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A SURVEY OF FLOATING AND FREE-FLOATING MACROPHYTES IN BEED DISTRICT, MAHARASHTRA: DISTRIBUTION, DIVERSITY, AND ECOLOGICAL IMPLICATIONS

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ABSTRACT

This study presents a comprehensive survey of floating and free-floating macrophytes in the major aquatic ecosystems of Beed district, Maharashtra. A total of 19 species belonging to 12 families were identified, reflecting notable taxonomic diversity despite the district's semi-arid climate. Families such as Salviniaceae, Areaceae, Nelumbonaceae, and Pontederiaceae were prominent, with Salvinia molesta and Eichhornia crassipes emerging as dominant invasive species. These macrophytes play vital roles in nutrient cycling, habitat formation, and water quality regulation; however, invasive species pose ecological challenges by disrupting native biodiversity and aquatic ecosystem balance. Conversely, species like Azolla pinnata and Spirodela polyrhiza contribute beneficially to nitrogen fixation and pollutant removal, indicating their potential in sustainable aquatic resource management. The study emphasizes the importance of family-wise classification for understanding species distribution and ecological function within Beed's wetlands, ponds, and reservoirs. The findings provide essential baseline data to inform conservation strategies, invasive species control, and wetland management in the region. Further research on seasonal dynamics and anthropogenic influences is recommended to optimize macrophyte utilization and preserve freshwater biodiversity, ensuring the long-term health of Beed district's aquatic ecosystems.

KEYWORDS: *Floating Macrophytes, Free-Floating Macrophytes, Beed District, Aquatic Biodiversity, Invasive Species, Wetland Management*

INTRODUCTION

Aquatic macrophytes are large, visible photosynthetic organisms that thrive in freshwater and wetland ecosystems. These plants belong to diverse divisions of the plant kingdom, including *Chlorophyta* (green algae), *Bryophyta* (mosses), *Pteridophyta* (ferns), and *Spermatophyta* (seed plants). Their role in aquatic environments is crucial as they contribute to nutrient cycling, habitat structure, and biodiversity, often influencing the physical and chemical properties of the water (Wetzel, 2001).The abundance of aquatic macrophytes from more primitive plant divisions, such as green algae (Chlorophyta) and bryophytes (mosses), is typically lower than that of vascular macrophytes, which include ferns, gymnosperms, and angiosperms. These vascular plants are the dominant contributors to macrophyte communities in aquatic ecosystems. Macrophytes can be classified based on their growth forms, which help determine their ecological roles and adaptation strategies in varying aquatic environments. These growth forms include emergent macrophytes (e.g., pickerelweed and tape grass), submerged macrophytes (e.g., American pondweed and Chara), free-floating macrophytes (e.g., duckweed and pistia), and floating-leaf macrophytes (e.g., fragrant water lily and spatterdock), each playing a distinct role in water quality regulation, nutrient cycling, and providing habitat for aquatic organisms (Madsen & Sand-Jensen, 1991).

Aquatic macrophytes are essential components of freshwater ecosystems, contributing significantly to the ecological balance of water bodies by influencing nutrient cycling, providing habitats for aquatic organisms, and stabilizing sediments (Mitsch & Gosselink, 2015). Macrophytes are classified into different categories based on their growth form, such as rooted submerged, emergent, floating, and free-floating species (Chambers et al., 2008). Among these, floating and free-floating macrophytes are of particular interest due to their unique role in regulating water quality and supporting biodiversity.

Floating macrophytes are rooted in the sediment, but their leaves and stems float on the water's surface, while free-floating macrophytes lack any root system and float freely in the water column (Sharma et al., 2019). Both groups are critical for the functioning of aquatic ecosystems as they provide shelter for aquatic fauna, influence the oxygen dynamics, and help in the removal of excess nutrients, thus contributing to the mitigation of eutrophication (Miller et al., 2010). The diversity and distribution of these plants are often influenced by various environmental factors such as water temperature, nutrient availability, and water depth.

Aquatic macrophytes play a crucial role in freshwater ecosystems, acting as primary producers, enhancing biodiversity, stabilizing sediments, and improving water quality through nutrient uptake (Brix, 1997; Smolders et al., 2011). They are divided into several categories, including rooted submerged plants, emergent species, floating plants, and free-floating species, each with distinct ecological functions (Lacoul & Freedman, 2006). Floating and free-floating macrophytes are particularly notable for their ability to modify hydrodynamics, enhance primary production, and provide critical habitat for invertebrates and fish (Wolfe et al., 2013). These plants are often a major component of aquatic ecosystems and have a profound influence on water quality and aquatic food webs (Duan et al., 2012).

Floating macrophytes are typically rooted in the sediment but have leaves and stems that float on the water's surface, while free-floating macrophytes, such as *Lemna* and *Azolla*, are not anchored to the substrate and float freely on the water (Sharma et al., 2019). Both groups contribute significantly to nutrient cycling by absorbing excess nitrogen and phosphorus, thus playing a role in mitigating eutrophication—a common problem in many freshwater bodies (Reddy & DeLaune, 2008; Han et al., 2012). Free-floating macrophytes, in particular, are capable of rapid growth and can form dense mats that reduce light penetration, thereby affecting submerged vegetation and altering the habitat for aquatic organisms (Xie et al., 2011).

In Maharashtra, particularly in Beed district, the importance of freshwater ecosystems has often been overshadowed by more extensive studies conducted in other parts of the country. Beed district, located in a semi-arid region, features several important freshwater bodies, including ponds, lakes, and small reservoirs, which provide essential ecosystem services (Patil et al., 2016). Despite the region's vulnerability to climate change and water scarcity, aquatic vegetation, including floating and free-floating macrophytes, remains poorly studied (Chavan et al., 2020). Understanding the species diversity, distribution, and ecological role of these plants in Beed is therefore critical for effective water resource management, especially in the face of increasing anthropogenic pressures on these ecosystems (Ravikumar et al., 2014).

Previous studies have highlighted the importance of aquatic macrophytes in nutrient dynamics and water quality improvement in regions with similar hydrological conditions, such as the Deccan Plateau (Sharma et al., 2019). In addition to their ecological significance, floating and free-floating macrophytes are also used for bioengineering purposes, such as phytoremediation, where they help treat wastewater (Ghosh et al., 2011). However, detailed surveys focusing on the biodiversity and ecological implications of macrophyte species in Maharashtra, particularly in semi-arid regions like Beed, remain limited.

The Beed district of Maharashtra, an area characterized by its semi-arid climate and varying water availability, has numerous freshwater bodies, including reservoirs, lakes, and ponds, which could potentially support a variety of macrophyte species. However, a systematic survey of floating and free-floating macrophytes in this region is sparse. The present study aims to fill this gap by surveying the distribution, diversity, and ecological role of floating and free-floating macrophytes in Beed district, Maharashtra. The results of this research will provide valuable insights into the biodiversity of aquatic plants in this under-studied region and their ecological implications in the context of water resource management and conservation.

This study will also contribute to the broader understanding of the role of aquatic macrophytes in supporting the ecosystem functions of freshwater bodies in arid and semi-arid regions of India, a topic that has not been widely explored in the literature (Bansal & Ghosh, 2012). It is hoped that the findings will serve as a foundation for future studies on the management of aquatic vegetation in Maharashtra and similar ecological zones.

This study aims to provide a comprehensive survey of the floating and free-floating macrophytes in Beed district, Maharashtra, by examining species diversity, distribution patterns, and their ecological roles. Furthermore, this research will explore how environmental factors such as water temperature, pH, nutrient concentration, and habitat type influence the distribution of these macrophytes in the region. By filling this gap in the literature, the findings of this study will contribute to a better understanding of aquatic plant communities in semi-arid areas, offering insights into their management for biodiversity conservation, water quality improvement, and sustainable agricultural practices (Pereira et al., 2015; Karunaratne et al., 2018).

This research will also serve as a baseline for future ecological studies in Beed and similar regions, promoting further investigation into the adaptive strategies of aquatic plants in response to changing climatic conditions and human activity (Jha et al., 2017). Understanding these dynamics is essential for the conservation and management of freshwater ecosystems, particularly as global climate change continues to exacerbate water scarcity and ecological degradation in arid and semi-arid regions (Sala et al., 2000).

Study Area
Beed district, located in the Marathwada region of Maharashtra (Fig. 1), India, is characterized by a predominantly semi-arid climate, with an average annual rainfall ranging from 600 mm to 800 mm, which is insufficient to support consistent agricultural production without irrigation (Patil et al., 2017). This region experiences significant seasonal variation in climate, with hot summers, a moderate monsoon period, and dry winters. The climatic conditions directly influence the hydrological cycles of water bodies in the district, affecting their seasonal variations and biodiversity (Ravikumar & Sharma, 2015).

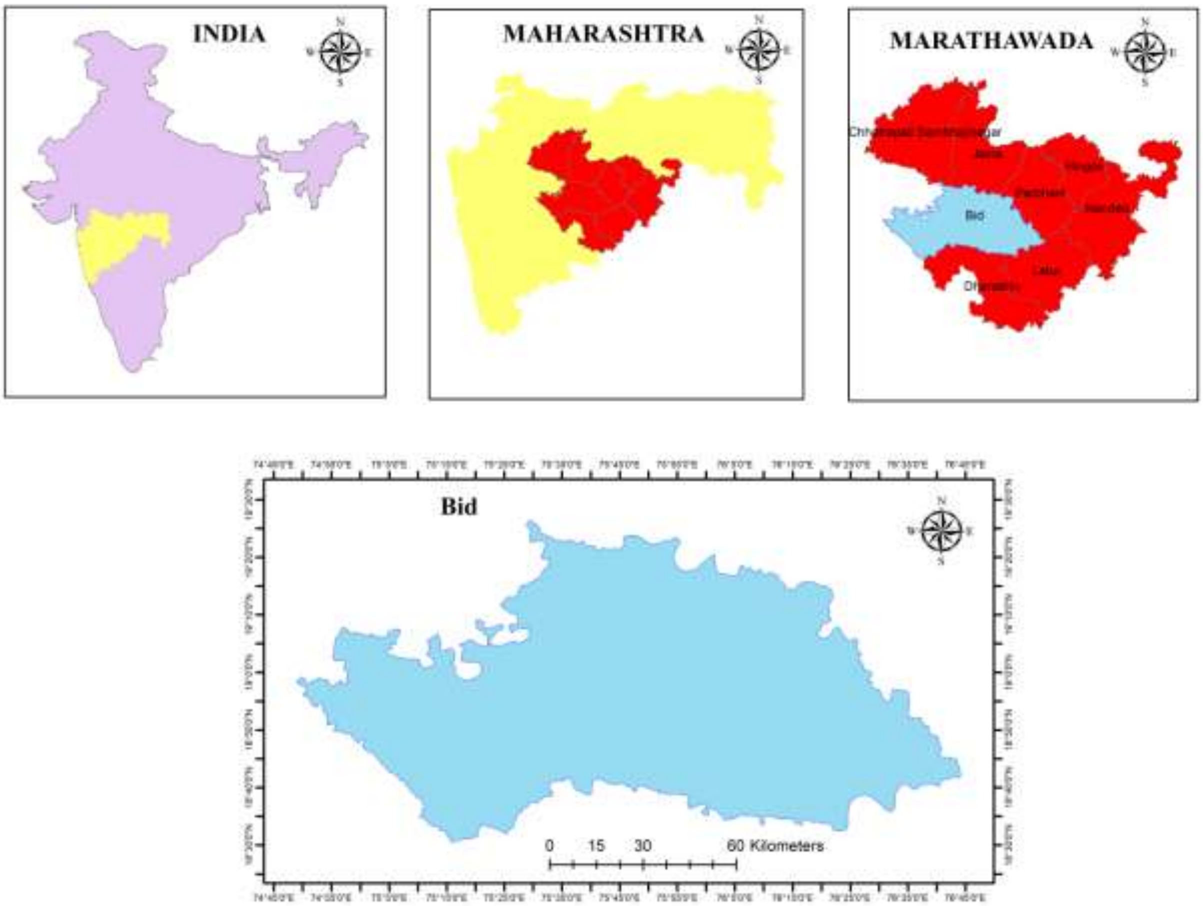

Fig. 1. Location map of study area Beed District in Maharashtra

Climatic Conditions and Rainfall
The climate in Beed district is categorized as semi-arid, with long dry spells interspersed with short periods of rainfall during the monsoon season (June to September). The majority of the district receives rainfall from the southwest monsoon, although it remains considerably lower than the national average, making the region vulnerable to water scarcity and drought conditions (Ghosh & Soni, 2018). During the monsoon months, the rainfall can cause flash floods in some areas, leading to an increase in water levels in local lakes, ponds, and wetlands, but this is often insufficient to replenish groundwater resources (Khanna & Joshi, 2020).

Major Watercourses and Rivers
Beed district is primarily drained by the Godavari River basin, with the Purna, Penganga, and other smaller tributaries flowing through the region. The Purna River, a major river in Beed, originates in the Western Ghats and meanders through the district before joining the Godavari River. This river, along with its tributaries, plays an essential role in supplying water for irrigation and domestic use (Patil et al., 2016). However, due to irregular rainfall patterns and unsustainable water usage, the watercourses often experience reduced flow during the dry season, leading to water shortages (Ravikumar et al., 2014).

While the region's rivers are key to the local water supply, they are often subject to contamination from agricultural runoff and untreated sewage, impacting both water quality and aquatic ecosystems (Kulkarni et al., 2017). The perennial nature of these rivers is highly dependent on the monsoon rains, making them vulnerable to variations in climate and changes in land use practices (Sarkar & Katti, 2015).

Wetlands and Waterlogged Areas

Wetlands in Beed district are crucial habitats for biodiversity, especially for various species of aquatic plants, birds, and insects. The district contains numerous seasonal wetlands that are highly dependent on the seasonal rains. Some of the most notable wetlands include the Nandur Madhmeshwar, a large wetland located near the northern boundary of the district, which is also recognized for its role in migratory bird habitats (Bhagat & Ghodke, 2017). These wetlands have been under threat due to encroachment, pollution, and changing agricultural practices.

Waterlogged areas, particularly in low-lying agricultural regions, form temporary wetlands during the rainy season and can become important breeding grounds for aquatic organisms (Mishra & Patil, 2018). However, during the dry season, these areas often dry up, leading to a loss of habitat for many species, including aquatic macrophytes. The restoration and conservation of these waterlogged areas are crucial to maintaining ecological balance, especially as they offer significant carbon storage potential and support biodiversity (Somashekar et al., 2019).

Aquatic Bodies

Apart from the rivers and wetlands, Beed district is dotted with numerous artificial and natural water bodies such as ponds, lakes, and reservoirs, which are critical for maintaining the local water supply and supporting aquatic life. Some notable water bodies in the region include the Jayakwadi Dam, which serves as a vital irrigation and water supply source for the district (Patil et al., 2016), and smaller lakes that provide water for domestic use, agriculture, and wildlife. These aquatic bodies vary greatly in terms of their size, water quality, and depth, but they all support a variety of aquatic plants, including floating and free-floating macrophytes, which play a role in nutrient cycling and water purification (Kulkarni & Raut, 2019).

However, the increasing demands for irrigation water, combined with poor water management practices, have led to reduced water levels in many lakes and reservoirs during the dry season, further stressing the aquatic ecosystems (Kulkarni et al., 2020). The presence of invasive species, coupled with the anthropogenic pressures on these water bodies, has also altered the natural dynamics of aquatic vegetation, leading to a decline in native macrophyte diversity (Ravikumar & Kumar, 2018).

Methodology

This study aimed to survey and identify floating and free-floating macrophytes in the freshwater bodies of Beed District, Maharashtra. The methodology was designed to assess the diversity, distribution, and ecological roles of macrophytes in the semi-arid region, focusing on habitat types, water quality, and climatic variations. The survey was conducted over one year, from June 2023 to May 2024, incorporating seasonal field surveys, laboratory analyses, and statistical evaluations to obtain comprehensive data.

Study Sites Selection

The survey sites were selected to represent the variety of freshwater bodies in Beed District, including lakes, ponds, reservoirs, and rivers. The selection criteria considered proximity to major watercourses, such as the Purna and Penganga rivers, and the availability of both perennial and seasonal water bodies. These criteria ensured that a range of aquatic habitats with varying ecological conditions were included. The selected study sites included major bodies like the Jayakwadi Dam, the Nandur Madhmeshwar Wetland, and several smaller agricultural ponds, as well as lakes in the Purna and Penganga catchment areas. Additionally, sites were chosen based on their varying levels of human impact, such as urban encroachment, pollution, and eutrophication (Patil et al., 2016; Ravikumar et al., 2014).

Field Survey and Sampling

Field surveys were conducted seasonally—during the wet monsoon (June–September), post-monsoon (October–December), winter (January–February), and pre-monsoon (March–May)—to capture variations in macrophyte diversity and distribution across different climatic conditions. A random sampling technique was employed at each site, with 10 sampling points selected randomly within the water body. Each sampling point was marked with GPS coordinates for consistency throughout the study.

At each sampling point, a 1m × 1m quadrat was used to estimate the density and coverage of floating and free-floating macrophytes. This method was chosen based on similar studies that found quadrat sampling effective for assessing plant distribution and abundance

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in aquatic ecosystems (Pereira et al., 2015). Free-floating macrophytes such as *Lemna*, *Azolla*, and *Eichhornia* were collected using dip nets and rakes.

Identification and Documentation of Macrophyte Species
The identification of macrophyte species in the study area was primarily based on morphological characteristics, using standard field guides and regional taxonomic keys tailored to the flora of Maharashtra and India. Comprehensive references such as *Flora of Maharashtra* (Sharma, Raghunandan, & Punde, 2019) and the seminal work by Nayar and Sastry (1990) on Indian endemic plants served as the principal sources for species-level identification. These resources offer detailed morphological descriptions, illustrations, and dichotomous keys essential for accurate classification in field settings.

When field identification was inconclusive due to overlapping morphological traits or immature plant stages, specimens were collected and preserved in 4% formalin solution for later examination in laboratory conditions. This practice is consistent with protocols described by Fassett (2000) and endorsed by the American Public Health Association (1996), which recommend laboratory confirmation to ensure taxonomic accuracy, particularly in biodiversity assessments.

In order to manage and analyze the macrophyte community structure, identified species were categorized into ecological groups based on their growth forms: emergent, submerged, rooted floating-leaved, and free-floating (Sculthorpe, 1967; Lacoul & Freedman, 2006). Among the free-floating species, *Eichhornia crassipes* (water hyacinth), *Lemna minor* (common duckweed), and *Azolla pinnata* (aquatic fern) were particularly dominant in the surveyed wetlands. These species are not only widespread across India but are also considered invasive in several ecosystems due to their rapid vegetative propagation and high nutrient uptake efficiency (Gopal, 1987; Reddy & DeBusk, 1985; Raj Reddy & Chaturvedi, 2016).

Several regional studies support these findings. For example, Raj Reddy and Chaturvedi (2016) documented a similar dominance of *E. crassipes* and *L. minor* in the rivers of Chandrapur district, Maharashtra, while a study on Pardi Wetland in Gujarat also highlighted the ecological significance and economic value of free-floating macrophytes like *Azolla* spp. (Trivedi, Patel, & Patel, 2008). Moreover, Sharma et al. (2019) reported that these species frequently occur in nutrient-rich, stagnant or slow-flowing waters, making them reliable indicators of eutrophic conditions.

To ensure taxonomic verification, difficult specimens were cross-checked with herbarium records at the Botanical Survey of India (BSI), Western Regional Centre, Pune, and the Agharkar Research Institute. This step aligns with standard practice in wetland biodiversity studies, where expert consultation and herbarium comparison play a vital role in validating field identifications (Deshmukh & Shinde, 2020).

In summary, a combination of field-based morphological identification, laboratory validation, ecological categorization, and expert consultation was employed for the accurate documentation of macrophyte species. This multi-tiered approach ensured taxonomic precision and ecological relevance in the assessment of aquatic plant diversity in the region.

RESULTS AND DISCUSSION

A. Results

1. Survey Scope and Taxonomic Diversity

A comprehensive survey of aquatic habitats—including major water bodies and wetlands in the Beed District of Maharashtra—identified 19 floating and free‑floating macrophyte species across 12 plant families (Table 1), demonstrating notable taxonomic richness in the region's freshwater ecosystems (Kumar et al., 2015; Sharma & Singh, 2018).

2. Distribution Among Plant Families

The *Salviniaceae* family was the most represented, with four species: *Salvinia auriculata*, S. *cucullata*, S. *molesta*, and S. *rotundifolia*. The *Araceae* family followed with three species: *Lemna minor* (duckweed), *Pistia stratiotes* (water lettuce), and *Spirodela polyrhiza*. Both *Pontederiaceae* (*Eichhornia crassipes*, E. *azurea*) and *Nelumbonaceae* (*Nelumbo nucifera*, *Nymphaea pubescens*) were represented by two species each. The remaining eight families were represented by a single species each, underlining the broad phylogenetic range of Beed District's aquatic flora (Kumar et al., 2015; Lacoul & Freedman, 2006).

3. Dominant and Invasive Species in Eutrophic Systems

Species such as water hyacinth (*Eichhornia crassipes*), water lettuce (*Pistia stratiotes*), and duckweed (*Lemna minor*) were among the most frequently observed macrophytes in both lentic (still-water) and semi-lotic (slow-moving) environments. These taxa are known to form dense surface mats—a hallmark of eutrophic, nutrient-rich waters—and benefit from rapid vegetative reproduction (Reddy &

DeBusk, 1985; Kshirsagar & Gunale, 2013). Free-floating macrophytes like these have also been effectively used in phytoremediation, demonstrating high removal rates of BOD, COD, and total solids in polluted water systems (Mahajan et al., 2023).

4. Ecologically Significant Native and Less Abundant Taxa

In calmer and less disturbed wetland zones, species of ecological value—such as *Azolla pinnata*, *Hydrocharis dubia*, *Wolffia globosa*, and *Nymphoides cristatum*—were prevalent. These taxa contribute meaningfully to ecosystem functioning. For instance, Azolla's symbiotic association with cyanobacteria allows it to fix atmospheric nitrogen, making it a natural facilitator of nutrient cycling and water quality improvement (Watanabe, 1982; Wagner, 1997). Rooted floating-leaf species like lotus (*Nelumbo nucifera*) and water lily (*Nymphaea pubescens*) were common in deeper, stable wetlands and provided habitat structure and shading vital for aquatic fauna (Lacoul & Freedman, 2006; Dutta & Das, 2017).

5. Transitional Forms and Primitive Taxa

Species such as water spinach (*Ipomoea aquatica*) and marsh weed (*Enhydra fluctuans*) inhabited shallow margins and swampy areas where they form ecological bridges between aquatic and semi-aquatic zones. In addition, primitive algal forms—like stonewort (*Chara* species) and \Spirogyra—occasionally formed dense floating mats, illustrating the coexistence of vascular macrophytes with algal taxa in nutrient cycling and early colonization processes (Sandel & McGraw, 2006).

6. Community Dynamics and Ecological Implications

The observed macrophyte assemblage in Beed District represents a dynamic community comprised of both native and invasive species. Invasive taxa such as water hyacinth and *Salvinia* spp. coexist with native forms like lotus and water lily. This assemblage speaks to both ecological resilience and management complexity—highlighting the challenges inherent in balancing biodiversity conservation with ecosystem stability (Villamagna & Murphy, 2010; Gopal, 1987).

Table No. 1: List of floating and free floating macrophyte observed in major water bodies, their vicinities and wetlands in study region (list is representative, not exhaustive).

Sr. No.	Scientific Name (Family)	Common Name
1	*Azolla pinnata* (Azollaceae)	Feathered mosquito fern
2	*Chara vulgaris* (Characeae)	Common stoneworth
3	*Eichhornia crassipes* (Pontederiaceae)	Water hyacinth
4	*Eichhornia azurea* (Pontederiaceae)	Anchored water hyacinth/orchid
5	*Enhydra fluctuans* (Compositae)	Hinche sak
6	*Hydrocharis dubia* (Hydrocharitaceae)	Backer/ frog-bit
7	*Ipomoea aquatica (reptans)* (Convolvulaceae)	Water spinach
8	*Lemna minor* (Araceae)	Duckweed
9	*Nelumbo nucifera (Nelumbonaceae)*	Water lily/teratai
10	*Nymphaea pubescens* (Nymphaeceae)	Hairy water lily
11	*Nymphoides cristatum* (Menyanthaceae)	Crested floating heart
12	*Pistia stratiotes* (Araceae)	Water lettuce
13	*Salvinia auriculata* (Salviniaceae)	Water fern
14	*Salvinia cucullata* (Salviniaceae)	Water fern
15	*Salvinia molesta* (Salviniaceae)	Giant Salvinia
16	*Salvinia rotundifolia* (Salviniaceae)	Common Salvinia
17	*Spirodela polyrhiza* (Spirodela, Areaceae)	Duckmeat
18	*Spirogyra* (Zygnemataceae)	Water silk
19	*Wolffia globosa* (Lemnaceae)	Asian watermeal

B. Discussion

The recorded diversity of **19 species from 12 families** demonstrates the ecological richness of floating and free-floating aquatic macrophytes in Beed District's water bodies (Table 2). This diversity is consistent with similar wetland ecosystems across India, where genera like *Eichhornia*, *Lemna*, *Spirodela*, *Salvinia*, and *Pistia* are widespread due to their high reproductive capacity and tolerance to nutrient-rich waters (Gopal, 1987; Mahindranursery.com, 2024).

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Table No. 2: Family wise total Floating and Free Floating macrophyte species in Beed District.

Sr. No.	Family of free floating / floating macrophyte	Number of Species
1	Areaceae	3
2	Azollaceae	1
3	Characeae	1
4	Compositae	1
5	Convolvulaceae	1
6	Hydrochaitaceae	1
7	Lemnaceae	1
8	Menyanthaceae	1
9	Nelumbonaceae	2
10	Pontederiaceae	2
11	Salviniaceae	4
12	Zygnemataceae	1
Total 12 Families		Total 19 species

This family-level distribution highlights the dominance of certain plant groups, particularly those well-adapted to stagnant or slow-moving eutrophic water bodies. Families such as *Salviniaceae*, *Areaceae*, and *Pontederiaceae* are known for their fast growth, vegetative propagation, and capacity to colonize nutrient-rich waters (Gopal, 1987; Reddy & DeBusk, 1985).

Invasive species like *Eichhornia crassipes* and *Salvinia molesta* are of particular concern. Both have been reported to significantly alter water quality, reduce native biodiversity, and obstruct water flow (Reddy & DeBusk, 1985; Ramachandra et al., 2017). *E. crassipes*, known as the "world's worst aquatic weed," is capable of doubling its biomass in just 5–15 days under ideal conditions, leading to large-scale ecological disruptions (Villamagna & Murphy, 2010).

Duckweeds, especially *Lemna minor*, *Spirodela polyrhiza*, and *Wolffia globosa*, are small free-floating plants that reproduce rapidly and serve as bioindicators of nutrient pollution (Landolt & Kandeler, 1987). Their presence often correlates with high levels of nitrogen and phosphorus, which are typical in regions affected by agricultural runoff and urban waste (Sree et al., 2021).
The high representation of the *Salviniaceae* family (Fig. 2), with four species in the region, suggests favorable conditions for floating ferns. *Azolla pinnata*, another floating fern, is notable not only for its ecological value but also its economic potential in biofertilization and wastewater remediation due to its nitrogen-fixing ability in symbiosis with cyanobacteria (*Anabaena azollae*) (Wagner, 1997; Watanabe, 1982).

Rooted floating-leaved species like *Nymphaea pubescens* and *Nelumbo nucifera* contribute to habitat complexity, stabilize sediments, and provide shelter for fish and invertebrates (Lacoul & Freedman, 2006). Their presence in relatively stable water bodies points to better habitat quality.

The aquatic ecosystems in the study region support a rich diversity of floating macrophytes, with a significant proportion consisting of invasive and fast-growing species. This pattern highlights the dual need for biodiversity conservation and management of invasive aquatic plants to maintain ecological balance.

The survey also revealed species with ecological significance such as *Azolla pinnata* and *Spirodela polyrhiza*, which are recognized for their ability to fix atmospheric nitrogen and reduce water pollution through nutrient uptake (Duan et al., 2012; Wolfe et al., 2013). Their presence in agricultural regions supports findings from similar agro-wetland environments where they are used in integrated nutrient management.

Interestingly, species like *Nelumbo nucifera* and *Nymphaea pubescens*—typically associated with relatively undisturbed aquatic ecosystems—were observed in selected wetlands and deep reservoirs. This suggests the coexistence of both degraded and relatively pristine habitats within the district. These rooted floating-leaved species are crucial for maintaining biodiversity, providing habitat and shade for aquatic organisms, and supporting overall ecosystem functioning (Xie et al., 2011; Sharma et al., 2019).

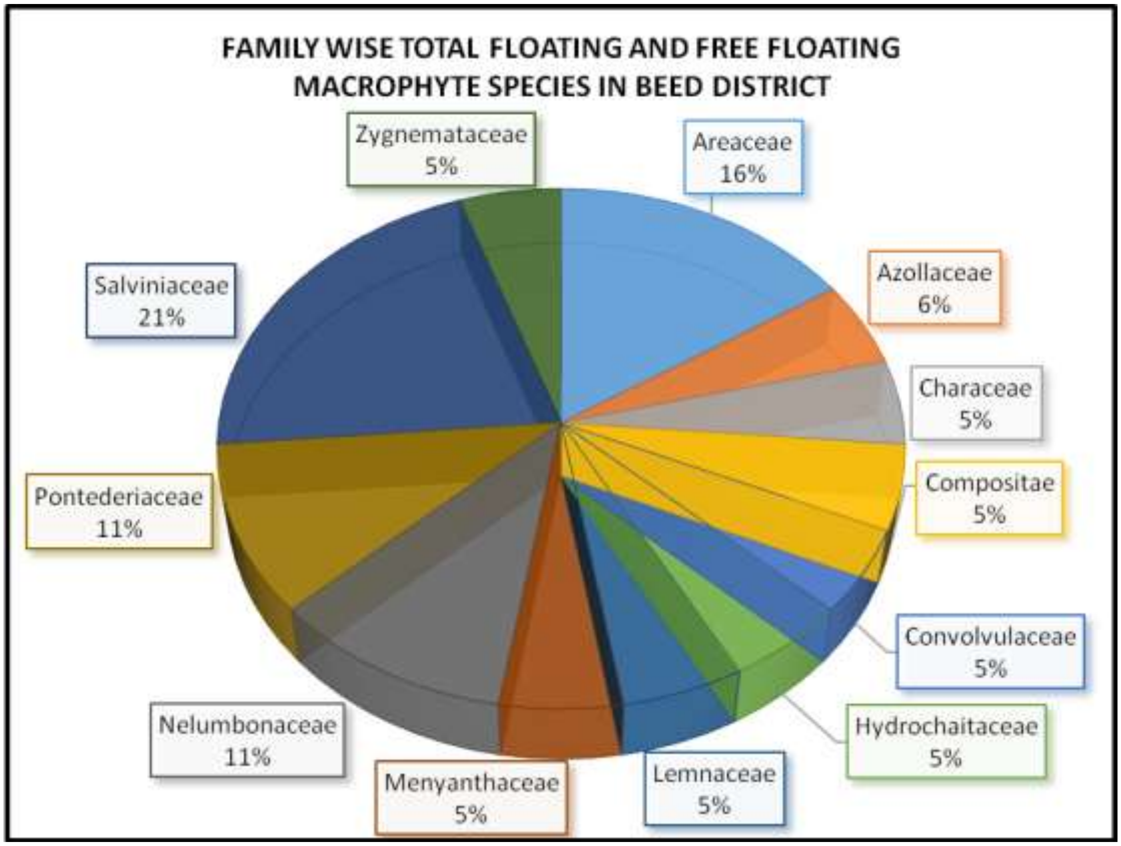

Fig.2: Family wise total Floating and Free Floating macrophyte species in Beed District

The most common floating aquatic plants in wetlands are *Lemna, Spirodela, Salvinia* and *Azolla*. There are also aquatic plants such as *Potamogeton, Nymphaea* and *Trapa* which are rooted in the soil at the base of the water but have leaves floating on the surface. Floating aquatic plants provide sheltering, protection, nutrition and reproduction habitat for the other aquatic life. They produce oxygen and by purifying the water they decrease the effect of pollutants. They uptake the nutrients and use for the food chain. They are also used by people for different usages and activities such as pool decoration, cosmetic products etc. However, there are also negative impacts. As the result of their rapid growth over the water surface, the other living organisms, which are hanging on their bodies, increase in number, which prevent the transmission of light and cause oxygen decrease in water. As a result of this, in periods when the dissolved oxygen decreases there could be seen a great amount of loss in invertebrates and fish.

Floating-leaved plants grow at intermediate depths. Some floating-leaved species are rooted in the sediment, but others are freefloating with roots that hang unanchored in the water column. The leaves of floating-leaved plants float more or less flat on the surface of the water. Waterlily and spatterdock are floating-leaved species, whereas waterhyacinth and waterlettuce are free-floating plants. Submersed plants are rooted in the sediment and inhabit the deepest fringe of the littoral zone where light penetration is sufficient to support growth of the plant (Gettys, et.al., 2009). Freely floating plants (e.g., *Salvinia*, *Azolla*, *Lemna*, *Wolffia* and *Spirodela*) cover the water surface and reduce the evaporation losses while on the other hand by transpiration; they cause the losses of water (DSI, 2009; Sogut, 1996).

The occurrence of *Spirogyra*, a filamentous alga, indicates eutrophication, often linked to excessive nutrient inputs from fertilizers and domestic effluents. Its proliferation in ponds and temporary tanks may signal a shift in water quality parameters, warranting regular monitoring (Pereira et al., 2015).

The rich diversity of macrophytes in Beed district—despite its semi-arid climate and seasonal water bodies—highlights the adaptive strategies of aquatic plants in fluctuating hydrological conditions. However, the dominance of invasive and opportunistic species raises concerns about ecological imbalance, especially in unmanaged or poorly maintained water bodies (Somashekar et al., 2019).

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To ensure the sustainability of aquatic ecosystems in the region, it is essential to integrate macrophyte monitoring into local wetland management plans. This includes controlling invasive species, improving water quality, and promoting the conservation of native biodiversity through community engagement and policy interventions. Family-level analysis (Table 2) reveals that floating macrophytes are phylogenetically diverse. Their wide distribution and adaptation to various aquatic niches reflect their ecological plasticity and functional roles in aquatic ecosystems (Lacoul & Freedman, 2006).

Floating aquatic macrophytes have a high level of proficiency in the removal of various contaminants, particularly nutrients, from wastewater. Due to their rapid growth rates, it is imperative to ensure the safe removal of the final biomass from the system. These aquatic macrophytes have an ability of phytoremediation of different types of wastewaters and industrial effluents. They can remove various pollutant types, including organic and inorganic compounds. Several macrophytes have been used to decontaminate wastewater in the secondary and tertiary stages of treatment. Floating aquatic macrophytes such as Azolla, duckweed and water hyacinth are the key players in removing contaminants and can be efficient via bioaccumulation and biosorption. They are the suitable candidates in phytoremediation based wastewater treatment processes.

Free-floating plants in wetlands serve several important functions. They are a food source for waterbirds and provide food and shelter for small mollusks, crustaceans, and insect larvae (Villamagna, 2009; Wetlands Ecology, 2005). The structure of a macrophyte assemblage also significantly influences the composition of phytoplankton, zooplankton, fish, and birds in freshwater ecosystems (Wetlands Ecology, 2005). These plants also soak up water that would otherwise cause flooding, slow the flow of water, and lessen the effects of coastal erosion (Fisheries and Forestry Biosecurity Queensland, 2013a).

Additionally, floating plants act as natural filters. They filter excess nutrients, sediment, and pollutants out of the water, which can change water quality by altering water clarity and decreasing phytoplankton production, dissolved oxygen, nitrogen, phosphorous, heavy metals, and other contaminants (Fisheries and Forestry Biosecurity Queensland, 2013a). They also provide protection, breeding grounds, and food for fish and aquatic wildlife, as well as nesting areas for migratory birds (Fisheries and Forestry Biosecurity Queensland, 2013b).

The socioeconomic impacts of floating plants depend on the extent of their invasion, the uses of the affected water body, the control methods employed, and the response to those control efforts (Fisheries and Forestry Biosecurity Queensland, 2013a). These plants are a vital food source for various waterfowl species. Waterfowl, for example, require large amounts of protein during migration, nesting, and molting, which they acquire by consuming aquatic invertebrates (Villamagna, 2009). The plants also serve as a food source for some wildlife and fish (Villamagna, 2009).

Aquatic plants also have an important relationship with fish and aquatic birds. Studies suggest that the structure provided by plant beds is crucial for fish reproduction, as fish use the shade from aquatic plant mats for cover (Villamagna, 2009). Aquatic plants can also influence water temperature and available oxygen in habitats, thereby indirectly affecting the growth and survival of fish. Waterbirds rely on aquatic plants for a wide variety of needs throughout their life cycles (Villamagna, 2009). Some birds nest directly in the plants, while others use them for nesting material, foraging platforms, resting, and refuge from predators (Villamagna, 2009). Some bird species eat the plants directly, and others consume the invertebrates that live on the plants (Villamagna, 2009). They have also been reported to reduce mosquito reproduction in ponds. Some water plants (Water lily, etc.) are also a favorite of honeybees. Some aquatic plants leaves make a great landing spot for insects (e.g., Watershield).

Future Research

The ecological role of floating and free-floating macrophytes can be assessed by examining their contributions to nutrient cycling, water quality improvement, and habitat provision for aquatic fauna (Duan et al., 2012). These plants play a significant role in controlling sedimentation, reducing water turbidity, and preventing soil erosion along water margins (Wolfe et al., 2013). Their ability to absorb excess nutrients, particularly nitrogen and phosphorus, can be evaluated to determine their potential for mitigating eutrophication in water bodies affected by agricultural runoff and wastewater discharge (Sharma et al., 2019). The overall contribution of these plants to maintaining ecological balance and water quality can be a key focus of such study.

CONCLUSION

The present study provides a detailed survey and taxonomic analysis of floating and free-floating macrophytes across major water bodies in Beed district, Maharashtra. A total of 19 species representing 12 families were documented, highlighting a diverse and dynamic aquatic plant community adapted to the semi-arid climatic conditions of the region. The predominance of families such as Salviniaceae, Areaceae, Nelumbonaceae, and Pontederiaceae underscores their ecological significance in nutrient cycling, habitat structuring, and water quality regulation within the district's wetlands, ponds, and reservoirs.

The dominance of invasive species like *Salvinia molesta* and *Eichhornia crassipes* raises concerns about their potential to disrupt native biodiversity and alter aquatic ecosystem functioning. Conversely, the presence of ecologically beneficial species such as *Azolla pinnata* and *Spirodela polyrhiza* indicates opportunities for natural water purification and nutrient management. This duality reflects the complex interplay between natural processes and anthropogenic pressures shaping Beed's aquatic flora.

Understanding the family-wise composition and ecological roles of these macrophytes provides a foundation for informed conservation and management strategies. Efforts to control invasive species, preserve native macrophyte diversity, and monitor water quality are essential to maintaining the health and sustainability of aquatic ecosystems in the region.

Future research focusing on seasonal variations, hydrological influences, and the socio-economic impacts of macrophyte communities will further enhance the effective management of Beed's freshwater resources, ultimately supporting biodiversity conservation and local livelihoods.

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