Macrophyte Diversity And Nutrient Dynamics In Asan Wetland, Dehradun: An Ecological Assessment

Sazia Tabassum[1]* • C.B. Kotnala[1] • A.K. Dobriyal[1] • Koshal Kumar[2]

[1]*Ecology Laboratory, Department of Zoology, HNB Garhwal University (A Central University), BGR Campus, 246001 Pauri Garhwal, Uttarakhand, India*

[2]*Department of Himalayan Aquatic Biodiversity, HNB Garhwal University (A Central University), Chauras Campus, Srinagar (Garhwal), Uttarakhand India*

*Corresponding Author Email id: saziatab20@gmail.com

Abstract: The Asan Wetland, a Ramsar site and Important Bird Area (IBA) in Uttarakhand supports significant biodiversity, including diverse macrophyte communities that are pivotal in nutrient cycling and ecological stability. This study systematically documented 24 macrophyte species from 18 families, categorized into floating, submerged, emergent, pollution-indicator, and invasive groups. Field surveys conducted from November 2021 to October 2023 across three sites (S1, S2, and S3) revealed site-specific variations in macrophyte abundance. Nutrient analysis indicated moderate sodium, potassium, and nitrogen levels, while phosphorus levels exceeded the critical thresholds (OECD guidelines: 0.01–0.03 mg/L). Elevated phosphorus highlighted the risk of eutrophication, promoting invasive species like *Eichhornia crassipes* and *Salvinia molesta*. Submerged and emergent species, such as *Vallisneria spiralis* and *Phragmites australis*, dominated stable habitats, contributing to nutrient uptake and sediment stabilization. These findings underscore the importance of macrophytes in nutrient regulation and the need for effective management to mitigate anthropogenic impacts, conserve native diversity, and maintain wetland health.

Keywords: Asan • Macrophytes • Nutrients • Wetland • Uttarakhand.

Introduction

Wetlands are among the most productive ecosystems in the world, supporting a rich diversity of flora and fauna. (Sharma and Naik 2024). They act as critical habitats for a wide range of aquatic and semi-aquatic species and play a pivotal role in maintaining ecological balance. According to Wetzel (2001), macrophytes are vital components of wetland ecosystems that play critical roles in biogeochemical cycling, water quality improvement, habitat provision, and sediment stabilization. Their primary categories include submerged, emergent, and floating macrophytes, each contributing uniquely to wetland dynamics. These plants are key bioindicators of water quality, as their presence, abundance, and diversity often reflect the ecological health of wetland ecosystems.

The Asan Wetland, situated at the foothills of the Western Himalayas in Dehradun, Uttarakhand, is a Ramsar Site and an Important Bird Area (IBA). Spanning an area of 444.4 hectares, it is renowned for its rich biodiversity and serves as a critical habitat for a variety of avian species, both resident and migratory. Alongside its faunal diversity, the wetland hosts a wide range of macrophytes, which form the backbone of its aquatic ecosystem. These macrophytes provide shelter and breeding grounds for aquatic organisms. In artificial water bodies like reservoirs and impoundments, macrophytes can exhibit both

beneficial and problematic effects. While they improve biodiversity and support fish breeding, excessive growth may lead to eutrophication and water flow obstruction (Chambers et al. 1994). The wetland's unique topography and hydrological regime create a variety of microhabitats, supporting a mix of native and invasive macrophytes (Zedler and Kercher 2004). Despite their ecological importance, macrophytes in wetlands like Asan face growing threats due to anthropogenic pressures, including habitat destruction, pollution, and the proliferation of invasive species. Documenting the diversity and distribution of macrophytes is therefore essential for understanding the ecological health of the wetland and for designing effective conservation strategies.

This study aims to provide a comprehensive inventory of the macrophyte diversity in the Asan Wetland, highlighting their ecological significance, distribution patterns, and the potential impact of invasive species. The findings will contribute to the growing knowledge on wetland conservation and emphasize the need for sustainable management practices to preserve these vital ecosystems.

Material and Methods

Study Area: The Asan Wetland, also known as Dhalipur Lake, is located at the confluence of the Asan River and the Eastern Yamuna Canal in Dehradun, Uttarakhand, India (30.26° N, 77.40° E). It spans an area of 444.4 hectares at an elevation of 400 meters above sea level. Created in 1967 with the construction of the Asan Barrage, this man-made wetland is recognized as Uttarakhand's first Ramsar Site (2020) and a Conservation Reserve (2005). As a critical habitat, the wetland supports diverse ecosystems, including open water, marshes, mudflats, and grasslands, which sustain a variety of flora and fauna. It is an Important Bird Area (IBA), hosting over 125 bird species, including residents and winter migrants (Tabassum *et al* 2024). Seasonal fluctuations in water levels and its subtropical climate foster a rich diversity of aquatic macrophytes. Despite its ecological significance, the wetland faces habitat degradation, pollution, and the spread of invasive species like *Eichhornia crassipes* (water hyacinth). Conservation initiatives are crucial to maintaining the wetland's biodiversity and ecological balance. Fig:1 shows the selected sampling sites named S1, S2, and S3.

Fig. 1: Showing the sampling sites

Methodology

The preparation of a comprehensive checklist of macrophytes in the Asan Wetland involved systematic field surveys, specimen collection, identification, and data documentation. In the Asan Wetland, including open water, marshes, and mudflats, Specific sampling sites were identified to cover a range of habitats, such as submerged areas, floating zones, and emergent vegetation zones. Field surveys were conducted monthly over two years (November 2021 to October 2023) to capture the species composition of macrophytic diversity. Each visit was scheduled during the morning (8:00 AM to 11:00 AM) to ensure better visibility and accessibility to the wetland's different zones. Transects were laid across the wetland to survey different habitat types systematically by documenting macrophytes visible along the path. Collected specimens were identified using standard taxonomic keys, field guides, and reference books (Dithie et al 1903). Species were classified into ecological categories (submerged, floating, and emergent) and grouped into families for further analysis. A checklist of macrophytes was prepared, including scientific names, common names, family names, and ecological categories and their divisions. Water samples were collected from all sites for nutrient analysis using the appropriate methods as suggested by APHA (2012).

Results and Discussion

A comprehensive study of macrophytes in the Asan Wetland, Dehradun, documented 23 species belonging to 18 families as shown in Table 1 categorized into floating, submerged, emergent, pollution-indicator, grasses/sedges, and invasive macrophytes. This highlights the ecological richness and significance of the wetland for supporting aquatic vegetation. The percentage composition according to the division & habit was illustrated in in Figure 2 & 3 respectively.

Floating Macrophytes: The study recorded 5 species of floating macrophytes, primarily adapted to free-floating or rooted-floating conditions: The Pontederiaceae family was represented by *Eichhornia crassipes* (Water Hyacinth), a widespread invasive species. The Araceae family included *Lemna minor* (Duckweed), common in stagnant waters. *Salvinia molesta* from the Salviniaceae family was observed. Additionally, *Nymphaea candida* and *Trapa* were identified, indicating diverse adaptations to floating habitats. The dominance of floating macrophytes, particularly invasive species like *Eichhornia crassipes and Salvinia molesta*, highlights the risk of habitat degradation due to their rapid spread.

Submerged Macrophytes: The survey documented 5 species of submerged macrophytes, which are entirely or largely underwater: Hydrocharitaceae included *Hydrilla spp* and *Vallisneria spiralis*, common submerged aquatic species critical for oxygenation and providing habitat (Mer *et al.*, no date). *Ceratophyllum demersum* (Hornwort) from the Ceratophyllaceae family was recorded as a key indicator of nutrient enrichment. *Potamogeton crassipes* from Potamogetonaceae was also identified, signifying their role in stabilizing aquatic ecosystems. *Sphagnum*, a bryophyte, highlights the wetland's ability to support diverse aquatic flora. (Cronk and Fennessy 2016)

Emergent Macrophytes: A total of 4 species of emergent macrophytes were observed, thriving in shallow water with exposed parts. Typhaceae was represented by *Typha sp.* (Cattail), a common emergent species in wetland margins. Cyperaceae included *Cyperus digitatus*, while *Phragmites australis* (Common Reed) from Poaceae played a significant role in wetland stabilization and nutrient cycling. *Sagittaria sagittifolia* (Arrowhead) from the Alismataceae family demonstrated the diversity of emergent species in the Asan Wetland.

Table 1: Checklist of Macrophytes studied at Asan Wetland showing the abundance at three different sites. (S1, S2 and S3)

S. No	Macrophytes	Common Name	Family	Division	S1	S2	S3
Floating Macrophytes					**Abundance**		
	Eichhornia crassipes	Water Hyacinth	Pontederiaceae	M	++	+++	+
	Salvinia molesta	Floating Fern	Salviniaceae	P	++	+++	+
	Lemna minor	Duckweed	Araceae	M	+	++	-
	Nymphaea candida	White Water Lily	Nymphaeaceae	D	+	++	-
	Trapa	Water Chestnut	Lythraceae	D	-	++	-
Submerged Macrophytes							
	Hydrilla sp.	Hydrilla	Hydrocharitaceae	M	++	+++	-
	Vallisneria sp.	Tape Grass	Hydrocharitaceae	M	+++	+++	-
	Ceratophyllum demersum	Hornwort	Ceratophyllaceae	M	+++	+++	-
	Potamogeton crassipes	Curly Pondweed	Potamogetonaceae	M	++	+++	-
	Sphagnum	Peat Moss	Sphagnaceae	D	+++	+++	-
Emergent Macrophytes							
	Typha	Narrow-leaved Cattail	Typhaceae	M	++	+++	++
	Cyperus digitatus	Nut Grass	Cyperaceae	M	+++	+++	+
	Phragmites sp.	Common Reed	Poaceae	M	++	++	+
	Sagittaria sagittifolia	Arrowhead)	Alismataceae	M	++	+++	+++
Pollution-Indicator Macrophytes							
	Bacopa monnieri	Water Hyssop	Plantaginaceae	D	-	+	-
	Ipomoea aquatica	Water Spinach	Convolvulaceae	D	++	++	++
	Alternanthera philoxeroides	Alligator Weed	Amaranthaceae	D	+	++	+
Grasses and Sedges							
	Eleocharis spp	Water Chestnut	Cyperaceae	M	+	+	+
	Cyperus iria	Rice Flat Sedge	Cyperaceae	M	+	++	+++
Invasive Macrophytes							
	Eichhornia crassipes	Water Hyacinth	Pontederiaceae	M	++	+++	+
	Alternanthera philoxeroides	Alligator Weed	Amaranthaceae	D	+	++	-
	Salvinia molesta	Floating Fern	Salviniaceae	P	++	+++	+
	Lantana camara	Lantana	Vebenaceae	D	+	+	+++
Acronym: Monocot=M, Dicot= D, Pteridophytes+ P, Highly Abundant = +++, Moderately Abundant= ++, Low Abundance= +, Absence= -							

Pollution-Indicator Macrophytes: The study identified 3 pollution-indicator species. *Bacopa monnieri* (Water Hyssop) from Plantaginaceae and *Ipomoea aquatica* (Water

Spinach) from Convolvulaceae indicate tolerance to nutrient-rich waters. *Alternanthera philoxeroides* (Alligator Weed) from Amaranthaceae was observed, known for thriving in polluted or disturbed habitats. These species reflect the nutrient status and potential anthropogenic influences on the wetland (Onaindia *et al* 2005). Macrophytes are extensively studied for their capacity to act as bioindicators of water quality and their use in phytoremediation. Species like *Lemna minor* and *Typha spp.* are used in constructed wetlands for wastewater treatment, showcasing high efficiency in removing heavy metals and nutrients. Wetland macrophytes are reliable indicators of ecological health in Ramsar wetlands and other designated conservation areas (Vymazal 2011

Grasses and Sedges: Two species of grasses and sedges were recorded, belonging to the Cyperaceae family. *Eleocharis spp.* (Water Chestnut) and *Cyperus iria.* These species are characteristic of marshy and shallow water habitats, contributing to soil stabilization and supporting associated fauna.

Invasive Macrophytes: The study highlighted 3 invasive macrophytes that pose ecological threats to the wetland. *Eichhornia crassipes* (Water Hyacinth) and *Salvinia molesta* (Floating Fern), both rapid colonizers from the Pontederiaceae and Salviniaceae families, respectively. *Alternanthera philoxeroides* (Alligator Weed) from Amaranthaceae was also observed, an aggressive species capable of outcompeting native vegetation.The presence of these invasive species emphasizes the need for targeted management strategies to preserve the ecological integrity of the Asan Wetland. The results show resemblance with the studies of macrophytes by different researchers as (Gupta 2014; Saini and Kumar 2017; Singh *et al* 2024) ,Adhikari and Babu 2008).

Nutrient Enrichment: Nutrient concentration studied at Asan Wetland during two years of study is presented in Table 2. During the study, it was found that annual values of all the nutrients were consistent at all sites. During the Years 2021-22 & 2022-23, In the first year of study phosphorus was found to be (0.80±0.17 mg/L, 0.83±0.2 mg/L, 0.67±0.26 mg/L) at sites S1, S2, and S3, respectively & next year (0.96±0.18 mg/l, 0.85±0.32 mg/l, 0.78±0.25 mg/L). Phosphorus levels at all three sites exceeded the desirable threshold for preventing eutrophication (0.05 mg/L as per OECD guidelines). Site 1 recorded the highest phosphorus concentration, indicating a greater influx of nutrients, likely from agricultural inputs or sediment resuspension. Total Nitrogen was (At S1=1.05±0.43 mg/l, S2=0.9±0.46 mg/L, S3=1.08±0.5 mg/L) in first year of study and was (1.04±0.36 mg/L, 1.1±0.47 mg/L, 1.19±0.53 mg/L) during 2022-23. Although nitrogen levels are moderate, a combination of high nitrogen and phosphorus can exacerbate eutrophication. (Weisner *et al.*, 1994). At sites S1, S2, S3, Sodium was found 3.26±0.83 mg/L, 3.1±0.57 mg/L, 3.32±0.53 mg/L in 2021-22 & .36±0.62 mg/L, 3.2±0.6 mg/L, 3.35±0.54 mg/L in 2022-23 respectively. Sodium levels were consistently low across all sites (<5 mg/L), suggesting minimal impact from saltwater intrusion or industrial effluents. Sodium concentrations are within the natural range for freshwater systems. Potassium was found to be 2.08±0.29 mg/L, 2.05±0.26 mg/L, 2.14±0.33 mg/L & 2.31±2.27 mg/L, 2.09±0.29 mg/L, 2.21±0.36 mg/L at Sites S1, S2, S3 respectively during 2021-22 & 2022-23. Potassium levels were stable and within the natural freshwater range (0–10 mg/L). Site 1 exhibited slightly higher concentrations, possibly due to agricultural runoff. Nutrient cycling by Macrophytes is given in Table 3, providing nutrient functions along with their key processes. (Brix, 1997; Rejmánková, 2011; Kochi *et al.*, 2020)
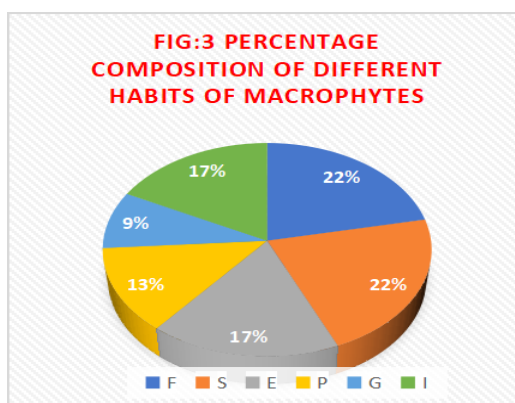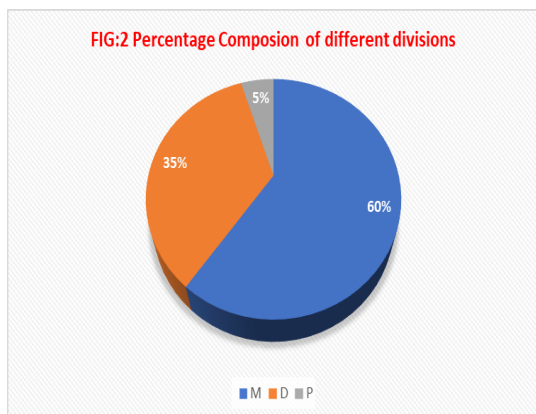
Fig. 2: Percentage Composition of different divisions

Fig. 3: Percentage Composition of different habits of Macrophytes

Acronyms: M: monocot, D: Dicot, P: Pteridophytes, B: Bryophytes.F: Free Floating, S: Submerged, E: Emergent, P: Pollution indicator species, G: Grass & Sedges , I: Invasive Species.

Table: 2 Summary of Nutrients Studied at Asan Wetland.

Nutrient	Threshold limit	Reference	S1 (mg/L)		S2 (mg/L)		S3 (mg/L)	
			2021-22	2022-23	2021-22	2022-23	2021-22	2022-23
Total Phosphorous	< 0.05 mg/L, (0.01–0.03 mg/L	OECD, 1982 (USEPA, 2000)	0.80±0.17	0.96±0.18	0.83±0.2	0.85±0.32	0.67±0.26	0.78±0.25
Total Nitrogen	1.5–2.0 mg/L	OECD, 1982	1.05±0.43	1.04±0.36	0.90±0.46	1.1±0.47	1.08±0.5	1.19±0.53
Sodium	0–30 mg/L (Normal), >50 mg/L (Stress)	Wetzel, 2001; USEPA, 2000	3.26±0.83	3.36±0.62	3.10±0.57	3.2±0.6	3.32±0.53	3.35±0.54
Potassium	0–10 mg/L (Natural), >10 mg/L (Elevated)	Boyd, 2015	2.08±0.29	2.31±2.27	2.05±0.26	2.09±0.29	2.14±0.33	2.21±0.36

Table 3: Nutrient Cycling by Macrophytes

Function	Examples of Macrophytes	Key Processes
Nutrient Uptake	*Hydrilla verticillata, Typha spp.*	Absorption of N, P, K, and C
Nutrient Transformation	*Azolla pinnata, Lemna minor*	Nitrogen fixation, denitrification
Nutrient Retention	*Phragmites australis, Typha spp.*	Sediment stabilization
Nutrient Release	*Ceratophyllum demersum, Potamogeton*	Decomposition and nutrient cycling
Pollutant Filtration	*Eichhornia crassipes, Bacopa spp.*	Removal of excess nutrients
Carbon Sequestration	*Sphagnum spp., Typha spp.*	Storage of carbon in sediments

Conclusion

The study identifies several key quality indicators for evaluating the ecological health and effective management of the Asan Wetland. A significant indicator is the documented diversity of 23 macrophyte species, categorized into floating, submerged, emergent, pollution-indicator, and invasive groups. This diversity reflects the wetland's ecological richness, while the dominance of invasive species such as *Eichhornia crassipes*

and *Salvinia molesta* signals ecological stress and competition with native flora.

Nutrient measurements, including phosphorus, nitrogen, sodium, and potassium levels, provide critical insights into the wetland's nutrient dynamics and potential ecological risks. For instance, phosphorus concentrations exceeding the OECD threshold (0.01–0.03 mg/L) indicate a heightened risk of eutrophication, leading to undesirable algal blooms. Moreover, moderate nitrogen levels and elevated phosphorus suggest nutrient imbalances that may disrupt ecological equilibrium.

The presence of specific macrophytes, such as *Bacopa monnieri*, *Ipomoea aquatica*, and *Alternanthera philoxeroides*, highlights their tolerance to nutrient-enriched or polluted environments, serving as bioindicators of water quality. Furthermore, macrophytes play essential ecological roles: species like *Hydrilla verticillata* and *Typha spp.* contribute to nutrient uptake; *Eichhornia crassipes* and *Bacopa spp.* assist in pollutant filtration; and *Sphagnum spp.* and *Typha spp.* facilitate carbon sequestration. These functions underline the significance of macrophytes in sediment stabilization, nutrient cycling, and water clarity improvement, making them invaluable ecological indicators.

Spatial variations in nutrient levels and species abundance across sampling sites (S1, S2, and S3) reflect localized environmental pressures and trends. Additionally, the wetland's unique topography and hydrological regime create diverse microhabitats, supporting a wide range of ecological niches and enhancing biodiversity. These indicators collectively emphasize the need for targeted conservation efforts to sustain the ecological integrity of the Asan Wetland.

References

Adhikari B and Babu M (2008) 'Floral diversity of Baanganga Wetland, Uttarakhand, India', *biotaxa.orgBS*.

APHA (2012) Standard Methods for the Examination of Water and Waste Water. 22nd Edition, American Public Health Association, American Water Works Association, Water Environment Federation

Brix, H. (1997) 'Do macrophytes play a role in constructed treatment wetlands?', in *Water Science and Technology*, pp. 11–17.

Chambers P A & Prepas E E (1994). "Nutrient dynamics in aquatic macrophytes." *Aquatic Botany*, 47(2), 1–15.

Cronk J and Fennessy M (2016) *Wetland plants: biology and ecology*.

Duthie, John Firminger, Parker, R. N. and Turrill, William Bertram (1903). Flora of the upper Gangetic plain, and of the adjacent Siwalik and sub-Himalayan tracts. Calcutta, Superintendent of Government Printing. http://www.biodiversitylibrary.org/permissions.

Gupta D K (2014) 'Angiospermic diversity of Asan Wetland, Doon valley (Uttarakhand), India', *Plant Archives*, 14(1), pp. 271–275.

Kochi, L. Y., Freitas, P. L., Maranho, L. T., Juneau, P. and Gomes, M. P. (2020) 'Aquatic macrophytes in constructed wetlands: a fight against water pollution', *mdpi.com*.

Mer, R., Vadher, K., Sciences, D. M.-A. in L. and 2016, undefined (no date) 'Importance of freshwater aquatic weeds: a review', *indianjournals.com*.

Onaindia M, Amezaga I, Garbisu C and García-Bikuña B (2005) 'Aquatic macrophytes as biological indicators of environmental conditions of rivers in north-eastern Spain', *Annales de Limnologie*, 41(3), pp. 175–182.

Rejmánková, E. (2011) 'The role of macrophytes in wetland ecosystems', *Journal of Ecology and Field Biology*, pp. 333–345.

Saini H and N Kumar (2017) 'Assessment and identification of aquatic diversity of wetlands of Yamuna Nagar district, Haryana, India', *academia.edu*.

Sharma L K and Naik R (2024). Wetland Ecosystems, *Conservation of Saline Wetland Ecosystems*. Singapore: Springer Nature Singapore, pp. 3–32.

Singh S, Naik R and Bahuguna A K (2024) 'Habitat Quality Characterization and Management of Asan Wetland Biodiversity', *ojs.nieindia.org*.

Tabassum S, Kotnala C. B, Salman M, Tariq M, Khan A H and Khan N A (2024) 'The impact of heavy metal concentrations on aquatic insect populations in the Asan Wetland of Dehradun, Uttarakhand *Scientific Reports*, 14(1).

Vymazal J (2011). Constructed wetlands for wastewater treatment: Five decades of experience. *Environmental Science & Technology*, 45(1), 61–69.

Weisner, S., Eriksson, P., Granéli, W., Ambio, L. L.- and 1994, U. (1994) 'Influence of macrophytes on nitrate', *academia.edu*.

Wetzel R G (2001). *Limnology: Lake and River Ecosystems*. Academic Press. P 985

Zedler J B and Kercher S (2004) Causes and consequences of invasive plants in wetlands:Opportunities, opportunists, and outcomes, *Critical Reviews in Plant Sciences*, 23(5), pp. 431–452.