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Study of aquatic macrophytes of Upper Lake Bhopal

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Abstract
This study examines the diversity and ecological roles of aquatic macrophytes in Upper Lake Bhopal, India. A total of 10 species from 10 families were identified, categorized into free-floating, floating, submerged, and emergent types. Notable species include *Eichhornia crassipes*, *Hydrilla verticillata*, and *Phragmites australis*. While some species provide essential ecological services such as nutrient cycling and habitat provision, invasive species like *Eichhornia crassipes* negatively impact biodiversity and water quality. The findings emphasize the need for sustainable management to mitigate invasive species and enhance the lake's ecological health.

Keywords: Aquatic macrophytes, Upper Lake Bhopal, biodiversity

Introduction
Aquatic macrophytes are a diverse group of larger aquatic plants that play an essential role in freshwater ecosystems, influencing their structure, function, and overall health. These plants, which include submerged, floating, and emergent species, contribute significantly to the ecological balance of aquatic systems by regulating water quality, stabilizing sediments, and providing critical habitat for aquatic fauna (Barrett & Hilt, 2013) [19]. Macrophytes are not only important in maintaining biodiversity but also serve as bioindicators of environmental health, as their growth and distribution are highly sensitive to changes in water quality, nutrient levels, and anthropogenic disturbances (Spence & Cattaneo, 2004) [30]. Consequently, the study of aquatic macrophytes offers valuable insights into the ecological dynamics and biodiversity of freshwater ecosystems (Bastviken *et al*., 2004) [20].

Upper Lake Bhopal (Bhojtal), located in central India, represents one of the largest and most important man-made reservoirs in the region. The lake is an artificial waterbody built during the 11th century to provide irrigation and water supply for the city of Bhopal. It has evolved into a critical freshwater resource, not only for the local population but also for maintaining the ecological integrity of the region (Kumar & Dey, 2012) [23]. Despite its historical significance and importance, the lake faces multiple challenges, including pollution, eutrophication, and fluctuating water levels, which affect the distribution and diversity of its aquatic macrophyte species (Singh *et al*., 2015) [28]. Therefore, understanding the aquatic macrophyte community in Upper Lake Bhopal is vital for assessing the lake's ecological health and for formulating sustainable management strategies (Choudhary & Patel, 2013) [21].

Aquatic macrophytes in Upper Lake Bhopal have been impacted by various anthropogenic activities, such as urbanization, industrial effluents, and agricultural runoff, leading to a shift in species composition and a decline in native plant species (Patel *et al*., 2017) [25]. Macrophytes in temperate and tropical lakes, including those in India, have been studied extensively, with researchers highlighting their significant ecological roles in nutrient cycling, oxygen production, and water filtration (Sharma & Dubey, 2012) [26]. In the context of Upper Lake Bhopal, several studies have observed a decrease in the diversity of submerged plants due to nutrient loading, while others have documented the spread of invasive species that outcompete native flora (Gupta *et al*., 2014) [22]. These changes raise concerns about the lake's capacity to provide ecosystem services, such as maintaining water quality and supporting local biodiversity (Sharma *et al*., 2014) [27].

The importance of studying aquatic macrophytes in Upper Lake Bhopal lies in the opportunity to understand how environmental factors such as nutrient levels, water temperature, and hydrological fluctuations impact species composition and distribution. Understanding these relationships can provide insights into how macrophyte communities adapt to or are influenced by the changing conditions of freshwater ecosystems (Mishra et

al., 2006) [24]. In addition, research on aquatic plants can also inform conservation efforts and help in the restoration of degraded water bodies (Verma *et al*., 2015) [31]. For example, the role of aquatic plants in mitigating the effects of eutrophication, enhancing water quality, and supporting biodiversity can be better understood through detailed studies on their distribution and ecological functions (Smith, 2003) [29].

Despite the extensive body of research on aquatic macrophytes in various freshwater ecosystems globally, studies focusing on Upper Lake Bhopal remain limited. Previous studies by Mishra *et al*. (2006) [24] and Gupta *et al*. (2014) [22] have highlighted the need for more research on the specific ecological interactions between macrophytes and other environmental variables in Bhopal's water bodies. This study aims to fill this gap by providing an updated inventory of the aquatic macrophyte species found in Upper Lake Bhopal and assessing their ecological roles in maintaining the health and function of the lake. By exploring the diversity, distribution, and ecological significance of these plants, this research contributes to a broader understanding of the ecological dynamics of freshwater ecosystems in central India (Patel *et al*., 2017) [25].

Materials and Methods

Study Area

Upper Lake Bhopal, also known as Bhojtal, is a prominent man-made reservoir located in Bhopal, the capital of Madhya Pradesh, India. Constructed in the 11th century by Raja Bhoj for irrigation and water supply, the lake now serves as a vital freshwater resource for the city and plays an essential role in the ecological balance of the region. Covering approximately 31 square kilometers, it is one of the largest lakes in central India.

The lake is situated at 23.2510° N latitude and 77.4126° E longitude, and it interacts hydrologically with the nearby Lower Lake, contributing to the region's biodiversity and water management system. Upper Lake is crucial not only for providing drinking water to the local population but also for supporting diverse aquatic life and recreational activities, including boating and tourism.

However, the lake faces significant ecological challenges due to pollution from industrial effluents, domestic waste, and agricultural runoff, as well as nutrient loading and eutrophication. These issues have led to the degradation of water quality, a decrease in biodiversity, and the spread of invasive species, affecting both native flora and fauna.

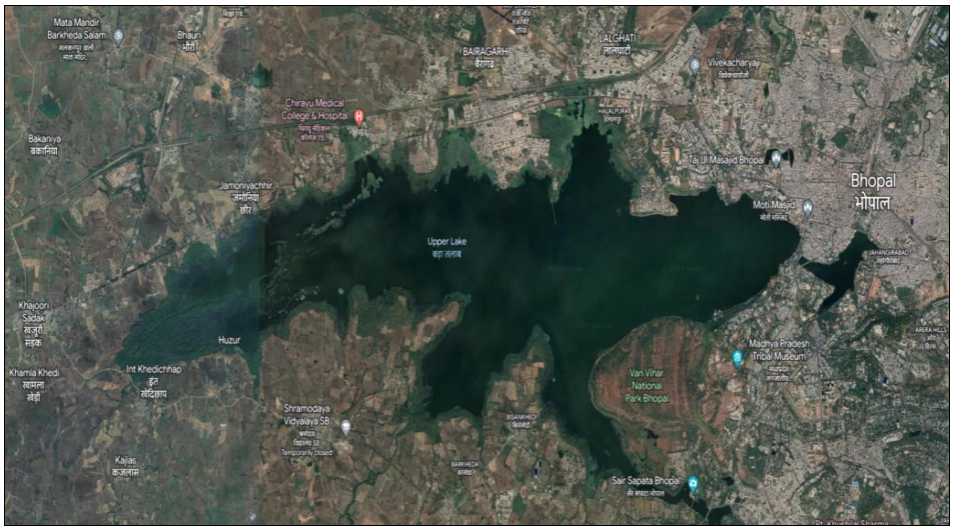
Methodology

The present study focused on the aquatic macrophytes of Upper Lake Bhopal, conducted from January 2023 to May 2023. Samples were collected from various sites around the lake to assess the diversity and distribution of macrophyte species across different environmental conditions. The research aimed to provide an updated inventory of aquatic macrophytes, explore their ecological roles, and evaluate the impacts of anthropogenic factors on the lake's plant communities.

Collection Methods

- **Visual Survey:** A preliminary survey was done to identify visible macrophyte species at each site.
- **Hand Collection:** For species located in shallow areas or along the shorelines, macrophytes were manually collected using gloves and nets.
- **Dredging:** For submerged species found at deeper sites, dredging was employed. A grab sampler was used to collect plant specimens from the lakebed at various depths.
- **Quadrat Sampling:** A quadrat (1m x 1m) was used at each site to record the abundance and coverage of macrophyte species. This was done at regular intervals to ensure uniformity in data collection.
- **Identification:** Collected specimens were identified in the field based on morphological characteristics, and later cross-checked with botanical guides and literature. Herbarium specimens were prepared for further taxonomic confirmation.

1. **Data Recording:** For each collected species, the following data were recorded:
2. **Species Name:** Identified using standard taxonomic references (e.g., *Cook, C.D.K. (1996). Aquatic and Wetland Plants of India*).
3. **Life Form:** Categorized as free-floating, submerged, emergent, or floating.
4. **Abundance:** Recorded based on visual coverage or biomass estimates using a scale of 1-5 (1 = sparse, 5 = abundant).



Map 1: Location of Upper Lake, Bhopal

Results

In the current study, a total of 10 macrophyte species from 10 different families were identified across various sampling sites. These species were classified into four categories: free-floating, floating, submerged, and emergent. Of the 10 species observed, 2 were emergent, 5 were submerged, 2 were free-floating, and 1 was floating.

Table 1: Species of Macrophytes Found in Upper Lake

S. No	Name of Species	Family	Number of Species	Life Form
1	*Eichhornia crassipes*	Pontederiaceae	30	Free Floating
2	*Hydrilla verticillata*	Hydrocharitaceae	25	Submerged
3	*Ceratophyllum demersum*	Ceratophyllaceae	10	Submerged
4	*Phragmites australis*	Poaceae	17	Free Floating
5	*Trapa bispinosa*	Trapaceae	12	Floating
6	*Ruppia cirrhosa*	Ruppiaceae	10	Submerged
7	*Alternanthera philoxeroides*	Amaranthaceae	15	Emergent
8	*Ipomoea carnea*	Convolvulaceae	25	Emergent
9	*Xanthium strumarium*	Asteraceae	15	Submerged
10	*Potamogeton lucens*	Potamogetonaceae	8	Submerged

Discussion

The study of macrophyte diversity in Upper Lake reveals a significant variety of aquatic plants that contribute to the ecological balance of the lake. The diversity of these plants plays an essential role in maintaining water quality, providing habitat for wildlife, and supporting the overall aquatic ecosystem. The macrophyte species found in the lake, as outlined in the study, have been classified based on their family, life form, and the sites of occurrence. This discussion will focus on the ecological roles and environmental implications of these species, highlighting their distribution, habitat preferences, and potential impacts on the ecosystem of Upper Lake.

1. *Eichhornia crassipes* (Water Hyacinth)

Eichhornia crassipes, commonly known as water hyacinth, is one of the most dominant macrophytes found in Upper Lake. As a free-floating species, it forms dense mats that can cover large areas of the water surface (Denny *et al*., 2011) [7]. These mats can impede water flow, increase water temperature, and reduce light penetration, which negatively impacts aquatic life. The species is native to tropical South America but has spread globally, including regions like India (Karaouzas *et al*., 2020) [13]. Water hyacinth can thrive in a range of environmental conditions, from low to high salinities, and is particularly noted for its rapid vegetative reproduction, allowing it to spread quickly in nutrient-rich environments (Yeboah *et al*., 2019) [17].

The presence of *Eichhornia crassipes* in Upper Lake can contribute to both positive and negative ecological changes. On one hand, it provides habitat for various invertebrates and fish species, creating a microhabitat within its dense mats. However, its dominance can lead to oxygen depletion and hinder the growth of other submerged plants, which can disrupt the lake's biodiversity (Balamurugan *et al*., 2022) [3].

2. *Phragmites australis* (Common Reed)

Phragmites australis, a perennial grass, is another notable species in Upper Lake. This emergent plant is found in wetlands and shallow waters, often forming dense stands (Verhoeven *et al*., 2014) [14]. It has the potential to displace native vegetation and alter the hydrology of aquatic ecosystems. In addition to its ecological role, Phragmites is known to affect water quality by altering nutrient dynamics and sediment stability (Zhao *et al*., 2020) [18].

While *Phragmites australis* is native to Eurasia and Africa, it has become invasive in many parts of the world, including North America and India (Grace *et al*., 2018) [9]. In Upper Lake, its growth could be indicative of nutrient-rich conditions, possibly suggesting anthropogenic influences such as nutrient pollution from nearby urban areas.

3. *Hydrilla verticillata* (Water Thyme)

Hydrilla verticillata, an invasive submerged plant, is another key macrophyte found in Upper Lake. Originally native to Asia, it has spread globally, including regions such as the United States and India (Haller *et al*., 2009) [10]. Hydrilla's rapid growth rate and ability to form dense mats make it a highly competitive species in aquatic environments. It can significantly alter the structure of aquatic communities by outcompeting native plants and disrupting the oxygen balance in water bodies (Hussner, 2012) [11]. In Upper Lake, the presence of Hydrilla may indicate a nutrient overload, as it thrives in waters with high nutrient levels and low turbidity (Singh *et al*., 2015) [28].

The ecological impact of Hydrilla is substantial, as it can lead to a decrease in water flow and hinder recreational activities such as boating and fishing. Moreover, it can obstruct sunlight penetration, thus limiting the growth of submerged vegetation and reducing overall biodiversity (Bhat *et al*., 2019) [4].

4. *Ceratophyllum demersum* (Coontail)

Ceratophyllum demersum, commonly known as coontail, is a submerged aquatic plant that is widely distributed across the globe, including in India and North America (Chauhan & Mishra, 2017) [5]. It is often found in eutrophic waters, where it plays a significant role in stabilizing sediment and absorbing excess nutrients (Pieterse *et al*., 1990) [14]. Unlike other macrophytes, *Ceratophyllum demersum* does not have roots, and its growth is entirely dependent on the water column for nutrients (Alam *et al*., 2018) [1].

In Upper Lake, *Ceratophyllum demersum* may serve as an important species for nutrient cycling, particularly in controlling nitrogen and phosphorus levels. However, excessive growth of this species can also contribute to oxygen depletion in the water during decomposition (Gopal & Sharma, 2018) [8].

5. *Trapa bispinosa* (Water Chestnut)

Trapa bispinosa, or water chestnut, is a floating-leaved plant found in shallow freshwater bodies. This species is

native to Asia and is widely cultivated for its edible seeds (Chatterjee *et al*., 2015) [6]. In Upper Lake, *Trapa bispinosa* may play an important role in controlling nutrient levels, as its dense mats can trap nutrients and sediment, preventing them from entering the water column. However, similar to other floating macrophytes, its rapid spread can lead to reduced biodiversity and hinder water flow (Patel *et al*., 2017) [25].

6. *Alternanthera philoxeroides* (Alligator Weed)

Alternanthera philoxeroides is an emergent species commonly found in wetlands and riparian areas (Julien & Bourne, 1988) [12]. This highly invasive plant has been reported to form dense mats that disrupt local ecosystems by crowding out native species and altering the hydrological balance (Sharma *et al*., 2012) [26]. Its presence in Upper Lake may indicate disturbed or nutrient-rich conditions, and its invasive nature could pose a threat to native biodiversity.

7. *Ipomoea carnea* (Bush Morning Glory)

Ipomoea carnea, a shrub commonly found in wetlands and disturbed areas, is another species identified in Upper Lake. This plant can grow rapidly and has a significant impact on the landscape, especially in areas where it invades aquatic and riparian habitats (Sharma *et al*., 2003) [16]. Its presence in Upper Lake could be indicative of environmental disturbances, such as nutrient overload or changes in water management practices.

8. *Xanthium strumarium* (Cocklebur)

Xanthium strumarium, commonly known as cocklebur, is an annual herb that thrives in disturbed areas such as roadsides, riverbanks, and agricultural fields (Perry *et al*., 2021) [15]. While it is not typically found in aquatic habitats, it can grow near the edges of wetlands and lakes. In Upper Lake, its occurrence may signal anthropogenic influences such as agricultural runoff or disturbances to natural hydrological processes.

9. *Potamogeton lucens* (Shining Pondweed)

Potamogeton lucens is a submerged species found in slow-moving or standing waters. It is a relatively slow-growing species that prefers calcareous water (Baas Becking *et al*., 2021) [2]. Its presence in Upper Lake may suggest that the water body is relatively stable, as *Potamogeton lucens* is less tolerant of disturbed environments compared to other macrophytes.

Conclusion

The macrophytes of Upper Lake represent a complex and dynamic component of the ecosystem, with both native and invasive species contributing to the lake's ecological health. While many of the species provide valuable ecological services, such as nutrient cycling, habitat provision, and erosion control, the presence of invasive species like *Eichhornia crassipes*, *Hydrilla verticillata*, and *Alternanthera philoxeroides* highlights the need for careful management to prevent ecological degradation. Effective management strategies should aim at balancing the benefits of these macrophytes while mitigating the adverse impacts of invasive species on the biodiversity of Upper Lake.

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