



Dynamics of key plant nutrients (N & P) in hokersar, a typical wetland of Kashmir Himalaya, India

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Abstract

Hokersar wetland suffers highly due by nutrient inputs from the catchment area, internal wetland processes and various types of anthropogenic pressures around. To characterize nutrient dynamics of the wetland, nitrogen (N) and phosphorus (P) samples were collected from six study sites in the Queen wetland of Kashmir Himalaya for a period of one year from Sep. 2012 to Aug. 2013. Clear spatial and temporal variations were observed among the recorded parameters (ammonical nitrogen, nitrate nitrogen, total orthophosphate phosphorus and total phosphorus) throughout the year. Ammonical nitrogen concentration was found to be maximum in winter ($242.3 \pm 10.1 \mu\text{g/L}$). Lower nitrate nitrogen was observed in summer, recording $259.6 \pm 35.3 \mu\text{g/L}$. Both the forms of phosphorus registered higher values in summer and lower values in winter. Scatter plot showed highly significant values among all the parameters ($R^2=0.748$ and 0.719). Principal component analysis showed highest principle component vector displacement among the sites IV and VI reflecting polluted nature of the sites. Further, higher Eigen-vector displacement values were due to ammonical nitrogen and nitrate nitrogen, registering values 3.36724 and 0.542639 respectively. Similarity matrix was highest between total phosphorus and ammonical nitrogen (92.9666%), followed by ammonical nitrogen and nitrate nitrogen making 58.5729% .

Keywords: Wetland, nutrient dynamics, eutrophication, macrophytes, principle component analysis

Introduction

Wetlands are reported to act as sources [1], sinks [2] or as transformers of inorganic forms into organic forms of nutrients [3,4] which largely depend upon the wetland type and the hydrological condition of the wetland [5,6]. Eutrophication as a result of excessive nutrient loading results in high primary production (weed infestation and algal blooms) is one of the most important and extensive water quality problems at global level. Wetlands, representing the most productive ecosystems in the world are thus usually dominated by aquatic macrophytes [7] and the aquatic vegetation in wetland ecosystems is in turn governed by the availability of nutrients particularly nitrogen and phosphorus [8,9].

Wetlands occupy about 7% of the earth's land surface [10,11]. However; wetlands in the world are degrading at an accelerated rate, more than other ecosystems critically disturbing their biodiversity. Due to their fast squeezing rate, some of the permanent wetlands have been transformed into semipermanent or temporary wetlands with groundwater table falling

down rapidly [12]. Lakes and wetlands, located in areas with exhaustive agriculture, are being gradually enriched with nitrogen and phosphorus, resulting in eutrophication of these shallow habitats [13], causing increase in their productivity [14]. In recent past three to four decades majority of the wetlands have undergone gradual to exhaustive eutrophication, mainly through human intervention, agricultural runoff and waste water from the catchment, causing degradation of both physical as well as biological systems [15-18]. Shallow inland lakes, particularly susceptible to eutrophication because their productivity can respond rapidly to nutrient enrichment and even reduction in external P loading; often fail to improve water quality because of internal P regeneration from the sediments [19-22]. In freshwater ecosystems the source of nutrients is generally from organic matter of plants that undergo mineralization and atmospheric nitrogen fixed by aquatic plants and P as associated with apatite bearing minerals [23,24]. However, anthropogenic activities are increasing throughout the world [25,26] at an alarming pace that greatly exceed natural N and

P for these aquatic ecosystems [27].

Various authors are of the view that permanent and seasonal changes within wetlands occur in response to a range of external factors, such as the changes in the land systems at the catchment scale [28-30], fluctuations in water table [31], climate change [32], besides other human activities [33]. Generally, wetlands are known to function as biofilters in hydrologic systems [34], besides retaining and transferring nutrients (N and P) from aquatic ecosystems [35]. They have been used as wastewater treatment plants to reduce pollution in nearby lakes and rivers [36] and are known to play significant role in carbon sequestration [32]. The earlier studies conducted on Hokersar were made by investigators like Kaul and Zutshi [37]; Handoo [38]; Handoo and Kaul [39]; Kak [40]; Kaul [41]; Pandit [42]; Khan [43]; Rather et al., [44]; Pandit and Kumar [45] and Kumar and Pandit [46], but most of these pertain to biological parameters. Till date very little published information is available in terms of spatiotemporal changes in dynamics of key plant nutrient [nitrogen and phosphorus] in Hokersar, the Queen of wetlands in Kashmir Himalaya having a tremendous socio-economic value.

Study area

Hokersar a natural perennial wetland (34°05'N-34°06'N latitude and 74°8'-74°12'E longitude) situated 10 km to the west of Srinagar on Srinagar–Baramullah Highway in the northern most part of Doodhganga catchment. The wetland, designated as Ramsar Site in 2005 is spread over an area of 7.5km² situated at an altitude of 1,584 m (amsl). The wetland harbours about five million migratory waterfowl during winter that migrate from Siberia and the Central Asian region. The wetland is fed by two inlet streams, Doodhganga [from east] and Sukhnag Nalla [from west]. The wetland attains a maximum depth of 2.5 m in spring due to appreciation in discharge from the snow-melt water in the upper reaches of Doodhganga catchment. Minimum water depth (0.7 m) was recorded in autumn [45]. The excess water is drained out through an outlet gate known as Needle- Gate on north-west of the wetland near the village Sozieth, having a weir and lock system, which regulates the water level to provide a better habitat for migratory waterfowl during winter.

Material and methods

Water samples were collected on monthly basis and the results were interpreted on seasonal basis. The analysis was carried out as per the standard of APHA, [47] and Wetzel and Likens, [48]. Color intensity was measured at 640nm (ammonical nitrogen), 410nm (nitrate nitrogen), 690 nm (ortho as well as for total-phosphate phosphorus), using Systronics-116 spectrophotometer modal. Among the six sites, three sites (II, III and IV) were located in the open water area having mostly submerged macrophytic growth while the remaining three sites (I, V and VI) were distributed in the rest of the wetland. Site I is located near the entry site of Doodhganga into the lake

near Hajibagh. Sites II and III have well developed macrophytic growth with little anthropogenic pressure. Site IV is located near the Zainakut area having anthropogenic pressure due to human interference. Site VI is located near the outlet of the wetland called Sozieth having direct influence of human as well as animal habitation (Figure 1). Statistical analysis was carried out by SPSS version 16 and PAST.

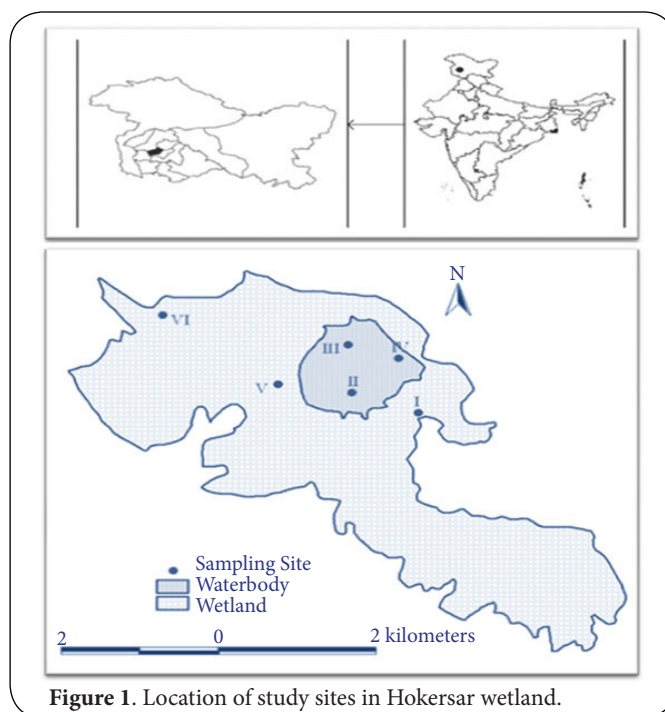
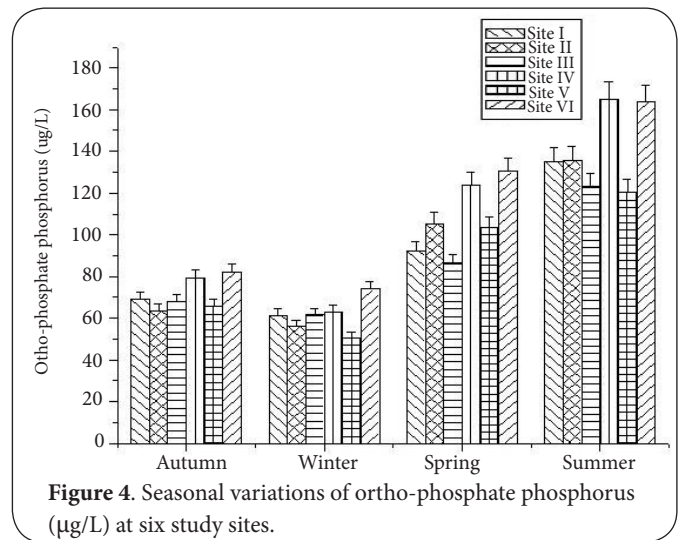
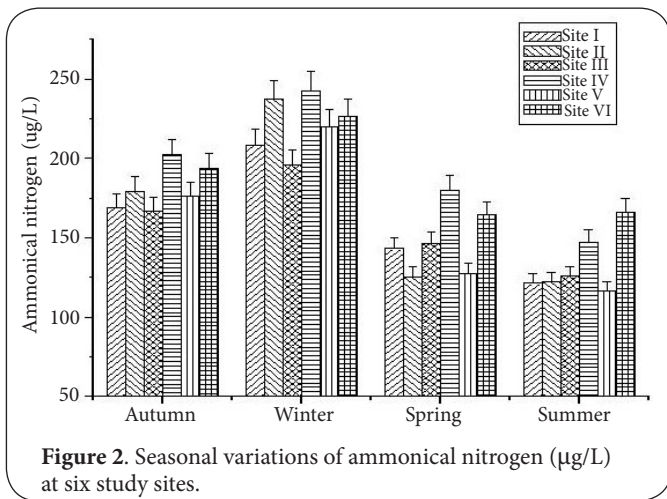


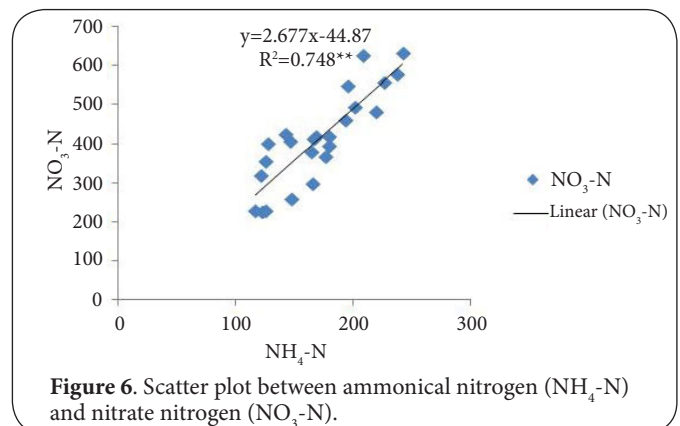
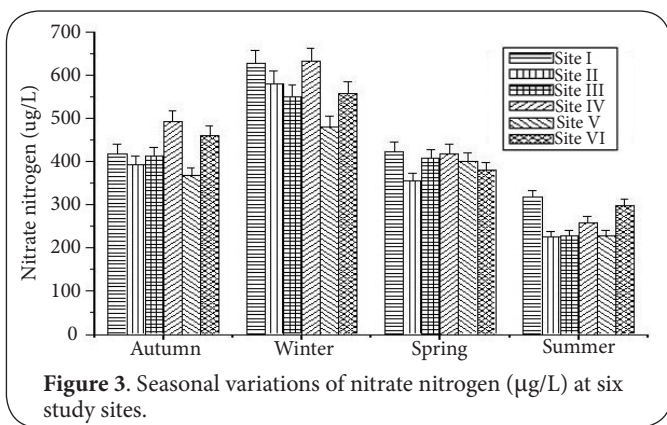
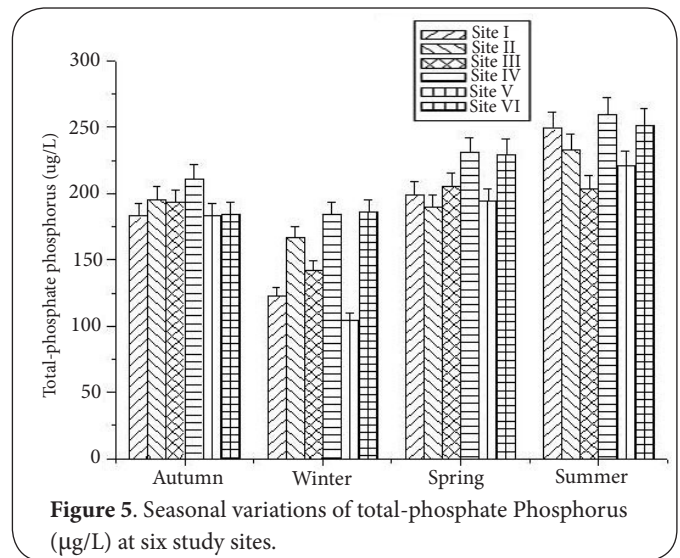
Figure 1. Location of study sites in Hokersar wetland.

Results and discussion

Major nutrients like nitrogen (N) and phosphorus (P) are crucial and are required to a large extent to support a variety of cell physiological functions [49]. These nutrients limit primary production especially in freshwater ecosystems [50,51]. Bioavailability of these nutrients in aquatic ecosystems varies among living organisms which mostly comprises of dissociated orthophosphate ions ($H_2PO_4^-$, HPO_4^{2-} and PO_4^{3-}) in the case of P [52] and nitrite (NO_2^-), nitrate (NO_3^-) and ammonium (NH_4^+) ions in the case of N [24]. Bottom-up control by phytoplankton also equally influences N and P, indicating co-limitation in aquatic ecosystems [53]. During the entire study period, distinct spatial and temporal variation were observed in ammonical nitrogen (NH_4-N) concentration which varied from a minimum of $116.2 \pm 18.8 \mu\text{g/L}$ in summer to a maximum of $242.3 \pm 10.1 \mu\text{g/L}$ in winter (Figure 2). In autumn the mean concentration was $181.2 \pm 24.8 \mu\text{g/L}$ with a minimum of $167 \pm 28.2 \mu\text{g/L}$ at site III and a maximum of $202 \pm 31 \mu\text{g/L}$ at site IV. Nitrate nitrogen (NO_3-N) concentration maintained a wide range fluctuating between $226.3 \pm 52.5 \mu\text{g/L}$ and $631.3 \pm 29.1 \mu\text{g/L}$. Lower values for the anion were observed in summer $259.6 \pm 35.3 \mu\text{g/L}$, where as higher values were registered in winter recording



570.6 \pm 51.5 $\mu\text{g/L}$ (Figure 3). Orthophosphate phosphorus (OPP) varied from 50.7 \pm 8.1 $\mu\text{g/L}$ during winter at site V to 165.3 \pm 21.1 $\mu\text{g/L}$ during summer at site IV. In general maximum concentration of OPP were registered in summer (140.4 \pm 16 $\mu\text{g/L}$), followed by spring (106.9 \pm 18.8 $\mu\text{g/L}$), autumn (71.3 \pm 5.7 $\mu\text{g/L}$) and decreasing to a minimum in winter (61.1 \pm 11 $\mu\text{g/L}$) (Figure 4). Total phosphate phosphorus (TPP) depicted a trend to similar that of OPP. Here again greater mean values of TPP were maintained in summer registering 236.2 \pm 13.6 $\mu\text{g/L}$ against the lower being registered for winter (151.2 \pm 15 $\mu\text{g/L}$) (Figure 5). Scatter plots showed highly significant correlation ($R^2=0.748$ and 0.719) within parameters (Figures 6 and 7).



Surplus input of N and P to waters is the major cause of eutrophication that degrades the water quality and ecological integrity of the systems [54-56]. Ammonical nitrogen is generated by heterotrophic bacteria as the primary end product of decomposition of organic matter and is readily assimilated by plants [57]. The lower concentrations of ammonical nitrogen and nitrate in summer can be attributed mainly due to sequestration by phytoplankton [58]. Higher concentrations of nitrate were recorded in winter, followed by

spring being attributable to combined result of nitrification at the mud water interface which eliminates any limiting effect of oxygen diffusion in the shallow lakes. The lower seasonal

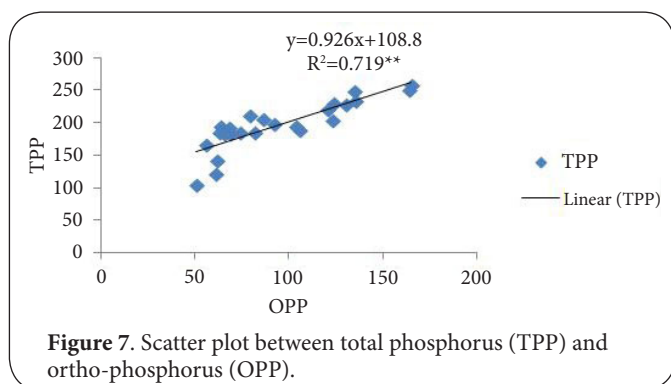


Figure 7. Scatter plot between total phosphorus (TPP) and ortho-phosphorus (OPP).

pattern of nitrate concentrations in growing season has been devoted to lower leaching [59]. Further, increase in nitrogen concentration in winters can also be ascribed to increasing nitrogen fluxes from the sediment and the decrease in burial rates are considered as potential drivers of rising nitrate concentrations in lakes [60]. Furthermore, increase in primary productivity in summer results in lowering the nitrate concentrations while in winter the biological activity is lowered, resulting in higher peaks of nitrate nitrogen [61-63].

Seasonal variations in concentrations of both the forms of phosphorus in the present study reflect a significant influence by internal lake processes [64]. A strong and similar seasonality have been attributed to high retention capacity of shallow lakes throughout world [65,66]. This capacity of retainability of P has been attributed to many factors, primary being the temperature simultaneously coupled with biological processes [64,67-70]. In summer the rise in temperature enhances the microbial activity which consequently results in the increase of diffusion process of P from the sediments to the overlying water column [71,72]. Besides diffusion process, change in pH and internal loading from sediments are considered to be the other plausible reasons [22,73-77]. Still further, seasonal variations in phytoplankton productivity are the other factors ascribed for higher peaks of P [78,79]. Likewise, TPP concentrations, showing more pronounced summer peaks, are attributable to increase in trophic level [80].

Principal component analysis (PCA) has been used to distinguish waters of different qualities [81] by chemometrics methods used for the classification and comparison of diverse variables [82]. In the principal components the vector displacement are directly related, being proportional to the level/extent of the effect of the parameters measured and the sites they refer to. The highest principle component vector displacement among the sites was concluded to be the most polluted site (e.g., sites IV and VI-**Figure 8**). In the present study Component 1 showed 17.189% variation with respect to nitrate nitrogen ($\text{NO}_3\text{-N}$), while Component 2 depicted highest variation of 81.701% with respect to ammonical nitrogen ($\text{NH}_4\text{-N}$). Greater influence of $\text{NH}_4\text{-N}$ and $\text{NO}_3\text{-N}$ was reflected by large Eigen-vector displacement values, contributing 3.36724 (%variance 84.181) and 0.542639 (%variance 13.566)

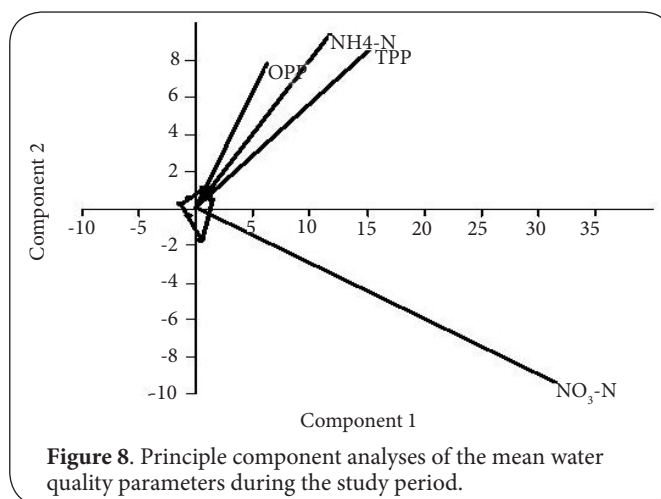


Figure 8. Principle component analyses of the mean water quality parameters during the study period.

respectively along the horizontal axis (**Table 1**). Similarity matrix was highest between $\text{NH}_4\text{-N}$ and TPP (92.9666%), followed by OPP and $\text{NH}_4\text{-N}$ [71.4259%] and OPP and TPP (65.094%) in a decreasing order (**Table 2**).

Table 1. Eigen value and percent variance within parameters.

Parameter	Eigen value	% variance
$\text{NH}_4\text{-N}$	3.36724	84.181
$\text{NO}_3\text{-N}$	0.542639	13.566
OPP	0.068808	1.7202
TPP	0.0213141	0.53285

Table 2. Similarity Matrix among the parameters.

Parameters	$\text{NO}_3\text{-N}$	OPP	TPP
$\text{NH}_4\text{-N}$	58.5729	71.4259	92.9666
$\text{NO}_3\text{-N}$	*	37.4081	64.5742
OPP	*	*	65.094
TPP	*	*	*

Bray-Curtis cluster analysis showed great similarity between sites IV and VI [0.97.8%] due to high anthropogenic pressure from the immediate catchment. Contrarily, site I showed maximum dissimilarity with all the remaining sites during the entire study period because it is located near the inlet of the wetland. Sites II and III showed immediate similarity (**Figure 9**) as both the sites are located within the open water with good growth of macrophytes. Carpenter and Adams [83] and Pandit [84] are of the opinion that macrophyte beds in the lake may be useful in retaining nutrients by locking them up in their tissues, some of which could afterwards be removed by harvesting these aquatic plants.

Conclusions

Management of these wetland ecosystems is important as

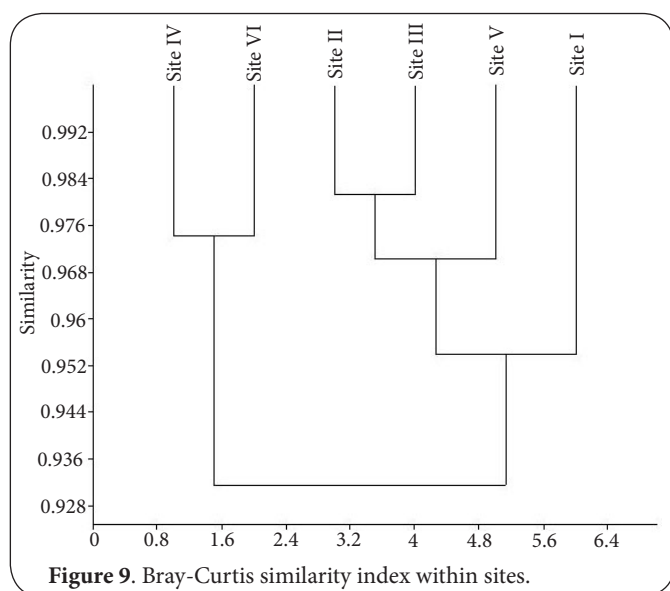


Figure 9. Bray-Curtis similarity index within sites.

they endow with a variety of repairment mechanisms naturally and behave as biofilters to a certain critical levels. The need of hour is to limit loading of N and P to these natural ecosystems and to control eutrophication has been widely recognized although some researchers advocate that a policy of control P-only should be adopted for the well being of water-dwelling organisms and that of the water itself to prevent it for further degradation.

Competing interests

The authors declare that they have no competing interests.

Authors' contributions

Authors' contributions	JAS	AKP	GMS
Research concept and design	✓	✓	✓
Collection and/or assembly of data	✓	--	--
Data analysis and interpretation	✓	--	--
Writing the article	✓	--	--
Critical revision of the article	✓	✓	✓
Final approval of article	✓	✓	✓
Statistical analysis	✓	--	--

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