Investigation of Submerged Aquatic Macrophytes in Chhatrapati Sambhajinagar District of Maharashtra

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ABSTRACT

Aquatic macrophytes, commonly known as hydrophytes, play a crucial role in providing structural habitat that influences fish communities. This, in turn, allows zooplankton and other macro-invertebrates to exert a top-down control on algal growth, a process that is largely unaffected by the nutrient levels in the water body. Nevertheless, their populations face significant threats from factors such as eutrophication, sewage discharge, and industrial pollutants. Additionally, seasonal variations can lead to a notable decline in the diversity of these aquatic plants. Therefore, it is vital to establish baseline data to evaluate these impacts and ensure the health of aquatic ecosystems.

A comprehensive survey was conducted to assess the presence of submerged macrophyte populations in the waterways of Chhatrapati Sambhajinagar District, with meticulous documentation of the results. The findings reveal that the Chhatrapati Sambhajinagar district boasts a rich diversity of submerged macrophytes. Notably, the district is distinguished by its significant representation of a remarkable variety of submerged macrophytes, comprising 24 species across 9 families. The study indicates that the Hydrocharitaceae family is the most prevalent, featuring 12 species, followed by Potamogetonaceae with 3 species, Ceratophyllaceae and Haloragaceae with 2 species each, and Characeae, Fabaceae, Nymphaeaceae, and Pontederiaceae families, each represented by 1 species.

Keywords: Aquatic vegetation, Management of lakes, Wetland areas, Emergent, submerged, and floating macrophytes, Biodiversity, Water resources.

INTRODUCTION

Submerged macrophytes play a crucial role in the functioning of shallow lakes and contribute to the maintenance of clear water conditions (Scheffer et al., 1993; Jeppesen et al., 2007). Aquatic macrophytes serve as a refuge for small animals from predation, alter the nutrient dynamics within the ecosystem, and prevent the resuspension of sediments, thereby regulating water turbidity, which has implications for physicochemical water quality and biotic communities (Kristensen et al., 1992; Horppila & Nurminen, 2001).

One of the primary ways in which macrophytes affect the status of lakes is through their involvement in nutrient cycling. Due to their ability to produce high biomass, aquatic plants possess a significant capacity for the accumulation of biogenic compounds (Clarke & Wharton, 2001; Abdo & Da Silva, 2002). Generally, the structural complexity and biomass of submerged macrophytes are influenced by nutrient enrichment. The regulation of phosphorus and nitrogen is critical for sustaining the biodiversity of lake ecosystems. Phosphorus is regarded as a key factor influencing primary production in lakes, especially for phytoplankton (Kalff, 2001).

Submerged macrophytes represent a crucial functional group within lake ecosystems (Jeppesen et al., 1997). Nevertheless, numerous submerged macrophytes in lakes have experienced a decline or have even vanished in recent years, both in China and globally, and there remain significant challenges in restoring all submerged macrophytes in lakes due to the ambiguous recession mechanisms (Qin et al., 2014; Zhang et al., 2017). A primary factor contributing to this issue is the widespread reduction in underwater light availability, which restricts the growth of submerged macrophytes (Chen et al., 2016; Jin et al., 2020). Furthermore, underwater light availability is essential for influencing freshwater biodiversity in lakes dominated by submerged macrophytes (Karlsson et al., 2009; Estlander et al., 2017; Yu et al., 2021).

Submerged macrophytes are essential in shallow lakes. They enhance water quality by taking up nutrients from the water column (Jeppesen et al., 1998; Liu et al., 2018) and by stabilizing the sediment at the bottom (Wu & Hua, 2014; Zhang et al., 2016). Furthermore, they offer food and shelter to aquatic organisms (Blindow et al., 2014; Wood et al., 2017; Choudhury et al., 2019). Nevertheless, the proliferation of human activities and eutrophication has led to a global decline in the population of submerged macrophytes in shallow lakes (Jeppesen et al., 1998; Wang et al., 2014; Yu et al., 2015). Given their significance for the ecology of shallow lakes, submerged macrophytes have garnered increasing attention, and their restoration is a critical component in the rehabilitation of hypertrophic urban lakes (Sondergaard et al., 2010; Dai et al., 2012; Bakker et al., 2013; Liu et al., 2020).

The restoration of submerged macrophytes in urban lakes frequently presents challenges due to various inherent limitations, including high nutrient loading, artificially controlled water levels, and restricted littoral zones (Guo, 2007; Van Geest et al., 2007; Mao et al., 2020). Additionally, recurrent algal blooms can adversely affect the survival of submerged macrophytes (Kibria et al., 2012; Wang et al., 2021), with light deficiency being a primary factor contributing to the decline of submerged macrophytes (Schelske, 2010; Arthaud et al., 2012; Olsen et al., 2015; Zhang et al., 2016). Therefore, enhancing underwater light availability is essential for the growth and reproduction of submerged macrophytes in urban lakes (O'Farrell et al., 2011; Paillisson & Marion, 2011; Zhang et al., 2016). Consequently, improving underwater light through artificial means may prove to be a beneficial strategy for restoring submerged macrophytes in urban lakes, particularly in areas with low fish populations or where fish are absent, as this would prevent macrophyte recovery from being impeded by fish grazing on the plants or fish predation on zooplankton, which could otherwise result in increased phytoplankton growth and reduced light availability for macrophyte development.

Aquatic Macrophytes are also utilized as bioindicators of water pollution due to their responsiveness to changes in water quality. They play a crucial role in mineral cycling and organic components, which in turn influences total biomass production within aquatic ecosystems. Numerous researchers have conducted studies related to aquatic and wetland flora across various regions of India (Mirashi, 1954; Sen & Chatterjee, 1959; Srivastva et al., 1987; Dhote & Dikxit, 2007; Chandra et al., 2008; Jadhav & Babare, 2025).

Research on aquatic macrophytes holds significant importance for limnologists, as it aids in comprehending the dynamics of aquatic ecosystems. For fisheries personnel, these studies serve as a catalog of fish food sources, while pollution control experts benefit from understanding their capacity to remove nutrients. The diversity of macrophytes has been thoroughly examined by various researchers, including Chakraborty (2008), Vardayan (2006), Devi et al. (2004), Manorama et al. (2007), and Laishram Kamla et al. (2007). Their findings indicate that many aquatic macrophytes can become problematic when they proliferate excessively, leading to their classification as aquatic weeds, which poses challenges for water management. Currently, freshwater systems are adversely affected, experiencing a decline in native biodiversity due to the influx of untreated sewage and pollution, which significantly alters the physicochemical parameters of water, impacting both quality and quantity. Macrophytes promote the growth of phytoplankton and facilitate the recycling of organic matter. Additionally, submerged species at the margins function as green manure, enhancing the abundance of zooplankton and benthic fauna. They also offer suitable breeding and sheltering habitats for macro-invertebrates and fish (Meshram, 2003). The proliferation of aquatic macrophytes can lead to nuisance conditions, categorizing them as aquatic weeds and raising concerns for water management. Conducting surveys of aquatic macrophytes can provide a solid foundation for developing management plans. The objective of the present study was to summarize the biodiversity of submerged aquatic macrophytes in the studied area and categorize them, thereby providing essential baseline data on species diversity for the conservation of water bodies in Chhatrapati Sambhajinagar District.

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MATERIALS AND METHODS

Study area:

Chhatrapati Sambhajinagar, previously known as Aurangabad, is situated in the Deccan region, primarily within the Godavari River basin, with some areas extending into the Tapi River basin. The city is distinguished by its hilly landscape and semi-arid climate. It is positioned at coordinates N 19° 53' 47" – E 75° 23' 54", with latitude ranging from 19 to 20 degrees north and longitude from 74 to 76 degrees east. The Ajanta mountain range encircles the city. Chhatrapati Sambhajinagar District, formerly Aurangabad District, is a significant area within the Marathwada region of Maharashtra (see Fig. 1). The district covers an area of 10,100 km², with 37.55% classified as urban and the remainder as rural. It is predominantly located in the Godavari River Basin, with portions extending towards the northwest of the Tapi River Basin.

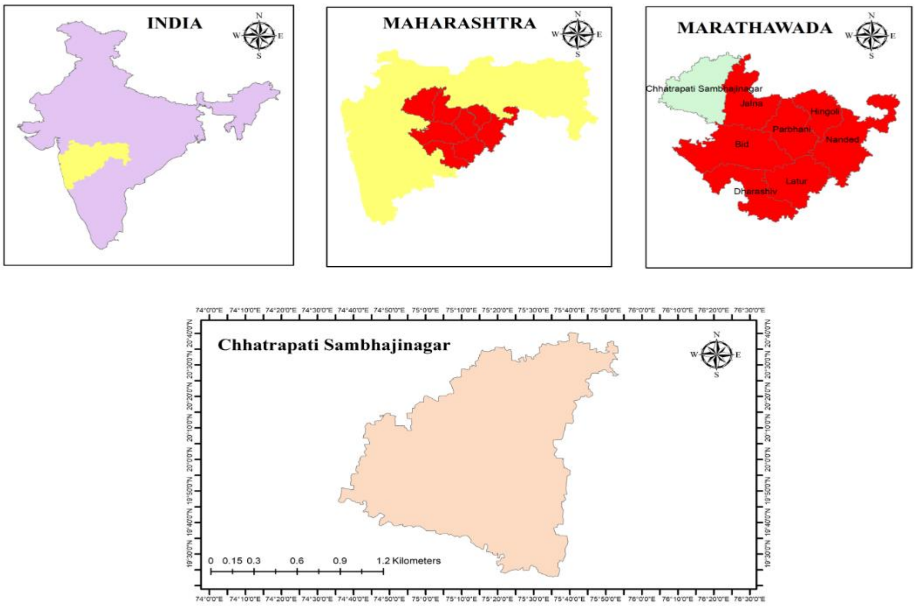

Figure 1: Map showing the location of the Chatrapati Sambhajinagar district within the study area.

The climate of Chhatrapati Sambhajinagar is semi-arid, with average annual temperatures ranging from 17 to 33 °C. The rainy season spans from June to September, followed by winter from October to February, and summer from March to May. The majority of the district's rainfall occurs during the monsoon season, with an average annual precipitation of 710 mm. Outside of the southwest monsoon period, when humidity levels rise, the air in the district is typically dry. The summer months are the driest, with afternoon relative humidity generally between 20 and 25%. Wind speeds are usually light to moderate, increasing during the latter part of the hot season and throughout the monsoon. During the hot season, winds primarily originate from the west to the north. In contrast, during the southwest monsoon season, they mainly come from the southwest to the northwest. Throughout the remainder of the year, winds predominantly blow from the northeast to the southeast, shifting to southwesterly and northwesterly directions in January and February. A significant portion of the district is situated within the Godavari basin, while a smaller area in the northeastern region falls within the Tapi Basin. The Godavari River, along with its tributaries—Purna, Dudhna, and Shivna—serves as the principal waterway in the district. Other notable tributaries include the Sukna, Khelna, Kham, Gulathi, Shivbhadra, and Girija rivers. Based on the drainage patterns and geomorphological features, the district has been comprised of 52 distinct watersheds.

Survey Methodology

Aquatic macrophytes from significant waterways and water bodies within the Chhatrapati Sambhajinagar district study area were systematically gathered across three distinct seasons: rainy, winter, and summer. Seasonal surveys, which included multiple visits, were carried out to gather data on both littoral and submerged vegetation, as detailed by Narayana and Somashekar (2002). Macrophytes were collected monthly from June 2005 to May 2007 from shallow, littoral zones using the hand-picking method. Specimens were thoroughly washed with water, excess moisture was absorbed with filter papers, and the specimens were stored in polythene bags before being transported to the laboratory in an ice box. They were preserved in 10% formalin and identified to the species level with the assistance of relevant literature from Edmondson (1959), Pennack (1978), Tonapi (1980), and Fasset (2000). Over a four-year span, from June 2018 to 2022, these surveys documented aquatic plants, particularly submerged macrophytes, through regular excursions at short intervals to collect and identify plant samples from the designated study locations. This paper specifically addresses the submerged macrophytes found in the Chhatrapati Sambhajinagar district.

A sufficient number of field excursions were conducted to sample and document observations throughout the study period, ensuring the collection of significant macrophyte species. The Aquatic Plant Sampling Protocols were carefully followed during the sampling process. Samples were manually collected from the littoral zone and the exposed marginal areas of the sampling sites. Since most of these species are herbaceous, they were carefully uprooted, rinsed, and cleaned to reduce mud content before being pressed between newspapers or placed in polyethylene bags, depending on availability and field conditions, for immediate identification. This methodology aligns with techniques employed in recent research published by Narasimha and Benarjee (2016). The collected plant specimens were identified and verified against regional floras and pertinent literature.

RESULTS AND DISCUSSION

This survey of aquatic plants primarily aimed to identify, document, and evaluate the abundance and distribution of various submerged aquatic plant species within the waterways of the study area. Aquatic plants are species that thrive in a range of saltwater and freshwater environments, including small fish tanks, home aquariums, lakes, ponds, and oceans. These plants can grow above water, be completely submerged, or exist in an intermediate state; the essential aspect is that they naturally thrive in wet habitats. Aquatic plants exhibit a variety of traits that facilitate their survival in these environments (Rascio, 2002). A compilation of submerged macrophytes identified in significant water bodies, their surrounding areas, and wetlands within the study region (the list is representative, not comprehensive) is provided in Table 1.

Table 1: List of Submerged Macrophytes 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	*Cabomba caroliniana* (Nymphaeaceae)	Fanwort
2	*Ceratophyllum demmersum* (Ceratophyllaceae)	Coontail
3	*Ceratophyllum submersum* (Ceratophyllaceae)	Soft Hornwort
4	*Chara globularis* (Characeae)	Green algae
5	*Elodea canadensis* (Hydrocharitaceae)	Canadian pondweed
6	*Elodea densa* (Hydrocharitaceae)	Brazilian pondweed
7	*Elodea bifoliata* (Hydrocharitaceae)	Earthpedia Plant
8	*Elodea trifoliate* (Hydrocharitaceae)	Pondweed
9	*Heterenthera dubia* (Pontederiaceae)	Water stargrass
10	*Hydrilla verticillata* (Hydrocharitaceae)	Oxygen weed

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11	*Myriophyllum aquaticum* (Haloragaceae)	Water milfoil/ Parrotfeather
12	*Myriophyllum spicatum* (Haloragaceae)	Eurasian water milfoil
13	*Najas graminea* (Hydrocharitaceae)	Water nymph
14	*Najas guadalupensis* (Hydrocharitaceae)	Guppy grass
15	*Najas indica* (Najadaceae)	Naiads
16	*Najas minor* (Najadaceae/ Hydrocharitaceae)	Water velvet/ Najas
17	*Ottelia alismoids* (Hydrocharitaceae)	Ottelia/ duck lettuce
18	*Potamogeton crispus* (Potamogetonaceae)	Curlyleaf pondweed
19	*Potamogeton gramineous* (Potamogetonaceae)	Pondweed
20	*Potamogeton Perfoliatus* (Potamogetonaceae)	Pond weed / Redhead grass
21	*Trifolium fragiferum* (Fabaceae)	Strawberry clover
22	*Vallisneria natans* (Hydrocharitaceae)	Tapegrass
23	*Vallisneria Americana* (Hydrocharitaceae)	Eelgrass / tapegrass
24	*Vallisneria spiralis* (Hydrocharitaceae)	Eelgrass /straight vallisneria

The previous studies (Jadhav & Babare, 2025) regarding emergent macrophyte vegetation in the **Chhatrapati Sambhajinagar district** have shown that the Cypereaceae family is the most dominant group among the emergent families in this area. Examining diversity indices within this district facilitates a deeper understanding of the ecological conditions of submerged macrophytes and their functional traits. This research provides vital baseline data related to the diversity of submerged aquatic macrophytes in the key water bodies of the **Chhatrapati Sambhajinagar district**, which encompasses significant water bodies, river systems, marshes, and wetlands. The results concerning submerged macrophytes in the Chhatrapati Sambhajinagar district of the Marathwada region in Maharashtra are essential for managing plant growth, addressing eutrophication, restoring aquatic ecosystems, and regulating plant species to enhance pollution control through phytoremediation methods in the study area. The total number of submerged macrophyte species by family in Chhatrapati Sambhajinagar District is presented in Table 2.

Table 2: Family-wise total of submerged macrophytes species in Chhatrapati Sambhajinagar District.

Sr. No.	Family of Submerged macrophyte	Number of Species
1	Ceratophyllaceae	2
2	Characeae	1
3	Fabaceae	1
4	Haloragaceae	2
5	Hydrocharitaceae	12
6	Najadaceae	1

7	Nymphaeaceae	1
8	Pontederiaceae	1
9	Potamogetonaceae	3
Total species		**24 species**

The investigation of submerged macrophytes in the **Chhatrapati Sambhajinagar district** indicates that the **Hydrocharitaceae** family is the most prevalent, comprising 12 species (see Table 2). **Potamogetonaceae** follows as the second most commonly found family, containing 3 species. The **Ceratophyllaceae** family Haloragaceae family were noted with 2 species each, while Characeae, Fabaceae, Nymphaeaceae, and Pontederiaceae families each have 1 species reported. The findings from the survey of Chhatrapati Sambhajinagar District demonstrate that the Hydrocharitaceae family dominates the area with 12 species. A graphical representation of the percentage comparison is illustrated in Fig. 2.

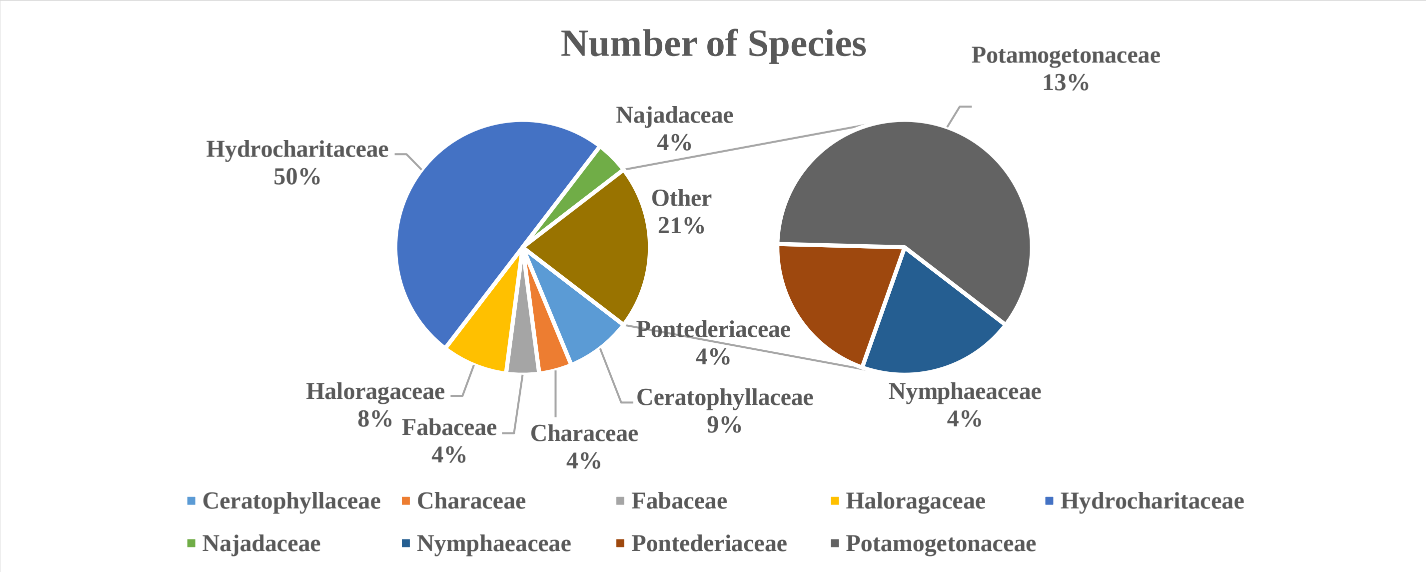

Fig. 2: Species percentagewise graphical representation of submerged species in Chhatrapati Sambhajinagar

Macrophytes play a significant role in ecosystem functioning. They serve as primary producers, providing structural habitat for numerous animal species, and offer shelter and nourishment to invertebrates (Castella et al., 1984) and fish (Rossier, 1995). Additionally, they are involved in ecosystem processes such as biomineralization, transpiration, sedimentation, elemental cycling, material transformation, and the release of biogenic trace gases into the atmosphere (Carpenter & Lodge, 1986). Recent research has highlighted the critical role of aquatic macrophytes in regulating nutrient availability in water and enhancing the stability of lakeshores (Carpenter & Lodge, 1986; Blindow et al., 2014). The composition of macrophyte assemblages can be affected by geology, land use, and the chemistry of water and sediment (Barko et al., 1991; Lougheed et al., 2001; del Pozo et al., 2011). The composition and distribution of macrophyte communities vary according to climate, hydrology, substrate type, and nutrient availability.

Numerous researchers have emphasized the importance of macrophytes. Aquatic macrophytes play a crucial role in aquatic ecosystems by providing food and shelter for invertebrates (Rejmankova, 2011) and stabilizing sediments and shorelines, thereby reducing turbidity in aquatic systems (Bamidele & Nyamali, 2008). Submerged macrophytes influence nutrient dynamics, light attenuation, temperature regimes, hydrodynamic cycles, and substrate characteristics (Rooney et al., 2003). The macrophytes are responsible for regulating and stabilizing mineral cycling in water bodies, thus serving as indicators of potential ecosystem damage (Pieczynska & Ozimek, 1976). Aquatic plants drive ecosystem productivity and biogeochemical cycles, partly because they act as a critical interface between sediments and the overlying water column (Carpenter & Lodge, 1986). Aquatic plants are vital components of aquatic ecosystems. Like all other photosynthetic organisms, they are essential for capturing the solar energy that fuels all other ecosystem components. They provide oxygen to other biota and contribute to the physical habitat (Cronk & Fennessy, 2001).

Submerged macrophytes serve a crucial function as producers within food webs, providing shelter and food for various organisms, and acting as indicators of water quality (Nieder et al., 2004). They are vital for the diversity of zoobenthos in aquatic ecosystems, offering shelter, breeding grounds, and food sources (Ali et al., 2007). Furthermore, submerged macrophytes generate oxygen in stagnant areas and extend the hydrologic retention time necessary for the removal of particulate nutrients (Nepf et al., 2007). However, despite their significance, the development of dense monotypic stands can negatively impact the diversity and abundance of invertebrates and fish (Buchan & Padilla, 2000). Thick beds of submerged macrophytes can generate organic matter from both actively growing and decaying plants, leading to eutrophication in the water column (Chambers et al., 1999). Additionally, their excessive growth can obstruct water flow, block reservoir inlets, and disrupt recreational activities (Kenneth, 1996).

In general, the growth of macrophytes is constrained by various factors including the type of substrate, water depth, water clarity, nutrient concentration, and different physical disturbances. The presence and quantity of submerged macrophytes are affected by both chemical and physical factors, such as water quality, availability of light (Dennison et al., 1993), water transparency, water depth (Canfield et al., 1985), channel slope, channel dimensions (O'Hare et al., 2011), and hydrological regime (Franklin et al., 2008). It is crucial to comprehend how various environmental factors influence the habitats of submerged macrophytes for purposes such as flow regulation, sediment transport (Jarvela, 2005), and evaluations of the ecological status of rivers (Clayton & Edwards, 2006).

The presence and distribution of submerged macrophytes within river ecosystems are influenced by water quality parameters (Nieder et al., 2004), water depth, and the velocity of water in flowing systems (Sousa, 2011). Biological elements, such as competition, herbivory, and disease, serve as significant habitat determinants for submerged macrophytes (Lacoul & Freedman, 2006). In river ecosystems, submerged macrophytes can transition from slow-moving streams to larger rivers following the construction of weirs (Son et al., 2017). Consequently, it is essential to comprehend the submerged macrophytes that possess high invasive potential for effective river management and conservation strategies. A limited number of studies have forecasted the distributions of submerged macrophytes in rivers utilizing generalized additive models (GAMs) (Ahmadi-Nedushan et al., 2006; Camporeale & Ridolfi, 2006). Furthermore, the GAMs that have been developed have seldom been validated with independent field data (Guisan et al., 2002).

The conducted survey of macrophytes in the designated study area of **Chhatrapati Sambhajinagar district** sought to evaluate vegetation in aquatic environments, which include water bodies, waterlogged regions, wetlands, and marshes. The main aim of the survey was to identify ecological species from various families or groups and to explore their diversity within the chosen area. Over the years, many researchers have participated in similar studies, such as Asri and Aftekhari (1999), Raizi (1996), Ghahreman and Attar (2003), Jalili et al. (2009), Zahed et al. (2013), and Naqinezhad and Hosseinzadeh (2014).

Macrophytes are beneficial for the phytoremediation of metal-contaminated wastewaters (Shingadgaon & Chavan, 2016; 2018; 2019). The presence and distribution of submerged macrophyte species in the study area indicate a considerable diversity, which is crucial for regulating the climatic conditions of **Chhatrapati Sambhajinagar district**, located in the Marathawada region of Maharashtra. Generally, macrophytes exhibit simpler structural complexity, as their growth predominantly occurs beneath the water's surface, rendering them less accessible to various aquatic organisms (Singadgaon & Chavan, 2017; 2018a; 2018b). As a result, it is frequently suggested that these species establish a uniform habitat (Daspute-Taur et al., 2018). The root systems of emergent macrophytes are recognized for influencing the movement of solutes in the subsurface. Moreover, it is posited that these macrophytes fulfill similar ecological roles across different trophic levels within ecosystems; however, submerged macrophytes have not been extensively studied by researchers and require greater attention from the scientific community, as there is currently insufficient scientific evidence to substantiate this assertion. Thorough scientific investigation is essential to clarify the role of submerged macrophytes in shaping aquatic habitats (Stahr & Kaemingk, 2017).

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CONCLUSIONS

The Chhatrapati Sambhajinagar district, situated in the Marathwada region of Maharashtra, showcases an impressive diversity of submerged macrophytes, comprising 24 species from 9 families. The findings indicate that the Hydrocharitaceae family is the most prevalent, containing 12 species, followed by Potamogetonaceae and Haloragaceae families with 3 species each. The **Ceratophyllaceae** family was noted to have 2 species, while Characeae, Fabaceae, Nymphaeaceae, and Pontederiaceae families were each documented with 1 species during the study.

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Jadhav & Babare's series of regional surveys in Maharashtra (Chhatrapati Sambhajinagar, Dharashiv, Jalna, Beed) documented the distribution of emergent aquatic macrophytes.