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Species Diversity and Composition of Macrophytes in Shallabugh Wetland, Ganderbal, Jammu, and Kashmir, India

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Macrophyte diversity, richness, and composition of the Shallabugh wetland Reserve, one of the Important Bird and Biodiversity Area in India. The wetland shows the presence of 39 plant species of 27 families and three tree species belonging to three families and a diversity index of H = 3.12 and Evenness e^H/S = 0.5836. The high Importance Value Index (IVI=22.8) was recorded for *Typha latifolia*, followed by *Ceratophyllum demersum* (IVI=19.2). The shift in macrophyte community structure is evidenced by the local extinction of *Nelumbo nucifera* from the Shallabugh wetland area and the near-disappearance of some economically important plants such as *Trapa natans* (IVI= 0.24). The investigation of various aspects of the wetland ecology of Shallabugh reveals that species composition has witnessed great changes over the years. The conversion of

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the 141 hectares of wetland into grassland gave way for terrestrial species to flourish. The study serves as the baseline study of the macrophyte community composition and structure of the Shallabugh wetland.

Keywords: Macrophyte; Shallabugh wetland; important bird area.

1. INTRODUCTION

The vegetation is a crucial component that reflects the health of an ecosystem as a whole. The vegetation composition of wetlands fluctuates from season to season, and over the years in a successional manner. These fluctuations suggest a response by each species to the prevailing biotic and abiotic factors as modified by the vegetation itself [1]. The study of species composition and the social interactions of species in communities are both included in vegetation ecology. It emphasizes the geographic distribution, composition, development, and plant community environmental interactions [2,3]. A detailed vegetation analysis provides information about species diversity, community structure, niche, and turnover rate of species in an ecosystem. Wetland ecology is dynamic and changes with the water depth, providing fluctuating transitional zones for vegetation to develop [4].

Kashmir wetlands have been well studied for limnology from time to time. Ecological studies have been carried out on Shallabugh by [5], [6], [7], [21]. But no attempts have been made to study the plant community structure of the Shallabugh wetland, therefore in the present study, an attempt was made to study the phytosociology of macrophytes.

In India, macrophytes, are vital components of aquatic ecosystems, face threats from pollution, habitat destruction, and invasive species [8]. Pollution sources, including agricultural runoff and industrial discharge, degrade water quality, impacting macrophyte populations [9]. Habitat destruction through wetland drainage and land conversion further threatens macrophyte habitats [10]. Invasive species compete with native macrophytes, leading to biodiversity loss and ecosystem degradation [11]. Conservation efforts focus on habitat protection, restoration, and sustainable management [11]. Research and monitoring programs aid in understanding macrophyte ecology and informing conservation strategies [10]. The objective of this study is to comprehensively investigate the plant community structure and phytosociology of macrophytes in the Shallabugh wetland of Kashmir, India. Through detailed field surveys and analysis, the study aims to characterize the species composition, diversity, and structural attributes of the macrophyte community. By assessing the distribution patterns of macrophytes across various habitats and water depth gradients within the wetland, the research seeks to discern the factors influencing their abundance and spatial arrangement.

Shallabugh is one of the important wetlands serving as a staging and wintering habitat for migratory waterfowl. This wetland harbors hundreds of thousands of migratory birds during winters. Macrophyte vegetation may have a direct impact on the use of wetlands by migratory water birds as food and shelter [12]. Nesting of resident water birds also showed different responses to vegetation. The objective of this study is to comprehensively investigate the plant community structure and phytosociology of macrophytes in the Shallabugh wetland of Kashmir, India. Through detailed field surveys and analysis, the study aims to characterize the species composition, diversity, and structural attributes of the macrophyte community.

1.1 Study Area

This study was carried out in the Shallabugh wetland reserve (34°10'13.80"N, 74°42'19.07"E to 34° 8'13.76"N, 74°45'59.03"E) in the Kashmir Valley of Jammu and Kashmir (Fig. 1). The wetland has an area of 1,700 hectares and the depth varies from 0.9 meters to 2.19 meters. It is situated 10 km from Srinagar city. The altitude is about 1,545 m above sea level, with the average temperature during winter months ranging between 3.8°C and -5.4°C. January is the coldest month. During summer, the average temperature fluctuates between 13°C and 27°C - the warmest month is July.

Shallabugh is a large bird reserve that serves as an important wintering and feeding ground for birds migrating from central Asia and Siberia [13,21]. Most of the wetland is marshy and several compartments have been made to retain water for migratory waterfowl. The marshy area

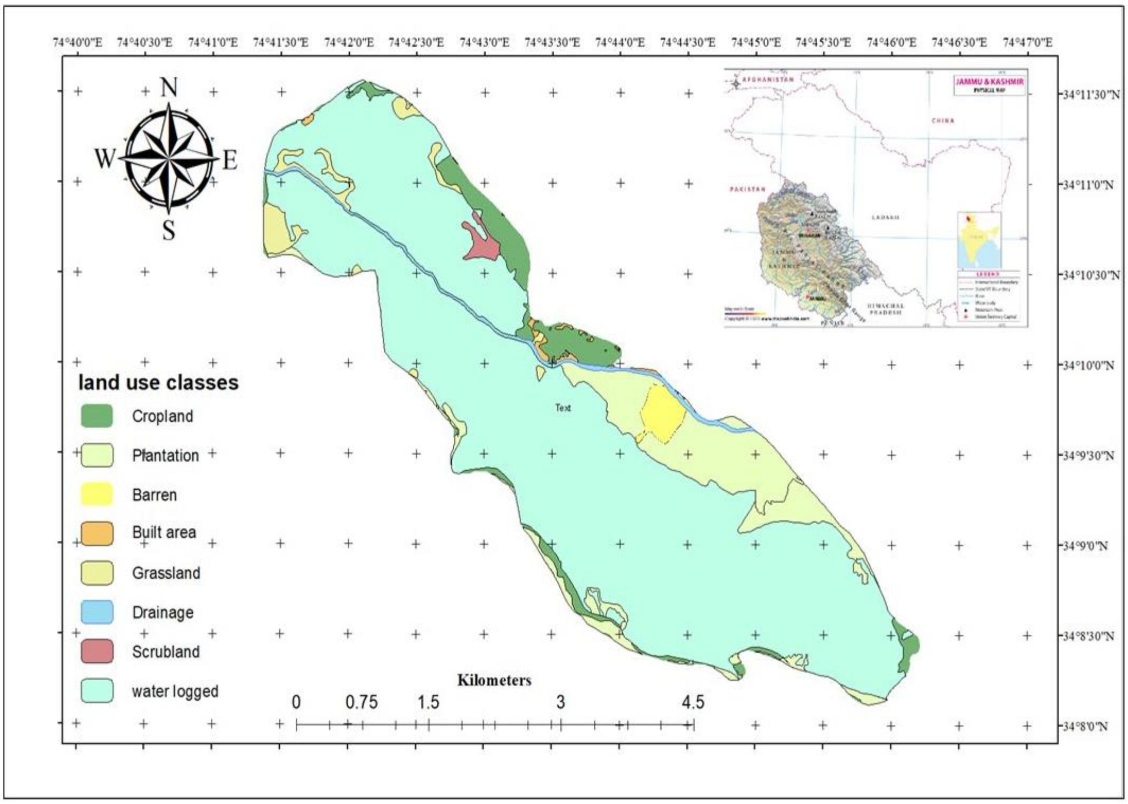

Fig. 1. Study area map Shallabugh wetland reserve

along with shallow open water also contained a variety of free-floating and submerged vegetation that provide food for waterfowl. Along with marshes, some parts of the reserve have Willow (*Salix alba*), Poplar (*Populus deltoides*), and Mulberry (*Morus* sp.).

2. METHODOLOGY

The phytosociological studies of the Shallabugh wetland were conducted during autumn 2020 when the plants were at the final stages of maturity and easy to identify. The vegetation was analyzed by stratified random sampling to obtain the most representative composition. The vegetation survey was carried out using the quadrat method and 209 quadrants of 1×1 meter were laid on predefined transects. For each quadrant, plants were counted and collar diameter was measured for representative plants. Along the buffer and boundary of the Shallabugh, tree density was estimated using 10-meter circular plots 43 plots were laid. In each plot, the circumference at the breast height of each tree (>10 cm Gbh) was measured. The dominance of the plant and tree species was determined using the species' IVI (Importance Value Index). Vegetation composition was evaluated by calculating the frequency, density, dominance, and IVI, using the following formula given by Curtis and McIntosh [14].

Frequency = (Total number of quadrants in which species occur)/(Total number of quadrants studied)×100

Relative frequency = (Frequency of a species)/(Frequency of all species)×100

$$Density = \frac{Total\ number\ of\ individuals\ of\ a\ species}{Total\ number\ of\ quadrants\ studied}$$

Relative density % = (Number of individuals of a species)/(Number of individuals of all species)×100

Relative dominance % = (Basal area of a species)/(Basal area of all the species)×100

Total basal cover=Mean basal area of a species × density of that species

IVI = Relative frequency + Relative density + Relative dominance

3. RESULTS

3.1 Herb Layer

The dominance of species (determined by their growth forms) based on IVI value is presented in Table 1. A total of 39 herb species belonging to 27 families were recorded from the core and buffer (forest area) of the Shallabugh wetland reserve. The highest number of species belonged to Poaceae (5), followed by Asteraceae (4) and Typhaceae (3). The most dominating vegetation of the wetland was emergents, followed by rooted, and free-floating.

The important value index of all the herb species was calculated. *Typha latifolia* was the dominant plant species with an IVI of 22.8, followed by *Ceratophyllum demersum* at 19.2. The density of Macrophytes was 188,052 plants per hectare with the highest density of *Typha latifolia at* 10,4567 plants per hectare (Table 1).

3.2 Tree Layer

The forest area surrounding the Shallabugh wetland was surveyed and tree density was calculated as three species of trees were present. The IVI was calculated highest for *Salix* spp. (147), followed by *Populus* spp. (117) and *Morus* sp. (34). The tree density of 274 trees was calculated in the buffer forest region of the Shallabugh wetland reserve which is a plantation forest. The *Salix* spp*.* showed the highest tree density per hectare (161), followed by *Populus* spp. (105) and *Morus* sp. (8).

In the present study, an attempt has been made to understand the patterns of species diversity of herbaceous plants. Species richness was 39 species, Shannon's Diversity was computed as H = 3.12 and Evenness _e^H/S = 0.5836. Besides bird diversity, Shallabugh wetland harbors a good diversity of macrophytes.

4. DISCUSSION

Aquatic macrophytes also called hydrophytes, are important components of aquatic and wetland ecosystems. They serve as primary producers and form the base of herbivorous and detritivorous food chains, providing food to invertebrates, fish, birds, and organic carbon for bacteria. Their stems, roots, and leaves serve as a substrate for periphyton, shelter for numerous invertebrates, nesting material, and habitat for water birds.

Altogether 39 species of macrophytes of 27 families were recorded from the study site, of which. Three were submerged, four were rooted floating-leaved and 32 were emergent species by growth form, *Azolla spp*. was seen as a free-floating macrophyte covering most of the open water in the wetland and blocking water flow. Rooted plants with main photosynthetic parts projecting above the water surface were classified as emergents, rooted plants with leaves floating on the water surface were classified as rooted floating-leaved macrophytes, and plants with crowns floating on the water surface were classified as free-floating macrophytes plants completely or largely submerged were classified as submerged macrophytes

The macrophyte richness especially emergent species is an indicator of irregular or shallow water depth with fine sediment advancing eutrophic conditions [15]. Emergent macrophytes were the most dominant form of vegetation throughout the year in the Shallabugh wetland reserve. Shallabugh wetland receives the water from Sindh *Nalla* which flows downstream from Sonamarg and brings a lot of silt and deposit in the wetland. The richness of emergent plants is also representative of siltation and water fluctuation in a wetland ecosystem. As they grow in less depth water and the areas which are exposed to the sun for a long time without having enough water, the germination starts quickly on barren ground with enough moisture.

Out of the total 1700 hectares, 141 hectares of land were converted to grassland and remained dry throughout the year. The area has now converted to cattle grazing ground, Livestock grazing is a crucial anthropogenic disturbance it reshapes the plant community assembly and affects ecosystem functions. Moreover, grazing can affect plant community structure by changing species composition, herb species can be inhibited [16]. Grazing has little influence on nestedness but can increase species turnover [17]. The changing macrophyte composition in Kashmir's landscape may have contributed to the attraction of new species to the region. Recent studies have described the appearance of the White-breasted Waterhen (Amaurornis phoenicurus) [18] and Lesser Black-backed Gull (Steppe Gull) (Larus fuscus barabensis) [19] in Kashmir. These new sightings suggest that shifts in habitat conditions, potentially influenced by changes in macrophyte populations, could be facilitating the expansion of the avian diversity in the area.

Table 1. relative dominance, density, frequency, and Important Value Index, along with the form of life, native or invasive status in Kashmir, and growth habit for various plant species

S.No	Species	Family	Relative dominance	Relative density	Relative frequency	Important Value Index	Form of Life	Native/ Invasive to Kashmir	Growth Habit
1	*Typha latifolia*	Typhaceae	8.431	8.585	5.857	22.873	Plant	Native	Creeper
2	*Ceratophyllum demersum*	Ceratophyllaceae	6.057	8.479	4.679	19.215	Plant	Native	Submerged
3	*Zizania aquatica*	Poaceae	5.613	6.986	5.536	18.135	Plant	Native	Floating
4	*Rorippa islandica*	Brassicaceae	9.637	3.482	3.714	16.833	Plant	Native	Creeper
5	*Axonopus compressus*	Poaceae	5.117	7.163	4.5	16.78	Plant	Native	Creeper
6	*Butamus umbellantus*	Butomaceae	5.401	6.049	4.893	16.342	Plant	Native	Creeper
7	*Poa annua*	Poaceae	2.633	7.371	5.179	15.183	Plant	Native	Creeper
8	*Cuscuta reflexa*	Cuscutaceae	6.012	5.612	3.464	15.088	Plant	Native	Climber
9	*Origanum vulgare*	Lamiaceae	6.025	4.82	4.036	14.881	Plant	Native	Creeper
10	*Nymphaea odorata*	Nymphaeaceae	5.586	4.469	3.964	14.019	Plant	Native	Floating
11	*Typha angustifolia*	Typhaceae	7.611	2.131	3.536	13.278	Plant	Native	Creeper
12	*Oxalis corniculata*	Oxalidaceae	1.547	4.33	4.857	10.734	Plant	Native	Creeper
13	*Echinochloa colona*	Poaceae	1.745	3.909	3.786	9.44	Plant	Invasive	Creeper
14	*Ranunculus arvensis*	Ranunculaceae	3.071	4.3	2.036	9.407	Plant	Invasive	Creeper
15	*Polygonum hydropiperoides*	Polygonaceae	2.818	3.507	2.607	8.933	Plant	Native	Creeper
16	*Sparganium erectum*	Typhaceae	2.808	1.966	4	8.774	Plant	Native	Creeper
17	*Cynodon dactylon*	Poaceae	1.627	3.644	2.821	8.092	Plant	Invasive	Creeper
18	*Berula erecta*	Apiaceae	3.316	1.857	2.75	7.923	Plant	Native	Creeper
19	*Ipomea aquatica*	Convolvulaceae	3.54	1.322	2.036	6.897	Plant	Invasive	Climber
20	*Taraxacum officinale*	Asteraceae	1.554	2.176	2.214	5.944	Plant	Invasive	Creeper
21	*Myriophyllum aquaticum*	Haloragaceae	1.26	1.568	2.679	5.506	Plant	Invasive	Submerged
22	*Scripus lacustris*	Cyperaceae	1.628	1.215	2	4.843	Plant	Native	Creeper
23	*Rumex nepalensis*	Polygonaceae	0.847	0.678	2.857	4.382	Plant	Native	Creeper
24	*Menyanthese trifoliate*	Menyanthaceae	0.975	0.91	2.286	4.171	Plant	Native	Creeper
25	*Euphorbia wallichii*	Euphorbiaceae	0.96	1.195	1.214	3.37	Plant	Native	Creeper
26	*Anagallis arvensis*	Primulaceae	0.168	0.235	2.893	3.295	Plant	Native	Creeper
27	*Cannabis sativa*	Cannabaceae	1.176	0.775	1.321	3.272	Plant	Native	Creeper
28	*Cirsium arvense*	Asteraceae	0.791	0.295	1.786	2.872	Plant	Invasive	Creeper
29	*Datura stramonium*	Solinaceae	0.489	0.238	1.214	1.942	Plant	Invasive	Creeper
30	*Acorus calamus*	Acoraceae	0.15	0.12	1.143	1.412	Plant	Native	Creeper
31	*Foeniculum vulgare*	Apiaceae	0.614	0.229	0.5	1.343	Plant	Native	Creeper
32	*Anthemis cotula*	Asteraceae	0.172	0.138	1	1.309	Plant	Native	Creeper
33	*Urtica dioica*	Urticaceae	0.223	0.357	0.5	1.08	Plant	Native	Creeper
34	*Valeriana hardwickii*	Caprifoliaceae	0.031	0.069	0.643	0.743	Plant	Native	Creeper
35	*Potamogeton natans*	Potamogetonaceae	0.24	0.045	0.393	0.677	Plant	Native	Submerged
36	*Nepeta cataria*	Lamiaceae	0.099	0.111	0.393	0.602	Plant	Native	Creeper
37	*Conyza bonariensis*	Asteraceae	0.018	0.025	0.393	0.435	Plant	Invasive	Creeper
38	*Trapa natans*	Lythraceae	0.013	0.012	0.214	0.24	Plant	Invasive	Floating
39	*Malva sylvestris*	Malvaceae	0.008	0.004	0.143	0.155	Plant	Native	Creeper

Hundreds of cattle of the locals living on the boundary graze continuously in the wetland area. Livestock in the wetland physically damages flora and fauna, causes soil disturbance, increases turbidity, compacts the soil, and creates bare ground. These changes can alter water clarity, microclimate, water, and air infiltration into the soil, soil strength, and carbon stores. This affects plant growth, results in compositional changes in vegetation, and can affect soil organisms and nutrient processing. Reduced native vegetation cover, soil disturbance, and compaction in the wetland buffer or the wetland catchment can also reduce water quality as they increase surface runoff and erosion, reduce sediment trapping in the buffer and increase the delivery of soil particles, nutrients, salts, and/or pollutants to the wetland [20].

The shift in the community structure of macrophytes affects avifaunal diversity by alteration of habitat characteristics. Clearwater is the foremost requirement to allow optimal underwater light conditions for macrophytes to germinate and grow. Shallabugh wetland being rich in macrophytes is highly productive but contrary to this, the number of invasive species has thrived more compared to the native ones, which is detrimental to the overall wetland ecology. Measures are to be taken to maintain the trophic status of the wetland to prevent its conversion into a terrestrial ecosystem as the depth of the wetland is decreasing continuously. Macrophytes enhance the transpiration loss and decrease the water table of the wetland day by day and enhance the siltation process. Controlling the macrophytes is major management practice to be implemented as soon as to conserve migratory waterfowl habitats in Kashmir wetlands. All the wetlands of Kashmir are been converting to grasslands as the water depth is decreasing and shallow water enhance the macrophyte growth.

5. CONCLUSION

The Shallabugh wetland reserve harbours a diverse array of herbaceous and macrophyte species, providing critical habitat for various organisms. However, anthropogenic activities, particularly livestock grazing, pose significant threats to the integrity of this ecosystem. The dominance of emergent macrophytes underscores the importance of shallow water depths and sunlight in supporting their growth. Nevertheless, the conversion of parts of the wetland into grazing grounds has led to soil disturbance, compaction, and diminished water quality, exacerbating the spread of invasive species and altering habitat conditions. The decline in water depth and the proliferation of macrophytes pose a risk of transforming the wetland into terrestrial ecosystems, endangering its role as a habitat for migratory waterfowl. Effective management strategies, including macrophyte control and measures to mitigate the impacts of grazing, are crucial to preserving the ecological balance of the Shallabugh wetland. Proactive conservation efforts are needed to safeguard water quality, habitat integrity, and biodiversity, ensuring the continued functioning of this vital ecosystem. By prioritizing these efforts, stakeholders can protect the Shallabugh wetland and its associated ecological services for future generations.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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