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Full Length Research Paper

Studies on biomass changes and nutrient lock-up efficiency in a Kashmir Himalayan wetland ecosystem, India

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Wetlands are landscape sinks which accumulate and sequester a wide range of nutrients, heavy metals and pesticides. Whilst some studies hitherto have addressed the phyto-sociology and sequestering potential of wetland plants in isolation, we attempted to integrate the two aspects in a Kashmir Himalayan Ramsar site (Hokersar wetland), India. The results of studies (November, 2000 – October, 2001) on the seasonal biomass fluctuations and nutrient accumulation of aquatic plant communities in Hokersar wetland ecosystem are presented. Phytosociological attributes show emergents dominated by *Sparganium erectum* and *Typha angustata*, colonizing mainly the littorals. *Nymphoides peltata*, a dominant rooted floating plant species, is of frequent occurrence in relatively shallow and open waters. *Ceratophyllum-Myriophyllum* association dominates the submersed forms whilst the free-floating *Lemna-Salvinia* complex grows luxuriantly in side-channels. The plant biomass levels on areal basis (m^{-2}) fluctuated from 35 - 1100 g and the mineral concentration varied between 1.318 - 15.86 g (N), 0.052 - 0.597 (P) and 1.83 - 18.33 (K). Annual computations for nutrient lock-up potential gave values of 0.77×10^6 g (N), 0.02×10^1 g (P) and 0.89×10^6 g (K). Positive correlation was observed between aquatic plant biomass and nutrient lock-up efficiency. The results of the present study have implications for efficient eco-restoration of the wetland ecosystem through scientific management of macrophytic vegetation.

Key words: Kashmir Himalaya, aquatic plants, phytosociology, biomass, nutrient dynamics, lock-up efficiency, wetland ecosystem.

INTRODUCTION

Wetland ecosystems sustain diverse taxonomic groups, and are rated highly productive often equally or more productive than the adjacent terrestrial and aquatic ecosystems. However, wetlands fed by surface waters and agricultural runoff from urbanized watersheds tend to be relatively less species rich with low quality species (Kercher and zedler, 2004). Many workers have highlighted the ecological role of aquatic plant life viz; reduction of nutrients from agricultural run-off (Howard-William 1981; Deaver et al., 2005), water quality biomonitors (Gopal and Chamanlal, 1991), nutrient cycling including their utilization in the partial removal of heavy metals and toxic substances from waste waters (Vymazal et al., 2010; Micheal, 1995; Christina et al., 2002). Nevertheless, considerable interspecific and geographical differences of plant nutrient removal efficiency along different environmental gradients do exist (Schmidt et al., 2010). In view of the effects of burgeoning anthropogenic pressures and climate change on alteration of plant biomass, dominance patterns and community composition (Kardol et al., 2010), assessment of nutrient sequestration efficiency of macrophytes in wetlands assumes pivotal significance.

Ecological research on Hokersar, a favourite Kashmir Himalayan wetland characterized by semi-urban ambience, has received little attention though some

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preliminary treatments are given in Kaul and Zutshi (1967), Kaul (1982), Pandit and Qadri (1990) and Khan (2000). However, initiation of comprehensive studies in 2000 on the ecology of Hokersar wetland under the aegis of the Ministry of Environment and Forests, New Delhi have yielded series of publications covering waterfowl species composition and environmental threat perceptions (Khan, 2003) habitat complexity in relation to avifaunal diversity (Khan and Bashir, 2003), demographic trends in the catchments and phosphorus loading (Khan and Shah, 2003) water budget, flushing rate and sediment retention (Khan and Shah, 2004), ecorestoration measures (Khan et al., 2004). The present communication deals with further information (November, 2000 – October, 2001) on the seasonal aquatic vegetation distribution/ mapping, biomass fluctuations and nutrient (nitrogen, phosphorus potassium) lock-up efficiency by plant communities in Hokersar wetland ecosystem, India. The specific objective of this study was to evaluate the potential of macrophytes growing in the Hokerar wetland to sequester major nutrients, the increasing concentration of which leads to rapid evolution of the wetland from mesotrophy to eutrophy.

METHODS

Study area and physical background

Hokersar (34°- 7` N and 74°- 39` E) lies at a distance of about 10 km towards the northwest of Srinagar city (altitude 1584 m a s l) in the Kashmir Himalayan valley (Figure 1). The wetland is a shallow but permanent water body surrounded by catchments with varied land-use/land-cover patterns. The water body is fed by Doodganga, the only perennial channel, and several small, seasonal channels and it discharges via an artificially constructed needle-gate system at Soziath. There are a number of orchards, crop fields and willow plantaions in its catchment. The adjoining local population utilizes the water body for multiple purposes including large-scale harvesting, fishing, bird shooting, drinking, washing and irrigation. The land-use patterns around the wetland have been documented in detail earlier by the authors (Khan and Shah, 2004b). The wetland area of 1326 ha is fragmented into marshland (550 ha) cultivated land (270 ha). Siltation, over the years, has claimed almost 72 ha thereby reducing the open water body to 17 ha. Aquatic vegetation is spread over 187 ha whilst the willow plantation in wetland covers 130 ha (DEARS, 2000). The wetland is fed by a main feeding channel (Doodganga) and two seasonal channels (Soibugh and Dharmuna). The outflow at Soziath is regulated by means of needle weir gate system.

Phyto-sociology and nutrient lockup studies

The standing crop of macrophytes was obtained by using quadrate method and harvesting the plants on seasonal basis during spring, summer autumn and winter. The quadrant size of 1 m^2 was used for sampling of emergents, and rooted floating leaf-type macrophytes and 0.5 m^2 was used to sample free floating types. Sampling for the submerged macrophytes was achieved using the Eckman dredge. The frequency, density and abundance of dominant macrophytes was done following (Misra, 1968). Identification is based on the published literature of Subramanyan (1962), Zutshi (1975), Kak (1985), Fassett (1992) and Cook (1996). The plant nutrients (Nitrogen, Phosphorus and Potassium) were determined following Jackson (1973). Nitrogen was estimated using micro-kjeldhal's method whilst phosphorus was determined by digestion following Vanadophosphoric acid yellow colour method. Flame photometer (Systronics) was used for the estimation of potassium content. Accumulation of nutrients such as N, P, and K, per kg of biomass in the macrophytes was worked out from the analysis of samples of plant as described above followed by multiplying the values obtained with the oven-dry weights of the respective plant parts. For calculating the nutrient accumulation per unit area, the respective mean values for macrophytes were multiplied with the plant density i.e. the number of plants per unit area.

RESULTS

Phytosociology and mapping of aquatic vegetation

Phytosociological observations revealed the categorization of diverse aquatic plants into emergents, rooted floating leaf type, free-floating type and submersed ones. The emergent (*Sparganium erectum, Typha angustata, Cyperus serotinus, Phragmites australis and Polygonum hydropiper)* colonize the littoral regions of the wetland. The dominant macrophyte, *S. erectum* is spread over expanded peripheral area with distinct tendency to invade open waters. Rooted floating-leaf type dominated by *Nymphoides peltata* and *Potamogeton natans* are distributed mainly in shallow waters of wetland and towards littoral marshes developing a complex physiognomy*, N. peltata* dominates open waters profusely. Some aquatic plants of medicinal importance (e.g *Acorus calamus, Euryal, ferox, Nelumbo nucifera)* were no more observed to be growing. The distribution of free-floating plants (*Lemna gibba, L. minor, Salvinia natans*) effectively influenced by hydrological fluctuations usually dominate the side-water channels, rich in organic matter. The increased water levels drift the free-floating species towards the littorals, water flow favouring plant accumulation near the semi-closed outlet at Soziath towards the western side of the wetland. Among submerged ones, dominants include *Potamogeton pectinatus*, *Potamogeton crispus, Potamogeton filiformis, Potamogeton lucens,* However *Ceratophyllum-Myriophyllum* complex conspicuously dominate the open waters whilst species of *Potamogeton* occur frequently in eastern part of the wetland and feeding channels.

The seasonal distribution of macrophytes in the Hokersar wetland shows considerable variation (Figure 2). The results indicate that during winter (December - February), macrophytes hibernate and appear in dormant state; the diversity and abundance of plants being considerably low. During spring (March-May), macrophytic vegetation starts growth again and towards end of season is seen spreading all over the wetland. Most of the species (e.g *Batrachium trichophyllum, Rananculus lingua, Potamogeton spp; N. peltata, N. stellata, S. erectum)* start flowering during spring season.

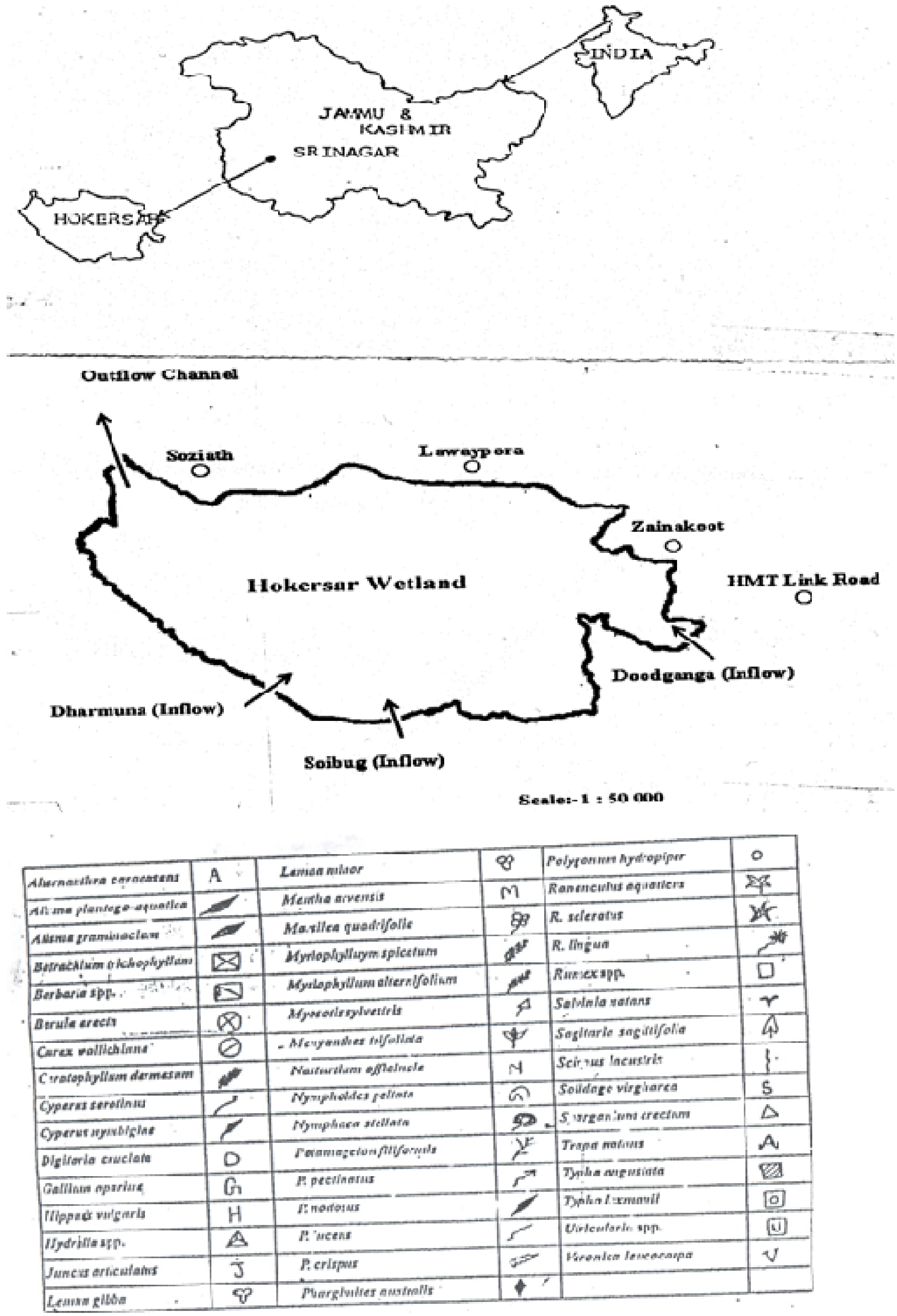

Figure 1. Location of Hokersar wetland near Srinagar (above) and outline map of the wetland showing adjoining areas (below).

Figure 2. Seasonal distribution of macrophytes in Hokersar (legend given separately).

Table 1. Nutrient accumulation per annum (November, 2000 - October, 2001) in macrophytes of Hokersar wetland.

Nutrient	Amount accumulated (Metric ton)
Nitrogen	0.77
Phosphorus	0.02
Potassium	0.8

However, *S. natans* was observed to be extremely rare or absent during March - April; the weed starts re-emerging from May onwards. During summer (June - August) *P. pectinatus and P. filiformis* dominating the western side of the wetland start declining and a large scale harvesting of macrophytes by local inhabitants is a common sight observed in the wetland. The aquatic vegetation generally enters the declining phase during autumn (September - November) which continues till winter (December - February)

Plant biomass changes

The macrophytic biomass fluctuated from 35 - 1100 g m^{-2} showing considerable site-specific variation. Highest biomass values were recorded at Shikarghat, representing the marshy littoral regions whilst relatively low values were obtained for open water areas in the centre of wetland. The biomass showed an evident increase from the onset of spring (March - May) reaching minimum during winter (December - February).

Nutrient concentration

The variability in nitrogen concentration (0.531 - 1.821%) of the macrophytes was markedly distinct; progressive increase observed with the onset of spring and decreasing to low records during winter, results showing direct correlation with biomass changes. The minimum nitrogen accumulation (1.318 g m^{-2}) was recorded during January and maximum (15.86 g m^{-2}) during April. The phosphorus content of aquatic plant life revealed site - specific variations ranging from (0.01 - 0.09%) showing an increasing tendency from spring onwards and again decreasing trend during winter. The phosphorus lock- up followed a similar trend like nitrogen showing maximum value (0.597 g m^{-2}) in April and minimum (0.052 g m^{-2}) in January.

The potassium content in aquatic vegetation in macrophytes ranged from 0.4209 - 2.6601% following a similar seasonal trend of nitrogen and phosphorus with increasing tendency observed from spring onwards and decreasing again in winter. Maximum lock- up of (18.33 g m^{-2}) was observed during April and minimum (1.83 g m^{-2}) in January. The pools of nutrient in the aquatic plants of Hokersar wetland (Table 1) showed maximum annual accumulation of potassium and minimum phosphorus level; the order of sequence being K>N>P.

DISCUSSION

Many wetland plants are beneficial for nutrient mitigation (Vymazal et al., 2010) and significant progress has been made for wetland restoration using macrophytes (Zedler, 2000). Important macrophytic species used generally for nutrient mitigation include Typha, Schoenoplectus (Malecki-Brown, 2010) and other species such as *P. australis*, *Myriophyllum spicatum and P. crispus*. The aquatic macrophytes for the most part are considered (Moss, 1980) to have a very rich nutrient supply in the sediments. Hokersar, a shallow wetland in the flood plain of Kashmir Valley also contains rich P-pool in the sediment (10 cm) accounting for 99% of the total pool (Khan and Shah, 2003). The ecosystem sustains luxuriant growth of diverse life forms of vegetation (emergent, submerged, floating). The changing hydrological regimes induce diverse habitat delineation which leads to distinct macrophytic zonations. Grazing pressure and plant-harvesting further alter the environmental mileau of aquatic vegetation in Hokersar wetland. The wetland littoral is comprised of mainly emergents. Sub-dominant emergent plants (covering 50 - 75% has *T. angustata* as an important member. Among rooted floating leaf type, *N. peltata* is the dominant plant (> 75%) whilst *Nymphaea stellata, P. natans and Marsilea quadrifolia* occur frequently (25 - 50% coverage) in the wetland. *Myriophyllum verticillatum and P. crispus*, both submersed plants revealed 50 - 75% coverage (sub-dominants). Free floating types were dominated (> 75%) by *Lemna minor and S. natans* (Figure 2) in the Hokersar wetland.

While the macrophytic species composition in the wetlands is generally quite diverse (Khan et al., 2004), occurrence of only 47 species presently in the Hokersar wetland, against 67 species listed in by Kaul and Zutshi (1967), is indicative of declining aquatic biodiversity. The decrease in the number of species may be attributed to accelerated eutrophication, and anthropogenic pressures. Plants at the extremes of an environmental gradient survive because of their great ecological tolerance to such environmental conditions. The life-form gradient of vegetation is maintained by competitive exclusion and displacement. Zones comprising of one plant species particularly emergents and submersed ones characterize Hokersar wetland. Such a situation is attributable to their position at the opposite ends of environmental gradient. According to Nilsson et al. (1991) increasing species diversity is linked with increasing habitat heterogeneity. Over the years, Hokersar wetland witnessed considerable shift in the vegetation pattern, and even some economically important plant species (*Nelumbo nucifera, Euryale ferox and Acorus calamus*) have almost disappeared. A notable change is reflected by the fast spread of *S. erectum* replacing *P. australis* to the greater extent in the wetland. This shift in aquatic macrophytic community structure may be attributed to changing environmental conditions especially nutrient status of the wetland which is in agreement with the studies done elsewhere by Hayati and Proctor (1991), Verhoeven et al. (1996) and Keddy (2000). Considerable site-specific variation ranging from 35 - 1100 g m^{-2} (= 0.35 - 11 metric tons) in plant biomass of Hokersar wetland was evidenced. Marshy littoral zones having emergents sustained maximum biomass whilst open waters especially wetland centre supported minimum biomass. Zutshi (1996) reported 52 metric tons (average of three wetlands) of biomass production of macrophytes. The author also reported much higher nutrient uptake by aquatic plants in highly eutrophic Trigamsar, Kashmir.

The macrophytic component of Hokersar wetland was estimated to lock up high quantities (metric tons) of nutrient viz. (0.77) nitrogen, (0.02) phosphorus and (0.89) of potassium respectively (Table 1) during the present study. Nitrogen and Phosphorus are closely linked in plant metabolism, especially with protein synthesis. In aquatic plants, close correlation has been reported (Duarte, 1992) between N and P levels. The increase in the nutrient content of the macrophytes from spring onwards corresponds to the luxuriant growth of vegetation during this season throughout the wetland, which dies and decays with the onset of late autumn to winter when least values of nutrient accumulation values were observed. The results are in agreement with Kaul et al. (1981) who estimated the total nitrogen accumulation of 15.9 metric tons ha^{-1}.

Thus, the lock up efficiency is positively related with the production of biomass and if harvested periodically it will greatly help in the reduction of nutrient load and check eutrophication. Kaul and Trisal (1985) working on the mineral nutrient accumulation of various macrophytes in Kashmir wetland (L. Anchar) obtained total nutrient (m.tons) of N = 10.7, P = 0.5, K = 5.15. Recently, Khan and Shah (2003) estimated the annual phosphorus load of 48.56 metric tons on the wetland with 18 metric tons brought through surface inflow and rest through anthropogenic input. Ishaq and Kaul (1989) estimated that in Dal Lake, macrophytes hold a phosphorus pool of 3.64 metric ton thereby acting as biological nutrient sinks. However, only a part of the vegetation in Hokersar wetland is transformed into animal biomass whilst the rest decays and decomposes thereby adding a large quantity of organic matter and debris brought to the wetland by various feeding channels. According to Gopal and Kulshreshtha (1980), emergent macrophytes because of larger biomass and production rates, have better nutrient removal potential / efficiency than other macrophytes.

In conclusion, the maintenance of congenial environmental conditions in Hokersar wetland entails, among other things, the reversal of nutrient enrichment, partially through periodic removal of nutrients by dredging the accumulated sediment mass. Pollution from point and non-point sources should be addressed on scientific grounds which should necessarily focus on catchments treatment to arrest the heavy input of nutrients into the system. The indiscriminate harvesting of aquatic macrophytes as a major nutrient-removal mechanism is not desirable since the wetland sustains myriad of water fowl population. However, selective manual/mechanical deweeding could be an alternative option for ensuring the proper ecology of the wetland ecosystem.

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