A Study of Rural Wetland of Bihar State: Effect of Nutrient Dynamics in the Physicochemical Properties of Water, Sediment and the Aquatic Flora of the Wetland

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Abstract: Wetlands are the sensitive ecosystems amongst the aquatic ecosystems that are subject to stress from human activities since long time. The wetlands functions are series of processes ranging from storage of water, transformation of nutrients, growth of living matter, biodiversity support to fish and paddy production and recreational, activities. Kabar (25◦35′ N; 86◦10′ E) is a large subtropical wetland in the Gangetic plain of eastern India having an area of 6043 ha. Despite its immense ecological significance for varieties of aquatic fauna and migratory birds, Kabar is under extreme anthropogenic influence from the nearby deem.

The present study endeavors to investigate the physicochemical parameters of water and nutrient dynamics of the wetland water, sediment and aquatic macrophytes affected by the sewage and agricultural runoff. Nutrient uptake (N, P, K and Na) by common aquatic plant species, namely, Eleocharis plantaginea, Eichhornia crassipes, Pistia stratiotes, and Hydrilla verticillata and Lemna minor was analyzed. Physicochemical properties of water were directly influenced by the seasonal changes and thereby affected the sediment chemistry and macrophytic tissue nutrient composition. Eleocharis, being the hardy emegrnt macrophytes showed the highest concentration of all the nutrients.

The least nutrient was found in the tissues of L.minor. Maximum dissolved oxygen (the 9.2 ± 0.52 mg l^{-1}) in the month of August, which is due to photosynthetic activities of phytoplanktons and macrophytic vegetation. Maximum (0.94 mgl^{-1}) NO_3 ^{-}N in water was found in the month July whereas PO_4^{-} P (0.39 mg l^{-1}) was in the month of August. The order of nutrient concentration in sediment composition was Total nitrogen>Available phosphorus>Potassium >Sodium. Kabar health had a great impact of theses nutrient inflow on the water and sediment chemistry and aquatic flora community thereby degrading the water quality and ecological status of the wetland.

Keywords: Aquatic flora, BOD, DO, Kabar, Nitrogen, phosphorus, physicochemical properties, water

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1. INTRODUCTION

Fresh water systems constitute dynamic and complex aquatic ecosystems on globe surface. They are vital for life and become a major concern because of its need for socioeconomic development and healthy human life. Growth of human population, Industrialization and technologies has created imbalance in the natural systems. The most exploited environmental entity is natural water systems receiving a large amount of pollution from a variety of sources such as agricultural practices, transport of industrial effluents, recreational activities and fish culture. These situations have generated a negative effect on the ecosystem, resulting in a decrease of water quality and biodiversity, loss of critical habitats. Presence of contamination in water degrades its physical, chemical and biological characteristics making it harmful for man, his need and various uses. Kabar, a residual oxbow lake is situated in rural area of Bihar (25◦35′ N; 86◦10′ E) and placed under Ramsar convention named as “Kabar” wetland.

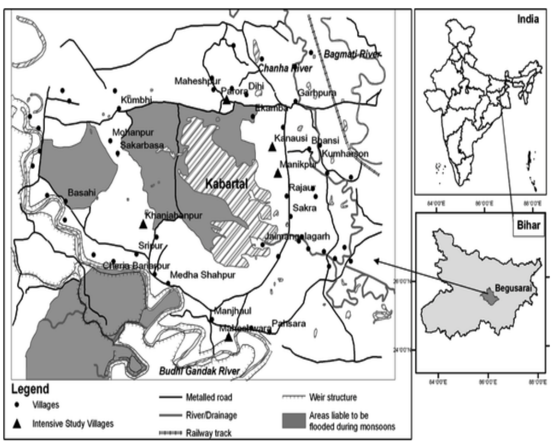


Fig 1- Map showing location of Kabar wetland in Bihar state of India

The Kabar wetland receives plenty of water from rain and through the flooded water of Burhi Gandak. The catchments arable lands are utilized for the cultivation of rice paddies. However, satellite image revealed shrinkage in the wetlands area of 6,043 ha in 2002 [1]. The environment surrounding the wetland has favorable temperature making it an ideal habitat for several migratory and local birds, which visits this wetland in winter months to escape severe cold in their respective habitats. The climate of the area is typical monsoon type with seasonal fluctuations and an average annual rainfall of 1,100 mm between July and September. The forest vegetation around Kabar is mixed of tropical trees and has a rich and diverse aquatic flora of emergent, floating and submerged macrophytes. At the banks of the Kabar wetland there is growth of sedges. *Eleocharis plantaginea* was the dominant emergent vegetation of the Kabar. Among the submerged vegetation *Hydrilla verticillata, Vallisneria spiralis, Potamogeton pectinatus* were selected. *Eichhornia crassipes*, *Pistia stratiotes* and *Lemna minor* were the dominant surface floating vegetation.

2. MATERIAL AND METHODS

Three sampling stations were selected and marked, considering nutrient enrichment and anthropogenic stress. The surface water samples were collected from 2 m depth from the water surface. Water temperature was measured at the site with Celsius thermometer, transparency was measured using Secchi disc [2] and electrical conductivity and pH of the water was measured with the help of Systronics digital pH meter and digital conductivity meter (Systronics model no-341) respectively. BOD and DO of the water sample was analyzed with the help of Winkler's iodometric method [3] and water samples were collected by biological oxygen demand (BOD) bottles of 300 ml capacity. Nitrate -N, Phosphate -P, Sodium and Potassium of surface water, sediment and selected aquatic flora of Kabar wetland were analyzed at monthly intervals for twelve months starting from July 2009 to June 2010. At all the stations sampling were performed in first week of each month. Nitrate content in the water sample was determined by using phenol di sulphonic acid method (PDSA). Phosphorus in the sample water was measured by stannous chloride method. Potassium and Sodium in the water sample were estimated with the help of Systronics type 121flame photometer with specific filters.

Biomass estimation- Standing crop biomass was measured by harvest method [4]. Plant samples were collected from 25*25cm area for emergent and free-floating zone at three different sampling points each month. Submerged zone macrophytes were collected using a vertical core sampler. Samples were collected in the polyethylene bags at three sampling points. Plant materials were brought to the laboratory. Plants were identified and separated and fresh weights Plant materials were oven dried at 80 c° for 72 hours. Biomass calculation was done on dry weight basis of the plant species and data are presented in g m^{-2}.

Sediment and macrophytes tissue nutrient analysis- Total nitrogen in sediment was estimated by micro kjeldhal method [5][6]. Available phosphorus was estimated in 5 g soil sample with the help of chlorostannous reduced molybdophosphoric acid in blue color Hydrochloric acid system [7]. For determination of potassium and sodium in soil, repeated leaching technique was used [8].

Total nitrogen content in plant samples was estimated by Kjeldahl digestion procedure, distillation in Markham unit and determination by volumetric method [7]. Phosphorus was estimated by chlorostannous reduced molybdophosphoric blue colour method. Potassium and sodium was estimated using systronic type 121-flame photometer with specific filters.

Statistical analysis- Statistical analysis of two factor ANOVA was performed by SPSS,(version10) for windows and graph was prepared using MS Excel 2007.

3. RESULT AND DISCUSSION

The rainy season showed less transparency in comparison to summer and winter. The visibility of Secchi disc ranged between 98.5 ± 2.0 cm to 35.2 ± 0.2 cm. The fluctuation in water temperature is affected by variation in atmospheric temperature. It was lowest in the month of January 17.3 ± 0.73 ºC and highest (17.3 ± 0.32 ºC) in the month of July. In Kabar wetland maximum value of 726 ± 36.3 µ mho and minimum value of 446 ± 36 µ mho was measured in July and January respectively. Seasonal variation of electrical conductivity shows higher values in rainy months followed by summer and winter months. Presence of more electrolytes may be due to the chemical exchange process between the sediments and water bodies. Presence of inorganic components in the water favors conductivity while organic components enriched water show poor conductance. The ionic concentration of water reflects the geology and the fertility of the lake [9] and that in turn favors the growth of free-floating macrophytes [10].

pH of Kabar ranged from 7.8 ± 0.28 to 6.82 ± 0.30 in June and August. Dissolved oxygen peak (9.2 ± 0.52 mg l^{-1}) in Kabar was in the month of August ($p<0.01$) whereas the lowest oxygen concentration was (4 ± 0.28 mg l^{-1}) in the month of May (Fig-2). Dissolved oxygen is the single most important component of surface water for self-purification processes and the maintenance of aquatic organisms and determines the quality and quantity of biota [11].

The prime source 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. BOD in Kabar wetland was (35.8 ± 0.71 mg l^{-1}) in the month of June $p<0.01$) and was minimum (5.4 ± 0.41 mg l^{-1}) in the month of December ($p<0.01$). High temperature supports the rapid microbial breakdown of the organic wastes available in the Kabar whereas, low water temperature slows down the bacterial decomposition of autochthonous materials in the winter season. Biologically available nitrogen and phosphorus determines the ecological status of aquatic systems [12]. Agricultural and urban activities provide a major share of N and P to aquatic ecosystems. Nitrate nitrogen (NO_3 -N) is inextricably involved with biological actions of the water bodies. The highest Nitrate-N (0.94 ± 0.10 mg l^{-1}) in Kabar was measured in the month of July while lowest (0.47 ± 0.01 mg l^{-1}) was determined in the month of October. Maximum concentration in nitrates during rainy season appears to arrive as a consequence of precipitation and runoff flow from nearby local deem. Lower values in summer and winter season are the result of assimilation by the primary producers and denitrification.

Maximum dissolved inorganic phosphorus in Kabar was (0.39 ± 0.04 mg l^{-1}) in the month of July ($p<0.01$) whereas minimum (0.01 ± 0.01 mg l^{-1}) in the month of January ($p<0.01$). Exchange of phosphorus between the bottom of the lake and the overlying water contributes to the phosphorus cycle. Decaying macrophytes wastes also contributes some phosphate. Natural sources of potassium in water are weathering of rock another reason for potassium could be sewage discharge from the surrounding population. The highest content of potassium (1.62 ± 0.57 mg l^{-1}) and sodium (6.2 ± 0.66 mg l^{-1}) in Kabar was in the month of December and June respectively (Fig 2).

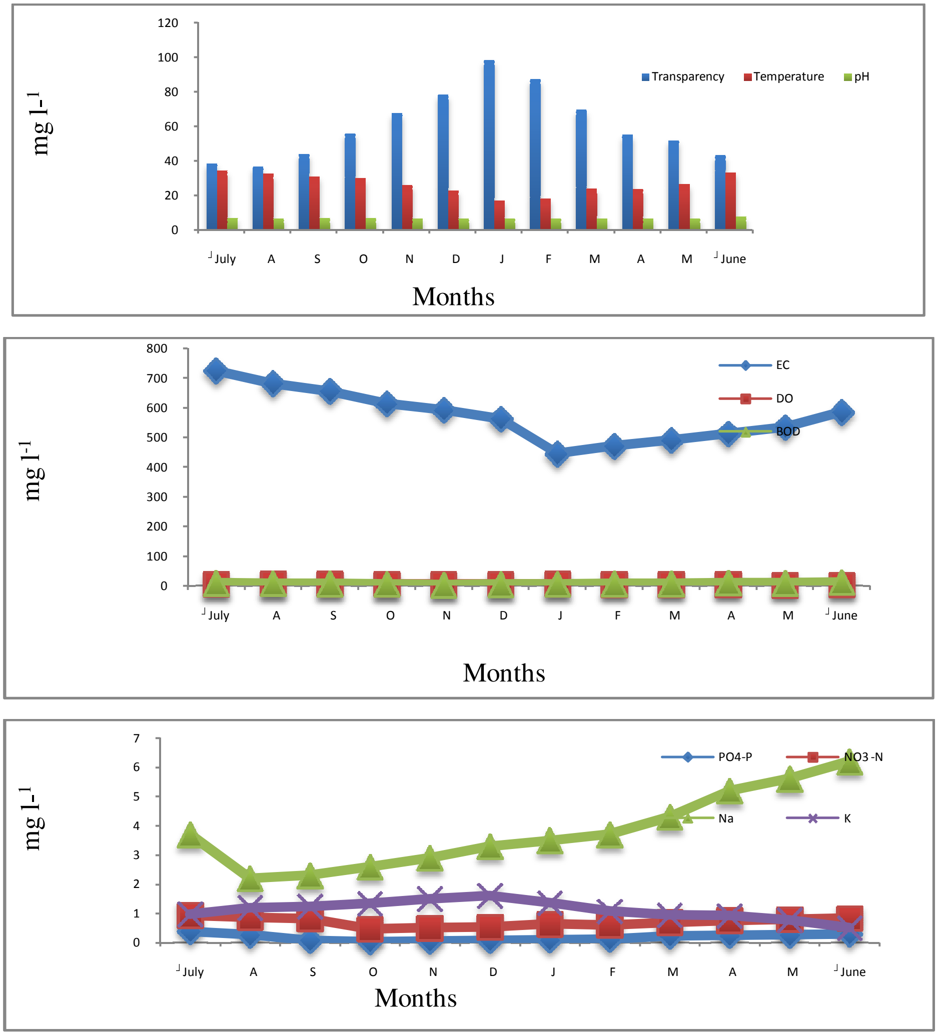
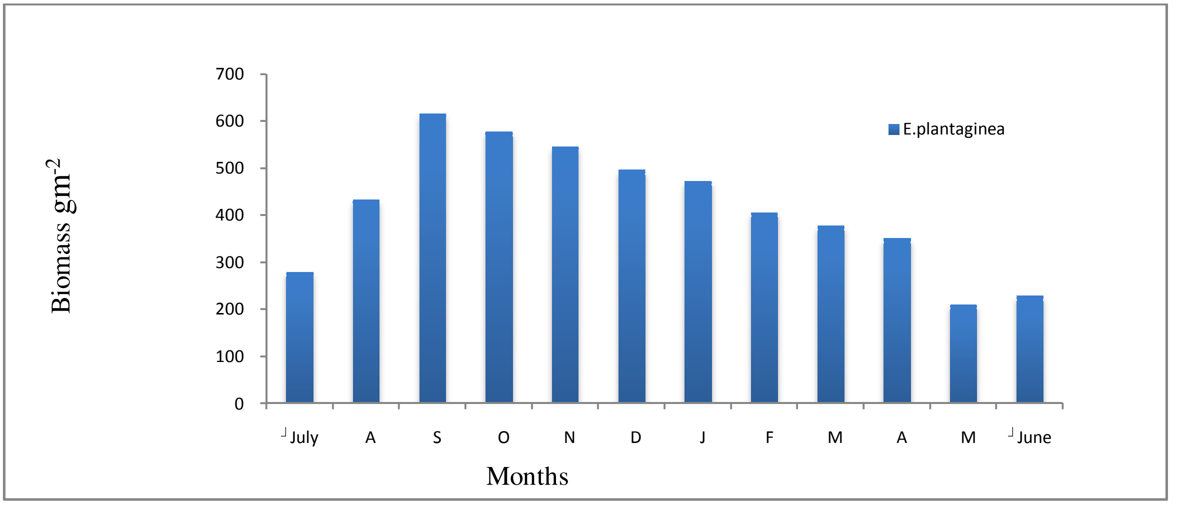


Fig 2- Monthly variation of physicochemical parameters of water of Kabar

<u>Biomass and nutrient analysis of macrophytes</u>-Biomass of *E. plantaginea* was highest (616 ± 45 g m^{-2}) in the month of September and lowest (211 ± 24 g m^{-2}) in the month of May ($p<0.01$) (Fig-3). The *E. crassipes* had maximum biomass value of (1018.4±36.5 gm^{-2}) in the month of October and minimum (440.8 ± 25 g m^{-2}) in the month of May ($p<0.01$) (Fig 3). The maximum biomass in the months of October coincides that monsoon months are favorable for aquatic vegetation with equilibrium of all the factors like, heat, light, and nutrients including several biological and geological factors. *Lemna minor* had maximum biomass value (3.64 ± 0.08 g m^{-2}) in the month of September ($p<0.01$). The value of biomass started decreasing and minimum was (1.32 ± 0.06 g m^{-2}) in the month of May (Fig-3). The low biomass of *Eichhornia crassipes* and *Lemna minor* was observed in summer months, which was due to dry and harsh weather and poor nutrient availability to the soil and water. The biomass of the macrophyte varied significantly between months ($p<0.01$). *Pistia stratiotes* had maximum value (192 ±7.2 g m^{-2}) calculated in the month of September while minimum biomass (74 ± 2 g m^{-2}) noted in the month of February (Fig-3). The minimum biomass (23 ± 66 g m^{-2}) of *H. verticillata* was in the month of June and there was a gradual increase in its biomass in the rainy season and reached the peak of 78 ± 23 g m^{-2} in the month of November with annual biomass value of 640 g m^{-2}. *V. spiralis* showed maximum biomass value (402 ± 12 g m^{-2}) in the month of September and minimum value (130 ± 4 gm^{-2}) in the month of June (Fig-3). *Vallisneria spiralis* and *Hydrilla verticillata* had their maximum biomass in the months of November ($p<0.01$) since slightly cold atmospheric climate favors flowering in these species. After wards there was decline in biomass, this might be possible due to presence of less nutrients in water body as well as low temperature. *P. pectinatus* was absent from October to December with maximum biomass value of (71.4 ± 8.35 g m^{-2}) in the month of August afterwards there was a decrease in standing crop biomass value in the month of September ($p<0.01$). It started germination in the month of January with minimum biomass value of 18.9 ± 6 g m^{-2} (Fig-3). Submerged communities are believed to be less productive than emergent communities and others, may be due to scattered, thin and sparse growth of vegetation, poor nutrient status of water that was only source of submerged vegetation and other biotic factors [13].



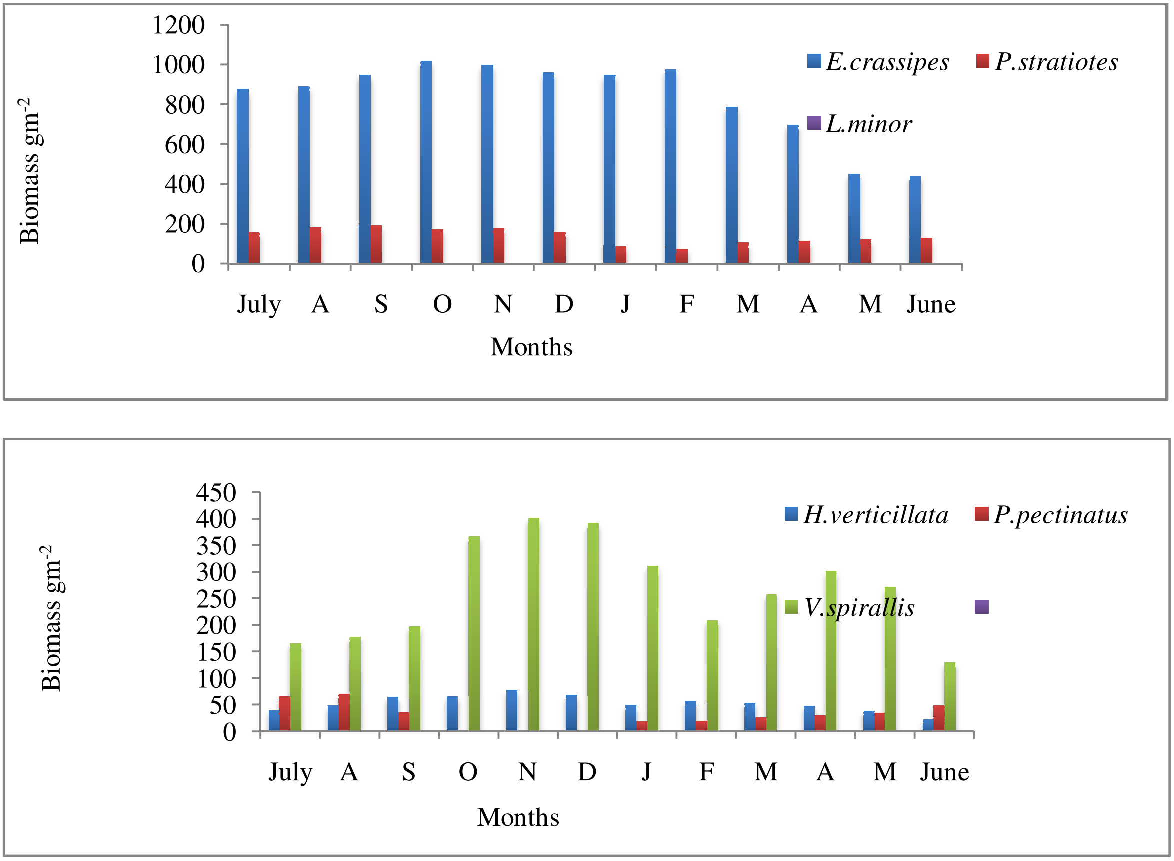
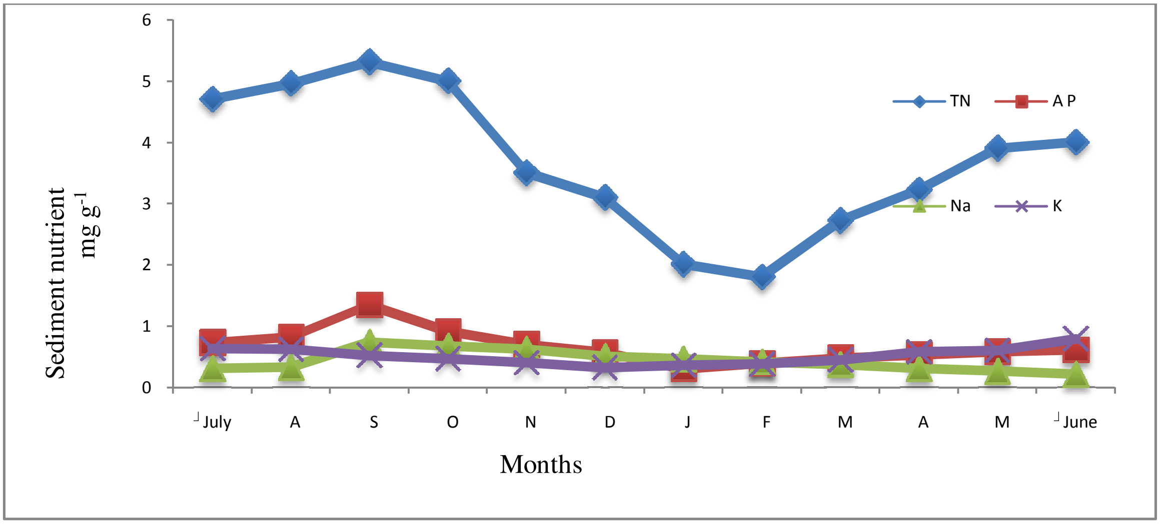


Fig 3- Biomass of aquatic macrophytes in Kabar

Dissolved nutrients in water and sediment play 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 acts as growth promoter in the growing and dividing tissues of the plants. In respect to seasonal change nitrogen content had regular rise and fall within the range of (5.32 ± 0.60 to 1.81 ± 0.01 mg g^{-1}) in Kabar. Runoff water from agricultural field inputs finer soil particles to the aquatic systems. Submerged plants also mobilize nutrients from sediment surface [14]. The nutrient concentration was reported maximum in rainy season. In littoral sediments of wetlands, nitrogen cycle progressed by transport of oxygen through aerenchymatous tissue of stems and roots into the root zone. Nitrogen loss from aquatic sediments to the atmosphere occurs mainly through the denitrification [15]. NO_3^- N acts as an electron acceptor, enhancing the redox potential of sediments and hence involve in phosphorous binding capacity of sediments. The nutrient composition of sediment between months varied significantly ($p<0.01$) for total nitrogen, available phosphorus, potassium and sodium in Kabar. Phosphates are long-term constituents of bottom sediment available as dissolved organic phosphorus where as the dissolved inorganic phosphorus is available in water column for the uptake by aquatic macrophytes.



Aquatic plants alter the sediment by accumulation of organic matter by their own production [16][17]. During the filling - in of lakes extensive organic matter to sediment also comes from emergent vegetation [16]. Sediment organic matter has inhibitory effect on the growth of submerged plants and to some extent emergent vegetation.

The range of variation of nutrients in *E. plantaginea* was 3.5 to 12.1 mg g^{-1} for nitrogen, 0.33 to 0.85 mg g^{-1} for phosphorus, 6.3 to 16.4 mg g^{-1} for potassium 0.75 to 1.84 mg g^{-1} for sodium (Fig-5).

Fig 4- Monthly nutrient variation in sediment of Kabar

The order of decrease in nutrient concentration for *E. plantaginea* was Potassium > nitrogen> sodium > phosphorus. Nitrogen and phosphorus containing compounds are hydrolyzed in the senescence stage and the nutrients are transported to vital parts for reuse or to special storage structures [18]. The mean nitrogen and potassium levels in *Eleocharis plantaginea* were high in summer than in winter due to rapid uptake of nitrogen and potassium during growth phase. High concentration of phosphorus in plant tissue in late rainy season may be due to its accumulation in fruiting bodies of the plants. The high potassium content in tissue was similar to the report of high content in emergent plant [19]

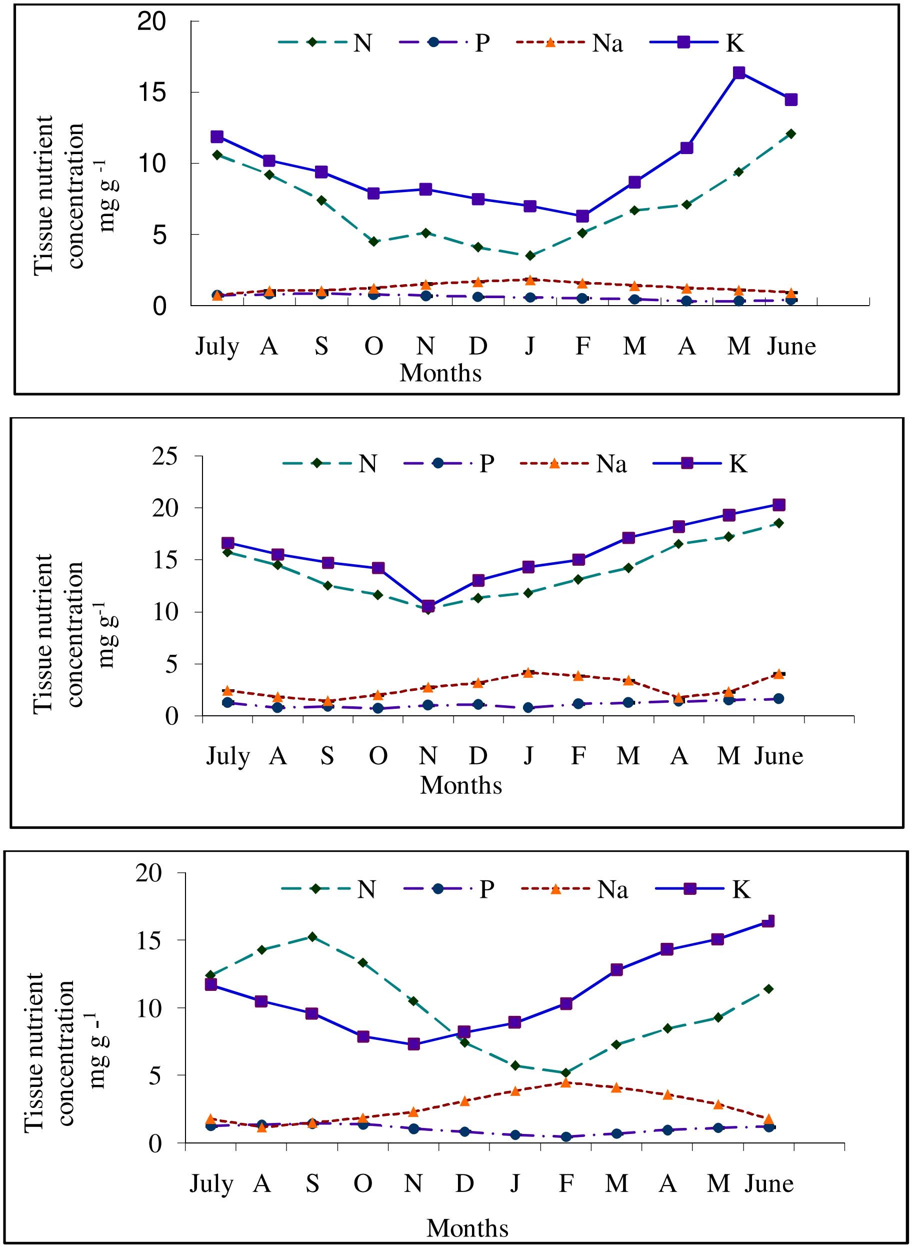
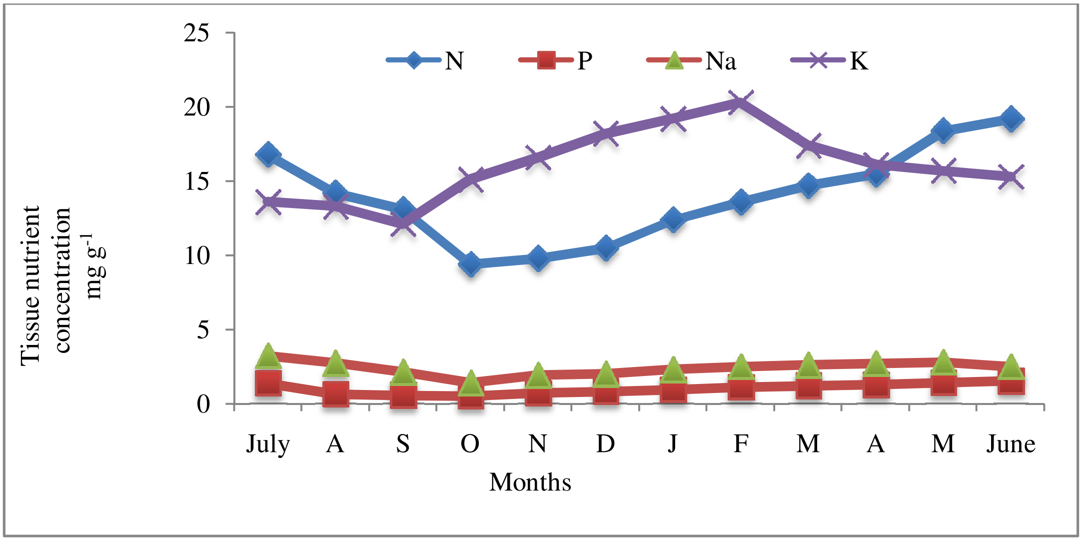
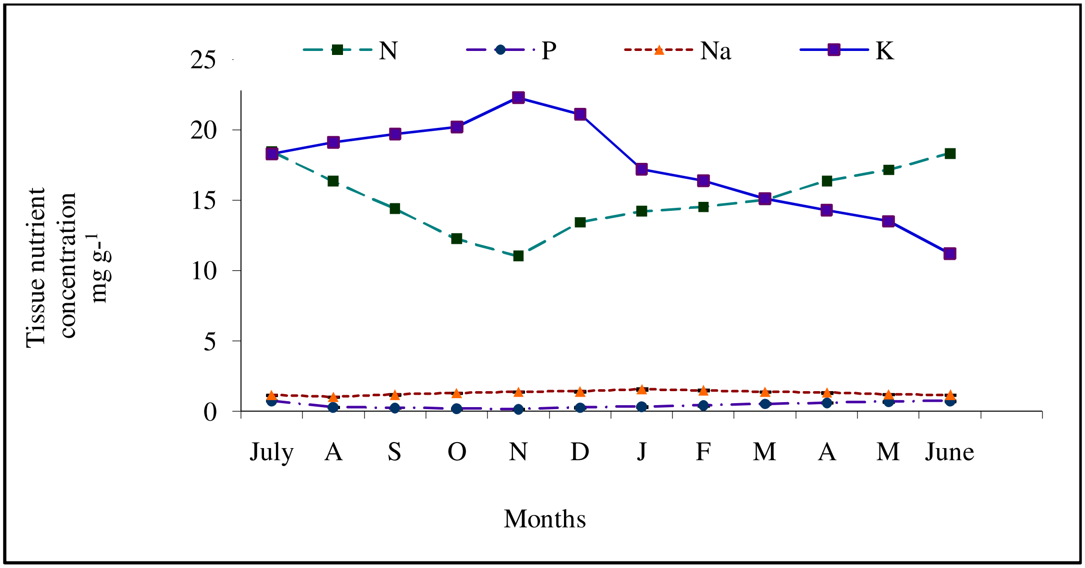


Fig 5- Monthly nutrient variation in *E. plantaginea* and *E. crassipes* and *P.stratiotes*

In *Eichhornia crassipes* the nutrient concentration varied from 10.2 to 18.5 mg g^{-1} for nitrogen, 0.71 to 1.62 mg g^{-1} for phosphorus, 10.5 to 20.3 mg g^{-1} for potassium, and 1.43 to 4.16 mg g^{-1} for sodium (Fig-5). The sequence of nutrient variation was potassium > nitrogen > sodium > phosphorus. In *Eichhornia crassipes* nitrogen, phosphorus and potassium were higher in summer season, protoplasm and were needed by plants during log phase of growth for protoplasm and protein synthesis. Maximum phosphorus uptake by macrophytes was during peak growing season, followed by decrease in winter season. *P.stratiotes* the nutrient concentration for all the four nutrients were recorded as 5.22 to 15.25 mg g^{-1} for nitrogen, 0.47 to 1.47 mg g^{-1} for phosphorus, 7.3 to 16.4 mg g^{-1} for potassium, 1.2 to 4.5 mg g^{-1} for sodium (Fig-5). There was a rapid uptake of nitrogen and phosphorus in the rainy season was supported by the growth phase of the *P. stratiotes*. In aquatic ecosystems macrophytes serve as the seasonal nutrient reservoir for phosphorus [20].





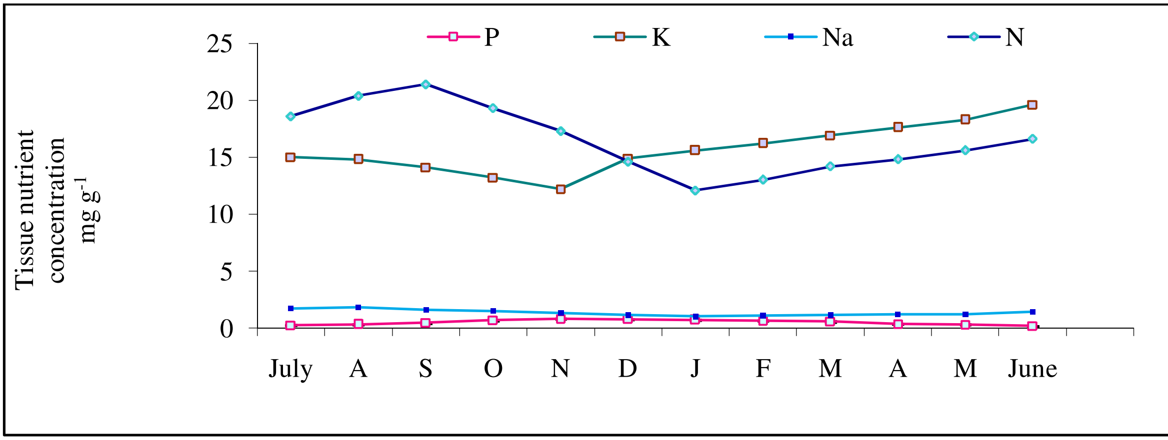


Fig 6- Monthly nutrient variation in *L.minor, H.verticillata* and *P.pectinatus*

Lemna minor in free-floating zone has the maximum nitrogen content of (19.2 ± 0.49 mg g^{-1}) was determined in the month of June while phosphorus was maximum (1.53 ± 0.06 mg g^{-1}) in the month of June (Fig-6). In *L.minor* monthly variation of nitrogen, phosphorus, potassium, and sodium were highly significant ($p<0.01$) between the months. The nutrient concentration of *H. verticillata* in Kabar wetland varied as 18.62 to 11.03 mg g^{-1} for nitrogen, 0.80 to 0.15 mg g^{-1} for phosphorus, 22.3 to 11.2 mg g^{-1} for potassium and 1.56 to 1.02 mg g^{-1} for sodium (Fig-6). In *P. pectinatus* of submerged zone, changes in nitrogen content ranged from 21.4 ± 0.52 mg g^{-1} in September to 12.1 ± 0.18 mg g^{-1} in the month of January (Fig-6). Phosphorus storage in plant tissue was minimum (0.18 ±0.01 mg g^{-1}) in the month of June followed by increase in the concentration, which peaked (0.82 ± 0.03 mg g^{-1}) in the month of November.

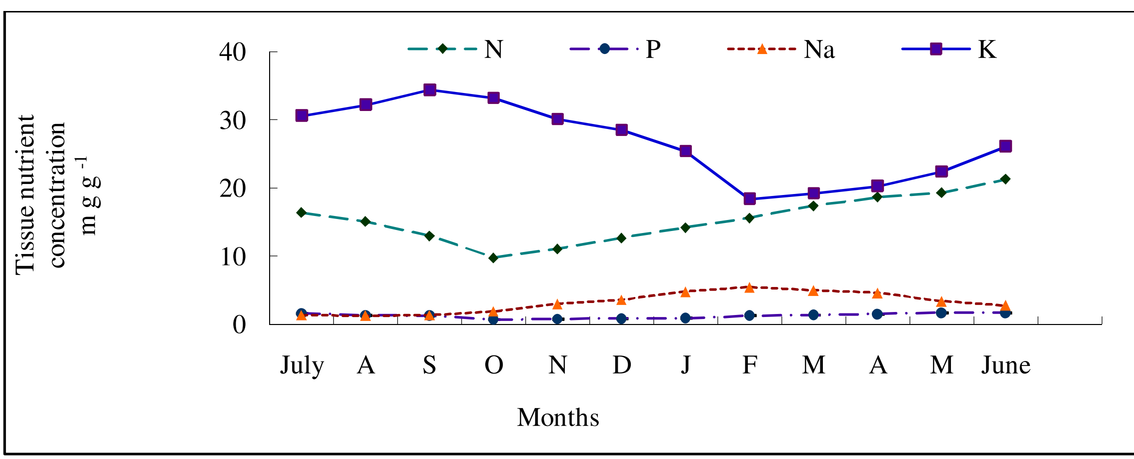


Fig 7- Monthly nutrient variation in *V. spirallis*

The range of concentration of nutrients in *V. spirallis* was 21.3 to 9.8 mg g^{-1} for nitrogen, 1.73 to 0.74 mg g^{-1} for phosphorus, 34.4 to 18.4 mg g^{-1} for potassium and 5.5 to 1.32 mg g^{-1} for sodium (Fig-7). Deposition of organic matter in sediments occurs as result of decomposition of decaying plant tissues while open water is readily available source of potassium supply than the sediment [21][22][23].

4. CONCLUSION

Nutrient and effluents inflow from the surrounding population affecting the physicochemical properties of water and aquatic flora leading to eutrophication and siltation of Kabar. Kabar has been declared as a bird sanctuary in the year 1989, but is still under anthropogenic pressures causing significant changes in the quality of water and pose some deleterious effect to the complex biota of the wetland. There is a continuous exploitation of wetland for fodder, fuel, fish and surplus removal of biomass by human population. Kabar is known to support the rich and diverse aquatic biota and protection of the habitat is required to maintain the biodiversity of the wetland.

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