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# Nutrient Availability Biomass and Productivity of the Wetland

**Sufia Irfan[1] and Aishah AlAtawi[2]**

[1,2]*Biology Department College of Science, Faculty of Science*
*University of Tabuk, Tabuk-71491, Saudia Arabia*
*E-mail: [1]irfan.sufia@gmail.com*

**Abstract—***This paper examines biomass, productivity, and nutrient storage capacity of dominant wetland macrophytes and nutrient concentrations in water and sediment to understand the relation between nutrient availability and their effects on wetland productivity. It is concluded that the wetland macrophytes capacity to process water nutrient within tissues managed by the biomass and seasonal productivity hence regulate the cycling of nutrient without stressing the macrophytes communities present, is considerable. Both nitrogen and phosphorus sources differ on their speciation, concentration, bioavailability and mode and timing of delivery. Nitrogen and phosphorus concentration and flux is a vital source for biological activity in aquatic systems and needs proper management techniques to slow down the impacts associated with urbanization and progressive agriculture.*

**Keywords***: Biomass, Nitrogen, phosphorus, productivity, wetland plants.*

## 1. INTRODUCTION

Wetlands are categorized as one of the most productive ecosystems of the biosphere [1] often denoted as 'Biological hotspots' providing numerous benefits to humankind, aquatic flora, and fauna, habitat for migratory birds and wildlife. Wetlands have sieve mechanism working against the polluted water entering the wetland causing threat to the biodiversity of the ecosystem. Organisms inhabiting the wetland niche represent the complex and dynamic relationships in the form of 'food web,' showing significant variance from one wetland to another wetland. Trophic dynamics exist by between inflow and outflow of energy at each trophic level [2]. In aquatic resources, primary producers (macrophytes and algae) are responsible for energy flow. The littoral zones, occupied by macrophytes represents the most productive biotopes on earth [3] and are the source of an organic pool for an ecosystem. In deep water bodies the role of aquatic macrophytes is conspicuous while in shallow lakes submerged macrophytes zone perform a key role in the trophic dynamics. Plants are the source of stored energy as tissue biomass, which they conserve through the process of photosynthesis. The International Biological Programme (IBP) also showed its consideration of productivity and human welfare. Aquatic macrophytes are the source of organic production for human and domestic animal nutrition. Fresh water systems have a bicyclic phase of primary production being regulated by phytoplankton and macrophytes, but productivity per unit area is more for macrophytes than phytoplankton communities [4]. Some tropical and subtropical springs, coral reefs and tropical coastal waters maintain a constant value for biomass. Leith & Whittaker [5] had worked extensively on the primary productivity of the biosphere. Like biomass production, another important function of plants is to store nutrients in their tissues through uptake from water and soil. Many researchers have investigated studies involving seasonal biomass changes and rate of production by macrophytic communities in different aquatic ecosystems. Some of the famous works are Odum [6]; Schalles and Schure [7], Lenssen-John et al. [8]; Richordson et al. [9]; Hart & Lovorn [10]. The presences of nutrients influence ecosystem functioning and plants life as well. Some of the traditional research on the nutrients storage in emergent vegetation are discussed by Boyd [11]; Barko [12]; and of submerged by DeMarte & Hartmann [13]; [14]; Shardendu & Ambasht [14]; Nicholas and keeny [15]. Economic importance and indicator value of aquatic plants are investigated by Schulz [16]; Rogers & Davis [17]. Nutrients inflow from domestic wastes and industries enrich the aquatic environment. The nutrient assimilative and storage ability of wetlands embedded within agricultural landscapes determines their role as nutrient sinks, but also as potential nutrient sources within the landscapes [18]. Plants can successfully consume these nutrients from polluted waters [19] as a valuable source of protein [20] and energy production [21]. Species composition influences nutrient retention of ecosystems because individual species differ in their tissue nutrient quality [22]. In wetlands, human activities can have profound effects on plant community composition and ultimately ecosystem function. Developing an understanding of how species respond to those activities is essential to predicting the impacts of human activities on both species composition and ecosystem function. Plants need a range of mineral nutrients. Nitrogen, phosphorous and potassium are the essential minerals required for the healthy growth of the macrophytes. But secondary minerals magnesium calcium and sodium also have some important role to play in plant physiology. Insufficient calcium is particularly problematic for individual plants causing calcium deficiency plant is notable for its stunted growth in new leaves and tissues.

Macrophytes are made up of spongy tissues with large pores in their stems and roots, allowing rapid exchange of oxygen between the leaf surface and the roots. Most of the Oxygen-dependent mechanism such as disintegration and decomposition of organic compounds and denitrification occurs when wetland plant roots oxidize the rhizosphere (root zone) [23].

## 2. MATERIAL AND METHODS

### 2.1. Study site

The Indian sub-continent has plenty of freshwater wetland resources occupying river courses and low-lying areas where precipitation exceeds the potential evapotranspiration leaving an accumuulated water surplus. The wetland situated in rural area of north eastern province of India, is part of the indo Gangetic great plain, largest fresh water oxbow lake listed under Ramsar convention as “Kabar” wetland (Fig1). Geographically, wetland is situated between 86° 05' E to 86° 09' E longitude and 25° 30' N to 25° 32' latitude (Fig 1). Kabar wetland is enriched with macrophytic vegetation serves as the good ecological habitat for several endangered migratory and local birds visiting the wetland during winter season, hence, preserving the structure and biological function of wetland ecosystems.

An initial survey was done to collect water samples and dominant wetland plants from three different sampling points to analyse the physichochemical parameters and biomass respectively. Seasonal nutrient concentrations were also analysed in water and in tissues of aquatic plants and sediments. Emergent zone was occupied by *Eleocharis plantaginea*, *Panicum auritum*, *Cynodon dactylon* and *Paspalum scrobiculatum*, *Phragmites australis*, rooted floating zone was occupied by *Nympheae stellata* and *Nelumbo nucifera*, free floating zone had *Eichhornia crassipes*, *Lemna minor* and *Pistia stratiotes* and submerged zone was occupied by *Hydrilla verticillata*, *Ceratophyllum demersum*, *Vallisneria spirallis*, *Potamogeton pectinatus* and *Aponogeton natans*.

Standing crop biomass was measured by harvest method [6] and harvesting the plants on monthly basis but calculated as summer, rainy and winter and data are presented in mg/g. The primary production was calculated as positive changes between the two respective months.

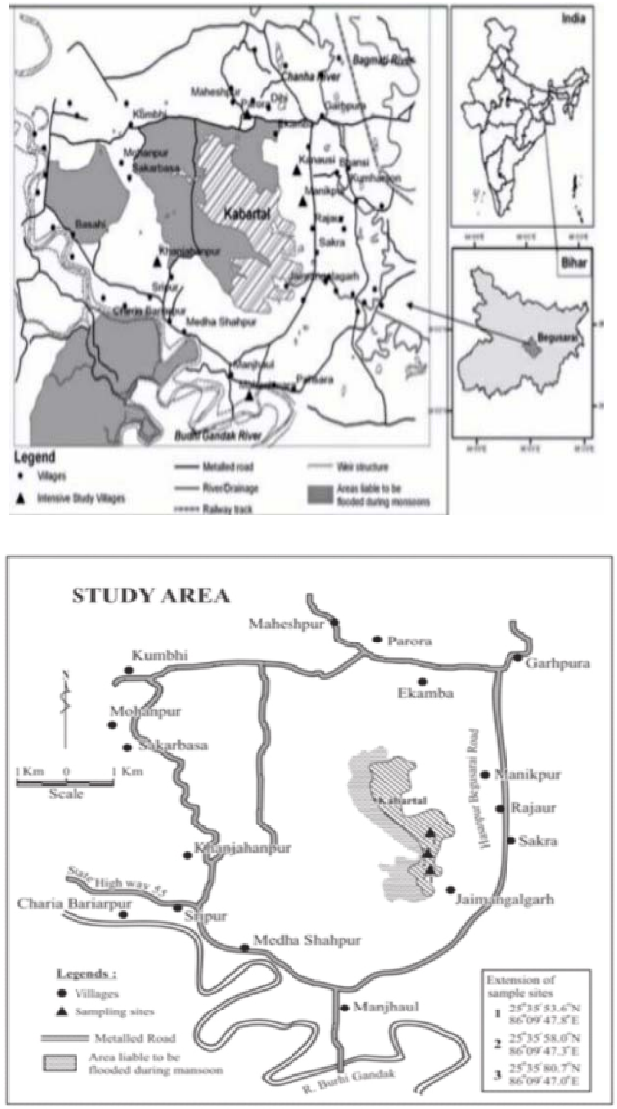


**Fig. 1: Map showing location of Kabar wetland**

## 3. RESULTS

### 3.1. Nutrient concentration in Water and Sediment

Physichochemical parametres and sediment nutrient concentration are shown in the table 1 and 2 respectively. In Kabar wetland mean nitrate nitrogen was reported maximum (0.99 mg $l^{-1}$) in the rainy season. The rainy season had highest values for the nitrate-N. The minimum concentration (0.69 mg $l^{-1}$) was recorded in the month of June. Sediment nutrient concentration decreased in the order of TN>Ca>K>AP>Mg>Na, in summer season while Ca concentration was high in the rainy and winter season whereas available phosphorus was more in rainy season than winter. The phosphorus deposition in sediment varied within a narrow range.

**Table 1: Physichochemical parameters of wetland water in different seasons**

| Physicochemical parameters | Summer | Rainy | Winter |
|---|---|---|---|
| Temperature (ºC) | 35.7 ± 0.81 | 29.7 ± 0.81 | 16.2 ± 0.50 |
| Transparency | 35.2 ± 0.18 | 38.8 ± 0.40 | 98.5 ± 1.98 |
| Electrical conductivity | 594 ± 40.3 | 664 ± 38.7 | 582 ± 4.46 |
| pH | 7.71 ± 0.29 | 6.93 ± 0.25 | 6.8 ± 0.26 |
| Dissolved oxygen | 6.2 ± 0.26 | 9.5 ± 0.85 | 12.0 ± 0.80 |
| Biochemical oxygen demand | 14.4 ± 0.61 | 9.3 ± 0.05 | 5.5 ± 0.04 |
| Phosphate phosphorus | 0.27 ± 0.04 | 0.78 ± 0.03 | 0.37 ± 0.04 |
| Total phosphorus | 0.46 ± 0.05 | 0.67 ± 0.09 | 0.32 ± 0.03 |
| Nitrate nitrogen | 0.69 ± 0.06 | 0.99 ± 0.08 | 0.89 ± 0.03 |
| Total nitrogen | 0.68 ± 0.14 | 1.39 ± 0.05 | 0.93 ± 0.04 |
| Na | 6.5 ± 0.40 | 3.10 ± 0.21 | 4.2 ± 0.32 |
| K | 0.59 ± 0.03 | 1.49 ± 0.08 | 1.67 ± 0.07 |
| Mg | 23.43 ± 1.05 | 25.6 ± 0.89 | 16.7 ± 0.93 |
| Ca | 8. 5 ± 0.08 | 10.65 ± 1.05 | 12. 5 ± 1.08 |

**Table 2: Nutrient concentrations in wetland sediment in different seasons**

| Nutrient (mg/g) | Summer | Rainy | Winter |
|---|---|---|---|
| TN | 3.91 ± 0.04 | 3.53 ± 0.04 | 3.11 ± 0.04 |
| AP | 0.62 ± 0.05 | 1.35 ± 0.03 | 0.67 ± 0.09 |
| K | 0.80 ± 0.06 | 0.63 ± 0.08 | 0.63 ± 0.08 |
| Na | 0.22 ± 0.40 | 0.74 ± 0.05 | 0.51± 0.03 |
| Mg | 0.59 ± 0.03 | 1.25 ± 0.05 | 1.49 ± 0.08 |
| Ca | 3.47 ± 0.09 | 7.28 ± 0.08 | 5.62 ± 0.05 |

## 3.2. Nutrient concentration in plant tissues

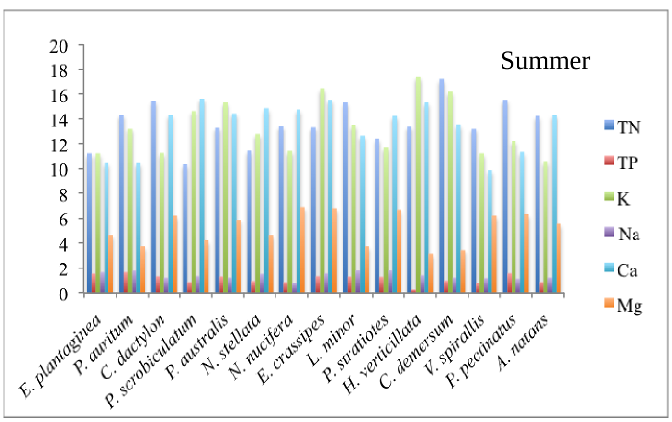


**Fig 2. Tissue nutrient distribution in wetland species of Kabar wetland in summer season**

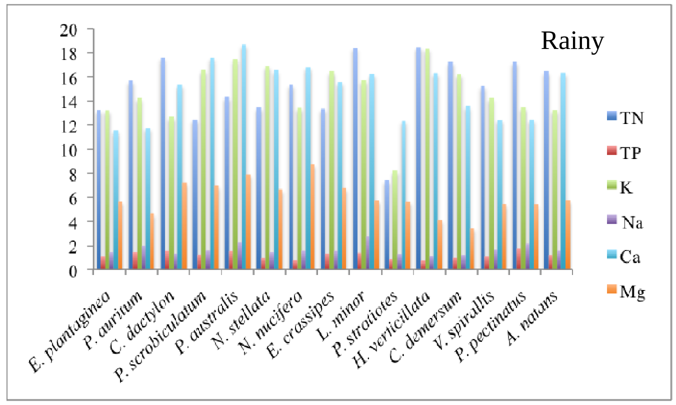


**Fig 3. Tissue nutrient distribution in wetland species of Kabar wetland in rainy season**

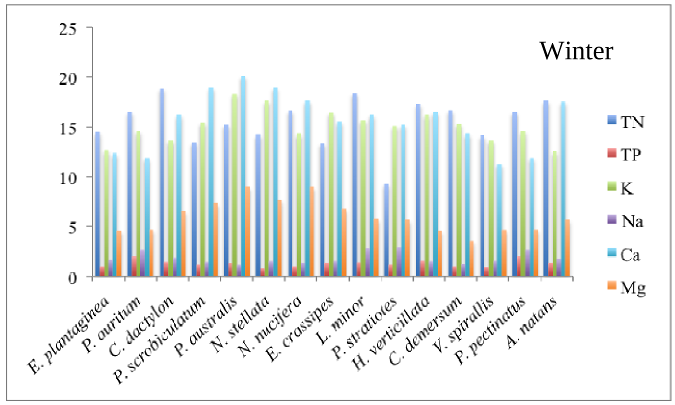


**Fig 4. Tissue nutrient distribution in wetland species of Kabar wetland in winter season**

Concentration of dissolved elements in water and sediment plays an important role in establishment and physiology of plants. Nitrogen and phosphorus are vital macronutrients in physiological performance of plants. Sodium and Potassium is categorized as trace elements but play an essential role in the growing and dividing tissues of the plants. The order of decrease in nutrient concentration for emergent zone was Potassium > nitrogen> sodium > phosphorus. Monthly changes in nutrient composition of *E.crassipes* showed maximum nitrogen accumulation (18.5 ± 0.72 m g $g^{-1}$) in the month of June and (10.2 ± 0.43 m g $g^{-1}$) in the month of November. Seasonally higher values were for summer followed by rainy and winter months. In case of phosphorus maximum value of (1.62 ± 0.02 mg $g^{-1}$) was reported in the month of June and minimum (0.71 ± 0.03 mg $g^{-1}$) was in the month of October. Phosphorus content in the tissues of *E. crassipes* varied within a narrow range. Maximum potassium content 20.3 ± 1.44 mg $g^{-1}$ was reported in the month of June followed by fall in nutrient concentration with minimum of 10.5 ± 0.11 mg $g^{-1}$ in the month of November. The mean annual nutrient con- centration in all wetland species differed considerably for Ca, Mg, Na and K but only slightly for nitrogen and phosphorus.

### 3.4. Biomass and productivity

The emergent zone was constituted by Eleocharis plantaginea, Panicum auritum, Cynodon dactylon and Paspalum scrobiculatum, Phragmites australis, which shared (30%) of total standing crop biomass of wetland. Nymphaea stellata and Nelumbo nucifera were the constituent plant species of this zone. Here two species were recorded in comparison to five species of the emergent zone and their contribution to the total annual biomass of the pond was 10%. N. nucifera had maximum annual biomass of 1596 g m-2 followed by 1329 g m-2 of N. stellata of the total annual standing crop biomass of the zone. The total annual biomass of rooted floating zone was calculated 2925 g m-2.

Free-floating zone was dominated by three species i.e. *Pistia stratiotes, Eichhornia crassipes and Lemna minor.* The value of standing crop biomass started decreasing and minimum was recorded (1.32 ± 0.06 g $m^{-2}$) in the end of summer (Fig 5). Total annual biomass for free-floating zone was 11693 g $m^{-2}$. Winter (37.6%) and rainy (37.9%) season was most suitable for the growth of all the three species of this zone while summer was least (24.3%) suitable. The total annual biomass for submerged zone was (9609 $gm^{-2}$), out of which *C. demersum* contributed maximum (54.7%) followed by *Vallisneria spiralis* (33%). Biomass contribution of *Hydrilla verticillata* (6.6%), *Potamogeton pectinatus* (3.6%), and *Aponogeton natans* (1.7%) was very nominal. Seasonal contribution of winter was maximum (40.8%) indicates that post-monsoonic months favoured rapid growth of macrophytes. Although, the three species were present throughout the study period, yet the maximum contribution by *Eichhornia crassipes* was 85.4%.

The contribution of submerged zone to the wetland was 32.8%. Emergent zone was constituted by five species where net primary productivity was highest (336 g $m^{-2}$) in the rainy season followed by summer (17.9 g $m^{-2}$) season. In winter season there was no increase in the biomass. The annual productivity for emergent zone was 384 g $m^{-2}$.

Annual productivity of rooted floating zone was (418.2 $gm^{-2}$) in which yearly contribution of *Nelumbo nucifera* was maximum 57% and *Nympheae stellata* 43%. *Eichhornia crassipes*, *Pistia stratiotes*, and *Lemna minor* have constituted free-floating zone of the Kabar wetland. *Eichhornia crassipes* was the dominant member whose rate of productivity was 472 g $m^{-2}$ in the rainy season, which was the maximum production in the wetland. This was followed by winter season where the rate was 29 g $m^{-2}$ $season^{-1}$. The maximum seasonal productivity (355 g $m^{-2}$) of submerged zone was in the rainy season for *Ceratophyllum demersum* and minimum production was (6.5 g m-2) for *A. natans*. *Hydrilla verticillata* and *Ceratophyllum demersum* showed no net increase in biomass value in the summer season. All other species of this zone produced in all the three season. *H. verticillata* had highest productivity (78.7 g m-2) in the winter season and lowest (42.4 g $m^{-2}$) in the rainy months.

**Table –3 Biomass ($gm^{-2}$) comparisons between different aquatic ecosystems zones**

| Zones | Study sites | Maximum Biomass (gm-2) | References |
|---|---|---|---|
| | Ramgarh Lake | 3540 | Verma, 1979 |
| | Chilwa Lake | 4340 | Srivastava, 1973 |
| Emergent Zone | Jalwania Pond | 674 | Singh, 1973 |
| | Agro farm Pond (Varanasi) | 610 | Shrdendu, 1991 |
| | Kabar Wetland | 615 | Present study |
| | | | |
| | Chilwa Lake | 130 | Srivastava, 1973 |
| | Jalwania Pond | 968 | Singh, 1973 |
| Rooted floating Zone | Agrofarm Pond (Varanasi) | 236.4 | Shrdendu, 1991 |
| | Kabar wetland | 245.6 | Present study |
| | | | |
| | Ramgarh Lake* | 858 | Verma, 1979 |
| | Chilwa Lake | 82 | Srivastava, 1973 |
| | Jalwania Pond | 676 | Singh, 1973 |
| Free Floating Zone | New Orleans, Missisippi | 1500 | Westlake, 1963 |
| | Agro farm Pond (Varanasi) | 1190 | Shrdendu, 1991 |
| | Kabar Wetland | 1018.4 | Present study |
| | | | |
| | Ramgarh Lake | 962 | Verma, 1979 |
| | Chilwa Lake | 1800 | Srivastava, 1973 |
| | Jalwania Pond | 1131 | Singh, 1973 |
| Submerged Zone | Florida, USA | 621 | Sculthorpe, 1967 |
| | Computation of different work | 500 | Westlake, 1975 |
| | Agro farm Pond (Varanasi) | 71.4 | Shrdendu, 1991 |
| | Kabar Wetland | 588 | Present study |

**Table 4. Biomass ($gm^{-2}$) comparison from various aquatic communities**

| Community | Biomass (gm-2) | References |
|---|---|---|
| English reed swamps | 800-1154 | Sculthorpe (1967) |
| Reed swaps in Minnesota (USA) | 630-4640 | Sculthorpe (1967) |
| New Zealand Lake | 50-1000 | Sculthorpe (1967) |
| Temperate Lakes | 0.07-680 | Sculthorpe (1967) |
| Agrofarm Pond (Varanasi) | 0.56-1190.7 | Shardendu (1991) |
| Kabar Wetland | 1.25-1018.4 | Present Study |

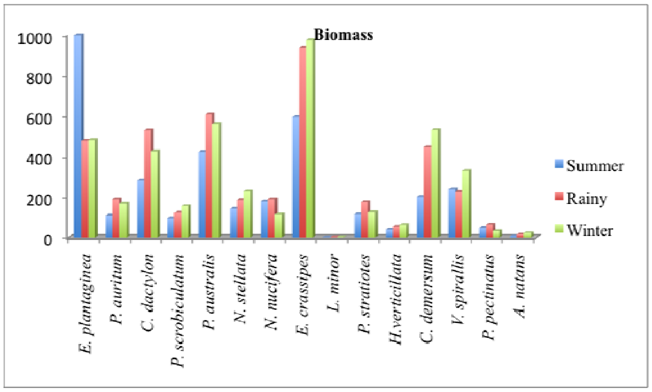


**Fig 5. Biomass of the wetland species in different seasons**

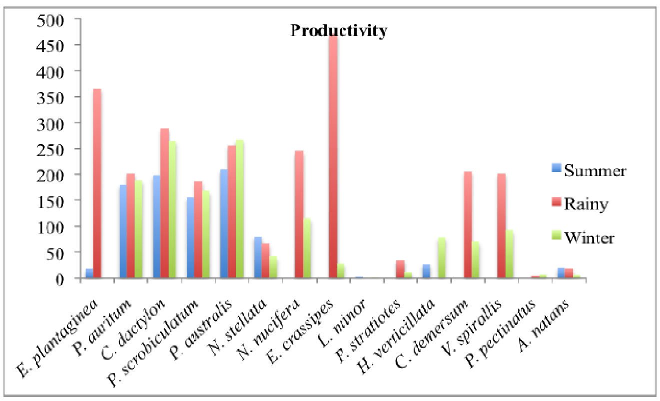


**Fig 6. Primary productivity of the wetland species in different seasons**

## 4. DISCUSSION

Altogether 15 species of plants were listed from the wetland. Generally, in this region of Indian subcontinent wide vriety of plants get established within a few weeks of lowering of water level after rainfall. Dissolved ionic concentration of water represents the geology and the fertility of lake [24]. Dissolved nutrients and gasses influence the growth and distribution of aquatic macrophytes. Tansley [25] has concluded that the chemistry of lake water influenced the distribution of macrophytes in English lakes. Availability of inorganic components in the water favors conductivity while organic components enriched water show poor conductance. Inorganic contents favor the growth of free-floating macrophytes [26]. Forsberg & Forsberg [27] proposed a direct relationship between water conductivity and distribution of certain aquatic macrophytes in European fresh water bodies. Hydrogen ion concentration of water is essential component of fresh water system, regulating biochemical processes including decomposition of dead organic matter and biochemical reactions. Dissolved oxygen determines the quality and quantity of biota. DO favours self-purification of surface water for the maintenance of aquatic organisms. The prime contribution of oxygen in water is photosynthesis by aquatic biota and mixing of atmospheric oxygen with surface water. After absorption oxygen either incorporates in to water body through existing internal currents or lost from the system. In hanuman tal lake, Jabalpur the dissolved oxygen varied between 3.0-8.2 mg $l^{-1}$ [28]. Rise in temperature alters the capacity of water to dissolve oxygen. In tropical region the winter shows plenty of dissolve oxygen. Biochemical oxygen demand is the amount of oxygen required for the disintegration of organic matter present in the water through microbial activity. BOD values in turn indicate the amount of pollutants in aquatic system responsible for the deterioration of water quality. Nitrate nitrogen is inextricably involved with biological phenomena in any fresh water system. Rainfall, runoff waters and decomposed waste materials are the sources of $PO_4$-P to the fresh water systems. Phosphorus forms a base for nucleic acids, and biochemical energy essential for life processes to occur. Organic phosphorus is present within the biological residue of the plants and animals. Hutchinson [29] reported that Phosphorus acts as a limiting factor in fresh water systems. Lakes and reservoirs are source of phosphorus sink. Increase in available phosphorus occurs as a result of release of phosphate from lake sediment. Potassium never produces toxic effect in the aquatic systems. Natural source of this potassium in water bodies is through weathering of rocks. Another addition of potassium in water system may be due to sewage discharge. The main source of sodium in fresh water bodies is rainwater and soil leachates. In wetland ecosystems dominated by perennial plants, there can be significant translocation of nutrients and energy from below ground to above ground components as above- ground tissues senesce [30]. At low nutrient and water availability, roots use relatively more of the limiting amounts of photosynthates, leaving less for the shoots (leaves) [31].

Rooted emergent macrophytes community starts germination mostly on wetland periphery and constitute a food for the aquatic fauna. Some of the important species under this group include large and thick mat of grasses (Poaceae) and sedges (Cyperaceae) surrounded the natural habitat within a short period of time. Primary production of aquatic macrophytes depends on the phosphorus supply in freshwater, while the nitrogen has a critical role in saline water [32]. The range of physicochemical processes involved in P cycling and the variable importance of these processes in different river environments according to stream size, stream geomorphology and anthropogenic pressures are summarized. Seasonal effects on temperate and tropical fresh water macrophytic communities have been reported by Westlake [33]. Standing crop biomass values in fresh waters of temperate zone was computed by Westlake [34]. The range of organic matter production was from 1500-3500 g $m^{-2}$. He concluded that underground parts produced about 2-5 times of the aerial parts. Determination of biomass and standing crop of any ecosystem is done to estimatr the carrying capacity of the particular habitat. Sculthorpe [35] has calculated the standing crop biomass at community level in different lakes of the world, which showed the biomass range from 0.07-680 $gm^{-2}$ in temperate lakes to 630-4640 $gm^{-2}$ in reed swamps of U.S.A. The biomass range of present study varied from (1.25-1018 $gm^{-2}$) which has lower value than reed swamps of U.S.A. [35]. This may be due to underground parts of the vegetation especially emergent one and rooted floating vegetation. This may be an ultimate cause of maximum biomass in free-floating zone. Previous studies have shown that aquatic macrophytes contributed between 1.2 and 30% of stream primary production [36]. In the emergent zone maximum productivity was 336 $gm^{-2}$. In summer season primary production was very low (18 g $m^{-2}$) whereas there was no production in winter season. During rainy season rooted emergent species of emergent zone showed rapid growth due to availability of moisture, soil nutrient, and light intensity in comparison to other seasons. Emergent species are more productive than free-floating and submerged plants [33]. The rate of seasonal production in attached floating zone ranged from 121.9 g $m^{-2}$ in summer and 115.5 $gm^{-2}$ in rainy season. The higher rate of production in summer was due to maximum range of temperature and bright sunlight because in this zone water or moisture was not a limiting factor (Fig 5).

The free- floating zone species had the intermediate position between emergent and submerged zone. A maximum seasonal productivity was reported (471.7 g $m^{-2}$) for *Eichhornia crassipes* in rainy season. These macrophytes are less productive than the emergent [33]. Higher rate of productivity in rainy season was on account of flowering and fruiting season of the species. However, data on productivity of floating macrophytes are very few. Verma [37] and Shardendu (14) reported maximum rate of 15 g $m^{-2}$ $day^{-1}$ dry matter production for free floating zone.

The maximum productivity in submerged zone was 663 g $m^{-2}$ in rainy season when optimum temperature and light conditions were suitable for the net increase in biomass value. In summer rate of productivity was 127.8 g $m^{-2}$ and in winter 222.4 g $m^{-2}$. Westlake [34] has presented the net productivity of macrophytes, which ranged between 2-10 g $m^{-2}$ $day^{-1}$. These ranges of production were concluded on the data of Owens and Edwards [38], Ikusima [39] and Westlake et al. [4]. Human disturbances to wetlands are frequently the result of agricultural practices and urban development [40], and their impacts can be divided into individual stressors that may have physical, chemical, and/or biological effects on wetlands. Many changes are typical of nutrient enrichment, including increased biomass production, dominance of faster growing plant species, accelerated N cycling and reduced N retention [41]. The mean annual nutrient con- centration in all wetland species differed considerably for Ca, Mg, Na and K but only slightly for nitrogen and phosphorus [42]. Emergent vegetation possesses an extensive network of roots and rhizomes, which provides them great potential to store phosphorus. They store high below ground biomass in comparison to above ground biomass due to their ideal anatomical structures for phosphorus storage. Phosphorus regeneration in soils and sediments is great in the surface layers and decreases with depth. Total phosphorus is usually greater in the surface layers and decreases with depth. In *Eichhornia crassipes* nitrogen, phosphorus and potassium were more in summer season while sodium was high in winter season. Accumulation of sodium in plant tissue was more after rainy season. Nitrogen, phosphorus and potassium are important component of protoplasm and were needed by plants during log phase of growth to synthesize protein. Phosphorus uptake was high by macrophytes during peak growing season, followed by decrease in winter season. Macrophytes are seasonally important nutrient reservoir for phosphorus.

## CONCLUSION

Wetland ecosystem absorbs and recycles essential nutrients, purifies contaminated inflows. Many agricultural and industrial wastes including detergents, oils, acids, and paper are also detoxified and decomposed by the biological activities. The physicochemical study of the wetland in Kaber wetland during this study revealed their physicochemical characteristics of water as being suitable for microbial growth. Wetland under study revealed high organic matter content due to vigorous growth of macrophytes in every zone of the wetland. Wetland was supporting various kinds of macrophytes, hence enhancing the productivity of the system.

## 5. ACKNOWLEDGMENT

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