SD	Sep	Oct	Nov	Mean±SD	Dec	Jan	Feb	Mean±SD
Site I	16	18	14	**16.0±2.0**	11	13	14	**12.7±1.5**	9	13	13	**11.7±2.3**	8	7	11	**8.7±2.1**
Site II	20	22	17	**19.7±2.5**	12	14	21	**15.7±4.7**	10	15	15	**13.3±2.9**	10	9	12	**10.3±1.5**
Site III	21	14	19	**18.0±3.6**	9	10	19	**12.7±5.5**	8	8	10	**8.7±1.2**	6	7	9	**7.3±1.5**
Site IV	15	16	13	**14.7±1.5**	12	19	12	**14.3±4.0**	10	12	13	**11.7±1.5**	8	10	8	**8.7±1.2**
Site V	20	28	17	**21.7±5.7**	13	13	21	**15.7±4.6**	11	14	12	**12.3±1.5**	9	9	12	**10±1.7**
Site VI	22	24	19	**21.7±2.5**	14	17	20	**17.0±3.0**	12	17	17	**15.3±2.9**	11	11	15	**12.3±2.3**
Site VII	20	21	20	**20.3±0.6**	11	11	18	**13.3±4.0**	8	12	12	**10.7±2.3**	7	9	7	**7.7±1.2**
Site VIII	17	19	18	**18.0±1.0**	12	12	10	**11.3±1.2**	10	14	13	**12.3±2.1**	9	11	9	**9.7±1.2**
Site IX	18	26	24	**22.7±4.2**	17	16	18	**17.0±1.0**	13	15	15	**14.3±1.2**	12	11	13	**12±1.0**

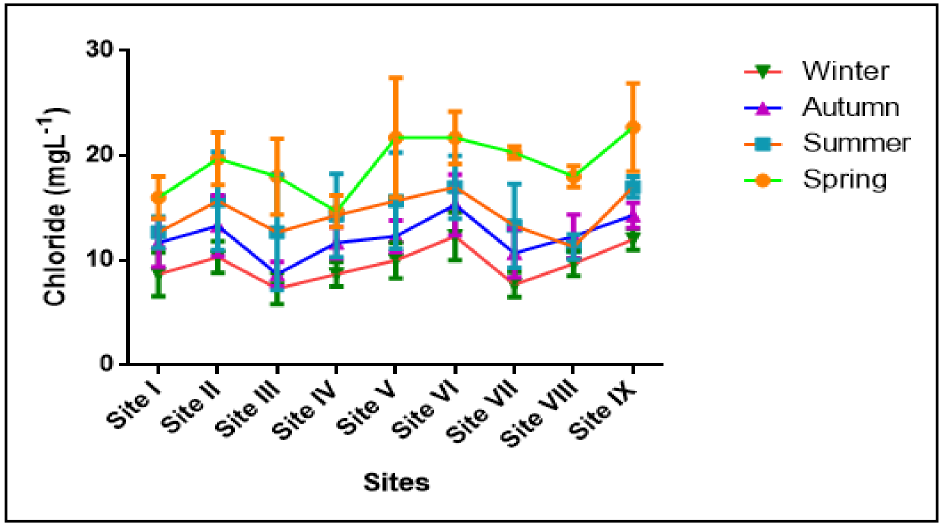


Fig. 5.1.19. Seasonal fluctuations (mean±SD) in chloride (mg/L) recorded in Wular lake from Mar. 2011 to Feb. 2012

Table 5.1.20. Monthly fluctuations (with seasonal mean±SD) in chloride (mg/L) of Wular lake from Mar. 2012 to Feb. 2013

	Mar	Apr	May	Mean±SD	Jun	Jul	Aug	Mean±SD	Sep	Oct	Nov	Mean±SD	Dec	Jan	Feb	Mean±SD
Site I	12	15	11	**12.7±2.1**	10	12	15	**12.3±2.5**	12	9	8	**9.7±2.1**	9	11	7	**9.0±2.0**
Site II	19	17	20	**18.7±1.5**	17	12	16	**15.0±2.6**	12	11	13	**12.0±1.0**	11	12	14	**12.3±1.5**
Site III	17	12	15	**14.7±2.5**	8	12	15	**11.7±3.5**	9	8	12	**9.7±2.1**	7	10	6	**7.7±2.1**
Site IV	12	18	13	**14.3±3.2**	10	13	17	**13.3±3.5**	11	9	11	**10.3±1.2**	9	7	6	**7.3±1.5**
Site V	17.5	23	19.8	**20.1±2.8**	12	15.5	18.3	**15.3±3.2**	8.1	10	8.8	**9.0±1.0**	8	7.8	7	**7.6±0.5**
Site VI	19	21	17	**19.0±2.0**	12	14	17	**14.3±2.5**	13	15	11	**13.0±2.0**	9	7	13	**9.7±3.1**
Site VII	13.3	21.5	15	**16.6±4.3**	11	8	14.2	**11.1±3.1**	7	13	10	**10.0±3.0**	10.2	9.6	9.3	**9.7±0.5**
Site VIII	18.5	26.5	18	**21.0±4.8**	12.7	10	9	**10.6±1.9**	10.2	12	10	**10.7±1.1**	12.3	8.7	7.9	**9.6±2.3**
Site IX	17.5	25.5	15	**19.3±5.5**	12.5	14.5	16.4	**14.5±2.0**	10	9	12	**10.3±1.5**	11	10	12	**11.0±1.0**

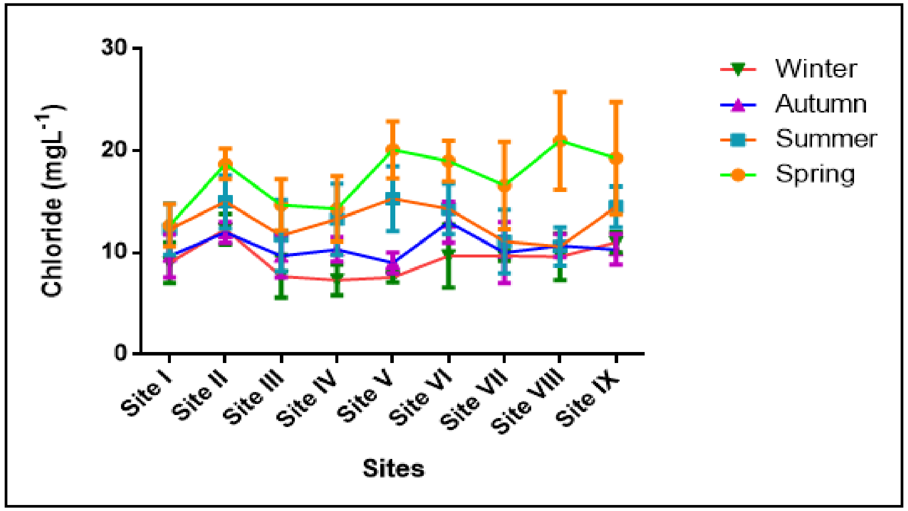


Fig. 5.1.20. Seasonal fluctuations (mean±SD) in chloride (mg/L) recorded in Wular lake from Mar. 2012 to Feb. 2013

Table 5.1.21. Monthly fluctuations (with seasonal mean±SD) in total hardness (mg/L) of Wular lake from Mar. 2011 to Feb. 2012

	Mar	Apr	May	Mean±SD	Jun	Jul	Aug	Mean±SD	Sep	Oct	Nov	Mean±SD	Dec	Jan	Feb	Mean±SD
Site I	220	200	190	**203.3±15.3**	180	170	195	**181.7±12.6**	170	230	240	**213.3±37.9**	265	275	290	**276.7±12.6**
Site II	205	180	170	**185.0±18.0**	155	140	162	**152.3±11.2**	150	210	225	**195.0±39.7**	240	265	270	**258.3±16.1**
Site III	95	80	70	**81.7±12.6**	70	60	55	**61.7±7.6**	55	85	95	**78.3±20.8**	110	115	125	**116.7±7.6**
Site IV	110	95	80	**95.0±15.0**	75	65	60	**66.7±7.6**	55	90	105	**83.3±25.7**	115	130	135	**126.7±10.4**
Site V	125	110	95	**110.0±15.0**	85	70	65	**73.3±10.4**	60	110	120	**96.7±32.1**	130	145	150	**141.7±10.4**
Site VI	210	190	185	**195.0±13.2**	170	160	150	**160.0±10.0**	150	225	245	**206.7±50.1**	255	270	280	**268.3±12.6**
Site VII	160	140	135	**145.0±13.2**	120	110	95	**108.3±12.6**	85	150	155	**130.0±39.1**	170	190	180	**180.0±10.0**
Site VIII	170	165	150	**161.7±10.4**	140	120	100	**120.0±20.0**	130	140	170	**146.7±20.8**	185	210	205	**200.0±13.2**
Site IX	195	180	165	**180.0±15.0**	140	125	100	**121.7±20.2**	90	160	180	**143.3±47.3**	200	225	235	**220.0±18.0**

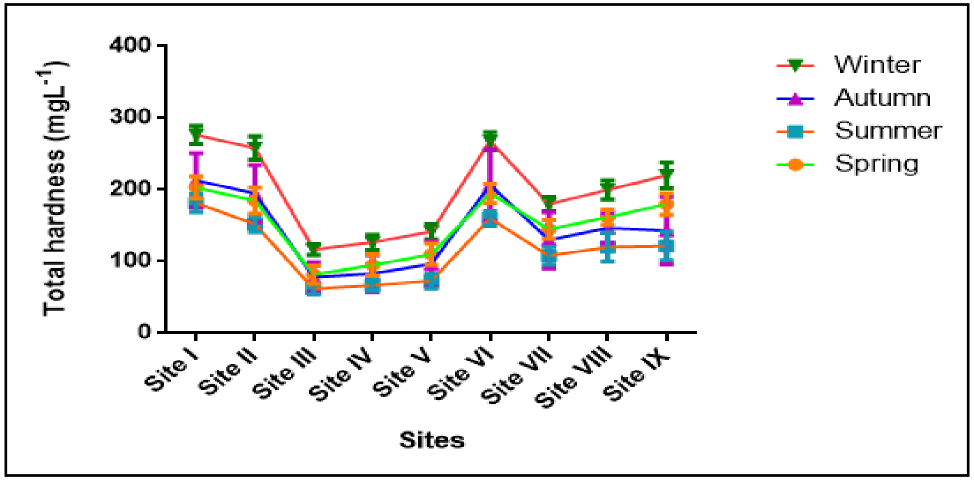


Fig. 5.1.21. Seasonal fluctuations (mean±SD) in total hardness (mg/L) recorded in Wular lake from Mar. 2011 to Feb. 2012

Table 5.1.22. Monthly fluctuations (with seasonal mean±SD) in total hardness (mg/L) of Wular lake from Mar. 2012 to Feb. 2013

	Mar	Apr	May	Mean±SD	Jun	Jul	Aug	Mean±SD	Sep	Oct	Nov	Mean±SD	Dec	Jan	Feb	Mean±SD
Site I	180	165	140	**161.7±20.2**	120	110	140	**123.3±15.3**	155	190	210	**185.0±27.8**	235	250	270	**251.7±17.6**
Site II	195	175	145	**171.7±25.2**	125	105	125	**118.3±11.5**	140	180	195	**171.7±28.4**	215	260	280	**251.7±33.3**
Site III	80	65	60	**68.3±10.4**	70	75	90	**78.3±10.4**	105	120	100	**108.3±10.4**	120	110	115	**115.0±5.0**
Site IV	100	80	70	**83.3±15.3**	60	80	105	**81.7±22.5**	100	110	125	**111.7±12.6**	120	125	130	**125.0±5.0**
Site V	115	105	80	**100.0±18.0**	65	60	85	**70.0±13.2**	120	140	130	**130.0±10.0**	115	130	145	**130.0±15.0**
Site VI	200	160	150	**170.0±26.5**	135	120	175	**143.3±28.4**	180	230	220	**210.0±26.5**	140	220	255	**205.0±58.9**
Site VII	145	120	110	**125.0±18.0**	90	95	115	**100.0±13.2**	140	145	135	**140.0±5.0**	155	170	160	**161.7±7.6**
Site VIII	150	130	115	**131.7±17.6**	105	90	125	**106.7±17.6**	155	150	155	**153.3±2.9**	170	190	210	**190.0±20.0**
Site IX	180	145	120	**148.3±30.1**	110	100	140	**116.7±20.8**	160	145	165	**156.7±10.4**	185	210	220	**205.0±18.0**

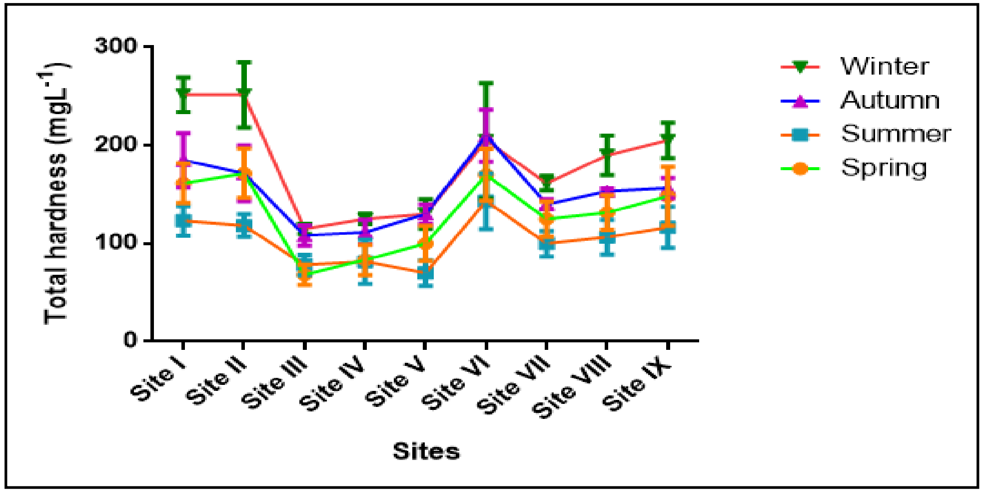


Fig. 5.1.22. Seasonal fluctuations (mean±SD) in total hardness (mg/L) recorded in Wular lake from Mar. 2012 to Feb. 2013

Table 5.1.23. Monthly fluctuations (with seasonal mean±SD) in calcium content (mg/L) of Wular lake from Mar. 2011 to Feb. 2012

	Mar	Apr	May	Mean±SD	Jun	Jul	Aug	Mean±SD	Sep	Oct	Nov	Mean±SD	Dec	Jan	Feb	Mean±SD
Site I	96.6	92.4	86.1	**91.7±5.3**	84	79.8	86.1	**83.3±3.2**	99	101	102.9	**100.8±2.1**	105	107	107	**106.4±1.2**
Site II	92.4	88.2	86.1	**88.9±3.2**	81.9	77.7	81.9	**80.5±2.4**	84	86.1	88.2	**86.1±2.1**	90.3	94.5	96.6	**93.8±3.2**
Site III	48.3	44.1	42	**44.8±3.2**	39.9	37.6	37.8	**38.5±1.3**	40	46.2	48.3	**44.8±4.4**	50.4	50.4	52.5	**51.1±1.2**
Site IV	52.5	48.3	44.1	**48.3±4.2**	42	39.9	39.9	**40.6±1.2**	42	44.1	46.1	**44.1±2.1**	50.4	48.3	50.4	**49.7±1.2**
Site V	56.7	52.7	44.1	**51.2±6.4**	48.3	44.1	42	**44.8±3.2**	44	48.3	52.7	**48.5±4.2**	56.7	60.9	60.9	**59.5±2.4**
Site VI	94.5	92.4	88.2	**91.7±3.2**	84	88.2	92.4	**88.2±4.2**	95	94.5	96.6	**95.2±1.2**	94.5	98.7	98.7	**97.3±2.4**
Site VII	63	60.9	56.7	**60.2±3.2**	52.5	52.5	48.3	**51.1±2.4**	53	56.7	58.8	**56.0±3.2**	60.9	63	65.1	**63.0±2.1**
Site VIII	73.5	71.4	67.2	**70.7±3.2**	65.1	63	60.9	**63.0±2.1**	63	65.1	67.2	**65.1±2.1**	71.4	75.6	75.6	**74.2±2.4**
Site IX	86.1	84	81.9	**84±2.1**	77.7	73.5	67.5	**72.9±5.1**	76	77.7	79.8	**77.7±2.1**	84	86.1	90.3	**86.8±3.2**

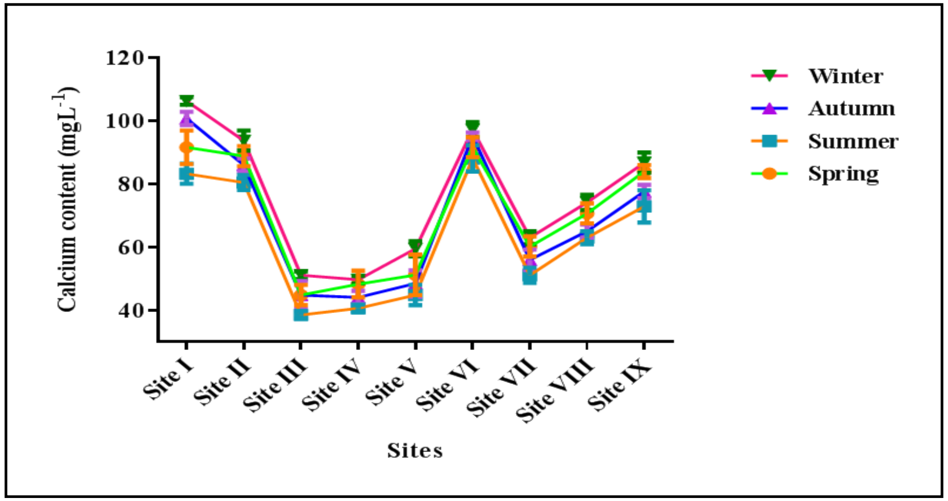


Fig. 5.1.23. Seasonal fluctuations (mean±SD) in calcium content (mg/L) recorded in Wular lake from Mar. 2011 to Feb. 2012

Table 5.1.24. Monthly fluctuations (with seasonal mean±SD) in calcium content (mg/L) of Wular lake from Mar. 2012 to Feb. 2013

	Mar	Apr	May	Mean±SD	Jun	Jul	Aug	Mean±SD	Sep	Oct	Nov	Mean±SD	Dec	Jan	Feb	Mean±SD
Site I	86.5	82.3	75.6	**81.5±5.5**	68.8	63.84	67.2	**66.6±2.5**	77.2	80.64	91.56	**83.1±7.5**	100.8	95.76	84	**93.5±8.6**
Site II	82.32	72.24	73.92	**76.2±5.4**	67.2	62.16	65.52	**65.0±2.6**	87.36	82.32	77.2	**82.3±5.1**	95.8	90.3	86.5	**90.9±4.7**
Site III	43.68	47	40.32	**43.7±3.3**	34.44	38.6	46.1	**39.7±5.9**	48.3	44.4	40.32	**44.3±4.0**	48.3	56.7	50.4	**51.8±4.4**
Site IV	39.9	42	46.1	**42.7±3.2**	33.6	30.24	39.9	**34.6±4.9**	38.6	39.9	40.32	**39.6±0.9**	47	50.4	43.68	**47.0±3.4**
Site V	44.1	48.3	42	**44.8±3.2**	33.6	31.92	43.68	**36.4±6.4**	42	45.36	48.3	**45.2±3.2**	58.8	67.2	57.12	**61.0±5.4**
Site VI	91.6	87.36	75.6	**84.9±8.3**	68.8	77.2	97.44	**81.1±14.7**	91.6	100.8	84	**92.1±8.4**	52.7	95.8	90.3	**79.6±23.5**
Site VII	67.2	63.8	62.16	**64.4±2.6**	56.7	50.4	45.36	**50.8±5.7**	50.4	47	52.7	**50.0±2.9**	56.7	62.16	67.2	**62.0±5.3**
Site VIII	74.7	70.56	63.84	**69.7±5.5**	58.8	56.28	59.64	**58.2±1.7**	67.2	65.52	62.16	**65.0±2.6**	75.6	77.28	80.64	**77.8±2.6**
Site IX	77.2	82.32	77.2	**78.9±3.0**	67.5	62.16	65.52	**65.1±2.7**	63.84	57.12	67.2	**62.7±5.1**	75.6	72.24	78.12	**75.3±2.9**

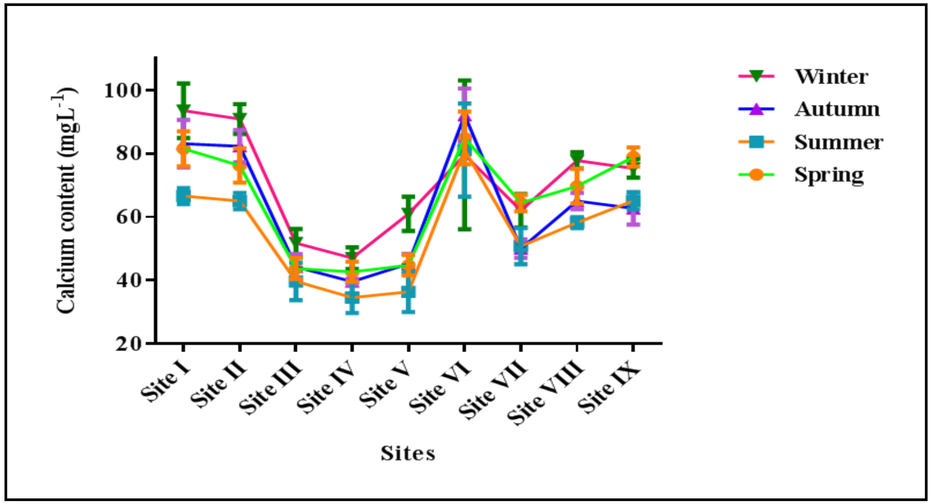


Fig. 5.1.24. Seasonal fluctuations (mean±SD) in calcium content (mg/L) recorded in Wular lake from Mar. 2012 to Feb. 2013

Table 5.1.25. Monthly fluctuations (with seasonal mean±SD) in magnesium content (mg/L) of Wular lake from Mar. 2011 to Feb. 2012

	Mar	Apr	May	Mean±SD	Jun	Jul	Aug	Mean±SD	Sep	Oct	Nov	Mean±SD	Dec	Jan	Feb	Mean±SD
Site I	29.9	25.6	25.2	**26.9±2.6**	23.3	21.9	23.3	**22.8±0.8**	32	34.1	39.14	**35.2±3.6**	41.1	43.2	44.9	**43.1±1.9**
Site II	27.3	22.7	20.3	**23.4±3.6**	17.5	14.4	19.4	**17.1±2.5**	26	30.1	33.2	**29.7±3.8**	36.8	41.4	42.1	**40.1±2.9**
Site III	11.3	8.9	7.04	**9.1±2.1**	7.3	5.8	4.6	**5.9±1.4**	6.3	9.1	11.3	**8.9±2.5**	13.5	15.6	16.8	**15.3±1.7**
Site IV	13.9	11.1	9.4	**11.5±2.3**	8.2	6.8	4.8	**6.6±1.7**	7.7	11.1	14.3	**11.0±3.3**	15.6	19.3	20.5	**18.5±2.6**
Site V	16.5	13.9	12.3	**14.2±2.1**	8.9	7.2	5.5	**7.2±1.7**	5.1	14.9	16.1	**12.0±6.1**	17.8	20.4	21.6	**19.9±1.9**
Site VI	28.1	23.9	23.5	**25.2±2.5**	21.3	18.6	23.7	**21.2±2.6**	29	31.7	36.06	**32.1±3.8**	39.7	41.6	44.2	**41.8±2.3**
Site VII	24.0	19.2	19	**20.7±2.8**	16.4	13.97	11.34	**13.9±2.5**	18	21.9	23.3	**20.9±3.0**	26.9	31.3	28.4	**28.9±2.2**
Site VIII	26.3	22.7	21.3	**23.4±2.6**	16.2	13.3	9.5	**13.0±3.4**	17	20.3	24.7	**20.6±4.0**	27.8	32.6	33.8	**31.4±3.2**
Site IX	26.2	22.8	19.9	**23.0±3.2**	15.1	12.5	8.38	**12.0±3.4**	15	20.9	23.8	**19.9±4.4**	27.7	33	34.9	**31.9±3.7**

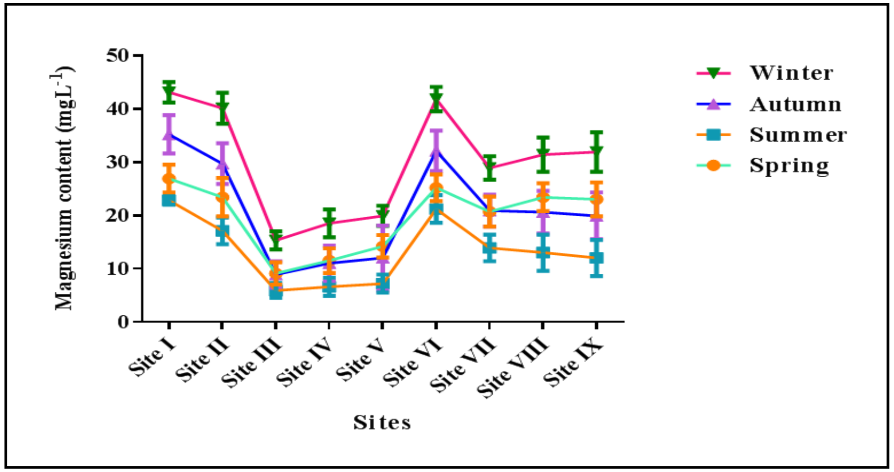


Fig. 5.1.25. Seasonal fluctuations (mean±SD) in magnesium content (mg/L) recorded in Wular lake from Mar. 2011 to Feb. 2012

Table 5.1.26. Monthly fluctuations (with seasonal mean±SD) in magnesium content (mg/L) of Wular lake from Mar. 2012 to Feb. 2013

	Mar	Apr	May	Mean±SD	Jun	Jul	Aug	Mean±SD	Sep	Oct	Nov	Mean±SD	Dec	Jan	Feb	Mean±SD
Site I	22.72	20.09	15.64	**19.5±3.6**	12.44	11.22	17.69	**13.8±3.4**	18.9	26.58	28.77	**24.8±5.2**	32.6	35.47	45.19	**37.8±6.6**
Site II	27.38	24.97	17.27	**23.2±5.3**	14.04	10.4	14.45	**13.0±2.2**	12.79	26.16	28.62	**22.5±8.5**	28.96	41.23	47.02	**39.1±9.2**
Site III	8.8	4.37	4.78	**6.0±2.4**	8.84	10.87	12.17	**10.6±1.7**	13.77	18.37	14.5	**15.5±2.5**	17.42	12.95	15.69	**15.4±2.3**
Site IV	14.6	9.23	5.8	**9.9±4.4**	6.21	10.06	14.31	**10.2±4.1**	14.92	17.03	20.57	**17.5±2.9**	17.73	18.12	20.97	**18.9±1.8**
Site V	17.22	13.77	9.23	**13.4±4.0**	7.63	6.82	10.04	**8.2±1.7**	18.95	22.99	19.85	**20.6±2.1**	13.65	15.26	21.35	**16.8±4.1**
Site VI	26.34	17.65	18.07	**20.7±4.9**	16.08	10.4	18.84	**15.1±4.3**	21.48	31.39	33.04	**28.6±6.3**	21.21	30.18	40.02	**30.5±9.4**
Site VII	18.9	13.65	11.62	**14.7±3.8**	8.09	10.83	16.92	**11.9±4.5**	21.77	23.81	19.99	**21.9±1.9**	23.88	26.2	22.55	**24.2±1.8**
Site VIII	18.29	14.44	12.43	**15.1±3.0**	11.22	8.19	15.88	**11.8±3.9**	21.33	20.52	22.56	**21.5±1.0**	22.9	27.39	31.43	**27.2±4.3**
Site IX	24.98	15.23	10.4	**16.9±7.4**	10.32	9.19	18.09	**12.5±4.8**	23.36	21.35	23.76	**22.8±1.3**	26.58	33.47	34.47	**31.5±4.3**

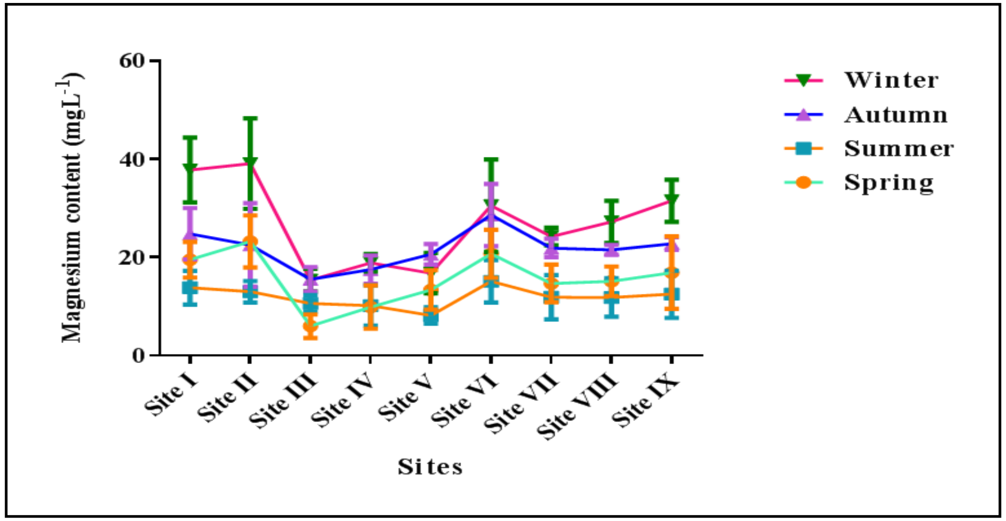


Fig. 5.1.26. Seasonal fluctuations (mean±SD) in magnesium content (mg/L) recorded in Wular lake from Mar. 2012 to Feb. 2013

Table 5.1.27. Monthly fluctuations (with seasonal mean±SD) in bicarbonate alkalinity (mg/L) of Wular lake from Mar. 2011 to Feb. 2012

	Mar	Apr	May	Mean±SD	Jun	Jul	Aug	Mean±SD	Sep	Oct	Nov	Mean±SD	Dec	Jan	Feb	Mean±SD
Site I	192	182	135	**169.7±30.4**	146	125	132	**134.3±10.7**	125	170	195	**163.3±35.5**	210	230	180	**206.7±25.2**
Site II	145	115	120	**126.7±16.1**	100	92	88	**93.3±6.1**	85	140	165	**130.0±40.9**	190	210	175	**191.7±17.6**
Site III	98	80	76	**84.7±11.7**	65	60	65	**63.3±2.9**	70	105	110	**95.0±21.8**	140	105	90	**111.7±25.7**
Site IV	105	95	90	**96.7±7.6**	85	74	82	**80.3±5.7**	80	90	95	**88.3±7.6**	90	120	125	**111.7±18.9**
Site V	110	95	84	**96.3±13.1**	80	85	75	**80.0±5.0**	70	85	110	**88.3±20.2**	140	130	165	**145.0±18.0**
Site VI	210	195	148	**184.3±32.3**	138	130	136	**134.7±4.2**	120	175	200	**165.0±40.9**	220	245	190	**218.3±27.5**
Site VII	156	130	120	**135.3±18.6**	110	95	80	**95.0±15.0**	75	90	120	**95.0±22.9**	190	182	175	**182.3±7.5**
Site VIII	165	160	110	**145±30.4**	86	74	62	**74.0±12.0**	60	120	150	**110.0±45.8**	180	170	164	**171.3±8.1**
Site IX	163	160	130	**151±18.2**	120	105	100	**108.3±10.4**	90	115	144	**116.3±27.0**	182	172	180	**178.0±5.3**

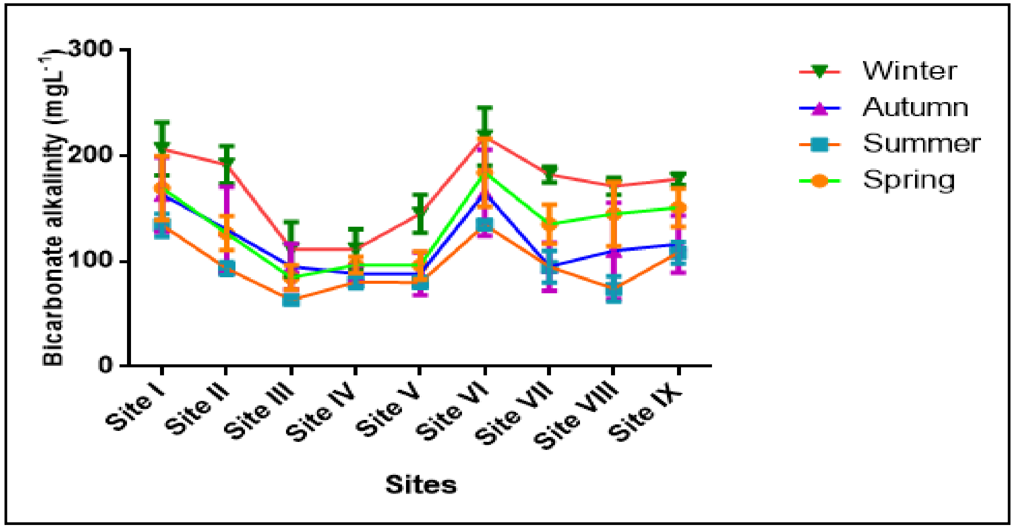


Fig. 5.1.27. Seasonal fluctuations (mean±SD) in bicarbonate alkalinity (mg/L) recorded in Wular lake from Mar. 2011 to Feb. 2012

Table 5.1.28. Monthly fluctuations (with seasonal mean±SD) in bicarbonate alkalinity (mg/L) of Wular lake from Mar. 2012 to Feb. 2013

	Mar	Apr	May	Mean±SD	Jun	Jul	Aug	Mean±SD	Sep	Oct	Nov	Mean±SD	Dec	Jan	Feb	Mean±SD
Site I	155	145	130	**143.3±12.6**	125	110	120	**118.3±7.6**	130	145	175	**150.0±22.9**	170	185	190	**181.7±10.4**
Site II	140	110	100	**116.7±20.8**	95	110	115	**106.7±10.4**	90	120	150	**120.0±30.0**	160	180	190	**176.7±15.3**
Site III	120	100	80	**100.0±20.0**	60	70	55	**61.7±7.6**	110	120	135	**121.7±12.6**	120	140	145	**135.0±13.2**
Site IV	110	90	95	**98.3±10.4**	80	65	70	**71.7±7.6**	90	75	70	**78.3±10.4**	95	105	110	**103.3±7.6**
Site V	120	80	90	**96.7±20.8**	60	75	70	**68.3±7.6**	90	80	100	**90.0±10.0**	125	140	135	**133.3±7.6**
Site VI	200	180	160	**180.0±20.0**	120	110	100	**110.0±10.0**	130	145	180	**151.7±25.7**	200	180	220	**200.0±20.0**
Site VII	160	135	110	**135.0±25.0**	115	80	90	**95.0±18.0**	80	110	100	**96.7±15.3**	140	160	180	**160.0±20.0**
Site VIII	130	120	130	**126.7±5.8**	90	80	95	**88.3±7.6**	80	100	115	**98.3±17.6**	130	155	140	**141.7±12.6**
Site IX	120	140	100	**120.0±20.0**	110	90	105	**101.7±10.4**	110	120	130	**120.0±10.0**	160	135	140	**145.0±13.2**

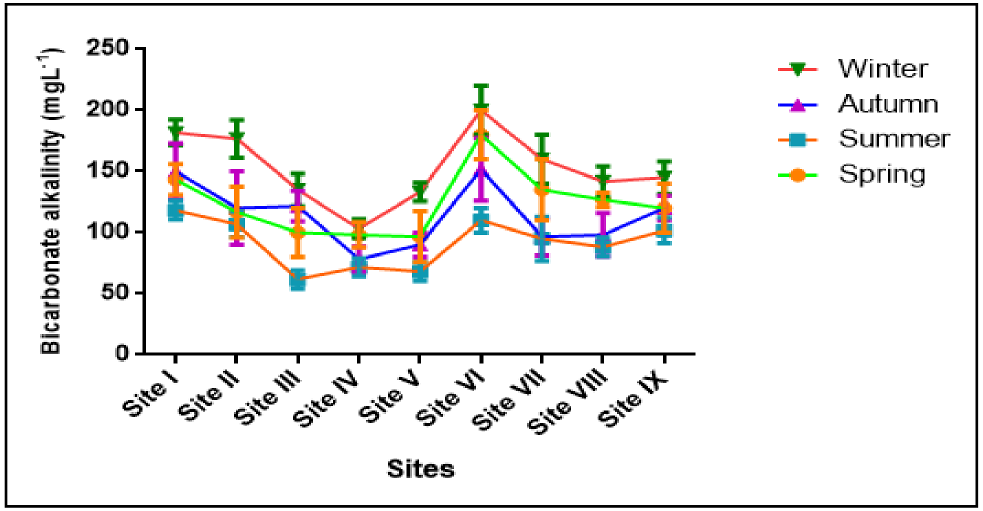


Fig. 5.1.28. Seasonal fluctuations (mean±SD) in bicarbonate alkalinity (mg/L) recorded in Wular lake from Mar. 2012 to Feb. 2013

Table 5.1.29. Monthly fluctuations (with seasonal mean±SD) in dissolved silica (mg/L) of Wular lake from Mar. 2011 to Feb. 2012

	Mar	Apr	May	Mean±SD	Jun	Jul	Aug	Mean±SD	Sep	Oct	Nov	Mean±SD	Dec	Jan	Feb	Mean±SD
Site I	13.4	15.3	14.8	**14.5±1.0**	12.9	11.5	10.4	**11.6±1.3**	9.8	9.2	8	**9.0±0.9**	7	6.8	9.3	**7.7±1.4**
Site II	12.4	14.2	13.6	**13.4±0.9**	11.3	9.6	8.4	**9.8±1.5**	7.9	7.3	6.3	**7.2±0.8**	5.1	5	7.9	**6.0±1.6**
Site III	12.8	13.7	13.3	**13.3±0.5**	11.5	9.5	8.3	**9.8±1.6**	7.9	7.4	6.4	**7.2±0.8**	5.3	5.1	8.1	**6.2±1.7**
Site IV	12	13	12.7	**12.6±0.5**	10.6	9.6	8.4	**9.5±1.1**	8	7.4	6.5	**7.3±0.8**	5.6	5.3	8	**6.3±1.5**
Site V	15	16.5	16	**15.8±0.8**	14.1	12.2	11	**12.4±1.6**	10	9.8	8.6	**9.6±0.9**	7.5	7.2	9.9	**8.2±1.5**
Site VI	13.6	15.4	14.9	**14.6±0.9**	12.7	11	9.9	**11.2±1.4**	9.5	9	7.8	**8.8±0.9**	6.7	6.4	9	**7.4±1.4**
Site VII	15.4	17.6	16.9	**16.6±1.1**	15	13.3	11.6	**13.3±1.7**	11	10.4	9.1	**10.2±1.0**	7.9	7.6	10.4	**8.6±1.5**
Site VIII	10	11.9	11.5	**11.1±1.0**	9.7	7.9	6.5	**8.0±1.6**	6.1	5.6	4.6	**5.4±0.8**	4	3.8	6.4	**4.7±1.4**
Site IX	13	14.9	14.4	**14.1±1.0**	12.4	10.5	9.3	**10.7±1.6**	8.9	8.3	7	**8.1±1.0**	6	5.9	8.4	**6.8±1.4**

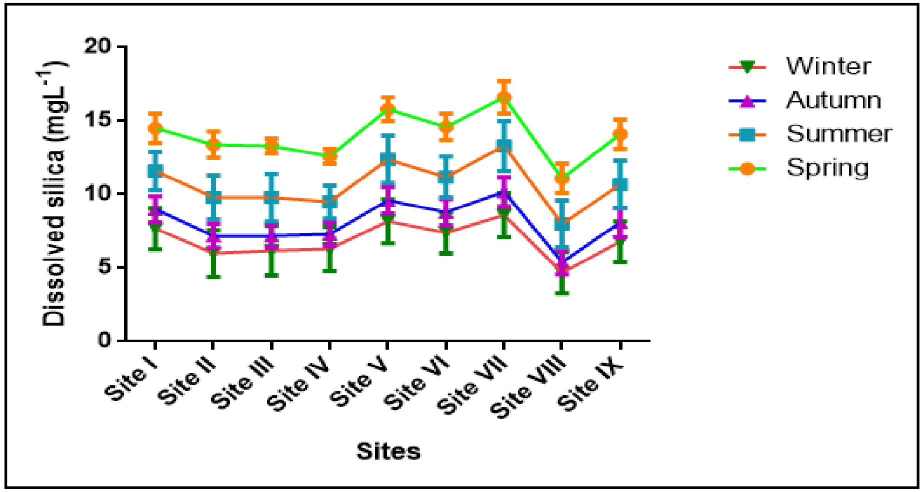


Fig. 5.1.29. Seasonal fluctuations (mean±SD) in dissolved silica (mg/L) recorded in Wular lake from Mar. 2011 to Feb. 2012

Table 5.1.30. Monthly fluctuations (with seasonal mean±SD) in dissolved silica (mg/L) of Wular lake from Mar. 2012 to Feb. 2013

	Mar	Apr	May	Mean±SD	Jun	Jul	Aug	Mean±SD	Sep	Oct	Nov	Mean±SD	Dec	Jan	Feb	Mean±SD
Site I	13.6	15.7	14.4	**14.6±1.1**	11.3	10.6	9.2	**10.4±1.1**	8.2	9	7.8	**8.3±0.6**	6.9	7.2	8.4	**7.5±0.8**
Site II	11.4	12.6	12.4	**12.1±0.6**	10.4	10.8	7.4	**9.5±1.9**	6.2	6.5	7.6	**6.8±0.7**	6.2	5.8	7.4	**6.5±0.8**
Site III	11	11.8	13.6	**12.1±1.3**	9.6	8.2	8.8	**8.9±0.7**	7.5	8.1	5.9	**7.2±1.1**	5.2	6	7.6	**6.3±1.2**
Site IV	12.4	13.2	13.2	**12.9±0.5**	11.9	12.3	7.4	**10.5±2.7**	8.3	7.8	7	**7.7±0.7**	7.2	5.8	6.8	**6.6±0.7**
Site V	13.7	14.3	15.2	**14.4±0.8**	13.8	12.8	10.4	**12.3±1.7**	11.2	8.8	8	**9.3±1.7**	7	6.7	8.3	**7.3±0.9**
Site VI	12.4	13.1	12.8	**12.8±0.4**	11.6	10.9	8.6	**10.4±1.6**	9.1	8.7	8.2	**8.7±0.5**	7.2	6.8	8.5	**7.5±0.9**
Site VII	16.2	18.4	14.9	**16.5±1.8**	16.2	12.1	10.3	**12.9±3.0**	10.6	9.3	8.5	**9.5±1.1**	7.4	7.1	9.2	**7.9±1.1**
Site VIII	11.2	12.3	10.8	**11.4±0.8**	10.4	8.2	7.6	**8.7±1.5**	7.2	6.8	5.3	**6.4±1.0**	6.2	6.7	7.2	**6.7±0.5**
Site IX	12.6	14.2	15.2	**14.0±1.3**	11.6	9.8	10.6	**10.7±0.9**	9.4	7.9	6.8	**8.0±1.3**	8.3	6.4	7.6	**7.4±1.0**

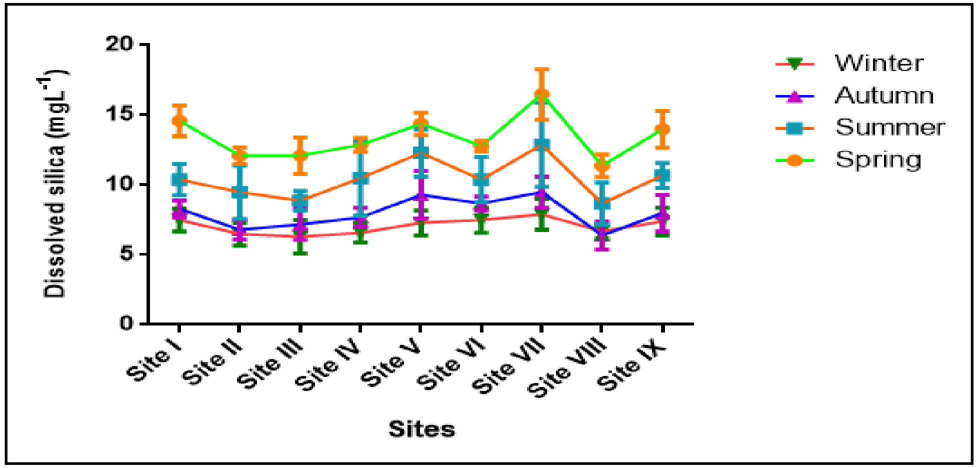


Fig. 5.1.30. Seasonal fluctuations (mean±SD) in dissolved silica (mg/L) recorded in Wular lake from Mar. 2012 to Feb. 2013

Table 5.1.31. Monthly fluctuations (with seasonal mean±SD) in orthophosphate-phosphorus (µg/L) of Wular lake from Mar. 2011 to Feb. 2012

	Mar	Apr	May	Mean±SD	Jun	Jul	Aug	Mean±SD	Sep	Oct	Nov	Mean±SD	Dec	Jan	Feb	Mean±SD
Site I	42	32	24	**32.7±9.0**	20	26	22	**22.7±3.1**	35	49	61	**48.3±13.0**	81	95	105	**93.7±12.1**
Site II	46	34	27	**35.7±9.6**	23	29	31	**27.7±4.2**	47	56	74	**59.0±13.7**	110	98	86	**98.0±12.0**
Site III	17	16	11	**14.7±3.2**	10	13	18	**13.7±4.0**	25	23	45	**31.0±12.2**	43	63	51	**52.3±10.1**
Site IV	15	13	10	**12.7±2.5**	9	15	19	**14.3±5.0**	32	24	37	**31.0±6.6**	41	58	49	**49.3±8.5**
Site V	37	36	21	**31.3±9.0**	15	19	22	**18.7±3.5**	39	27	54	**40.0±13.5**	58	65	51	**58.0±7.0**
Site VI	54	41	32	**42.3±11.1**	28	36	29	**31.0±4.4**	54	68	88	**70.0±17.1**	103	118	80	**100.3±19.1**
Site VII	30	30	19	**26.3±6.4**	16	19	29	**21.3±6.8**	35	30	48	**37.7±9.3**	58	65	55	**59.3±5.1**
Site VIII	13	11	10	**11.3±1.5**	10	12	29	**17.0±10.4**	22	39	35	**32.0±8.9**	42	30	25	**32.3±8.7**
Site IX	27	26	17	**23.3±5.5**	13	18	32	**21.0±9.8**	38	46	55	**46.3±8.5**	50	57	47	**51.3±5.1**

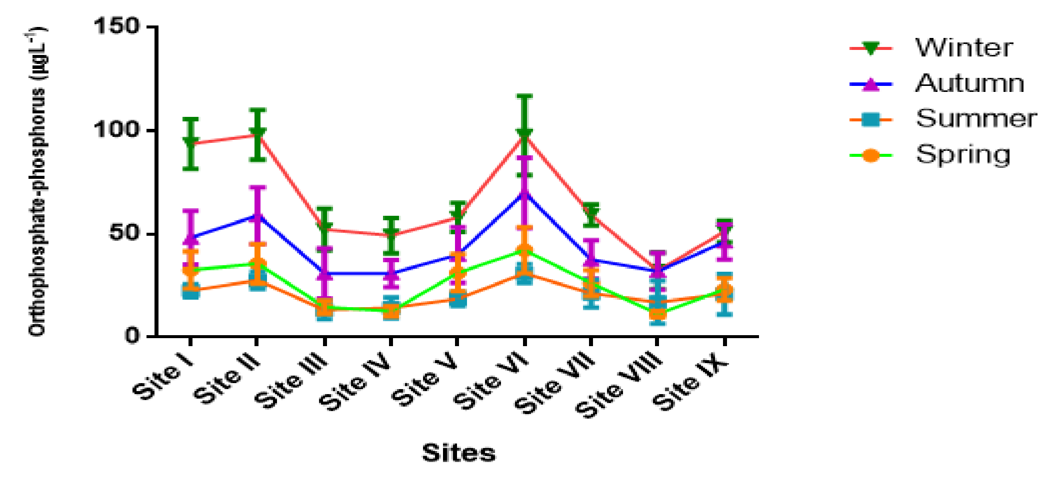


Fig. 5.1.31. Seasonal fluctuations (mean±SD) in orthophosphate-phosphorus (µg/L) recorded in Wular lake from Mar. 2011 to Feb. 2012

Table 5.1.32. Monthly fluctuations (with seasonal mean±SD) in orthophosphate-phosphorus (µg/L) of Wular lake from Mar. 2012 to Feb. 2013

	Mar	Apr	May	Mean±SD	Jun	Jul	Aug	Mean±SD	Sep	Oct	Nov	Mean±SD	Dec	Jan	Feb	Mean±SD
Site I	44	30	28	**34.0±8.7**	24	20	28	**24.0±4.0**	32	43	56	**43.7±12.0**	84	89	94	**89.0±5.0**
Site II	42	38	30	**36.7±6.1**	26	22	28	**25.3±3.1**	45	51	66	**54.0±10.8**	102	86	74	**87.3±14.0**
Site III	22	19	16	**19.0±3.0**	14	18	12	**14.7±3.1**	28	26	50	**34.7±13.3**	36	50	42	**42.7±7.0**
Site IV	20	16	14	**16.7±3.1**	14	10	16	**13.3±3.1**	24	28	34	**28.7±5.0**	38	46	42	**42.0±4.0**
Site V	47	34	22	**34.3±12.5**	17	22	17	**18.7±2.9**	27	37	53	**39.0±13.1**	41	68	53	**54.0±13.5**
Site VI	50	42	38	**43.3±6.1**	22	30	24	**25.3±4.2**	42	50	68	**53.3±13.3**	78	96	84	**86.0±9.2**
Site VII	32	31	23	**28.7±4.9**	16	20	15	**17.0±2.6**	37	32	42	**37.0±5.0**	41	64	45	**50.0±12.3**
Site VIII	22	29	19	**23.3±5.1**	15	22	16	**17.7±3.8**	29	27	40	**32.0±7.0**	52	45	37	**44.7±7.5**
Site IX	37	25	19	**27.0±9.2**	16	19	14	**16.3±2.5**	32	29	57	**39.3±15.4**	39	56	42	**45.7±9.1**

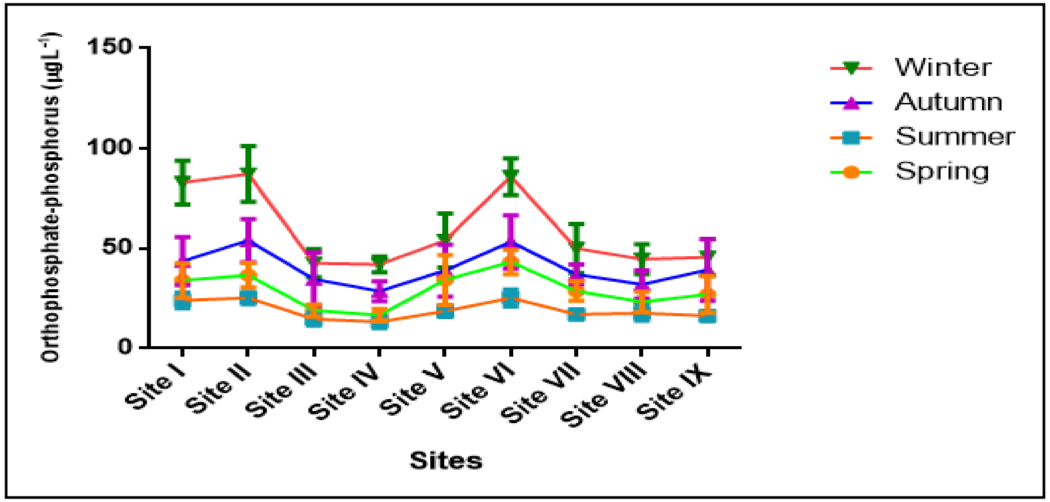


Fig. 5.1.32. Seasonal fluctuations (mean±SD) in orthophosphate-phosphorus (µg/L) recorded in Wular lake from Mar. 2012 to Feb. 2013

Table 5.1.33. Monthly fluctuations (with seasonal mean±SD) in total phosphorus (µg/L) of Wular lake from Mar. 2011 to Feb. 2012

	Mar	Apr	May	Mean±SD	Jun	Jul	Aug	Mean±SD	Sep	Oct	Nov	Mean±SD	Dec	Jan	Feb	Mean SD
Site I	205	175	192	**190.7±15.0**	155	110	150	**138.3±24.7**	185	210	290	**228.3±54.8**	305	320	325	**316.7±10.4**
Site II	195	170	205	**190.0±18.0**	150	120	155	**141.7±18.9**	170	205	275	**216.7±53.5**	295	310	315	**306.7±10.4**
Site III	155	140	145	**146.7±7.6**	135	90	110	**111.7±22.5**	135	155	230	**173.3±50.1**	255	285	290	**276.7±18.9**
Site IV	125	105	130	**120.0±13.2**	95	75	100	**90.0±13.2**	95	110	180	**128.3±45.4**	200	220	235	**218.3±17.6**
Site V	185	175	185	**181.7±5.8**	155	110	145	**136.7±23.6**	165	190	285	**213.3±63.3**	315	325	393	**344.3±42.4**
Site VI	260	205	275	**246.7±36.9**	185	130	215	**176.7±43.1**	220	250	310	**260.0±45.8**	320	341	390	**350.3±35.9**
Site VII	205	195	195	**198.3±5.8**	145	95	132	**124.0±25.9**	165	215	301	**227.0±68.8**	309	335	291	**311.7±22.1**
Site VIII	95	85	110	**96.7±12.6**	70	65	85	**73.3±10.4**	60	75	105	**80.0±22.9**	110	120	115	**115.0±5.0**
Site IX	207	155	215	**192.3±32.6**	135	95	140	**123.3±24.7**	165	195	295	**218.3±68.1**	305	335	300	**313.3±18.9**

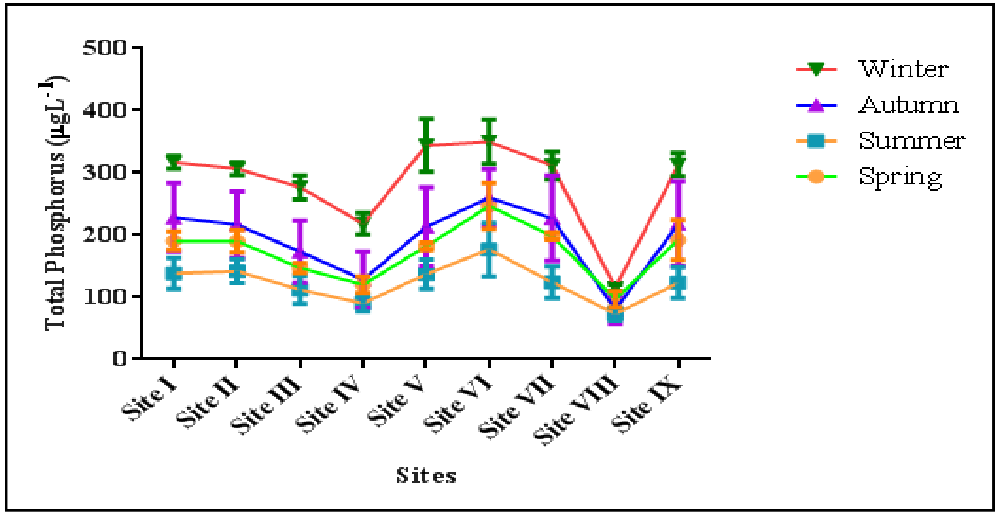


Fig. 5.1.33. Seasonal fluctuations (mean±SD) in total phosphorus (µg/L) recorded in Wular lake from Mar. 2011 to Feb. 2012

Table 5.1.34. Monthly fluctuations (with seasonal mean±SD) in total phosphorus (µg/L) of Wular lake from Mar. 2012 to Feb. 2013

	Mar	Apr	May	Mean±SD	Jun	Jul	Aug	Mean±SD	Sep	Oct	Nov	Mean±SD	Dec	Jan	Feb	Mean±SD
Site I	220	190	164	**191.3±28.0**	145	130	163	**146.0±16.5**	190	202	245	**212.3±28.9**	287	310	296	**297.7±11.6**
Site II	200	160	151	**170.3±26.1**	111	134	128	**124.3±11.9**	160	183	221	**188.0±30.8**	280	320	274	**291.3±25.0**
Site III	160	135	141	**145.3±13.1**	151	132	143	**142.0±9.5**	160	190	172	**174.0±15.1**	220	239	272	**243.7±26.3**
Site IV	110	125	133	**122.7±11.7**	90	105	83	**92.7±11.2**	100	121	163	**128.0±32.1**	210	200	239	**216.3±20.3**
Site V	175	135	166	**158.7±21.0**	130	100	120	**116.7±15.3**	150	165	220	**178.3±36.9**	300	340	283	**307.7±29.3**
Site VI	205	183	170	**186.0±17.7**	160	122	181	**154.3±29.9**	192	215	291	**232.7±51.8**	330	305	357	**330.7±26.0**
Site VII	185	136	155	**158.7±24.7**	135	130	145	**136.7±7.6**	205	163	292	**220.0±65.8**	310	320	281	**303.7±20.3**
Site VIII	203	117	173	**164.3±43.7**	133	110	145	**129.3±17.8**	200	181	231	**204.0±25.2**	257	291	267	**271.7±17.5**
Site IX	205	145	165	**171.7±30.6**	145	173	155	**157.7±14.2**	185	174	256	**205.0±44.5**	302	345	293	**313.3±27.8**

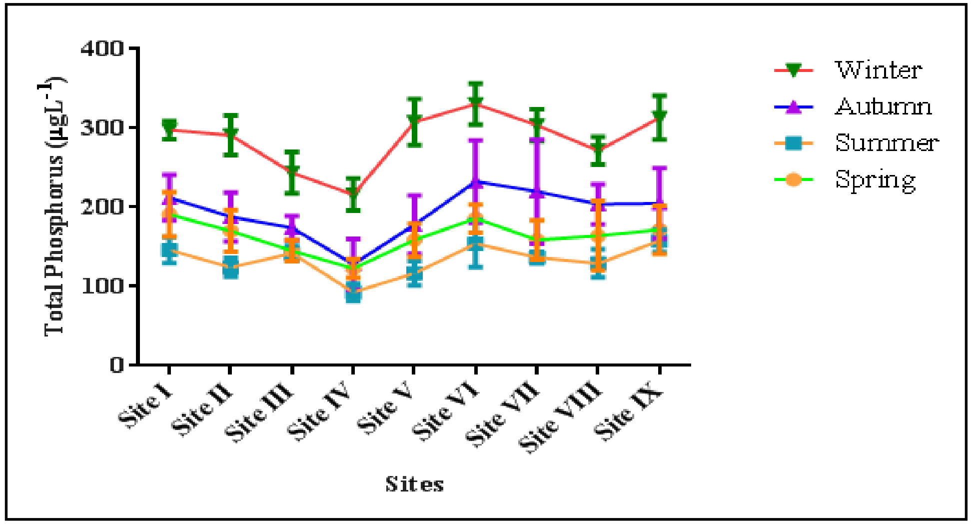


Fig. 5.1.34. Seasonal fluctuations (mean±SD) in total phosphorus (µg/L) recorded in Wular lake from Mar. 2012 to Feb. 2013

Table 5.1.35. Monthly fluctuations (with seasonal mean±SD) in ammonical-nitrogen (µg/L) of Wular lake from Mar. 2011 to Feb. 2012

	Mar	Apr	May	Mean±SD	Jun	Jul	Aug	Mean±SD	Sep	Oct	Nov	Mean±SD	Dec	Jan	Feb	Mean±SD
Site I	190	110	95	**131.7±51.1**	80	90	104	**91.3±12.1**	69	111	200	**126.7±66.9**	290	310	270	**290.0±20.0**
Site II	130	65	55	**83.3±40.7**	48	55	77	**60.0±15.1**	59	95	160	**104.7±51.2**	250	280	245	**258.3±18.9**
Site III	`120	55	42	**48.5±9.2**	52	60	85	**65.7±17.2**	55	80	145	**93.3±46.5**	220	240	215	**225.0±13.2**
Site IV	115	50	44	**69.7±39.4**	40	46	76	**54.0±19.3**	50	75	140	**88.3±46.5**	190	215	200	**201.7±12.6**
Site V	170	100	98	**122.7±41.0**	77	102	97	**92.0±13.2**	79	142	270	**163.7±97.3**	300	275	289	**288.0±12.5**
Site VI	200	120	106	**142±50.7**	90	76	91	**85.7±8.4**	79	125	180	**128.0±50.6**	240	280	260	**260.0±20.0**
Site VII	150	84	76	**103.3±40.6**	64	47	60	**57.0±8.9**	50	155	260	**155.0±105.0**	330	253	233	**272.0±51.2**
Site VIII	95	60	55	**70±21.8**	50	45	52	**49.0±3.6**	35	75	110	**73.3±37.5**	140	170	220	**176.7±40.4**
Site IX	180	95	85	**120±52.2**	75	54	69	**66.0±10.8**	55	160	310	**175.0±128.2**	330	287	225	**280.7±52.8**

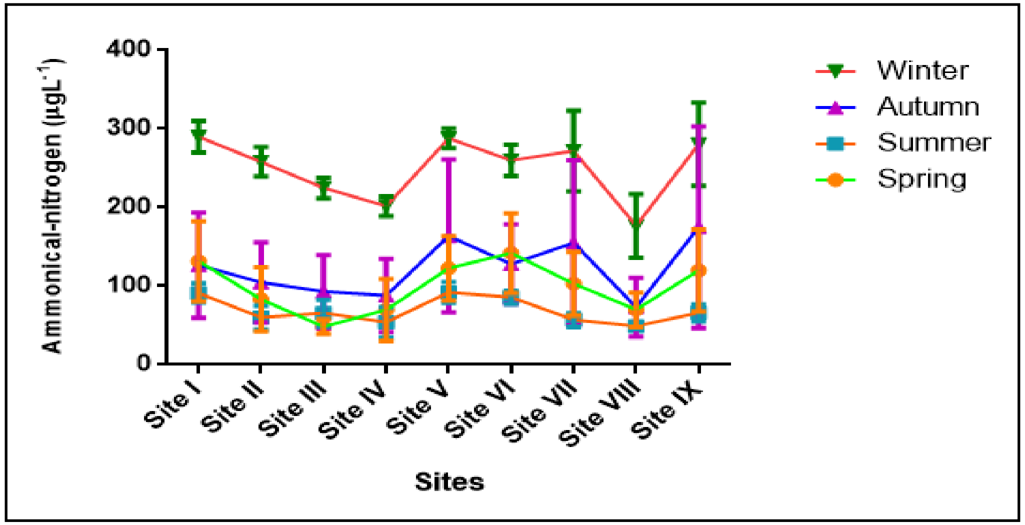


Fig. 5.1.35. Seasonal fluctuations (mean±SD) in ammonical-nitrogen (µg/L) recorded in Wular lake from Mar. 2011 to Feb. 2012

Table 5.1.36. Monthly fluctuations (with seasonal mean±SD) in ammonical-nitrogen (µg/L) of Wular lake from Mar. 2012 to Feb. 2013

	Mar	Apr	May	Mean±SD	Jun	Jul	Aug	Mean±SD	Sep	Oct	Nov	Mean±SD	Dec	Jan	Feb	Mean±SD
Site I	205	100	85	**130.0±65.4**	65	76	100	**80.3±17.9**	82	98	165	**115.0±44.0**	284	265	255	**268.0±14.7**
Site II	135	70	60	**88.3±40.7**	55	67	73	**65.0±9.2**	75	105	135	**105.0±30.0**	215	234	221	**223.3±9.7**
Site III	130	72	55	**85.7±39.3**	50	64	73	**62.3±11.6**	66	85	127	**92.7±31.2**	180	215	200	**198.3±17.6**
Site IV	122	63	50	**78.3±38.4**	46	52	61	**53.0±7.5**	73	87	121	**93.7±24.7**	165	205	190	**186.7±20.2**
Site V	95	120	88	**101.0±16.8**	87	51	86	**74.7±20.5**	134	88	240	**154.0±77.9**	250	265	280	**265.0±15.0**
Site VI	180	130	110	**140.0±36.1**	95	70	92	**85.7±13.7**	105	117	152	**124.7±24.4**	215	290	245	**250.0±37.7**
Site VII	140	82	86	**102.7±32.4**	60	42	66	**56.0±12.5**	92	140	241	**157.7±76.1**	210	263	213	**228.7±29.8**
Site VIII	87	67	50	**68.0±18.5**	63	48	40	**50.3±11.7**	60	70	125	**85.0±35.0**	122	148	182	**150.7±30.1**
Site IX	190	93	75	**119.3±61.9**	72	64	80	**72.0±8.0**	211	38	179	**142.7±92.0**	240	277	235	**250.7±22.9**

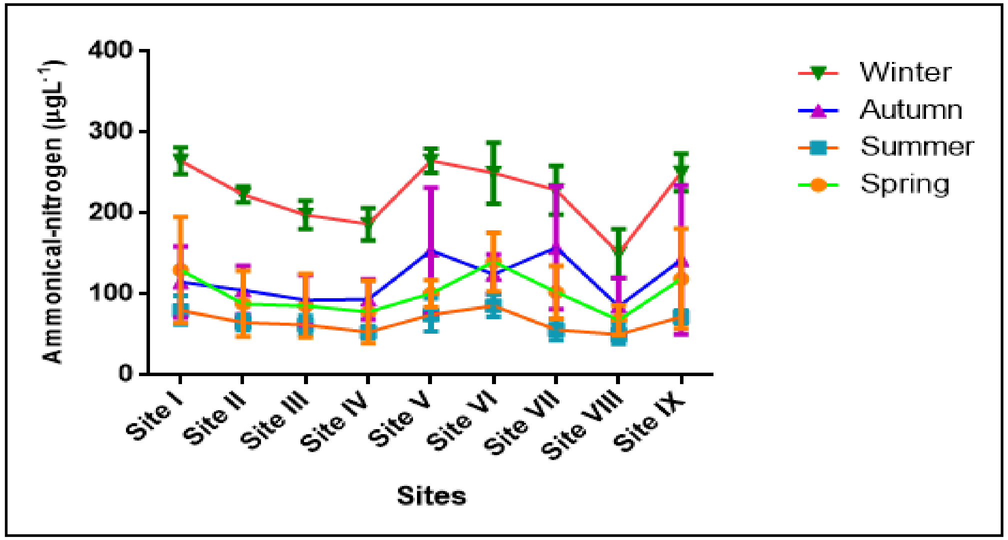


Fig. 5.1.36. Seasonal fluctuations (mean±SD) in ammonical-nitrogen (µg/L) recorded in Wular lake from Mar. 2012 to Feb. 2013

Table 5.1.37. Monthly fluctuations (with seasonal mean±SD) in nitrate-nitrogen (µg/L) of Wular lake from Mar. 2011 to Feb. 2012

	Mar	Apr	May	Mean±SD	Jun	Jul	Aug	Mean±SD	Sep	Oct	Nov	Mean±SD	Dec	Jan	Feb	Mean±SD
Site I	880	470	240	**530.0±324.2**	215	270	400	**295.0±95.0**	310	405	630	**448.0±164.3**	810	1030	1140	**993.3±168.0**
Site II	990	500	270	**586.7±367.7**	240	290	410	**313.3±87.4**	330	420	700	**483.0±193.0**	920	1110	1230	**1086.7±156.3**
Site III	570	350	195	**371.7±188.4**	170	205	315	**230.0±75.7**	220	280	470	**323.0±130.5**	660	860	920	**813.3±136.1**
Site IV	490	300	170	**320.0±160.9**	130	170	270	**190.0±72.1**	185	235	410	**277.0±118.1**	590	780	830	**733.3±126.6**
Site V	870	470	330	**556.7±280.2**	206	360	535	**367.0±164.6**	354	460	790	**535.0±227.4**	1010	1410	1430	**1283.3±236.9**
Site VI	930	610	350	**630.0±290.5**	330	390	530	**416.7±102.6**	430	520	790	**580.0±187.3**	1050	1490	1710	**1416.7±336.1**
Site VII	900	500	250	**550.0±327.9**	228	280	534	**347.3±163.7**	325	410	710	**482.0±202.3**	1030	1390	1300	**1240.0±187.3**
Site VIII	320	210	190	**240.0±70.0**	180	185	215	**193.3±18.9**	190	230	290	**237.0±50.3**	350	450	510	**436.6±80.8**
Site IX	970	380	325	**558.3±357.6**	325	290	430	**348.3±72.9**	421	465	680	**522.0±138.6**	930	1230	1360	**1173.3±220.5**

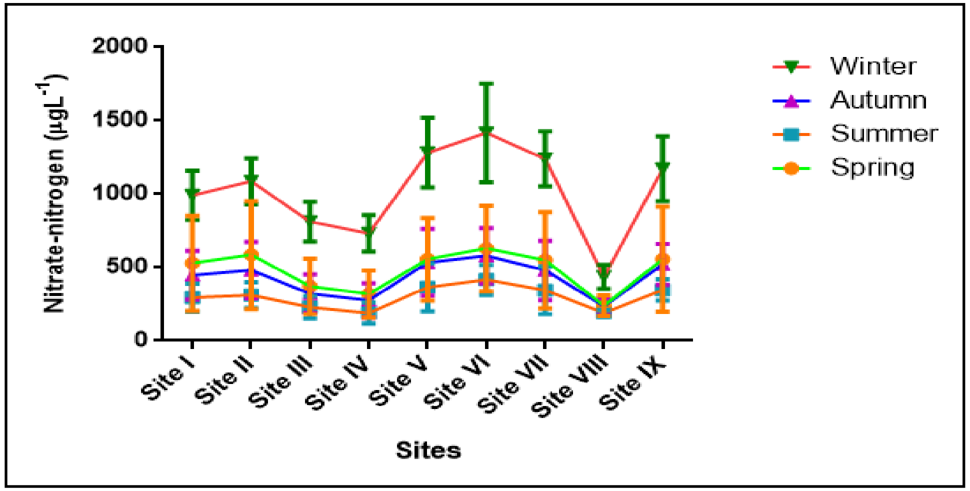


Fig. 5.1.37. Seasonal fluctuations (mean±SD) in nitrate-nitrogen (µg/L) recorded in Wular lake from Mar. 2011 to Feb. 2012

Table 5.1.38. Monthly fluctuations (with seasonal mean±SD) in nitrate-nitrogen (µg/L) of Wular lake from Mar. 2012 to Feb. 2013

	Mar	Apr	May	Mean±SD	Jun	Jul	Aug	Mean±SD	Sep	Oct	Nov	Mean±SD	Dec	Jan	Feb	Mean±SD
Site I	790	510	300	**533.3±245.8**	200	260	365	**275.0±83.5**	380	415	525	**440.0±75.7**	755	955	1015	**908.3±136.1**
Site II	910	480	310	**566.7±309.2**	220	265	395	**293.3±90.9**	410	445	565	**473.3±81.3**	880	1042	1170	**1030.7±145.3**
Site III	550	380	180	**370.0±185.2**	155	210	310	**225.0±78.6**	245	265	362	**290.7±62.6**	590	765	834	**729.7±125.8**
Site IV	510	330	135	**325.0±187.5**	240	180	120	**180.0±60.0**	250	220	335	**268.3±59.7**	540	755	805	**700.0±140.8**
Site V	810	430	323	**521.0±255.9**	212	336	364	**304.0±80.9**	483	318	680	**493.7±181.2**	810	1255	1310	**1125.0±274.2**
Site VI	850	450	340	**546.7±268.4**	300	345	515	**386.7±113.4**	530	455	690	**558.3±120.0**	965	1520	1180	**1221.7±279.8**
Site VII	830	450	225	**501.7±305.8**	217	240	315	**257.3±51.2**	470	289	510	**423.0±117.8**	885	1210	1270	**1121.7±207.1**
Site VIII	340	200	175	**238.3±88.9**	160	172	204	**178.7±22.7**	220	240	255	**238.3±17.6**	310	390	500	**400.0±95.4**
Site IX	870	440	315	**541.7±291.1**	300	275	355	**310.0±40.9**	445	420	590	**485.0±91.8**	855	1165	1330	**1116.7±241.2**

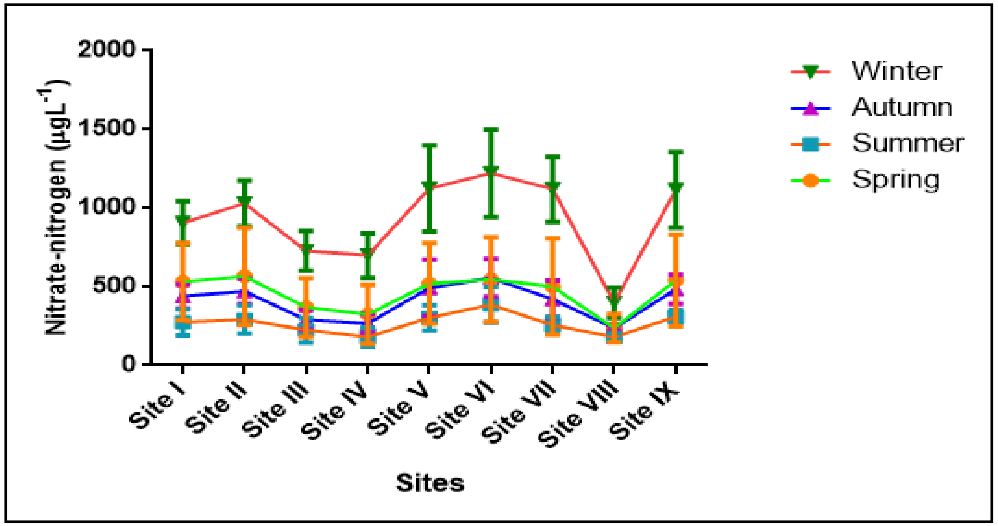


Fig. 5.1.38. Seasonal fluctuations (mean±SD) in nitrate-nitrogen (µg/L) recorded in Wular lake from Mar. 2012 to Feb. 2013

Table 5.1.39. Monthly fluctuations (with seasonal mean±SD) in total iron (µg/L) of Wular lake from Mar. 2011 to Feb. 2012

	Mar	**Apr**	**May**	**Mean±SD**	**Jun**	**Jul**	**Aug**	**Mean±SD**	**Sep**	**Oct**	**Nov**	**Mean±SD**	**Dec**	**Jan**	**Feb**	**Mean±SD**
Site I	310	298	322	**310.0±12.0**	271.0	257	243	**257.0±14.0**	255.0	271.0	309	**278.3±27.7**	317	298.0	346.0	**320.3±24.2**
Site II	321	305	287	**304.3±17.0**	276.0	235	261	**257.3±20.7**	276.0	297.0	316	**296.3±20.0**	291	338.0	362.0	**330.3±36.1**
Site III	335	291	307	**311.0±22.3**	284.0	258	243	**261.7±20.7**	271.0	312.0	333	**305.3±31.5**	352	341.0	381.0	**358.0±20.7**
Site IV	345	309	289	**314.3±28.4**	319.0	267	252	**279.3±35.2**	268.0	319.0	346	**311.0±39.6**	357	369.0	393.0	**373.0±18.3**
Site V	316	286	267	**289.7±24.7**	251.0	285	231	**255.7±27.3**	243.0	257.0	278	**259.3±17.6**	326	337.0	353.0	**338.7±13.6**
Site VI	295	290	243	**276.0±28.7**	232.0	251	210	**231.0±20.5**	233.0	246.0	261	**246.7±14.0**	311	328.0	341.0	**326.7±15.0**
Site VII	360	322	303	**328.3±29.0**	286.0	261	276	**274.3±12.6**	289.0	332.0	363	**328.0±37.2**	373	381.0	413.0	**389.0±21.2**
Site VIII	272	251	233	**252.0±19.5**	246.0	214	189	**216.3±28.6**	235.0	216.0	201	**217.3±17.0**	256	277.0	294.0	**275.7±19.0**
Site IX	281	263	239	**261.0±21.1**	249.0	196	223	**222.7±26.5**	238.0	251.0	257	**248.7±9.7**	328	309.0	289.0	**308.7±19.5**

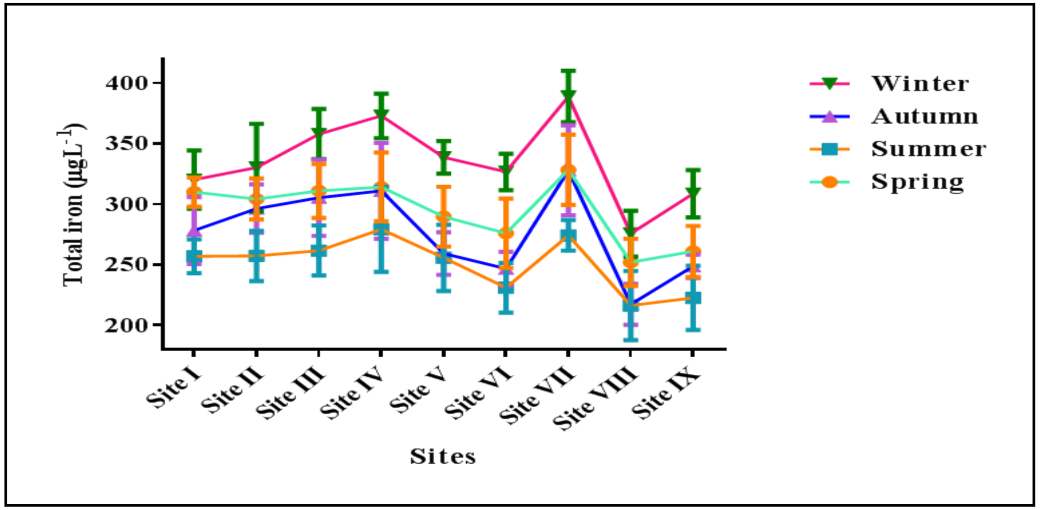


Fig. 5.1.39. Seasonal fluctuations (mean±SD) in total iron (µg/L) recorded in Wular lake from Mar. 2011 to Feb. 2012

Table 5.1.40. Monthly fluctuations (with seasonal mean±SD) in total iron (µg/L) of Wular lake from Mar. 2012 to Feb. 2013

	Mar	Apr	May	Mean±SD	Jun	Jul	Aug	Mean±SD	Sep	Oct	Nov	Mean±SD	Dec	Jan	Feb	Mean±SD
Site I	321	303	328	**317.3±12.9**	283	262	251	**265.3±16.3**	249	276	316	**280.3±33.7**	324	308	357	**329.7±25.0**
Site II	313	310	293	**305.3±10.8**	281	222	239	**247.3±30.4**	247	263	305	**271.7±30.0**	316	317	347	**326.7±17.6**
Site III	343	284	315	**314.0±29.5**	293	243	232	**256.0±32.5**	276	346	296	**306.0±36.1**	358	346	375	**359.7±14.6**
Site IV	341	272	332	**315.0±37.5**	302	273	256	**277.0±23.3**	265	302	323	**296.7±29.4**	329	345	405	**359.7±40.1**
Site V	322	294	275	**297.0±23.6**	259	292	243	**264.7±25.0**	248	263	287	**266.0±19.7**	333	346	359	**346.0±13.0**
Site VI	306	252	288	**282.0±27.5**	243	259	222	**241.3±18.6**	242	268	252	**254.0±13.1**	322	334	328	**328.0±6.0**
Site VII	345	239	310	**298.0±54.0**	259	290	271	**273.3±15.6**	281	310	336	**309.0±27.5**	372	351	401	**374.7±25.1**
Site VIII	283	240	237	**253.3±25.7**	232	196	220	**216.0±18.3**	221	190	205	**205.3±15.5**	243	264	306	**271.0±32.1**
Site IX	265	279	246	**263.3±16.6**	206	238	217	**220.3±16.3**	221	263	245	**243.0±21.1**	339	272	305	**305.3±33.5**

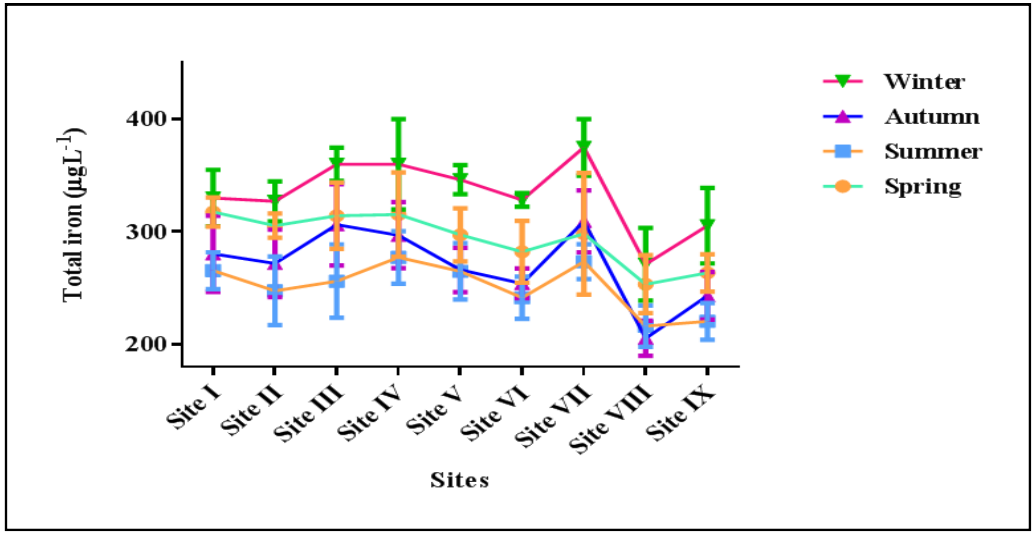


Fig. 5.1.40. Seasonal fluctuations (mean±SD) in total iron (µg/L) recorded in Wular lake from Mar. 2012 to Feb. 2013

Table 5.1.41. Correlation coefficients between various physico-chemical parameters of water in Wular lake

	AT	WT	TR	DE	TDS	SC	pH	FC	BA	DO	TH	CC	MC	CL	AN	NN	TP	OP	DS	TI
WT	.896(**)	1																		
TR	-0.598	-.670(*)	1																	
DE	-.670(*)	-.722(*)	.990(**)	1																
TDS	0.363	0.274	-0.253	-0.319	1															
SC	0.379	0.302	-0.263	-0.33	.999(**)	1														
pH	-0.104	0.118	0.059	0.094	-.875(**)	-.858(**)	1													
FC	0.117	0.04	-0.049	-0.134	.877(**)	.874(**)	-.754(*)	1												
BA	0.466	0.321	-0.245	-0.338	.953(**)	.953(**)	-.799(**)	.903(**)	1											
DO	-0.664	-.781(*)	.788(*)	.838(**)	-0.507	-0.525	0.121	-0.401	-0.573	1										
TH	0.299	0.186	-0.213	-0.276	.981(**)	.978(**)	-.907(**)	.873(**)	.940(**)	-0.441	1									
CC	0.331	0.198	-0.292	-0.356	.969(**)	.964(**)	-.907(**)	.870(**)	.941(**)	-0.47	.991(**)	1								
MC	0.29	0.193	-0.164	-0.229	.982(**)	.980(**)	-.888(**)	.874(**)	.939(**)	-0.436	.996(**)	.975(**)	1							
CL	0.286	-0.018	-0.124	-0.137	0.446	0.428	-0.623	0.345	0.424	0.063	0.482	0.513	0.446	1						
AN	.816(**)	0.635	-0.261	-0.332	0.491	0.498	-0.358	0.236	0.514	-0.321	0.392	0.398	0.392	0.042	1					
NN	.759(*)	0.572	-0.158	-0.237	0.496	0.503	-0.363	0.331	0.533	-0.243	0.438	0.437	0.44	0.641	.903(**)	1				
TP	.752(*)	0.553	-0.18	-0.286	0.647	0.654	-0.487	0.545	.720(*)	-0.358	0.591	0.603	0.588	0.546	.893(**)	.942(**)	1			
OP	0.494	0.472	-0.302	-0.379	.848(**)	.857(**)	-0.616	.795(*)	.818(**)	-0.52	.806(**)	.802(**)	.807(**)	0.524	0.576	.722(*)	.792(*)	1		
DS	0.609	0.514	0.158	0.095	0.138	0.152	0.034	-0.041	0.192	-0.075	0.027	-0.025	0.073	0.1	.807(**)	.726(*)	0.65	0.257	1	
TI	0.253	0.527	0.076	0.05	-0.355	-0.323	.697(*)	-0.356	-0.318	-0.149	-0.413	-0.468	-0.359	-0.359	0.072	0.123	0.03	-0.038	0.452	1

The marked correlations are significant at P=<0.05 (1- tailed) and P=<0.01 (2-tailed).

AT – Air temperature, WT- Water temperature, De – Depth, TDS – Total dissolved solids, Sc – Specific conductivity, pH – pH, FC –Free carbon dioxide, BA – Bicarbonate alkalinity, DO – Dissolved oxygen, TH – Total hardness, CC – Calcium content, MC– Magnesium content, CL – Chloride, AN – Ammonical-nitrogen, NN – Nitrate-nitrogen, TP – Total phosphorus, OP – Ortho-phosphate phosphorus, DS – Dissolved silica, TI – Total iron.

Table 5.1.42.Analysis of variance of various physico-chemical characteristics of water during 2011

		Sum of Squares	df	Mean Square	F	Sig.
Air temperature	Between Groups	898.003	3	299.334	35.64	.000
	Within Groups	268.747	32	8.398		
	Total	1166.75	35			
Water temperature	Between Groups	673.432	3	224.477	45.47	.000
	Within Groups	157.973	32	4.937		
	Total	831.406	35			
Specific conductivity	Between Groups	96437.31	3	32145.77	3.973	0.000
	Within Groups	258885.018	32	8090.157		
	Total	355322.328	35			
pH	Between Groups	1.586	3	0.529	23.06	.000
	Within Groups	0.733	32	0.023		
	Total	2.319	35			
Free carbon dioxide	Between Groups	488.798	3	162.933	19.49	.000
	Within Groups	267.502	32	8.359		
	Total	756.3	35			
Bicarbonate alkalinity	Between Groups	25328.056	3	8442.685	8.013	.000
	Within Groups	33714.953	32	1053.592		
	Total	59043.009	35			
Dissolved oxygen	Between Groups	9.71	3	3.237	11.54	.000
	Within Groups	8.978	32	0.281		
	Total	18.688	35			
Chloride	Between Groups	443.316	3	147.772	32.05	.000
	Within Groups	147.531	32	4.61		
	Total	590.848	35			
Depth	Between Groups	10.94	3	3.647	2.896	0.000
	Within Groups	40.3	32	1.259		
	Total	51.24	35			
Calcium content	Between Groups	795.803	3	265.268	0.628	0.602
	Within Groups	13517.084	32	422.409		
	Total	14312.887	35			
Magnesium content	Between Groups	1293.892	3	431.297	6.171	0.002
	Within Groups	2236.351	32	69.886		
	Total	3530.243	35			
Dissolved silica	Between Groups	268.766	3	89.589	39.61	.000
	Within Groups	72.384	32	2.262		
	Total	341.15	35			
Nitrate-nitrogen	Between Groups	2407291.162	3	802430.387	18.55	.000
	Within Groups	1384220.353	32	43256.886		
	Total	3791511.516	35			
Ammonical-nitrogen	Between Groups	171738.763	3	57246.254	54.05	.000
	Within Groups	33894.504	32	1059.203		
	Total	205633.268	35			
Ortho-phosphate phosphorus	Between Groups	7492.047	3	2497.349	10.66	.000
	Within Groups	7500.462	32	234.389		
	Total	14992.51	35			
Total phosphorus	Between Groups	61897.899	3	20632.633	6.396	0.002
	Within Groups	103231.64	32	3225.989		
	Total	165129.539	35			
Total dissolved solids	Between Groups	35471.912	3	11823.971	3.924	0.017
	Within Groups	96432.424	32	3013.513		
	Total	131904.336	35			

Table 5.1.42 Cont……….

Total hardness	Between Groups	31809.403	3	10603.134	4.062	0.015
	Within Groups	83536	32	2610.5		
	Total	115345.403	35			
Total iron	Between Groups	34398.34	3	11466.113	12.51	.000
	Within Groups	29337.269	32	916.79		
	Total	63735.609	35			
Water transparency	Between Groups	0.86	3	0.287	1.659	0.195
	Within Groups	5.529	32	0.173		
	Total	6.389	35			

Table 5.1.43. Analysis of variance of various physico-chemical characteristics of water during 2012

		Sum of Squares	df	Mean Square	F	Sig.
Air temperature	Between Groups	1962.856	3	654.285	933.582	.000
	Within Groups	22.427	32	.701		
	Total	1985.283	35			
Water temperature	Between Groups	1614.099	3	538.033	854.869	.000
	Within Groups	20.140	32	.629		
	Total	1634.239	35			
Specific conductivity	Between Groups	78246.824	3	26082.275	4.940	.006
	Within Groups	168960.238	32	5280.007		
	Total	247207.062	35			
pH	Between Groups	.770	3	.257	6.158	.002
	Within Groups	1.333	32	.042		
	Total	2.103	35			
Free carbon dioxide	Between Groups	236.394	3	78.798	14.247	.000
	Within Groups	176.989	32	5.531		
	Total	413.383	35			
Bicarbonate alkalinity	Between Groups	17646.528	3	5882.176	8.885	.000
	Within Groups	21185.851	32	662.058		
	Total	38832.379	35			
Dissolved oxygen	Between Groups	9.433	3	3.144	12.351	.000
	Within Groups	8.147	32	.255		
	Total	17.580	35			
Chloride	Between Groups	343.441	3	114.480	28.913	.000
	Within Groups	126.702	32	3.959		
	Total	470.143	35			
Depth	Between Groups	7.599	3	2.533	3.139	.000
	Within Groups	25.824	32	.807		
	Total	33.423	35			
Calcium content	Between Groups	1144.903	3	381.634	1.274	.300
	Within Groups	9585.464	32	299.546		
	Total	10730.367	35			
Magnesium content	Between Groups	1183.109	3	394.370	12.766	.000
	Within Groups	988.587	32	30.893		
	Total	2171.696	35			
Dissolved silica	Between Groups	218.312	3	72.771	48.518	.000
	Within Groups	47.996	32	1.500		
	Total	266.308	35			
Nitrate-nitrogen	Between Groups	2215429.159	3	738476.386	28.484	.000
	Within Groups	829618.211	32	25925.569		
	Total	3045047.370	35			
Ammonical-nitrogen	Between Groups	124994.503	3	41664.834	54.653	.000
	Within Groups	24395.247	32	762.351		
	Total	149389.750	35			
Ortho-phosphate phosphorus	Between Groups	8329.833	3	2776.611	18.324	.000
	Within Groups	4849.009	32	151.532		
	Total	13178.842	35			

Table 5.1.43 Cont……….

Total phosphorus	Between Groups	118249.999	3	39416.666	50.351	.000
	Within Groups	25050.764	32	782.836		
	Total	143300.763	35			
Total dissolved solids	Between Groups	33130.540	3	11043.513	5.187	.005
	Within Groups	68126.882	32	2128.965		
	Total	101257.422	35			
Total hardness	Between Groups	29408.088	3	9802.696	6.686	.001
	Within Groups	46920.269	32	1466.258		
	Total	76328.356	35			
Total iron	Between Groups	33863.218	3	11287.739	14.455	.000
	Within Groups	24989.142	32	780.911		
	Total	58852.360	35			
Water transparency	Between Groups	1.032	3	.344	3.037	.043
	Within Groups	3.624	32	.113		
	Total	4.656	35			

5.2. VEGETATION

5.2.1. Species Composition

In the present study a total of 55 species of macrophytes belonging to 38 genera spread over 27 families were found to inhabit Wular lake (Table 5.2.1.1). The families with highest number of species were Cyperaceae and Potamogetonaceae, being represented by five species each. Family Cyperaceae was represented by four genera namely *Carex* (*Carex* sp.), *Cyperus* (*Cyperus serotinus*), *Eleocharis* (*Eleocharis palustris*) and *Scirpus* (*S. lacustris* and *S. palustris*), while five species of *Potamogeton* (*P. crispus*, *P. lucen*s, *P. natans*, *P. pectinatus* and *P. perfoliatus*) represented the family Potamogetonaceae.These were followed by families Lemnaceae and Ranunculaceae, being represented by four species each. Family Lemnaceae was represented by four species belonging to two different genera (*Lemna major*, *Lemna minor*, *Lemna trisulca* and *Spirodela polyrhiza*), while Ranunculaceae was represented by *Batrachium trichophyllum*, *Ranunculus lingua*, *Ranunculus muricatus* and *Ranunculus sceleratus.*

Alternanthera philoxeroides was the single representative of the family Amaranthaceae. Family Alismataceae was represented by three species belonging to two different genera (*Alisma lanceolatum*, *Alisma plantago-aquatica* and *Sagittaria sagittifolia*), while the families Apiaceae, Asteraceae, Azollacea, Butomaceae and Brassicaceae were represented by single species each - *Sium latijugum, Bidens cernua*, *Azolla* sp., *Butomus umbellatus* and *Nasturtium officinalis* respectively.

Ceratophyllum demersum was the single representative of the family Ceratophyllaceae. The three species of *Myriophyllum* (*M. aquaticum*, *M. spicatum* and *M. verticillatum*) represented the family Haloragaeae. A species of *Hippuris vulgaris* belonging to the family Hippuridaceae and two species (*Hydrocharis dubia* and *Hydrilla verticillata*) belonging to the family Hydrocharitaceae were recorded from the lake. Further, the family Juncaceae was monospecific having a single species (*Juncus bufonius*), as compared to Lamiaceae being represented by two different taxa (*Lycopus europaeus* and *Mentha arvensis*). *Marsilea quadrifolia* was the distinctive member of family Marsiliaceae. *Menyanthes trifoliata* and *Nymphoides peltatum* represented the family Menyanthaceae. *Najas graminea* and *Nelumbo nucifera* were the sole representatives of the families Najadaceae and Nelumbonaceae respectively. Family Nymphaeaceae was represented by a single genus having three species (*Nymphaea* *alba*, *N. mexicana* and *N. pygmea*). Two species belonging to two different genera (*Echinocloa cruss-galli* and *Phragmites australis*) represented the family Poaceae.

Family Polygonaceae was represented by a single genus with two species (*Polygonum amphibium* and *P.hydropiper*) while Salviniaceae and Sparganaceae were represented by single species each (*Salvinia natans and Sparganium ramosum*) respectively. Family Trapaceae was represented by a single genus having two species (*Trapa bispinosa* and *T. natans*) and the two species of *Typha* (*T. angustata* and *T. latifolia*) were identified in the family Typhaceae.

The macrophytic community of the lake was represented by 30 species of emergents, 10 species of rooted-floating leaf type, 09 submergeds and 06 free-floating species. The representatives of emergent class in the lake were *Alisma lanceolatum, Alisma plantigo-aquatica, Alternanthera philoxeroides, Bidens cernua, Butomus umbellatus, Carex* sp., *Cyperus serotinus, Echinocloa crus-galli, Eleocharis palustris, Hippurus vulgaris, Juncus buffonius, Lycopus europaeus, Mentha arvensis, Menyanthes trifoliata, Myriophyllum aquaticum, Myriophyllum verticillatum, Nasturtium officinalis, Phragmites australis, Polygonum amphibium, Polygonum hydropiper, Ranunculus lingua, Ranunuculus muricatus, Ranunculus sceleratus, Sagittaria sagittifolia, Scirpus lacustris, Scirpus palustris, Sium latijugum, Sparganium ramosum, Typha angustata* and *Typha latifolia.* The members of the rooted-floating leaf type community included *Hydrocharis dubia, Marsilea quadrifolia, Nelumbo nucifera, Nymphaea alba, Nymphaea mexicana, Nymphaea pygmea, Nymphoides peltatum, Potamogetan natans, Trapa bispinosa* and *Trapa natans* while as the submergeds were represented by *Batrachium trichophyllum, Ceratophyllum demersum, Hydrilla verticillata, Najas gramineum, Myriophyllum spicatum, Potamogeton crispis, P. lucens, P. pectinatus* and *P. perfoliatus. Azolla* sp., *L. major, Lemna minor, L. trisulca, Spirodela polyrhiza* and *Salvinia natans* were the representatives of free-floating class.

Table 5.2.1.1. List of macrophytes species recorded during the present study

S.No	Life Form Class	Family	Species name
1	Emergents	Alismataceae	*Alisma lanceolatum* With.
2		Alismataceae	*Alisma plantago-aquatica* L.
3		Amaranthaceae	*Alternanthera philoxeroides* (Mart.) Griseb.
4		Asteraceae	*Bidens cernua* L.
5		Butomaceae	*Butomus umbellatus* L.
6		Cyperaceae	*Carex* sp.
7		Cyperaceae	*Cyperus serotinus* Rottb.
8		Poaceae	*Echinocloa crus-galli* (L.) Beauv.
9		Cyperaceae	*Eleocharis palustris* (L.) R.Br.
10		Hippuridaceae	*Hippuris vulgaris* L.
11		Juncaceae	*Juncus buffonius* L.
12		Lamiaceae	*Lycopus europaeus* L.
13		Lamiaceae	*Mentha arvensis* L.
14		Menyanthaceae	*Menyanthes trifoliata* L.
15		Haloragaceae	*Myriophyllum aquaticum* L.
16		Haloragaceae	*Myriophyllum verticillatum* L.
17		Brassicaceae	*Nasturtium officinalis* (L.) R.Br.
18		Poaceae	*Phragmites australis* Trin.
19		Polygonaceae	*Polygonum amphibium* L.
20		Polygonaceae	*Polygonum hydropiper* L.
21		Ranunculaceae	*Ranunculus lingua* L.
22		Ranunculaceae	*Ranunculus muricatus* L.
23		Ranunculaceae	*Ranunculus sceleratus* L.
24		Alismataceae	*Sagittaria sagittifolia* L.
25		Cyperaceae	*Scirpus lacustris* L.
26		Cyperaceae	*Scirpus palustris* L.
27		Apiaceae	*Sium latijugam* Clarke
28		Sparganaceae	*Sparganium ramosum* Huds.
29		Typhaceae	*Typha angustata* Bory & Chaub.
30		Typhaceae	*Typha latifolia* Edgew.
31	Rooted-floating leaf type	Hydrocharitaceae	*Hydrocharis dubia* (Blame) Bacquer.
32		Marsiliaceae	*Marsilea quadrifolia* L.
33		Nelumbonaceae	*Nelumbo nucifera* Gaertn.
34		Nymphacaceae	*Nymphaea alba* L.
35		Nymphacaceae	*Nymphaea mexicana* L.
36		Nymphacaceae	*Nymphaea pygmea* L.
37		Menyanthaceae	*Nymphoides peltatum* Kuntze
38		Potamogetonaceae	*Potamogeton natans* L.
39		Trapaceae	*Trapa bispinosa* L.
40		Trapaceae	*Trapa natans* L.
41	Free-floating type	Azollaceae	*Azolla* sp. R. Br.
42		Lemnaceae	*Lemna major* L.
43		Lemnaceae	*Lemna minor* L.
44		Lemnaceae	*Lemna trisulca* L.
45		Lemnaceae	*Spirodela polyrhiza* (L.) Schleid.
46		Salviniaceae	*Salvinia natans* L.
47	Submergeds	Ranunculaceae	*Batrachium trichophyllum* v.d.Borsche
48		Ceratophyllaceae	*Ceratophyllum demersum* L.

Table 5.2.1.1 Cont……….

49		Hydrocharitaceae	*Hydrilla verticillata* (L.f.) Royle
50		Najadaceae	*Najas graminea* Del.
51		Haloragaceae	*Myriophyllum spicatum* L.
52		Potamogetonaceae	*Potamogeton crispus* L.
53		Potamogetonaceae	*Potamogeton lucens* L.
54		Potamogetonaceae	*Potamogeton pectinatus* L.
55		Potamogetonaceae	*Potamogeton perfoliatus* L.

5.2.2. Community Features of Macrophytes

The macrophytes of Wular lake under study exhibited different patterns of community architecture and showed marked variations at different sites, being governed by hydrological regime during different periods of the year.

Site I

A total of 35 species of macrophytes with 25 species of emergents, 06 species of rooted floating-leaf type, 01 species of submergeds and 03 species of free-floating type were recorded at Site I in Wular lake (Table 5.2.2.1-4) .The minimum number of 12 species was recorded in spring, 2012 as against the maximum number of 32 species, being registered during summer, 2011. *Nymphoides peltatum* recorded the highest mean frequency (53.3±5.8 %) at this Site, followed by *Myriophyllum verticillatum* (50.0±17.3 %), *Azolla* sp. (46.7±20.8 %) and *Polygonum hydropiper* (43.3±5.8 %) while as lowest value was obtained for *Scirpus lacustris* (3.3±5.8 %). As against this, the highest value for density was recorded for *Lemna minor* (7.8 ind. /m^2) in summer 2011. In general, annual mean density (ind. /m^2) at Site I ranged between 0.1±0.1 (each for *Scirpus lacustris* and *Scirpus palustris*) and 7.3±0.4 (*Lemna minor*). *Azolla* sp. and *salvinia natans* with mean density values (ind. /m^2) of 4.5±1.1 and 4.3±1.4 respectively were the other noticeable species in terms of density. *Lemna minor* was the most abundant species at Site I, recording an abundance of 19.9±4.9 during 2012, followed by *Azolla* sp. (9.8 ±2.3), *Salvinia natans* (8.5±2.8) and *Nymphoides peltatum* (4.5±1.4), being recorded during the year 2011. Out of the 35 species recorded at Site I, the highest Importance Value Index of 45.2±13.9 was registered for *Salvinia natans*, followed by *Lemna minor* (44.8±6.3) and *Ceratophyllum demersum* (20.8±2.2). However, the least IVI of 0.3±0.6 was registered for *Scirpus palustris*. Site I recorded greater number of emergent macrophytic species compared to other sites.

Site II

Out of 30 species of macrophytes recorded at Site I, 14 species belonged to emergents, 06 to rooted floating-leaf type, 04 to submergeds and 06 to free-floating class (Table 5.2.2.5 - 8). The minimum number of 18 species was recorded during spring, 2012 and maximum number of 28 species in summer, 2011. At Site II, *Nymphoides peltatum* emerged as the most frequent species with a frequency of 66.7 ±7.6 % and was followed by *Azolla* sp. (48.3±2.9 %) and *Salvinia natans* (46.7±12.6

%). Highest density (7.7 ±1.0 ind. /m^2) and highest abundance (22.0±2.7) at this site was noted for *Lemna minor*. In density (ind. /m^2), it was followed by *Lemna major* (7.1±10.4), *Azolla* sp. (5.2±0.7) and *Nymphoides peltatum* (4.8±0.4) and as for as abundance is concerned, *Azolla* sp. (12.4±2.7) and *Salvinia natans* (11.6±1.4) followed *Lemna minor*. Among a total of 30 species recorded at Site II, the maximum IVI of 174.0±68.6 was recorded for *Nymphoides peltatum*, followed by *Ceratophyllum demersum* (142.6±68.7) and *Lemna minor* (131.9±37.9). The least IVI of 1.0±1.7 was recorded for *Eleocharis palustris*.

Site III

Site III in Wular lake registered a total of 21 species of macrophytes of which 07 species belonged to emergents, 09 to rooted floating-leaf type, 02 to submergeds and 03 to free-floating community. The maximum number of 20 species was recorded in summer, 2011 as against the minimum number of 15 species in spring, 2012 (Table 5.2.2.9-12).The site recorded maximum mean frequency value for *Nymphoides peltatum* (53.3±15.3 %), followed by *Myriophylllum verticillatum* and *Phragmites australis* with 43.3±5.8 % each and *Azolla* sp. (36.7±5.8 %) in a decreasing order. In contrast, the minimum mean frequency value of 3.3±5.8 % was registered for *Typha latifolia*. The mean density (ind. /m^2) on the other hand, recorded highest value for *Lemna minor* (6.3±0.9), followed by *Azolla* sp. (4.6±0.5), *Salvinia natans* (3.3±0.5) and *Nymphoides peltatum* (3.2±0.2) while as the abundance varied between a mean value of 0.4±0.8 each for *Eleocharis palustris* and *Trapa bispinosa* and 23.9±3.2 for *Lemna minor*, with other notable contributions from *Azolla* sp. (19.3 ±3.1), *Salvinia natans* (14.0±1.7) and *Ceratophyllum demersum* (6.5±0.5). The species which depicted significant mean values for IVI were *Salvinia natans* (55.5±2.5), *Lemna minor* (40.6±1.4), *Ceratophyllum demersum* (29.9±1.2), *Potamogeton natans* (27.4±0.2) and *Potamogeton crispus* (20.8±1.8). The noteworthy features of the site were (i) presence of *Nymphaea pygmea* and (ii) appreciable contribution by *Potamogeton natans* (27.4±0.2) and *Potamogeton crispus* (20.8±1.8) to overall IVI.

Site IV

As compared to other sites, Site IV in Wular lake recorded lesser number of macrophytic species as only 18 species including 04 emergents, 05 rooted floating-leaf type, 04 submergeds and 05 free-floating type, were recorded at this site. The minimum number of 13 species was recorded in spring 2012 and maximum number of 17 species during summer and autumn 2011 and summer 2012 (Table 5.2.2.13-16). *Nymphoides peltatum*, *Ceratophyllum demersum*, *Potamogeton crispus* and *Potamogeton natans* covering significant areas at Site IV, recording mean frequency values of 53.3±5.8 %, 46.7±5.8 %, 36.7±5.8 % and 33.3±5.8 % respectively. The mean density (ind. /m^2) at Site IV was highest for *Azolla* sp. (5.4±1.3), followed by *Lemna minor* (5.3±0.6), *Ceratophyllum demersum* (2.9±0.4), *Nymphoides peltatum* (2.7±0.6) and *Salvinia natans* (2.3±0.5) in a decreasing order. *Lemna minor*, *Azolla* sp., *Salvinia natans*, *Ceratophyllum demersum* and *Nymphoides peltatum* depicted higher values for abundance with mean values of 23.7±3.8, 12.6±11.1, 7.0±1.0, 6.7 ±0.2 and 5.0 ±0.7 respectively. *Lemna minor* revealed highest mean values for IVI (54.8±12.1) at Site IV followed by *Azolla* sp. (42.5±3.2), *Ceratophyllum demersum* (28.2±8.5), *Nymphoides peltatum* (26.2±1.9) and *Salvinia natans* (23.3±1.7) in a decreasing order.

Site V

At Site V, a total of 29 species of macrophytes including 13 species of emergents, 09 species of rooted floating-leaf type, 02 species of submergeds and 05 species of free-floating type were recorded throughout the study period. The number of species varied from 17 (spring 2012) to 28 (summer 2011) (Table 5.2.2.17-20). *Nymphoides peltatum* recorded the highest mean frequency (53.3±5.8 %) at this site, followed by *Ceratophyllum demersum* (46.7±5.8 %), *Azolla* sp. and *Potamogeton natans* each recording mean frequency values of 40.0±10.0 % while as lowest value was obtained for *Bidens cernua* (3.3±5.8 %). The mean density values (ind. /m^2) at Site V ranged between 0.1±0.1 for *Bidens cernua* and 7.8±1.2 for *Lemna minor*. The other species recording appreciable values for mean density (ind. /m^2) were *Azolla* sp. (5.5±1.0), *Salvinia natans* (4.1±0.8), *Ceratophyllum demersum* (2.8±0.5), *Nymphoides peltatum* (2.8±0.3) and *Myriophyllum verticillatum* (1.3±0.3). On the basis of abundance, *Lemna minor* was most abundant species with the mean abundance value of (24.2±6.9), followed by *Azolla* sp. (21.0±4.6), *Salvinia natans* (14.6±4.7), *Ceratophyllum demersum* (7.4±0.9), *Nymphoides peltatum* (6.3±0.3) and *Lemna major* (3.9±6.7) in a decreasing order. The species which registered maximum mean values for IVI was *Lemna minor* (264.0±373.7). Species such as *Azolla* sp. (220.8±311.2), *Salvinia natans* (175.5±250.7), *Ceratophyllum demersum* (116.0±161.4), *Nymphoides peltatum* (109.2±147.7) and *Potamogeton crispus*

(44.9±56.9) were the other significant contributors to IVI. The most notable features of Site V were (i) appreciable coverage of *Trapa natans* compared to other sites and (ii) restricted distribution of *Nelumbo nucifera* and *Juncus buffonius* to this site only.

Site VI

Site VI in Wular lake supported 29 species of macrophytes with emergents comprising of 19 species, rooted floating-leaf type 06, submergeds 01 and free-floating 03 species (Table 5.2.2.21-24). The number of species varied from 14 (spring 2012) to 27 (summer 2011). The frequency at Site VI varied between a mean value of 1.7±2.9 %, being obtained for *Sium latijugam* and 53.3±5.8 % obtained for *Nymphoides peltatum*. The other significant contributions being made by *Myriophyllum verticillatum* (50.0±10.0 %), *Phragmites australis* (45.0±5.0 %), *Polygonum hydropiper* (43.3±5.8 %) and *Azolla* sp. (36.7±5.8 %). The density (ind. /m^2) at Site VI recorded significant mean values for *Lemna minor* (5.2±1.1), *Azolla* sp. (4.5±0.3), *Nymphoides peltatum* (2.8±0.5), *Ceratophyllu*m *demersum* (2.0±0.3) and *Myriophyllum verticillatum* (1.8±0.3). On the other hand, maximum mean values for abundance was recorded for *Lemna minor* (20.4±2.9) and minimum value of 0.5±0.9 each for *Echinocloa crusgalli* and *Rununculus lingua*. *Azolla* sp., *Ceratophyllum demersum*, *Salvinia natans*, *Nymphoides peltatum* and *Myriophyllum verticillatum* also registered appreciable mean values of 11.2±1.3, 6.7±0.9, 5.7±5.1, 4.9±0.4 and 3.9±0.4 respectively for abundance. Like density, the maximum mean value for IVI at the site was registered for *Lemna minor* (57.8±2.7), followed by *Azolla* sp. (40.8±1.7), *Nymphoides peltatum* (26.6±4.5) and *Ceratophyllum demersum* (19.7±1.7) with minimum value of 1.4±2.4, being obtained for *Sium latijugam*.

Site VII

In all 35 species of macrophytes were recorded at Site VII in Lake Wular spreading over 15 species of emergents, 06 rooted floating-leaf type, 08 submergeds and 06 free-floating types. The minimum number of 21 species was recorded in spring 2012 and maximum number of 33 species in summer 2011 (Table 5.2.2.25-28). *Nymphoides peltatum*, *Ceratophyllum demersum*, *Potamogeton natans*, *Azolla* sp. and *Myriophyllum verticillatum* with mean frequency values of 68.3±7.6 %, 45.0±5.0 %, 41.7±7.6 %, 40.0±5.0 % and 38.3±2.0 % respectively were the species having maximum coverage at Site VII. The maximum value for mean density (ind. /m^2) at Site VII was obtained for *Lemna minor* (6.2±0.5). The other significant contributions being made by *Azolla* sp. (5.3±0.7), *Nymphoides peltatum* (4.4±0.4), *Salvinia natans* (3.4±0.5) and *Ceratophyllum demersum* (3.3±0.6). Abundance of macrophytes at Site VII in Wular lake varied between a mean value of 0.8±1.4 each for *Menyanthes trifoliata* and *Sagittaria sagittifolia* and 24.0±5.5 for *Lemna minor*. *Azolla* sp., *Salvinia natans* and *Ceratophyllum demersum* were other notable species in terms of mean abundance values of 19.4±5.2, 12.4±2.2 and 7.9±1.8 respectively. *Lemna minor* recorded highest mean values of 35.4±6.7 for IVI at this site followed by *Azolla* sp. (33.4±5.9), *Salvinia natans* (20.3±3.3), *Nymphoides peltatum* (18.0±1.4) and *Ceratophyllum demersum* (17.8±3.7) with lowest value of 0.9±1.5, being obtained for *Menyanthes trifoliata*.

Site VIII

Site VIII in Wular lake registered a total of 22 species of macrophytes of which 04 species belonged to emergent, 04 to rooted floating-leaf type, 09 to submerged and 05 to free-floating community. The maximum number of 19 species was recorded in summer 2011 as against the minimum number of 16 species during spring 2012 (Table 5.2.2.29-32). In general, mean frequency values at Site VIII ranged between 5.0±8.7 % for *Potamogeton perfoliatus* and 50.0±5.0 % for *Nymphoides peltatum*. The other species with appreciable mean frequency values were *Ceratophyllum demersum* (45.0 ±5.0 %) and *Myriophyllum verticillatum* (35.0 ±5.0 %). On the other hand, the mean density (ind. /m^2) at Site VIII fluctuated from a value of 0.1±0.2 for *Myriophyllum spicatum* to 6.0±0.5 for *Lemna minor*. While as the abundance varied between 0.5±1.4 for *Potamogeton perfoliatus* and 21.2±1.8 for *Lemna minor*. The overall IVI recorded its highest mean value for *Lemna minor* (57.8 ±3.9).The other species which recorded significant values for IVI were *Azolla* sp. (39.3 ±4.9), *Salvinia natans* (35.1 ±1.6), *Ceratophyllum demersum* (26.9 ±2.8) and *Nymphoides peltatum* (24.4 ±2.3). In general, submergeds recorded lower values for IVI than emergents, rooted floating-leaf type and free-floating species. The most notable feature of Site VIII was the presence of greater number of submerged macrophytes compared to other sites.

Site IX

Site IX in Wular lake recorded a total of 21 species of macrophytes which included 10 species of emergents, 05 species of rooted floating-leaf type, 03 species of submergeds and 03 species of free-floating type. The maximum number of 20 species was recorded in summer 2011 against the minimum of 15 species in spring 2012 (Table 5.2.2.33-36). The mean frequency at Site IX ranged from a minimum of 5.0±8.7 % for *Carex* sp. to a maximum of 41.7±7.6 % for *Ceratophyllum demersum*. The highest value for mean density (ind. /m^2) at this site was obtained for *Lemna minor* (6.0 ±1.0), followed by *Azolla* sp. (5.1 ±0.9), *Salvinia natans* (3.9 ±1.0), *Ceratophyllum demersum* (2.9 ±0.5) and decreasing to a lowest of 0.1±0.1 for *Echinocloa crus-galli*. *Lemna minor* depicted maximum value of abundance (23.0 ±5.6), followed by *Azolla* sp. (16.2 ±4.4), *Salvinia natans* (11.5 ±0.9), *Ceratophyllum demersum* (7.7 ±1.0) and *Nymphoides peltatum* (6.7 ±0.8) in a decreasing order. Like that of density, the lowest value of abundance was, however, obtained for *Echinocloa crus-galli* (0.3 ±0.6). The overall mean value for IVI ranged between 2.0±3.5 for *Echinocloa crus-galli* to 49.2±6.9 for *Lemna minor*. The other notable contributions to overall mean IVI were due to *Azolla* sp. (42.4 ±5.3), *Salvinia natans* (32.8 ±2.4), *Ceratophyllum demersum* (31.5 ±4.1), *Nymphoides peltatum* (31.1 ±2.8) and *Marsilea quadrifolia* (19.9 ±3.3).

Table 5.2.2.1. Seasonal variations in frequency (%) of macrophytic species at Site I during the study period

S.No	**Species**	**2011**				**2012**			
		Spring	**Summer**	**Autumn**	**Mean±SD**	**Spring**	**Summer**	**Autumn**	**Mean±SD**
	Emergents								
1	*Alisma lanceolatum*	0.0	30.0	0.0	**10.0±17.3**	0.0	0.0	0.0	**0.0±0.0**
2	*Alisma plantago-aquatica*	0.0	40.0	30.0	**23.3±20.8**	0.0	30.0	20.0	**16.7±15.3**
3	*Bidens cernua*	0.0	10.0	20.0	**10.0±10.0**	0.0	10.0	10.0	**6.7±5.8**
4	*Butomus umbellatus*	0.0	20.0	20.0	**13.3±11.5**	0.0	0.0	0.0	**0.0±0.0**
5	*Carex* sp.	0.0	20.0	10.0	**10.0±10.0**	0.0	20.0	10.0	**10.0±10.0**
6	*Cyperus serotinus*	0.0	30.0	30.0	**20.0±17.3**	0.0	0.0	0.0	**0.0±0.0**
7	*Echinocloa crus-galli*	0.0	40.0	0.0	**13.3±23.1**	0.0	20.0	0.0	**6.7±11.5**
8	*Eleocharis palustris*	0.0	30.0	20.0	**16.7±15.3**	0.0	20.0	10.0	**10.0±10.0**
9	*Hippuris vulgaris*	40.0	0.0	40.0	**26.7±23.1**	30.0	30.0	20.0	**26.7±5.8**
10	*Lycopus europaeus*	10.0	0.0	20.0	**10.0±10.0**	0.0	0.0	0.0	**0.0±0.0**
11	*Mentha arvensis*	30.0	0.0	30.0	**20.0±17.3**	20.0	30.0	20.0	**23.3±5.8**
12	*Myriophyllum aquaticum*	30.0	50.0	40.0	**40.0±10.0**	0.0	0.0	0.0	**0.0±0.0**
13	*Myriophyllum verticillatum*	40.0	70.0	40.0	**50.0±17.3**	30.0	50.0	40.0	**40.0±10.0**
14	*Nasturtium officinalis*	20.0	40.0	0.0	**20.0±20.0**	0.0	20.0	40.0	**20.0±20.0**
15	*Phragmites australis*	30.0	40.0	40.0	**36.7±5.8**	30.0	40.0	30.0	**33.3±5.8**
16	*Polygonum hydropiper*	40.0	50.0	40.0	**43.3±5.8**	20.0	40.0	20.0	**26.7±11.5**
17	*Ranunculus muricatus*	0.0	20.0	20.0	**13.3±11.5**	0.0	0.0	0.0	**0.0±0.0**
18	*Ranunculus sceleratus*	20.0	30.0	20.0	**23.3±5.8**	0.0	20.0	10.0	**10.0±10.0**
19	*Sagittaria sagittifolia*	0.0	40.0	30.0	**23.3±20.8**	0.0	30.0	0.0	**10.0±17.3**
20	*Scirpus lacustris*	0.0	10.0	0.0	**3.3±5.8**	0.0	10.0	0.0	**3.3±5.8**
21	*Scirpus palustris*	0.0	20.0	0.0	**6.7±11.5**	0.0	0.0	0.0	**0.0±0.0**
22	*Sium latijugam*	20.0	30.0	0.0	**16.7±15.3**	0.0	20.0	0.0	**6.7±11.5**
23	*Sparganium ramosum*	30.0	40.0	30.0	**33.3±5.8**	0.0	30.0	20.0	**16.7±15.3**
24	*Typha angustata*	30.0	40.0	20.0	**30.0±10.0**	20.0	40.0	30.0	**30.0±10.0**
25	*Typha latifolia*	30.0	40.0	30.0	**33.3±5.8**	0.0	20.0	0.0	**6.7±11.5**
	Rooted floating-leaf type								
26	*Hydrocharis dubia*	20.0	30.0	30.0	**26.7±5.8**	20.0	30.0	20.0	**23.3±5.8**
27	*Marsilea quadrifolia*	20.0	30.0	30.0	**26.7±5.8**	30.0	40.0	20.0	**30.0±10.0**
28	*Nymphaea mexicana*	20.0	30.0	20.0	**23.3±5.8**	0.0	20.0	20.0	**13.3±11.5**
29	*Nymphoides peltatum*	50.0	60.0	50.0	**53.3±5.8**	30.0	50.0	40.0	**40.0±10.0**
30	*Potamogeton natans*	30.0	40.0	30.0	**33.3±5.8**	20.0	20.0	30.0	**23.3±5.8**
31	*Trapa natans*	20.0	30.0	40.0	**30.0±10.0**	0.0	20.0	20.0	**13.3±11.5**
	Free-floating								
32	*Azolla* sp.	30.0	40.0	70.0	**46.7±20.8**	0.0	30.0	50.0	**26.7±25.2**
33	*Lemna minor*	20.0	40.0	60.0	**40.0±20.0**	30.0	20.0	30.0	**26.7±5.8**
34	*Salvinia natans*	40.0	50.0	50.0	**46.7±5.8**	10.0	30.0	20.0	**20.0±10.0**
	Submergeds								
35	*Ceratophyllum demersum*	40.0	20.0	30.0	**30.0±10.0**	0.0	20.0	40.0	**20.0±20.0**

Table 5.2.2.2. Seasonal variations in density (individuals/m^2) of macrophytic species at Site I during the study period

S.No	Species	2011				2012			
		Spring	Summer	Autumn	Mean±SD	Spring	Summer	Autumn	Mean±SD
	Emergents								
1	*Alisma lanceolatum*	0.0	1.2	0.0	**0.4±0.7**	0.0	0.0	0.0	**0.0±0.0**
2	*Alisma plantago-aquatica*	0.0	1.2	0.6	**0.6±0.6**	0.0	0.6	0.4	**0.3±0.3**
3	*Bidens cernua*	0.0	0.3	0.4	**0.2±0.2**	0.0	0.2	0.1	**0.1±0.1**
4	*Butomus umbellatus*	0.0	0.4	0.3	**0.2±0.2**	0.0	0.0	0.0	**0.0±0.0**
5	*Carex* sp.	0.0	0.3	0.2	**0.2±0.2**	0.0	0.2	0.1	**0.1±0.1**
6	*Cyperus serotinus*	0.0	0.4	0.5	**0.3±0.3**	0.0	0.0	0.0	**0.0±0.0**
7	*Echinocloa crus-galli*	0.0	0.8	0.0	**0.3±0.5**	0.0	0.5	0.0	**0.2±0.3**
8	*Eleocharis palustris*	0.0	0.4	0.3	**0.2±0.2**	0.0	0.3	0.2	**0.2±0.2**
9	*Hippuris vulgaris*	0.7	0.0	0.9	**0.5±0.5**	0.5	0.7	0.6	**0.6±0.1**
10	*Lycopus europaeus*	0.2	0.0	0.4	**0.2±0.2**	0.0	0.0	0.0	**0.0±0.0**
11	*Mentha arvensis*	0.5	0.0	0.7	**0.4±0.4**	0.3	0.5	0.4	**0.4±0.1**
12	*Myriophyllum aquaticum*	0.7	1.1	0.9	**0.9±0.2**	0.0	0.0	0.0	**0.0±0.0**
13	*Myriophyllum verticillatum*	1.3	2.2	1.6	**1.7±0.5**	0.8	1.5	1.2	**1.2±0.4**
14	*Nasturtium officinalis*	0.3	0.9	0.0	**0.4±0.5**	0.0	0.7	0.4	**0.4±0.4**
15	*Phragmites australis*	1.1	1.5	1.3	**1.3±0.2**	0.7	1.0	0.8	**0.8±0.2**
16	*Polygonum hydropiper*	0.8	1.3	1.0	**1.0±0.3**	0.6	0.9	0.7	**0.7±0.2**
17	*Ranunculus muricatus*	0.0	0.3	0.2	**0.2±0.2**	0.0	0.0	0.0	**0.0±0.0**
18	*Ranunculus sceleratus*	0.3	0.5	0.4	**0.4±0.1**	0.0	0.3	0.2	**0.2±0.2**
19	*Sagittaria sagittifolia*	0.0	1.1	0.8	**0.6±0.6**	0.0	0.7	0.0	**0.2±0.4**
20	*Scirpus lacustris*	0.0	0.2	0.0	**0.1±0.1**	0.0	0.3	0.0	**0.1±0.2**
21	*Scirpus palustris*	0.0	0.2	0.0	**0.1±0.1**	0.0	0.0	0.0	**0.0±0.0**
22	*Sium latijugam*	0.2	0.5	0.0	**0.2±0.3**	0.0	0.4	0.0	**0.1±0.2**
23	*Sparganium ramosum*	0.4	0.9	0.6	**0.6±0.3**	0.0	0.6	0.4	**0.3±0.3**
24	*Typha angustata*	0.8	1.0	0.6	**0.8±0.2**	0.6	0.8	0.7	**0.7±0.1**
25	*Typha latifolia*	0.4	0.6	0.5	**0.5±0.1**	0.0	0.4	0.0	**0.1±0.2**
	Rooted floating-leaf type								
26	*Hydrocharis dubia*	0.5	0.9	0.7	**0.7±0.2**	0.4	0.7	0.5	**0.5±0.2**
27	*Marsilea quadrifolia*	0.5	0.8	0.6	**0.6±0.2**	0.4	0.6	0.5	**0.5±0.1**
28	*Nymphaea mexicana*	0.3	0.4	0.2	**0.3±0.1**	0.0	0.5	0.4	**0.3±0.3**
29	*Nymphoides peltatum*	1.6	3.6	2.1	**2.4±1.0**	1.3	1.6	1.4	**1.4±0.2**
30	*Potamogeton natans*	0.8	1.4	1.0	**1.1±0.3**	0.4	0.6	0.7	**0.6±0.2**
31	*Trapa natans*	0.6	1.0	0.7	**0.8±0.2**	0.0	0.3	0.2	**0.2±0.2**
	Free-floating								
32	*Azolla* sp.	3.6	5.8	4.2	**4.5±1.1**	0.0	5.6	4.0	**3.2±2.9**
33	*Lemna minor*	7.0	7.8	7.2	**7.3±0.4**	4.6	5.8	5.0	**5.1±0.6**
34	*Salvinia natans*	3.0	5.8	4.0	**4.3±1.4**	2.0	2.6	2.2	**2.3±0.3**
	Submergeds								
35	*Ceratophyllum demersum*	1.4	1.7	1.5	**1.5±0.2**	0	1.1	1.0	**0.7±0.6**

Table 5.2.2.3. Seasonal variations in abundance of macrophytic species at Site I during the study period

S.No	Species	2011				2012			
		Spring	Summer	Autumn	Mean±SD	Spring	Summer	Autumn	Mean±SD
	Emergents								
1	*Alisma lanceolatum*	0.0	3.0	0.0	**1.0±1.7**	0.0	0.0	0.0	**0.0±0.0**
2	*Alisma plantago-aquatica*	0.0	3.0	2.0	**1.7±1.5**	0.0	2.0	2.0	**1.3±1.2**
3	*Bidens cernua*	0.0	3.0	2.0	**1.7±1.5**	0.0	2.0	1.0	**1.0±1.0**
4	*Butomus umbellatus*	0.0	2.0	1.5	**1.2±1.0**	0.0	0.0	0.0	**0.0±0.0**
5	*Carex* sp.	0.0	1.5	2.0	**1.2±1.0**	0.0	1.0	1.0	**0.7±0.6**
6	*Cyperus serotinus*	0.0	1.3	1.7	**1.0±0.9**	0.0	0.0	0.0	**0.0±0.0**
7	*Echinocloa crus-galli*	0.0	2.0	0.0	**0.7±1.2**	0.0	2.5	0.0	**0.8±1.4**
8	*Eleocharis palustris*	0.0	1.3	1.5	**0.9±0.8**	0.0	1.5	1.0	**0.8±0.8**
9	*Hippuris vulgaris*	1.8	0.0	2.3	**1.3±1.2**	1.7	2.3	2.0	**2.0±0.3**
10	*Lycopus europaeus*	2.0	0.0	2.0	**1.3±1.2**	0.0	0.0	0.0	**0.0±0.0**
11	*Mentha arvensis*	1.7	0.0	2.3	**1.3±1.2**	1.5	1.7	2.0	**1.7±0.3**
12	*Myriophyllum aquaticum*	2.3	2.2	2.3	**2.3±0.1**	0.0	0.0	0.0	**0.0±0.0**
13	*Myriophyllum verticillatum*	3.3	3.1	4.0	**3.5±0.5**	2.7	3.0	3.0	**2.9±0.2**
14	*Nasturtium officinalis*	1.5	2.3	0.0	**1.3±1.1**	0.0	2.3	1.3	**1.2±1.2**
15	*Phragmites australis*	3.7	3.8	3.3	**3.6±0.3**	2.3	3.3	2.7	**2.8±0.5**
16	*Polygonum hydropiper*	2.0	2.6	2.5	**2.4±0.3**	3.0	3.0	2.3	**2.8±0.4**
17	*Ranunculus muricatus*	0.0	1.5	1.0	**0.8±0.8**	0.0	0.0	0.0	**0.0±0.0**
18	*Ranunculus sceleratus*	1.5	1.7	2.0	**1.7±0.3**	0.0	1.5	2.0	**1.2±1.0**
19	*Sagittaria sagittifolia*	0.0	2.8	2.7	**1.8±1.6**	0.0	2.3	0.0	**0.8±1.3**
20	*Scirpus lacustris*	0.0	2.0	0.0	**0.7±1.2**	0.0	3.0	0.0	**1.0±1.7**
21	*Scirpus palustris*	0.0	1.0	0.0	**0.3±0.6**	0.0	0.0	0.0	**0.0±0.0**
22	*Sium latijugam*	1.0	1.7	0.0	**0.9±0.8**	0.0	2.0	0.0	**0.7±1.2**
23	*Sparganium ramosum*	1.3	2.3	2.0	**1.9±0.5**	0.0	2.0	2.0	**1.3±1.2**
24	*Typha angustata*	2.7	3.3	2.0	**2.7±0.7**	2.0	2.7	2.3	**2.3±0.3**
25	*Typha latifolia*	1.3	1.5	1.7	**1.5±0.2**	0.0	2.0	0.0	**0.7±1.2**
	Rooted floating-leaf type								
26	*Hydrocharis dubia*	2.5	3.0	2.3	**2.6±0.3**	2.0	2.3	2.5	**2.3±0.3**
27	*Marsilea quadrifolia*	2.5	2.7	2.0	**2.4±0.3**	1.3	2.0	2.5	**1.9±0.6**
28	*Nymphaea mexicana*	1.5	2.0	1.0	**1.5±0.5**	0.0	2.5	2.0	**1.5±1.3**
29	*Nymphoides peltatum*	3.2	6.0	4.2	**4.5±1.4**	3.3	4.0	3.5	**3.6±0.4**
30	*Potamogeton natans*	2.7	3.5	3.3	**3.2±0.4**	2.0	2.0	2.3	**2.1±0.2**
31	*Trapa natans*	2.0	3.3	2.3	**2.6±0.7**	0.0	1.5	1.0	**0.8±0.8**
	Free-floating								
32	*Azolla* sp.	7.2	11.6	10.5	**9.8±2.3**	0.0	14.0	10.0	**8.0±7.2**
33	*Lemna minor*	17.5	19.5	18.0	**18.3±1.0**	15.3	19.3	25.0	**19.9±4.9**
34	*Salvinia natans*	6.0	11.6	8.0	**8.5±2.8**	10.0	13.0	11.0	**11.3±1.5**
	Submergeds								
35	*Ceratophyllum demersum*	4.7	5.7	5.0	**5.1±0.5**	0.0	3.7	3.3	**2.3±2.0**

Table 5.2.2.4. Seasonal variations in IVI of macrophytic species at Site I during the study period

S.No	**Species**	**2011**				**2012**			
		Spring	**Summer**	**Autumn**	**Mean±SD**	**Spring**	**Summer**	**Autumn**	**Mean±SD**
	Emergents								
1	*Alisma lanceolatum*	0.0	7.8	0.0	**2.6±4.5**	0.0	0.0	0.0	**0.0±0.0**
2	*Alisma plantago-aquatica*	0.0	8.7	5.2	**4.7±4.4**	0.0	5.9	5.8	**3.9±3.4**
3	*Bidens cernua*	0.0	6.0	5.9	**4.0±3.5**	0.0	5.2	4.7	**3.3±2.9**
4	*Butomus umbellatus*	0.0	4.1	4.8	**3.0±2.6**	0.0	0.7	0.5	**0.4±0.3**
5	*Carex* sp.	0.0	3.9	4.0	**2.6±2.3**	0.0	3.6	2.9	**2.2±1.9**
6	*Cyperus serotinus*	0.0	4.5	5.5	**3.3±2.9**	0.0	0.7	0.5	**0.4±0.3**
7	*Echinocloa crus-galli*	0.0	6.2	1.5	**2.5±3.2**	0.0	5.0	0.0	**1.7±2.9**
8	*Eleocharis palustris*	0.0	5.6	3.7	**3.1±2.8**	0.0	5.7	2.9	**2.9±2.9**
9	*Hippuris vulgaris*	8.4	0.9	7.4	**5.6±4.1**	13.9	7.2	6.7	**9.2±4.0**
10	*Lycopus europaeus*	6.7	0.0	6.8	**4.5±3.9**	4.0	2.3	2.7	**3.0±0.9**
11	*Mentha arvensis*	7.5	0.0	6.7	**4.7±4.1**	10.1	5.5	5.8	**7.1±2.6**
12	*Myriophyllum aquaticum*	9.5	6.4	8.6	**8.2±1.6**	2.4	1.7	1.8	**2.0±0.4**
13	*Myriophyllum verticillatum*	12.9	11.3	11.0	**11.8±1.0**	16.0	9.4	10.4	**12.0±3.5**
14	*Nasturtium officinalis*	9.8	10.2	4.7	**8.2±3.1**	6.3	9.9	14.0	**10.1±3.8**
15	*Phragmites australis*	10.5	8.7	7.6	**8.9±1.5**	15.3	10.8	10.1	**12.1±2.8**
16	*Polygonum hydropiper*	12.8	9.9	10.6	**11.1±1.5**	18.8	11.5	9.8	**13.4±4.8**
17	*Ranunculus muricatus*	3.0	5.9	6.1	**5.0±1.7**	4.8	3.0	3.2	**3.6±1.0**
18	*Ranunculus sceleratus*	5.0	4.8	4.8	**4.8±0.1**	0.0	4.1	4.0	**2.7±2.3**
19	*Sagittaria sagittifolia*	1.1	7.0	7.1	**5.1±3.4**	0.0	7.2	0.9	**2.7±3.9**
20	*Scirpus lacustris*	0.0	5.0	2.3	**2.4±2.5**	0.0	6.5	0.0	**2.2±3.8**
21	*Scirpus palustris*	0.0	3.1	0.0	**1.0±1.8**	0.0	1.0	0.0	**0.3±0.6**
22	*Sium latijugam*	4.4	4.5	0.0	**3.0±2.6**	0.0	4.5	0.0	**1.5±2.6**
23	*Sparganium ramosum*	7.0	6.6	5.2	**6.3±0.9**	0.0	7.2	5.8	**4.3±3.8**
24	*Typha angustata*	9.5	8.4	5.9	**7.9±1.8**	11.1	9.8	9.7	**10.2±0.8**
25	*Typha latifolia*	9.3	7.0	6.6	**7.6±1.4**	4.8	7.2	3.2	**5.0±2.0**
	Rooted floating-leaf type								
26	*Hydrocharis dubia*	7.8	6.5	7.0	**7.1±0.6**	11.1	7.5	6.4	**8.3±2.5**
27	*Marsilea quadrifolia*	8.2	6.9	7.3	**7.5±0.7**	16.3	9.5	8.6	**11.5±4.2**
28	*Nymphaea mexicana*	6.9	6.1	4.9	**6.0±1.0**	3.2	7.0	8.0	**6.1±2.6**
29	*Nymphoides peltatum*	12.9	11.4	10.2	**11.5±1.4**	17.2	12.1	12.8	**14.0±2.8**
30	*Potamogeton natans*	14.0	14.3	12.7	**13.7±0.8**	21.5	9.9	14.3	**15.2±5.8**
31	*Trapa natans*	8.6	8.5	9.6	**8.9±0.6**	3.2	6.1	7.8	**5.7±2.3**
	Free-floating								
32	*Azolla* sp.	16.3	15.6	20.3	**17.4±2.5**	0.0	18.3	21.1	**13.1±11.5**
33	*Lemna minor*	39.5	32.7	37.1	**36.4±3.5**	42.9	39.8	51.8	**44.8±6.3**
34	*Salvinia natans*	39.9	31.1	34.5	**35.2±4.4**	61.2	35.7	38.7	**45.2±13.9**
	Submergeds								
35	*Ceratophyllum demersum*	23.3	19.1	20.0	**20.8±2.2**	15.9	14.8	20.8	**17.1±3.2**

Table 5.2.2.5. Seasonal variations in frequency (%) of macrophytic species at Site II during the study period

S.No	Species	2011				2012			
		Spring	Summer	Autumn	Mean±SD	Spring	Summer	Autumn	Mean±SD
	Emergents								
1	*Alternanthera philoxeroides*	0.0	20.0	20.0	**13.3±11.5**	0.0	25.0	0.0	**8.3±0.0**
2	*Eleocharis palustris*	0.0	10.0	0.0	**3.3±5.8**	0.0	0.0	0.0	**0.0±0.0**
3	*Myriophyllum aquaticum*	40.0	50.0	40.0	**43.3±5.8**	15.0	25.0	0.0	**13.3±12.6**
4	*Myriophyllum verticillatum*	45.0	50.0	40.0	**45.0±5.0**	35.0	45.0	30.0	**36.7±7.6**
5	*Nasturtium officinalis*	30.0	30.0	0.0	**20.0±17.3**	0.0	25.0	20.0	**15.0±13.2**
6	*Phragmites australis*	25.0	40.0	40.0	**35.0±8.7**	25.0	30.0	30.0	**28.3±2.9**
7	*Polygonum amphibium*	35.0	45.0	40.0	**40.0±5.0**	25.0	30.0	30.0	**28.3±2.9**
8	*Polygonum hydropiper*	30.0	40.0	30.0	**33.3±5.8**	25.0	35.0	40.0	**33.3±7.6**
9	*Ranunculus muricatus*	0.0	20.0	10.0	**10.0±10.0**	0.0	0.0	0.0	**0.0±0.0**
10	*Ranunculus sceleratus*	30.0	0.0	20.0	**16.7±15.3**	0.0	15.0	10.0	**8.3±7.6**
11	*Sium latijugam*	0.0	20.0	20.0	**13.3±11.5**	0.0	15.0	30.0	**15.0±15.0**
12	*Sparganium ramosum*	30.0	0.0	20.0	**16.7±15.3**	0.0	15.0	20.0	**11.7±10.4**
13	*Typha angustata*	30.0	35.0	30.0	**31.7±2.9**	15.0	25.0	30.0	**23.3±7.6**
14	*Typha latifolia*	0.0	30.0	0.0	**10.0±17.3**	0.0	15.0	0.0	**5.0±8.7**
	Rooted-floating leaf type								
15	*Hydrocharis dubia*	30.0	20.0	30.0	**26.7±5.8**	15.0	30.0	30.0	**25.0±8.7**
16	*Marsilea quadrifolia*	20.0	30.0	40.0	**30.0±10.0**	15.0	25.0	30.0	**23.3±7.6**
17	*Nymphaea mexicana*	20.0	20.0	30.0	**23.3±5.8**	15.0	25.0	10.0	**16.7±7.6**
18	*Nymphoides peltatum*	65.0	75.0	60.0	**66.7±7.6**	55.0	50.0	45.0	**50.0±5.0**
19	*Potamogeton natans*	30.0	40.0	30.0	**33.3±5.8**	25.0	30.0	30.0	**28.3±2.9**
20	*Trapa natans*	20.0	35.0	30.0	**28.3±7.6**	25.0	30.0	35.0	**30.0±5.0**
	Free-floating type								
21	*Azolla* sp.	50.0	45.0	50.0	**48.3±2.9**	25.0	30.0	35.0	**30.0±5.0**
22	*Lemna major*	0.0	20.0	20.0	**13.3±11.5**	0.0	0.0	0.0	**0.0±0.0**
23	*Lemna minor*	45.0	30.0	40.0	**38.3±7.6**	25.0	25.0	30.0	**26.7±2.9**
24	*Lemna trisulca*	20.0	30.0	0.0	**16.7±15.3**	0.0	0.0	0.0	**0.0±0.0**
25	*Spirodela polyrhiza*	30.0	30.0	0.0	**20.0±17.3**	0.0	25.0	20.0	**15.0±13.2**
26	*Salvinia natans*	60.0	35.0	45.0	**46.7±12.6**	25.0	30.0	35.0	**30.0±5.0**
	Submergeds								
27	*Ceratophyllum demersum*	40.0	50.0	50.0	**46.7±5.8**	45.00	30.00	40.00	**38.3±7.6**
28	*Myriophyllum spicatum*	0.0	20.0	30.0	**16.7±15.3**	0.00	20.00	0.00	**6.7±11.5**
29	*Potamogeton crispus*	30.0	20.0	30.0	**26.7±5.8**	25.00	30.00	20.00	**25.0±5.0**
30	*Potamogeton lucens*	30.0	20.0	20.0	**23.3±5.8**	25.00	20.00	30.00	**25.0±5.0**

Table 5.2.2.6. Seasonal variations in density (individuals/m^2) of macrophytic species at Site II during the study period

S.No	**Species**	**2011**				**2012**			
		Spring	**Summer**	**Autumn**	**Mean±SD**	**Spring**	**Summer**	**Autumn**	**Mean±SD**
	Emergents								
1	*Alternanthera philoxeroides*	0.0	0.9	0.7	**0.5±0.5**	**0.0**	0.5	0.0	**0.2±0.3**
2	*Eleocharis palustris*	0.0	0.2	0.0	**0.1±0.1**	0.0	0.0	0.0	**0.0±0.0**
3	*Myriophyllum aquaticum*	0.8	1	0.9	**0.9±0.1**	0.4	0.8	0.0	**0.4±0.4**
4	*Myriophyllum verticillatum*	1.5	1.9	1.7	**1.7±0.2**	1.2	1.3	1.1	**1.2±0.1**
5	*Nasturtium officinalis*	0.5	0.7	0.0	**0.4±0.4**	0.0	0.5	0.3	**0.3±0.3**
6	*Phragmites australis*	1.0	1.2	1.1	**1.1±0.1**	0.6	0.8	0.6	**0.7±0.1**
7	*Polygonum amphibium*	0.8	1.1	1.0	**1.0±0.2**	0.5	0.7	0.5	**0.6±0.1**
8	*Polygonum hydropiper*	0.7	1.2	1.0	**1.0±0.3**	0.6	0.9	0.7	**0.7±0.2**
9	*Ranunculus muricatus*	0.0	0.4	0.2	**0.2±0.2**	0.0	0.0	0.0	**0.0±0.0**
10	*Ranunculus sceleratus*	0.4	0.0	0.4	**0.3±0.2**	0.0	0.4	0.2	**0.2±0.2**
11	*Sium latijugam*	0.0	0.3	0.2	**0.2±0.2**	0.0	0.2	0.4	**0.2±0.2**
12	*Sparganium ramosum*	0.4	0.0	0.3	**0.2±0.2**	0.0	0.3	0.2	**0.2±0.2**
13	*Typha angustata*	0.8	1.1	0.9	**0.9±0.2**	0.5	0.7	0.5	**0.6±0.1**
14	*Typha latifolia*	0.0	0.5	0.0	**0.2±0.3**	0.0	0.3	0.0	**0.1±0.2**
	Rooted-floating leaf type								
15	*Hydrocharis dubia*	0.5	0.8	0.6	**0.6±0.2**	0.4	0.8	0.6	**0.6±0.2**
16	*Marsilea quadrifolia*	0.4	0.8	0.9	**0.7±0.3**	0.3	0.6	0.5	**0.5±0.2**
17	*Nymphaea mexicana*	0.5	0.7	0.6	**0.6±0.1**	0.3	0.5	0.2	**0.3±0.2**
18	*Nymphoides peltatum*	4.8	5.2	4.5	**4.8±0.4**	2.4	3.0	2.5	**2.6±0.3**
19	*Potamogeton natans*	1.2	1.5	1.1	**1.3±0.2**	0.7	0.9	0.6	**0.7±0.2**
20	*Trapa natans*	0.8	1.1	0.9	**0.9±0.2**	0.6	0.7	0.5	**0.6±0.1**
	Free-floating type								
21	*Azolla* sp.	4.4	5.8	5.4	**5.2±0.7**	3.0	4.6	3.6	**3.7±0.8**
22	*Lemna major*	0.0	2.2	19.0	**7.1±10.4**	0.0	0.0	0.0	**0.0±0.0**
23	*Lemna minor*	8.0	6.6	8.6	**7.7±1.0**	5.8	7.4	6.6	**6.6±0.8**
24	*Lemna trisulca*	1.0	1.3	0.0	**0.8±0.7**	0.0	0.0	0.0	**0.0±0.0**
25	*Spirodela polyrhiza*	0.9	1.3	0.0	**0.7±0.7**	0.0	1.2	1.0	**0.7±0.6**
26	*Salvinia natans*	4.0	4.6	4.2	**4.3±0.3**	3.0	3.8	3.6	**3.5±0.4**
	Submergeds								
27	*Ceratophyllum demersum*	2.9	3.5	3.1	**3.2±0.3**	2.5	2.6	2.3	**2.5±0.2**
28	*Myriophyllum spicatum*	0.0	0.5	0.4	**0.3±0.3**	0.0	0.4	0.0	**0.1±0.2**
29	*Potamogeton crispus*	0.8	1.1	1.2	**1.0±0.2**	0.9	1.0	0.7	**0.9±0.2**
30	*Potamogeton lucens*	0.4	0.6	0.5	**0.5±0.1**	0.6	0.8	0.6	**0.7±0.1**

Table 5.2.2.7. Seasonal variations in abundance of macrophytic species at Site II during the study period

S.No	Species	2011				2012			
		Spring	Summer	Autumn	Mean±SD	Spring	Summer	Autumn	Mean±SD
	Emergents								
1	*Alternanthera philoxeroides*	0.0	4.5	3.5	**2.7±2.4**	0.0	2.5	0.0	**0.8±1.4**
2	*Eleocharis palustris*	0.0	2.0	0.0	**0.7±1.2**	0.0	0.0	0.0	**0.0±0.0**
3	*Myriophyllum aquaticum*	2.0	2.0	2.3	**2.1±0.1**	2.0	2.7	0.0	**1.6±1.4**
4	*Myriophyllum verticillatum*	3.0	3.8	4.3	**3.7±0.6**	3.0	3.3	3.7	**3.3±0.3**
5	*Nasturtium officinalis*	1.7	2.3	0.0	**1.3±1.2**	0.0	1.7	1.5	**1.1±0.9**
6	*Phragmites australis*	2.5	3.0	2.8	**2.8±0.3**	2.0	2.7	2.0	**2.2±0.4**
7	*Polygonum amphibium*	2.0	2.8	2.5	**2.4±0.4**	1.7	2.3	1.7	**1.9±0.4**
8	*Polygonum hydropiper*	2.3	3.0	3.3	**2.9±0.5**	2.0	3.0	1.8	**2.3±0.7**
9	*Ranunculus muricatus*	0.0	2.0	2.0	**1.3±1.2**	0.0	0.0	0.0	**0.0±0.0**
10	*Ranunculus sceleratus*	1.3	0.0	2.0	**1.1±1.0**	0.0	2.0	2.0	**1.3±1.2**
11	*Sium latijugam*	0.0	1.5	1.0	**0.8±0.8**	0.0	1.0	1.3	**0.8±0.7**
12	*Sparganium ramosum*	1.3	0.0	1.5	**0.9±0.8**	0.0	1.5	1.0	**0.8±0.8**
13	*Typha angustata*	2.7	3.7	3.0	**3.1±0.5**	2.5	2.3	1.7	**2.2±0.4**
14	*Typha latifolia*	0.0	1.7	0.0	**0.6±1.0**	0.0	1.5	0.0	**0.5±0.9**
	Rooted-floating leaf type								
15	*Hydrocharis dubia*	1.7	4.0	2.0	**2.6±1.3**	2.0	2.7	2.0	**2.2±0.4**
16	*Marsilea quadrifolia*	2.0	2.7	2.3	**2.3±0.3**	1.5	2.0	1.7	**1.7±0.3**
17	*Nymphaea mexicana*	2.5	3.5	2.0	**2.7±0.8**	1.5	1.7	2.0	**1.7±0.3**
18	*Nymphoides peltatum*	6.9	7.4	7.5	**7.3±0.4**	4.0	6.0	5.0	**5.0±1.0**
19	*Potamogeton natans*	4.0	3.8	3.7	**3.8±0.2**	2.3	3.0	2.0	**2.4±0.5**
20	*Trapa natans*	2.7	3.7	3.0	**3.1±0.5**	2.0	2.3	1.7	**2.0±0.3**
	Free-floating type								
21	*Azolla* sp.	8.8	11.6	10.8	**10.4±1.4**	10.0	15.3	12.0	**12.4±2.7**
22	*Lemna major*	0.0	11.0	9.5	**6.8±6.0**	0.0	0.0	0.0	**0.0±0.0**
23	*Lemna minor*	20.0	22.0	21.5	**21.2±1.0**	19.3	24.7	22.0	**22.0±2.7**
24	*Lemna trisulca*	5.0	4.3	0.0	**3.1±2.7**	0.0	0.0	0.0	**0.0±0.0**
25	*Spirodela polyrhiza*	3.0	4.3	0.0	**2.4±2.2**	0.0	3.0	5.0	**2.7±2.5**
26	*Salvinia natans*	8.0	9.2	10.5	**9.2±1.3**	10.0	12.7	12.0	**11.6±1.4**
	Submergeds								
27	*Ceratophyllum demersum*	7.3	7.0	6.2	**6.8±0.5**	5.0	6.5	5.8	**5.8±0.8**
28	*Myriophyllum spicatum*	0.0	2.5	1.3	**1.3±1.3**	0.0	2.0	0.0	**0.7±1.2**
29	*Potamogeton crispus*	2.7	5.5	4.0	**4.1±1.4**	3.0	3.3	3.5	**3.3±0.3**
30	*Potamogeton lucens*	1.3	3.0	2.5	**2.3±0.9**	2.0	4.0	2.0	**2.7±1.2**

Table 5.2.2.8. Seasonal variations in IVI of macrophytic species at Site II during the study period

S.No	**Species**	**2011**				**2012**			
		Spring	**Summer**	**Autumn**	**Mean±SD**	**Spring**	**Summer**	**Autumn**	**Mean±SD**
	Emergents								
1	*Alternanthera philoxeroides*	0.0	7.5	6.8	**4.8±4.1**	0.0	48.9	0.0	**16.3±28.2**
2	*Eleocharis palustris*	0.0	3.0	0.0	**1.0±1.7**	0.0	0.0	0.0	**0.0±0.0**
3	*Myriophyllum aquaticum*	9.3	9.5	8.6	**9.2±0.5**	66.0	50.2	0.0	**38.7±34.5**
4	*Myriophyllum verticillatum*	12.9	12.4	11.6	**12.3±0.6**	152.9	88.1	115.8	**118.9±32.5**
5	*Nasturtium officinalis*	6.9	6.5	0.0	**4.5±3.9**	0.0	48.2	74.6	**40.9±37.8**
6	*Phragmites australis*	8.5	9.2	9.3	**9.0±0.4**	108.0	59.0	112.2	**93.1±29.6**
7	*Polygonum amphibium*	8.7	9.3	8.9	**9.0±0.3**	107.1	58.4	111.5	**92.3±29.5**
8	*Polygonum hydropiper*	8.2	9.2	8.4	**8.6±0.5**	108.0	68.6	148.3	**108.3±39.8**
9	*Ranunculus muricatus*	0.0	4.5	3.4	**2.6±2.4**	0.0	0.0	0.0	**0.0±0.0**
10	*Ranunculus sceleratus*	6.3	0.0	4.9	**3.7±3.3**	0.0	30.1	38.8	**23.0±20.4**
11	*Sium latijugam*	0.0	4.0	3.7	**2.6±2.2**	0.0	28.6	110.8	**46.5±57.5**
12	*Sparganium ramosum*	6.3	0.0	4.3	**3.5±3.2**	0.0	29.4	73.7	**34.4±37.1**
13	*Typha angustata*	8.8	8.9	7.9	**8.5±0.5**	67.1	49.3	111.5	**76.0±32.0**
14	*Typha latifolia*	0.0	5.6	0.0	**1.9±3.2**	0.0	29.4	0.0	**9.8±16.9**
	Rooted-floating leaf type								
15	*Hydrocharis dubia*	6.9	6.9	6.5	**6.8±0.2**	66.0	59.0	112.2	**79.1±28.9**
16	*Marsilea quadrifolia*	5.7	7.0	8.5	**7.1±1.4**	64.9	48.8	111.5	**75.1±32.6**
17	*Nymphaea mexicana*	6.5	6.3	6.5	**6.4±0.1**	64.9	48.2	38.8	**50.7±13.2**
18	*Nymphoides peltatum*	28.3	24.8	21.8	**25.0±3.3**	241.5	104.4	176.2	**174.0±68.6**
19	*Potamogeton natans*	11.3	10.4	8.8	**10.2±1.2**	108.8	59.6	112.2	**93.5±29.5**
20	*Trapa natans*	7.5	8.9	7.9	**8.1±0.7**	108.0	58.4	129.5	**98.6±36.5**
	Free-floating type								
21	*Azolla* sp.	27.4	25.9	25.0	**26.1±1.2**	128.4	81.0	151.7	**120.4±36.1**
22	*Lemna major*	0.0	15.1	43.4	**19.5±22.0**	0.0	0.0	0.0	**0.0±0.0**
23	*Lemna minor*	48.2	33.8	38.9	**40.3±7.3**	152.3	88.1	155.3	**131.9±37.9**
24	*Lemna trisulca*	10.5	9.3	0.0	**6.6±5.7**	0.0	0.0	0.0	**0.0±0.0**
25	*Spirodela polyrhiza*	9.4	9.3	0.0	**6.2±5.4**	0.0	51.4	80.9	**44.1±40.9**
26	*Salvinia natans*	26.8	20.5	22.1	**23.1±3.3**	128.4	76.3	151.7	**118.8±38.6**
	Submergeds								
27	*Ceratophyllum demersum*	20.5	18.2	17.0	**18.6±1.8**	202.1	67.5	158.3	**142.6±68.7**
28	*Myriophyllum spicatum*	0.0	5.1	5.6	**3.6±3.1**	0.0	39.1	0.0	**13.0±22.6**
29	*Potamogeton crispus*	8.8	8.7	9.3	**8.9±0.4**	110.5	60.1	78.2	**83.0±25.5**
30	*Potamogeton lucens*	6.3	5.7	5.6	**5.9±0.4**	108.0	42.0	112.2	**87.4±39.4**

Table 5.2.2.9. Seasonal variations in frequency (%) of macrophytic species at Site III during the study period

S.No	**Species**	**2011**				**2012**			
		Spring	**Summer**	**Autumn**	**Mean±SD**	**Spring**	**Summer**	**Autumn**	**Mean±SD**
	Emergents								
1	*Eleocharis palustris*	0.0	0.0	30.0	**10.0±17.3**	0.0	0.0	0.0	**0.0±0.0**
2	*Myriophyllum verticillatum*	40.0	50.0	40.0	**43.3±5.8**	40.0	40.0	30.0	**36.7±5.8**
3	*Phragmites australis*	40.0	50.0	40.0	**43.3±5.8**	30.0	40.0	30.0	**33.3±5.8**
4	*Polygonum amphibium*	30.0	30.0	40.0	**33.3±5.8**	20.0	30.0	20.0	**23.3±5.8**
5	*Polygonum hydropiper*	30.0	30.0	40.0	**33.3±5.8**	20.0	30.0	20.0	**23.3±5.8**
6	*Typha angustata*	20.0	30.0	40.0	**30.0±10.0**	20.0	30.0	20.0	**23.3±5.8**
7	*Typha latifolia*	0.0	10.0	0.0	**3.3±5.8**	0.0	0.0	0.0	**0.0±0.0**
	Rooted-floating leaf type								
8	*Hydrocharis dubia*	20.0	40.0	40.0	**33.3±11.5**	20.0	40.0	20.0	**26.7±11.5**
9	*Marsilea quadrifolia*	20.0	30.0	50.0	**33.3±15.3**	30.0	20.0	40.0	**30.0±10.0**
10	*Nymphaea alba*	20.0	30.0	20.0	**23.3±5.8**	0.0	20.0	20.0	**13.3±11.5**
11	*Nymphaea mexicana*	30.0	40.0	30.0	**33.3±5.8**	20.0	30.0	20.0	**23.3±5.8**
12	*Nymphaea pygmea*	0.0	30.0	0.0	**10.0±17.3**	0.0	30.0	30.0	**20.0±17.3**
13	*Nymphoides peltatum*	40.0	70.0	50.0	**53.3±15.3**	50.0	60.0	40.0	**50.0±10.0**
14	*Potamogeton natans*	30.0	40.0	30.0	**33.3±5.8**	30.0	30.0	20.0	**26.7±5.8**
15	*Trapa bispinosa*	0.0	30.0	0.0	**10.0±17.3**	0.0	20.0	0.0	**6.7±11.5**
16	*Trapa natans*	30.0	50.0	30.0	**36.7±11.5**	20.0	40.0	20.0	**26.7±11.5**
	Free-floating type								
17	*Azolla* sp.	40.0	40.0	30.0	**36.7±5.8**	30.0	20.0	20.0	**23.3±5.8**
18	*Lemna minor*	40.0	20.0	30.0	**30.0±10.0**	20.0	40.0	20.0	**26.7±11.5**
19	*Salvinia natans*	30.0	40.0	30.0	**33.3±5.8**	10.0	30.0	20.0	**20.0±10.0**
	Submergeds								
20	*Ceratophyllum demersum*	40.0	30.0	30.0	**33.3±5.8**	40.0	20.0	30.0	**30.0±10.0**
21	*Potamogeton crispus*	20.0	30.0	40.0	**30.0±10.0**	20.0	30.0	20.0	**23.3±5.8**

Table 5.2.2.10. Seasonal variations in density (individuals/m^2) of macrophytic species at Site III during the study period

S.No	**Species**	**2011**				**2012**			
		Spring	**Summer**	**Autumn**	**Mean±SD**	**Spring**	**Summer**	**Autumn**	**Mean±SD**
	Emergents								
1	*Eleocharis palustris*	0	0.0	0.4	**0.1±0.2**	0.0	0.0	0.0	**0.0±0.0**
2	*Myriophyllum verticillatum*	1.2	1.5	1.3	**1.3±0.2**	1.0	1.4	1.2	**1.2±0.2**
3	*Phragmites australis*	0.9	1.2	0.9	**1.0±0.2**	0.7	0.9	0.6	**0.7±0.2**
4	*Polygonum amphibium*	0.8	1.0	0.7	**0.8±0.2**	0.4	0.6	0.3	**0.4±0.2**
5	*Polygonum hydropiper*	0.5	0.8	0.6	**0.6±0.2**	0.3	0.6	0.4	**0.4±0.2**
6	*Typha angustata*	0.5	0.9	0.7	**0.7±0.2**	0.3	0.5	0.3	**0.4±0.1**
7	*Typha latifolia*	0	0.3	0.0	**0.1±0.2**	0.0	0.0	0.0	**0.0±0.0**
	Rooted-floating leaf type								
8	*Hydrocharis dubia*	0.6	0.8	0.6	**0.7±0.1**	0.5	0.7	0.5	**0.6±0.1**
9	*Marsilea quadrifolia*	0.8	1.1	1.2	**1.0±0.2**	0.5	0.8	0.6	**0.6±0.2**
10	*Nymphaea alba*	0.3	0.5	0.4	**0.4±0.1**	0.0	0.3	0.4	**0.2±0.2**
11	*Nymphaea mexicana*	0.5	0.7	0.6	**0.6±0.1**	0.3	0.5	0.3	**0.4±0.1**
12	*Nymphaea pygmea*	0.0	0.6	0.0	**0.2±0.3**	0.0	0.4	0.3	**0.2±0.2**
13	*Nymphoides peltatum*	3.1	3.4	3.2	**3.2±0.2**	2.4	3.1	2.6	**2.7±0.4**
14	*Potamogeton natans*	0.9	1.1	0.9	**1.0±0.1**	0.7	1.0	0.6	**0.8±0.2**
15	*Trapa bispinosa*	0.0	0.4	0.0	**0.1±0.2**	0.0	0.3	0.0	**0.1±0.2**
16	*Trapa natans*	0.8	1.1	0.8	**0.9±0.2**	0.6	0.8	0.5	**0.6±0.2**
	Free-floating type								
17	*Azolla* sp.	4.2	5.2	4.4	**4.6±0.5**	3.2	4.4	4.0	**3.9±0.6**
18	*Lemna minor*	6.0	4.2	4.0	**4.7±1.1**	6.2	7.2	5.4	**6.3±0.9**
19	*Salvinia natans*	3.0	3.8	3.0	**3.3±0.5**	2.6	3.2	2.6	**2.8±0.3**
	Submergeds								
20	*Ceratophyllum demersum*	1.8	2.6	2.1	**2.2±0.4**	1.6	2.0	1.7	**1.8±0.2**
21	*Potamogeton crispus*	0.6	0.8	0.9	**0.8±0.2**	0.7	1.0	0.8	**0.8±0.2**

Table 5.2.2.11. Seasonal variations in abundance of macrophytic species at Site III during the study period

S.No	**Species**	**2011**				**2012**			
		Spring	**Summer**	**Autumn**	**Mean±SD**	**Spring**	**Summer**	**Autumn**	**Mean±SD**
	Emergents								
1	*Eleocharis palustris*	0.0	0.0	1.3	**0.4±0.8**	0.0	0.0	0.0	**0.0±0.0**
2	*Myriophyllum verticillatum*	3.0	3.0	2.6	**2.9±0.2**	2.5	3.5	4.0	**3.3±0.8**
3	*Phragmites australis*	2.3	3.0	3.0	**2.8±0.4**	2.3	2.3	2.0	**2.2±0.2**
4	*Polygonum amphibium*	2.7	3.3	2.3	**2.8±0.5**	2.0	2.0	1.5	**1.8±0.3**
5	*Polygonum hydropiper*	1.7	2.7	2.0	**2.1±0.5**	1.5	2.0	2.0	**1.8±0.3**
6	*Typha angustata*	2.5	4.5	2.3	**3.1±1.2**	1.5	1.7	1.5	**1.6±0.1**
7	*Typha latifolia*	0.0	1.5	0.0	**0.5±0.9**	0.0	0.0	0.0	**0.0±0.0**
	Rooted-floating leaf type								
8	*Hydrocharis dubia*	2.0	2.7	2.0	**2.2±0.4**	1.7	2.3	2.5	**2.2±0.4**
9	*Marsilea quadrifolia*	2.7	3.7	3.0	**3.1±0.5**	1.7	2.7	2.0	**2.1±0.5**
10	*Nymphaea alba*	1.5	2.5	2.0	**2.0±0.5**	0.0	1.5	2.0	**1.2±1.0**
11	*Nymphaea mexicana*	1.7	2.3	2.0	**2.0±0.3**	1.5	1.7	1.5	**1.6±0.1**
12	*Nymphaea pygmea*	0.0	2.0	0.0	**0.7±1.2**	0.0	1.3	1.0	**0.8±0.7**
13	*Nymphoides peltatum*	6.2	6.8	6.4	**6.5±0.3**	4.8	5.2	6.5	**5.5±0.9**
14	*Potamogeton natans*	3.0	3.7	3.0	**3.2±0.4**	2.3	3.3	3.0	**2.9±0.5**
15	*Trapa bispinosa*	0.0	1.3	0.0	**0.4±0.8**	0.0	1.5	0.0	**0.5±0.9**
16	*Trapa natans*	2.7	2.2	2.7	**2.5±0.3**	2.0	2.7	2.5	**2.4±0.3**
	Free-floating type								
17	*Azolla* sp.	10.5	13.0	14.7	**12.7±2.1**	16.0	22.0	20.0	**19.3±3.1**
18	*Lemna minor*	15.0	21.0	13.3	**16.4±4.0**	20.7	24.0	27.0	**23.9±3.2**
19	*Salvinia natans*	10.0	9.5	10.0	**9.8±0.3**	13.0	16.0	13.0	**14.0±1.7**
	Submergeds								
20	*Ceratophyllum demersum*	6.0	6.5	7.0	**6.5±0.5**	5.3	6.7	5.7	**5.9±0.7**
21	*Potamogeton crispus*	2.0	2.7	4.5	**3.1±1.3**	2.3	3.3	4.0	**3.2±0.8**

Table 5.2.2.12. Seasonal variations in IVI of macrophytic species at Site III during the study period

S.No	Species	2011				2012			
		Spring	Summer	Autumn	Mean±SD	Spring	Summer	Autumn	Mean±SD
	Emergents								
1	*Eleocharis palustris*	0.0	0.0	7.8	**2.6±4.5**	0.0	0.0	0.0	**0.0±0.0**
2	*Myriophyllum verticillatum*	0.0	0.0	7.8	**2.6±4.5**	0.0	0.0	0.0	**0.0±0.0**
3	*Phragmites australis*	16.2	14.7	14.2	**15.0±1.0**	17.2	14.7	15.9	**15.9±1.2**
4	*Polygonum amphibium*	14.1	13.8	13.2	**13.7±0.5**	13.2	11.8	11.4	**12.1±0.9**
5	*Polygonum hydropiper*	12.3	10.7	11.6	**11.6±0.8**	9.0	8.9	7.3	**8.4±1.0**
6	*Typha angustata*	9.9	9.4	10.9	**10.0±0.8**	8.0	8.9	8.2	**8.4±0.5**
7	*Typha latifolia*	9.1	11.6	11.6	**10.8±1.5**	8.0	8.3	7.3	**7.9±0.5**
	Rooted-floating leaf type								
8	*Hydrocharis dubia*	0.0	3.9	0.0	**1.3±2.2**	0.0	0.0	0.0	**0.0±0.0**
9	*Marsilea quadrifolia*	8.8	10.8	10.9	**10.1±1.2**	9.1	11.2	9.2	**9.8±1.2**
10	*Nymphaea alba*	10.4	11.3	15.9	**12.5±2.9**	11.5	8.5	13.7	**11.2±2.6**
11	*Nymphaea mexicana*	7.0	8.3	7.0	**7.4±0.8**	0.0	5.8	8.2	**4.7±4.2**
12	*Nymphaea pygmea*	9.9	10.1	9.3	**9.8±0.4**	8.0	8.3	7.3	**7.9±0.5**
13	*Nymphoides peltatum*	0.0	8.1	0.0	**2.7±4.7**	0.0	7.6	9.1	**5.6±4.9**
14	*Potamogeton natans*	27.6	27.3	27.4	**27.4±0.2**	28.7	25.3	26.7	**26.9±1.7**
15	*Trapa bispinosa*	13.2	12.7	11.6	**12.5±0.8**	13.2	11.5	10.1	**11.6±1.6**
16	*Trapa natans*	0.0	6.8	0.0	**2.3±3.9**	0.0	5.8	0.0	**1.9±3.3**
	Free-floating type								
17	*Azolla* sp.	12.3	12.6	10.8	**11.9±1.0**	10.0	11.9	9.2	**10.3±1.4**
18	*Lemna minor*	37.5	35.1	38.6	**37.1±1.8**	41.4	39.0	41.5	**40.6±1.4**
19	*Salvinia natans*	50.3	37.4	35.5	**41.1±8.0**	58.4	53.7	54.5	**55.5±2.5**
	Submergeds								
20	*Ceratophyllum demersum*	30.4	27.1	27.8	**28.4±1.7**	30.2	30.9	28.6	**29.9±1.2**
21	*Potamogeton crispus*	22.5	18.9	20.9	**20.8±1.8**	23.4	16.4	19.7	**19.8±3.5**

Table 5.2.2.13. Seasonal variations in frequency (%) of macrophytic species at Site IV during the study period

S.No	**Species**	**2011**				**2012**			
		Spring	**Summer**	**Autumn**	**Mean±SD**	**Spring**	**Summer**	**Autumn**	**Mean±SD**
	Emergents								
1	*Myriophyllum verticillatum*	20.0	30.0	30.0	**26.7±5.8**	30.0	30.0	20.0	**26.7±5.8**
2	*Polygonum amphibium*	10.0	30.0	40.0	**26.7±15.3**	20.0	30.0	20.0	**23.3±5.8**
3	*Polygonum hydropiper*	30.0	40.0	30.0	**33.3±5.8**	20.0	30.0	30.0	**26.7±5.8**
4	*Typha angustata*	20.0	10.0	30.0	**20.0±10.0**	0.0	20.0	20.0	**13.3±11.5**
	Rooted-floating leaf type								
5	*Hydrocharis dubia*	40.0	20.0	30.0	**30.0±10.0**	30.0	20.0	40.0	**30.0±10.0**
6	*Marsilea quadrifolia*	10.0	20.0	30.0	**20.0±10.0**	20.0	30.0	30.0	**26.7±5.8**
7	*Nymphoides peltatum*	50.0	60.0	50.0	**53.3±5.8**	30.0	50.0	50.0	**43.3±11.5**
8	*Potamogeton natans*	20.0	40.0	20.0	**26.7±11.5**	30.0	40.0	30.0	**33.3±5.8**
9	*Trapa natans*	30.0	40.0	30.0	**33.3±5.8**	20.0	30.0	30.0	**26.7±5.8**
	Free-floating type								
10	*Azolla* sp.	40.0	50.0	40.0	**43.3±5.8**	0.0	30.0	20.0	**16.7±15.3**
11	*Lemna major*	0.0	30.0	30.0	**20.0±17.3**	0.0	0.0	0.0	**0.0±0.0**
12	*Lemna minor*	30.0	40.0	30.0	**33.3±5.8**	20.0	10.0	30.0	**20.0±10.0**
13	*Spirodela polyrhiza*	0.0	30.0	0.0	**10.0±17.3**	0.0	20.0	0.0	**6.7±11.5**
14	*Salvinia natans*	30.0	40.0	30.0	**33.3±5.8**	0.0	30.0	20.0	**16.7±15.3**
	Submergeds								
15	*Ceratophyllum demersum*	40.0	50.0	50.0	**46.7±5.8**	40.0	50.0	40.0	**43.3±5.8**
16	*Hydrilla verticillata*	0.0	40.0	20.0	**20.0±20.0**	30.0	30.0	20.0	**26.7±5.8**
17	*Potamogeton crispus*	10.0	20.0	30.0	**20.0±10.0**	30.0	40.0	40.0	**36.7±5.8**
18	*Potamogeton lucens*	30.0	0.0	30.0	**20.0±17.3**	30.0	30.0	20.0	**26.7±5.8**

Table 5.2.2.14. Seasonal variations in density (individuals/m^2) of macrophytic species at Site IV during the study period

S.No	Species	2011				2012			
		Spring	Summer	Autumn	Mean±SD	Spring	Summer	Autumn	Mean±SD
	Emergents								
1	*Myriophyllum verticillatum*	0.8	1.3	1	**1.0±0.3**	0.6	0.8	0.6	**0.7±0.1**
2	*Polygonum amphibium*	0.8	1	0.8	**0.9±0.1**	0.6	0.8	0.5	**0.6±0.2**
3	*Polygonum hydropiper*	0.6	0.9	0.7	**0.7±0.2**	0.5	0.7	0.6	**0.6±0.1**
4	*Typha angustata*	0.4	0.6	0.5	**0.5±0.1**	0.0	0.4	0.3	**0.2±0.2**
	Rooted-floating leaf type								
5	*Hydrocharis dubia*	0.5	0.7	0.6	**0.6±0.1**	0.5	0.7	0.6	**0.6±0.1**
6	*Marsilea quadrifolia*	0.7	0.8	0.5	**0.7±0.2**	0.5	0.7	0.5	**0.6±0.1**
7	*Nymphoides peltatum*	2.1	3.2	2.8	**2.7±0.6**	1.9	2.3	2	**2.1±0.2**
8	*Potamogeton natans*	1.2	1.2	0.8	**1.1±0.2**	0.8	1.0	0.9	**0.9±0.1**
9	*Trapa natans*	0.8	1.2	0.8	**0.9±0.2**	0.6	0.7	0.5	**0.6±0.1**
	Free-floating type								
10	*Azolla* sp.	4.0	6.6	5.6	**5.4±1.3**	0.0	5.0	4.2	**3.1±2.7**
11	*Lemna major*	0.0	4.0	0.0	**1.3±2.3**	0.0	0.0	0	**0.0±0.0**
12	*Lemna minor*	5.0	6.0	5.0	**5.3±0.6**	4.4	5.6	4.2	**4.7±0.8**
13	*Spirodela polyrhiza*	0.0	1.1	0.0	**0.4±0.6**	0.0	0.9	0	**0.3±0.5**
14	*Salvinia natans*	1.8	2.8	2.4	**2.3±0.5**	0.0	2.4	2	**1.5±1.3**
	Submergeds								
15	*Ceratophyllum demersum*	2.1	3.5	2.9	**2.8±0.7**	2.6	3.4	2.7	**2.9±0.4**
16	*Hydrilla verticillata*	0.0	1.6	1.3	**1.0±0.9**	1.3	1.5	0.6	**1.1±0.5**
17	*Potamogeton crispus*	0.6	0.9	0.6	**0.7±0.2**	1.0	1.3	0.9	**1.1±0.2**
18	*Potamogeton lucens*	0.5	0.0	0.6	**0.4±0.3**	0.6	0.9	0.5	**0.7±0.2**

Table 5.2.2.15. Seasonal variations in abundance of macrophytic species at Site IV during the study period

S.No	Species	2011				2012			
		Spring	Summer	Autumn	Mean±SD	Spring	Summer	Autumn	Mean±SD
	Emergents								
1	*Myriophyllum verticillatum*	4.0	4.3	3.3	**3.9±0.5**	2.0	2.7	3.0	**2.6±0.5**
2	*Polygonum amphibium*	2.7	3.3	2.7	**2.9±0.4**	3.0	2.7	2.5	**2.7±0.3**
3	*Polygonum hydropiper*	2.0	2.3	2.3	**2.2±0.2**	2.5	2.3	2.0	**2.3±0.3**
4	*Typha angustata*	2.0	3.0	2.5	**2.5±0.5**	0.0	2.0	1.5	**1.2±1.0**
	Rooted-floating leaf type								
5	*Hydrocharis dubia*	2.5	2.3	2.0	**2.3±0.3**	1.7	2.3	2.0	**2.0±0.3**
6	*Marsilea quadrifolia*	3.5	4.0	2.5	**3.3±0.8**	2.5	2.3	1.7	**2.2±0.4**
7	*Nymphoides peltatum*	4.2	5.3	5.6	**5.0±0.7**	4.8	5.8	4.0	**4.8±0.9**
8	*Potamogeton natans*	4.0	4.0	2.7	**3.6±0.8**	2.7	2.5	3.0	**2.7±0.3**
9	*Trapa natans*	2.7	3.0	2.7	**2.8±0.2**	2.0	2.3	1.7	**2.0±0.3**
	Free-floating type								
10	*Azolla* sp.	10.0	13.2	14.0	**12.4±2.1**	0.0	16.7	21.0	**12.6±11.1**
11	*Lemna major*	0.0	13.3	0.0	**4.4±7.7**	0.0	0.0	0.0	**0.0±0.0**
12	*Lemna minor*	16.7	15.0	16.7	**16.1±1.0**	22.0	28.0	21.0	**23.7±3.8**
13	*Spirodela polyrhiza*	0.0	3.7	0.0	**1.2±2.1**	0.0	4.5	0.0	**1.5±2.6**
14	*Salvinia natans*	6.0	7.0	8.0	**7.0±1.0**	0.0	8.0	10.0	**6.0±5.3**
	Submergeds								
15	*Ceratophyllum demersum*	5.3	7.0	5.8	**6.0±0.9**	6.5	6.8	6.8	**6.7±0.2**
16	*Hydrilla verticillata*	0.0	4.0	3.3	**2.4±2.1**	3.3	5.0	3.0	**3.8±1.1**
17	*Potamogeton crispus*	3.0	4.5	3.0	**3.5±0.9**	3.3	3.3	2.3	**2.9±0.6**
18	*Potamogeton lucens*	1.7	0.0	2.0	**1.2±1.1**	2.0	3.0	2.5	**2.5±0.5**

Table 5.2.2.16. Seasonal variations in IVI of macrophytic species at Site IV during the study period

S.No	**Species**	**2011**				**2012**			
		Spring	**Summer**	**Autumn**	**Mean±SD**	**Spring**	**Summer**	**Autumn**	**Mean±SD**
	Emergents								
1	*Myriophyllum verticillatum*	14.2	12.9	13.4	**13.5±0.7**	13.0	9.8	6.2	**9.6±3.4**
2	*Polygonum amphibium*	9.9	11.1	13.6	**11.5±1.9**	14.7	9.8	5.2	**9.9±4.8**
3	*Polygonum hydropiper*	12.9	11.5	11.0	**11.8±1.0**	13.2	11.3	5.1	**9.8±4.3**
4	*Typha angustata*	9.6	6.3	10.5	**8.8±2.2**	3.8	7.7	3.1	**4.9±2.5**
	Rooted-floating leaf type								
5	*Hydrocharis dubia*	15.6	7.6	10.2	**11.1±4.1**	9.8	13.4	5.1	**9.4±4.2**
6	*Marsilea quadrifolia*	10.6	9.6	10.5	**10.2±0.6**	13.2	11.3	4.2	**9.6±4.7**
7	*Nymphoides peltatum*	27.8	24.1	26.6	**26.2±1.9**	29.7	24.5	13.8	**22.7±8.1**
8	*Potamogeton natans*	16.1	14.0	10.0	**13.4±3.1**	17.3	12.5	7.6	**12.4±4.9**
9	*Trapa natans*	14.8	13.0	11.8	**13.2±1.5**	13.0	11.3	4.2	**9.5±4.6**
	Free-floating type								
10	*Azolla* sp.	42.3	39.4	45.8	**42.5±3.2**	5.8	38.2	43.4	**29.1±20.4**
11	*Lemna major*	0.0	29.2	5.5	**11.6±15.5**	0.0	0.0	0.0	**0.0±0.0**
12	*Lemna minor*	53.9	37.9	45.1	**45.7±8.0**	67.4	53.7	43.4	**54.8±12.1**
13	*Spirodela polyrhiza*	0.0	11.7	0.0	**3.9±6.8**	3.8	7.6	0.0	**3.8±3.8**
14	*Salvinia natans*	24.1	21.3	24.5	**23.3±1.7**	5.8	20.6	20.6	**15.7±8.6**
	Submergeds								
15	*Ceratophyllum demersum*	26.8	24.9	27.2	**26.3±1.3**	37.1	27.2	20.2	**28.2±8.5**
16	*Hydrilla verticillata*	0.0	15.1	12.6	**9.2±8.1**	19.5	14.5	6.2	**13.4±6.7**
17	*Potamogeton crispus*	9.5	10.3	11.5	**10.4±1.0**	19.7	16.4	6.7	**14.3±6.7**
18	*Potamogeton lucens*	12.0	0.0	10.2	**7.4±6.5**	13.0	10.4	5.2	**9.5±4.0**

Table 5.2.2.17. Seasonal variations in frequency (%) of macrophytic species at Site V during the study period

S.No	**Species**	**2011**				**2012**			
		Spring	**Summer**	**Autumn**	**Mean±SD**	**Spring**	**Summer**	**Autumn**	**Mean±SD**
	Emergents								
1	*Alisma lanceolatum*	0.0	30.0	0.0	**10.0±17.3**	0.0	0.0	0.0	**0.0±0.0**
2	*Alisma plantago-aquatica*	0.0	30.0	20.0	**16.7±15.3**	0.0	20.0	10.0	**10.0±10.0**
3	*Bidens cernua*	0.0	20.0	20.0	**13.3±11.5**	0.0	10.0	0.0	**3.3±5.8**
4	*Juncus buffonius*	10.0	20.0	10.0	**13.3±5.8**	0.0	0.0	0.0	**0.0±0.0**
5	*Mentha arvensis*	30.0	30.0	20.0	**26.7±5.8**	20.0	30.0	20.0	**23.3±5.8**
6	*Menyanthes trifoliata*	10.0	30.0	0.0	**13.3±15.3**	0.0	0.0	0.0	**0.0±0.0**
7	*Myriophyllum verticillatum*	30.0	40.0	30.0	**33.3±5.8**	20.0	30.0	30.0	**26.7±5.8**
8	*Phragmites australis*	30.0	40.0	30.0	**33.3±5.8**	30.0	35.0	40.0	**35.0±5.0**
9	*Polygonum amphibium*	20.0	40.0	50.0	**36.7±15.3**	30.0	35.0	20.0	**28.3±7.6**
10	*Polygonum hydropiper*	30.0	40.0	30.0	**33.3±5.8**	30.0	40.0	20.0	**30.0±10.0**
11	*Ranunculus muricatus*	0.0	20.0	20.0	**13.3±11.5**	0.0	0.0	0.0	**0.0±0.0**
12	*Ranunculus sceleratus*	20.0	0.0	20.0	**13.3±11.5**	0.0	20.0	20.0	**13.3±11.5**
13	*Typha angustata*	20.0	30.0	30.0	**26.7±5.8**	20.0	30.0	20.0	**23.3±5.8**
	Rooted-floating leaf type								
14	*Hydrocharis dubia*	40.0	30.0	30.0	**33.3±5.8**	20.0	30.0	30.0	**26.7±5.8**
15	*Marsilea quadrifolia*	20.0	30.0	30.0	**26.7±5.8**	30.0	40.0	30.0	**33.3±5.8**
16	*Nelumbo nucifera*	0.0	30.0	20.0	**16.7±15.3**	0.0	20.0	20.0	**13.3±11.5**
17	*Nymphaea alba*	20.0	30.0	20.0	**23.3±5.8**	0.0	20.0	10.0	**10.0±10.0**
18	*Nymphaea mexicana*	20.0	30.0	20.0	**23.3±5.8**	20.0	30.0	20.0	**23.3±5.8**
19	*Nymphoides peltatum*	50.0	60.0	50.0	**53.3±5.8**	40.0	50.0	40.0	**43.3±5.8**
20	*Potamogeton natans*	40.0	50.0	30.0	**40.0±10.0**	30.0	40.0	20.0	**30.0±10.0**
21	*Trapa bispinosa*	0.0	30.0	0.0	**10.0±17.3**	0.0	20.0	0.0	**6.7±11.5**
22	*Trapa natans*	30.0	40.0	40.0	**36.7±5.8**	30.0	40.0	30.0	**33.3±5.8**
	Free-floating type								
23	*Azolla* sp.	40.0	30.0	50.0	**40.0±10.0**	30.0	35.0	20.0	**28.3±7.6**
24	*Lemna major*	0.0	40.0	0.0	**13.3±23.1**	0.0	30.0	0.0	**10.0±17.3**
25	*Lemna minor*	40.0	30.0	40.0	**36.7±5.8**	40.0	30.0	20.0	**30.0±10.0**
26	*Lemna trisulca*	0.0	30.0	0.0	**10.0±17.3**	0.0	0.0	0.0	**0.0±0.0**
27	*Salvinia natans*	30.0	20.0	40.0	**30.0±10.0**	30.0	40.0	20.0	**30.0±10.0**
	Submergeds								
28	*Ceratophyllum demersum*	50.0	40.0	50.0	**46.7±5.8**	40.0	30.0	40.0	**36.7±5.8**
29	*Potamogeton crispus*	30.0	20.0	30.0	**26.7±5.8**	30.0	20.0	40.0	**30.0±10.0**

Table 5.2.2.18. Seasonal variations in density (individuals/m^2) of macrophytic species at Site V during the study period

S.No	Species	2011				2012			
		Spring	Summer	Autumn	Mean±SD	Spring	Summer	Autumn	Mean±SD
	Emergents								
1	*Alisma lanceolatum*	0.0	0.6	0.0	**0.6±0.3**	0.0	0.0	0.0	**0.0±0.0**
2	*Alisma plantago-aquatica*	0.0	0.8	0.5	**0.4±0.4**	0.0	0.4	0.2	**0.2±0.2**
3	*Bidens cernua*	0.0	0.3	0.2	**0.2±0.2**	0.0	0.2	0.0	**0.1±0.1**
4	*Juncus buffonius*	0.1	0.3	0.1	**0.2±0.1**	0.0	0.0	0.0	**0.0±0.0**
5	*Mentha arvensis*	0.4	0.6	0.3	**0.4±0.2**	0.2	0.4	0.3	**0.3±0.1**
6	*Menyanthes trifoliata*	0.3	0.7	0.0	**0.3±0.4**	0.0	0.0	0.0	**0.0±0.0**
7	*Myriophyllum verticillatum*	1.1	1.6	1.2	**1.3±0.3**	0.6	0.7	0.5	**0.6±0.1**
8	*Phragmites australis*	1.0	1.2	0.8	**1.0±0.2**	0.7	0.9	0.7	**0.8±0.1**
9	*Polygonum amphibium*	0.9	1.2	1.0	**1.0±0.2**	0.6	0.8	0.5	**0.6±0.2**
10	*Polygonum hydropiper*	0.7	1.0	0.7	**0.8±0.2**	0.5	0.8	0.6	**0.6±0.2**
11	*Ranunculus muricatus*	0.0	0.3	0.2	**0.2±0.2**	0.0	0.0	0.0	**0.0±0.0**
12	*Ranunculus sceleratus*	0.4	0.0	0.3	**0.2±0.2**	0.0	0.3	0.2	**0.2±0.2**
13	*Typha angustata*	0.4	0.7	0.5	**0.5±0.2**	0.6	0.7	0.5	**0.6±0.1**
	Rooted-floating leaf type								
14	*Hydrocharis dubia*	0.6	0.9	0.7	**0.7±0.2**	0.5	0.8	0.6	**0.6±0.2**
15	*Marsilea quadrifolia*	0.5	0.8	0.5	**0.6±0.2**	0.5	0.8	0.6	**0.6±0.2**
16	*Nelumbo nucifera*	0.0	0.5	0.3	**0.3±0.3**	0.0	0.3	0.2	**0.2±0.2**
17	*Nymphaea alba*	0.3	0.5	0.3	**0.4±0.1**	0.0	0.3	0.2	**0.2±0.2**
18	*Nymphaea mexicana*	0.4	0.6	0.5	**0.5±0.1**	0.5	0.6	0.4	**0.5±0.1**
19	*Nymphoides peltatum*	2.7	3.2	2.6	**2.8±0.3**	2.5	3.3	2.4	**2.7±0.5**
20	*Potamogeton natans*	1.1	1.4	1.0	**1.2±0.2**	0.9	1.2	1.0	**1.0±0.2**
21	*Trapa bispinosa*	0.0	0.6	0.0	**0.2±0.3**	0.0	0.4	0.0	**0.1±0.2**
22	*Trapa natans*	1.1	1.4	1.0	**1.2±0.2**	0.9	1.1	0.7	**0.9±0.2**
	Free-floating type								
23	*Azolla* sp.	5.0	5.6	4.8	**5.1±0.4**	4.8	6.6	5.0	**5.5±1.0**
24	*Lemna major*	0.0	4.0	0.0	**1.3±2.3**	0.0	3.5	0.0	**1.2±2.0**
25	*Lemna minor*	7.0	9.2	7.2	**7.8±1.2**	6.6	7.8	6.0	**6.8±0.9**
26	*Lemna trisulca*	0.0	1.3	0.0	**0.4±0.8**	0.0	0.0	0.0	**0.0±0.0**
27	*Salvinia natans*	2.8	3.4	3.0	**3.1±0.3**	3.4	5.0	4.0	**4.1±0.8**
	Submergeds								
28	*Ceratophyllum demersum*	2.8	3.3	2.4	**2.8±0.5**	2.9	2.5	2.6	**2.7±0.2**
29	*Potamogeton crispus*	0.8	1.2	0.7	**0.9±0.3**	1.0	1.3	0.9	**1.1±0.2**

Table 5.2.2.19. Seasonal variations in abundance of macrophytic species at Site V during the study period

S.No	**Species**	**2011**				**2012**			
		Spring	**Summer**	**Autumn**	**Mean±SD**	**Spring**	**Summer**	**Autumn**	**Mean±SD**
	Emergents								
1	*Alisma lanceolatum*	0.0	2.0	0.0	**0.6±1.2**	0.0	0.0	0.0	**0.0±0.0**
2	*Alisma plantago-aquatica*	0.0	2.7	2.5	**1.7±1.5**	0.0	2.0	2.0	**1.3±1.2**
3	*Bidens cernua*	0.0	1.5	1.0	**0.8±0.8**	0.0	2.0	0.0	**0.7±1.2**
4	*Juncus buffonius*	1.0	1.5	1.0	**1.2±0.3**	0.0	0.0	0.0	**0.0±0.0**
5	*Mentha arvensis*	1.3	2.0	1.5	**1.6±0.3**	1.0	1.3	1.5	**1.3±0.3**
6	*Menyanthes trifoliata*	3.0	2.3	0.0	**1.8±1.6**	0.0	0.0	0.0	**0.0±0.0**
7	*Myriophyllum verticillatum*	3.7	4.0	3.0	**3.6±0.5**	3.0	2.3	1.7	**2.3±0.7**
8	*Phragmites australis*	3.3	3.0	2.7	**3.0±0.3**	2.3	3.0	2.3	**2.6±0.4**
9	*Polygonum amphibium*	3.0	3.0	2.5	**2.8±0.3**	2.0	2.7	2.5	**2.4±0.3**
10	*Polygonum hydropiper*	2.3	2.5	2.3	**2.4±0.1**	1.7	2.0	3.0	**2.2±0.7**
11	*Ranunculus muricatus*	0.0	1.5	1.0	**0.8±0.8**	0.0	0.0	0.0	**0.0±0.0**
12	*Ranunculus sceleratus*	2.0	0.0	2.5	**1.5±1.3**	0.0	1.5	1.0	**0.8±0.8**
13	*Typha angustata*	2.0	3.5	1.7	**2.4±1.0**	3.0	2.3	2.5	**2.6±0.3**
	Rooted-floating leaf type								
14	*Hydrocharis dubia*	2.0	3.0	2.3	**2.4±0.5**	2.5	2.7	2.0	**2.4±0.3**
15	*Marsilea quadrifolia*	2.5	2.7	1.7	**2.3±0.5**	1.7	2.7	2.0	**2.1±0.5**
16	*Nelumbo nucifera*	0.0	1.7	1.5	**1.1±0.9**	0.0	1.5	1.0	**0.8±0.8**
17	*Nymphaea alba*	1.5	2.5	1.5	**1.8±0.6**	0.0	1.5	2.0	**1.2±1.0**
18	*Nymphaea mexicana*	1.3	2.0	1.7	**1.7±0.3**	2.5	2.0	2.0	**2.2±0.3**
19	*Nymphoides peltatum*	5.4	5.3	5.2	**5.3±0.1**	6.3	6.6	6.0	**6.3±0.3**
20	*Potamogeton natans*	2.8	2.8	3.3	**3.0±0.3**	3.0	4.0	3.3	**3.4±0.5**
21	*Trapa bispinosa*	0.0	2.0	0.0	**0.7±1.2**	0.0	2.0	0.0	**0.7±1.2**
22	*Trapa natans*	3.7	3.5	2.5	**3.2±0.6**	3.0	2.8	2.3	**2.7±0.3**
	Free-floating type								
23	*Azolla* sp.	12.5	14.0	12.0	**12.8±1.0**	16.0	22.0	25.0	**21.0±4.6**
24	*Lemna major*	0.0	10.0	0.0	**3.3±5.8**	0.0	11.7	0.0	**3.9±6.7**
25	*Lemna minor*	17.5	23.0	18.0	**19.5±3.0**	16.5	26.0	30.0	**24.2±6.9**
26	*Lemna trisulca*	0.0	4.3	0.0	**1.4±2.5**	0.0	0.0	0.0	**0.0±0.0**
27	*Salvinia natans*	9.3	11.3	10.0	**10.2±1.0**	11.3	12.5	20.0	**14.6±4.7**
	Submergeds								
28	*Ceratophyllum demersum*	5.6	6.6	4.8	**5.7±0.9**	7.3	8.3	6.5	**7.4±0.9**
29	*Potamogeton crispus*	2.7	4.0	2.3	**3.0±0.9**	3.3	4.3	3.0	**3.6±0.7**

Table 5.2.2.20. Seasonal variations in IVI of macrophytic species at Site V during the study period

S.No	Species	2011				2012			
		Spring	**Summer**	**Autumn**	**Mean±SD**	**Spring**	**Summer**	**Autumn**	**Mean±SD**
	Emergents								
1	*Alisma lanceolatum*	0.0	7.7	0.0	**0.6±4.5**	0.0	0.0	0.0	**0.0±0.0**
2	*Alisma plantago-aquatica*	0.0	8.7	7.7	**5.5±4.8**	0.0	6.6	25.9	**10.8±13.5**
3	*Bidens cernua*	0.0	5.1	5.1	**3.4±2.9**	0.0	4.1	0.0	**1.4±2.4**
4	*Juncus buffonius*	3.1	5.1	3.1	**3.8±1.1**	0.0	0.0	0.0	**0.0±0.0**
5	*Mentha arvensis*	7.7	7.7	5.9	**7.1±1.0**	6.0	8.1	38.6	**17.6±18.3**
6	*Menyanthes trifoliata*	6.0	8.2	0.0	**4.7±4.3**	0.0	0.0	0.0	**0.0±0.0**
7	*Myriophyllum verticillatum*	12.7	13.1	12.2	**12.6±0.4**	9.7	9.6	63.0	**27.5±30.8**
8	*Phragmites australis*	12.0	11.4	10.5	**11.3±0.7**	11.3	11.7	87.9	**37.0±44.1**
9	*Polygonum amphibium*	9.6	11.4	14.3	**11.8±2.3**	10.6	11.2	61.7	**27.8±29.3**
10	*Polygonum hydropiper*	9.9	10.6	9.8	**10.1±0.5**	9.9	11.7	73.2	**31.6±36.1**
11	*Ranunculus muricatus*	0.0	5.1	5.1	**3.4±2.9**	0.0	0.0	0.0	**0.0±0.0**
12	*Ranunculus sceleratus*	6.9	0.0	7.1	**4.6±4.0**	0.0	6.0	27.1	**11.0±14.3**
13	*Typha angustata*	6.9	9.1	8.4	**8.1±1.2**	9.7	9.6	61.7	**27.0±30.0**
	Rooted-floating leaf type								
14	*Hydrocharis dubia*	10.8	9.2	9.8	**9.9±0.8**	8.8	10.1	74.4	**31.1±37.5**
15	*Marsilea quadrifolia*	7.8	8.7	8.4	**8.3±0.5**	9.9	12.2	74.4	**32.2±36.6**
16	*Nelumbo nucifera*	0.0	7.3	5.9	**4.4±3.9**	0.0	6.0	27.1	**11.0±14.3**
17	*Nymphaea alba*	6.0	7.9	5.9	**6.6±1.1**	0.0	6.0	25.9	**10.6±13.6**
18	*Nymphaea mexicana*	6.1	7.7	6.8	**6.9±0.8**	8.8	9.1	50.2	**22.7±23.8**
19	*Nymphoides peltatum*	23.2	20.8	22.5	**22.2±1.2**	24.4	23.4	279.8	**109.2±147.7**
20	*Potamogeton natans*	13.3	13.3	11.9	**12.9±0.8**	12.8	14.2	117.9	**48.3±60.3**
21	*Trapa bispinosa*	0.0	7.7	0.0	**2.6±4.5**	0.0	6.6	0.0	**2.2±3.8**
22	*Trapa natans*	12.7	12.3	12.6	**12.5±0.2**	12.8	13.0	85.8	**37.2±42.1**
	Free-floating type								
23	*Azolla* sp.	37.1	27.7	37.3	**34.1±5.5**	42.0	40.3	580.2	**220.8±311.2**
24	*Lemna major*	0.0	22.8	0.0	**7.6±13.2**	0.0	23.7	0.0	**7.9±13.7**
25	*Lemna minor*	49.4	42.4	50.3	**47.3±4.3**	51.1	45.3	695.4	**264.0±373.7**
26	*Lemna trisulca*	0.0	11.0	0.0	**3.7±6.4**	0.0	0.0	0.0	**0.0±0.0**
27	*Salvinia natans*	24.7	19.3	27.6	**23.9±4.2**	31.5	30.1	465.0	**175.5±250.7**
	Submergeds								
28	*Ceratophyllum demersum*	23.7	18.7	21.4	**21.3±2.5**	27.0	18.7	302.4	**116.0±161.4**
29	*Potamogeton crispus*	10.6	8.9	9.8	**9.8±0.8**	13.6	10.6	110.6	**44.9±56.9**

Table 5.2.2.21. Seasonal variations in frequency (%) of macrophytic species at Site VI during the study period

S.No	**Species**	**2011**				**2012**			
		Spring	**Summer**	**Autumn**	**Mean±SD**	**Spring**	**Summer**	**Autumn**	**Mean±SD**
	Emergents								
1	*Alisma lanceolatum*	0.0	30.0	0.0	**10.0±17.3**	0.0	0.0	0.0	**0.0±0.0**
2	*Alternanthera philoxeroides*	0.0	40.0	35.0	**25.0±21.8**	0.0	0.0	0.0	**0.0±0.0**
3	*Bidens cernua*	0.0	20.0	20.0	**13.3±11.5**	0.0	10.0	10.0	**6.7±5.8**
4	*Butomus umbellatus*	0.0	20.0	10.0	**10.0±10.0**	0.0	0.0	0.0	**0.0±0.0**
5	*Carex* sp.	0.0	20.0	20.0	**13.3±11.5**	0.0	15.0	5.0	**6.7±7.6**
6	*Cyperus serotinus*	0.0	30.0	20.0	**16.7±15.3**	0.0	0.0	0.0	**0.0±0.0**
7	*Echinocloa crus-galli*	0.0	30.0	0.0	**10.0±17.3**	0.0	20.0	0.0	**6.7±11.5**
8	*Hippuris vulgaris*	40.0	0.0	20.0	**20.0±20.0**	0.0	0.0	30.0	**10.0±17.3**
9	*Mentha arvensis*	30.0	0.0	30.0	**20.0±17.3**	20.0	25.0	15.0	**20.0±5.0**
10	*Myriophyllum verticillatum*	40.0	50.0	60.0	**50.0±10.0**	40.0	45.0	30.0	**38.3±7.6**
11	*Phragmites australis*	40.0	45.0	50.0	**45.0±5.0**	30.0	25.0	30.0	**28.3±2.9**
12	*Polygonum hydropiper*	40.0	40.0	50.0	**43.3±5.8**	30.0	35.0	25.0	**30.0±5.0**
13	*Ranunculus lingua*	20.0	30.0	0.0	**16.7±15.3**	0.0	15.0	0.0	**5.0±8.7**
14	*Ranunculus muricatus*	0.0	10.0	0.0	**3.3±5.8**	0.0	0.0	0.0	**0.0±0.0**
15	*Ranunculus sceleratus*	20.0	30.0	20.0	**23.3±5.8**	0.0	20.0	0.0	**6.7±11.5**
16	*Scirpus palustris*	0.0	10.0	0.0	**3.3±5.8**	0.0	0.0	0.0	**0.0±0.0**
17	*Sium latijugam*	10.0	20.0	20.0	**16.7±5.8**	0.0	5.0	0.0	**1.7±2.9**
18	*Sparganium ramosum*	20.0	30.0	0.0	**16.7±15.3**	0.0	0.0	0.0	**0.0±0.0**
19	*Typha angustata*	30.0	40.0	35.0	**35.0±5.0**	30.0	25.0	30.0	**28.3±2.9**
	Rooted-floating leaf type								
20	*Hydrocharis dubia*	30.0	40.0	30.0	**33.3±5.8**	20.0	30.0	35.0	**28.3±7.6**
21	*Marsilea quadrifolia*	30.0	35.0	30.0	**31.7±2.9**	20.0	30.0	25.0	**25.0±5.0**
22	*Nymphaea mexicana*	20.0	30.0	30.0	**26.7±5.8**	20.0	30.0	25.0	**25.0±5.0**
23	*Nymphoides peltatum*	50.0	60.0	50.0	**53.3±5.8**	50.0	55.0	40.0	**48.3±7.6**
24	*Potamogeton natans*	30.0	35.0	30.0	**31.7±2.9**	20.0	30.0	15.0	**21.7±7.6**
25	*Trapa natans*	20.0	30.0	30.0	**26.7±5.8**	20.0	30.0	25.0	**25.0±5.0**
	Free-floating type								
26	*Azolla* sp.	40.0	30.0	40.0	**36.7±5.8**	25.0	40.0	30.0	**31.7±7.6**
27	*Lemna minor*	20.0	30.0	20.0	**23.3±5.8**	15.0	30.0	25.0	**23.3±7.6**
28	*Salvinia natans*	0.0	30.0	30.0	**20.0±17.3**	0.0	20.0	15.0	**11.7±10.4**
	Submergeds								
29	*Ceratophyllum demersum*	30.0	40.0	30.0	**33.3±5.8**	15.0	30.0	40.0	**28.3±12.6**

Table 5.2.2.22. Seasonal variations in density (individuals/m^2) of macrophytic species at Site VI during the study period

S.No	Species	2011				2012			
		Spring	Summer	Autumn	Mean±SD	Spring	Summer	Autumn	Mean±SD
	Emergents								
1	*Alisma lanceolatum*	0.0	7.8	0.0	**2.6±4.5**	0.0	0.0	0.0	**0.0±0.0**
2	*Alternanthera philoxeroides*	0.0	17.1	20.3	**12.5±10.9**	0.0	8.3	0.0	**2.8±4.8**
3	*Bidens cernua*	0.0	4.7	4.8	**3.2±2.7**	0.0	5.1	4.1	**3.1±2.7**
4	*Butomus umbellatus*	0.0	4.7	3.0	**2.6±2.4**	0.0	0.0	0.0	**0.0±0.0**
5	*Carex* sp.	0.0	5.5	4.8	**3.4±3.0**	0.0	4.7	4.8	**3.2±2.7**
6	*Cyperus serotinus*	0.0	6.0	5.8	**3.9±3.4**	0.0	0.0	0.0	**0.0±0.0**
7	*Echinocloa crus-galli*	0.0	7.2	0.0	**2.4±4.2**	0.0	6.7	0.0	**2.2±3.8**
8	*Hippuris vulgaris*	10.9	0.0	6.8	**5.9±5.5**	0.0	0.0	13.6	**4.5±7.9**
9	*Mentha arvensis*	9.6	0.0	8.2	**5.9±5.2**	11.3	8.6	6.8	**8.9±2.2**
10	*Myriophyllum verticillatum*	19.1	16.1	19.2	**18.1±1.7**	22.4	18.1	17.9	**19.5±2.5**
11	*Phragmites australis*	16.9	14.4	16.0	**15.8±1.2**	17.6	11.9	12.3	**13.9±3.2**
12	*Polygonum hydropiper*	16.9	12.8	15.3	**15.0±2.1**	21.0	17.0	11.2	**16.4±5.0**
13	*Ranunculus lingua*	7.9	8.5	0.0	**5.4±4.7**	0.0	5.8	0.0	**1.9±3.3**
14	*Ranunculus muricatus*	0.0	3.7	0.0	**1.2±2.1**	0.0	0.0	0.0	**0.0±0.0**
15	*Ranunculus sceleratus*	8.9	8.2	6.8	**8.0±1.1**	0.0	7.7	0.0	**2.6±4.4**
16	*Scirpus palustris*	0.0	3.7	0.0	**1.2±2.1**	0.0	0.0	0.0	**0.0±0.0**
17	*Sium latijugam*	5.2	5.5	4.8	**5.2±0.3**	0.0	4.2	0.0	**1.4±2.4**
18	*Sparganium ramosum*	7.9	7.2	0.0	**5.0±4.4**	0.0	0.0	0.0	**0.0±0.0**
19	*Typha angustata*	12.1	11.5	11.2	**11.6±0.4**	15.3	10.2	10.4	**12.0±2.9**
	Rooted-floating leaf type								
20	*Hydrocharis dubia*	0.4	0.6	0.5	**0.5±0.1**	0.5	0.7	0.4	**0.5±0.2**
21	*Marsilea quadrifolia*	0.6	0.8	0.5	**0.6±0.2**	0.4	0.7	0.6	**0.6±0.2**
22	*Nymphaea mexicana*	0.4	0.6	0.5	**0.5±0.1**	0.4	0.5	0.4	**0.4±0.1**
23	*Nymphoides peltatum*	2.8	3.2	2.3	**2.8±0.5**	1.9	2.2	1.8	**2.0±0.2**
24	*Potamogeton natans*	0.9	1.1	0.7	**0.9±0.2**	0.5	0.7	0.5	**0.6±0.1**
25	*Trapa natans*	0.5	0.8	0.5	**0.6±0.2**	0.4	0.4	0.3	**0.4±0.1**
	Free-floating type								
26	*Azolla* sp.	4.2	4.8	4.4	**4.5±0.3**	3	4.4	3.8	**3.7±0.7**
27	*Lemna minor*	4.2	5.2	4.6	**4.7±0.5**	4	6	5.6	**5.2±1.1**
28	*Salvinia natans*	0.0	2.4	2.2	**1.5±1.3**	0	1.4	2	**1.1±1.0**
	Submergeds								
29	*Ceratophyllum demersum*	1.9	2.3	1.8	**2.0±0.3**	1.1	1.3	1.2	**1.2±0.1**

Table 5.2.2.23. Seasonal variations in abundance of macrophytic species at Site VI during the study period

S.No	Species	2011				2012			
		Spring	Summer	Autumn	Mean±SD	Spring	Summer	Autumn	Mean±SD
	Emergents								
1	*Alisma lanceolatum*	0.0	2.3	0.0	**0.8±1.3**	0.0	0.0	0.0	**0.0±0.0**
2	*Bidens cernua*	0.0	1.5	1.0	**0.8±0.8**	0.0	2.0	1.0	**1.0±1.0**
3	*Alternanthera philoxeroides*	0.0	5.8	6.0	**3.9±3.4**	0.0	3.3	0.0	**1.1±1.9**
4	*Butomus umbellatus*	0.0	1.5	1.0	**0.8±0.8**	0.0	0.0	0.0	**0.0±0.0**
5	*Carex* sp.	0.0	2.0	1.0	**1.0±1.0**	0.0	1.0	2.0	**1.0±1.0**
6	*Cyperus serotinus*	0.0	1.3	1.5	**0.9±0.8**	0.0	0.0	0.0	**0.0±0.0**
7	*Echinocloa crus-galli*	0.0	2.0	0.0	**0.7±1.2**	0.0	1.5	0.0	**0.5±0.9**
8	*Hippuris vulgaris*	1.3	0.0	2.0	**1.1±1.0**	0.0	0.0	3.0	**1.0±1.7**
9	*Mentha arvensis*	1.7	0.0	1.7	**1.1±1.0**	2.0	1.7	1.5	**1.7±0.3**
10	*Myriophyllum verticillatum*	4.0	4.2	3.4	**3.9±0.4**	2.8	3.5	4.0	**3.4±0.6**
11	*Phragmites australis*	3.3	4.3	3.3	**3.6±0.6**	2.7	3.0	2.0	**2.6±0.5**
12	*Polygonum hydropiper*	3.3	3.8	3.0	**3.3±0.4**	3.7	4.3	2.0	**3.3±1.2**
13	*Ranunculus lingua*	2.0	2.7	0.0	**1.6±1.4**	0.0	1.5	0.0	**0.5±0.9**
14	*Ranunculus muricatus*	0.0	2.0	0.0	**0.7±1.2**	0.0	0.0	0.0	**0.0±0.0**
15	*Ranunculus sceleratus*	2.5	3.0	2.0	**2.5±0.5**	0.0	2.0	0.0	**0.7±1.2**
16	*Scirpus palustris*	0.0	2.0	0.0	**0.7±1.2**	0.0	0.0	0.0	**0.0±0.0**
17	*Sium latijugam*	2.0	2.0	1.0	**1.7±0.6**	0.0	2.0	0.0	**0.7±1.2**
18	*Sparganium ramosum*	2.0	2.0	0.0	**1.3±1.2**	0.0	0.0	0.0	**0.0±0.0**
19	*Typha angustata*	2.3	3.7	2.7	**2.9±0.7**	2.0	2.3	1.3	**1.9±0.5**
Rooted-floating leaf type									
20	*Hydrocharis dubia*	1.3	2.0	1.7	**1.7±0.3**	2.5	2.3	1.3	**2.1±0.6**
21	*Marsilea quadrifolia*	2.0	2.7	1.7	**2.1±0.5**	2.0	2.3	2.0	**2.1±0.2**
22	*Nymphaea mexicana*	2.0	2.0	1.7	**1.9±0.2**	2.0	1.7	1.3	**1.7±0.3**
23	*Nymphoides peltatum*	4.7	5.3	4.6	**4.9±0.4**	3.8	4.4	4.5	**4.2±0.4**
24	*Potamogeton natans*	3.0	3.7	2.3	**3.0±0.7**	2.5	2.3	2.5	**2.4±0.1**
25	*Trapa natans*	2.5	2.7	1.7	**2.3±0.5**	2.0	1.3	1.5	**1.6±0.3**
Free-floating type									
26	*Azolla* sp.	10.5	12.0	11.0	**11.2±0.8**	10.0	11.0	12.7	**11.2±1.3**
27	*Lemna minor*	21.0	17.3	23.0	**20.4±2.9**	20.0	20.0	18.7	**19.6±0.8**
28	*Salvinia natans*	0.0	8.0	7.3	**5.1±4.4**	0.0	7.0	10.0	**5.7±5.1**
Submergeds									
29	*Ceratophyllum demersum*	6.3	7.7	6.0	**6.7±0.9**	5.5	1.3	3.0	**3.3±2.1**

Table 5.2.2.24. Seasonal variations in IVI of macrophytic species at Site VI during the study period

S.No	**Species**	**2011**				**2012**			
		Spring	**Summer**	**Autumn**	**Mean±SD**	**Spring**	**Summer**	**Autumn**	**Mean±SD**
	Emergents								
1	*Alisma lanceolatum*	0.0	7.8	0.0	**2.6±4.5**	0.0	0.0	0.0	**0.0±0.0**
2	*Bidens cernua*	0.0	17.1	20.3	**12.5±10.9**	0.0	8.3	0.0	**2.8±4.8**
3	*Alternanthera philoxeroides*	0.0	4.7	4.8	**3.2±2.7**	0.0	5.1	4.1	**3.1±2.7**
4	*Butomus umbellatus*	0.0	4.7	3.0	**2.6±2.4**	0.0	0.0	0.0	**0.0±0.0**
5	*Carex* sp.	0.0	5.5	4.8	**3.4±3.0**	0.0	4.7	4.8	**3.2±2.7**
6	*Cyperus serotinus*	0.0	6.0	5.8	**3.9±3.4**	0.0	0.0	0.0	**0.0±0.0**
7	*Echinocloa crus-galli*	0.0	7.2	0.0	**2.4±4.2**	0.0	6.7	0.0	**2.2±3.8**
8	*Hippuris vulgaris*	10.9	0.0	6.8	**5.9±5.5**	0.0	0.0	13.6	**4.5±7.9**
9	*Mentha arvensis*	9.6	0.0	8.2	**5.9±5.2**	11.3	8.6	6.8	**8.9±2.2**
10	*Myriophyllum verticillatum*	19.1	16.1	19.2	**18.1±1.7**	22.4	18.1	17.9	**19.5±2.5**
11	*Phragmites australis*	16.9	14.4	16.0	**15.8±1.2**	17.6	11.9	12.3	**13.9±3.2**
12	*Polygonum hydropiper*	16.9	12.8	15.3	**15.0±2.1**	21.0	17.0	11.2	**16.4±5.0**
13	*Ranunculus lingua*	7.9	8.5	0.0	**5.4±4.7**	0.0	5.8	0.0	**1.9±3.3**
14	*Ranunculus muricatus*	0.0	3.7	0.0	**1.2±2.1**	0.0	0.0	0.0	**0.0±0.0**
15	*Ranunculus sceleratus*	8.9	8.2	6.8	**8.0±1.1**	0.0	7.7	0.0	**2.6±4.4**
16	*Scirpus palustris*	0.0	3.7	0.0	**1.2±2.1**	0.0	0.0	0.0	**0.0±0.0**
17	*Sium latijugam*	5.2	5.5	4.8	**5.2±0.3**	0.0	4.2	0.0	**1.4±2.4**
18	*Sparganium ramosum*	7.9	7.2	0.0	**5.0±4.4**	0.0	0.0	0.0	**0.0±0.0**
19	*Typha angustata*	12.1	11.5	11.2	**11.6±0.4**	15.3	10.2	10.4	**12.0±2.9**
	Rooted-floating leaf type								
20	*Hydrocharis dubia*	8.8	8.4	8.2	**8.4±0.3**	12.7	11.1	11.5	**11.8±0.8**
21	*Marsilea quadrifolia*	10.5	9.0	8.2	**9.2±1.2**	11.3	11.1	11.2	**11.2±0.1**
22	*Nymphaea mexicana*	7.9	7.2	8.2	**7.7±0.5**	11.3	9.4	9.3	**10.0±1.1**
23	*Nymphoides peltatum*	26.9	21.7	21.6	**23.4±3.0**	31.8	24.2	23.7	**26.6±4.5**
24	*Potamogeton natans*	13.1	10.9	9.8	**11.2±1.7**	12.7	11.1	9.1	**11.0±1.8**
25	*Trapa natans*	8.9	8.5	8.2	**8.5±0.4**	11.3	8.6	9.0	**9.6±1.4**
	Free-floating type								
26	*Azolla* sp.	38.6	29.3	36.1	**34.7±4.8**	41.3	38.9	42.2	**40.8±1.7**
27	*Lemna minor*	48.5	35.7	48.2	**44.2±7.3**	60.5	55.1	57.9	**57.8±2.7**
28	*Salvinia natans*	0.0	18.4	21.6	**13.3±11.7**	0.0	18.1	26.5	**14.9±13.5**
	Submergeds								
29	*Ceratophyllum demersum*	21.6	18.9	18.4	**19.7±1.7**	19.7	12.2	18.8	**16.9±4.1**

Table 5.2.2.25. Seasonal variations in frequency (%) of macrophytic species at Site VII during the study period

S.No	**Species**	**2011**				**2012**			
		Spring	**Summer**	**Autumn**	**Mean±SD**	**Spring**	**Summer**	**Autumn**	**Mean±SD**
	Emergents								
1	*Alisma plantago-aquatica*	0.0	25.0	30.0	**18.3±16.1**	0.0	20.0	15.0	**11.7±10.4**
2	*Alternanthera philoxeroides*	0.0	25.0	30.0	**18.3±16.1**	0.0	25.0	30.0	**18.3±16.1**
3	*Bidens cernua*	0.0	15.0	20.0	**11.7±10.4**	0.0	20.0	15.0	**11.7±10.4**
4	*Lycopus europaeus*	20.0	15.0	0.0	**11.7±10.4**	0.0	15.0	5.0	**6.7±7.6**
5	*Mentha arvensis*	30.0	25.0	20.0	**25.0±5.0**	15.0	20.0	15.0	**16.7±2.9**
6	*Menyanthes trifoliata*	0.0	15.0	0.0	**5.0±8.7**	0.0	0.0	0.0	**0.0±0.0**
7	*Myriophyllum verticillatum*	40.0	35.0	40.0	**38.3±2.9**	30.0	40.0	35.0	**35.0±5.0**
8	*Nasturtium officinalis*	0.0	25.0	30.0	**18.3±16.1**	0.0	25.0	15.0	**13.3±12.6**
9	*Phragmites australis*	25.0	35.0	40.0	**33.3±7.6**	25.0	30.0	35.0	**30.0±5.0**
10	*Polygonum amphibium*	25.0	30.0	20.0	**25.0±5.0**	15.0	30.0	35.0	**26.7±10.4**
11	*Polygonum hydropiper*	25.0	30.0	40.0	**31.7±7.6**	25.0	30.0	45.0	**33.3±10.4**
12	*Sagittaria sagittifolia*	0.0	25.0	0.0	**8.3±14.4**	0.0	20.0	0.0	**6.7±11.5**
13	*Sium latijugam*	20.0	0.0	30.0	**16.7±15.3**	0.0	5.0	15.0	**6.7±7.6**
14	*Sparganium ramosum*	25.0	30.0	20.0	**25.0±5.0**	0.0	0.0	0.0	**0.0±0.0**
15	*Typha angustata*	20.0	30.0	35.0	**28.3±7.6**	20.0	30.0	25.0	**25.0±5.0**
	Rooted-floating leaf type								
16	*Hydrocharis dubia*	25.0	35.0	40.0	**33.3±7.6**	25.0	30.0	40.0	**31.7±7.6**
17	*Marsilea quadrifolia*	25.0	30.0	40.0	**31.7±7.6**	15.0	30.0	25.0	**23.3±7.6**
18	*Nymphaea mexicana*	20.0	30.0	20.0	**23.3±5.8**	15.0	30.0	20.0	**21.7±7.6**
19	*Nymphoides peltatum*	70.0	75.0	60.0	**68.3±7.6**	55.0	55.0	45.0	**51.7±5.8**
20	*Potamogeton natans*	40.0	50.0	35.0	**41.7±7.6**	25.0	40.0	35.0	**33.3±7.6**
21	*Trapa natans*	30.0	40.0	45.0	**38.3±7.6**	25.0	35.0	25.0	**28.3±5.8**
	Free-floating type								
22	*Azolla* sp.	40.0	35.0	45.0	**40.0±5.0**	25.0	30.0	15.0	**23.3±7.6**
23	*Lemna major*	0.0	30.0	25.0	**18.3±16.1**	0.0	0.0	0.0	**0.0±0.0**
24	*Lemna minor*	30.0	25.0	20.0	**25.0±5.0**	15.0	30.0	25.0	**23.3±7.6**
25	*Lemna trisulca*	30.0	25.0	0.0	**18.3±16.1**	0.0	0.0	0.0	**0.0±0.0**
26	*Spirodela polyrhiza*	0.0	30.0	25.0	**18.3±16.1**	0.0	20.0	0.0	**6.7±11.5**
27	*Salvinia natans*	30.0	25.0	35.0	**30.0±5.0**	20.0	30.0	25.0	**25.0±5.0**
	Submergeds								
28	*Ceratophyllum demersum*	50.0	45.0	40.0	**45.0±5.0**	35.0	40.0	45.0	**40.0±5.0**
29	*Hydrilla verticillata*	30.0	35.0	25.0	**30.0±5.0**	25.0	30.0	25.0	**26.7±2.9**
30	*Najas graminea*	0.0	0.0	25.0	**8.3±14.4**	0.0	0.0	0.0	**0.0±0.0**
31	*Myriophyllum spicatum*	0.0	25.0	30.0	**18.3±16.1**	0.0	20.0	0.0	**6.7±11.5**
32	*Potamogeton crispus*	30.0	25.0	35.0	**30.0±5.0**	25.0	40.0	35.0	**33.3±7.6**
33	*Potamogeton lucens*	20.0	15.0	20.0	**18.3±2.9**	25.0	40.0	25.0	**30.0±8.7**
34	*Potamogeton pectinatus*	20.0	20.0	15.0	**18.3±2.9**	15.0	0.0	0.0	**5.0±8.7**
35	*Potamogeton perfoliatus*	30.0	20.0	0.0	**16.7±15.3**	15.0	30.0	25.0	**23.3±7.6**

Table 5.2.2.26. Seasonal variations in density (individuals/m^2) of macrophytic species at Site VII during the study period

S.No	Species	2011				2012			
		Spring	Summer	Autumn	Mean±SD	Spring	Summer	Autumn	Mean±SD
	Emergents								
1	*Alisma plantago-aquatica*	0.0	0.8	0.5	**0.4±0.4**	0.0	0.4	0.3	**0.2±0.2**
2	*Alternanthera philoxeroides*	0.0	2.6	2.4	**1.7±1.4**	0.0	1.5	1.3	**0.9±0.8**
3	*Bidens cernua*	0.0	0.5	0.3	**0.3±0.3**	0.0	0.3	0.2	**0.2±0.2**
4	*Lycopus europaeus*	0.3	0.4	0.0	**0.2±0.2**	0.0	0.3	0.2	**0.2±0.2**
5	*Mentha arvensis*	0.5	0.6	0.4	**0.5±0.1**	0.5	0.4	0.3	**0.4±0.1**
6	*Menyanthes trifoliata*	0.0	0.5	0.0	**0.2±0.3**	0.0	0.0	0.0	**0.0±0.0**
7	*Myriophyllum verticillatum*	1.1	1.4	0.8	**1.1±0.3**	0.8	1.0	0.7	**0.8±0.2**
8	*Nasturtium officinalis*	0.0	0.8	0.5	**0.4±0.4**	0.0	0.6	0.4	**0.3±0.3**
9	*Phragmites australis*	1.1	1.5	0.8	**1.1±0.4**	0.6	0.9	0.7	**0.7±0.2**
10	*Polygonum amphibium*	0.7	0.9	0.6	**0.7±0.2**	0.5	0.7	0.6	**0.6±0.1**
11	*Polygonum hydropiper*	0.6	1.0	0.7	**0.8±0.2**	0.5	0.7	0.7	**0.6±0.1**
12	*Sagittaria sagittifolia*	0.0	1.0	0.0	**0.3±0.6**	0.0	0.5	0.0	**0.2±0.3**
13	*Sium latijugam*	0.3	0.0	0.4	**0.2±0.2**	0.0	0.2	0.3	**0.2±0.2**
14	*Sparganium ramosum*	0.5	0.7	0.4	**0.5±0.2**	0.0	0.0	0.0	**0.0±0.0**
15	*Typha angustata*	0.5	0.8	0.6	**0.6±0.2**	0.3	0.5	0.4	**0.4±0.1**
	Rooted-floating leaf type								
16	*Hydrocharis dubia*	0.7	0.9	0.6	**0.7±0.2**	0.5	0.8	0.5	**0.6±0.2**
17	*Marsilea quadrifolia*	0.6	0.9	0.6	**0.7±0.2**	0.6	0.7	0.5	**0.6±0.1**
18	*Nymphaea mexicana*	0.5	0.8	0.5	**0.6±0.2**	0.4	0.5	0.3	**0.4±0.1**
19	*Nymphoides peltatum*	4.3	4.8	4.1	**4.4±0.4**	3.8	4.2	3.3	**3.8±0.5**
20	*Potamogeton natans*	1.2	1.6	1.1	**1.3±0.3**	1.0	1.2	0.8	**1.0±0.2**
21	*Trapa natans*	0.8	1.1	0.7	**0.9±0.2**	0.6	0.8	0.5	**0.6±0.2**
	Free-floating type								
22	*Azolla* sp.	5.4	6.0	4.6	**5.3±0.7**	4.4	5.6	5.0	**5.0±0.6**
23	*Lemna major*	0.0	2.2	1.7	**1.3±1.2**	0.0	0.0	0.0	**0.0±0.0**
24	*Lemna minor*	5.8	6.8	6.0	**6.2±0.5**	4.4	5.8	4.6	**4.9±0.8**
25	*Lemna trisulca*	0.9	1.2	0.0	**0.7±0.6**	0.0	0.0	0.0	**0.0±0.0**
26	*Spirodela polyrhiza*	0.0	0.7	0.6	**0.4±0.4**	0.0	1.4	0.0	**0.5±0.8**
27	*Salvinia natans*	3.0	4.0	3.2	**3.4±0.5**	2.2	3.4	3.0	**2.9±0.6**
	Submergeds								
28	*Ceratophyllum demersum*	3.5	3.7	2.6	**3.3±0.6**	3.7	3.4	2.9	**3.3±0.4**
29	*Hydrilla verticillata*	0.7	1.1	0.8	**0.9±0.2**	1.3	0.7	1.0	**1.0±0.3**
30	*Najas graminea*	0.0	0.0	1.1	**0.4±0.6**	0.0	0.0	0.0	**0.0±0.0**
31	*Myriophyllum spicatum*	0.0	0.8	0.5	**0.4±0.4**	0.0	0.6	0.0	**0.2±0.3**
32	*Potamogeton crispus*	0.8	1.0	0.6	**0.8±0.2**	0.7	0.8	0.6	**0.7±0.1**
33	*Potamogeton lucens*	0.6	0.8	0.5	**0.6±0.2**	0.7	0.7	0.5	**0.6±0.1**
34	*Potamogeton pectinatus*	0.5	0.6	0.3	**0.5±0.2**	0.4	0.0	0.0	**0.1±0.2**
35	*Potamogeton perfoliatus*	0.5	0.7	0.0	**0.4±0.4**	0.6	0.8	0.5	**0.6±0.2**

Table 5.2.2.27. Seasonal variations in abundance of macrophytic species at Site VII during the study period

S.No	**Species**	**2011**				**2012**			
		Spring	**Summer**	**Autumn**	**Mean±SD**	**Spring**	**Summer**	**Autumn**	**Mean±SD**
	Emergents								
1	*Alisma plantago-aquatica*	0.0	2.7	1.7	**1.4±1.3**	0.0	2.0	1.5	**1.2±1.0**
2	*Alternanthera philoxeroides*	0.0	2.5	1.5	**1.3±1.3**	0.0	1.5	1.0	**0.8±0.8**
3	*Bidens cernua*	0.0	10.4	8.0	**6.1±5.4**	0.0	6.0	4.3	**3.4±3.1**
4	*Lycopus europaeus*	1.5	2.0	0.0	**1.2±1.0**	0.0	1.5	2.0	**1.2±1.0**
5	*Mentha arvensis*	1.7	2.0	2.0	**1.9±0.2**	2.5	2.0	1.5	**2.0±0.5**
6	*Menyanthes trifoliata*	0.0	2.5	0.0	**0.8±1.4**	0.0	0.0	0.0	**0.0±0.0**
7	*Myriophyllum verticillatum*	2.8	3.5	2.0	**2.8±0.8**	2.7	2.5	1.8	**2.3±0.5**
8	*Nasturtium officinalis*	0.0	2.7	1.7	**1.4±1.3**	0.0	2.0	2.0	**1.3±1.2**
9	*Phragmites australis*	3.7	3.8	2.0	**3.1±1.0**	2.0	3.0	1.8	**2.3±0.7**
10	*Polygonum amphibium*	2.3	3.0	3.0	**2.8±0.4**	2.5	2.3	1.5	**2.1±0.5**
11	*Polygonum hydropiper*	2.0	3.3	1.8	**2.4±0.8**	1.7	2.3	1.8	**1.9±0.4**
12	*Sagittaria sagittifolia*	0.0	3.3	0.0	**1.1±1.9**	0.0	2.5	0.0	**0.8±1.4**
13	*Sium latijugam*	1.5	0.0	1.3	**0.9±0.8**	0.0	2.0	1.5	**1.2±1.0**
14	*Sparganium ramosum*	1.7	2.3	2.0	**2.0±0.3**	0.0	0.0	0.0	**0.0±0.0**
15	*Typha angustata*	2.5	2.7	2.0	**2.4±0.3**	1.5	1.7	1.3	**1.5±0.2**
	Rooted-floating leaf type								
16	*Hydrocharis dubia*	2.3	3.0	1.5	**2.3±0.8**	1.7	2.7	1.3	**1.9±0.7**
17	*Marsilea quadrifolia*	2.0	3.0	1.5	**2.2±0.8**	3.0	2.3	1.7	**2.3±0.7**
18	*Nymphaea mexicana*	2.5	2.7	2.5	**2.6±0.1**	2.0	1.7	1.5	**1.7±0.3**
19	*Nymphoides peltatum*	6.1	6.9	6.8	**6.6±0.4**	6.3	7.0	6.6	**6.6±0.3**
20	*Potamogeton natans*	3.0	3.2	2.8	**3.0±0.2**	3.3	3.0	2.0	**2.8±0.7**
21	*Trapa natans*	2.7	2.8	1.8	**2.4±0.6**	2.0	2.7	1.7	**2.1±0.5**
	Free-floating type								
22	*Azolla* sp.	13.5	15.0	11.5	**13.3±1.8**	14.7	18.7	25.0	**19.4±5.2**
23	*Lemna major*	0.0	7.3	5.7	**4.3±3.8**	0.0	0.0	0.0	**0.0±0.0**
24	*Lemna minor*	19.3	22.7	30.0	**24.0±5.5**	22.0	19.3	23.0	**21.4±1.9**
25	*Lemna trisulca*	3.0	4.0	0.0	**2.3±2.1**	0.0	0.0	0.0	**0.0±0.0**
26	*Spirodela polyrhiza*	0.0	2.3	2.0	**1.4±1.3**	0.0	7.0	0.0	**2.3±4.0**
27	*Salvinia natans*	10.0	13.3	10.7	**11.3±1.8**	11.0	11.3	15.0	**12.4±2.2**
	Submergeds								
28	*Ceratophyllum demersum*	7.0	7.4	6.5	**7.0±0.5**	9.3	8.5	5.8	**7.9±1.8**
29	*Hydrilla verticillata*	2.3	2.8	2.7	**2.6±0.2**	4.3	2.3	3.3	**3.3±1.0**
30	*Najas graminea*	0.0	0.0	3.7	**1.2±2.1**	0.0	0.0	0.0	**0.0±0.0**
31	*Myriophyllum spicatum*	0.0	2.7	1.7	**1.4±1.3**	0.0	3.0	0.0	**1.0±1.7**
32	*Potamogeton crispus*	2.7	3.3	1.5	**2.5±0.9**	2.3	2.0	1.5	**1.9±0.4**
33	*Potamogeton lucens*	3.0	4.0	2.5	**3.2±0.8**	2.3	1.8	1.7	**1.9±0.4**
34	*Potamogeton pectinatus*	1.7	3.0	1.5	**2.1±0.8**	2.0	0.0	0.0	**0.7±1.2**
35	*Potamogeton perfoliatus*	1.7	3.5	0.0	**1.7±1.8**	3.0	2.7	1.7	**2.4±0.7**

Table 5.2.2.28. Seasonal variations in IVI of macrophytic species at Site VII during the study period

S.No	**Species**	**2011**				**2012**			
		Spring	**Summer**	**Autumn**	**Mean±SD**	**Spring**	**Summer**	**Autumn**	**Mean±SD**
	Emergents								
1	*Alisma plantago-aquatica*	0.0	3.4	2.8	**2.1±1.8**	0.0	2.7	2.4	**1.7±1.5**
2	*Alternanthera philoxeroides*	0.0	12.1	13.5	**8.5±7.4**	0.0	8.9	8.5	**5.8±5.0**
3	*Bidens cernua*	0.0	2.7	2.1	**1.6±1.4**	0.0	2.0	1.6	**1.2±1.1**
4	*Lycopus europaeus*	2.3	2.1	0.0	**1.5±1.3**	0.0	2.0	2.5	**1.5±1.3**
5	*Mentha arvensis*	3.0	2.5	2.8	**2.8±0.3**	4.2	2.7	2.4	**3.1±1.0**
6	*Menyanthes trifoliata*	0.0	2.7	0.0	**0.9±1.5**	0.0	0.0	0.0	**0.0±0.0**
7	*Myriophyllum verticillatum*	5.8	5.1	3.9	**4.9±1.0**	5.4	4.7	4.0	**4.7±0.7**
8	*Nasturtium officinalis*	0.0	3.4	2.8	**2.1±1.8**	0.0	3.2	3.2	**2.2±1.9**
9	*Phragmites australis*	6.7	5.5	3.9	**5.4±1.4**	4.1	4.8	4.0	**4.3±0.5**
10	*Polygonum amphibium*	4.3	3.8	4.2	**4.1±0.3**	4.2	3.8	3.5	**3.8±0.4**
11	*Polygonum hydropiper*	3.7	4.2	3.4	**3.8±0.4**	3.4	3.8	4.0	**3.7±0.3**
12	*Sagittaria sagittifolia*	0.0	4.2	0.0	**1.4±2.4**	0.0	3.4	0.0	**1.1±2.0**
13	*Sium latijugam*	2.3	0.0	2.2	**1.5±1.3**	0.0	2.2	2.4	**1.5±1.3**
14	*Sparganium ramosum*	3.0	2.9	2.8	**2.9±0.1**	0.0	0.0	0.0	**0.0±0.0**
15	*Typha angustata*	3.9	3.4	3.4	**3.5±0.3**	2.5	2.7	2.6	**2.6±0.1**
	Rooted-floating leaf type								
16	*Hydrocharis dubia*	4.3	3.8	2.9	**3.7±0.7**	3.4	4.3	2.9	**3.5±0.7**
17	*Marsilea quadrifolia*	3.7	3.8	2.9	**3.5±0.5**	5.0	3.8	3.3	**4.0±0.9**
18	*Nymphaea mexicana*	3.9	3.4	3.5	**3.6±0.3**	3.4	2.7	2.4	**2.8±0.5**
19	*Nymphoides peltatum*	18.2	14.1	17.2	**16.5±2.1**	19.6	16.9	17.5	**18.0±1.4**
20	*Potamogeton natans*	6.3	5.3	5.4	**5.7±0.6**	6.8	5.6	4.6	**5.7±1.1**
21	*Trapa natans*	4.9	4.0	3.4	**4.1±0.7**	4.1	4.3	3.3	**3.9±0.5**
	Free-floating type								
22	*Azolla* sp.	28.5	21.9	22.5	**24.3±3.6**	29.8	30.2	40.3	**33.4±5.9**
23	*Lemna major*	0.0	9.3	9.5	**6.3±5.4**	0.0	0.0	0.0	**0.0±0.0**
24	*Lemna minor*	35.3	28.7	42.2	**35.4±6.7**	37.1	31.3	37.1	**35.1±3.4**
25	*Lemna trisulca*	5.5	5.1	0.0	**3.5±3.0**	0.0	0.0	0.0	**0.0±0.0**
26	*Spirodela polyrhiza*	0.0	2.9	3.4	**2.1±1.8**	0.0	9.5	0.0	**3.2±5.5**
27	*Salvinia natans*	18.3	16.9	17.9	**17.7±0.7**	18.5	18.3	24.2	**20.3±3.3**
	Submergeds								
28	*Ceratophyllum demersum*	16.7	12.3	12.7	**13.9±2.5**	22.1	16.0	15.4	**17.8±3.7**
29	*Hydrilla verticillata*	4.3	4.0	4.5	**4.3±0.2**	8.8	3.8	6.5	**6.4±2.5**
30	*Najas graminea*	0.0	0.0	6.2	**2.1±3.6**	0.0	0.0	0.0	**0.0±0.0**
31	*Myriophyllum spicatum*	0.0	3.4	2.8	**2.1±1.8**	0.0	4.1	0.0	**1.4±2.3**
32	*Potamogeton crispus*	4.9	4.2	2.9	**4.0±1.0**	4.7	3.8	3.5	**4.0±0.7**
33	*Potamogeton lucens*	4.6	4.3	3.5	**4.1±0.6**	4.7	3.3	3.3	**3.8±0.8**
34	*Potamogeton pectinatus*	3.0	3.2	2.1	**2.8±0.6**	3.4	0.0	0.0	**1.1±1.9**
35	*Potamogeton perfoliatus*	3.0	3.7	0.0	**2.3±2.0**	5.0	4.3	3.3	**4.2±0.9**

Table 5.2.2.29. Seasonal variations in frequency (%) of macrophytic species at Site VIII during the study period

S.No	Species	2011				2012			
		Spring	Summer	Autumn	Mean±SD	Spring	Summer	Autumn	Mean±SD
	Emergents								
1	*Myriophyllum verticillatum*	30.0	35.0	40.0	**35.0±5.0**	25.0	30.0	35.0	**30.0±5.0**
2	*Phragmites australis*	20.0	25.0	30.0	**25.0±5.0**	0.0	30.0	35.0	**21.7±18.9**
3	*Polygonum hydropiper*	30.0	35.0	30.0	**31.7±2.9**	20.0	30.0	25.0	**25.0±5.0**
4	*Typha angustata*	20.0	25.0	30.0	**25.0±5.0**	15.0	30.0	20.0	**21.7±7.6**
	Rooted-floating leaf type								
5	*Hydrocharis dubia*	20.0	30.0	40.0	**30.0±10.0**	20.0	30.0	40.0	**30.0±10.0**
6	*Nymphoides peltatum*	50.0	55.0	45.0	**50.0±5.0**	35.0	40.0	35.0	**36.7±2.9**
7	*Potamogeton natans*	30.0	25.0	20.0	**25.0±5.0**	20.0	30.0	25.0	**25.0±5.0**
8	*Trapa natans*	30.0	35.0	20.0	**28.3±7.6**	25.0	35.0	40.0	**33.3±7.6**
	Free-floating type								
9	*Azolla* sp.	40.0	35.0	30.0	**35.0±5.0**	25.0	30.0	40.0	**31.7±7.6**
10	*Lemna minor*	30.0	25.0	30.0	**28.3±2.9**	15.0	25.0	30.0	**23.3±7.6**
11	*Lemna trisulca*	30.0	25.0	0.0	**18.3±16.1**	0.0	0.0	0.0	**0.0±0.0**
12	*Spirodela polyrhiza*	30.0	25.0	40.0	**31.7±7.6**	0.0	25.0	20.0	**15.0±13.2**
13	*Salvinia natans*	30.0	40.0	30.0	**33.3±5.8**	25.0	30.0	30.0	**28.3±2.9**
	Submergeds								
14	*Batrachium trichophyllum*	0.0	25.0	20.0	**15.0±13.2**	20.0	0.0	0.0	**6.7±11.5**
15	*Ceratophyllum demersum*	50.0	45.0	40.0	**45.0±5.0**	40.0	35.0	50.0	**41.7±7.6**
16	*Hydrilla verticillata*	30.0	0.0	0.0	**10.0±17.3**	25.0	0.0	0.0	**8.3±14.4**
17	*Najas graminea*	0.0	0.0	30.0	**10.0±17.3**	0.0	0.0	0.0	**0.0±0.0**
18	*Myriophyllum spicatum*	0.0	30.0	0.0	**10.0±17.3**	0.0	20.0	0.0	**6.7±11.5**
19	*Potamogeton crispus*	20.0	15.0	30.0	**21.7±7.6**	15.0	25.0	30.0	**23.3±7.6**
20	*Potamogeton lucens*	20.0	15.0	20.0	**18.3±2.9**	15.0	25.0	30.0	**23.3±7.6**
21	*Potamogeton pectinatus*	30.0	0.0	25.0	**18.3±16.1**	20.0	15.0	20.0	**18.3±2.9**
22	*Potamogeton perfoliatus*	0.0	15.0	0.0	**5.0±8.7**	0.0	15.0	20.0	**11.7±10.4**

Table 5.2.2.30. Seasonal variations in density (individuals/m^2) of macrophytic species at Site VIII during the study period

S.No	**Species**	**2011**				**2012**			
		Spring	**Summer**	**Autumn**	**Mean±SD**	**Spring**	**Summer**	**Autumn**	**Mean±SD**
	Emergents								
1	*Myriophyllum verticillatum*	0.8	1.2	0.9	**1.0±0.2**	0.5	0.7	0.6	**0.6±0.1**
2	*Phragmites australis*	0.7	0.8	0.5	**0.7±0.2**	0	0.5	0.4	**0.3±0.3**
3	*Polygonum hydropiper*	0.5	0.7	0.5	**0.6±0.1**	0.5	0.7	0.5	**0.6±0.1**
4	*Typha angustata*	0.3	0.5	0.4	**0.4±0.1**	0.2	0.4	0.3	**0.3±0.1**
Rooted-floating leaf type									
5	*Hydrocharis dubia*	0.5	0.8	0.6	**0.6±0.2**	0.4	0.7	0.6	**0.6±0.2**
6	*Nymphoides peltatum*	2.3	2.7	1.8	**2.3±0.5**	1.9	2.3	1.5	**1.9±0.4**
7	*Potamogeton natans*	0.8	1.1	0.5	**0.8±0.3**	0.6	0.8	0.5	**0.6±0.2**
8	*Trapa natans*	0.8	1.0	0.7	**0.8±0.2**	0.6	0.8	0.6	**0.7±0.1**
Free-floating type									
9	*Azolla* sp.	4.6	5.0	4.0	**4.5±0.5**	3	4	4.2	**3.7±0.6**
10	*Lemna minor*	5.4	6.4	6.2	**6.0±0.5**	4.6	6.4	5.8	**5.6±0.9**
11	*Lemna trisulca*	0.6	0.9	0.0	**0.5±0.5**	0	0	0	**0.0±0.0**
12	*Spirodela polyrhiza*	0.0	1.8	1.5	**1.1±1.0**	0	1.5	1.2	**0.9±0.8**
13	*Salvinia natans*	3.6	4.8	4.0	**4.1±0.6**	3.2	3.8	2.4	**3.1±0.7**
Submergeds									
14	*Batrachium trichophyllum*	0.0	0.4	0.3	**0.2±0.2**	0.4	0	0	**0.1±0.2**
15	*Ceratophyllum demersum*	2.4	2.9	2.0	**2.4±0.5**	1.8	2.3	2.2	**2.1±0.3**
16	*Hydrilla verticillata*	0.8	0.0	0.0	**0.3±0.5**	0.6	0	0	**0.2±0.3**
17	*Najas graminea*	0.0	0.0	0.7	**0.2±0.4**	0	0	0	**0.0±0.0**
18	*Myriophyllum spicatum*	0.0	0.6	0.0	**0.2±0.3**	0	0.4	0	**0.1±0.2**
19	*Potamogeton crispus*	0.4	0.7	0.6	**0.6±0.2**	0.6	0.6	0.5	**0.6±0.1**
20	*Potamogeton lucens*	0.5	0.7	0.4	**0.5±0.2**	0.4	0.6	0.5	**0.5±0.1**
21	*Potamogeton pectinatus*	0.4	0.0	0.5	**0.3±0.3**	0.5	0.7	0.5	**0.6±0.1**
22	*Potamogeton perfoliatus*	0.0	0.5	0.0	**0.5±0.3**	0	0.3	0.2	**0.2±0.2**

Table 5.2.2.31. Seasonal variations in abundance of macrophytic species at Site VIII during the study period

S.No	**Species**	**2011**				**2012**			
		Spring	**Summer**	**Autumn**	**Mean±SD**	**Spring**	**Summer**	**Autumn**	**Mean±SD**
	Emergents								
1	*Myriophyllum verticillatum*	2.7	4.0	2.3	**3.0±0.9**	1.7	2.3	2.0	**2.0±0.3**
2	*Phragmites australis*	3.5	4.0	1.7	**3.1±1.2**	0.0	1.7	1.3	**1.0±0.9**
3	*Polygonum hydropiper*	1.7	2.3	1.7	**1.9±0.4**	2.5	2.3	1.7	**2.2±0.4**
4	*Typha angustata*	1.5	2.5	1.3	**1.8±0.6**	1.0	1.3	1.5	**1.3±0.3**
	Rooted-floating leaf type								
5	*Hydrocharis dubia*	2.5	2.7	1.5	**2.2±0.6**	2.0	2.3	1.5	**1.9±0.4**
6	*Nymphoides peltatum*	4.6	5.4	3.6	**4.5±0.9**	4.8	5.8	3.8	**4.8±1.0**
7	*Potamogeton natans*	2.7	3.7	2.5	**2.9±0.6**	2.0	2.7	1.7	**2.1±0.5**
8	*Trapa natans*	2.7	3.3	3.5	**3.2±0.4**	2.0	2.7	1.5	**2.1±0.6**
	Free-floating type								
9	*Azolla* sp.	11.5	12.5	13.3	**12.4±0.9**	10.0	13.3	10.5	**11.3±1.8**
10	*Lemna minor*	18.0	21.3	20.7	**20.0±1.8**	23.0	21.3	19.3	**21.2±1.8**
11	*Lemna trisulca*	2.0	3.0	0.0	**1.7±1.5**	0.0	0.0	0.0	**0.0±0.0**
12	*Spirodela polyrhiza*	0.0	6.0	3.8	**3.3±3.0**	0.0	5.0	6.0	**3.7±3.2**
13	*Salvinia natans*	12.0	12.0	13.3	**12.4±0.8**	10.7	12.7	8.0	**10.4±2.3**
	Submergeds								
14	*Batrachium trichophyllum*	0.0	1.3	1.5	**0.9±0.8**	2.0	0.0	0.0	**0.7±1.2**
15	*Ceratophyllum demersum*	4.8	5.8	5.0	**5.2±0.5**	4.5	5.8	4.4	**4.9±0.8**
16	*Hydrilla verticillata*	2.7	0.0	0.0	**0.9±1.5**	2.0	0.0	0.0	**0.7±1.2**
17	*Najas graminea*	0.0	0.0	2.3	**0.8±1.3**	0.0	0.0	0.0	**0.0±0.0**
18	*Myriophyllum spicatum*	0.0	2.0	0.0	**0.7±1.2**	0.0	2.0	0.0	**0.7±1.2**
19	*Potamogeton crispus*	2.0	3.5	2.0	**2.5±0.9**	3.0	2.0	1.7	**2.2±0.7**
20	*Potamogeton lucens*	2.5	3.5	2.0	**2.7±0.8**	2.0	2.0	1.7	**1.9±0.2**
21	*Potamogeton pectinatus*	1.3	0.0	1.7	**1.0±0.9**	2.5	3.5	2.5	**2.8±0.6**
22	*Potamogeton perfoliatus*	0.0	2.5	0.0	**0.5±1.4**	0.0	1.5	1.0	**0.8±0.8**

Table 5.2.2.32. Seasonal variations in IVI of macrophytic species at Site VIII during the study period

S.No	Species	2011				2012			
		Spring	Summer	Autumn	Mean±SD	Spring	Summer	Autumn	Mean±SD
	Emergents								
1	*Myriophyllum verticillatum*	12.1	13.8	13.5	**13.1±0.9**	11.7	13.5	15.2	**13.5±1.8**
2	*Phragmites australis*	10.9	11.0	9.5	**10.4±0.9**	0.0	12.0	13.4	**8.5±7.4**
3	*Polygonum hydropiper*	9.6	10.9	9.5	**10.0±0.8**	11.4	13.5	11.5	**12.1±1.2**
4	*Typha angustata*	6.8	8.6	8.7	**8.0±1.1**	6.5	11.3	9.0	**8.9±2.4**
	Rooted-floating leaf type								
5	*Hydrocharis dubia*	8.9	10.6	11.5	**10.3±1.3**	10.2	13.5	15.9	**13.2±2.9**
6	*Nymphoides peltatum*	24.2	23.6	19.5	**22.4±2.5**	25.6	25.9	21.7	**24.4±2.3**
7	*Potamogeton natans*	12.1	11.5	8.6	**10.7±1.9**	11.2	14.2	11.5	**12.3±1.6**
8	*Trapa natans*	12.1	12.8	10.6	**11.8±1.1**	12.6	15.6	15.9	**14.7±1.8**
	Free-floating type								
9	*Azolla* sp.	40.2	33.7	36.8	**36.9±3.2**	35.3	37.7	44.8	**39.3±4.9**
10	*Lemna minor*	49.7	44.8	54.0	**49.5±4.6**	57.8	53.9	61.7	**57.8±3.9**
11	*Lemna trisulca*	10.5	10.3	0.0	**6.9±6.0**	0.0	0.0	0.0	**0.0±0.0**
12	*Spirodela polyrhiza*	5.6	15.9	17.6	**13.0±6.5**	0.0	17.9	19.5	**12.5±10.8**
13	*Salvinia natans*	35.0	33.6	36.8	**35.1±1.6**	37.2	36.2	30.4	**34.6±3.7**
	Submergeds								
14	*Batrachium trichophyllum*	0.0	7.1	6.6	**4.6±4.0**	10.2	0.0	0.0	**3.4±5.9**
15	*Ceratophyllum demersum*	24.8	22.7	21.1	**22.9±1.9**	26.2	24.5	30.0	**26.9±2.8**
16	*Hydrilla verticillata*	12.1	0.0	0.0	**4.0±7.0**	12.6	0.0	0.0	**4.2±7.3**
17	*Najas graminea*	0.0	0.0	11.0	**3.7±6.4**	0.0	0.0	0.0	**0.0±0.0**
18	*Myriophyllum spicatum*	0.0	9.3	0.0	**3.1±5.4**	0.0	9.2	0.0	**3.1±5.3**
19	*Potamogeton crispus*	7.8	8.3	10.2	**8.8±1.3**	11.2	11.3	12.9	**11.8±1.0**
20	*Potamogeton lucens*	8.9	8.3	7.6	**8.3±0.6**	8.8	11.3	12.9	**11.0±2.1**
21	*Potamogeton pectinatus*	8.8	0.0	8.5	**5.8±5.0**	11.4	10.6	11.3	**11.1±0.4**
22	*Potamogeton perfoliatus*	0.0	6.7	0.0	**0.5±3.9**	0.0	6.9	7.9	**4.9±4.3**

Table 5.2.2.33. Seasonal variations in frequency (%) of macrophytic species at Site IX during the study period

S.No	**Species**	**2011**				**2012**			
		Spring	**Summer**	**Autumn**	**Mean±SD**	**Spring**	**Summer**	**Autumn**	**Mean±SD**
	Emergents								
1	*Alisma lanceolatum*	0.0	25.0	30.0	**18.3±16.1**	0.0	0.0	0.0	**0.0±0.0**
2	*Alisma plantago-aquatica*	20.0	15.0	20.0	**18.3±2.9**	0.0	20.0	0.0	**6.7±11.5**
3	*Carex* sp.	0.0	15.0	0.0	**5.0±8.7**	0.0	0.0	0.0	**0.0±0.0**
4	*Echinocloa crus-galli*	0.0	20.0	0.0	**6.7±11.5**	0.0	20.0	0.0	**6.7±11.5**
5	*Myriophyllum verticillatum*	30.0	35.0	40.0	**35.0±5.0**	25.0	30.0	40.0	**31.7±7.6**
6	*Phragmites australis*	40.0	35.0	40.0	**38.3±2.9**	25.0	35.0	40.0	**33.3±7.6**
7	*Polygonum amphibium*	30.0	30.0	40.0	**33.3±5.8**	20.0	25.0	30.0	**25.0±5.0**
8	*Polygonum hydropiper*	30.0	35.0	20.0	**28.3±7.6**	20.0	30.0	35.0	**28.3±7.6**
9	*Ranunculus sceleratus*	0.0	20.0	0.0	**6.7±11.5**	0.0	25.0	20.0	**15.0±13.2**
10	*Typha angustata*	30.0	25.0	30.0	**28.3±2.9**	20.0	30.0	25.0	**25.0±5.0**
Rooted-floating leaf type									
11	*Hydrocharis dubia*	30.0	35.0	30.0	**31.7±2.9**	20.0	30.0	25.0	**25.0±5.0**
12	*Marsilea quadrifolia*	40.0	25.0	35.0	**33.3±7.6**	25.0	35.0	35.0	**31.7±5.8**
13	*Nymphoides peltatum*	40.0	40.0	35.0	**38.3±2.9**	35.0	45.0	40.0	**40.0±5.0**
14	*Potamogeton natans*	20.0	30.0	15.0	**21.7±7.6**	15.0	30.0	20.0	**21.7±7.6**
15	*Trapa natans*	20.0	30.0	20.0	**23.3±5.8**	15.0	30.0	35.0	**26.7±10.4**
Free-floating type									
16	*Azolla* sp.	40.0	35.0	20.0	**31.7±10.4**	25.0	35.0	30.0	**30.0±5.0**
17	*Lemna minor*	40.0	35.0	20.0	**31.7±10.4**	30.0	20.0	25.0	**25.0±5.0**
18	*Salvinia natans*	40.0	45.0	30.0	**38.3±7.6**	30.0	35.0	35.0	**33.3±2.9**
Submergeds									
19	*Ceratophyllum demersum*	40.0	35.0	50.0	**41.7±7.6**	30.0	40.0	45.0	**38.3±7.6**
20	*Najas graminea*	0.0	0.0	30.0	**10.0±17.3**	0.0	0.0	0.0	**0.0±0.0**
21	*Potamogeton crispus*	30.0	25.0	40.0	**31.7±7.6**	35.0	40.0	40.0	**38.3±2.9**

Table 5.2.2.34. Seasonal variations in density (individuals/m^2) of macrophytic species at Site IX during the study period

S.No	Species	2011				2012			
		Spring	Summer	Autumn	Mean±SD	Spring	Summer	Autumn	Mean±SD
	Emergents								
1	*Alisma lanceolatum*	0.0	0.6	0.0	**0.2±0.3**	0.0	0.0	0.0	**0.0±0.0**
2	*Alisma plantago-aquatica*	0.4	0.5	0.4	**0.4±0.1**	0.0	0.3	0.0	**0.1±0.2**
3	*Carex* sp.	0.0	0.3	0.0	**0.1±0.2**	0.0	0.0	0.0	**0.0±0.0**
4	*Echinocloa crus-galli*	0.0	0.3	0.0	**0.1±0.2**	0.0	0.2	0.0	**0.1±0.1**
5	*Myriophyllum verticillatum*	0.9	1.2	0.8	**1.0±0.2**	0.7	1.0	0.7	**0.8±0.2**
6	*Phragmites australis*	1.3	1.6	1.0	**1.3±0.3**	0.8	1.0	0.8	**0.9±0.1**
7	*Polygonum amphibium*	0.5	0.7	0.6	**0.6±0.1**	0.6	0.7	0.5	**0.6±0.1**
8	*Polygonum hydropiper*	0.7	0.9	0.7	**0.8±0.1**	0.5	0.8	0.6	**0.6±0.2**
9	*Ranunculus sceleratus*	0.0	0.5	0.0	**0.2±0.3**	0.0	0.4	0.3	**0.2±0.2**
10	*Typha angustata*	0.6	0.8	0.7	**0.7±0.1**	0.4	0.6	0.3	**0.4±0.2**
	Rooted-floating leaf type								
11	*Hydrocharis dubia*	0.5	0.7	0.6	**0.6±0.1**	0.5	0.7	0.6	**0.6±0.1**
12	*Marsilea quadrifolia*	0.8	1.1	0.9	**0.9±0.2**	0.6	0.9	0.7	**0.7±0.2**
13	*Nymphoides peltatum*	2.8	2.9	2.3	**2.7±0.3**	2.1	2.9	2.4	**2.5±0.4**
14	*Potamogeton natans*	0.7	1.1	0.6	**0.8±0.3**	0.6	0.8	0.5	**0.6±0.2**
15	*Trapa natans*	0.7	1.0	0.6	**0.8±0.2**	0.4	0.6	0.4	**0.5±0.1**
	Free-floating type								
16	*Azolla* sp.	5.0	6.0	4.2	**5.1±0.9**	3.8	5.2	5.0	**4.7±0.8**
17	*Lemna minor*	6.0	7.0	5.0	**6.0±1.0**	5.4	5.8	4.4	**5.2±0.7**
18	*Salvinia natans*	3.6	5.0	0.0	**2.9±2.6**	3.2	5.0	3.4	**3.9±1.0**
	Submergeds								
19	*Ceratophyllum demersum*	3.0	3.3	2.3	**2.9±0.5**	2.5	3.3	2.6	**2.8±0.4**
20	*Najas graminea*	0.0	0.0	0.5	**0.2±0.3**	0.0	0.0	0.0	**0.0±0.0**
21	*Potamogeton crispus*	0.7	1.0	0.8	**0.8±0.2**	0.8	0.9	0.7	**0.8±0.1**

Table 5.2.2.35. Seasonal variations in abundance of macrophytic species at Site IX during the study period

S.No	Species	2011				2012			
		Spring	Summer	Autumn	Mean±SD	Spring	Summer	Autumn	Mean±SD
	Emergents								
1	*Alisma lanceolatum*	0.0	2.0	0.0	**0.7±1.2**	0.0	0.0	0.0	**0.0±0.0**
2	*Alisma plantago-aquatica*	2.0	2.5	1.3	**1.9±0.6**	0.0	1.5	0.0	**0.5±0.9**
3	*Carex* sp.	0.0	1.5	0.0	**0.5±0.9**	0.0	0.0	0.0	**0.0±0.0**
4	*Echinocloa crus-galli*	0.0	1.5	0.0	**0.5±0.9**	0.0	1.0	0.0	**0.3±0.6**
5	*Myriophyllum verticillatum*	3.0	4.0	2.0	**3.0±1.0**	2.3	3.3	1.8	**2.5±0.8**
6	*Phragmites australis*	3.3	4.0	2.5	**3.3±0.8**	2.7	2.5	2.0	**2.4±0.3**
7	*Polygonum amphibium*	1.7	2.3	1.5	**1.8±0.4**	3.0	2.3	1.7	**2.3±0.7**
8	*Polygonum hydropiper*	2.3	3.0	3.5	**2.9±0.6**	2.5	2.7	2.0	**2.4±0.3**
9	*Ranunculus sceleratus*	0.0	2.5	0.0	**0.8±1.4**	0.0	1.3	1.5	**0.9±0.8**
10	*Typha angustata*	2.0	2.7	2.3	**2.3±0.3**	2.0	2.0	1.5	**1.8±0.3**
	Rooted-floating leaf type								
11	*Hydrocharis dubia*	1.7	2.3	2.0	**2.0±0.3**	2.5	2.3	2.0	**2.3±0.3**
12	*Marsilea quadrifolia*	2.0	3.7	2.3	**2.6±0.9**	2.0	2.3	2.3	**2.2±0.2**
13	*Nymphoides peltatum*	7.0	7.3	5.8	**6.7±0.8**	5.3	5.8	6.0	**5.7±0.4**
14	*Potamogeton natans*	3.5	3.7	3.0	**3.4±0.3**	3.0	2.7	2.5	**2.7±0.3**
15	*Trapa natans*	3.5	3.3	3.0	**3.3±0.3**	2.0	2.0	1.3	**1.8±0.4**
	Free-floating type								
16	*Azolla* sp.	12.5	15.0	21.0	**16.2±4.4**	12.7	13.0	16.7	**14.1±2.2**
17	*Lemna minor*	15.0	17.5	25.0	**19.2±5.2**	18.0	29.0	22.0	**23.0±5.6**
18	*Salvinia natans*	9.0	12.5	0.0	**7.2±6.4**	10.7	12.5	11.3	**11.5±0.9**
	Submergeds								
19	*Ceratophyllum demersum*	7.5	8.3	4.6	**6.8±1.9**	8.3	8.3	6.5	**7.7±1.0**
20	*Najas graminea*	0.0	0.0	1.7	**0.6±1.0**	0.0	0.0	0.0	**0.0±0.0**
21	*Potamogeton crispus*	2.3	3.3	2.0	**2.6±0.7**	2.7	2.3	1.8	**2.2±0.5**

Table 5.2.2.36. Seasonal variations in IVI of macrophytic species at Site IX during the study period

S.No	**Species**	**2011**				**2012**			
		Spring	**Summer**	**Autumn**	**Mean±SD**	**Spring**	**Summer**	**Autumn**	**Mean±SD**
	Emergents								
1	*Alisma lanceolatum*	0.0	8.4	5.8	**4.7±4.3**	0.0	0.0	0.0	**0.0±0.0**
2	*Alisma plantago-aquatica*	7.8	6.7	7.3	**7.3±0.6**	0.0	11.8	0.0	**3.9±6.8**
3	*Carex* sp.	0.0	5.2	0.0	**1.7±3.0**	0.0	0.0	0.0	**0.0±0.0**
4	*Echinocloa crus-galli*	0.0	6.1	0.0	**2.0±3.5**	0.0	11.5	0.0	**3.8±6.6**
5	*Myriophyllum verticillatum*	12.8	13.9	13.7	**13.5±0.6**	16.6	19.4	24.6	**20.2±4.0**
6	*Phragmites australis*	16.5	15.0	15.2	**15.6±0.8**	17.0	22.1	25.0	**21.4±4.0**
7	*Polygonum amphibium*	9.7	10.0	12.2	**10.6±1.4**	13.4	15.8	18.3	**15.8±2.4**
8	*Polygonum hydropiper*	11.2	12.1	11.2	**11.5±0.5**	13.0	18.8	21.4	**17.7±4.3**
9	*Ranunculus sceleratus*	0.0	7.6	0.0	**2.5±4.4**	0.0	14.8	12.1	**9.0±7.9**
10	*Typha angustata*	10.5	9.6	11.7	**10.6±1.1**	12.6	18.1	14.8	**15.2±2.8**
	Rooted-floating leaf type								
11	*Hydrocharis dubia*	9.7	10.9	10.9	**10.5±0.7**	13.0	18.5	16.0	**15.8±2.7**
12	*Marsilea quadrifolia*	13.1	11.4	13.5	**12.7±1.1**	16.1	21.8	21.8	**19.9±3.3**
13	*Nymphoides peltatum*	26.6	22.7	24.1	**24.4±2.0**	28.1	33.6	31.7	**31.1±2.8**
14	*Potamogeton natans*	10.8	12.3	9.2	**10.8±1.6**	10.7	18.8	12.9	**14.1±4.2**
15	*Trapa natans*	10.8	11.7	10.2	**10.9±0.8**	9.9	18.1	20.6	**16.2±5.6**
	Free-floating type								
16	*Azolla* sp.	41.4	37.8	48.1	**42.4±5.3**	30.1	35.6	37.1	**34.3±3.7**
17	*Lemna minor*	48.2	42.9	56.5	**49.2±6.9**	39.8	29.5	31.9	**33.7±5.4**
18	*Salvinia natans*	32.0	34.5	5.8	**24.1±15.9**	30.2	35.0	33.1	**32.8±2.4**
	Submergeds								
19	*Ceratophyllum demersum*	27.9	23.8	25.6	**25.8±2.1**	27.1	32.2	35.2	**31.5±4.1**
20	*Najas graminea*	0.0	0.0	10.0	**3.3±5.8**	0.0	0.0	0.0	**0.0±0.0**
21	*Potamogeton crispus*	11.2	10.8	13.7	**11.9±1.6**	22.4	24.5	24.6	**23.8±1.2**

5.2.3. Distribution of Macrophytes

In the present study a total of 55 species of macrophytes were recorded in Wular lake, of which 30 belonged to emergents, 10 to rooted floating-leaf types, 06 to free floating types and 09 to submergeds (Table 5.2.3.1). The maximum number of species in the lake were recorded at Site I (35) with 25 species of emergents, 06 rooted floating- leaf type, 01 submergeds and 03 free floating type as against the minimum number of 18 species, being registered at Site IV .The sites VII, VIII and IX were the intermediates between the two extremes supporting 34, 22 and 21 species of macrophytes respectively. The species showing restricted distribution to a particular site were *Scirpus lacustris* (Site I), *Nelumbo nucifera* (Site V), *Rununculus lingua* (Site VI) and *Batrachium trichophyllum* (Site VIII).

There were also considerable seasonal variations in the number of macrophytic species in Wular lake during the entire study period (Table 5.2.3.2). Seasonally, summer recorded the highest number of species while the lowest number of species was recorded in spring. At Site I, the highest number of 32 species was recorded in summer, 2012 while the lowest number of 12 species was recorded in spring, 2012. Site II depicted the minimum number of 18 species in spring, 2012 and the maximum number of 28 species in summer, 2011. Site III registered the highest number of 20 species in summer, 2011 as against the lowest number of 15 species being recorded in spring, 2012. At Site IV, the minimum number of 13 species was recorded in spring, 2012 and maximum number of 17species in summer and autumn 2011 and summer 2012. The number of species at Site V varied from a minimum of 17 species in spring, 2012 to a maximum of 28 species in summer, 2011. Site VI recorded the highest number of 27species in summer, 2011 while the lowest number of 14 species was recorded in spring, 2012. At Site VII, the maximum number of 33 species was recorded in summer, 2011 and the minimum number of 21 species in spring, 2012. Site VIII registered the minimum number of 16 species in summer 2012 as against the maximum number of 19 species being recorded in spring, 2012. Site IX depicted the maximum number of 20 species in summer, 2011 and the minimum of 15 species in spring, 2012. During the entire growth period of macrophytes summer was distinctive in harbouring the highest number of 34 species and that too at Site I which comprised of 24 species of emergents, 06 species of rooted floating-leaf type, 03 species of free floating type and 01species of submergeds. It was followed by 33 species at Site VII, 28 species each at sites II and V and 27 species at Site VI in a decreasing order. The lowest number of 17 species was, however, noticed at Site IV during this season.

During the entire period of study, most of the recorded species belonged to the emergent class which contributed 55 % of the total number of species (Table 5.2.3.2). Significant spatial as well as temporal variations were noticeable in the number of emergent macrophytic species. Thus, Site VIII recorded comparatively lesser number of species (3 in spring, 2012). The highest number of 24 species was recorded at Site I during summer, 2012. The data clearly reveals the greater fluctuations during the first half of growing season and least fluctuations during the later half.

Rooted floating-leaf type species did not fluctuate much all through the growing period. A maximum of 09 species of this life-form class was recorded at sites III and V during summer season. The least number of 04 species was however, recorded at Site VIII throughout the entire growing period.

Free floating class of macrophytes was represented by six species namely *Azolla* sp., *Lemna major, Lemna minor, Lemna trisulca, Spirodela polyrhiza* and *Salvinia natans*. A maximum of 06 species of this life-form class, involving all the species, was recorded at sites II and VII during summer, 2011 and the number of species towards the second half of the growing period did not fluctuate at all.

Submerged class recorded a highest number of 07 species at Site VII during summer and autumn, 2011. The least number of 01 species was recorded at sites I and VI throughout the entire growing period. There were again very little fluctuations in the number of species belonging to this class at different sites.

An overall view of the entire Wular lake on the basis of the occurrence of species revealed that the number of species was at minimal in spring (Table 5.2.3.2). Thereafter the total number of species kept on increasing abruptly till the highest number of species was attained during summer, the peak season of growth and development of macrophytes. After summer a slight decline in the number of species was followed though very little fluctuations in the number of species were registered during the second half of the growing period.

All the life-form classes viz., emergents, rooted floating-leaf type, submergeds and free floating type constituting the macrophytic community of the wetland embraced a distinct assemblage of plant species which grew intermixed at places resulting in complex physiognomy. The different life-form classes, in general, do not exhibit great regularity. The distribution of various macrophytic species in Wular lake is shown in Figure 5.2.3.1. *Typha angustata* and *Phragmites australis*, the chief occupants of littoral zone, extended all along the eastern, north-western and parts of south-eastern side of the lake upto a depth of 2.0m, being accompanied by widespread stands of rooted floating-leaf type species (*Nymphoides peltatum*, *Potamogetan natans* and *Trapa natans*). Overall, almost 20-25 % of the lake area is occupied by emergent macrophytes (Table 5.2.3.3). At Site VIII, they were scattered towards the shoreline but form less dense stands at Site IV. These macrophytes formed small aggregations in between rooted floating-leaf type macrophytes at sites II, III and IX. The maximum area under emergents was seen at Site I where large aggregations of these plant species were found distributed throughout. The other emergent macropjytic species viz., *Myriophyllum verticillatum*, *Polygonum hydropiper* and *Polygonum amphibium* formed a mosaic of several small scattered aggregations in Wular lake. However, at Site I these three species of emergents were mainly confined to the shallow protected areas. Certain emergents such as *Nasturtium officinalis*, *Ranunculus sceleratus*, *Sparganium ramosum*, *Echinocloa crus-galli*, *Hippuris vulgaris* and *Carex* sp. were found occasionally scattered in the shallower areas of the lake towards the shoreline. Besides these above species, there were a number of other emergent species which showed patchy distribution and were mostly confined towards the lake shore.

Rooted floating-leaf type macrophytes occupied near about 35-40 % of the total area of Wular lake and formed widespread dense beds at sites II, III, V and VII. Among these macrophytes *Trapa natans* was the chief constituent species and form large beds at sites III, V and VII. Its area has been purposefully extended in the Wular lake for its economic use by local inhabitants. However, *Nymphaea mexicana* and *Nymphaea alba* formed pure isolated stands of its own at sites III and V. On the other hand, *Nelumbo nucifera* formed small scattered aggregations towards the littoral zone only at Site V. *Nymphoides peltatum*, being widely distributed among rooted floating-leaf type macrophytes, formed dense stands of its own at sites II, III, V and VII. Among this life-form class *Hydrocharius dubia* was distributed within a network of channels in Wular lake and was often seen growing intermixed with other constituent species. *Potamogeton natans* as such did not form pure stands in the Wular lake but was seen intermixed with other rooted floating-leaf type species.

The free-floating species, being dispersed were confined mostly towards littorals and side water channels contributing only 5-10 % to the total area covered by aquatic macrophytes in the entire lake. In this life-form class *Azolla* sp., *Salvinia natans,* and *Lemna minor* were the dominant free-floating species. Among the free floating species *Azolla* sp., *Lemna minor*, *Spirodela polyrhiza* and *Salvinia natans* were seen forming a mosaic of several small scattered aggregations at sites I, VIII and IX. Amongst the free floating species, *Azolla* sp., *Salvinia natans,* and *Lemna minor* formed thick dense mats over extensive areas in the littorals at sites II, V and VI. However, at Site IV, the shoreline was mostly colonised by patchy free floating forms like *Azolla* sp., *Salvinia natans, Spirodela polyrhiza* and *Lemna minor.*

Submerged macrophytes, due to their high aggressive capacity, covered the maximum area all along the western side of the Wular lake. This life-form class dominated by *Ceratophyllum demersum*, *Potamogeton crispus* and *Potamogeton lucens* association formed dense meadows in the open water areas at sites VII, VIII and IV, occupying < 10 % of the total area of the Wular lake. However, at other sites submerged macrophytes showed patchy distribution and are seen growing intermixed mostly with rooted floating-leaf type macrophytes which resulted in complex physiognomy of the wetland. Other submerged macrophytic species like *Myriophyllum spicatum, Hydrilla verticillata* and *Potamogeton pectinatus*, however, formed small aggregations and occupied lesser area.

Table 5.2.3.1. Distribution pattern of macrophytes at nine sites in Wular lake during the study period

S.No	Life-form class	Site I	Site II	Site III	Site IV	Site V	Site VI	Site VII	Site VIII	Site IX
	(A) Emergents									
1.	*Alisma lanceolatum*	+	-	-	-	+	+	-	-	+
2.	*Alisma plantago-aquatica*	+	-	-	-	+	-	+	-	+
3.	*Alternanthera philoxeroides*	-	+	-	-	-	+	+	-	-
4.	*Bidens cernua*	+	-	-	-	+	+	+	-	-
5.	*Butomus umbellatus*	+	-	-	-	-	+	-	-	-
6.	*Carex* sp.	+	-	-	-	-	+	-	-	+
7.	*Cyperus serotinus*	+	-	-	-	-	+	-	-	-
8.	*Echinocloa crus-galli*	+	-	-	-	-	+	-	-	+
9.	*Eleocharis palustris*	+	+	+	-	-	-	-	-	-
10.	*Hippuris vulgaris*	+	-	-	-	-	+	-	-	-
11.	*Juncus buffonius*	-	-	-	-	+	-	-	-	-
12.	*Lycopus europaeus*	+	-	-	-	-	-	+	-	-
13.	*Mentha arvensis*	+	-	-	-	+	+	+	-	-
14.	*Menyanthes trifoliata*	-	-	-	-	+	-	+	-	-
15.	*Myriophyllum aquaticum*	+	+	-	-	-	-	-	-	-
16.	*Myriophyllum verticillatum*	+	+	+	+	+	+	+	+	+
17.	*Nasturtium officinalis*	+	+	-	-	-	-	+	-	-
18.	*Phragmites australis*	+	+	+	-	+	+	+	+	+
19.	*Polygonum amphibium*	-	+	+	+	+	-	+	-	+
20.	*Polygonum hydropiper*	+	+	+	+	+	+	+	+	+
21.	*Ranunculus lingua*	-	-	-	-	-	+	-	-	-
22.	*Ranunculus muricatus*	+	+	-	-	+	+	-	-	-
23.	*Ranunculus sceleratus*	+	+	-	-	+	+	-	-	+
24.	*Sagittaria sagittifolia*	+	-	-	-	-	-	+	-	-
25.	*Scirpus lacustris*	+	-	-	-	-	-	-	-	-
26	*Scirpus palustris*	+	-	-	-	-	+	-	-	-
27.	*Sium latijugam*	+	+	-	-	-	+	+	-	-
28.	*Sparganium ramosum*	+	-	-	-	-	+	+	-	-
29.	*Typha angustata*	+	+	+	+	+	+	+	+	+

Table 5.2.3.1. **Conti………**

30.	*Typha latifolia*	+	+	+	-	-	-	-	-	-
	(B) Rooted floating-leaf type									
31.	*Hydrocharis dubia*	+	+	+	+	+	+	+	+	+
32.	*Marsilea quadrifolia*	+	+	+	+	+	+	+	-	+
33.	*Nelumbo nucifera*	-	-	-	-	+	-	-	-	-
34.	*Nymphaea alba*	-	-	+	-	+	-	-	-	-
35.	*Nymphaea mexicana*	+	+	+	-	+	+	+	-	-
36.	*Nymphaea pygmea*	-		+	-	-	-	-	-	-
37.	*Nymphoides peltatum*	+	+	+	+	+	+	+	+	+
38.	*Potamogeton natans*	+	+	+	+	+	+	+	+	+
39.	*Trapa bispinosa*	-	-	+	-	+	-	-	-	-
40.	*Trapa natans*	+	+	+	+	+	+	+	+	+
	(C)Free-floating type									
41.	*Azolla* sp.	+	+	+	+	+	+	+	+	+
42.	*Lemna major*	-	+	-	+	+	-	+	-	-
43.	*Lemna minor*	+	+	+	+	+	+	+	+	+
44.	*Lemna trisulca*	-	+	-	-	+	-	+	+	-
45.	*Spirodela polyrhiza*	-	+	-	+	-	-	+	+	-
46.	*Salvinia natans*	+	+	+	+	+	+	+	+	+
	(D) Submergeds									
47.	*Batrachium trichophyllum*	-	-	-	-	-	-	-	+	-
48.	*Ceratophyllum demersum*	+	+	+	+	+	+	+	+	+
49.	*Hydrilla verticillata*	-	-	-	+	-	-	+	+	-
50.	*Najas graminea*	-	-	-	-	-	-	+	+	+
51.	*Myriophyllum spicatum*	-	+	-	-	-	-	+	+	-
52.	*Potamogeton crispus*	-	+	+	+	+	-	+	+	+
53.	*Potamogeton lucens*	-	+	-	+	-	-	+	+	-
54.	*Potamogeton pectinatus*	-	-	-	-	-	-	+	+	-
55.	*Potamogeton perfoliatus*	-	-	-	-	-	-	+	+	-

Where, + = Present, -- = Absent

Table 5.2.3.2. Seasonal fluctuations in the number of macrophyte species at different sites in Wular lake

Site	Life-form class	2011			2012		
		Spring	Summer	Autumn	Spring	Summer	Autumn
I	Emergents	15	23	22	11	24	20
	Rooted floating-leaf type	6	6	6	6	6	6
	Free floating type	3	3	3	2	3	3
	Submergeds	1	1	1	1	1	1
II	Emergents	9	12	11	6	12	9
	Rooted floating-leaf type	6	6	6	6	6	6
	Free floating type	5	6	4	3	4	4
	Submergeds	3	4	4	3	4	3
III	Emergents	5	5	7	5	5	5
	Rooted floating-leaf type	6	9	6	5	8	7
	Free floating type	3	3	3	3	3	3
	Submergeds	2	2	2	2	2	2
IV	Emergents	4	4	4	4	4	4
	Rooted floating-leaf type	5	5	5	5	5	5
	Free floating type	3	5	4	4	4	3
	Submergeds	3	3	4	4	4	4
V	Emergents	9	12	11	6	9	8
	Rooted floating-leaf type	7	9	8	6	9	8
	Free floating type	3	5	3	3	4	3
	Submergeds	2	2	2	2	2	2
VI	Emergents	10	17	13	5	12	8
	Rooted floating-leaf type	6	6	6	6	6	6
	Free floating type	2	3	3	2	3	3
	Submergeds	1	1	1	1	1	1
VII	Emergents	9	14	12	6	13	12
	Rooted floating-leaf type	6	6	6	6	6	6
	Free floating type	4	6	5	3	4	3
	Submergeds	6	7	7	6	6	5
VIII	Emergents	4	4	4	3	4	4
	Rooted floating-leaf type	4	4	4	4	4	4
	Free floating type	5	5	4	3	4	4
	Submergeds	5	6	6	6	6	5
IX	Emergents	6	10	7	5	8	6
	Rooted floating-leaf type	5	5	5	5	5	5
	Free floating type	3	3	3	3	3	3
	Submergeds	2	2	3	2	2	2

Table 5.2.3.3. Percentage (%) coverage of different life-form classes of macrophytes at different sites in Wular lake

Site	Coverage of different life-form classes			
	Emergents	Rooted floating-leaf type	Free-floating type	Submergeds
I	Dense	Sparse	Sparse	Sparse
II	Moderate	Dense	Sparse	Sparse
III	Sparse	Dense	Sparse	Sparse
IV	Sparse	Sparse	Sparse	Sparse
V	Sparse	Dense	Moderate	Sparse
VI	Dense	Sparse	Sparse	Sparse
VII	Sparse	Moderate	Sparse	Moderate
VIII	Sparse	Sparse	Sparse	Sparse
IX	Sparse	Moderate	Sparse	Sparse

Where,

Sparse = 0 to 25 % cover

Moderate = >25 to 50 % cover

Dense = >50 to 75 % cover

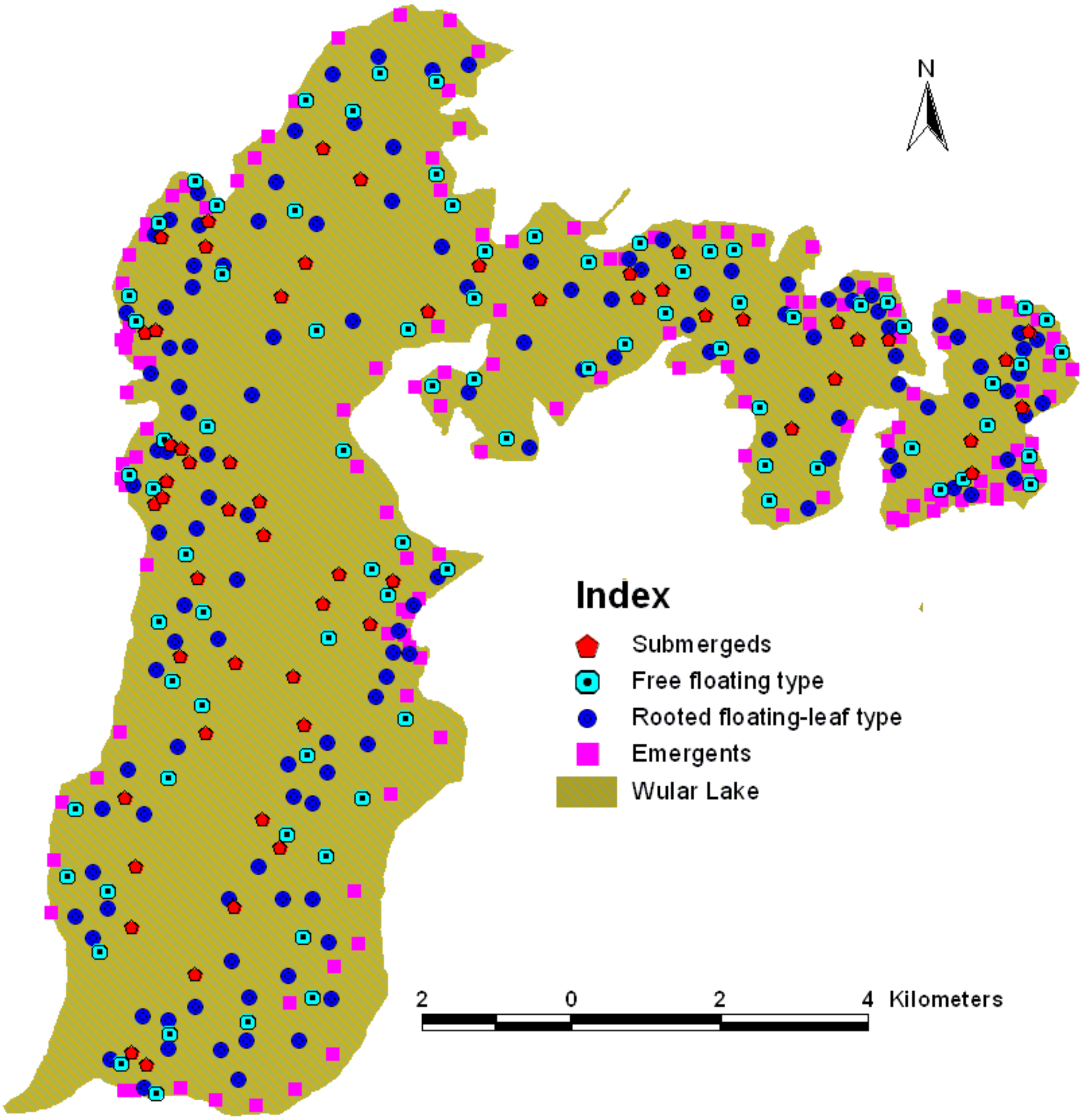


Fig. 5.2.3.1. Distribution patterns of macrophytes in Wular lake

5.2.4. Zonation of Macrophytes

In the wetland under study, unlike lakes, no typical macrophytic zonation was distinguishable except at Site VII (Watlab); instead various macrophytic species either grow intermixed with one another which result in the complex physiognomy of the wetland vegetation or grow in pure communities to form a characteristic type of vegetation which differs qualitatively and quantitatively from the lake vegetation (Fig. 5.2.3.1).The macrophyte dominant lake has well developed littoral zone. Extended littorals in general, were dominated by (i) emergents like *Phragmites australis, Typha angustata, Myriophyllum verticillatum, Polygonum amphibium* and *Polygonum hydropiper,* (ii) rooted floating-leaf types like *Hydrocharis dubia, Nymphoides peltatum, Nymphaea mexicana, Marsilea quadrifolia, Potamogetan natans* and *Trapa natans,* (iii) free-floating types dominated by *Azolla* sp., *Salvinia natans,* and *Lemna minor,* all growing together intermixed and forming a complex physiognomy. The slightly deeper zone has abundant growth of submergeds like *Ceratophyllum demersum* and *Potamogeton crispus* forming meadows at various places. The littorals towards the north-eastern side are densely populated with *Salix* plantation which is eating the vitals of the lake. However, at Site VII, the open water site, macrophytes depicted slight zonation with water depth forming three distinguishable vegetational zones viz., (i) emergents, (ii) rooted floating-leaf type, and (iii) submergeds. The zone of emergent vegetation was narrow and extended from the waterlogged margins upto the depth of 1 m. It was represented by 16 species of both short growing and tall growing species. Except *Alisma plantigo-aquatica, Alternanthera philoxeroides, Bidens cernua, Lycopus europaeus, Mentha arvensis, Menyanthes trifoliata, Nasturtium officinalis, Ranunculus sceleratus, Sagittaria sagittifolia, Sium latijugam and Sparganium ramosum* most of the other species including *Phragmites australis, Typha angustata, Myriophyllum verticillatum, Polygonum amphibium* and *Polygonum hydropiper* depicted significant abundance. *Phragmites australis* was the deep colonizer with its stands extending upto the depth of 2 m. The zone of rooted floating-leaf type vegetation was the broadest vegetational zone and extended from almost inundated margins upto the depth of 4.0 m. *Hydrocharis dubia, Marsilea quadrifolia, Nymphaea mexicana, Nymphoides peltatum, Potamogetan natans* and *Trapa natans* were the dominant species of this zone. While *Hydrocharis dubia* and *Nymphoides peltatum* colonized shallow water zone, *Potamogetan natans* and *Trapa natans* were seen extending upto the depth of 4.0 m.The zone of submerged vegetation was comparatively broader extending upto the depth of 5.0 m.The zone was colonized by the species like *Ceratophyllum demersum*, *Potamogeton crispus*, *Myriophyllum spicatum*, *Hydrilla verticillata*, *Potamogeton lucens* and *Potamogeton pectinatus* with the former two species forming dense meadows. The zone of submerged vegetation covered the central portion of the lake exclusively upto the profundal zone but the individuals were also sparsely dispersed in the less dense stands of rooted floating-leaf type and emergent vegetation. The free-floating species did not form any distinct zone and were dispersed and confined mostly towards littorals and side water channels. *Azolla* sp., *Salvinia natans,* and *Lemna minor* were the dominant free-floating species.

5.2.5. Relationships between physico-chemical characteristics of water and density of macrophytes

Correlation coefficients worked out between the physico-chemical parameters of water and density of different life-form classes of macrophytes depicted highly significant positive as well negative correlations (Table 5.2.5.1).

The most significant positive correlations of density (individuals/m^2) in emergents were recorded with ammonical-nitrogen ($p<0.01$, $r = 0.733$), orthophosphate-phosphorus ($p<0.01$, $r = 0.721$) and water temperature ($p<0.01$, $r = 0.667$), its most significant negative correlations were maintained only with depth ($p<0.05$, $r = -0.712$).

The parameters depicting strong positive correlations with density of rooted floating-leaf type macrophytes were depth ($p<0.01$, $r = 0.711$), water temperature ($p<0.05$, $r = 0.672$) and ammonical-nitrogen ($p<0.01$, $r = 0.668$). Density of rooted floating-leaf types also did not show strong negative correlations with any of the parameters.

Among free floating macrophytes, density of species (individuals/m^2) revealed highly significant positive correlations with ammonical-nitrogen ($p<0.05$, $r = 0.673$), orthophosphate-phosphorus ($p<0.05$, $r = 0.668$) and water temperature ($p<0.05$, $r = 0. 702$). Density of free floating macrophytes, however, did not depict highly significant negative correlations with any of the parameters.

The density of submerged macrophytes (individuals/m^2) depicted highly significant positive correlations with transparency ($p<0.01$, $r = 0.891$), depth ($p<0.01$, $r = 0.806$), ammonical-nitrogen ($p<0.01$, $r = 0.787$), orthophosphate-phosphorus ($p<0.01$, $r = 0.765$) and water temperature ($p<0.01$, $r = 0.645$). Density (individuals/m^2) of submergeds, however, did not depict highly significant negative correlations with any of the parameters.

Table 5.2.5.1. Correlation coefficient between various physico-chemical parameters of water and density of macrophytes in Wular lake

	DEP	**TRAN**	**WT**	**pH**	**CON**	**TDS**	**FC**	**DO**	**TH**	**CC**	**TA**	**AN**	**NN**	**OP**	**TP**	**DS**	**EM**	**RF**	**FF**	**SUB**
EMER	-0.712(*)	-0.109	0.667(**)	0.35	-0.24	-0.254	-0.01	-0.07	-0.2	-0.135	-0.2	0.733(**)	-0.26	0.721(**)	-0.114	-0.404	1			
RF	.711(**)	0.85	0.672(*)	-0.042	0.033	0.03	0.091	0.431	0.04	-0.068	0.05	0.668(**)	0.046	-0.08	0.063	0.454	-0.22	1		
FF	-0.482	-0.318	0.702(*)	0.014	0.106	0.099	0.309	-0.4	0.11	0.175	0.29	0.673(*)	-0.159	0.668(*)	0.225	-0.168	0.71	-0.2	1	
SUB	0.806(**)	0.891(**)	0.645(**)	-0.307	0.334	0.331	0.4	0.081	0.41	0.392	0.23	0.787(**)	0.26	0.765(**)	0.217	-0.247	0.275	-0	-0.259	1

The marked correlations are significant at P=<0.05 (1- tailed) and P=<0.01 (2-tailed).

Where, WT - Water temperature, TDS – Total dissolved solids, CON – Specific conductivity, pH – pH, FC –Free carbon dioxide, DO – Dissolved oxygen, TH – Total hardness, CC – Calcium content, AN – Ammonical-nitrogen, NN – Nitrate-nitrogen, TP – Total phosphorus, OP – Ortho-phosphate phosphorus, DS – Dissolved silica, EMER – Emergents, RF – Rooted floating-leaf type, FF – Free-floating type, SUB – Submergeds.

5.2.6. Diversity Indices

The Shannon-Weiner index was computed to analyse the species diversity at nine different sites for a period of two years to ascertain the structural features of the community. The index values at different sites are given in figure 5.2.6.1. A perusal of the data showed the highest index value of species diversity for Site VII (3.06), followed by Site I (2.86), Site VI (2.84) and Site II (2.80) and decreasing to minimum of 2.38 at Site IX.

A perusal of data on the Simpson's diversity index revealed that the maximum value of 0.989 was recorded at Site V as against the minimum value of 0.939 being recorded at Site I. The other sites showed values intermediate between the two extremes (Fig. 5.2.6.2).

There were clear variations in the distribution of various species of macrophytes in Wular lake. The Sorenson's similarity index based on species composition generally showed good similarity between all sites (Table 5.2.6.3). On the basis of Sorensen's similarity index, the sites that showed close similarity were sites I and VI (81. 3 %), followed by sites VII and VIII (76.9 %), IV and VIII (75.0 %), II and VI (73.8%) and V and IX (72.0 %). On the other hand, least value for Sorensen's similarity coefficient was observed for sites I and IV (45.3 %) and VI and VIII (47.1 %).

5.2.7. Cluster Analysis

The relationship among the sites was obtained through cluster analysis using Bray-Curtis method (linkage between groups). Spatial data set analysis resulted in a dendrogram, grouping all the nine sites in to four meaning full clusters (Fig. 5.2.7.1). Cluster I included Site I and VI that resemble to almost one another with a similarity of 78% in terms of macrophyte presence. Sites VIII and IV fall under cluster II with an 81% similarity in terms of macrophytes. Another cluster was made up of Sites IX and III with a similarity of 90 % and simultaneously having 84 % similarity with Site V, while Site II and VII made up the other group with 78 % similarity in terms of presence of macrophytes.

Fig. 5.2.6.1. Site-wise variations in Shannon –Weiner index during the two years of study period

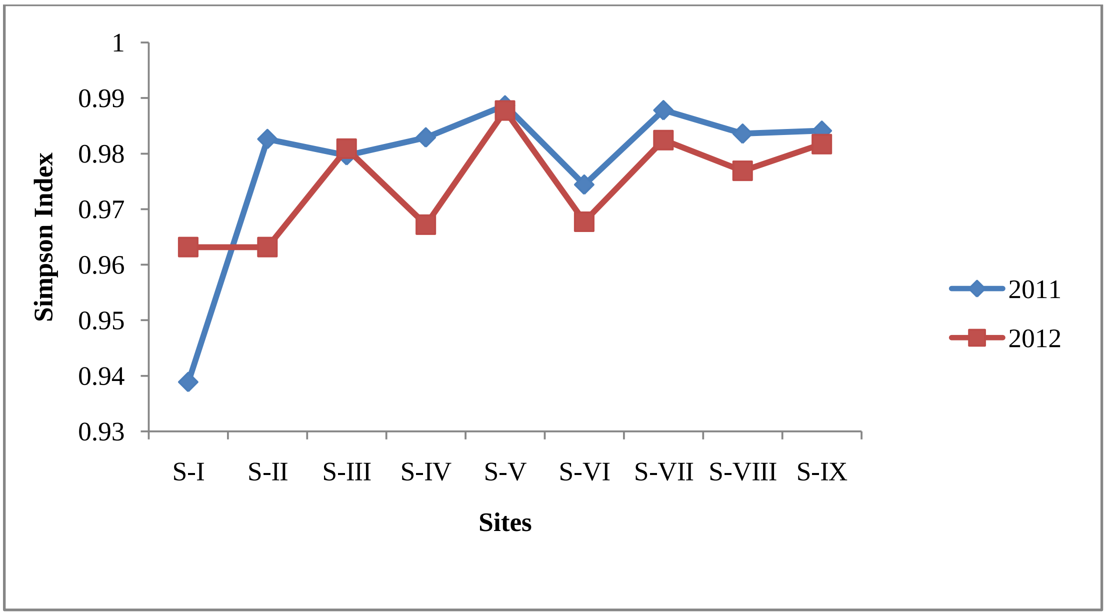


Fig. 5.2.6.2. Site-wise variations in Simpson diversity index during the two years of study period

Table 5.2.6.3. Sorenson similarity coefficient (%) between different selected sites on the basis of macrophytes

	S-I	S-II	S-III	S-IV	S-V	S-VI	S-VII	S-VIII
S-II	64.6							
S-III	57.1	70.6						
S-IV	45.3	70.8	71.8					
S-V	62.5	67.8	68.0	63.8				
S-VI	81.3	61.0	56.0	59.6	69.0			
S-VII	60.0	73.8	57.1	67.9	68.8	64.6		
S-VIII	42.1	65.4	60.5	75.0	58.8	47.1	76.9	
S-IX	64.3	66.7	71.4	71.8	72.0	68.0	57.1	60.5

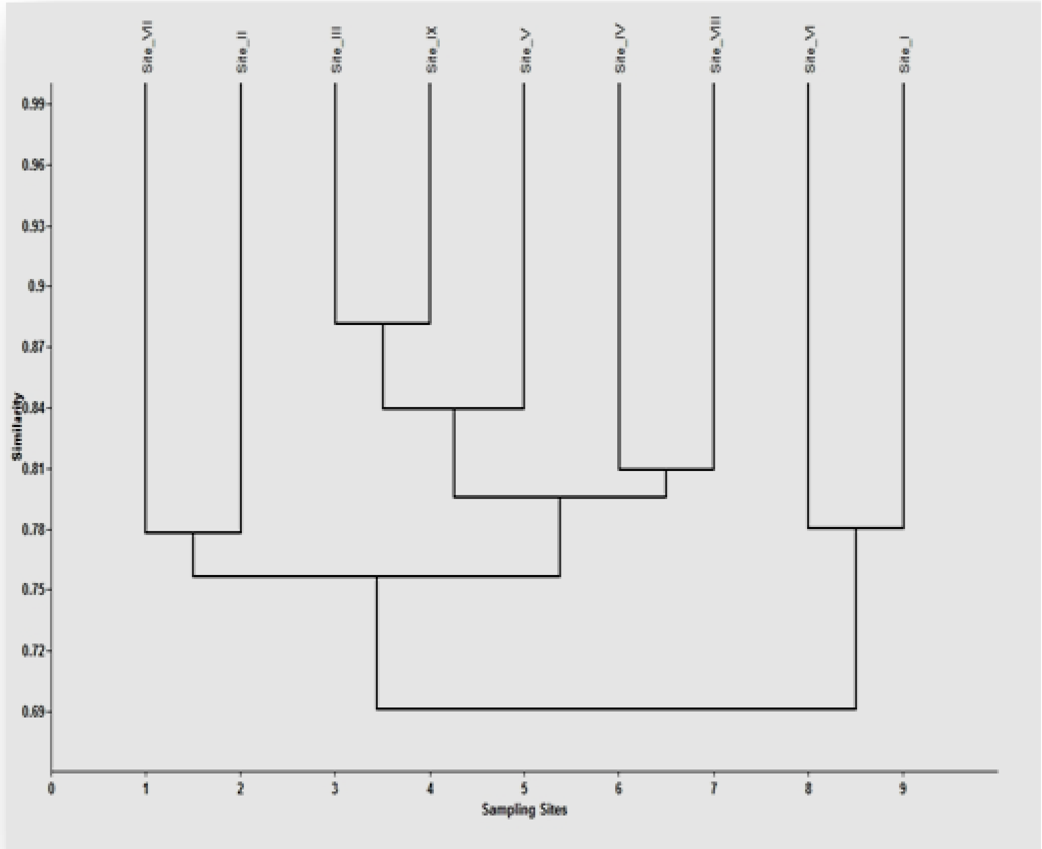


Fig. 5.2.7.1. Bray-Curtis cluster analysis of macrophytes at nine study sites

5.2.8. Primary productivity

Wular lake, a Ramsar Site in Kashmir Himalaya, has a complex physiognomy of macro-vegetation and is colonized by all the four life-form classes of macrophytes viz. emergent type, rooted floating-leaf type, free-floating type and submerged type. Among these, emergent (reeds and cattails) and rooted floating-leaf type classes, being the dominant and sub-dominant classes respectively, contribute much towards the primary productivity of the lake.

Production estimates in Wular lake were undertaken for a total of 16 species of macrophytes comprising 05 emergents, 06 rooted floating- leaf types, 03 free floating type and 02 submergeds (Table 5.2.8.1 and 5.2.8.2).The production of dominant macrophytes, calculated on the basis of dry weight biomass, depicted emergents and rooted-floating leaf types to accumulate more biomass during the entire study period. During the year 2011 the maximum production was recorded for *Typha angustata* (1,800 g dwt. m^{-2}) and minimum for *Lemna minor* (22 g dwt. m^{-2}).

Among the emergents, the highest production was exhibited by *Typha angustata* (1,800 g dwt. m^{-2}), followed by *Phragmites australis* (1,450 g dwt. m^{-2}), *Myriophyllum verticillatum* (380 g dwt. m^{-2}), *Polygonum hydropiper* (225 g dwt. m^{-2}) and decreasing to the lowest of 210 g dwt. m^{-2} for *Polygonum amphibium*.

Trapa natans, with a production value of 450 g dwt. m^{-2} was recorded to be the most productive species among the rooted floating - leaf type class, followed by *Nymphaea mexicana* (340 g dwt. m^{-2}) and *Nymphoides peltatum* (310 g dwt. m^{-2}) .The lowest productive species, among rooted floating-leaf type class, was *Marsilea quadrifolia* recording the production of 60 g dwt. m$^{-2.}$.

Three free floating species were estimated for primary productivity and among these the maximum production was recorded for *Salvinia natans* (33 g dwt. m^{-2}) and minimum for *Lemna minor* (22 g dwt. m^{-2}). *Azolla* sp. ranked second in terms of production among the free-floating class with the value of 26 g dwt. m^{-2}.

In the submerged class, *Ceratophyllum demersum* registered the highest production of 170 g dwt. m^{-2} as against the lowest of 110 g dwt. m^{-2} being recorded for *Potamogetan crispus*.

The net primary productivity in Wular lake during 2011 fluctuated between a minimum of 0.10 g dwt. m^{-2} day^{-1} for *Azolla* sp. and a maximum of 6.94 g dwt. m^{-2} day^{-1} for *Typha angustata*. *Phragmites australis* was the second most productive species with net primary productivity of 5.59 g dwt. m^{-2} day^{-1} (Table 5.2.8.1). *Trapa natans* dominated among rooted floating leaf-types with net primary productivity of 1.73 g dwt. m^{-2} day^{-1}, followed by *Nymphaea mexicana* and *Nymphoides peltatum* recording net primary productivity value of 1.35 g dwt. m^{-2} day^{-1} each. Among the free floating species, *Salvinia natans* with a value of 0.28 g dwt. m^{-2} day^{-1} depicted highest net primary productivity. It was followed by *Lemna minor* (0.12 g dwt. m^{-2} day^{-1}) and *Azolla* sp. (0.10 g dwt. m^{-2} day^{-1}). In the submerged class, *Ceratophyllum demersum* depicted highest net primary productivity recording a value of 0.65 g dwt. m^{-2} day^{-1} against the lowest value of 0.42 g dwt. m^{-2} day^{-1} being recorded for *Potamogetan crispus*.

A perusal of data on the production values of dominant macrophytes in Wular lake shows that during 2012 the maximum production was again recorded for *Typha angustata* (1,390 g dwt. m^{-2}) and minimum for *Lemna minor* (16 g dwt. m^{-2}). *Phragmites australis* ranked second in terms of production with the value of 905 g dwt. m^{-2}. *Trapa natans* and *Nymphoides peltatum* were the two most productive species among rooted floating-leaf types recording production values of 445 g dwt. m^{-2} and 280 g dwt. m^{-2} respectively (Table 5.2.8.2).The production of free-floating species varied from 16 g dwt. m^{-2} (*Lemna minor*) to 32 g dwt. m^{-2} (*Salvinia natans*). Among submergeds, *Ceratophyllum demersum* depicted highest production with a value of 151 g dwt. m^{-2} against the lowest value of 83 g dwt. m^{-2} being recorded for *Potamogetan crispus*.

During 2012 the net primary productivity in Wular lake varied from a minimum of 0.09 g dwt. m^{-2} day^{-1} each for *Lemna minor* and *Azolla* sp. to a maximum of 5.36 g dwt. m^{-2} day^{-1} for *Typha angustata*. The other species with significant net primary productivity were: *Phragmites australis* (3.49 g dwt. m^{-2} day^{-1}), *Trapa natans* (1.71 g dwt. m^{-2} day^{-1}), *Myriophyllum verticillatum* (1.38 g dwt. m^{-2} day^{-1}) and *Nymphoides peltatum* (1.22 g dwt. m^{-2} day^{-1}). Among the free-floating species, *Azolla* sp. and *Lemna minor* were found to be equally productive species with net primary productivity value of 0.09 g dwt. m^{-2} day^{-1} each. However, *Salvinia natans*, among the free-floating species depicted the maximum net primary productivity of 0.27 g dwt. m^{-2} day^{-1}. Among submergeds, the maximum net primary productivity was recorded for *Ceratophyllum demersum* (0.57 g dwt. m^{-2} day^{-1}) and minimum for *Potamogetan crispus* (0.31 g dwt. m^{-2} day^{-1}).

In general, among the 16 species of macrophytes estimated for the primary production in Wular lake, *Typha angustata* depicted the maximum productivity, followed by *Phragmites australis* and *Trapa natans* in a decreasing order. The lowest production was recorded for free floating *Lemna minor*. It is clear from the data that most of the emergent macrophytic species are highly productive contributing much towards the total primary productivity of the lake, being followed by the rooted floating-leaf type species especially *Trapa natans*, *Nymphaea mexicana* and *Nymphoides peltatum*.

The overall percentage contributions of various life-form classes of macrophytes towards the total production of the Wular lake are presented in figure 5.2.8.1 and 5.2.8.2. The emergent class of macrophytes contributed a maximum of about 69 %, followed by rooted floating- leaf type (24.5 %), submergeds (5 %) and decreasing to the minimum of 1.5 % by the free-floating type. The dominance pattern of emergent macrophytes is thus well established in Wular lake which is supported by the fact that cummulative productivity of all the other life-form classes is even much less than half of the primary productivity of emergent class. Even if all the species are taken into account for the estimation of productivity in the lake, the emergents alone contributed almost 90 % to the overall production as there are proportionally more than one half of the species belonging to this class of macrophytes recorded during the present study in the Wular lake.

A perusal of data on the annual production values of dominant macrophytes in Wular lake during the two years of study period revealed that the production values of macrophytes were significantly higher in the year 2011 as compared to the year 2012 (Table 5.2.8.1 and 5.2.8.2) . It is clear from the data that during the year 2012 a significant decrease in the productivity values was recorded for almost all the macrophytic species. However, insignificant differences in the productivity values of certain macrophytes such as *Potamogeton natans, Hydrocharis dubia, Lemna minor,* and *Salvinia natans* were noticeable during the two years of study period.

Table 5.2.8.1. Average production (g dwt. m^{-2}) and net primary production (g dwt. m^{-2} day^{-1}) of dominant macrophytes in Wular lake during 2011

S.No.	Species	Plant part	Production* (g dwt. m^{-2})	NPP (g dwt. m^{-2} day^{-1})
	Emergents			
1	*Phragmites australis*	Whole plant	1450.0	5.59
2	*Typha angustata*	Whole plant	1800.0	6.94
3	*Myriophyllum verticillatum*	Whole plant	380.0	1.46
4	*Pologonum amphibium*	Whole plant	210.0	0.80
5	*Polygonum hydropiper*	Whole plant	225.0	0.86
	Rooted floating-leaf type			
6	*Trapa natans*	Whole plant	450.0	1.73
7	*Potamogeton natans*	Whole plant	64.0	0.26
8	*Nymphaea mexicana*	Leaf lamina	340.0	1.35
9	*Hydrocharis dubia*	Whole plant	95.0	0.36
10	*Nymphoides peltatum*	Leaf lamina	310.0	1.35
11	*Marselia quadrifolia*	Whole plant	60.0	0.23
	Free-floating type			
12	*Azolla* sp.	Whole plant	26.0	0.10
13	*Lemna minor*	Whole plant	22.0	0.12
14	*Salvinia natans*	Whole plant	33.0	0.28
	Submergeds			
15	*Potamogeton crispus*	Whole plant	110.0	0.42
16	*Ceratophyllum demersum*	Whole plant	170.0	0.65

*** Sum of positive increments in biomass of species; NPP= Net Primary Productivity**

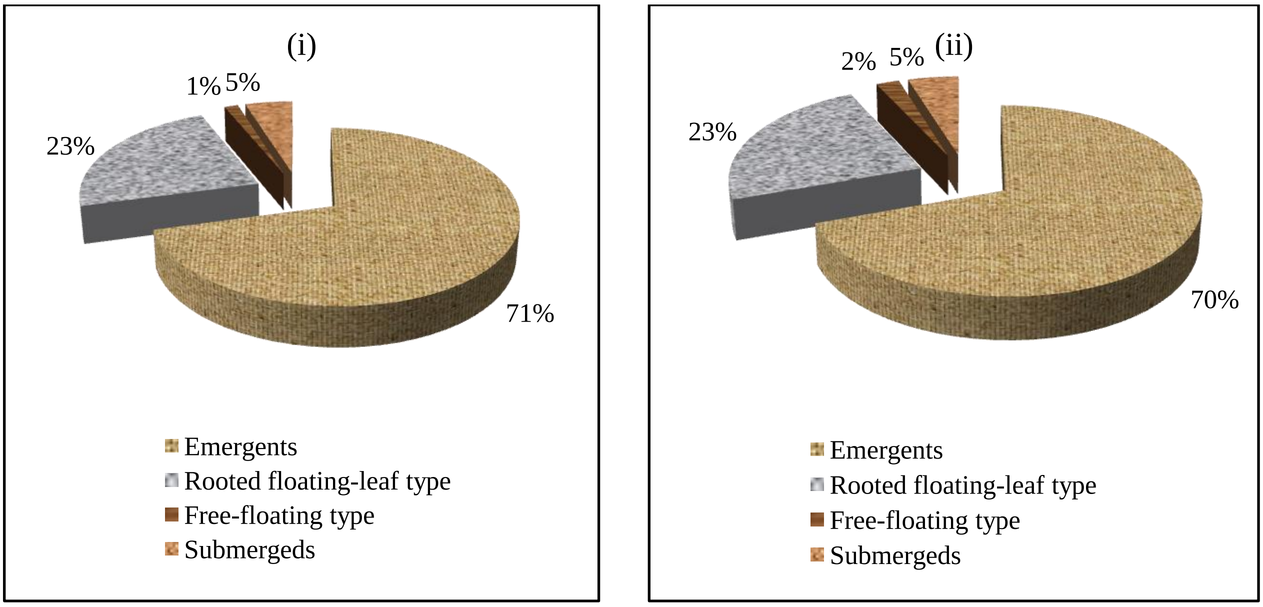


Fig. 5.2.8.1. Percentage contribution of various life-form classes of macrophytes towards (i) production and (ii) net primary productivity in Wular lake during 2011

Table 5.2.8.2. Average production (g dwt. m^{-2}) and net primary production (g dwt. m^{-2} day^{-1}) of dominant macrophytes in Wular lake during 2012

S.No	Species	Plant part	Production* (g dwt. m^{-2})	NPP(g dwt. m^{-2} day^{-1})
Emergents				
1	*Phragmites australis*	Whole plant	905.0	3.49
2	*Typha angustata*	Whole plant	1390.0	5.36
3	*Myriophyllum verticillatum*	Whole plant	360.0	1.38
4	*Pologonum amphibium*	Whole plant	197.0	0.75
5	*Polygonum hydropiper*	Whole plant	208.0	0.79
Rooted floating-leaf type				
6	*Trapa natans*	Whole plant	445.0	1.71
7	*Potamogeton natans*	Whole plant	66.0	0.27
8	*Nymphaea mexicana*	Leaf lamina	275.0	1.09
9	*Hydrocharis dubia*	Whole plant	92.0	0.34
10	*Nymphoides peltatum*	Leaf lamina	280.0	1.22
11	*Marselia quadrifolia*	Whole plant	55.0	0.21
Free-floating type				
12	*Azolla* sp.	Whole plant	24.0	0.09
13	*Lemna minor*	Whole plant	16.0	0.09
14	*Salvinia natans*	Whole plant	32.0	0.27
Submergeds				
15	*Potamogeton crispus*	Whole plant	83.0	0.31
16	*Ceratophyllum demersum*	Whole plant	151.0	0.57

*** Sum of positive increments in biomass of species; NPP= Net Primary Productivity**

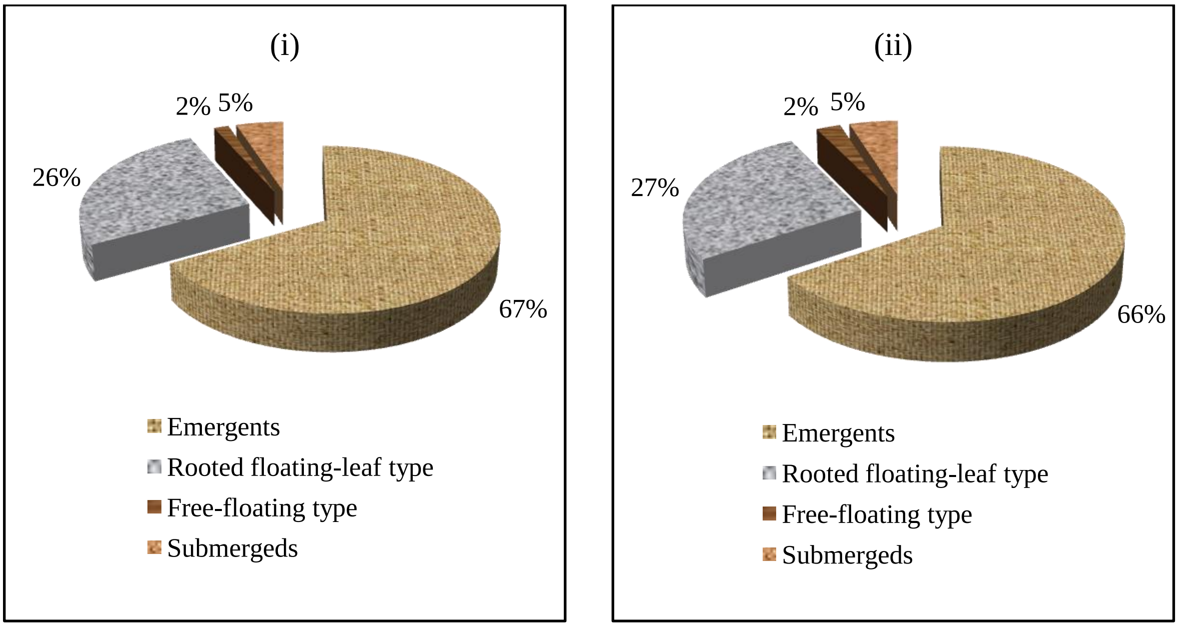


Fig. 5.2.8.2. Percentage contribution of various life-form classes of macrophytes towards (i) production and (ii) net primary productivity in Wular lake during 2012

5.2.9. Biochemical Composition of Macrophytes

In all, sixteen macrophytic species, including 05 emergent, 06 rooted floating-leaf type species, 03 free-floating and 02 submerged species, were analysed, on seasonal basis, for various biochemical constituents viz. total lipids, total carbohydrates, total proteins and chlorophyll content. The concentration of various biochemical constituents varied not only between different species but also depicted temporal variations within the same species.

5.2.9.1. Protein Content (% fresh weight)

The concentration of proteins (on % fresh wt, basis) depicted discernable seasonal variations in different macrophytic species during the two years of study period. In general, on temporal scale, the maximum concentrations of proteins in various plant tissues were recorded during autumn, followed by summer and spring and decreasing to the minimum in winter. However, there were significant differences in the concentration of proteins in different species. Thus, during the year 2011 the maximum concentration of proteins was recorded for *Azolla sp.* (23.8 %) in autumn against the minimum for *Nymphoides peltatum* (5.2 %) in winter. Further, among emergents, the highest concentration of proteins was recorded during autumn for *Typha angustata* (15.6 %), followed by *Phragmites australis* and *Polygonum amphibium* with 14.2 % each and *Polygonum hydropiper* (13.2 %) in a decreasing order. In contrast, the lowest concentration of proteins (4.5 %) was registered for *Myriophyllum verticillatum* during winter. Except *Marsilea quadrifolia* recording a low of 11.0 %, rooted floating-leaf type macrophytes recorded comparatively higher values as evinced by *Nymphaea mexicana* (20.2 %), *Hydrocharis dubia* (19.7 %) and *Potamogeton natans* (18.2 %) again during autumn. Submergeds maintained slightly higher concentration of proteins compared to emergents with *Potamogeton crispus* registering 19.2 %, followed by *Ceratophyllum demersum* (14.4 %) during autumn. Among all the four life-form classes, the free-floating species registered the highest concentrations of proteins with *Azolla* sp. recording a highest of 23.8 % as against the lowest of 14.8 %, being recorded for *Salvinia natans* (Table 5.2.9.1a). However, irrespective of life-form classes, the highest annual mean concentration of proteins (17.2 ±6.2 %) was recorded for *Azolla* sp., followed by *Lemna minor* (15.0±6.1 %), *Hydrocharis dubia* (12.1 ±6.1 %) as against the lowest of 5.9 ±2.0 %, being obtained for *Myriophyllum verticillatum* (Fig. 5.2.9.1a). It is clear from the data that during the year 2011 the concentration of total proteins depicted greater variations in different periods, though significant increases for *Azolla* sp., *Lemna minor* and *Salvinia natans* were evinced in the early autumn season.

A perusal of the data on the total protein concentrations of dominant macrophytes in Wular lake during the two years of study period revealed that the total protein concentrations of macrophytes were slightly higher in the year 2011 as compared to the year 2012 (Table 5.2.9.1a and 5.2.9.1b). During 2012 the concentration of total proteins of dominant macrophytes in Wular lake fluctuated between a minimum of 3.2 % for *Polygonum amphibium* during winter and a maximum of 21.7 % each for *Azolla* sp. during autumn. For emergents, the highest concentration, being recorded during autumn, was noted for *Typha angustata* (13.9 %), followed by *Phragmites australis* (12.8 %), *Polygonum amphibium* (12.4 %), *Polygonum hydropiper* (10.4 %) and *Myriophyllum verticillatum* (8.6 %) in a decreasing order. However, among the rooted floating-leaf type species, the maximum concentration of total proteins (18.2 %) was obtained for *Hydrocharis dubia* in autumn, which was followed by *Nymphaea mexicana* (17.3 %), *Potamogeton natans* (16.0 %) and *Nymphoides peltatum* (12.8 %) again in autumn. Among the free-floating species, *Azolla* sp. with a value of 21.7 % recorded the highest total protein concentration during autumn, followed by 19.4 % for *Lemna minor* and 13.7 % for *Salvinia natans* during the same season. Among submergeds, *Potamogeton crispus* registered the highest percentage of 16.6 during autumn as against the lowest of 5.2 % being recorded for *Ceratophyllum demersum* during winter.

During 2012 the highest annual mean concentration of total proteins of 15.2 ±4.8 % was obtained for *Azolla* sp., followed by 13.2±4.4 % for *Lemna minor* and 12.0±4.7 % for *Potamogeton crispus*. However, the lowest annual mean concentration (5.1±1.8 %) was obtained for *Myriophyllum verticillatum* (Fig. 5.2.9.1b).

Correlation coefficients worked out between the physico-chemical parameters of water and protein content (% fresh weight) in different life-form classes of macrophytes depicted highly significant positive as well negative correlations between the various parameters (Table 5.2.9.1c). Free-floating species were the only exception which could not depict strong correlation with any of the parameters.

In emergents, the concentration of proteins (% fresh weight) depicted a strong positive correlation with dissolved oxygen ($p<0.05$, $r = 0.930$). It, however, did not show any significant negative correlations with any of the other parameters.

In rooted floating-leaf type macrophytes, the concentration of proteins (% fresh weight) could not depict strong positive correlation with any of the parameters. Protein content (% fresh weight) in rooted floating-leaf types, however, depicted highly significant negative correlations with ammonical-nitrogen ($p<0.01$, $r = -0.855$) and dissolved silica ($p<0.01$, $r = -0.889$).

The concentration of proteins (% fresh weight) in submergeds depicted highly significant positive correlations with transparency ($p<0.01$, $r = 0.773$), conductivity ($p<0.01$, $r = 0.856$), total alkalinity ($p<0.01$, $r = 0.873$), ammonical-nitrogen ($p<0.01$, $r = 0.831$), total phosphorus ($p<0.01$, $r = 0.813$) and dissolved silica ($p<0.01$, $r = 0.723$) and its most significant negative correlations were noticeable with nitrate-nitrogen ($p<0.01$, $r = -0.755$) and orthophosphate-phosphorus ($p<0.01$, $r = -0.722$).

Table 5.2.9.1a. Seasonal variations in the protein content (% on fresh wt. basis) of dominant macrophytes in Wular lake during 2011

S.No.	Species	Plant part	Spring	Summer	Autumn	Winter	Mean±S.D
Emergents							
1	*Myriophyllum verticillatum*	AGP	7.3	8.4	9.8	4.5	5.9±2.0
2	*Phragmites australis*	AGP	10.6	13.5	14.2	5.8	8.2±3.4
3	*Polygonum amphibium*	AGP	10.7	11.6	14.2	6.9	8.8±2.7
4	*Polygonum hydropiper*	AGP	9.5	10.8	13.2	5.8	7.7±2.6
5	*Typha angustata*	AGP	12.0	14.4	15.6	7.4	9.7±3.3
Rooted floating-leaf type							
6	*Trapa natans*	AGP	9.3	10.8	13.6	6.3	7.8±2.1
7	*Potamogeton natans*	AGP	14.4	16.6	18.2	8.7	11.6±4.0
8	*Nymphaea mexicana*	Leaf lamina	15.1	17.2	20.2	8.3	11.7±4.8
9	*Hydrocharis dubia*	AGP	16.4	18.6	19.7	7.8	12.1±6.1
10	*Marsilea quadrifolia*	AGP	7.8	9.4	11.0	5.4	6.6±1.7
11	*Nymphoides peltatum*	Leaf lamina	9.8	12.6	14.8	5.2	7.5±3.3
Submergeds							
12	*Potamogeton crispus*	Whole plant	14.6	16.4	19.2	8.2	11.4±4.5
13	*Ceratophyllum demersum*	Whole plant	9.3	11.4	14.4	5.6	7.5±2.6
Free-floating type							
14	*Azolla* sp.	Whole plant	16.3	21.1	23.8	11.4	17.2±6.2
15	*Lemna minor*	Whole plant	14.4	17.6	21.4	9.2	15.0±6.1
16	*Salvinia natans*	Whole plant	10.1	12.8	14.8	6.1	10.3±4.4

ABP=Above ground part

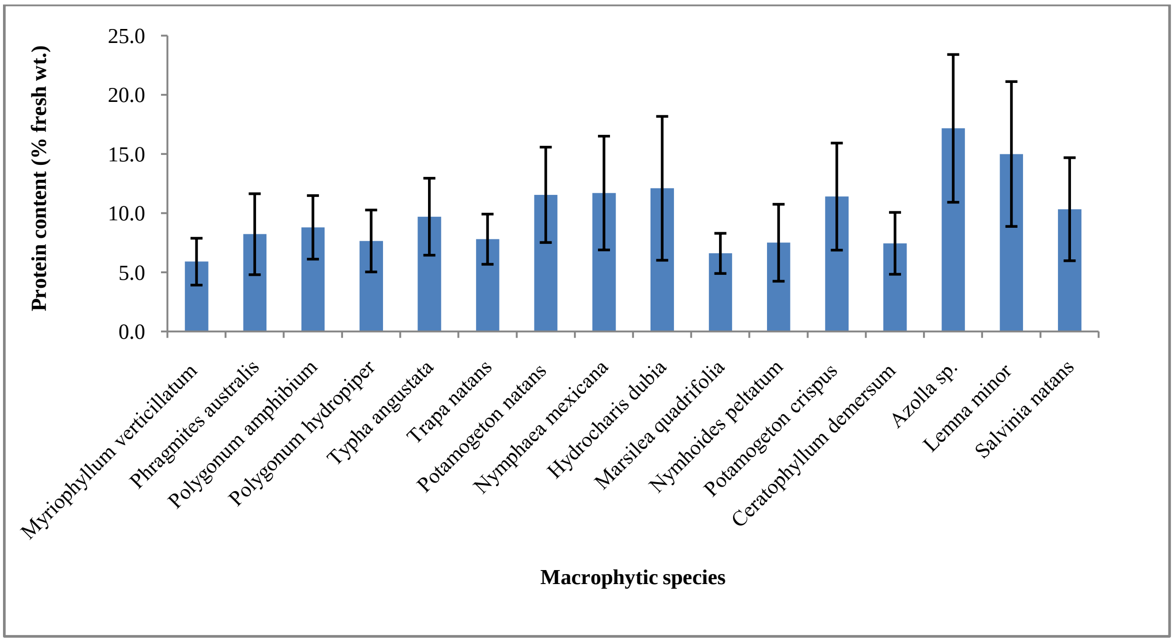


Fig. 5.2.9.1a. Average concentration of proteins (% on fresh wt. basis) in dominant macrophytic species of Wular lake during 2011

Table 5.2.9.1b. Seasonal variations in the protein content (% on fresh wt. basis) of dominant macrophytes in Wular lake during 2012

S.No.	Species	Plant part	Spring	Summer	Autumn	Winter	Mean±S.D
Emergents							
1	*Myriophyllum verticillatum*	ABP	6.4	7.2	8.6	3.8	5.1±1.8
2	*Phragmites australis*	ABP	9.2	11.3	12.8	3.6	6.4±4.0
3	*Polygonum amphibium*	ABP	8.8	11.2	12.4	3.2	6.0±4.0
4	*Polygonum hydropiper*	ABP	7.2	9.0	10.4	3.3	5.3±2.8
5	*Typha angustata*	ABP	10.2	12.8	13.9	5.2	7.7±3.5
Rooted floating-leaf type							
6	*Trapa natans*	ABP	8.4	9.6	12.4	4.5	6.5±2.8
7	*Potamogeton natans*	ABP	12.6	14.8	16.0	6.2	9.4±4.5
8	*Nymphaea mexicana*	Leaf lamina	13.3	15.4	17.3	7.1	10.2±4.4
9	*Hydrocharis dubia*	ABP	13.2	16.1	18.2	7.7	10.5±3.9
10	*Marsilea quadrifolia*	ABP	6.8	8.4	11.2	4.2	5.5±1.8
11	*Nymphoides peltatum*	Leaf lamina	8.6	9.8	12.8	5.3	7.0±2.3
Submergeds							
12	*Potamogeton crispus*	Whole plant	12.2	14.4	16.6	7.3	12.0±4.7
13	*Ceratophyllum demersum*	Whole plant	9.6	11.3	12.8	5.2	9.2±3.8
Free-floating type							
14	*Azolla* sp.	Whole plant	16.2	19.5	21.7	10.0	15.2±4.8
15	*Lemna minor*	Whole plant	13.8	17.3	19.4	8.6	13.2±4.4
16	*Salvinia natans*	Whole plant	9.7	11.4	13.7	6.2	9.1±2.7

ABP=Above ground part

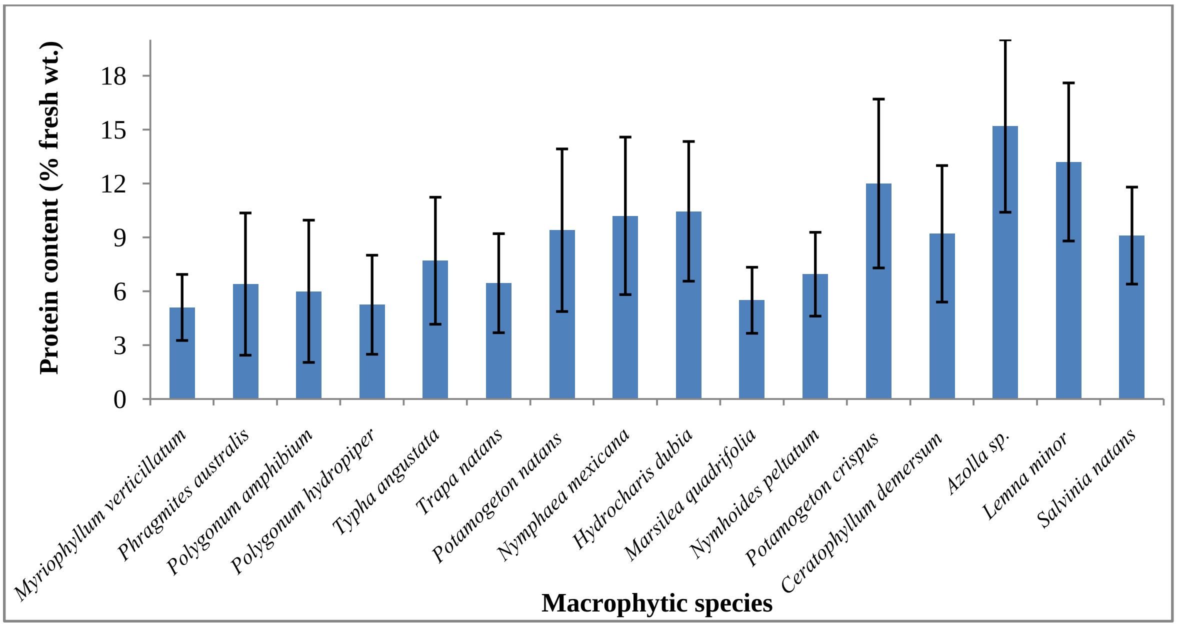


Fig. 5.2.9.1b. Average concentration of proteins (% on fresh wt. basis) in dominant macrophytic species of Wular lake during 2012

Table 5.2.9.1c. Correlation coefficients between various physico-chemical parameters of water and protein content in different life- form classes of macrophytes in Wular lake

	TR	WT	pH	CON	DO	TA	TH	CC	AN	NN	OP	TP	DS	TI
TR	1													
WT	-.678(*)	1												
pH	0.135	0.156	1											
CON	-0.328	0.288	-.862(**)	1										
DO	.814(**)	-.792(*)	0.202	-0.531	1									
TA	-0.309	0.314	-.816(**)	.953(**)	-0.587	1								
TH	-0.275	0.174	-.918(**)	.978(**)	-0.451	.940(**)	1							
CC	-0.351	0.187	-.922(**)	.964(**)	-0.483	.941(**)	.991(**)	1						
AN	-0.287	0.632	-0.199	0.498	-0.335	0.514	0.392	0.397	1					
NN	-0.182	0.569	-0.304	0.503	-0.275	0.532	0.438	0.438	.903(**)	1				
OP	-0.351	0.459	-.704(*)	.857(**)	-0.547	.818(**)	.806(**)	.802(**)	0.575	.721(*)	1			
TP	-0.214	0.547	-0.436	0.654	-0.392	.719(*)	0.591	0.603	.893(**)	.943(**)	.792(*)	1		
DS	0.152	0.507	0.185	0.16	-0.073	0.196	0.036	-0.018	.803(**)	.718(*)	0.256	0.645	1	
TI	0.103	0.522	0.658	-0.323	-0.152	-0.318	-0.412	-0.467	0.073	0.124	-0.037	0.031	0.452	1
EM	0.866	-0.795	0.404	-0.628	.930(*)	-0.681	-0.643	-0.628	0.072	0.263	-0.362	0.001	0.195	-0.175
RF	0.265	-0.372	0.178	-0.284	0.227	-0.369	-0.157	-0.183	-0.855(*)	-0.631	-0.269	-0.634	-0.889(*)	0.651
SUB	0.773(**)	0.651(**)	0.684(**)	0.856(**)	-0.657(**)	0.873(**)	0.678(**)	0.740(**)	0.831(**)	-0.755(**)	-0.722(**)	0.813(**)	0.723(**)	0.633(**)
FF	-0.826	0.822	-0.691	0.948	-0.825	0.99	0.889	0.898	0.979	0.666	0.741	0.963	0.9	-0.763

The marked correlations are significant at P=<0.05 (1- tailed) and P=<0.01 (2-tailed).

Where, TR- Transparency, WT- Water temperature, TDS – Total dissolved solids, CON – Specific conductivity, pH – pH, DO – Dissolved oxygen, TH – Total hardness, CC– Calcium content, AN – Ammonical-nitrogen, NN – Nitrate-nitrogen, TP – Total phosphorus, OP – Ortho-phosphate phosphorus, DS – Dissolved silica, TI – Total iron, EM – Emergents, RF – Rooted floating-leaf type, FF – Free-floating type, SUB – Submergeds.

5.2.9.2. Carbohydrate Content (% fresh weight)

A perusal of data on the carbohydrate content (on % fresh wt. basis) of dominant macrophytes in Wular lake revealed distinct seasonal variations during the two years of study period. In general, on temporal scale, the maximum concentrations of carbohydrates in various plant tissues were recorded during summer, followed by spring and autumn and decreasing to the minimum in winter. Significant differences were observed in the carbohydrate concentration of different species. It is clear from the data that the carbohydrate content of macrophytes was slightly higher in the year 2011 as compared to the year 2012 (Table 5.2.9.2a and 5.2.9.2b).

During the year 2011 the maximum concentration of carbohydrates was recorded for *Phragmites australis* (27.0 %) in summer against the minimum for *Ceratophyllum demersum* (1.6 %) in winter. Further, among emergents, the highest concentration of carbohydrates was obtained for *Phragmites australis* (27.0 %), followed by *Typha angustata* (26.4 %), *Polygonium amphibium* (12.5 %) and *Myriophyllum verticillatum* (10.9 %), being recorded during summer. In contrast, the lowest concentration of carbohydrates (3.0 %) was registered for *Polygonum hydropiper* during winter. Among all the four life-form classes, the rooted floating-leaf type macrophytes registered the highest concentration of carbohydrates as evinced by *Potamogeton natans* (26.0 %), *Marsilea quadrifolia* (21.9 %), *Nymphaea mexicana* (20.4 %) and *Hydrocharis dubia* (17.8 %) again during summer. However, compared to rooted floating-leaf type and emergent macrophytes, free-floating species maintained slightly lower concentration of carbohydrates with *Lemna minor* registering 13.3 %, followed by *Salvinia natans* (12.4 %) and *Azolla* sp. (6.5 %) during summer. The submergeds registered the lowest concentration of carbohydrates with *Potamogeton crispus* recording a highest of 9.5 % during summer as against the lowest of 1.4 %, being recorded for *Ceratophyllum demersum* during autumn (Table 5.2.9.2a).. However, irrespective of life-form classes, the highest annual mean concentration of carbohydrates (16.4±8.1 %) was recorded for *Typha angustata*, followed by *Phragmites australis* (15.6±8.7 %), *Marsilea quadrifolia* (14.9 ±6.3 %), *Nymphaea mexicana* (14.7±5.4 %) as against the lowest of 3.6±2.9 %, being obtained for *Ceratophyllum demersum* (Fig. 5.2.9.2a).

A different scenario was noticed during the year 2012 in which the carbohydrate concentration of dominant macrophytes fluctuated between a minimum of 2.8 % for *Myriophyllum verticillatum* during winter and a maximum of 23.4 % for

Typha angustata during summer (Table 5.2.9.2b). For emergents, the highest concentration being recorded during summer was noted for *Typha angustata* (23.4 %), followed by *Phragmites australis* (22.2 %), *Polygonum amphibium* (11.9 %), *Myriophyllum verticillatum* (10.1 %) and *Polygonum hydropiper* (9.0 %) in a decreasing order. However, among the rooted floating-leaf type species, the maximum concentration of carbohydrates (20.5 %) was obtained for *Marsilea quadrifolia* in summer, which was followed by *Nymphaea mexicana* (19.7 %), *Potamogeton natans* (19.1 %) and *Hydrocharis dubia* (17.9 %) again in summer. Among the free-floating species, *Lemna minor* with a value of 11.3 % recorded the highest carbohydrate concentration during summer, followed by 10.6 % for *Salvinia natans* and 5.1 % for *Azolla* sp. during the same season. Among submergeds, *Potamogeton crispus* registered the highest value of 9.3 % during summer as against the lowest of 2.8 % being recorded for *Ceratophyllum demersum* during winter.

During 2012 the highest annual mean concentration of carbohydrates of 15.0 ±7.3 % was again obtained for *Typha angustata*, followed by 14.9±4.0 % for *Nymphaea mexicana* and 13.7±6.1 % for *Marsilea quadrifolia*. However, the lowest annual mean concentration (4.0±0.8 %) was obtained for *Azolla* sp. (Fig. 5.2.9.2b).

Correlation coefficients worked out between the physico-chemical parameters of water and carbohydrate content (% on fresh weight basis) in different life-form classes of macrophytes depicted highly significant positive as well negative correlations only in case of rooted floating-leaf type and submerged macrophytes (Table 5.2.9.2c).

In rooted floating-leaf type macrophytes, the concentration of carbohydrates (% on fresh weight basis) depicted a strong positive correlations with transparency ($p<0.01$, $r = 0.941$) and dissolved oxygen ($p<0.05$, $r = 0.898$). Carbohydrate content (% on fresh weight basis) in rooted floating-leaf types, however, depicted highly significant negative correlations only with water temperature ($p<0.01$, $r = -0.949$).

The concentration of carbohydrates (% on fresh weight basis) in submergeds depicted highly significant positive correlations with transparency ($p<0.01$, $r = 0.785$), water temperature ($p<0.01$, $r = 0.853$), pH ($p<0.01$, $r = 0.811$) and dissolved silica ($p<0.01$, $r = 0.712$) and its most significant negative correlations were noticeable with total phosphorus ($p<0.01$, $r = -0.833$), nitrate-nitrogen ($p<0.01$, $r = -0.867$) and orthophosphate-phosphorus ($p<0.01$, $r = -0.833$).

Table 5.2.9.2a. Seasonal variations in the carbohydrate content (% on fresh wt. basis) of dominant macrophytes in Wular lake during 2011

S.No.	Species	Plant part	Spring	Summer	Autumn	Winter	Mean±S.D
			Emergents				
1	*Myriophyllum verticillatum*	AGP	7.0	10.9	5.2	3.0	6.5±3.4
2	*Phragmites australis*	AGP	15.2	27.0	13.7	6.2	15.6±8.7
3	*Polygonum amphibium*	AGP	8.7	12.5	7.1	3.5	7.9±3.8
4	*Polygonum hydropiper*	AGP	6.2	9.5	5.2	3.0	6.0±2.7
5	*Typha angustata*	AGP	17.4	26.4	15.3	6.7	16.4±8.1
			Rooted floating-leaf type				
6	*Trapa natans*	AGP	6.4	10.5	4.5	2.8	6.0±3.3
7	*Potamogeton natans*	AGP	14.0	26.0	10.7	5.2	14.0±8.8
8	*Nymphaea mexicana*	Leaf lamina	17.0	20.4	13.8	7.6	14.7±5.4
9	*Hydrocharis dubia*	AGP	11.9	17.8	9.1	4.4	10.8±5.6
10	*Marsilea quadrifolia*	AGP	17.4	21.9	13.4	7.1	14.9±6.3
11	*Nymphoides peltatum*	Leaf lamina	11.6	15.8	7.9	4.3	9.9±4.9
			Submergeds				
12	*Potamogeton crispus*	Whole plant	6.6	9.5	5.6	3.2	6.2±2.6
13	*Ceratophyllum demersum*	Whole plant	4.0	7.6	1.4	1.6	3.6±2.9
			Free-floating type				
14	*Azolla* sp.	Whole plant	4.3	6.5	3.6	2.0	4.1±1.9
15	*Lemna minor*	Whole plant	10.6	13.3	9.5	4.5	9.5±3.7
16	*Salvinia natans*	Whole plant	8.4	12.4	7.6	3.7	8.0±3.6

ABP=Above ground part

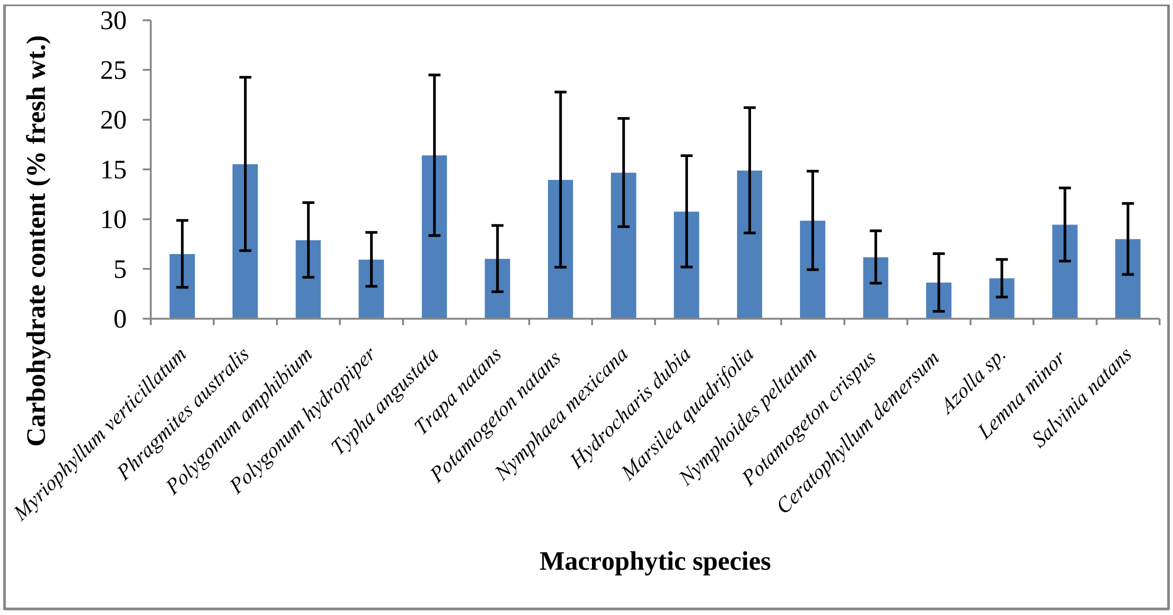


Fig. 5.2.9.2a. Average concentration of carbohydrates (% on fresh wt. basis) in dominant macrophytic species of Wular lake during 2011

Table 5.2.9.2b. Seasonal variations in the carbohydrate content (% on fresh wt. basis) of dominant macrophytes in Wular lake during 2012

S.No.	Species	Plant part	Spring	Summer	Autumn	Winter	Mean±S.D
			Emergents				
1	*Myriophyllum verticillatum*	AGP	6.0	10.1	4.8	2.2	5.8±3.3
2	*Phragmites australis*	AGP	14.5	22.2	12.0	5.5	13.5±6.9
3	*Polygonum amphibium*	AGP	8.1	11.9	6.5	2.9	7.3±3.7
4	*Polygonum hydropiper*	AGP	5.4	9.0	4.5	2.6	5.3±2.7
5	*Typha angustata*	AGP	16.6	23.3	14.4	5.5	15.0±7.3
			Rooted floating-leaf type				
6	*Trapa natans*	AGP	5.8	10.4	4.0	2.5	5.7±3.4
7	*Potamogeton natans*	AGP	13.3	19.1	10.6	4.6	11.9±6.0
8	*Nymphaea mexicana*	Leaf lamina	16.3	19.7	13.2	10.3	14.9±4.0
9	*Hydrocharis dubia*	AGP	11.2	17.9	7.6	4.0	10.2±5.9
10	*Marsilea quadrifolia*	AGP	16.2	20.5	11.8	6.2	13.7±6.1
11	*Nymphoides peltatum*	Leaf lamina	11.1	14.3	7.3	3.3	9.0±4.8
			Submergeds				
12	*Potamogeton crispus*	Whole plant	6.7	9.3	6.4	3.1	6.4±2.6
13	*Ceratophyllum demersum*	Whole plant	4.1	7.0	4.3	2.8	4.5±1.8
			Free-floating type				
14	*Azolla* sp.	Whole plant	3.9	5.1	4.2	3.0	4.0±0.8
15	*Lemna minor*	Whole plant	9.8	11.3	8.4	4.4	8.5±3.0
16	*Salvinia natans*	Whole plant	8.1	10.6	6.8	3.2	7.2±3.1

AGP=Above ground part

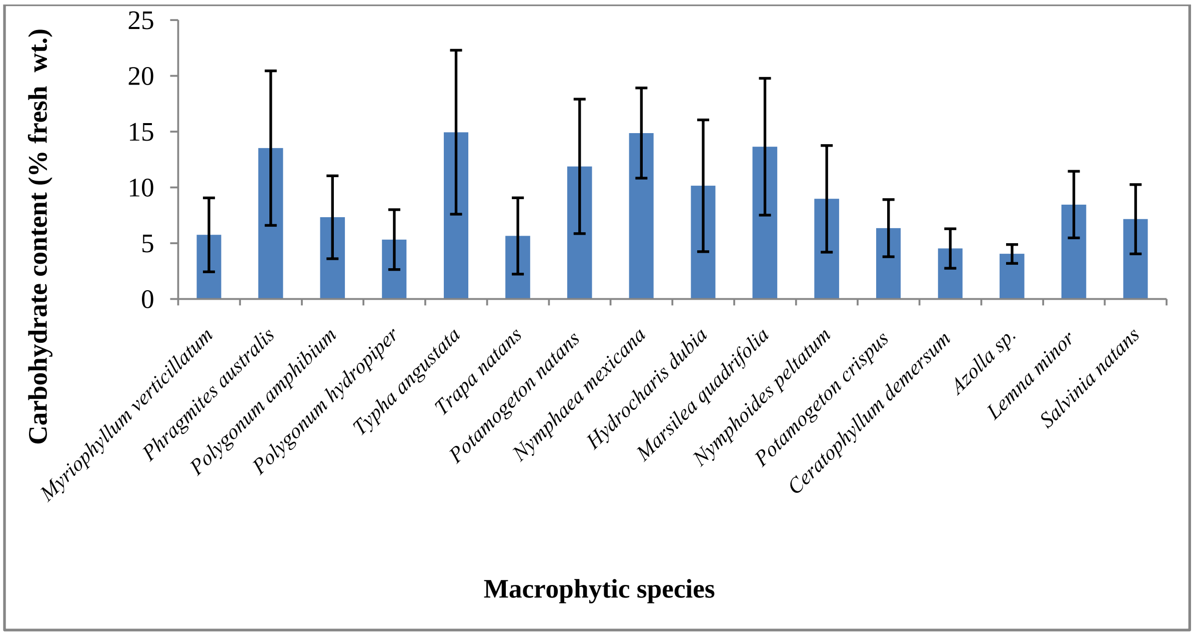


Fig. 5.2.9.2b. Average concentration of carbohydrates (% on fresh wt. basis) in dominant macrophytic species of Wular lake during 2012

Table 5.2.9.2c. Correlation coefficients between various physico-chemical parameters of water and carbohydrate content in different life- form classes of macrophytes in Wular lake

	TR	WT	pH	CON	DO	TA	TH	CC	AN	NN	OP	TP	DS	TI
TR	1													
WT	-.678(*)	1												
pH	0.135	0.156	1											
CON	-0.328	0.288	-.862(**)	1										
DO	.814(**)	-.792(*)	0.202	-0.531	1									
TA	-0.309	0.314	-.816(**)	.953(**)	-0.587	1								
TH	-0.275	0.174	-.918(**)	.978(**)	-0.451	.940(**)	1							
CC	-0.351	0.187	-.922(**)	.964(**)	-0.483	.941(**)	.991(**)	1						
AN	-0.287	0.632	-0.199	0.498	-0.335	0.514	0.392	0.397	1					
NN	-0.182	0.569	-0.304	0.503	-0.275	0.532	0.438	0.438	.903(**)	1				
OP	-0.351	0.459	-.704(*)	.857(**)	-0.547	.818(**)	.806(**)	.802(**)	0.575	.721(*)	1			
TP	-0.214	0.547	-0.436	0.654	-0.392	.719(*)	0.591	0.603	.893(**)	.943(**)	.792(*)	1		
DS	0.152	0.507	0.185	0.16	-0.073	0.196	0.036	-0.018	.803(**)	.718(*)	0.256	0.645	1	
TI	0.103	0.522	0.658	-0.323	-0.152	-0.318	-0.412	-0.467	0.073	0.124	-0.037	0.031	0.452	1
EM	0.804	-0.723	-0.388	0.097	0.819	-0.047	0.103	0.096	0.41	0.816	0.417	0.508	0.309	-0.743
RF	.941(**)	-.949(**)	0.434	-0.703	.898(*)	-0.696	-0.652	-0.632	-0.352	-0.115	-0.435	-0.29	-0.266	0.208
SUB	-0.785(**)	0.853(**)	0.811(**)	0.616(**)	-0.741(**)	0.567(**)	0.645(**)	0.678(**)	0.693(**)	-0.867(**)	-0.833(**)	0.654(**)	0.712(**)	0.546(**)
FF	0.988	-0.989	0.009	-0.475	0.988	-0.624	-0.336	-0.354	-0.853	0.025	-0.08	-0.517	-0.955	0.114

The marked correlations are significant at P=<0.05 (1- tailed) and P=<0.01 (2-tailed).

Where, TR- Transparency, WT- Water temperature, TDS – Total dissolved solids, CON – Specific conductivity, pH – pH, DO – Dissolved oxygen, TH – Total hardness, CC – Calcium content, AN – Ammonical-nitrogen, NN – Nitrate-nitrogen, TP – Total phosphorus, OP – Ortho-phosphate phosphorus, DS – Dissolved silica, TI – Total iron, EM – Emergents, RF – Rooted floating-leaf type, FF – Free-floating type, SUB – Submergeds.

5.2.9.3. Total lipids (% fresh weight)

The concentration of total lipids (on % fresh wt. basis) depicted clear seasonal variations in different macrophytic species during the two years of study period. In general, on temporal scale, the maximum concentrations of total lipids in various plant tissues were recorded during autumn, followed by summer and spring and decreasing to the minimum in winter. However, there were significant differences in the concentration of biomolecules in different species. Thus, during the year 2011 the maximum concentration of total lipids was recorded for *Potamogeton crispus* (7.6 %) in autumn and minimum for *Polygonum hydropiper* (0.7 %) in winter. Further, among emergents, the highest concentration of total lipids was obtained for *Myriophyllum verticillatum* (7.2 %), followed by *Phragmites australis* (6.6 %), *Typha angustata* (6.0 %) and *Polygonum amphibium* (3.6 %), being recorded during autumn. In contrast, the lowest concentration of total lipids (0.7 %) was registered for *Polygonum hydropiper* during winter. Excepting *Trapa natans* recording a high of 6.3 %, rooted floating-leaf type macrophytes recorded comparatively lower values as evinced by *Marsilea quadrifolia* (5.0 %), *Nymphaea mexicana* (4.5 %) and *Potamogeton natans* (4.4 %) during autumn. Free-floating species maintained slightly higher concentration of total lipids compared to rooted floating-leaf type macrophytes with *Azolla* sp. registering 5.6 %, followed by *Lemna minor* (5.2 %) and *Salvinia natans* (4.2 %) during autumn. Among submergeds, *Potamogeton crispus* registered the highest concentration of total lipids with a value of 7.6 % as against the lowest of 7.1 %, being recorded for *Ceratophyllum demersum* (Table 5.2.9.3a). However, irrespective of life-form classes, the highest annual mean concentration of total lipids (4.7 ±2.3 %) was recorded for *Myriophyllum verticillatum*, followed by *Phragmites australis* (4.2±2.1 %), *Trapa natans* (4.0±1.9 %) as against the lowest of 1.3±0.7 %, being obtained for *Polygonum hydropiper* (Fig. 5.2.9.3a). It is clear from the data that during the year 2011 the concentration of total lipids depicted greater variations in different periods, though significant increases for *Ceratophyllum demersum* and *Potamogeton crispus* (about 4 times each) were evinced in the early autumn season experiencing frequent rains.

A perusal of data on the total lipid concentrations of dominant macrophytes in Wular lake during the two years of study period revealed that the total lipid concentrations of macrophytes were slightly higher in the year 2012 as compared to the year 2011 (Table 5.2.9.3a and 5.2.9.3b). During 2012 the concentration of total lipids of dominant macrophytes in Wular lake fluctuated between a minimum of 0.4 % for *Polygonum hydropiper* during winter against a maximum of 7.4 % each for *Myriophyllum verticillatum* and *Phragmites australis* during autumn. For emergents, the highest concentration of 7.4 % was noted each for *Myriophyllum verticillatum* and *Phragmites australis*, followed by 6.8 % for *Typha angustata*, 4.0 % for *Polygonum amphibium* and 2.5 % for *Polygonum hydropiper* during autumn. However, among the rooted floating-leaf type species, the maximum concentration of total lipids (6.8 %) was recorded for *Trapa natans* in autumn, which was followed by *Nymphaea mexicana* (5.2 %), *Marsilea quadrifolia* (5.0 %) and *Potamogeton natans* (4.6 %) again in autumn. Among the free-floating species, *Lemna minor* with a value of 5.8 % recorded the highest total lipid concentration during autumn as against the lowest of 1.3 % being recorded for *Azolla* sp. during winter. Among submergeds, *Potamogeton crispus* registered the highest percentage of 6.8 during autumn, followed by 6.6 % recorded for *Ceratophyllum demersum* during the same season.

During 2012 the highest annual mean concentration of total lipids of 4.8±2.6 % was obtained for *Myriophyllum verticillatum*, followed by 4.5±2.2 % for *Trapa natans* and 4.3±2.5 % for *Phragmites australis*. However, the lowest annual mean concentration (1.4±0.9 %) was obtained for *Polygonum hydropiper* (Fig. 5.2.9.3b).

Correlation coefficients worked out between the physico-chemical parameters of water and total lipid concentration (% fresh weight) in different life-form classes of macrophytes depicted highly significant positive as well negative correlations between the various parameters (Table 5.2.9.3c).

The concentration of total lipids (% fresh weight) in emergents depicted highly significant positive correlations with conductivity ($p<0.05$, $r = 0.856$), free carbon dioxide ($p<0.05$, $r = 0.890$), nitrate-nitrogen ($p<0.05$, $r = 0.814$), total phosphorus ($p<0.01$, $r = 0.977$) and orthophosphate-phosphorus ($p<0.05$, $r = 0.901$) and its most significant negative correlation was noted with pH ($p<0.05$, $r = -0.922$) and total iron ($p<0.05$, $r = -0.889$).

In rooted floating-leaf type macrophytes, the concentration of total lipids (% fresh weight) maintained highly significant positive correlations with water temperature ($p<0.05$, $r = 0.996$), ammonical-nitrogen ($p<0.01$, $r = 0.962$) and dissolved silica ($p<0.01$, $r = 0.990$). The concentration of total lipids (% fresh weight) in rooted floating-leaf types, however, showed highly significant negative correlation with dissolved oxygen ($p<0.01$, $r = -0.993$) only.

The most significant positive correlations of total lipids (% fresh weight) in free-floating macrophytes was recorded with calcium content ($p<0.05$, $r = 0.999$), free carbon dioxide ($p<0.05$, $r = 0.990$) and orthophosphate-phosphorus ($p<0.01$, $r = 0.948$) and its most significant negative correlations was noted with pH ($p<0.05$, $r = -0.988$) and total iron ($p<0.05$, $r = 0.958$).

In submergeds, the concentration of total lipids (% fresh weight) was found to exhibit highly significant positive correlations with total dissolved solid ($p<0.05$, $r = 0.984$), free carbon dioxide ($p<0.05$, $r = 0.971$), calcium content ($p<0.01$, $r = 0.980$), nitrate-nitrogen ($p<0.05$, $r = 0.957$) and orthophosphate-phosphorus ($p<0.05$, $r = 0.981$). Total lipids (% fresh weight) in submergeds, however, depicted highly significant negative correlations with conductivity ($p<0.05$, $r = -0.982$), pH ($p<0.01$, $r = -0.998$) and total iron ($p<0.05$, $r = -0.965$).

The present study revealed highly significant variations in the total lipid content (% fresh weight) among different life-form classes of macrophytes ($t= 14.373$, $p= 0.0001$; $t=14.189$, $p=0.0001$).

Table 5.2.9.3a. Seasonal variations in the total lipid content (% on fresh wt. basis) of dominant macrophytes in Wular lake during 2011

S.No.	Species	Plant part	Spring	Summer	Autumn	Winter	Mean±S.D
			Emergents				
1	*Myriophyllum verticillatum*	AGP	3.6	5.9	7.2	2.1	4.7±2.3
2	*Phragmites australis*	AGP	3.2	5.2	6.6	1.8	4.2±2.1
3	*Polygonum amphibium*	AGP	2.0	3.2	3.6	1.7	2.6±0.9
4	*Polygonum hydropiper*	AGP	1.0	1.2	2.2	0.7	1.3±0.7
5	*Typha angustata*	AGP	2.8	4.0	6.0	1.4	3.6±1.9
			Rooted floating-leaf type				
6	*Trapa natans*	AGP	2.9	4.9	6.3	2.0	4.0±1.9
7	*Potamogeton natans*	AGP	2.2	3.0	4.4	1.6	2.8±1.2
8	*Nymphaea mexicana*	Leaf lamina	2.0	3.2	4.5	1.4	2.8±1.4
9	*Hydrocharis dubia*	AGP	1.8	2.2	3.7	1.2	2.2±1.1
10	*Marsilea quadrifolia*	AGP	2.6	3.6	5.0	2.0	3.3±1.3
11	*Nymphoides peltatum*	Leaf lamina	1.4	1.8	3.3	1.2	1.9±1.0
			Submergeds				
12	*Potamogeton crispus*	Whole plant	2.0	3.2	7.6	1.2	3.5±2.9
13	*Ceratophyllum demersum*	Whole plant	1.8	2.8	7.1	1.4	3.3±2.6
			Free-floating type				
14	*Azolla* sp.	Whole plant	2.2	4.2	5.6	1.4	3.4±1.9
15	*Lemna minor*	Whole plant	2.0	4.0	5.2	1.8	3.3±1.6
16	*Salvinia natans*	Whole plant	2.1	3.6	4.2	1.1	2.8±1.4

AGP=Above ground part

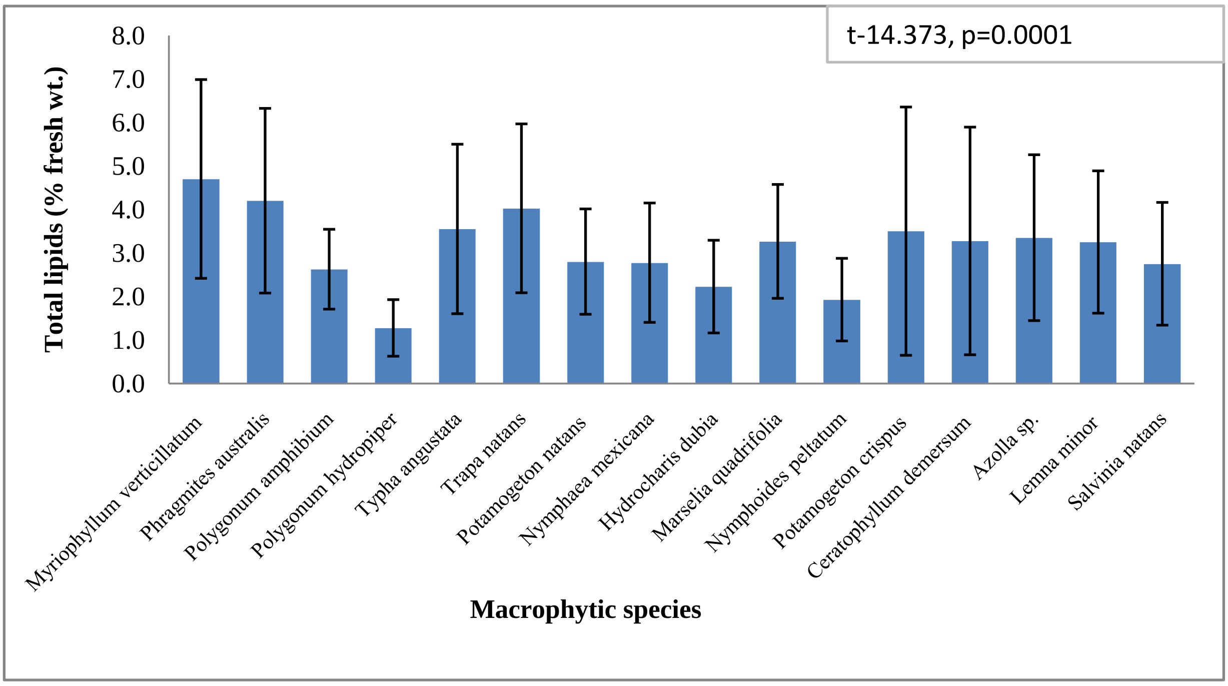


Fig. 5.2.9.3a. Average concentration of total lipids (% on fresh wt. basis) in dominant macrophytic species of Wular lake during 2011

Table 5.2.9.3b. Seasonal variations in the total lipid content (% on fresh wt. basis) of dominant macrophytes in Wular lake during 2012

S.No.	Species	Plant part	Spring	Summer	Autumn	Winter	Mean±S.D
Emergents							
1	*Myriophyllum verticillatum*	AGP	4.3	6.2	7.4	1.4	4.8±2.6
2	*Phragmites australis*	AGP	2.8	5.0	7.4	1.8	4.3±2.5
3	*Polygonum amphibium*	AGP	2.0	3.5	4.0	1.0	2.6±1.4
4	*Polygonum hydropiper*	AGP	1.0	1.6	2.5	0.4	1.4±0.9
5	*Typha angustata*	AGP	2.7	4.4	6.8	1.5	3.9±2.3
Rooted floating-leaf type							
6	*Trapa natans*	AGP	3.4	5.9	6.8	2.0	4.5±2.2
7	*Potamogeton natans*	AGP	2.1	3.0	4.6	1.5	2.8±1.3
8	*Nymphaea mexicana*	Leaf lamina	2.1	3.3	5.2	1.4	3.0±1.7
9	*Hydrocharis dubia*	AGP	1.7	2.4	3.7	1.1	2.2±1.1
10	*Marsilea quadrifolia*	AGP	2.4	3.4	5.0	1.9	3.2±1.3
11	*Nymphoides peltatum*	Leaf lamina	1.5	2.1	3.6	1.2	2.1±1.1
Submergeds							
12	*Potamogeton crispus*	Whole plant	2.1	3.6	6.8	1.3	3.4±2.5
13	*Ceratophyllum demersum*	Whole plant	1.6	3.0	6.6	0.6	3.0±2.6
Free-floating type							
14	*Azolla* sp.	Whole plant	2.3	3.9	5.4	1.3	3.2±1.8
15	*Lemna minor*	Whole plant	1.9	4.1	5.8	1.4	3.3±2.0
16	*Salvinia natans*	Whole plant	2.4	4.0	4.6	1.4	3.1±1.5

ABP=Above ground part

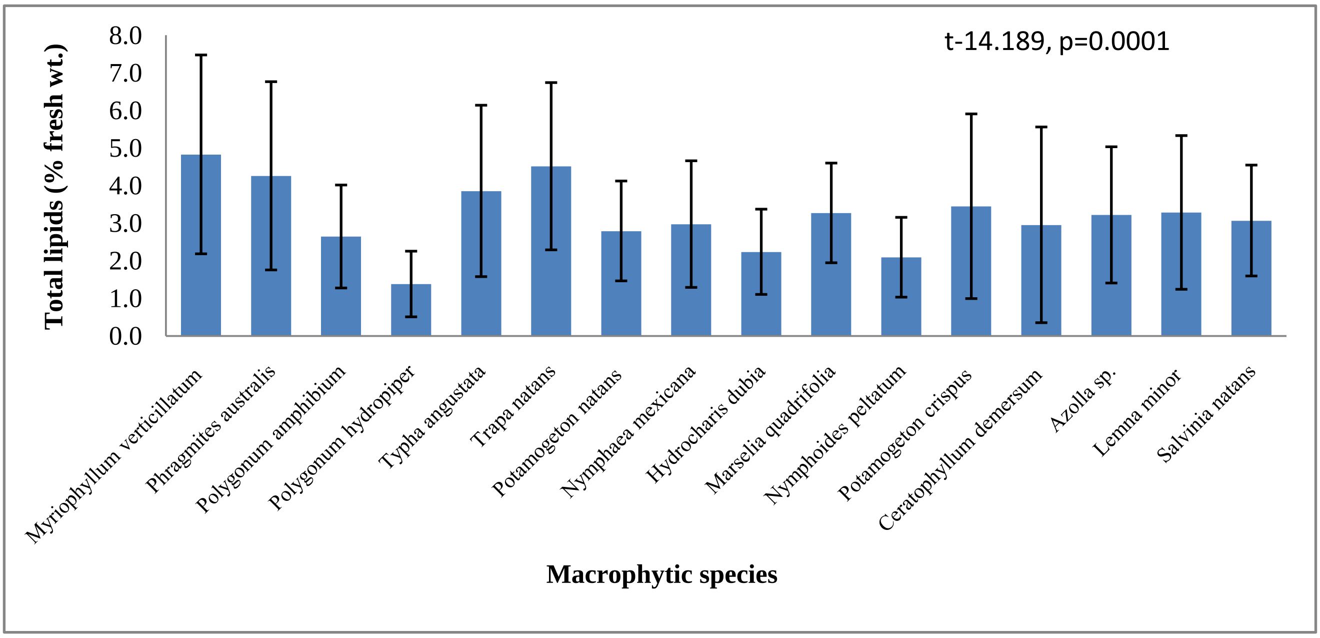


Fig. 5.2.9.3b. Average concentration of total lipids (% on fresh wt. basis) in dominant macrophytic species of Wular lake during 2012

Table 5.2.9.3c. Correlation coefficients between various physico-chemical parameters of water and total lipid content in different life-form classes of macrophytes in Wular lake

	WT	**CON**	**TDS**	**pH**	**FC**	**DO**	**TH**	**CC**	**MC**	**AN**	**NN**	**TP**	**OP**	**DS**	**TI**
WT	1														
CON	0.302	1													
TDS	0.274	.999(**)	1												
pH	0.118	-.858(**)	-.875(**)	1											
FC	0.04	.874(**)	.877(**)	-.754(*)	1										
DO	-.781(*)	-0.525	-0.507	0.121	-0.401	1									
TH	0.186	.978(**)	.981(**)	-.907(**)	.873(**)	-0.441	1								
CC	0.198	.964(**)	.969(**)	-.907(**)	.870(**)	-0.47	.991(**)	1							
MC	0.193	.980(**)	.982(**)	-.888(**)	.874(**)	-0.436	.996(**)	.975(**)	1						
CH	-0.018	0.428	0.446	-0.623	0.345	0.063	0.482	0.513	0.446						
AN	0.635	0.498	0.491	-0.358	0.236	-0.321	0.392	0.398	0.392	1					
NN	0.572	0.503	0.496	-0.363	0.331	-0.243	0.438	0.437	0.44	.903(**)	1				
TP	0.553	0.654	0.647	-0.487	0.545	-0.358	0.591	0.603	0.588	.893(**)	.942(**)	1			
OP	0.472	.857(**)	.848(**)	-0.616	.795(*)	-0.52	.806(**)	.802(**)	.807(**)	0.576	.722(*)	.792(*)	1		
DS	0.514	0.152	0.138	0.034	-0.041	-0.075	0.027	-0.025	0.073	.807(**)	.726(*)	0.65	0.257	1	
TI	0.527	-0.323	-0.355	.697(*)	-0.356	-0.149	-0.413	-0.468	-0.359	0.072	0.123	0.03	-0.038	0.452	1
EMER	0.175	0.856(*)	0.86	-.922(*)	.890(*)	-0.1	0.824	0.846	0.808	0.766	0.814(*)	.977(**)	.901(*)	0.406	-.889(*)
RF	0.996(*)	0.697(*)	0.69	-0.5	0.61	-0.993(**)	0.58	0.597	0.589	0.962(**)	0.249	0.732	0.348	0.990(**)	-0.38
FF	0.555	0.996	0.997	-0.988(*)	0.990(*)	-0.535	.998	.999(*)	.999	0.816	0.910	0.990	0.948(**)	0.629	-0.958(*)
SUB	0.298	-0.982(*)	.984(*)	-.998(**)	.971(*)	-0.287	.996	0.980(**)	.991	0.852	.957(*)	0.902	.981(*)	0.532	-.965(*)

The marked correlations are significant at P=<0.05 (1- tailed) and P=<0.01 (2-tailed).

Where, WT- Water temperature, TDS – Total dissolved solids, CON – Specific conductivity, pH – pH, FC –Free carbon dioxide, DO – Dissolved oxygen, TH – Total hardness, CC – Calcium content, MC– Magnesium content, AN – Ammonical-nitrogen, NN – Nitrate-nitrogen, TP – Total phosphorus, OP – Ortho-phosphate phosphorus, DS – Dissolved silica, TI – Total iron, EMER – Emergents, RF – Rooted floating-leaf type, FF – Free-floating type, SUB – Submergeds

5.2.9.4. Chlorophyll Content (mg/g fresh weight)

A perusal of data on the chlorophyll content (mg/g on fresh wt. basis) of dominant macrophytes in Wular lake revealed distinct seasonal variations during the two years of study period. In general, on temporal scale, the maximum pigment content was recorded during the period of active growth in summer. The autumn and spring season registered almost equal concentration of Chlorophyll-a and Chlorophyll-b and the values peaked during summer. However, relative content of total chlorophyll in the macrophytes under study was notably lower in spring season than in autumn. Significant differences were observed in the chlorophyll concentration of different species except that of *Ceratophyllum demersum* and *Potamogeton crispus* where slight fluctuations were noticed. It is clear from the data that the pigment content of macrophytes was slightly higher in the year 2011 as compared to the year 2012 (Tables 5.2.9.4a, 5.2.9.4b and 5.2.9.4c).

Among emergents, *Polygonum amphibium* with a value of 4.3 mg/g recorded the highest concentration of Chlorophyll-a during summer 2011 as against the lowest of 1.3 mg/g being recorded for *Polygonum hydropiper* during spring 2012. Rooted floating-leaf type macrophytes maintained slightly higher concentration of Chlorophyll-a compared to emergents with *Hydrocharis dubia* and *Marsilea quadrifolia* registering 3.6 mg/g each, followed by *Trapa ntans* (3.5 mg/g) and *Nymphaea mexicana* (3.4 mg/g) during summer 2011. Free-floating species recorded comparatively lower values as evinced by *Lemna minor* (2.6 mg/g), *Salvinia natans* (0.9 mg/g) and *Azolla* sp. (0.8 mg/g) during spring 2012. Among all the four life-form classes, the submergeds registered the highest concentration of Chlorophyll-a with *Ceratophyllum demersum* recording a highest of 3.7 mg/g as against the lowest of 3.1 mg/g, being recorded for *Potamogeton crispus*. However, irrespective of life-form classes, the highest annual mean concentration of Chlorophyll-a (3.7±0.6 mg/g) was recorded for *Ceratophyllum demersum*, followed by *Polygonum amphibium* (3.5±0.7 mg/g), *Potamogeton crispus* (3.1±0.7 mg/g) as against the lowest of 1.8±1.0 mg/g, being obtained for *Azolla* sp. (Fig. 5.2.9.4a and 5.2.9.4d).

The concentration of Chlorophyll-b in different species of macrophytes fluctuated between a minimum of 0.1 mg/g each for *Azolla* sp. and *Lemna minor* during spring 2012 against a maximum of 2.6 mg/g for *Ceratophyllum demersum* during summer of the same year (Table 5.2.9.4b and 5.2.9.4e). For emergents, the highest concentration of 2.3 mg/g was noted for *Typha angustata*, followed by 2.1

mg/g for *Polygonum amphibium*, 1.7 mg/g for *Myriophyllum verticillatum*, 1.2 mg/g for *Phragmites australis* and 0.6 mg/g for *Polygonum hydropiper* during summer 2011. However, among the rooted floating-leaf type species, the maximum concentration of Chlorophyll-b was recorded for *Nymphaea mexicana* (1.9 mg/g) in summer, which was followed by 1.1 mg/g each for *Trapa natans and Marsilea quadrifolia* and 1.0 mg/g for *Hydrocharis dubia* during summer 2011. Among the free-floating species, *Lemna minor* with a value of 2.2 mg/g recorded the highest concentration of Chlorophyll-b during summer 2011 as against the lowest of 0.1 mg/g being recorded for *Azolla* sp. during springs of 2011 and 2012. Among submergeds, *Ceratophyllum demersum* registered the highest concentration of 2.6 mg/g during summer 2012, followed by 2.2 mg/g being recorded for *Potamogeton crispus* during summers of 2011 and 2012.

In general, the highest annual mean concentration of Chlorophyll-b of 1.8 ±0.7 mg/g was obtained for *Ceratophyllum demersum*, followed by 1.7±0.6 mg/g for *Typha angustata* and 1.5±0.8 mg/g for *Potamogeton crispus*. However, the lowest annual mean concentration (0.2±0.2 mg/g) was obtained for *Azolla* sp. (Fig. 5.2.9.4b and 5.2.9.4e).

A perusal of the data on the total chlorophyll content (mg/g fresh wt. basis) of dominant macrophytes in Wular lake during the two years of study period revealed that the total chlorophyll concentrations of macrophytes depicted summer maxima for most of the species in the lake. However, clear temporal variations were found among the species inhabiting the lake. The maximum value for total chlorophyll content was recorded for *Polygonum amphibium* (5.0 mg/g) in summer 2012 while as the minimum value (0.4mg/g) was obtained for *Azolla* sp. in spring of the same year. Further, among emergents, the highest concentration of total chlorophyll was obtained for *Polygonum amphibium* (5.0 mg/g), followed by *Typha angustata* (4.1 mg/g) and *Myriophyllum verticillatum* (3.4 mg/g), being recorded during summer 2011. In contrast, the lowest concentration of total chlorophyll (1.1 mg/g) was registered for *Phragmites australis* during spring 2012. On the other hand, rooted floating-leaf type macrophytes recorded slightly higher values as evinced by *Nymphaea mexicana* (4.9 mg/g), *Marsilea quadrifolia* (3.9 mg/g) and *Hydrocharis dubia* (3.7 mg/g) during summer 2011. Free-floating species maintained lower concentration of total chlorophyll compared to rooted floating-leaf type and emergent macrophytes with *Lemna minor* registering 4.8 mg/g, followed by *Salvinia natans* (3.5 mg/g) and

Azolla sp. (1.6 mg/g) during summer 2012. The submergeds registered the highest concentrations of Total Chlorophyll with *Ceratophyllum demersum* recording a highest of 4.5 mg/g as against the lowest of 4.3 mg/g, being recorded for *Potamogeton crispus* (Table 5.2.9.4c and 5.2.9.4f). However, irrespective of life-form classes, the highest annual mean concentration of total chlorophyll (4.1±0.6 mg/g) was recorded for *Ceratophyllum demersum*, followed by *Lemna minor* (4.0±0.9 mg/g), *Polygonum* amphibium (3.9 ±0.9 mg/g) as against the lowest of 1.1±0.6 mg/g, being obtained for *Azolla* sp. (Fig. 5.2.9.4c and 5.2.9.4f).

Correlation coefficients worked out between the physico-chemical parameters of water and pigment content (mg/g fresh weight) in different life-form classes of macrophytes depicted highly significant positive as well negative correlations only in case of submerged macrophytes (Table 5.2.9.4g, 5.2.9.4h and 5.2.9.4i). The other life-form classes could not depict strong correlation with any of the parameters.

The concentration of Chlorophyll-a (mg/g fresh weight) in submergeds depicted highly significant positive correlations with orthophosphate-phosphorus ($p<0.01$, $r = 0.834$) and water temperature ($p<0.01$, $r = 0.762$) and its most significant negative correlations were noted with transparency ($p<0.01$, $r = -0.922$), pH ($p<0.01$, $r = -0.839$), total alkalinity ($p<0.01$, $r = -0.912$), ammonical-nitrogen ($p<0.01$, $r = -0.875$), total phosphorus ($p<0.01$, $r = -0.812$) and dissolved silica ($p<0.01$, $r = -0.789$).

The most significant positive correlations of Chlorophyll-b (mg/g fresh weight) in submergeds was recorded with water temperature ($p<0.01$, $r = 0.798$), orthophosphate-phosphorus ($p<0.01$, $r = 0.786$) and its most significant negative correlations were maintained with transparency ($p<0.01$, $r = -0.866$), ammonical-nitrogen ($p<0.01$, $r = -0.765$), total phosphorus ($p<0.01$, $r = -0.843$) and dissolved silica ($p<0.01$, $r = -0.791$).

In submergeds, the concentration of Total Chlorophyll content (mg/g fresh weight) depicted highly significant positive correlation only with water temperature ($p<0.01$, $r = 0.888$). Total Chlorophyll content (mg/g fresh weight) in submergeds, however, depicted highly significant negative correlations with transparency ($p<0.01$, $r = -0.892$), pH ($p<0.01$, $r = -0.879$), conductivity ($p<0.01$, $r = -0.876$), ammonical-nitrogen ($p<0.01$, $r = -0.876$), total phosphorus ($p<0.01$, $r = -0.786$) and dissolved silica ($p<0.01$, $r = -0.721$).

Table 5.2.9.4a. Seasonal variations in the Chlorophyll-a content (mg/g on fresh wt. basis) of dominant macrophytes in Wular lake during 2011

S.No.	Species	Plant part	Spring	Summer	Autumn	Mean±S.D
Emergents						
1	*Myriophyllum verticillatum*	Leaf lamina	2.0	2.5	1.9	2.1±0.3
2	*Phragmites australis*	Leaf lamina	2.2	2.6	1.9	2.2±0.3
3	*Polygonum amphibium*	Leaf lamina	3.1	4.3	3.2	3.5±0.7
4	*Polygonum hydropiper*	Leaf lamina	1.4	2.7	2.0	2.0±0.7
5	*Typha angustata*	Leaf lamina	2.2	2.7	2.1	2.3±0.3
Rooted floating-leaf type						
6	*Trapa natans*	Leaf lamina	2.0	3.5	2.4	2.6±0.8
7	*Potamogeton natans*	Leaf lamina	1.5	3.2	2.5	2.4±0.9
8	*Nymphaea mexicana*	Leaf lamina	2.6	3.4	2.4	2.8±0.5
9	*Hydrocharis dubia*	Leaf lamina	1.7	3.6	2.2	2.5±1.0
10	*Marsilea quadrifolia*	Leaf lamina	2.7	3.6	2.1	2.8±0.8
11	*Nymphoides peltatum*	Leaf lamina	2.0	3.1	2.1	2.4±0.6
Submergeds						
12	*Potamogeton crispus*	Leaf lamina	3.9	2.7	2.6	3.1±0.7
13	*Ceratophyllum demersum*	Leaf lamina	4.0	4.1	3.0	3.7±0.6
Free-floating type						
14	*Azolla* sp.	Leaf lamina	1.0	3.2	2.1	2.1±1.1
15	*Lemna minor*	Leaf lamina	2.8	3.4	2.3	2.8±0.6
16	*Salvinia natans*	Leaf lamina	1.0	3.4	2.4	2.3±1.2

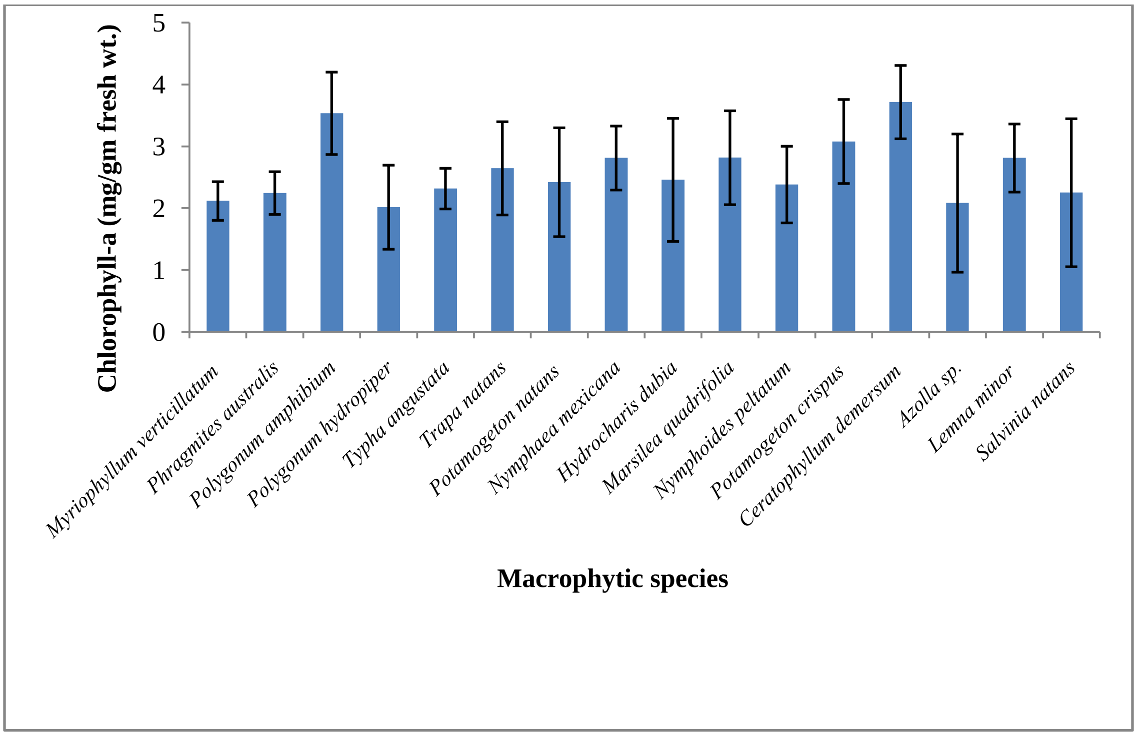


Fig. 5.2.9.4a. Average concentration of Chlorophyll-a (mg/g on fresh wt. basis) in dominant macrophytic species of Wular lake during 2011

Table 5.2.9.4b. Seasonal variations in the Chlorophyll-b content (mg/g on fresh wt. basis) of dominant macrophytes in Wular lake during 2011

S.No.	Species	Plant part	Spring	Summer	Autumn	Mean±S.D
Emergents						
1	*Myriophyllum verticillatum*	Leaf lamina	1.3	1.7	1.1	1.4±0.3
2	*Phragmites australis*	Leaf lamina	0.3	1.2	0.8	0.8±0.4
3	*Polygonum amphibium*	Leaf lamina	1.1	2.1	1.2	1.4±0.5
4	*Polygonum hydropiper*	Leaf lamina	0.2	0.6	0.3	0.4±0.2
5	*Typha angustata*	Leaf lamina	1.0	2.3	1.7	1.7±0.6
Rooted floating-leaf type						
6	*Trapa natans*	Leaf lamina	0.5	1.1	0.5	0.7±0.4
7	*Potamogeton natans*	Leaf lamina	0.2	0.8	0.4	0.5±0.3
8	*Nymphaea mexicana*	Leaf lamina	1.1	1.9	0.7	1.2±0.6
9	*Hydrocharis dubia*	Leaf lamina	0.4	1.0	0.3	0.6±0.4
10	*Marsilea quadrifolia*	Leaf lamina	0.6	1.1	0.3	0.6±0.4
11	*Nymphoides peltatum*	Leaf lamina	0.3	0.8	0.4	0.5±0.3
Submergeds						
12	*Potamogeton crispus*	Leaf lamina	1.5	2.2	1.1	1.6±0.6
13	*Ceratophyllum demersum*	Leaf lamina	1.5	2.5	1.3	1.7±0.6
Free-floating type						
14	*Azolla* sp.	Leaf lamina	0.1	0.5	0.4	0.3±0.2
15	*Lemna minor*	Leaf lamina	1.3	2.2	0.8	1.4±0.7
16	*Salvinia natans*	Leaf lamina	0.2	1.4	1.0	0.9±0.6

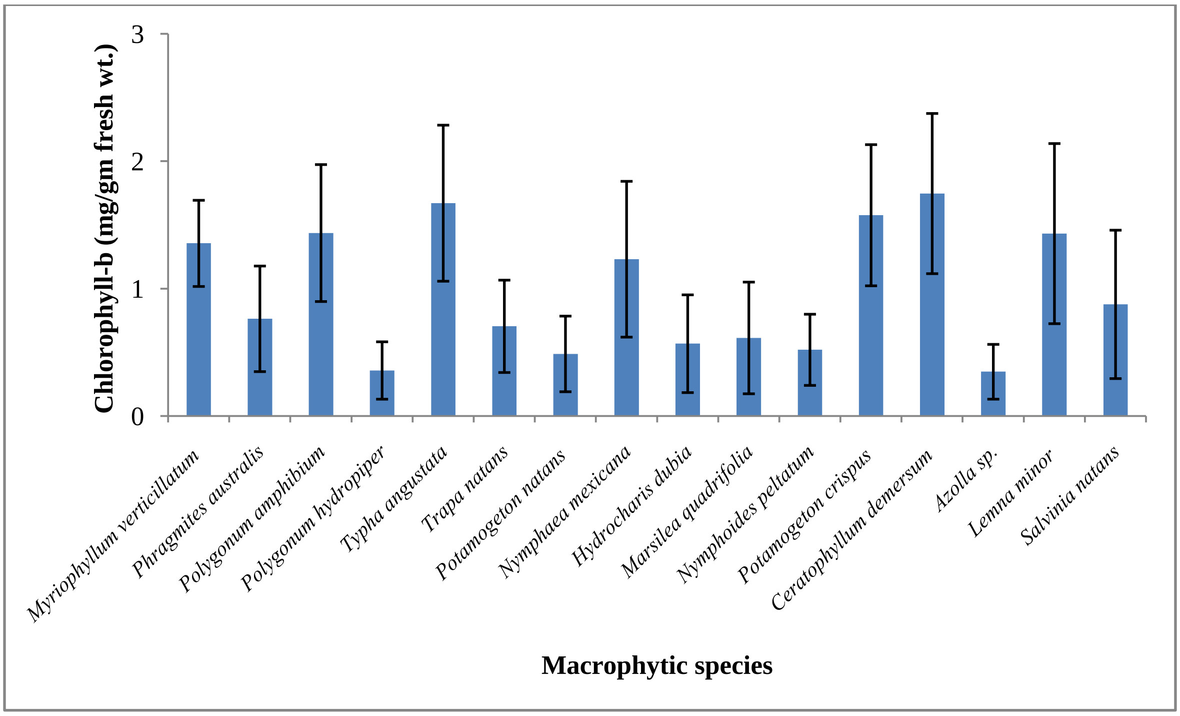


Fig.5.2.9.4b. Average concentration of Chlorophyll-b (mg/g on fresh wt. basis) in dominant macrophytic species of Wular lake during 2011

Table 5.2.9.4c. Seasonal variations in the Total Chlorophyll content (mg/g on fresh wt. basis) of dominant macrophytes in Wular lake during 2011

S.No.	Species	Plant part	Spring	Summer	Autumn	Mean±S.D
Emergents						
1	*Myriophyllum verticillatum*	Leaf lamina	2.4	3.4	2.6	2.8±0.6
2	*Phragmites australis*	Leaf lamina	1.3	3.0	3.0	2.4±1.0
3	*Polygonum amphibium*	Leaf lamina	3.5	4.9	3.3	3.9±0.9
4	*Polygonum hydropiper*	Leaf lamina	1.5	2.9	2.1	2.2±0.7
5	*Typha angustata*	Leaf lamina	2.0	4.1	3.3	3.1±1.1
Rooted floating-leaf type						
6	*Trapa natans*	Leaf lamina	2.2	3.6	2.5	2.8±0.7
7	*Potamogeton natans*	Leaf lamina	1.7	3.5	2.8	2.7±0.9
8	*Nymphaea mexicana*	Leaf lamina	3.3	4.9	3.1	3.7±1.0
9	*Hydrocharis dubia*	Leaf lamina	1.8	3.7	2.2	2.6±1.0
10	*Marsilea quadrifolia*	Leaf lamina	2.8	3.9	2.3	3.0±0.8
11	*Nymphoides peltatum*	Leaf lamina	1.5	3.3	2.2	2.4±0.9
Submergeds						
12	*Potamogeton crispus*	Leaf lamina	4.3	3.1	3.0	3.5±0.7
13	*Ceratophyllum demersum*	Leaf lamina	4.3	3.5	4.5	4.1±0.6
Free-floating type						
14	*Azolla* sp.	Leaf lamina	0.5	1.7	1.5	1.2±0.7
15	*Lemna minor*	Leaf lamina	3.7	4.9	3.3	4.0±0.9
16	*Salvinia natans*	Leaf lamina	0.6	3.6	1.7	2.0±1.5

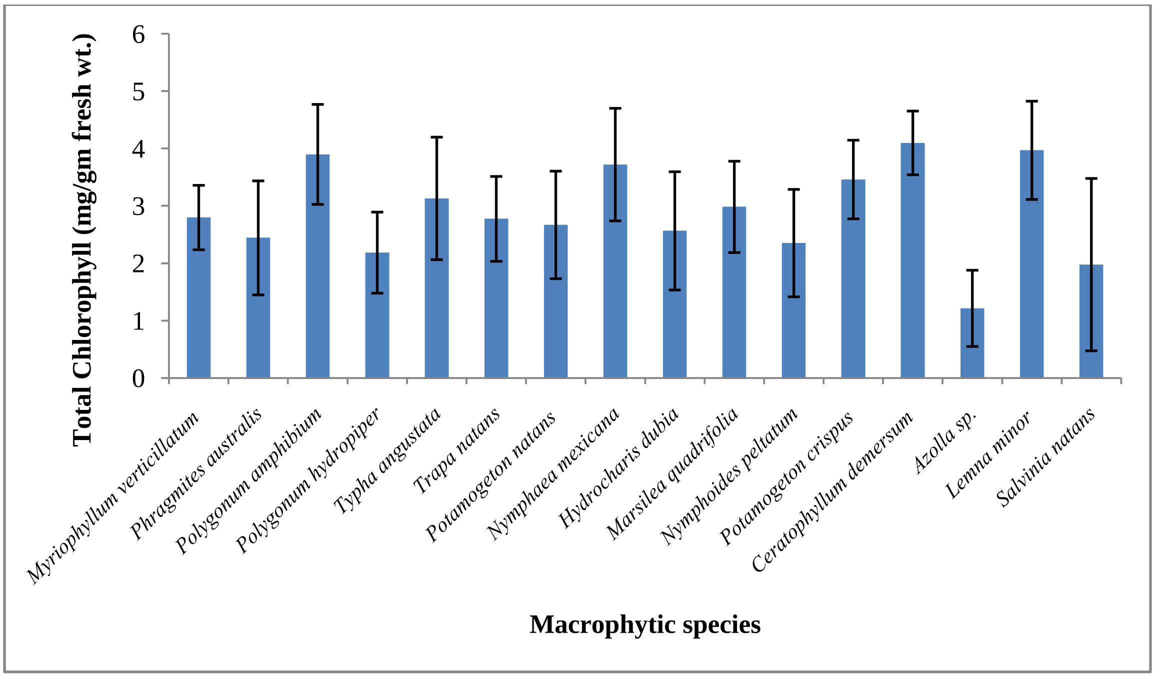


Fig. 5.2.9.4c. Average concentration of Total Chlorophyll (mg/g on fresh wt. basis) in dominant macrophytic species of Wular lake during 2011

Table 5.2.9.4d. Seasonal variations in the Chlorophyll-a content (mg/g fresh wt. basis) of dominant macrophytes in Wular lake during 2012

S.No.	Species	Plant part	Spring	Summer	Autumn	Mean±S.D
Emergents						
1	*Myriophyllum verticillatum*	Leaf lamina	1.9	2.4	1.7	2.0±0.4
2	*Phragmites australis*	Leaf lamina	1.9	2.4	1.6	2.0±0.4
3	*Polygonum amphibium*	Leaf lamina	2.7	4.1	2.8	3.2±0.8
4	*Polygonum hydropiper*	Leaf lamina	1.3	2.5	1.8	1.9±0.6
5	*Typha angustata*	Leaf lamina	2.0	2.5	1.8	2.1±0.4
Rooted floating-leaf type						
6	*Trapa natans*	Leaf lamina	1.7	3.2	2.3	2.4±0.7
7	*Potamogeton natans*	Leaf lamina	1.4	2.8	2.2	2.1±0.7
8	*Nymphaea mexicana*	Leaf lamina	2.4	3.1	2.1	2.6±0.5
9	*Hydrocharis dubia*	Leaf lamina	1.5	3.3	2.0	2.3±0.9
10	*Marsilea quadrifolia*	Leaf lamina	2.4	3.4	2.1	2.6±0.7
11	*Nymphoides peltatum*	Leaf lamina	1.8	2.9	1.9	2.2±0.6
Submergeds						
12	*Potamogeton crispus*	Leaf lamina	3.7	2.6	2.4	2.9±0.7
13	*Ceratophyllum demersum*	Leaf lamina	3.9	3.8	2.8	3.5±0.6
Free-floating type						
14	*Azolla* sp.	Leaf lamina	0.8	2.8	1.8	1.8±1.0
15	*Lemna minor*	Leaf lamina	2.6	3.2	2.2	2.7±0.5
16	*Salvinia natans*	Leaf lamina	0.9	3.3	2.3	2.2±1.2

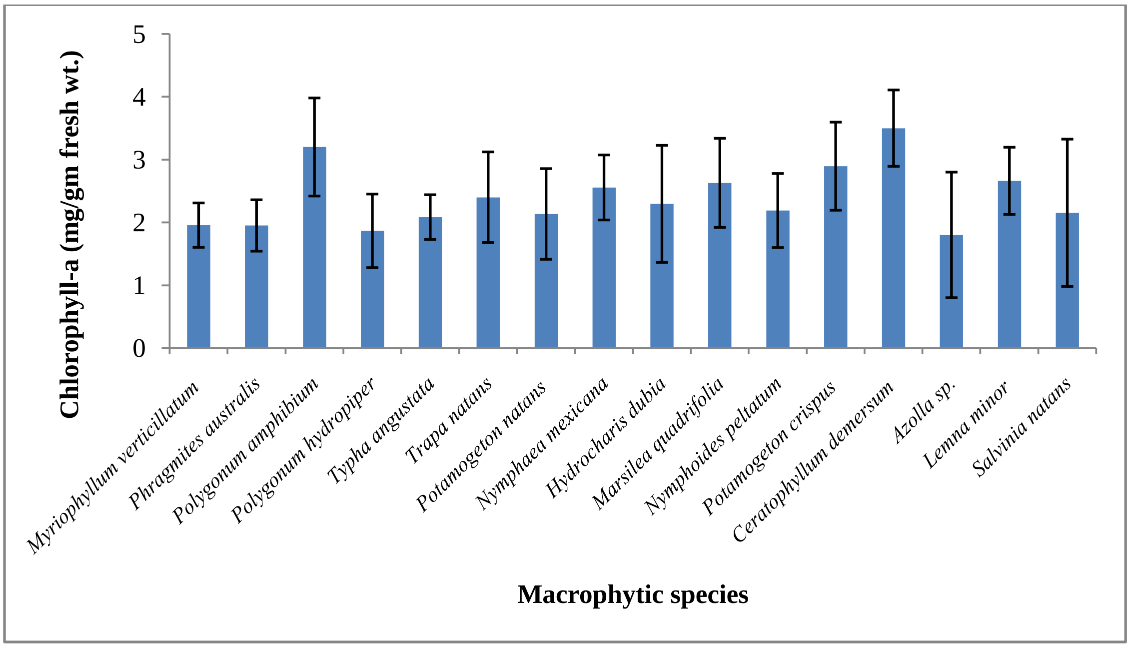


Fig. 5.2.9.4d. Average concentration of Chlorophyll-a (mg/g on fresh wt. basis) in dominant macrophytic species of Wular lake during 2012

Table 5.2.9.4e. Seasonal variations in the Chlorophyll-b content (mg/g fresh wt. basis) of dominant macrophytes in Wular lake during 2012

S.No.	Species	Plant part	Spring	Summer	Autumn	Mean±S.D
Emergents						
1	*Myriophyllum verticillatum*	Leaf lamina	1.1	1.6	0.9	1.2±0.3
2	*Phragmites australis*	Leaf lamina	0.3	1.0	0.7	0.6±0.4
3	*Polygonum amphibium*	Leaf lamina	1.0	1.8	1.0	1.3±0.5
4	*Polygonum hydropiper*	Leaf lamina	0.2	0.5	0.2	0.3±0.2
5	*Typha angustata*	Leaf lamina	0.9	2.0	1.5	1.5±0.6
Rooted floating-leaf type						
6	*Trapa natans*	Leaf lamina	0.4	1.0	0.4	0.6±0.3
7	*Potamogeton natans*	Leaf lamina	0.2	0.7	0.3	0.4±0.2
8	*Nymphaea mexicana*	Leaf lamina	0.9	1.7	0.7	1.1±0.6
9	*Hydrocharis dubia*	Leaf lamina	0.3	0.9	0.2	0.5±0.3
10	*Marsilea quadrifolia*	Leaf lamina	0.4	0.9	0.2	0.5±0.4
11	*Nymphoides peltatum*	Leaf lamina	0.3	0.7	0.3	0.4±0.2
Submergeds						
12	*Potamogeton crispus*	Leaf lamina	1.5	2.2	0.7	1.5±0.8
13	*Ceratophyllum demersum*	Leaf lamina	1.7	2.6	1.2	1.8±0.7
Free-floating type						
14	*Azolla* sp.	Leaf lamina	0.1	0.4	0.2	0.2±0.2
15	*Lemna minor*	Leaf lamina	1.1	2.1	0.7	1.3±0.7
16	*Salvinia natans*	Leaf lamina	0.3	1.2	0.9	0.8±0.5

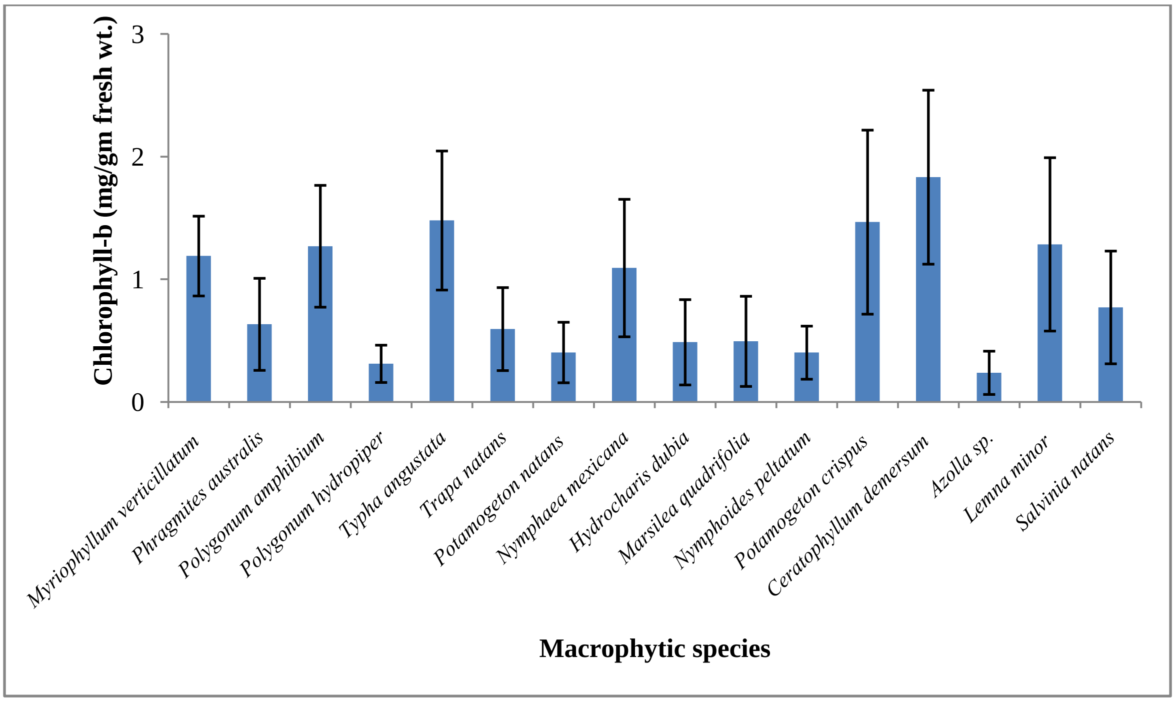


Fig. 5.2.9.4e. Average concentration of Chlorophyll-b (mg/g on fresh wt. basis) in dominant macrophytic species of Wular lake during 2012

Table 5.2.9.4f. Seasonal variations in the Total Chlorophyll content (mg/g fresh wt. basis) of dominant macrophytes in Wular lake during 2012

S.No.	Species	Plant part	Spring	Summer	Autumn	Mean±S.D
Emergents						
1	*Myriophyllum verticillatum*	Leaf lamina	2.2	3.3	2.4	2.6±0.6
2	*Phragmites australis*	Leaf lamina	1.1	2.8	2.7	2.2±0.9
3	*Polygonum amphibium*	Leaf lamina	3.5	5.0	3.3	3.9±0.9
4	*Polygonum hydropiper*	Leaf lamina	1.4	2.8	2.0	2.1±0.7
5	*Typha angustata*	Leaf lamina	1.8	4.0	3.1	3.0±1.1±
Rooted floating-leaf type						
6	*Trapa natans*	Leaf lamina	2.0	3.4	2.4	2.6±0.7
7	*Potamogeton natans*	Leaf lamina	1.5	3.4	2.6	2.5±0.9
8	*Nymphaea mexicana*	Leaf lamina	3.1	4.7	3.0	3.6±1.0
9	*Hydrocharis dubia*	Leaf lamina	1.7	3.6	2.2	2.5±1.0
10	*Marsilea quadrifolia*	Leaf lamina	2.7	3.7	2.1	2.8±0.8
11	*Nymphoides peltatum*	Leaf lamina	1.5	3.3	2.1	2.3±0.9
Submergeds						
12	*Potamogeton crispus*	Leaf lamina	4.3	3.2	2.9	3.5±0.7
13	*Ceratophyllum demersum*	Leaf lamina	4.4	3.4	4.3	4.1±0.5
Free-floating type						
14	*Azolla* sp.	Leaf lamina	0.4	1.6	1.3	1.1±0.6
15	*Lemna minor*	Leaf lamina	3.6	4.8	3.1	3.8±0.8
16	*Salvinia natans*	Leaf lamina	0.6	3.5	1.6	1.9±1.5

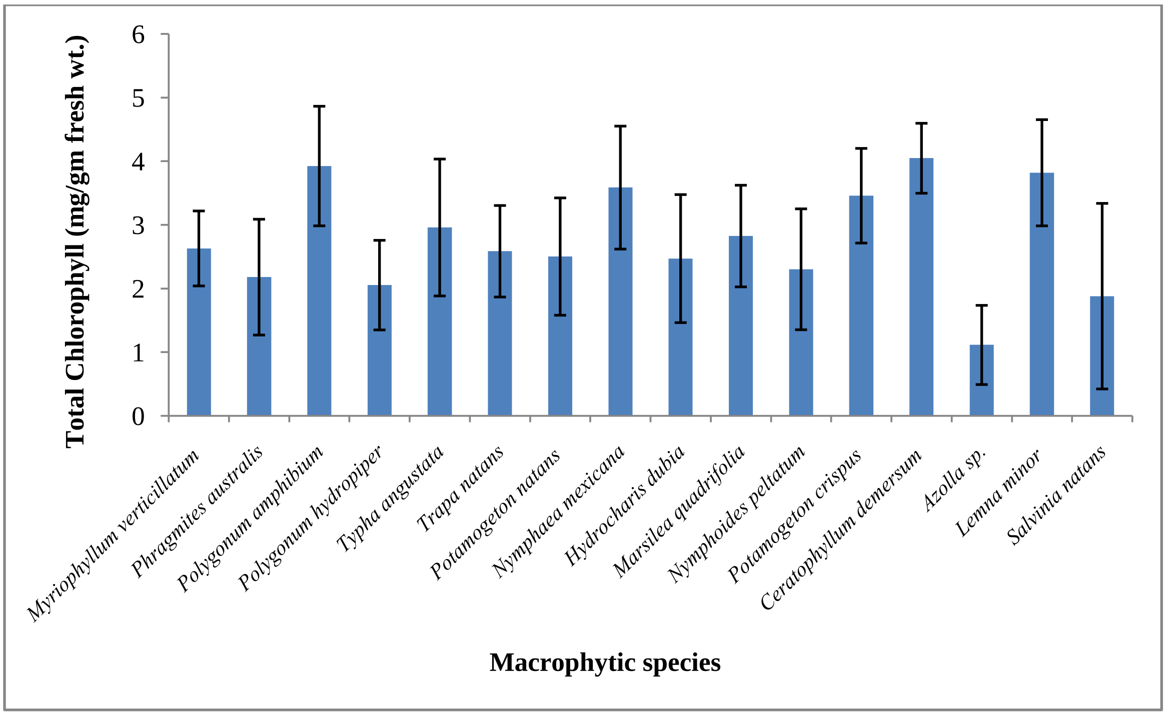


Fig. 5.2.9.4f. Average concentration of Total Chlorophyll (mg/g on fresh wt. basis) in dominant macrophytic species of Wular lake during 2012

Table 5.2.9.4g. Correlation coefficients between various physico-chemical parameters of water and Chlorophyll-a content in different life- form classes of macrophytes in Wular lake

	TR	**WT**	**pH**	**CON**	**DO**	**TA**	**TH**	**CC**	**AN**	**NN**	**OP**	**TP**	**DS**	**TI**
TR	1													
WT	-.678(*)	1												
pH	0.135	0.156	1											
CON	-0.328	0.288	-.862(**)	1										
DO	.814(**)	-.792(*)	0.202	-0.531	1									
TA	-0.309	0.314	-.816(**)	.953(**)	-0.587	1								
TH	-0.275	0.174	-.918(**)	.978(**)	-0.451	.940(**)	1							
CC	-0.351	0.187	-.922(**)	.964(**)	-0.483	.941(**)	.991(**)	1						
AN	-0.287	0.632	-0.199	0.498	-0.335	0.514	0.392	0.397	1					
NN	-0.182	0.569	-0.304	0.503	-0.275	0.532	0.438	0.438	.903(**)	1	.721(*)	.943(**)	.718(*)	
OP	-0.351	0.459	-.704(*)	.857(**)	-0.547	.818(**)	.806(**)	.802(**)	0.575	.721(*)	1	.792(*)	0.256	
TP	-0.214	0.547	-0.436	0.654	-0.392	.719(*)	0.591	0.603	.893(**)	.943(**)	.792(*)	1	0.645	
DS	0.152	0.507	0.185	0.16	-0.073	0.196	0.036	-0.018	.803(**)	.718(*)	0.256	0.645	1	
TI	0.103	0.522	0.658	-0.323	-0.152	-0.318	-0.412	-0.467	0.073	0.124	-0.037	0.031	0.452	1
EM	0.367	-0.391	0.456	-0.534	0.233	-0.366	-0.486	-0.415	-0.331	-0.36	-0.44	-0.114	-0.39	0.314
RF	0.385	-0.257	0.678	-0.59	0.482	-0.57	-0.665	-0.641	0.082	-0.272	-0.619	-0.222	0.294	0.333
SUB	-0.922(**)	0.762(**)	-0.839(**)	-0.871(**)	0.568(**)	-0.912(**)	-0.689(**)	-0.823(**)	-0.875(**)	0.655(**)	0.834(**)	-0.812(**)	-0.789(**)	-0.678(**)
FF	0.799	-0.803	-0.463	-0.005	0.801	-0.183	0.147	0.128	-0.506	0.492	0.398	-0.054	-0.703	-0.367

The marked correlations are significant at P=<0.05 (1- tailed) and P=<0.01 (2-tailed).

Where, TR- Transparency, WT- Water temperature, TDS – Total dissolved solids, CON – Specific conductivity, pH – pH, DO – Dissolved oxygen, TH – Total hardness, CC – Calcium content, AN – Ammonical-nitrogen, NN – Nitrate-nitrogen, TP – Total phosphorus, OP – Ortho-phosphate phosphorus, DS – Dissolved silica, TI – Total iron, EM – Emergents, RF – Rooted floating-leaf type, FF – Free-floating type, SUB – Submergeds.

Table 5.2.9.4h. Correlation coefficients between various physico-chemical parameters of water and Chlorophyll-b content in different life- form classes of macrophytes in Wular lake

	TR	WT	pH	CON	DO	TA	TH	CC	AN	NN	OP	TP	DS	TI
TR	1													
WT	-.678(*)	1												
pH	0.135	0.156	1											
COND.	-0.328	0.288	-.862(**)	1										
DO	.814(**)	-.792(*)	0.202	-0.531	1									
TA	-0.309	0.314	-.816(**)	.953(**)	-0.587	1								
TH	-0.275	0.174	-.918(**)	.978(**)	-0.451	.940(**)	1							
CC	-0.351	0.187	-.922(**)	.964(**)	-0.483	.941(**)	.991(**)	1						
AN	-0.287	0.632	-0.199	0.498	-0.335	0.514	0.392	0.397	1					
NN	-0.182	0.569	-0.304	0.503	-0.275	0.532	0.438	0.438	.903(**)	1				
OP	-0.351	0.459	-.704(*)	.857(**)	-0.547	.818(**)	.806(**)	.802(**)	0.575	.721(*)	1			
TP	-0.214	0.547	-0.436	0.654	-0.392	.719(*)	0.591	0.603	.893(**)	.943(**)	.792(*)	1		
DS	0.152	0.507	0.185	0.16	-0.073	0.196	0.036	-0.018	.803(**)	.718(*)	0.256	0.645	1	
TI	0.103	0.522	0.658	-0.323	-0.152	-0.318	-0.412	-0.467	0.073	0.124	-0.037	0.031	0.452	1
EM	0.229	-0.076	0.012	0.057	0.224	0.127	-0.042	0.007	0.709	0.499	0.091	0.656	0.622	-0.544
RF	0.189	-0.179	0.569	-0.525	0.135	-0.381	-0.513	-0.458	-0.326	-0.521	-0.547	-0.273	-0.312	0.464
SUB	-0.866(**)	0.798(**)	-0.644(**)	-0.675(**)	0.564(**)	-0.689(**)	-0.671(**)	-0.589(**)	-0.765(**)	0.675(**)	0.786(**)	-0.843(**)	-0.791(**)	-0.645(**)
FF	0.914	-0.917	-0.25	-0.231	0.916	-0.401	-0.081	-0.1	-0.688	0.282	0.18	-0.278	-0.846	-0.147

The marked correlations are significant at P=<0.05 (1- tailed) and P=<0.01 (2-tailed).

Where, TR- Transparency, WT- Water temperature, TDS – Total dissolved solids, CON – Specific conductivity, pH – pH, DO – Dissolved oxygen, TH – Total hardness, CC – Calcium content, AN – Ammonical-nitrogen, NN – Nitrate-nitrogen, TP – Total phosphorus, OP – Ortho-phosphate phosphorus, DS – Dissolved silica, TI – Total iron, EM – Emergents, RF – Rooted floating-leaf type, FF – Free-floating type, SUB – Submergeds.

Table 5.2.9.4i. Correlation coefficients between various physico-chemical parameters of water and Total Chlorophyll content in different life- form classes of macrophytes in Wular lake

	TR	WT	pH	CON	DO	TA	TH	CC	AN	NN	OP	TP	DS	TI
TR	1													
WT	-.678(*)	1												
pH	0.135	0.156	1											
CON	-0.328	0.288	-.862(**)	1										
DO	.814(**)	-.792(*)	0.202	-0.531	1									
TA	-0.309	0.314	-.816(**)	.953(**)	-0.587	1								
TH	-0.275	0.174	-.918(**)	.978(**)	-0.451	.940(**)	1							
CC	-0.351	0.187	-.922(**)	.964(**)	-0.483	.941(**)	.991(**)	1						
AN	-0.287	0.632	-0.199	0.498	-0.335	0.514	0.392	0.397	1					
NN	-0.182	0.569	-0.304	0.503	-0.275	0.532	0.438	0.438	.903(**)	1				
OP	-0.351	0.459	-.704(*)	.857(**)	-0.547	.818(**)	.806(**)	.802(**)	0.575	.721(*)	1			
TP	-0.214	0.547	-0.436	0.654	-0.392	.719(*)	0.591	0.603	.893(**)	.943(**)	.792(*)	1		
DS	0.152	0.507	0.185	0.16	-0.073	0.196	0.036	-0.018	.803(**)	.718(*)	0.256	0.645	1	
TI	0.103	0.522	0.658	-0.323	-0.152	-0.318	-0.412	-0.467	0.073	0.124	-0.037	0.031	0.452	1
EM	0.321	-0.274	0.407	-0.41	0.233	-0.251	-0.424	-0.352	0.042	-0.109	-0.35	0.144	-0.01	0.057
RF	0.491	-0.445	0.604	-0.611	0.464	-0.545	-0.603	-0.56	-0.281	-0.452	-0.581	-0.3	-0.23	0.468
SUB	-0.892(**)	0.888(**)	-0.879(**)	-0.876(**)	0.675(**)	-0.668(**)	-0.656(**)	-0.679(**)	-0.876(**)	0.634(**)	0.628(**)	-0.786(**)	-0.721(**)	-0.675(**)
FF	0.799	-0.803	-0.463	-0.005	0.801	-0.183	0.147	0.128	-0.506	0.492	0.398	-0.054	-0.703	-0.367

The marked correlations are significant at P=<0.05 (1- tailed) and P=<0.01 (2-tailed).

Where, TR- Transparency, WT- Water temperature, TDS – Total dissolved solids, CON – Specific conductivity, pH – pH, DO – Dissolved oxygen, TH – Total hardness, CC– Calcium content, AN – Ammonical-nitrogen, NN – Nitrate-nitrogen, TP – Total phosphorus, OP – Ortho-phosphate phosphorus, DS – Dissolved silica, TI – Total iron, EM – Emergents, RF – Rooted floating-leaf type, FF – Free-floating type, SUB – Submergeds.

5.2.10. Correlations between biomass and biochemical constituents of macrophytes

Correlation coefficients worked out between the biomass and various biochemical constituents of macrophytes depicted only significant positive correlations between the various parameters.

The biomass of macrophytes depicted highly significant positive correlations with the chlorophyll content ($p<0.01$, $r = 0.866$) as was highlighted in the observations recording a summer peak in their concentrations. Lower values for biomass as well as chlorophyll content were also corresponding to each other. Biomass of macrophytes also revealed significant positive correlations with the carbohydrate content ($p<0.01$, $r = 0.800$). However, biomass of macrophytes also depicted positive correlations with protein ($p<0.01$, $r = 0.658$) and lipid contents ($p<0.01$, $r = 0.630$).

The strong positive relationship between chlorophyll content and carbohydrate content of macrophytes was evident from the results which was proved statistically ($p<0.01$, $r = 0.854$). Protein content of macrophytes maintained highly significant perfect positive correlations with total lipid content ($p<0.01$, $r = 0.997$).

Table 5.2.10.1. Correlation coefficients between biomass and various biochemical constituents of macrophytes in Wular lake

	Biomass	Carbohydrates	Lipid content	Proteins	Chlorophyll content
Biomass	1				
Carbohydrates	0.800(**)	1			
Lipid content	0.630(**)	0.400	1		
Proteins	0.658(**)	0.400	0.997(**)	1	
Chlorophyll content	0.866(**)	0.854(**)	0.000	0.000	1

The marked correlations are significant at P=<0.01 (2-tailed).

Alisma lanceolatum

Alisma plantago-aquatica

Alternanthera philoxeroides

***Azolla* sp.**

Batrachium trichophyllum

Bidens cernua

PLATE - IV

Butomus umbellatus

Ceratophyllum demersum

Cyperus serotinus

Echinocloa crus-galli

Eleocharis palustris

Hippuris vulgaris

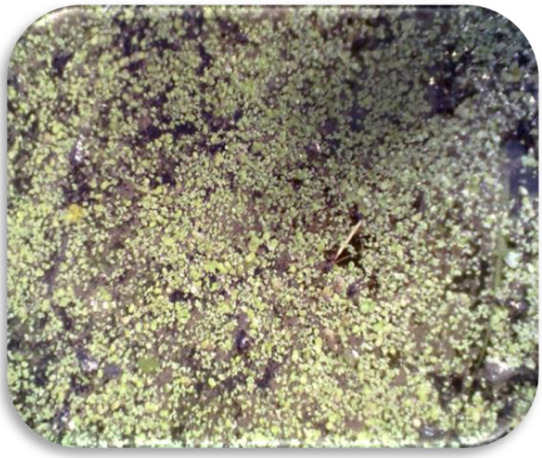
PLATE - V

Hydrilla verticillata

Hydrocharis dubia

Juncus buffonius

Lemna major



Lemna minor

Lycopus europaeus

PLATE - VI

Marsilea quadrifolia

Menyanthes trifoliata

Myriophyllum aquaticum

Myriophyllum spicatum

Myriophyllum verticillatum

Nasturtium officinalis

PLATE - VII

Nelumbo nucifera

Nymphaea alba

Nymphaea mexicana

Nymphaea pygmea

Nymphoides peltatum

Phragmites australis

PLATE - VIII

Polygonum amphibium

Polygonum hydropiper

Potamogeton crispus

Potamogeton lucens

Potamogeton natans

Potamogeton pectinatus

PLATE - IX

Potamogeton perfoliatus

Ranunculus muricatus

Ranunculus sceleratus

Sagittaria sagittifolia

Salvinia natans

Scirpus lacustris

PLATE - X

Sium latijugam

Sparganium ramosum

Trapa bispinosa

Trapa natans

Typha angustata

Typha latifolia

PLATE - XI

6.1. Physico-chemical characteristics of water

Limnological studies include the physico-chemical and biological parameters of fresh waters (Idowu *et al*., 2013). The interaction of various physico-chemical variables of water not only reflect the productivity and quality of an aquatic ecosystem but also play important role in determining the distribution, composition, abundance and productivity of aquatic organisms (Bagenal, 1978; Boyd and Tucker, 1998; Ghavzan *et al*., 2006; Tas and Gonulol, 2007). It also gives an insight in understanding the structure and function of a particular water body in relation to its inhabitants. The equilibrium between physico-chemical characteristics of water in shallow lakes and wetlands is an important factor for successful production of aquatic resources (Mustapha and Omotosho, 2005). As water is a binding element between different factors that play a significant role in wetland ecology, water quality and water management is a vital component of wetland conservation programs.

The Kashmir Himalayan lakes and wetlands acts as suitable niches for fish and habitat for a variety of waterfowl, migrating from neighbouring countries, besides being a very rich source of food, fodder and other economically important biological products. These shallow water bodies are undergoing trophic evolution under various natural and anthropogenic factors which makes them to exhibit considerable differences in their physical, chemical and biological set up. Of late, there has been a cry about deterioration of these water bodies and a subsequent decline in their area. The severe biotic interference coupled with cultural activities along the drainage basins are the factors responsible for their degradation. Hence, it becomes imperative to undergo a detailed study of these aquatic ecosystems, as such inventories are basic for management and sustainable development.

The present study carried out on Wular lake revealed appreciable variations in its physical and chemical milieu. Wular lake enjoys special status of being the largest freshwater body within Indian sub-continent and plays a major role in the hydrological regime of the Kashmir valley by acting as a huge absorption basin for floodwaters of Jhelum floodplain. The ox- bow type lake is mono- basined, elliptical in shape and is of fluviatile in origin, formed by the meandering of River Jhelum. Its depth on average is 3.6 m throughout length, reaching 5.8 m at its deepest point (Pandit, 2002). Like most of the Kashmir Himalayan lakes and wetlands, Wular lake is under the influence of varied anthropogenic pressures. The immediate catchment, comprising mostly of agricultural land and domestic households, has a direct impact on the water quality of Wular lake.

The depth of a water body is one of the major physical factors which act as a controlling factor for determining the water quality. Depth of a water body is determined by the hydrological factors like the amount of water brought in and sent out (Steward and Kantrud, 1971). The depth of the water body under study ranged between a mean maximum of 4.6 m (at Site VII) during spring 2011 as against the mean minimum depth of 0.3 m (at Site I), being recorded during winter 2012. Lower values of mean depth have been used as an important criterion to establish the trophic status of lakes (Hayes, 1957; Pandit, 2002). Further, on the basis of low water depth ranges making a large expanse of wetland zone, Wular lake was in 1990 recognized as Ramsar Site, along with other attributes. The greater water depth in Wular lake during spring is the result of more direct precipitation input than the evaporation output, thus serving as a source of water during spring and as a strong sink for other seasons (Kumar and Pandit, 2005). During summer the total output of water increased by virtue of evapotranspiration and surface water output for irrigation purposes of the adjoining fields which continued throughout the autumn as well. Wular lake, on the basis of low mean depth values (0.3-1.5 m) can be placed in shallow lake type of Buraschi *et al*. (2005). Depth and water volume are related factors that influences temperature of a water body (Atobatele and Ugumba, 2008).Wular lake, in general, having little depth, did not show any thermal stratification.

Secchi disc transparency, being a function of the amount of light reflected from the surface of water, is influenced by the absorption characteristics of water and the amount of dissolved and particulate matter contained in the water (Wetzel and Likens, 2000). The light in water is of paramount importance for its role in the photosynthetic processes of all chlorophyll bearing aquatic plants and thus for the primary production (Mahar, 2003). The secchi disc transparency showed slight insignificant spatial as well as temporal variations (F= 1.659, P= 0.195), though low transparency of water was found in lake invariably during the spring. The high biological activity particularly that of phytoplanktons and addition of silt-laiden runoff may explain the low values of water transparency recorded in spring (Hakanson and Boulion, 2002). In contrast, the high values of transparency observed during winter may be attributed to the low plankton population and to the reduction in allochthonous substances that find their way into the lake (Ikomi *et al.*, 2003; Mahar, 2003). Similar observations were made by Mustapha and Omotosho (2005) in Moro lake and Ayoade *et al.* (2006) in Asejire and Oyan lakes. In Wular lake the littoral macrophytes act as sinks and filter the nutrients and suspended particles, thus helping in maintaining relatively clear water in the limnetic areas (Lindholm *et al.,* 2008). Higher values of transparency at Site VII may be attributed to the presence of dense submerged macrophytic vegetation which acts as effective barrier for sediment resuspension, resulting in improving the transparency (De-Vicente *et al*., 2006; Huang *et al*., 2007).

Water temperature is an important factor that influences limnological phenomenon such as stratification, solubility of gases, pH, conductivity and occurrence, distribution and productivity of aquatic organisms as well (Nazneen, 1980; Singh, 1990; Lewis, 2000). It depends on the climate, sun light and depth (Akinyemi and Nwakwo, 2006; Atobatele and Ugumba, 2008). In the present study, the annual cycle of the surface water temperature showed a close relationship to that of air temperature. This type of observation for shallow water bodies is in conformity with the earlier findings of Ried and Wood (1976), Singhal *et al.* (1985) and Mahar (2003). In the lake under study the atmospheric temperature showed a difference of 27.2 ^{0}C (5.1-32.3 ^{0}C) while, the water temperature recorded a fluctuation of 22.2 ^{0}C (4.2-26.4 ^{0}C), thereby showing that the former has a large influence on the latter. The temperature variations recorded during the study were optimal for normal growth and survival of aquatic organisms (Boyd, 1979). Increase in both air and water temperature from April to August is attributed to the increase in solar radiation due to comparatively longer day length. Similarly, a gradual reduction in solar radiation may explain fall in temperature from October to February and again it begins to increase from March onwards. A direct relationship of water temperature with bright sunshine and its duration has also been reported by Munawar (1970) and Harshey *et al*. (1982).

Specific conductivity, being principally a function of ions and an indication of total salt concentration, is often related with the trophic status of aquatic ecosystems (Berg *et al*., 1958). Rainfall patterns, incoming waters, evaporation rates, drainage type and nutrient status are the major factors that influence conductivity of a lake (Kinnear and Garnett, 1999).Wular lake, witnessed a seasonal trend and depicted comparatively higher values of conductivity. The seasonal fluctuations in conductivity of waters is mostly related with biological activity as the low value during summer months is due to uptake of ions by macrophytes and their attached microflora during their growing season along with precipitation of calcium carbonate which is the main contributor to conductivity (Otsuki and Wetzel, 1974; Vymazal, 2002; Mustapha and Omotosho, 2005). Absence of most of the vegetation during winter causes accumulation of nutrients in the water, hence higher specific conductivity was recorded during the winter evincing lowest biological activity (Kumar and Pandit, 2007; Bhat, 2010). The strongly significant positive correlation of conductivity with calcium ($p<0.01$, $r = 0.964$) and alkalinity ($p<0.01$, $r = 0.953$) suggests that these parameters have a major influence on the conductivity of the lake. Wular lake, on the basis of specific conductivity (200-500 μScm^{-1}), can be placed in β-mesotrophic category of Olson (1950).

Total dissolved solids (TDS) indicates the amount of organic and inorganic matter in the samples. Total dissolved solids are very useful parameters describing chemical constituents of the water and can be, in general, related to the edaphic factor that contributes to the productivity of the water body (Goher, 2002). Depending upon solubility of minerals the concentration of total dissolved solids (TDS) in water varies in different geological regions (Connolly *et al.*, 1990). Total dissolved solids followed the same trend as that of specific conductivity, witnessing its peak amount during winter and then following a decline to reach the lowest value during summer where after an increasing trend was evinced towards the autumn. The highly significant perfect positive correlation between total dissolved solids and conductivity was evident from the results which was proved statistically ($p<0.01$, $r = 0.999$). The seasonal fluctuations in TDS values of waters is mostly related with biological activity as the low concentration during summer months is due to very high macrophytic cover in Wular lake which enhances sedimentation and counteracts resuspension of sediment particles, and therefore restricts the return of nutrients from sediments (Sondergaard *et al*., 1992; Kufel and Kufel, 2002; Bhat, 2010). Absence of most of the vegetation during winter causes accumulation of salts ions in the water, hence higher TDS values were recorded during the winter evincing lowest biological activity (Sondergaard *et al*., 2003).

The free CO_2 depicted well marked seasonal fluctuations at all the sites, registering a minimum values (5.7±0.6 mg/L at Site IV) in summer and a maximum in winter (24.3±3.5 mg/L at Site VI). The lower values of free carbon dioxide in Wular lake during summer is due to removal of carbon dioxide from the water column by the photosynthetic activity of phytoplankton and macrophytes (Otsuki and Wetzel, 1972; Kaul and Trisal, 1984; Wetzel, 2001), as well as the important role of temperature in increasing photosynthetic activity (Aboul Kassim, 1987). In contrast, the higher values of free carbon dioxide during winter may be attributed to the higher CO_2 content produced as a result of algal degeneration, as well as the increased decomposition of organic matter under least water depth (Reimer *et al*., 2008). The high value of the free carbon dioxide content is an indication of high degree of pollution (Todda, 1970; Cole, 1979). An inverse relation between carbon dioxide and pH was found which is in consonance with the observations made by Swarup and Singh (1979), Jhingran (1982) and Mahar (2003).

Dissolved oxygen is a parameter of immense importance in aquatic ecosystems and is considered to be the most reliable criterion in assessing the trophic status and magnitude of eutrophication of aquatic ecosystems (Edmondson, 1966; Wetzel, 2001). In aquatic ecosystems, the dissolved oxygen is the fundamental factor that reveals more about the metabolism of the aerobic aquatic organisms than any other single measurement and, therefore, its dynamics is important for the understanding of their distribution, behaviour and growth (Wetzel, 2001). Being required by producers, consumers and decomposers, dissolved oxygen, therefore, regulates nutrient availability and hence productivity of aquatic ecosystems (Wetzel, 2001). The dynamics of oxygen distribution in lakes is governed by balance between inputs from atmosphere and photosynthesis and losses by way of chemical and biological oxidation (Wetzel, 2001; Gupta and Gupta, 2006). The ability of water to hold oxygen is greatly affected by the temperature of the water body (Wetzel, 2001; Singh, 1990). The results of the present study showed that Wular lake had adequate dissolved oxygen with a mean concentration ranging from 6.7 mg l^{-1} to 9.6 mg l^{-1}. Contrary to the findings of Egborge (1994), dissolved oxygen showed inverse relationship with temperature in Wular lake. Lower levels of dissolved oxygen in summer than the other seasons could be due to the combined effect of the rise in temperature, increased biological activity, respiration of organisms and the increased rate of decomposition of organic matter (Lewis, 2000; Okbah and El-Gohary, 2002). In productive lakes and wetlands like Wular, during periods of maximum biotic activities, there is discernible oxygen deficit on account of respiration by organisms especially algae and the oxidation of organic humus (Wetzel, 2001; Mwaitega, 2003; Kumar and Pandit, 2007). Conversely, high dissolved oxygen concentration during winter can be attributed to low biological activity, under saturation of oxygen, low temperature and instability of water masses, caused by loss of sufficient heat (Serruya and Serruya, 1972; Idowu, 2013**).** At Site VII high concentration of dissolved oxygen is due to luxuriant growth of submerged macrophytes which act as main sources of aeration for the lake, thereby enhancing light penetration and hence photosynthesis (Kumar and Pandit, 2007; Srivastava *et al*., 2008).The strong positive correlation between transparency and dissolved oxygen in the Wular lake also substantiate the fact that increased transparency increases dissolved oxygen content by enhancing photosynthetic input.

Wular waters were alkaline with pH ranging from 7.1 to 8.5 recorded over a period of two years. pH, principally a function of amounts of calcium, magnesium, carbonates and carbon dioxide in the water expresses the intensity of acidity or alkalinity of an aqueous solution (Wetzel, 2001). The interaction of both the H^+ generated by dissociation of H_2CO_3 and OH^- produced during the hydrolysis of HCO_3^- governs the pH of natural waters to a large extent (Wetzel, 2001). Both spatial as well as temporal variations in pH were found to be statistically significant in Wular lake ($F= 23.06$, $P< 0.01$). The gradual increase in pH during summer is due to removal of carbon dioxide from the water column by the photosynthetic activity of phytoplankton and macrophytes (Otsuki and Wetzel, 1972; Nassar and Dutta-Munshi, 1975; Wetzel, 2001). Large pH changes of one unit or more have been reported under a combination of low to moderate alkalinity and high algal or submerged macrophyte biomass resulting in large daytime CO_2 and HCO_3^- withdrawal (depletion), thereby increasing pH (Boyd, 1990).On the other hand, lower pH during winter is because of the increased decomposition of organic matter under least water depth (Reimer *et al*., 2008). The pH variations recorded during the present study fall within the recommended range for the support of aquatic life (Boyd, 1979; Kamran *et al*., 2003).

In aquatic ecosystems the concentration of chloride is not only an index of eutrophication, but also of pollution caused by sewage and other waste waters (Munawar, 1970; Hasalan, 1991; Berzas-Nevado *et al.,* 2009). Dissolution of rock minerals, pollution and run off from catchment area are the major sources of chloride.

The concentration of chloride is generally low in natural waters and its higher amount always comes from the contamination of sewage. In general, the waters of Wular showed high amounts of chlorides ranging from 7.3 mg l^{-1} to 22.7 mg l^{-1}. Lake waters, during both the years of study, recorded very noticeable seasonal trend in the amounts of chloride, registering its highest during spring and lowest during winter at all the sites. However, clear spatial variations occurred in the lake with sites in the vicinity of human habitation (Site IX) receiving domestic sewage depicting higher concentration of the ion. The higher amount of chloride during spring season is attributed to inflow through direct precipitation and subsequent run-off from the catchment area. This view point further gains support from the recent studies of Bhat *et al*. (2001) , Kumar *et al*. (2004), Kumar and Pandit (2007) and Bhat (2010), who opined that the high chloride content, an indicator of organic pollution, owes its origin to the influx of sewage from human settlement. Metabolic utilization of chlorides does not cause significant variations in spatial and seasonal variations within a water body and therefore, the variations observed in Wular lake can be associated with hydrological factors like inflow through direct precipitation and run-off reaching the lake through inflow channels.

In fresh water ecosystems the hardness of water is mostly governed by the carbonates and bicarbonates of calcium and magnesium (Cole, 1983). The type of minerals in the soil and watershed bedrock, and the amount of lake water coming into contact with these minerals are the major factors that influence hardness of a lake (Tepe *et al*., 2005). The hardness was significantly higher in winter months as compared to summer months. This may be due to the high density of macrophytes and plankton in summer which use most of the salts for their growth and life processes, thereby increasing the pH of water and accelerating the de-calcification, resulting in decrease of hardness (Wetzel, 2001; Kufel and Kufel, 2002; Kumar and Pandit, 2007; Bhat, 2010). This is also substantiated by highly significant positive correlations of pH with total hardness ($p<0.01$, $r = -0.907$), calcium content ($p<0.01$, $r = -0.907$) and magnesium content ($p<0.01$, $r = -0.888$) in this lake.

Calcium is generally the dominant cation in Kashmir lakes on account of the predominance of lime rich bed rock in the catchment area (Zutshi *et al*., 1980; Pandit, 1993). The amounts of Ca^{2+} depicted summer fall in Wular lake, a trend similar to that of alkalinity, due to uptake of CO_2 by photosynthetic activity especially by submergeds and subsequent precipitation of calcium as calcium carbonate as a result of combination of elevated temperature in macrophytes beds and reduced $CaCO_3$ solubility (Kaul and Trisal, 1984; Wetzel, 2001; Kufel and Kufel, 2002; Kumar and Pandit, 2007). The deposition of calcite crystals is easily seen on submerged plants in the lake as white encrustations.

Like calcium, magnesium also varied seasonally in the lake with decrease in its concentration during summer months corresponding to peak growth of macrophytes. Low values of magnesium content in summer period is possibility due to its uptake by the plants in the formation of chlorophyll-porphyrin metal complexes and in enzymatic transformation (Wetzel, 1975).This is also substantiated by significant positive correlation of magnesium with calcium content ($p<0.01$, $r = 0.975$). The dominance of calcium over magnesium in Wular lake could be attributable to calcium rich lime rocks in the catchment (Zutshi, *et al*., 1980; Pandit, 1993; Jeelani and Shah, 2006).

Alkalinity, the acid consuming capacity of water, is mainly imparted by the presence of HCO_3^- and CO_3^{-2}. Most of the alkalinity present in water is due to dissolution of carbonates and aluminosilicates (Das and Dhiman, 2003). The formation of carbonic acid by the interaction of CO_2 and H_2O in soil play significant role in the dissolution of carbonate rocks in the catchment, producing calcium bicarbonate which is soluble in water and this increases the alkalinity of the water (Wetzel, 2001). In the present investigation, the alkalinity of water was exclusively due to bicarbonate ions. However, there was a predominance of bicarbonates and calcium over chloride and magnesium as is true for all fresh waterbodies (Rodhe, 1949). On the basis of total alkalinity values, Wular lake can be categorised as “hard water type “as per the classification of Moyle (1945). The total alkalinity depicted summer minima in Wular lake, a trend opposite to that of pH, due to removal of CO_2 and HCO_3^- by the photosynthetic activity of phytoplankton and macrophytes which exhibit luxuriant growth during this period. Thus, this increases pH and consequently shift the chemical equilibrium towards the formation of carbonate ions which then precipitate with calcium in the form of calcite that significantly leads to decline of alkalinity (Stumm and Morgan, 1996; Wetzel, 2001; Kufel and Kufel, 2002). The strongly significant negative correlation of alkalinity with pH ($p<0.01$, $r = -0.799$) suggests that pH has a major influence on the alkalinity of Wular lake. In contrast, the higher values of total alkalinity during winter may be due to fall in water level. Researchers like Cook and Powers (1958) and Singhal *et al*. (1986) also reported that bicarbonates increase with the fall in water level.

The most abundant minerals in the earth's crust are aluminosilicate minerals (Schlesinger, 1997) but, due to their limited solubility, they are not the major dissolved ion in water (Stumm and Morgan, 1981). Lower silicate values were recorded in Wular lake during winter for all sites. This may be due to the slow rate of regeneration of silicate from the sediments as well as to the decreased decomposition of siliceous compounds under the influence of oxygen rich waters (Kinawy, 1974; Okbah and. El-Gohary, 2002). In contrast, the higher content of silicate in spring and summer months is a result of inflow through direct precipitation and subsequent run-off from the catchment and increased silt laden inflow from inlet channels into the lake. This view point further gains support from the studies of Okbah and. El-Gohary (2002) who opined that the high content of reactive silicate is directly proportional to drainage water discharged into a lake. Further, the solubility of silica is known to increase at higher pH values and higher temperatures (Willen, 1991) and, therefore, a combination of warm water and elevated pH values may have caused the observed enhanced silicate concentrations during spring and summer months. The slight higher values of silicate obtained in the present study suggest the dissolution of aluminium silicate minerals in the rocks that are found around the lake.

Phosphorous is the key nutrient which controls the reproduction and growth of aquatic organisms (Wetzel, 2001; Sondergaard *et al.,* 2003a, b; Mehner *et al.*, 2008). Many organisms utilize both organic and inorganic forms of phosphorous; however plants have been reported to preferentially take up the inorganic phosphorous than organic phosphorous (Riley and Chester, 1971). There was a general trend of decrease in the concentration of dissolved inorganic phosphorus during summer months owing to its utilization by primary producers and its precipitation induced by photosynthesis. The increased pH associated with high temperature and higher alkalinity are favourable for precipitation of calcium carbonate due to rapid carbon assimilation from dissolved bicarbonates and under such conditions phosphate ion is reported to co-precipitate with carbonate (Kaul and Trisal, 1984; Wetzel, 2001; Dittrich *et al*., 2004). The high concentration of both the forms of phosphorous during winter months may be due to decay and subsequent mineralization of dead organic matter (Cole, 1975). The strong positive correlation between the two forms of phosphorus in Wular lake ($p<0.05$, $r = 0.792$) suggests their co-fluctuation. The concentration of total phosphate phosphorous was quite high as compared to the orthophosphate phosphorous. Thornton and Nduku (1982) suggested the values of dissolved inorganic phosphorus >30 μg/L as indicative of eutrophic status in temperate lakes. The average concentration of both total phosphorus and orthophosphate phosphorus, remained generally high placing the wetland in hypertrophic category according to Wetzel (1983).This is substantiated by the fact that almost the whole water body is infested by the macrophytes, which is possible only when this important nutrient is available in sufficient quantities (Shah and Pandit, 2012).

In aquatic ecosystems the rate of nitrification is regulated by factors like NH_4^+ availability, pH, temperature, dissolved oxygen concentration and organic carbon availability (Triska *et al*., 1990; Verhagen and Laanbroek 1991; Jones *et al*., 1995; Strauss and Dodds, 1997; Strauss and Lamberti, 2000). On the other hand, the distribution of ammonia, the end-product of the breakdown of nitrogenous organic and inorganic matter in soil and water as well as excretion by biota and reduction of nitrogen gas by microbes (Wetzel 2001), is highly variable in lakes and depends upon the level of productivity, sewage inflow, decomposition, input of nitrogen fertilizers and organic loading (Heathwaite and Johnes, 1995; Ogato, 2007; Lumbreras, *et al.*, 2009). The higher level of nitrate-nitrogen than ammonical-nitrogen is probably related to the fact that plants have been reported to preferentially take up the reduced NH_4^+ rather than oxidized NO_3^-, so that lower levels of ammonia occur in water (Kalff, 2002). The spatial and temporal variations within the lake were obvious for both the forms of nitrogen. The decrease in their concentration from spring till late summer is related to rapid uptake and assimilation by autotrophs i.e., phytoplankton and macrophytes which exhibit luxuriant growth during this period (Xie, *et al.*, 2004; Shilla *et al*., 2006; Bhat, 2010). It has been emphasized that quick flushing away of nutrients during high water level periods (spring and summer) may also be the possible reason for low nitrogen content in waters which again seems to be true for Wular waters (Kaul, 1977; Mwaitega, 2003). The strong positive correlation between the two forms of nitrogen in Wular lake ($p=<0.01$, $r= 0.903$) suggests their co-fluctuation. The increase in NO_3–N concentration during winter may be attributed to the fact that under high oxygen concentration, the nitrogen rich sediments add appreciable quantity of nitrate-nitrogen to the water (Kaul and Trisal, 1984; Kumar and Pandit, 2007). On the other hand, the winter increase in the concentration of ammonia may be due to decomposition of organic matter (Kaul and Trisal, 1984; Wetzel, 2001; Okbah and. El-Gohary, 2002) and bird droppings into the lake as it is visited by many aquatic birds (Zuber, 2007).

Iron is an important micronutrient of microflora, plants and animals as it plays an important role in many enzymatic transformations. The quantity of total iron in oxygenated surface waters of neutral or alkaline lakes ranges from about 50-200 µg/L and much higher levels may occur in certain alkaline and closed lakes rich in organic matter. A perusal of the data revealed that there was a summer fall in total iron content in the lake waters. The autumn and spring season registered modest amounts of total iron and the values peaked during winter. Similar observations were made by Kumar and Pandit (2007) in Hokersar wetland, Kashmir Himalaya and Ramesh and Selvanayagam (2013) in Kolavoi lake, India. On the other hand, the winter increase in the concentration of total iron may be due to the release of phosphorus bound iron compounds from the sediments at lower pH during mineralization (Golterman, 2001). Akram (1992) related higher iron content in lake waters to agricultural activities and increased diffusion of ferrous ion from the sediments at lower oxygen concentration near the sediment surface.

6.2. Vegetation

6.2.1. Species composition

Biotic communities are dynamic in nature changing more or less regularly in time and space. There exists direct relationship between environmental conditions and structure and function of biotic communities as any change in the environment is manifested by changes in the structure and function of the community. Macrophytes constituting ecologically dominant community of shallow lakes and wetlands, therefore, form an important tool for biomonitoring of such ecosystems (Wetzel, 2001; Lacoul and Freedman, 2006).

The present study on Wular lake revealed clear differences in the community structure of macrophytes. Even though all the life-form classes viz., emergents, rooted floating-leaf type, submergeds and free floating type constituted the macrophytic community of the wetland, their contribution to overall community structure varied considerably. The wetland not only depicted spatial variability in species composition but significant spatial differences were also observed regarding various community characteristics and, therefore, community architecture. This could be due to the presence of significant variations in physicochemical variables that determine the species composition and community architecture of macrophytes (Wetzel, 2001; Jafari *et al*., 2003).

It is well known that aquatic plants show relatively little taxonomic differentiation compared with the terrestrial groups (Less, 1988; Cook, 1990).The amount of evolutionary diversification dwindles as one goes from amphibious and emergents groups to fully submerged hydrophytes. Since the wetland ecosystems, as in case of Wular lake, represent the transition between the two extreme diversifications, sustaining both amphibious as well as purely aquatic taxa, harbour a very complex taxonomic makeup of the macrophytic community (Smith, 1980). In Wular lake, unlike lakes, no typical macrophytic zonation was distinguishable; instead various macrophytic species either grow intermixed with one another which result in the complex physiognomy of the wetland vegetation or grow in pure communities to form a characteristic type of vegetation which differs qualitatively and quantitatively from the lake vegetation. According to Wilson and Keddy (1986) complex macrophytic physiognomy and multi-specific meadow formations in the wetlands is an example of mutualism, where neighbours help to protect other plants from the damage caused by waves. The study revealed that the wetland harbours the mixed vegetation comprised of families, both advanced (e.g., Asteraceae) as well as primitive (e.g., Alismataceae). Though the open water areas of Wular lake exhibited the growth of all the types of macrophytes growing intermixed, the emergents out-numbered all other life-form classes of macrophytes in the wetland which could be due to their ability to tolerate greater water-level fluctuations (Kumar and Pandit, 2008; Tamire and Mengistou, 2012). Moreover, emergents also depicted greater variations regarding species composition compared to other life-form classes.

6.2.2. Community features

Significant spatial and temporal and variations were found in the density and abundance of macrophytes in Wular lake during the two years of study period. This is in consonance with the results of many other workers who reported a definite seasonality in the density and diversity of macrophytes in their studies (Pompeo and Moschini-Carlos, 1996). According to Pompeo and Moschini-Carlos (1996), the seasonal variation in the density of macrophytes is attributable to seasonal fluctuations in water levels. The presence of significant difference in density and abundance of macrophytes in Wular lake could be due to the presence of significant seasonal variation in physicochemical variables that determine the density and abundance of macrophytes (Barko *et al*., 1991; Wetzel, 2001; Jafari *et al*., 2003). Further, the density and abundance of these macrophytes in the lake seems to be affected by differences in the nutrient levels among sites, and their ability to colonize these varied sites indicates their potential to adapt to diverse trophic conditions. Their density was higher at sites where nutrient concentrations were higher, which implies that increase in the concentration of nutrients particularly nitrogen and phosphorus in the lake to a certain level would further encourage infestation by these macrophytes (Heegaard *et al.*, 2001; Murphy, 2002). The strong positive correlation between density and nutrients in the Wular lake also substantiate the fact that increased nutrient concentration increases the diversity of macrophytes. The study of IVI values revealed that *Lemna-Salvinia* complex dominated all the sites and was co-dominant at Site II indicating its absolute dominance over other species in the Wular lake. The dominance of *Lemna-Salvinia* weed complex *over* other species is attributed to its high aggressive capacity, colonization of sites rich in organic matter and also lake littorals (Pandit, 2008). The author further opined that there occurs a shift in the under-water vegetation by the development of *Lemna-Salvinia* association with excessive eutrophication resulting in the replacement of *Potamogeton lucens* by more eutrophic *Ceratophyllum demersum*. In the present study it was growing as free floating at all the sites indicating the high pollution load of Wular lake.

6.2.3. Species richness

Species richness in the wetland under study reflected a seasonal trend with maximum richness being recorded during summer and early autumn. Grime (1973) opined that perturbations increases the species richness by allowing new species to establish which seems to be a probable explanation for greater species richness in Wular lake where water draw-down during summer, the main growing season, results in the invasion of new species and the subsequent richer and diverse growth of emergents and rooted floating-leaf types. The study further gains support from the findings of Nurminen (2003), who reported that higher turbidity and fluctuations in water level limits the distribution of macrophytes to mainly turbidity tolerant species, for example rooted floating-leaf types and emergents. Temperature can influence plant performance, especially photosynthetic rates and is considered to be the single environmental variable profoundly influencing the propagule germination and shoot elongation in many aquatic plants over the whole range of their occurrence (Gorham, 1974; Madsen and Adams, 1988; Pilon and Santamaria, 2002). In the present study it also seems that temperature have profound influence on the species richness and diversity of macrophytes. The diverse growth for most of the macrophytes corresponds to the period of maximum atmospheric temperature. Further, the species richness and diversity during spring were found to be lower which might be due to higher precipitation and comparative low temperatures during spring. There seems to be a greater correlation between species diversity and lake area as Wular lake depicted higher species diversity and species richness. A few studies have indicated that this relationship may be due to the habitat heterogeneity, as larger lakes encompass more microhabitats more species are able to find a suitable habitat with increasing area (Rorslett 1991; Jones *et al*., 2003; Heegaard, 2004; Capers *et al*., 2010). Further, greater diversity of macrophytes in Wular lake seems to be linked with its slightly eutrophic status (Heegaard *et al.*, 2001; Lougheed *et al*., 2001; Murphy, 2002).

6.2.4. Distribution and zonation

Macrophytes play an important role in the structure and functioning of freshwater ecosystems (Wetzel, 2001; Hrivnak *et al*., 2009). The function of macrophytes in these ecosystems is related to their structural attributes like species composition, distribution, abundance and diversity which in turn depend on a myriad of factors. Foremost, among these are light, depth and fluctuations in water levels, water temperature, water quality changes and nutrient enrichment and sediment composition (Kaul *et al*., 1978; Pandit 1984, 1992; Barko and Smart, 1986; Wetzel, 2001; Hudon *et al*., 2004). In Wular lake, unlike lakes, no typical macrophytic zonation was distinguishable; instead various macrophytic species either grow intermixed with one another which result in the complex physiognomy of the wetland vegetation or grow in pure communities to form a characteristic type of vegetation which differs qualitatively and quantitatively from the lake vegetation. However, the distribution patterns of macrophytes depicted considerable spatial variations in Wular lake. This is possibly due to the significant spatial difference in the physical and chemical properties of Wular lake waters (Toivonen and Huttunen, 1995; Sraj- Krzic *et al*., 2007).

Water depth is considered to be the major factor in affecting the distribution of macrophytes (Spence, 1982; Daniel *et al*., 2006). In the present study it also seems that water depth acts as a major factor in affecting distribution patterns of emergent and submerged macrophytes. This is because the maximum area under emergents was present at the shallowest Site I where large aggregations of emergents plant species are found distributed throughout. Moreover, this site also harbours lesser number of submerged macrophytic species. Among emergent macrophytes *Typha angustata* and *Phragmites australis* were the dominant ones and were widely distributed over the entire littoral zone of the wetland. *Myriophyllum verticillatum, Polygonum hydropiper* and *Polygonum amphibium* were also seen scattered all over the emergent zone. The dense population of emergent vegetation in the littoral zone seems to be linked with the decreased depth of the wetland caused by increased siltation carried from the catchment area by its inlets. It is in agreement with the findings of Wetzel (1983) and Tamire and Mengistou (2012) who reported that decreasing water level indicates a succession towards a marsh.

Rooted floating-leaf type macrophytes (*Nymphoides peltatum* and *Trapa natans*) also form widespread dense beds in Wular lake. This is due to the higher turbidity and fluctuations in water level that limits the distribution of macrophytes to mainly turbidity tolerant species, for example rooted floating-leaf types and emergents (Nurminen, 2003). Moreover, the increased water depth at certain portions of the Wular lake results in the establishment of rooted floating-leaf type macrophytes which is further corroborated by the studies of Spence (1967, 1982) who suggested an adaptive connection between deep waters and broad-leaf species. As the floating-leaf species are capable of growing under permanently inundated conditions in Wular lake, it appears that they are capable of anaerobic metabolism (Kaul *et al*., 1978).

It has been well emphasized that the distribution and growth of aquatic macrophytes is associated with nutrient rich environments particularly nitrate and phosphate which have been noted to favour macrophytes growth (Frankouich *et al*., 2006). Several studies have established that the nutrient enrichment can cause significant changes in the density, species composition and richness of aquatic vegetation in lakes (Lougheed *et al*., 2001; Rosset *et al*., 2010; Alahuhta, 2011).

Greater species richness at Site I in Wular lake can also be linked to the increase in the concentration of nutrients particularly nitrogen and phosphorus at this site. This is due to the fact that increase in the concentration of nutrients particularly nitrogen and phosphorus in freshwater ecosystems to a certain level would encourage infestation by macrophytes (Heegaard *et al.*, 2001; Murphy, 2002). Further, emergent macrophytes have also been reported to be very efficient in the uptake of many plant nutrients from the sediments and thus helping in pollution abatement (Pandit, 1984, 1992). The strong positive correlation between density of macrophytes with ammonical-nitrogen ($p<0.01$, $r = 0.733$) and orthophosphate-phosphorus ($p<0.01$, $r = 0.765$) in the Wular lake suggests that nutrients can cause considerable changes in the density and distribution of macrophytes.

Among the varied environmental factors affecting the distribution of submerged macrophytes water depth and water transparency associated with light availability are of paramount importance (Spence, 1982; Chambers and Kalff, 1985; Daniel *et al*., 2006). It is well documented that the underwater light plays an important role in determining the depth distribution of different groups of aquatic macrophytes (Sculthorpe, 1971; Chambers and Kalff, 1985; Dale, 1986; Chambers and Prepas, 1988; Hrivnak *et al*., 2006). A number of reports indicate that certain species of aquatic macrophytes, mostly submerged ones, usually extend into the depths in order to maximize their absorption of the light and CO_2 needed for photosynthesis (Barko and Smart, 1981; Maberly and Madsen, 2002). Submerged macrophytes have also been reported to grow to a depth of two to three times the Secchi depth (Chambers and Kalff, 1985). In the present study it also seems that the distribution of submerged macrophytes is mainly dependent on water depth and transparency. This is because submerged macrophytes cover the maximum area at Site VII in Wular lake due to its greater depth and transparency. This observation is further confirmed by the significant positive correlation of density of submerged macrophytes with transparency ($p<0.01$, $r = 0.891$) and water depth ($p<0.01$, $r = 0.806$). In Wular lake, despite moderate depth, submerged forms except a few did not show luxuriant growth because of greater water turbidity (Gasith and Hoyer, 1998) and dense growth of rooted floating-leaf type macrophytes which limit light penetration. Data on physico-chemical parameters of Wular lake reveals lower transparency in the lake resulting in the suppression of this life form. However, the dominance of *Ceratophyllum demersum* among submergeds seems to be linked with its adaptation to the low irradiation conditions which are practically prevalent in Wular lake (Vander Valk and Bliss, 1971). On the other hand, Hernández *et al.* (1999) and Foroughi *et al.* (2010) further opined that the dominance of *Ceratophyllum demersum* is due to its high vegetative propagation, lack of true roots, and high surface area: volume ratio, which makes it a strong competitor for nutrients. A number of studies indicate that nutrient enrichment is responsible for the changes that occur in the species richness, composition, and density of aquatic vegetation in lakes (Bini *et al.*, 1999; Magee *et al.*, 1999). Our results confirm that diversity of submerged macrophytes in Wular lake declines with deterioration in water quality. This is in consistent with the study of Lougheed *et al.* (2001) who also found reduced species richness of submerged macrophytes with the deterioration in water quality.

Temperature can influence plant performance, especially photosynthetic rates and is considered to be the single environmental variable profoundly influencing the propagule germination and shoot elongation in many aquatic plants over the whole range of their occurrence (Gorham, 1974; Madsen and Adams, 1988; Pilon and Santamaria, 2002). In the present study it also seems that temperature have profound influence on the diversity and distribution of macrophytes. The diverse growth of most of the macrophytes corresponds to the period of maximum atmospheric temperature. The strong positive correlation between density of free floating macrophytes and water temperature ($p<0.05$, $r = 0.702$) in the Wular lake also validate the fact that the temperature can cause significant changes in the density and distribution of macrophytes. This is in consistency with the findings of other studies (Vilbaste *et al.*, 2008; Hrivnak *et al.*, 2009b).

6.2.5. Diversity indices and cluster analysis

The diversity indices, being more reliable, incorporate species richness, commonness and rarity in an integrated manner (Washington, 1984). Various diversity indices pointed towards the heterogeneous species composition and complexity of Wular lake. In the present study the Shannon's Diversity Index (H) showed high diversity of macrophytes at Site VII (3.06) and lowest at Site IX (2.38). The low diversity at Site IX may be related to high concentration of ammonia and low transparency (Kufel and Kufel, 2002). Gerritsen *et al.* (1998) reported that as the number and distribution of taxa (biotic diversity) within the community increases, so does the value of “H”. Moreover, the reasons for high diversity at Site VII may be due to slightly lower nitrate and phosphate concentration and relatively high transparency (Oertli *et al.*, 2000). The Simpson’s Diversity Index showed low variability with Site V recording the highest value of 0.989 while Site I recorded the lowest value of 0.939. According to Magurran (2004) Simpson Index is heavily weighted towards the most abundant species in the sample and being less sensitive to species richness. A greater value of Simpson Diversity Index at Site V is an indication of increase in the diversity and abundance of macrophytes at this site. The Sorenson’s similarity index based on species composition indicate that Site I had high degree of similarity with Site VI (81.3 %), which may be due to their littoral nature and similarity in their water characteristics as was observed during the present study. Moreover, these sites have almost similar dominance pattern of macrophytes which may also have resulted in high similarity between the sites. Further Bray-curtis cluster analysis also showed greater similarity between Site I and Site VI (78 %) which is also an indication of similar dominance pattern of macrophytes between the sites.

6.2.6. Primary productivity of macrophytes

The productivity of an ecosystem is vital and indispensable for ecosystem analysis as the same integrates the cumulative effects of the various physiological processes and interactions occurring simultaneously within the ecosystem (Jordan, 1985). According to Odum and Barrett (2008) the primary productivity of an ecological system is the rate at which radiant energy is converted to organic substances by the photosynthetic and chemosynthetic activity of the producer organisms. The aquatic resources have been till date the potential source of organic production for the entire living organisms. Many ecologists of the world have laid emphasis on the importance of the primary productivity as an important functional attribute of the biosphere because of its controlling effects on the rate of multiplication and growth of the living organisms of the ecosystem (Westlake, 1963). The productivity of a lake is often reflection of its nutrient status and trophic level. On the other hand, the productivity of aquatic macrophytes is often related with the growth form strategy of the species.

The present study reveals that the emergent macrophytes contribute more than 50 % of total macrophytic production in Wular lake. Though these macrophytes occupy lesser area as compared to rooted- floating leaf types and submergeds, they are unique in utilizing the available space and light with maximum efficiency and great economy because they are capable of regulating spatial patterns, particularly in leaf density and leaf inclinations, to distribute light evenly between the photosynthetic tissues and optimize light utilization efficiency as the terrestrials do (Wetzel, 2001). Besides, emergent macrophytes contain structural tissue whose cell walls are heavily thickened with cellulose, which is relatively refractory to rapid microbial decomposition (Atkinson and Cairns, 2001). The large underground stems and perennial roots and rhizomes of emergent macrophytes give them an edge over the other life-form classes in biomass accumulation (Wetzel, 1983, 2001). On the other hand, the other life-form classes, especially free-floating type and submergeds, on account of the strong drag and pull force generated by the moving water, cannot maintain their well defined three dimensional structures, do not trap much of the solar radiations, thus depicting lower rates of primary productivity (Westlake, 1965).

During the present investigation, emergent species of *Typha angustata* and *Phragmites australis* dominated the production in Wular lake whereas free-floating species were least productive with submerged and rooted floating-leaf types as intermediates. Dominance of emergents in terms of productivity has also been reported by Westlake (1969), Dykyjova (1971), Wetzel (1975, 2001), Kumar (2009), Rather (2009), Atkinson *et al*. (2010) and Khan and Shah (2010). The annual primary production of emergent stands is sometimes the highest of all the populations in the temperate zone and it is generally accepted that helophyte coenoses are the most productive of plant communities (Westlake, 1963, 1965; Wetzel, 2001). Net primary productivity for temperate areas ranges from 900 to 5500 gdwt. m^{-2} yr^{-1} (Mitsh and Gosselink, 1986). Shoot density also influences the primary production of aquatic macrophytes to a greater extent. The higher production of emergent macrophytes is directly related to highest shoot density. It is due to the fact that with the increasing water depth the shoot diversity decreases causing a decrease in productivity and most emergents also suffer significantly decreased growth in response to a large, sudden depth increase (Wetzel, 1983, 2001; Tamire and Mengistou, 2012). In accordance with the above mentioned attributes it is predictable that emergent macrophytes in Wular lake have greater shoot types for their greater productivity over others.

On the other hand, the macrophytes with floating leaves occupied an intermediate position between submergeds and emergents, being dependent on water for support and yet having some access to both gaseous as well as aqueous carbon dioxide sources (Kaul *et al*., 1978; Camargo and Florentino, 2000). The rooted floating-leaf type species such as *Nymphoides peltata* characterized by a long flowering period are often found to accumulate more biomass compared to the submergeds (Marion and Paillisson, 2003). The higher productivity of rooted floating leaf-type macrophytes compared to submergeds could also be attributed to the increased water depth of Wular lake that results in greater establishment of rooted floating-leaf type species (Kaul *et al*., 1978; Pandit, 2008).In addition to these factors, the biomass production dynamics is significantly affected by biotic factors such as the rate of colonization by epiphytic organisms, which is especially conspicuous in the case of species with large leaf area (Hopson and Zimba, 1993). The productivity values recorded in the present study for various rooted floating-leaf type species are somewhat similar to the values reported by Kaul *et al*. (1978), Brock *et al*. (1983) and Ravinder (2009). In Wular lake *Trapa natans*, *Nymphoides peltatum* and *Nymphaea mexicana* were, however, the main constituent species of rooted floating-leaf zone and contributed a great deal towards annual production.

The production of submerged macrophytes is mainly determined by light penetration contrary to the rooted floating-leaf types which not only get direct radiation but also hinder the rays to reach deep to the submergeds (Chambers and Kalff, 1985; Pandit, 1992; Hrivnak *et al*., 2006).Therefore, transparency has a direct bearing on the production of submergeds. Submerged macrophytes usually extend into the depths in order to maximize their absorption of the light and CO_2 needed for photosynthesis (Barko and Smart, 1981; Maberly and Madsen, 2002).Light stress results in plants reallocating more resources towards shoots and leaves than to tubers (Madsen, 1991). Further, Pandit (2008) reported that in Wular lake, the growth of submerged vegetation is greatly restricted due to heavy turbidity brought about by the suspended silt, as is true for other wetlands of Kashmir also. Thus, in the present study the underwater light seems to play a major role in determining the production of submerged macrophytes.

In the present study, the free-floating macrophytes were found to be least productive. Which may be due to the fact that open water areas of the Wular lake are exposed more to wind and wave action which are colonized mostly by rooted floating-leaf type and free-floating class of macrophytes and not by the dominant emergents. The findings of the present study corroborates with those of other studies (Kaul, 1970; Hudon *et al*., 2000; Rather, 2009; Kumar, 2009). But, the findings are in partial contrast to the findings of Thomaz and Bini (1998) who advocated that the open water areas lakes are rarely colonized by free-floating and emergent classes.

Temperature can influence plant performance, especially photosynthetic rates and is considered to be the single environmental variable profoundly influencing the standing crop of aquatic plants over the whole range of their occurrence (Gorham, 1974; Pilon and Santamaria, 2002).Temperature may also have an effect on propagule germination and shoot elongation in many aquatic plants (Madsen and Adams, 1988). Moreover, during periods of cooler temperatures plant production is generally less due to the lower photosynthetic rates (Scheffer, 1998). Numerous authors have emphasized that there is a direct relationship between the primary production dynamics of macrophytes and temperature (Hopson and Zimba, 1993; Vis *et al*., 2007; Shilla and Dativa, 2008).In the present study it also seems that temperature have profound influence on the standing crop values and biomass of macrophytes. The biomass peak for most of the macrophytes corresponds to the period of maximum atmospheric temperature. Further, the production values of macrophytes during the year 2012 were found to be lower as compared to the year 2011 which might be due to: (i) comparatively lower temperatures during the early growth and sprouting season of macrophytes, causing a delay in the flowering season of these plants, and (ii) early decomposition of macrophytes caused by rapid rise in temperature during the peak growth season. In the latter case it is likely that the higher temperature increased microbial activity and, therefore, oxygen consumption in the water, consequently affecting the pH and the rate of ion and nutrient liberation into the aquatic ecosystem and thus causing early decomposition of macrophytes (Carvalho *et al*., 2005). Esteves (1988) also advocated that in temperate regions, the seasonal variation of the biomass presented by aquatic macrophytes occurs mainly because of the seasonal variation of the temperature. The results of the present study corroborate with those of other studies (Esteves, 1998; Bini, 2001; Carvalho *et al*., 2005; Kumar, 2009).

6.2.7. Biochemical composition of macrophytes

In the present study, macrophytes of Wular lake, besides showing considerable temporal variations, were observed to exhibit interspecies and interclass variations in their biochemical compositions viz. total lipids, carbohydrate and protein contents. In most cases, proteins were found to make up the greatest proportions as compared to carbohydrates and lipids. However, there were only a few exceptions where carbohydrates made significant proportions. In all likelihood, lipids contributed relatively smallest proportions in all macrophytes.

From the present study, it is evident that the various biochemical constituents viz. total lipids, carbohydrate and protein content of macrophytes of Wular lake exhibited considerable seasonal variations. Numerous authors have emphasized that these variations may be due to the fact that the various biochemical constituents of macrophytes are primarily influenced by the environmental factors such as temperature, light available for photosynthesis, nutrient concentration in the ambient waters as well as the development stage of the macrophytes (Haroon *et al*., 2000; Kalesh, 2003; Ortiz *et al*., 2006).

6.2.7.1. Protein content

During the present investigation, total protein content of macrophytes varied from 3.2 to 23.8 % on fresh weight basis which is comparable with those of Pandit and Qadri, 1986 (6.87 to 21.8 %), Banerjee and Matai, 1990 (8.7 to 25.8 %) and Olele, 2012 (15.8 to 21.65 %) but lower than those reported by Boyd and Blackburn, 1970 (9.3 to 43.3 %) and Dewanji *et al*., 1997 (32.9 to 62.7 %). Moreover, the comparative analysis of data showed significant interclass and interspecies variations in the protein content of macrophytes which may be attributed to the differential nutrient uptake potential of macrophytes especially that of nitrogen which in turn is influenced by various environmental and biological factors such as the type of tissue, the age of the plant part, its nutrient past history, interplant variability etc. (Lobban and Harrison, 1997; Kalesh, 2003). In the present study, it was observed that free floating-type macrophytes such as *Azolla* sp., *Lemna minor* and *Salvinia natans* contain more amounts of protein than other life-form classes. This is in consistency with the findings of other studies (NAS, 1984; Meyers, 1977; Edwards, 1980; Pandit, 1984; Pandit and Qadri, 1986; Banerjee and Matai, 1990; Dewanji *et al*., 1997).

In general, on temporal scale, the maximum concentrations of proteins in various plant tissues were recorded during autumn, followed by summer and spring and decreasing to the minimum in winter. The higher concentration of proteins during autumn may be attributed to the fact that the accumulation and subsequent conversion of nitrogen into protein building in the mature tissues during the metabolic process is at its maximum during the peak growth of macrophytes (Sahyun, 2008; Ahmad *et al*., 2011). This observation is further confirmed by the significant negative correlation of protein content of macrophytes with ammonical-nitrogen ($P< 0.05$, $r= -0.855$). The dependence of protein level in aquatic plants on available nitrogen was also pointed out by Lapointe (1981), Dawes (1998) and Banerjee *et al*. (2009). Edwards (1980) advocated that the crude protein content increases as the nutrient content of the water in which the plant is grown increases.

6.2.7.2. Carbohydrate content

Data revealed that the concentration of carbohydrates in various macrophytes of Wular lake varied in the range 1.6 - 27.0 % on fresh weight basis. An earlier study on the biochemical composition of aquatic plants of Dal lake in Kashmir Himalaya revealed carbohydrates including fibre making 46.41 – 85.74 % on dry weight basis (Pandit and Qadri, 1986). However, the carbohydrate content registered during the present study remained within the reported values of Mishra and Jha (1996), Prasannakumari *et al*. (2000), Mini (2003) and Arathy (2004) in various aquatic and riparian vegetation. Comparatively higher values than those reported in the present study were recorded by FAO (1993) and Prasannakumari and Gangadevi (2012) in different aquatic plants. Significant differences were observed in the carbohydrate content of macrophytes with a distinct pattern between the seasons. This may be due to the variation in the nature of synthetic efficiency as well as the environmental factors such as temperature, nutrients etc. which influence carbohydrate synthesis (Kalesh, 2003; Prasannakumari and Gangadevi, 2012). It is also believed that the vegetative growth as well as development also influence the fluctuations in the carbohydrate concentration in the macrophytes. In general, maximum seasonal mean values of carbohydrate in most of the macrophytic species were recorded during summer whereas carbohydrate content attained least value during winter season. The observed increase in the carbohydrate content of macrophytes during summer may be due to an increase in the growth rate of macrophytes resulting from the favourable environmental conditions (Jayasankar, 1999; Banerjee *et al*., 2009). The positive impact of temperature on the carbohydrate metabolism of aquatic plants has been supported by various authors (Rosenberg and Ramus, 1982; Rotem *et al*., 1986; Banerjee *et al*., 2009). This observation is further confirmed by the significant positive correlation of carbohydrate content of macrophytes with temperature ($P< 0.01$, $r= 0.853$). Thus, the active period of carbohydrate synthesis in macrophytes of Wular lake coincides with the increase in water temperature. On the other hand, the decrease in carbohydrate content during winter suggests that stored photosynthetic products are used for cold season maintenance (Terrados and Ros, 1992; Robledo and Freile-Pelegrin, 2005).

A perusal of data on the carbohydrate content of macrophytes in Wular lake revealed appreciable variations in the carbohydrate content among different groups of macrophytes which may be due to variation in the accumulation efficiency in terms of their phenology which is further corroborated by the studies of Mini (2003), Arathy (2004) and Prasannakumari and Gangadevi (2012) while working on aquatic and riparian vegetation. Among all the four life-form classes, the rooted floating-leaf type macrophytes registered the highest concentration of carbohydrates as evinced by *Potamogeton natans* (26.0 %), *Marsilea quadrifolia* (21.9 %), *Nymphaea mexicana* (20.4 %) and *Hydrocharis dubia* (17.8 %). The results of the present study also corroborate with those of other authors (Wikfort *et al*., 1992).

6.2.7.3. Lipid content

The lipid content of macrophytes in the present study varied in the range of 0.4-7.6 on % fresh weight basis. These values are in tune with those reported in literature for some aquatic macrophytes (Banerjee and Matai, 1990). However, they are lower than those reported by Rozentsvet *et al*. (1995). This variability in the chemical composition of macrophytes is believed to depend upon the differences in the species, season and location (Annon, 1984). In the present study also significant differences were observed in the total lipid content of macrophytes with a distinct pattern between the seasons. Fluctuations noticed in the concentration of lipid in the different genera may be due to the changes in the environmental factors that might have influenced the vegetative growth and development including availability of nutrients, allochthonous materials as well as variation in the efficiency of lipid accumulation among the plants (Prasannakumari and Gangadevi, 2012; Yasser and Samir, 2014).

A perusal of data on the lipid content of macrophytes in Wular lake revealed that, like proteins, the maximum concentration of total lipids in various plant tissues were recorded during autumn, followed by summer and spring and decreasing to the minimum in winter. The higher concentration of total lipids during autumn may be because of the reduction in the levels of carbohydrates (Haroon *et al*., 2000; Nelson *et al*., 2002). Under this condition, more photosynthetic intermediates can be utilized in the synthesis of lipid molecule. During autumn, most of the macrophytes in Wular lake complete their life cycle and start drying up. As lipids are the end products of metabolic reactions in mature and aged tissues, they are naturally higher at this stage (Akingbade *et al*., 2001; Sahyun, 2008; Ahmad *et al*., 2011).

From the study it is clear that the concentration of lipids depicted highly significant variations among different groups of macrophytes. The concentration of lipids was generally higher in emergent macrophytes such as *Myriophyllum verticillatum*, *Phragmites australis* and *Typha angustata* which gains further support from the studies of Banerjee and Matai (1990) and Rozentsvet *et al*. (1995) who also reported higher lipid content in emergent aquatic plants. It is clear from the data that during the year 2011 the concentration of total lipids depicted greater variations in different periods, though significant increases for *Ceratophyllum demersum* and *Potamogeton crispus* (about 4 times each) were evinced in the early autumn season experiencing frequent rains. These differences indicate an acceleration of productive metabolic activity during this period and/or higher consumption of this organic compound during the dry period (Esteves and Suzuki, 2010). The significant increases in the lipid content (about 5 times) have also been reported for C*eratophyllum demersum* in the rainy season (Esteves and Suzuki, 2010). The tendency to accumulate higher concentration of total lipids in the tissues of submerged macrophytes in this period suggests that this period presents better conditions to the development of these macrophytes.

6.2.7.4. Chlorophyll content

Macrophytes and their parts are vertically stratified in different positions in the water body. The productive structures i.e. parts rich in chlorophyll in different plants are concentrated at different levels. The chlorophyll content per unit weight of plant parts is higher in leaf lamina than other green parts. The analysis of the data revealed distinct seasonal variations in the chlorophyll content of macrophytes during the two years of study period. In the present work, maximum pigment content of the macrophytes was obtained during summer season; the period characterized by optimum nutrient load and water temperature. Chlorophyll- a and chlorophyll-b contents were significantly lower in autumn, Total chlorophyll was the only exception. This trend may be attributed to the positive role of water temperature in promoting greater chlorophyll concentration and photosynthesis (Barko *et al*., 1982, 1986; Chambers,1982; Nekrasova *et al*., 2003) .The summer fall in the amounts of nutrients (ammonia, total phosphorus and dissolved silica) is attributed to the greater photosynthetic activity of macrophytes especially submergeds leaving very small quantities of such nutrients in water (Rich *et al*., 1971; Xie, *et al.*, 2004; Shilla *et al*., 2006).This is confirmed from the significant positive correlations between Chlorophyll-a, Chlorophyll -b and total chlorophyll and water temperature and negative correlations with nutrients (ammonia, total phosphorus and dissolved silica). Lower concentration of chlorophyll-a obtained in autumn may be attributed to the fact that the values of chlorophyll-a decreases when the light transmission increases (Atici and Alas, 2012). The strong negative correlation between transparency and chlorophyll-a in the submerged macrophytes also substantiate the fact that increased transparency decreases chlorophyll-a content by reducing photosynthetic input. A relative Chlorophyll-b enrichment in spring in submerged species suggests that these species exhibit a sun shade adaptation similar to higher plants and green algae (Robledo and Freile-Pelegrin, 2005). It has been advocated by Yokohama (1983) and Robledo and Freile-Pelegrin (2005) that under low light transmission the concentration of Chlorophyll-b is favourable for growth based on the fact that Chlorophyll-b absorbs shortwave light more efficiently than Chlorophyll-a. The lower quantity of chlorophyll pigment in macrophytes in other seasons reflects their adaptation to decreased water temperature (Dembitsky, 1996). The results of the present study corroborate with those of other studies (Kizevetter, 1981; Goncharova, 2004). Thus, the active period of pigment synthesis in macrophytes coincides with the increase in water temperature and decrease in nutrient load.

The macrophytes, as a whole, were characterized by low chlorophyll pigment content (mg/g on fresh weight basis) in comparison to the terrestrial plants

(Popova *et al*., 1984). The comparative analysis of data showed appreciable variations in the pigment content among different groups of macrophytes with different degree of leaf submergence (emergent, rooted floating, free floating and submerged). In emergent and rooted floating-leaf type macrophytes, the low chlorophyll pigment content might have been due to their existence at high irradiance (Ronzhina *et al*., 2004). In rooted floating-leaf type macrophytes the leaves are perpendicular to incident radiation. As a consequence of which they contain lower pigment content compared to submerged aquatic plants. In submerged macrophytes, the leaves are almost vertically oriented (Ronzhina *et al*., 2004). As a result of which they do not shade each other, enabling the plants to accumulate higher pigment content in them. Moreover, in the submerged leaves, in contrast to the emergent and floating ones, an increase in the photosynthetic rate of a single chloroplast as well as their existence in water under low light conditions results in an increase in the pigment content in their chloroplast. Further, it is believed that submerged aquatic plants are characterised by specific features of the pigment complex, ensuring plant adaptation to light conditions in water stratum (Ronzhina *et al*., 2004). Our results further gain support from the findings of Ronzhina *et al*. (2004) and Nikolic *et al*. (2009) who also reported higher pigment content in submerged aquatic plants. The free floating macrophytes represented in our study by *Azolla* sp., *Salvinia natans* and *Lemna minor* were characterised by slightly lower pigment levels. This might have been due to their existence at high irradiance and presence of homogenous type of mesophyll structure in their leaves (Ronzhina *et al*., 2004). Barko *et al*. (1986) advocated that within individual plants, total chlorophyll can vary significantly in response to light, with greatest chlorophyll concentration at the basal (darkest) portion of the plant. The normal life activity is ensured by low pigment content in plants adapted to high radiation. This is because lower pigment content prevents the danger of cell damage caused due to photooxidation (Popova *et al*., 1984).

Temperature is considered to be the single environmental variable profoundly influencing the photosynthetic rates and standing crop of aquatic plants over the whole range of their occurrence (Gorham, 1974; Pilon and Santamaria, 2002).Temperature may also have an effect on propagule germination and shoot elongation in many aquatic plants (Madsen and Adams, 1988). Moreover, during periods of cooler temperatures plant production is generally less due to the lower photosynthetic rates (Scheffer, 1998). The positive impact of temperature on the photosynthetic rates of macrophytes has been supported by various authors (Hopson and Zimba, 1993; Vis *et al*., 2007; Shilla and Dativa, 2008). In the present study it also seems that temperature have profound influence on the photosynthetic pathway of macrophytes. The peak chlorophyll concentration for most of the macrophytes corresponds to the period of maximum atmospheric temperature. Further, the chlorophyll values of macrophytes during the year 2012 were found to be lower as compared to the year 2011 which might be due to: (i) comparatively lower temperatures during the early growth and sprouting season of macrophytes, causing a delay in the flowering season of these plants, and (ii) early decomposition of macrophytes caused by rapid rise in temperature during the peak growth season. In the latter case it is likely that the higher temperature increased microbial activity and, therefore, oxygen consumption in the water, consequently affecting the pH and the rate of ion and nutrient liberation into the aquatic ecosystem and thus causing early decomposition of macrophytes (Carvalho *et al*., 2005). The results of the present study corroborate with those of other studies (Barko *et al*., 1982, 1986; Chambers, 1982; Nekrasova *et al*., 2003).

7.1 Summary

Wetlands are often described as "*nature's kidneys*" for their ability to filter waste and pollutants, as well as "*nature's supermarket*" for their high productivity and ability to act as a source of food to many organisms. The ecological significant services provided by the wetlands include climate regulation, turnover of organic matter, biomass accumulation, as well as substrate for phytophilous organisms and a source of food for aquatic as well as terrestrial organisms. These ecological services are often considered in anthropocentric terms, because of their ability to ameliorate floods, stabilize shoreline, prevent erosion, as well as removal of contaminants from the water. Wetlands also play significant role in the biogeochemical cycling of nutrients by acting as nutrient source, as well as sink of nutrients.

Macrophytes, as a component of shallow lakes and wetlands, have diverse roles to play in the functioning of these ecosystems. The macrophytes serve as a base of aquatic food-chains, besides they also actively contribute to the promotion and maintenance of food webs and services in freshwater ecosystems especially the macrophyte dominated ones. Aquatic macrophytes also act as important bioindicators of environmental conditions and long-term ecological changes in water quality. The function of macrophytes in these ecosystems is related to their structural attributes like species composition, distribution, abundance and diversity which in turn depend on various environmental factors. Because of their high rate of biomass production, macrophytes act as an important primary food resource for aquatic organisms. The complex tropic dynamics and primary productivity of wetlands is greatly influenced by the higher diversity and biomass of macrophytes. For the assessment of nutritional value and evaluation of food potential of aquatic plants, the knowledge of their ecological significance and chemical composition is essential. It is well known that seasonal variations in certain abiotic factors such as light, temperature, sediment composition and water chemistry can influence photosynthetic rates and biochemical composition of macrophytes, thus necessitating the determination of their biochemical composition.

Among the fresh water bodies of the valley Wular lake enjoys special status for being the largest freshwater body within Indian sub-continent and a designated Ramsar Site (a Wetland of International Importance). It is spread over an area of 48-54 km^2, being situated at a surface elevation of 1580 m (a.m.s.l) and positioned between geographical coordinates of 34^o 16′ 24.67″ N latitude and 74^o 33′ 41.42″ longitude. It plays a major role in the hydrological regime of the Kashmir valley by acting as a huge absorption basin for floodwaters of Jhelum floodplain. Wular lake and its associated wetlands act as an important habitat for migratory water birds within Central Asian Flyway and supports rich biodiversity. It also supports a large population living along its fringes owing to its huge fishery potential.

Since the wetland is dominated by macrophytes, considerable efforts have gone into the field studies to correlate the spatial distribution pattern of aquatic plants with major physico-chemical environment of their habitat. There are only few reports regarding the distribution patterns and community characteristics of macrophytes including the studies pertaining to physiognomy of wetland vegetation in Kashmir. It is only very recently some work, yet to be published, has been conducted on the production and nutrient dynamics of macrophytes in Hokersar wetland which as such has remained untouched as far as the distribution patterns and biochemical composition of macrophytes is concerned (Kumar, 2009). In this backdrop the present study on "Distribution, production and biochemical status of dominant macrophytes in Wular lake, a Ramsar Site in Kashmir Himalaya" has been undertaken to work out a generalized relation between water and macro- vegetation distribution, production and biochemical composition. This study can latter on in future help in determining the pattern in which distribution, production and biochemical composition of macrophytes change as the water quality deteriorates.

Water depth in the Wular lake showed slight significant spatial as well as temporal variations. The maximum depth of water was recorded during spring as against the minimum being recorded during winter. The secchi disc transparency in the Wular waters revealed slight insignificant spatial as well as temporal variations. Wular waters, having the permanence of water all through the year remained, least turbid except during spring and early summer season when least transparency on account of increased silt laden inflows was noticed. Water temperature in Wular lake followed the general thermal cycle of the region with peak temperatures being recorded during summer and the lowest temperature registered in winter.

Total dissolved solids followed the same trend as that of specific conductivity, witnessing its peak amount during winter and then following a decline to reach the lowest value during summer where after an increasing trend was evinced towards the autumn. The overall absolute values for total dissolved solids fluctuated between a low of 64 mg/L (August) and a high of 320 mg/L (January).Water conductivity, reflecting total ionic concentration of salts, witnessed a seasonal trend and depicted comparatively higher values. Maximum specific conductivity (508.7±17.0 μScm^{-1} at 25 ^{0}C) was recorded during winter as against the minimum (115±10.0 μScm^{-1} at 25 ^{0}C), being recorded during summer.

Dissolved free carbon dioxide in Wular waters depicted an inverse trend to that of pH registering its higher concentration during winter and lowest during summer. The maximum and minimum concentrations of free carbon dioxide in water were 28 mg/L (December) and 5 mg/L (August) respectively. Dissolved oxygen, showing inverse relationship with temperature, witnessed a summer fall recording its maximum values in winter. The maximum amounts of dissolved oxygen (11 mg/L) were registered in November while as the minimum amounts (6.4 mg/L) were recorded during July, August and September respectively.

The alkaline waters of Wular lake registered the pH ranging between a low of 7.1 (December) and a high of 8.5 (June). Chloride content of water did not depict noticeable seasonal trend. However, the absolute values ranged between 6.0 mg/L (December and February) and 28.0 mg/L (April).

Total hardness recorded very noticeable temporal variations with greater amounts being recorded during winters as against the least being recorded during summers. The highest amount of total hardness (290 mg/L) was recorded in February as against the lowest of 55 mg/L being recorded during August and September. Calcium and magnesium concentrations in the lake waters revealed comparatively harder waters during winter and spring. The seasonal values of calcium ranged from a low of 34.6±4.9 mg/L (summer) to a high of 106.4±1.2 mg/L (winter) and that of magnesium content from 5.9±1.4 mg/L (summer) to 43.1±1.9 mg/L (winter). The alkalinity of Wular waters varied greatly with regard to time but experienced least spatial variations. The alkalinity of water was solely due to bicarbonates as the carbonates, were not recorded at any of the sites throughout the study. The highest value of bicarbonate alkalinity (245 mg/L) was recorded during January as against the lowest value of 55 mg/L, being recorded during August.

Greater amounts of dissolved silica were recorded during spring, followed by summer and autumn and decreasing to the lowest during the winter. The maximum amounts of silicate (18.4 mg/L) were noticed in April while as the minimum amounts (3.8 mg/L) were recorded during December. The amounts of orthophosphate-phosphorus in Wular waters depicted a peak concentration in winter, moderate in autumn and further experienced a fall in the concentration during summer. The minimum and maximum concentrations of orthophosphate-phosphorus in water were 9 µg/L (June) and 118 µg/L (January) respectively. Same was true for total phosphorus, depicting peak values in winter. The ranges of total phosphorus over the whole period of investigation were much wider and thus fluctuated from the lowest value (60 µg/L) during September 2011 to the highest value (393 µg/L) during February.

Ammonical-nitrogen and nitrate-nitrogen in water depicted the same trend as that of phosphorus registering their higher concentrations during winters and lowest during summers. The maximum and minimum seasonal amounts of 290.0±20.0 µg/L (winter) and 48.5±9.2 µg/L (summer) were obtained for ammonical-nitrogen and for nitrate-nitrogen such values were 1416.7±336.1 µg/L (winter) and 178.7±22.7 µg/L (summer) respectively.

Lake waters recorded the maximum amounts of iron in winter, moderate amounts in autumn and spring and the lowest amounts in summer. The overall absolute values for iron ranged from a low of 189 µg/L (August) to a high of 413 µg/L (February).

Wular lake, harbouring a complex physiognomy of macrophytes, was represented by 55 species belonging to 38 genera that are spread over 27 families. Greater variations in macrophytic distribution with regard to time and space were registered in the wetland. The first half of the growing season recorded the significant fluctuations but the later half did not reflect much change in the species make up. During the entire growing period the highest number of 24 species was recorded at Site I during summer, 2012. Spatially the highest number of species (35) was recorded at Site I with 25 species of emergents, 06 rooted floating- leaf type, 01 submergeds and 03 free floating type as against the lowest number of 18 species being registered at Site IV. However, among the various life-form classes the greater fluctuations were witnessed in the number of emergents. The macrophytic community of Wular lake was represented by all the four life form-classes belonging to emergents (42.6 %), rooted floating leaf type (24.7 %), submerged (15.4 %) and free floating (17.3 %) and each life-form class embraced a distinct assemblage of plant species. However, the rooted floating-leaf type macrophytes cover significant area of the lake, while as submergeds cover least area of the wetland. *Typha angustata* and *Phragmites australis*, the chief occupants of littoral zone, extend all along the eastern, north-western and parts of south-eastern side of the lake upto a depth of 2.0 m accompanied by widespread stands of rooted floating-leaf type species (*Nymphoides peltatum, Potamogetan natans* and *Trapa natans*). The maximum area under emergents was seent at Site I where large aggregations of these plant species were found distributed throughout. Rooted floating-leaf type macrophytes formed widespread dense beds in Wular lake. *Trapa natans* was the chief constituent species among these macrophytes and formed large beds at sites V, VII and III. The free-floating species being dispersed were confined mostly towards littorals and side water channels. Amongst, the free floating species, *Azolla* sp., *Salvinia natans*, and *Lemna minor* formed thick dense mats over extensive areas in the littorals at sites II, V and VI. Submerged macrophytes, due to their high aggressive capacity, covered the maximum area all along the western side of the Wular lake. This life-form class dominated by *Ceratophyllum demersum*, *Potamogeton crispus* and *Potamogeton lucens* association formed dense meadows in the open water areas at sites VII, VIII and IV. Certain species of macrophytes showed restricted distribution to a particular site. These were *Scirpus lacustris* (Site I), *Nelumbo nucifera* (Site V), *Rununculus lingua* (Site VI) and *Batrachium trichophyllum* (Site VIII).

Various community characteristics again depicted noticeable variations in Wular lake. The Sorenson’s similarity index based on species composition indicate that Site I had high degree of similarity with Site VI (81.3 %) which may be due to their littoral nature and similarity in their water characteristics as was observed during the present study. The study of IVI values revealed that *Lemna-Salvinia* complex dominated all the sites and was co-dominant at Site II indicating its absolute dominance over other species in the Wular lake. The Shannon's Diversity Index showed high diversity of macrophytes at Site VII (3.06) and lowest at Site IX (2.38). On the other hand, Simpson's diversity index revealed its maximum value of 0.989 at Site V as against the minimum value of 0.939 being recorded at Site I on the basis of occurrence of macrophytes. Bray-Curtis cluster analysis revealed that the sites III, V and IX are very much similar in terms of their macrophytic composition.

Production estimates in Wular lake were undertaken for a total of 16 species of macrophytes comprising 05 emergents, 06 rooted floating- leaf types, 03 free floating type and 02 submergeds. Among the emergents *Typha angustata* registered the maximum primary productivity (1,800 g dwt. m^{-2}), followed by *Phragmites australis* (1,450 g dwt. m^{-2}). Among the rooted floating-leaf types, *Trapa natans* with a production value of 450 g dwt. m^{-2} was the most productive species. *Salvinia natans* depicted the maximum productivity (33 g dwt. m^{-2}) among the free-floating class. Among submergeds, *Ceratophyllum demersum* registered the highest productivity with a value of 170 g dwt. m^{-2} against the lowest value of 83 g dwt. m^{-2}, being recorded for *Potamogetan crispus*. On the other hand, net primary productivity fluctuated between a minimum of 0.09 g dwt. m^{-2} day^{-1} for *Lemna minor* and a maximum of 6.94 g dwt. m^{-2} day^{-1} for *Typha angustata*. *Phragmites australis* was the second most productive species with net primary productivity of 5.59 g dwt. m^{-2} day^{-1}. In general, among the dominant species of macrophytes estimated for the primary production in Wular lake, *Typha angustata* depicted the maximum productivity, followed by *Phragmites australis* and *Trapa natans* in a decreasing order. The lowest production was recorded for free floating *Lemna minor*. Emergents, contributing a maximum of about 69 % to the overall primary productivity, were followed by rooted floating-leaf type class (24.5 %), submergeds (5 %) and free-floating type (1.5 %).

In all, sixteen macrophytic species, including 05 emergent, 06 rooted floating-leaf type species, 03 free-floating and 02 submerged species, were analysed, on seasonal basis, for various biochemical constituents viz. total lipids, carbohydrate, protein and chlorophyll contents. Different macrophytic species besides showing considerable temporal variations were observed to exhibit interspecies and interclass variations in their biochemical compositions. Total lipids (on % fresh wt. basis) depicted the maximum concentrations in various plant tissues during autumn, followed by summer and spring and decreasing to the minimum in winter. For emergents, *Myriophyllum verticillatum* registered the maximum concentration of total lipids (4.8±2.6 %), followed by *Phragmites australis* (4.3±2.5 %) and *Typha angustata* (3.9±2.3 %). However, among the rooted floating-leaf type species, the maximum concentration of total lipids (4.5±2.2 %) was recorded for *Trapa natans*, followed by *Marsilea quadrifolia* (3.3±1.3 %). Among free-floating species, the maximum concentration of total lipids (3.4±1.9 %) was noted for *Azolla* sp. as against the minimum of 2.8±1.4 %, being recorded for *Salvinia natans*. *Potamogetan crispus* depicted the maximum concentration of total lipids (3.5±2.9 %) among the submergeds. The concentration of total lipids depicted greater variations in different periods, though significant increases for *Ceratophyllum demersum* and *Potamogeton crispus* (about 4 times each) were evinced in the early autumn season.

Maximum concentrations of carbohydrates in various plant tissues were recorded during summer, followed by spring and autumn and decreasing to the minimum in winter. Among all the four life-form classes, the rooted floating-leaf type macrophytes registered the highest concentration of carbohydrates as evinced by *Marsilea quadrifolia* (14.9±6.3 %), *Nymphaea mexicana* (14.7±5.4 %), *Potamogeton natans* (14.0±8.8 %) and *Hydrocharis dubia* (10.8±5.6 %). The submergeds registered the lowest concentration of carbohydrates with *Potamogeton crispus* recording a highest of 6.4±2.6 %) as against the lowest of 3.6±2.9 %), being recorded for *Ceratophyllum demersum*.

Like lipids, the maximum concentration of proteins in various plant tissues were recorded during autumn, followed by summer and spring and decreasing to the minimum in winter. The free-floating species registered the highest concentrations of proteins with *Azolla* sp. recording a highest of 17.2±6.2 % as against the lowest of 9.1±2.7 %, being recorded for *Salvinia natans*. On the other hand, emergents recorded the lowest concentration of proteins as evinced by *Phragmites australis* (6.4±4.0 %), *Polygonum amphibium* (6.0±4.0 %), *Polygonum hydropiper* (5.3±2.8 %) and *Myriophyllum verticillatum* (5.1±1.8 %) in a decreasing order.

The maximum pigment content in different species of macrophytes was recorded during the period of active growth in summer. The autumn and spring season registered almost equal concentration of Chlorophyll-a and Chlorophyll-b and the values peaked during summer. However, relative content of Total Chlorophyll in the macrophytes was notably lower in spring season than in autumn. The concentration of

Chlorophyll-a in different species of macrophytes fluctuated between a minimum of 0.8 mg/g for *Azolla* sp. and a maximum of 4.3 mg/g for *Ceratophyllum demersum*. The Chlorophyll-b content recorded its highest concentration in *Ceratophyllum demersum* (2.5 mg/g), followed closely by *Potamogeton crispus* (2.2 mg/g) The lowest Chlorophyll-b values were obtained in *Azolla* sp. (0.1 mg/g). Total Chlorophyll content recorded its highest concentration in *Polygonum amphibium* (5.0 mg/g), followed by *Nymphaea mexicana* having a value of 4.9 mg/g and decreasing to a lowest of 0.4 mg/g in *Azolla* sp. In general, among the different life-form classes of macrophytes, submergeds accumulated greater pigment content.

7.2 Conclusions and Suggestions

On the basis of present ecological study carried out on the Wular lake the following facts were revealed which gave rise to a number of conclusions:

- The data on water chemistry clearly revealed that there were significant spatial as well as temporal variations in most of the parameters while as few parameters fluctuated between the narrow ranges.
- The alkaline and hard waters of the lake are nutrient rich.
- The dominance of calcium over magnesium in the lake is related with the calcium rich lime rocks in the catchment.
- The relatively high concentration of NH_4-N and NO_3-N of the lake is related to organic loading and high inputs of autochthonous organic matter from the macrophytic vegetation.
- The average concentration of both total phosphorus and orthophosphate phosphorus, remained generally high indicating the slightly higher trophic of the lake.
- The wetland harbours all the four life-form classes viz. emergents, rooted floating-leaf type, free floating and submergeds growing intermixed at places, giving it a physiognomy of the wetland.
- During the first half of the growing season, emergents and rooted floating-leaf type macrophytes dominated and, thereafter the dominance was shifted to the free-floating and submergeds.
- The emergents colonize the peripheral areas, landmasses within the open waters and shallower parts of the wetland, and there is no perfect zonation of vegetation as evinced in a typical lake.
- The open water areas are mainly colonized by rooted floating-leaf type, free-floating type and submergeds.
- The profuse and intermixed growth of various life-form classes add up large quantities of organic matter to the wetland.
- The diversity indices point towards the complex physiognomy of the macrophytes in Wular lake with higher diversity and richness of species.
- The higher species diversity and species richness in the wetland is reflected by its habitat heterogeneity- as larger lakes encompass more microhabitats more species are able to find a suitable habitat with increasing area.

- The distribution and diversity of macrophytes reflected significant temporal as well as spatial variability in the wetland.
- The temporal changes in the distribution of macrophytes were mostly associated with water level fluctuations.
- Changes during the vegetation period were strongly related to water temperature, depth, transparency and nutrient concentration.
- The availability of light and depth appears to be the most important factors in determining the macrophyte distribution (with depth and season), there by influencing productivity as well as species composition of submerged and emergent macrophytes. However, it is very difficult to assess the impact of various physico-chemical variables on overall distribution patterns of aquatic macrophytes. Therefore, future research should focus on the influence of potential environmental variables (land use patterns, climatic change) leading to change in the community structure and productivity of macrophytes.
- Emphasis should be given to the impact of eutrophication on distribution, diversity and density as well as productivity of macrophytes-making an important component of aquatic ecosystem.
- The net primary productivity values of macrophytes were found to be in the range of 0.10 to 6.94 g dwt. m^{-2} day^{-1} indicating that the lake at present study is approaching eutrophic state.
- It is evident from the study that the different groups of macrophytes showed distinct profile in their biochemical constituents. The concentration of total lipids depicted greater variations in different seasons with significant increases for *Ceratophyllum demersum* and *Potamogeton crispus* (about 4 times each) in the early autumn season. Among all the four life-form classes, the rooted floating-leaf type macrophytes registered the highest concentration of carbohydrates. The concentration of proteins depicted higher values in free-floating species. Whereas, submergeds accumulated greater pigment content.
- Significant correlation values computed among the environmental parameters and biochemical constituents of macrophytes suggest that the abiotic parameters seem to have potential role in biochemical pathways of macrophytes.

- Biochemical composition of the macrophytes points out to the fact that certain macrophytes such as *Azolla* sp., *Hydrocharis dubia*, *Lemna* sp., *Nymphaea mexicana*, *Potamogeton crispus*, *Salvinia natans* and *Trapa natans* were potentially, very rich sources of concentrated protein and lipids with higher levels in autumn and as such these plants can be used as potential food supplements for humans and animals. These plants need special attention as regards their exploitation and conservation.
- On the basis of overall ecological setup based on water and vegetation characteristics it can be inferred that Wular lake is enjoying a racing eutrophication as evinced by slightly higher concentration of most of the nutrients especially nitrogen and phosphorus in water column. The eutrophication of the wetland is also revealed from higher population density, production and biochemical constituents of macrophytes. Thus, the study of macrophytes becomes imperative for the future management of this ecologically important wetland ecosystem, being designated as a Ramsar Site.

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