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Plant species richness and community composition along the land–water interface in lacustrine wetland of Gorakhpur, India

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In wetland, the disturbances that influence the distributional pattern of plant community along the land-water interface are thought to be driven by spatial variations in water regime. Tropical wetlands are among the most productive ecosystems, containing unique aquatic and terrestrial communities. In the lacustrine wetlands a distinct zonation from aquatic to terrestrial vegetation exists. This study was aimed to investigate the effect of water regime in plant species composition and richness in wetlands of Tal-Kandala, north-eastern Uttar Pradesh, India. The analysis of data shows that highly disturbed communities were poor in species richness while communities with moderate disturbances were comparatively richer. The deep-water community showed low species richness due to various disturbance regimes and homogeneity of the aquatic habitats where most of the species are highly specific to habitat conditions. The richness of species in periodically flooded lowland community was considerably greater due to invasion by weeds from the surrounding agricultural field. Our results indicate that shallow water community showed negative relationship between species frequency and abundance while the rest five communities were positively correlated. This study is a step towards a better understanding of plant communities within the landscape; and provides basic information to manage the conservation of wetland vegetation.

Key words: Tal-Kandala, water regime, phytosociology, plant community.

INTRODUCTION

Changes in the structure and species composition of vegetation are sensitive indicators of the prevailing impact of both physical and biological environmental factors (Odum, 1963). In wetlands for example, the disturbances cause community change and/or maintain communities in early successional stages include allogenic hydrological alterations, herbivory and anthropogenic influences (van der Valk, 1981).

The distributional pattern of plant community along the land-water interface in wetlands is thought to be driven by spatial variations in water regime (Brock and Casanova, 1997; Magee and Kentula, 2005; Zhou et al., 2006). The most important factor that determines the position of vegetation zones along coenoclines in wetland is the water regime (van der Valk, 1994); this also importantly influences community composition (Hall et al., 2008).

Wetlands are the ecosystem that provides numerous biological and economic benefits, including ground water recharge, filtration and storage of sediments, nutrients and pollutants and flood water storage and attenuation as well as providing habitat to numerous species across a broad array of taxa (MEA, 2005). Tropical wetlands are among the most productive ecosystems, containing unique aquatic and terrestrial communities (Posa et al., 2011). Several studies have been carried out on the wetlands of India (see Ghavzan et al., 2006; Sunil et al., 2010; Kumar et al., 2011), including in-depth ecological investigations (Sen and Chatterjee, 1959; Sahai and Sinha, 1969; Mishra and Narain, 2010; Dwivedi et al., 2015). However, the wetland communities of north-eastern Uttar Pradesh remained largely underexplored.

Lacustrine wetlands are wetlands and deep-water habitats situated in a topographical depression or dammed river channel; lacking trees, shrubs, persistent emergent vegetation and with a total area larger than 20 acres (Cowardin et al., 1979). Lacustrine wetlands include permanently flooded lakes, intermittent lakes, reservoirs and tidal lakes. Lacustrine wetlands have distinct zonation from aquatic to terrestrial vegetation. The present study, therefore, aimed to investigate the plant species composition of communities with respect to water regime of the lacustrine wetland of north-eastern Uttar Pradesh.

MATERIAL AND METHODS

Study site

For this study, Tal-Kandala wetlands were selected as representative of lacustrine wetland vegetation of north-eastern Uttar Pradesh. Tal-Kandala Wetlands are a series of small interconnected freshwater lakes (Narahi, Berra, Gonahia, Jatiya and Bahari) located in south-east of Gorakhpur city which connect to the river Rapti through the Goura-Nala. The study sites lie between 26°13′ to 27°29′ N and 83°05′ to 83°56′ E and 84 m asl. These area experience regular anthropogenic activities, fuel wood collection, foraging and grazing by wild and domestic animals in the dry season. The use of Nitrogen and Phosphorus fertilizers, mostly urea and di-ammonium phosphate (DAP), for agriculture in the catchment area enhances eutrophication of this study site (Figure 1).

The climate of Gorakhpur is humid subtropical, that is typically monsoonal. The total average annual rainfall is about 1814 mm and 93 per cent of it occurs during wet summer or rainy season. The number of rainy days per annum is 51 ± 3.2 and the annual mean of relative humidity ranges between 74-87%. Mean maximum temperature during wet summer is 35.2 ºC and the mean minimum temperature is 26.2 ºC (Dwivedi et al., 2015).

The geology of the district is primarily river born alluvium. The soil in the district is a part of trans-sarju plain and has been derived by the sinking of the crust under the weight of alluvial deposits brought down by river Ghaghra, Rapti and Rohin from the Himalayas. The soil is sandy loam to clay loam of yellowish brown colour and the soil reaction is moderately alkaline.

Identification of plant communities

Plant communities of Tal-Kandala wetlands were identified on the basis of local ecological factors determined by topography, water/moisture status. The six concrete communities are **A:** Deep water, **B: S**hallow water, **C:** Marginal marshes, **D:** Seepage slopes, **E:** Periodically flooded lowland and **F:** Intermittently flooded upland (Figure 2). These concrete communities were analysed for various phytosociological attributes based on data recorded during rainy season (July-Oct.) of 2013 and 2014. Species present in 50% of the plant communities were treated as commonly occurring species and those restricted only to a particular community were treated as exclusive species of that community.

Sampling

For the observation of quantitative characters of communities square quadrat method was used. The square quadrats (Relevė of Braun–Blanquet) of 1m^2 (manufactured with hollow PVC pipe) were laid within each concrete community. Plant species were identified with the help of regional floras, taxonomic revisions and monographs by using identification keys (Hooker, 1872-1897; Subramanyam, 1962; Cook, 1996; Srivastava, 1976; Saini et al., 2010). Unidentified species were collected and verified from the voucher specimens from the herbarium of the Department of Botany, Deen Dayal Upadhyaya Gorakhpur University, Gorakhpur.

The vegetal cover was estimated through chart quadrat method. The occurrence and numerical strength data was used to estimate frequency, density, abundance and per cent vegetal cover. The relative values of these indices (relative frequency, relative density and relative vegetal cover) for different species were determined for the computation of Importance Value Index (IVI). The above phyto-sociological indices were calculated on the basis of conventional methods described by Mueller-Dombois and Ellenberg (1974) after Oosting (1956) and Kershaw (1964). The indices of similarity between any two communities were estimated by the formula of Sørensen (1948).

Data analysis

Cluster analysis (unweighted-paired group method with arithmetic means, UPGMA) was used to analyse floristic similarity among the concrete communities. Groups were determined by using the arithmetic average of Sørensen similarity index which generate a dendrogram (Sneath and Sokal, 1973). Species were examined using non-metric multi-dimensional scaling (NMDS) ordination method with 95% concentration ellipse in PAST (Hammer et al. 2001) software to compare them across the various plant communities. A matrix with IVI of each species in each community was arranged to calculate similarity by Bray-Curtis method which has been found to provide a robust

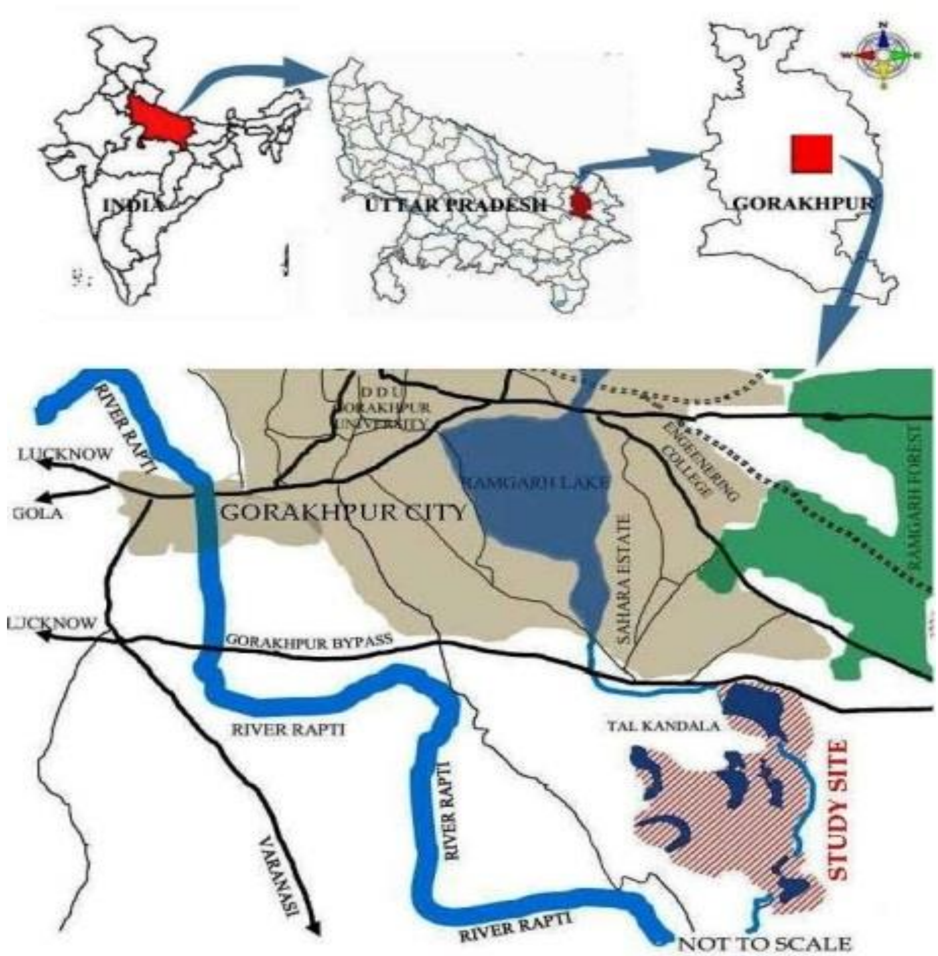

Figure 1. Map of study area with study site and wetlands.

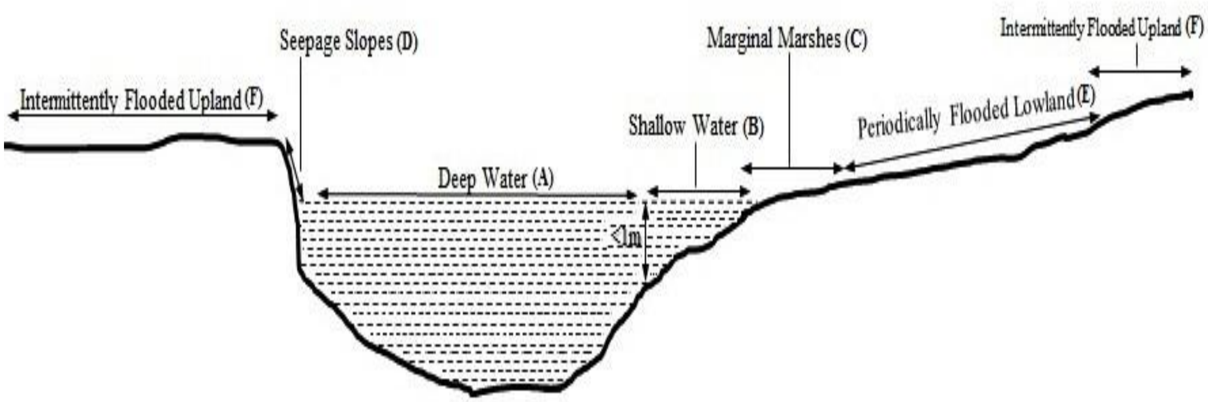

Figure 2. Schematic diagram of plant communities and zonation within Tal-Kandala (Lacustrine) wetlands.

index of dissimilarity among species (Faith et al., 1987; Clarke, 1993). We also used linear regression to determine the relationship between species frequency and species abundance using Graph Pad

Prism version 6 software (Motulsky, 1999).

RESULTS

A total of 108 species belonging to 77 genera under 39 families were recorded in the sampled area during the study of general quantitative characters of wetland communities. The number of species in concrete communities varied from 65 (periodically flooded lowland community, E) to 14 (deep water community, A). Deep water community has no any exclusive species while periodically flooded lowland contains greater number of exclusive species (28%). The number of common species sharing more than 50% of communities varied from 2 to 9 in each community (Table 1).

Cluster analysis, UPGMA (Figure 3) showed that two groups were formed at a low level (0.16) of similarity of the plant communities at the study site. In terms of species richness, community B was closely similar to community C in first cluster while in second; communities D and E were closely similar.

The final configuration of NMDS ordination, that mimics the original positions of wetland species in multidimensional space, produced a lowest solution in two dimensions with a final stress of 0.2833. As evident from 95% concentration ellipse, 3 species namely *Croton bonplandianum, Kohautia gracillis* and *Scirpus articulatus* appeared isolated from the others (red dots).

Clustering of species with green dots was represented by the exclusive species of shallow water community; Violet dots of the NMDS diagram also shows clustering of exclusive species such as - *Bacopa monnieri*, *Caesulia axillaris*, *Corchorus capsularis*, *Cyperus digitatus* and *Melochia corchorifolia*.

These exclusives were of marginal marshy community. A larger group of clustered species denoted by cyan dots belong to exclusives of periodically flooded lowland community. Magenta colour squares show distribution of commonly occurring species across different plant communities.

Anchored floating, free floating and submerged species showed more dispersion than other species probably because of their greater frequency/density (e.g. *Lemna minor*, *Spirodela polyrrhiza*) or vegetal cover (e.g. *Nelumbo nucifera*, *Euryale ferox*). Most of the species grow at transitional depth or land water interface were arranged towards the center of the ordination diagram such as - *Echinochloa colonum*, *Enhydra fluctuans*, *Hygrophila polysperma*, *Ipomoea aquatica*, *Polygonum glabrum, Polygonum lanigerum* and *Polygonum limbatum* (Figure 4).

Regression analysis indicated that species abundance increased with species frequency in communities A, C, E and F. Community D showing a much weaker relationship while community B showing negative correlation of species abundance with increased species frequency. Only community E shows significant correlation between abundance and frequency of species (Figure 5).

DISCUSSION

The variability in species composition of communities depends on water regimes within the wetlands (Barbour et al., 2003; San Martin and Alvarez, 2009). On the margins of lakes, variation in species composition can be driven by elevation relative to water level and disturbances (flood, harvesting, grazing, anthropogenic) The deep-water community however showed low species richness and may be related to homogeneity of the aquatic habitats compared to the terrestrial ones (Singh, 2015). Moreover, the poor species richness of the deep water zone may be because most of the species are highly specific to habitat conditions, thus, the same species occur at nearly all sites. Submerged plants are often highly disturbed by boats, grazing water fowl, waves and lower water levels (Jupp and Spence, 1977) persisting through recolonization, usually by vegetative propagules (Combroux et al., 2001).

The primary result shows that the community B (Shallow water) was more similar to community C (Marginal marshes) due to their characteristic species such as - *Alternanthera philoxeroides*, *Cyperus flabelliformis*, *Hygroryza aristata*, *Leersia hexandra*, *Paspalum distichum*, *Potamogeton nodosus*, *Sagittaria sagittifolia* and *Sparganium ramosum*. Further, quite similar results were found in respect to community D and E. Some species namely, *Alternanthera sessilis*, *Ammannia multiflora*, *Dentella repens*, *Heliotropium indicum*, *Mazus pumilus*, *Mollugo pentaphylla and Nicotiana plumbaginifolia* were exclusive but common in these communities. The richness of species in periodically flooded lowland community (E) was of considerable importance as they hold a disproportionate number of species (Wheeler and Shaw, 1991; Johnson and Leopold, 1994). In this community species richness was also enhanced due to invasion by weeds from the surrounding agricultural field.

Frequency is a measure of the uniformity of the distribution of a species; thus a low frequency indicates that a species is either irregular or rare in a particular stand (Chen et al., 2008). *Eichhornia crassipes* and *Ipomoea aquatica* were most frequent within the site due to their ecological adaptations in both aquatic and semi-aquatic conditions.

Our results also showed the negative relationship between species frequency and abundance of shallow water communities. Species common at

Table 1. Plant species composition of different communities in the study site as observed in quadrat sampling.

Communities	Family	Genera	Species	Exclusive Species/ (%)	Commonly Occurring Species
Deep water (A)	12	13	14	-	2
Shallow water (B)	26	38	45	8 (18)	7
Marginal marshes (C)	24	35	49	5 (10)	7
Seepage slopes (D)	18	27	34	1 (3)	9
Periodically flooded lowland (E)	23	42	65	18 (28)	9
Intermittently flooded upland (F)	11	16	17	3 (18)	3
Total (Abstract community)	**39**	**77**	**108**		**10**

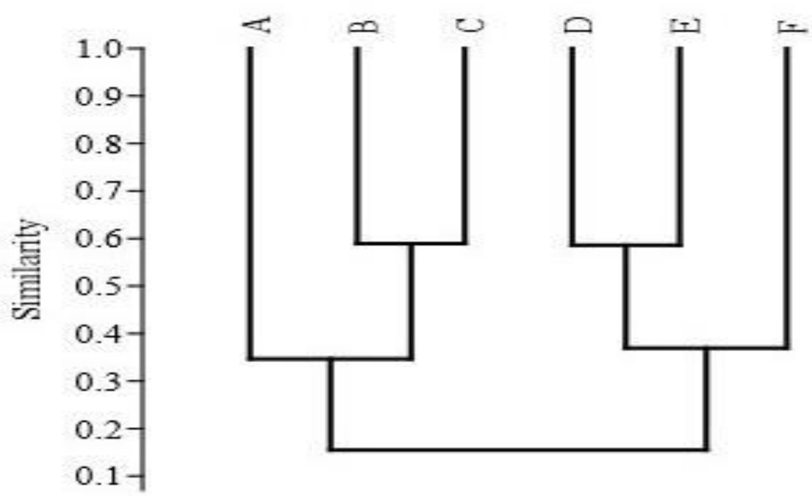

Figure 3. Dendrogram showing similarity of species among plant communities (A-F).

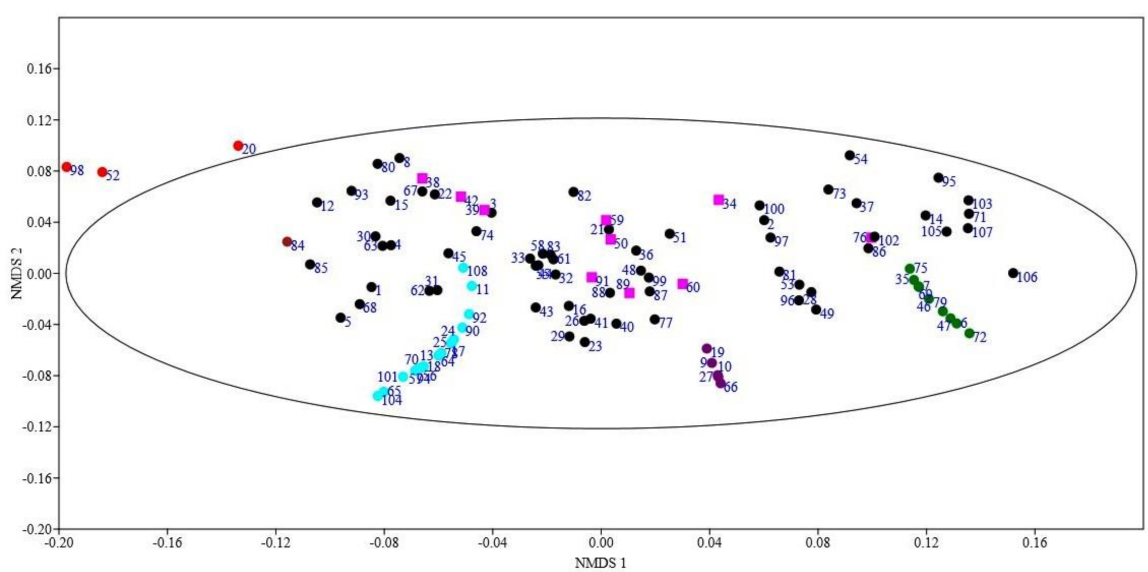

Figure 4. Ordination diagram of non-metric multidimensional scaling (NMDS) for comparing composition of wetland species on the basis of their IVI. Coloured dots show exclusive species of the communities viz. Green-B, Violet-C, Brown-D, Cyan-E and Red-F. Magenta coloured squares shows commonly ocuring species across different communities.

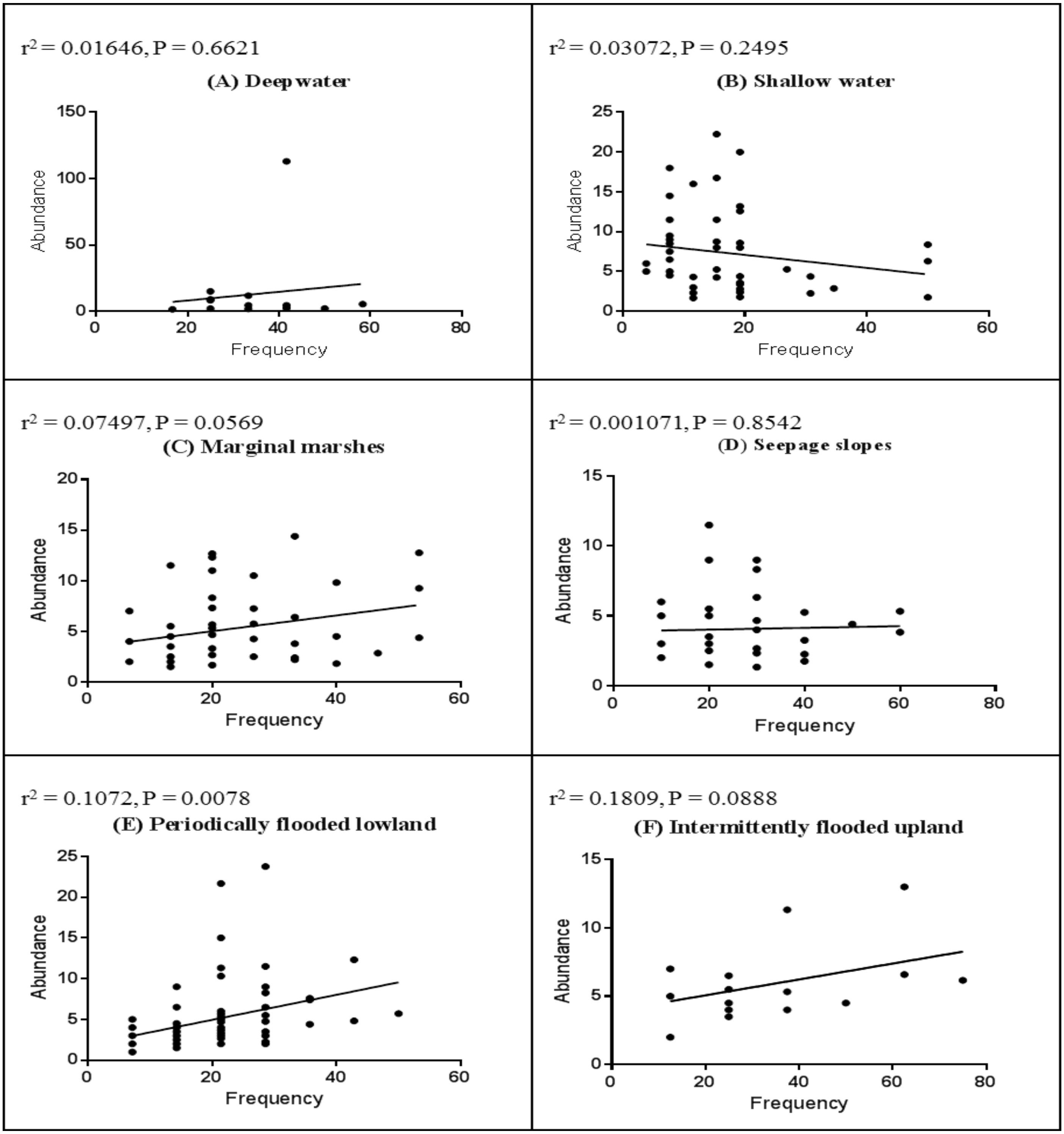

Figure 5. The relationship between species frequency and abundance in different plant communities (A-F) of lacustrine wetland.

local scale tend to have both high abundance and high frequency, and consequently there might be a few species dominating a large area (Pitman et al., 2001).

The intermittently flooded upland communities have only open places to grazers when lowland species were submerged during normal floods. The poor species composition of upland community is a cause of severe grazing and scraping. Most of the upland species such as - *Atylosia scarabaeoides*, *Centaurium centaurioides*, *Parthenium hysterophorus*, *Phyllanthus urinaria*, *Croton bonplandianum*, *Kohautia gracillis* were ruderal (Grime, 1977), and they maintained their population through rapid production of seed rather than storage organs (Pulliam, 1988).

Different disturbance regimes or different moments after disturbance may underlie different processes with different resource limitations. Different animals have different grazing behavior and feeding preferences, which affect species composition (Menard et al., 2002) hence, grazing, flooding, eutrophication and other disturbances, had positive effects on frequency and density values of some species and negative effects on others. Grazing might be interacting to water regime in wetland (Crosslé and Brock, 2002). Trampling also affect species composition, which creates bare patches. These patches were further colonized by opportunist's annuals and/or stoloniferous species. Grace and Ford (1996) found that grazing and clipping combined with flooding reduced the ability of marsh plants like *Sagittaria sagittifolia*.

On the basis of IVI, different species were dominant in different communities such as - *Lemna minor* in A, *Eichhornia crassipes* in B, *Cyanotis axillaris* and *Sparganium ramosum* in C, *Atylosia scarabaeoides* and *Lippia alba* in D, *Xanthium strumarium* and *Ipomoea fistulosa* in E and *Evolvulus nummularius* in community F. The dominance of one or two species in each community explains distribution pattern influenced by water regime (raising and lowering water level), grazing and anthropogenic disturbances (van der Valk, 1991).

The greater IVI of species like *Eichhornia crassipes*, *Alternanthera philoxeroides*, *Cyanotis axillaris*, *Ipomoea aquatica*, *Potamogeton crispus* and *Sagittaria sagittifolia* may be related to their characteristic growth pattern through clonal growth organs and flowering after longer period of flooding disturbance. They behave as stress-tolerant category of Grime (1974, 1979).

For instance, *Eichhornia crassipes*, *Fimbristylis aestivalis*, *Fimbristylis miliacea*, *Ipomoea aquatica*, *Lippia alba*, *Merremia gangetica*, *Polygonum lanigerum* and *Polygonum limbatum* were generalists species showing high presence values within the communities, indicating wide ecological amplitude covering various microhabitats (Oosting, 1956). In the context of IVI, *Lindernia crustacea*, *Spilanthes acmella*, *Kohautia gracillis*, *Scirpus articulatus*, *Melilotus indica* and *Trianthema portulacastrum* were among the rarest ones, in these wetlands. Hubbell and Foster (1986) found that most rare species are specialists either in habitat or in regeneration niche.

The analysis of data shows that highly disturbed communities A and F were poor in species richness while communities B, C, D and E were comparatively richer due to moderate disturbances (Grime, 1973; Huston 1979) which promote the growth of both semiaquatic and terrestrial species. Mostly, these species may reproduce, either through clonal growth organs (Klimeš and Klimešová, 1999) or by means soil seed bank (Leck, 1989). In wetland ecosystems, seed banks are relatively homogeneously distributed across elevation gradients (Haukos and Smith, 1993). Indisputably, it was recorded that water regime was a crucial factor that influenced the species richness and community composition in wetland vegetation.

Conclusion

The study shows that variability in species composition of communities can be driven by elevation relative to water level and disturbances. The interaction of disturbances with fluctuating water availability may influence species richness in various communities. These species may be aquatic, semiaquatic, terrestrial, invasive, rare or dominant in a particular community, which may depend on their adaptability through reproductive and dispersal ability. The study points out that intense biotic pressure interacting with water regime causes heterogeneity within community. This study is a step towards a better understanding of plant communities within the landscape; they provide basic information to manage the conservation of wetland vegetation. This study is additive to a needed ecological base line on plant ecology in regional wetland. Ultimately, this become a key factor in developing plans for managing and preserving aquatic and wetland habitats in north - eastern Uttar Pradesh.

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