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Study of submerged aquatic macrophytes in Beed District, Maharashtra

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Abstract

Aquatic vegetation plays a crucial role in aquatic ecosystems, particularly within wetland environments. These plants provide essential food and habitat for fish, wildlife, and various aquatic species. However, the communities of aquatic plants face significant threats from factors such as eutrophication, sewage discharge, and industrial pollutants. Additionally, seasonal variations can lead to a substantial decline in the diversity of these plants. Therefore, it is essential to establish baseline data to evaluate these impacts and ensure the health of aquatic ecosystems. A comprehensive survey was conducted in the Beed District of Maharashtra to assess the presence of submerged macrophyte populations in the area's waterways. The findings were meticulously documented and are presented in this paper. The findings reveal that the Beed district hosts a rich variety of submerged macrophytes, comprising a total of 20 identified species. Notably, the Hydrocharitaceae family is the most prevalent, featuring 8 species. Following this, the Potamogetonaceae family is represented by 3 species, while the Ceratophyllaceae and Haloragaceae families each include 2 species. Additionally, the Characeae, Fabaceae, Najadaceae, Nymphaeaceae, and Pontederiaceae families each contribute to one species.

Keywords: Aquatic ecosystem; Submerged macrophytes; Phytoremediation; Wetlands; Water resources

1 Introduction

Aquatic macrophytes are visible plants that thrive in or around water. Surveys of these plants may be necessary when a development project has the potential to impact a watercourse. Given their sensitivity to water quality, macrophytes serve as valuable indicators for assessing and monitoring the health of aquatic environments. These plants can be categorized as emergent, submerged, or floating vegetation. The classification of aquatic macrophytes encompasses not only submerged and emergent flowering plants but also ferns and bryophytes. They play a vital role in the aquatic ecosystem by providing habitat, nesting areas, and food for various aquatic organisms within the food chain (Tripathi et al, 2024). Additionally, they contribute to the regulation of nutrient levels, the accumulation of toxins, and the management of gaseous exchange (Cook et al., 1974).

The interactions between aquatic macrophytes and littoral fauna play a crucial role in ecosystem processes (Carpenter and Lodge, 1986). Aquatic plants are extensively found in aquatic environments due to their unique adaptive characteristics, primarily facilitated by their morphology. A prevalent adaptation is the presence of lightweight internal packing cells known as aerenchyma, which are located in floating leaves and finely dissected leaves (Sculthorpe, 1967). Nevertheless, other factors may also influence their distribution and abundance, including nutrient levels, wave disturbances, grazing, and salinity in the aquatic environment (Keddy, 2010). Consequently, only a limited number of aquatic plants can thrive in brackish, saline, and saltwater conditions (Sculthorpe, 1967). Additionally, some species can endure specific nutrient concentrations, while others cannot tolerate sudden nutrient increases. It is evident that human activities in river catchments significantly impact the nutrient dynamics of adjacent water bodies. The unregulated application of fertilizers and other agrochemicals easily enters water bodies through runoff and direct discharges. Given that rivers are subject to various activities in their catchment areas, it is essential to evaluate their macrophyte inventory.

Submergent species or forms refer to plants that primarily thrive beneath the water's surface. While some upper leaves may float at the surface and flowers can extend above, these plants are generally anchored to the bottom, although their inflorescences may rise above the water. Examples of such plants include bladderworts (Utricularia spp.), waterweeds (Elodea spp.), and milfoils (Myriophyllum spp.). Submerged plants predominantly grow under the water and may or may not be anchored to the lakebed. Their flowers can be found either above or below the water's surface. Many submerged plants exhibit heterophylly, possessing both submerged and floating leaves, although the majority of their vegetative growth occurs underwater. These heterophyllous plants are classified as submerged. Notable examples include coontail (Ceratophyllumdemersum), bladderworts (Utricularia spp.), and macroalgae. Submerged macrophytes play a crucial role in providing habitats and serve as significant ecological indicators for evaluating the health of aquatic environments and understanding the effects of climate change.

This research centers on submerged aquatic plant communities, specifically aquatic macrophytes. These macrophytes are characterized as plants that are typically anchored in the substrate, with their vegetative structures primarily underwater. Comprising vascular plants that thrive entirely beneath the water's surface, submerged macrophytes are crucial for the structural integrity of small, shallow aquatic systems, as they affect both biological composition and physico-chemical dynamics (Jeppesen, 1998). However, they are frequently neglected in botanical and biodiversity assessments, which often prioritize terrestrial and emergent wetland flora. Most aquatic macrophytes are found in the shallow littoral zones of lakes and streams, typically at depths of 5 to 6 meters, although certain species can extend to greater depths (Hutchinson, 1975).

These aquatic plants are essential for providing habitat for fish and invertebrates, serving as food for waterfowl, generating oxygen, and enhancing the overall primary productivity of lakes. Submerged macrophytes help to slow down water movement, leading to sediment accumulation and reducing erosion and resuspension (Horppila and Nurminen, 2005). When present in large quantities, aquatic macrophytes can outcompete algae for nutrients and light, resulting in improved water clarity (Blindlow et al., 2002; Mulderij et al., 2007; Hilt and Gross, 2008). Some species may also release allelopathic substances that inhibit algal growth (van Dunk, 2002). Aquatic ecosystems, particularly macrophytes, are vulnerable to the effects of climate change (Vedpathak et al., 2024). Further research is necessary to establish baseline data on emergent, submerged, and floating macrophytes to understand the impacts of a changing climate. For this study, submerged aquatic macrophytes are defined as any vegetation that is fully submerged, capable of living entirely underwater throughout the growing season, except for the growing tip, floating leaves, or emergent flower stalks.

Submerged macrophytes serve a crucial function as primary producers within food webs, providing habitat and food for various organisms, as well as acting as indicators of water quality (Nieder et al., 2004). Furthermore, they 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 and Padilla, 2000). Such dense beds can generate organic matter from both actively growing and decaying macrophytes, 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).

Aquatic macrophytes, commonly known as hydrophytes, include a diverse range of macroscopic plants that either entirely or partially complete their life cycles in aquatic environments. These plants have developed various adaptive strategies that enable them to successfully navigate environmental changes and thrive in a variety of aquatic habitats, such as freshwater lakes, rivers, wetlands, swamps, regions prone to seasonal flooding, and both brackish and marine environments (Mironova, 2014; Rajmankova, 2011; Wetzel, 2001).

From a taxonomic perspective, the flora of aquatic macrophytes encompasses several categories, including green macroalgae (Chlorophyta, such as Cladophora spp.), charophytes (Charophyceae, which includes Chara and Nitella spp.), and higher aquatic plants that consist of both vascular plants (Tracheophyta) and bryophytes (de Nie, 1987; Srivastava et al., 2008). Research indicates that macroalgae from the Rhodophyta and Xanthophyta divisions may also be classified as aquatic macrophytes (Chambers et al., 2008). In aquatic ecosystems, vascular plants are significantly less diverse and abundant compared to their terrestrial counterparts, representing only about 1% of the overall vascular flora. It is estimated that aquatic tracheophytes comprise 33 orders and 88 families, totaling approximately 2,614 species across 412 genera (Chambers et al., 2008). The most prevalent group among aquatic vascular plants is angiosperms (Magnoliopsida), although the aquatic flora also features members from the classes Polypodiopsida and Lycopodiopsida (Chambers et al., 2008; Wetzel, 2001).

Traditionally, it is widely believed that aquatic vascular plants originated from terrestrial species that later adapted to life in water (Cook, 1999). However, recent research suggests that certain groups of aquatic angiosperms may have evolved directly in aquatic environments (Du and Wang, 2016). The aquatic ecosystem consists of both plant and animal species that interact to sustain ecological equilibrium. Among these, aquatic weeds constitute a significant component of global aquatic ecosystems. These unwanted plants thrive in various water bodies, including ponds, lakes, reservoirs, and even oceans. Aquatic macrophytes, which encompass large forms of aquatic vegetation such as macroalgae, mosses, ferns, and angiosperms, fulfill essential functions within their ecosystems. The variety, abundance, and types of macrophytes present in freshwater ecosystems serve as critical indicators of the health of these water bodies.

Furthermore, aquatic vegetation plays a significant role in determining water quality. Macrophytes are crucial components of the aquatic ecosystem, providing habitat and nourishment for various aquatic organisms. Among the biological approaches to managing eutrophication, both emergent and submerged macrophytes have demonstrated the highest effectiveness. There are multiple strategies to harness the benefits of these aquatic plants, including phytoremediation, which has resulted in their reclassification from 'aquatic weeds' to 'aquatic plants.' Aquatic macrophytes are divided into several categories, such as planktonic algae, filamentous algae, surface-floating plants, emergent plants, submerged plants, and marginal plants. The existence of floating and emergent vegetation in lakes induces gradual transformations and fosters a nutrient-rich ecosystem (Sharma and Singhal, 1988). These aquatic plants are essential as they offer food, shade, and shelter for a wide variety of aquatic organisms. Moreover, they act as a substrate for numerous micro and macro-fauna, which depend on the roots, stems, and leaves of both floating and submerged macrophytes for habitat and attachment.

Macrophytes serve as vital elements within aquatic ecosystems, functioning not only as a food source for aquatic invertebrates but also significantly contributing to the accumulation of heavy metals (Chung and Jeng, 1974). Specific aquatic plants, including water hyacinth, water lettuce, and duckweeds, exhibit substantial potential for phytoremediation (bioremediation) of contaminated water due to their remarkable capacity to eliminate toxic substances (Nirmalkumar et al., 2008). This field of study is anticipated to receive further attention from contemporary researchers. The present investigation offers critical insights into the diversity of emergent macrophytes in the Beed district of Maharashtra, which will be instrumental for the management and regulation of aquatic plant species.

2. Materials and methods

2.1 Study area

The Beed district, located in the Marathwada region of Maharashtra, is the central subject of this research. It is one of the districts within the Marathwada area. Geographically, Beed is positioned at a latitude of 18° 99' North and a longitude of 75° 76' East, with an elevation of 457 meters above sea level. The district encompasses a total area of 10,693 square kilometers (4,129 square miles) and is subdivided into eleven tehsils: Beed, Ashti, Patoda, ShirurKasar, Gevarai, Ambajogai, Vadwani, Kaij, Dharur, Parali (Vaijanath), and Majalgaon. It shares its northern boundaries with the Chhatrapati Sambhajinagar (formerly Aurangabad) and Jalna districts, while Parbhani district lies to the east, Latur district to the southeast, Dharashiv district (formerly Osmanabad) to the south, and Ahilyanagar (formerly Ahmadnagar) district to the west and southwest. The administrative center of the district is situated in Beed city. For administrative organization, the district is divided into 11 talukas: Beed, Georai, Patoda, Ashti, Shirur (Kasar), Ambajogai, Kaij, Majalgaon, Dharur, Parli (Vaijnath), and Wadwani. According to the 2011 census, the district has a population of 2.585 million, consisting of six towns and 1,360 villages. The Godavari River is the primary waterway, flowing along the border between Georai and Majalgaon tehsils, with most of the district situated within the Godavari river basin. Furthermore, the major rivers traversing the district include the Godavari, Manjra, and Sina, along with their tributaries.

2.2 Climatic conditions

The Beed district is situated within two distinct agro-climatic zones: the Central Maharashtra Plateau (CMP) Zone and the Western Maharashtra Dry or Scarcity (SC) Zone. The monsoon season typically commences in the second week of June and persists until the end of September, with rainfall amounts ranging from 458 mm to 814 mm. The district's average annual rainfall is deemed reliable. From October to February, the climate is characterized by cold and dry conditions, with sporadic cold waves occurring between November and January. During the summer months, temperatures can escalate significantly, reaching between 40 and 45 degrees Celsius. Overall, the climate is generally pleasant, marked by hot summers and a prevailing dryness throughout the year, except during the southwest monsoon from June to September. The year can be categorized into four distinct seasons: the cold season from December to February, followed by the hot season from March to May. The southwest monsoon extends from June to September, while October and November are recognized as the post-monsoon period. Temperatures rise sharply after February, peaking in May, which is the hottest month, with an average daily maximum temperature of 42.0°C. In contrast, the average daily minimum temperature in December is 12.0°C. The normal annual rainfall varies from approximately 600 to 800 mm, with the lowest amounts recorded in the western region near Ashti, gradually increasing towards the east, reaching a maximum around Majalgaon (Lokhande et al., 2017). Except for the western part of the district near Ashti, most areas experience moderate to severe drought conditions for over 20% of the year, thus designating it as a 'drought area.' In summary, the climate of Beed district is predominantly dry, with the exception of the southwest monsoon season.

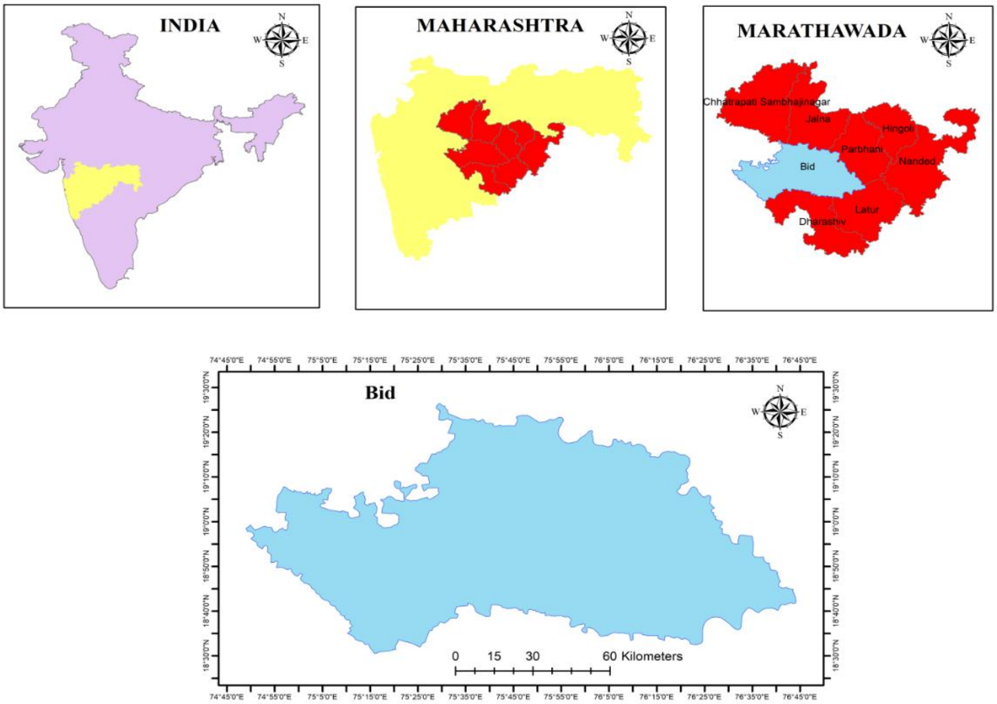


Figure 1: *A diagram depicting the location of the Beed district within the study area.*

The rainfall data for the district is collected from nine rain-gauge stations, with records ranging from 29 to 39 years. On average, the district experiences approximately 40 rainy days each year, defined as days with a minimum of 2.5 mm of rainfall. This figure varies, with Roti documenting 31 rainy days and the Beed observatory recording 44 days. The maximum rainfall observed in a 24-hour period at any station in the district was 346.0 mm, which took place at the Beed observatory on July 24, 1989. The district's average annual rainfall is 726.0 mm, with precipitation levels increasing from west to east; Roti, situated near the western border, receives 599.7 mm, while Majalgaon, located near the eastern border, receives 807.4 mm. Approximately 81% of the total annual rainfall occurs during the southwest monsoon season, with September typically being the month with the highest precipitation. Year-to-year variations in annual rainfall are generally slight. Between 1941 and 1990, the highest annual rainfall recorded was in 1983, reaching 145% of the normal, while the lowest was in 1972, at only 40% of the normal. During this fifty-year span, there were 13 instances where annual rainfall fell below 80% of the normal, including two occurrences of consecutive years and one instance of three consecutive years of below-normal rainfall. Beed primarily receives its rainfall during the monsoon season, which lasts from June to September. Beed experiences an average annual precipitation of approximately 66.6 cm (26.22 inches), with September generally recognized as the month with the highest rainfall and July noted for the greatest number of rainy days. It is important to mention that Beed is situated in a rain shadow region, leading to reduced rainfall in comparison to other areas in Maharashtra. The climate of Beed closely resembles that of Pune city. Monthly rainfall in Beed varies from 4.39 mm to 190.41 mm, with the total annual precipitation recorded at 758.23 mm and an average of 37.6 rainy days per year.

2.3 Meteorological conditions

The sole meteorological observatory in the district is located in Beed. The temperature and other meteorological data from this station provide a dependable representation of the district's overall climatic conditions. Cold weather typically begins in late November, with December being the coldest month, where the average daily minimum temperature is recorded at 12.3 °C and the average daily maximum at 29 °C. During the cold season, the district may experience cold waves linked to the movement of western disturbances across northern India, occasionally causing minimum temperatures to fall to around 4 °C. A noticeable increase in temperatures generally occurs in early March, with May being the hottest month, averaging a daily maximum temperature of approximately 40 °C. On particularly hot days, temperatures can soar to as high as 49 °C. As the southwest monsoon advances into the district by the second week of June, temperatures drop significantly, resulting in pleasant weather throughout the monsoon season. By the first week of October, the monsoon recedes, leading to a slight rise in daytime temperatures, which peak again in October. Following this period, temperatures gradually decline. The highest recorded maximum temperature in Beed was 48.5 °C on May 5, 1983, while the lowest minimum temperature was 4.0 °C on January 17, 1968. Relative humidity during the southwest monsoon season is notably high, ranging from 65% to 85%. After September, humidity levels gradually decrease, and during the cold and summer seasons, the air tends to be dry, particularly in the afternoons when relative humidity can drop below 30%. During the southwest monsoon, the skies are mostly overcast or heavily clouded, with a significant reduction in cloud cover occurring in the post-monsoon months. For the remainder of the year, the skies are typically clear or only slightly clouded. Winds are generally light, but their intensity tends to increase in the latter part of summer and throughout the southwest monsoon season. Following the monsoon, there is a swift decline in cloud cover. Throughout the year, the skies remain predominantly clear or only marginally overcast. Winds are usually gentle, becoming more robust during the latter summer months and the southwest monsoon. During this monsoon period, winds primarily flow from the southwest to the northwest. In the post-monsoon and winter months, winds are generally calm, originating from the southeast in the mornings and shifting to a northeasterly direction by the afternoon. In February, wind patterns are variable, while in the summer months, winds mainly come from the northwest. Thundershowers are common during the summer and monsoon months, with the highest occurrence noted in June and September. Furthermore, fog may occasionally manifest during the winter season.

The Beed district, located in Maharashtra, is characterized by a hot and arid climate, which includes a prominent monsoon season. This region experiences prolonged, severe summer and brief, mild winters, with the majority of rainfall occurring from June to September during the monsoon period. Summer temperatures typically range from 31 °C (87.8 °F) to 40 °C (104 °F), with some particularly sweltering summers witnessing temperatures surpassing 40 °C. May is acknowledged as the hottest month, with an average daily temperature of 42 °C (107.6 °F). The winter season is short-lived, with temperatures fluctuating between 12 °C (53.6 °F) and 20 °C (68 °F). During the wet season in Beed district, the atmosphere is often humid and overcast, while the dry season remains predominantly clear and hot throughout the year. Annually, temperatures generally range from 59°F to 103°F, seldom dropping below 52°F or exceeding 107°F. The summer season extends from mid-February to June, frequently featuring temperatures above 40°C (104°F). December is recognized as the coldest month, with temperatures occasionally dipping to 3°C (37.4 °F) or 4°C (39.2 °F) due to cold waves.

2.5 Survey Design

A comprehensive array of sampling and survey methodologies has been developed by various countries for targeted applications such as conservation, ecological assessment, drainage impact analysis, management, ecological habitat evaluation, and river restoration or enhancement. By utilizing the most appropriate methodologies from this collection, an assessment survey of submerged aquatic vegetation in the primary water-bodies and wetlands of the study area was conducted. This survey aimed to establish baseline data on submerged macrophytes in Beed District, Maharashtra. Survey locations were systematically established at regular intervals. At each site, three distinct habitat zones were independently evaluated based on specific habitat-related characteristics. The surveyed streams, rivers, major river courses, dams, wetland areas, and significant waterbodies were documented as per the existing literature (Dawson et al., 1999; Riis et al., 2001; 2013; Park et al., 2013).

Samples of submerged aquatic macrophytes that could not be identified in the field were collected and preserved for subsequent identification using suitable keys. Species-level identification was attempted wherever feasible, and specimens that could not be identified to the species level were submitted for formal identification, following the specimen collection and vouchering protocols established by the Queensland Herbarium (Jain and Rao, 1976; Queensland Herbarium, 2013).

2.5.1 Survey Methodology

The methodology employed for the survey involved a diverse array of recording and sampling techniques, tailored to the characteristics of river courses, wetlands, dams, and water bodies, as well as the specific objectives of the research. Aquatic macrophytes from significant waterways and water bodies within the study area were systematically collected across three distinct seasons: rainy, winter, and summer. Sampling and surveys of submerged aquatic macrophyte communities were primarily conducted from June to September during the years 2018 to 2022. The decision to deviate from the standard sampling period and the interpretation of results were guided by professional judgment to account for seasonal variations. These seasonal surveys included multiple visits aimed at assessing and gathering data on both littoral and submerged vegetation, as detailed by Narayana and Somashekar (2002). Over the four-year span from June 2018 to 2022, these surveys documented aquatic plants, particularly macrophytes, through regular excursions at short intervals to collect and identify plant samples from the designated study areas. This paper specifically examines the submerged macrophytes found in the Beed district. The Aquatic Plant Sampling Protocols (Parsons, 2001) were rigorously followed throughout the sampling process.

Samples were collected manually from the littoral zone and the exposed marginal areas of the sampling sites. 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. Each submerged plant sample was collected in duplicates. Each sample was placed into a separate bag and stored in an ice chest for transport back to the laboratory. In the laboratory, these samples were rinsed again to remove epiphytes and sediment from the plants, and any attached underground biomass was eliminated. The samples were then placed into separate pre-dried and weighed paper bags or aluminum weigh pans (depending on sample volume) and dried to a constant weight at 60 ◦ C before being sent for identification to experts for confirmation. The collected plant specimens were identified and verified against regional floras and relevant literature. This methodology aligns with techniques employed in recent research published by various researchers (Adoni, 1985; Cook, 1996; Garad et al., 2015; Gupta, 2001; Henry et al., 1989; Jain and Rao, 1976; Narasimha and Benarjee, 2016; Subramanyam, 1962; Yadav and Sardesai, 2002), as well as regional checklists for hydrophytes from multiple credible sources, with additional confirmation from botanists when available.

Macrophytes are typically defined as visible aquatic plants that can be easily recognized by field experts. These submerged plants exhibit significant spatiotemporal variability in aquatic ecosystems, complicating assessments and increasing the likelihood of errors when compared to terrestrial vegetation surveys. The lack of comprehensive research on their quantification and sampling, along with challenges such as depth variations, boundary uncertainties, difficulties in identifying taxa within the same plant group, and low detection rates, further contribute to these inaccuracies. Consequently, the survey was organized into four distinct phases: the first phase involved a pilot survey to establish the methodology and locations for the main survey; the second phase focused on documenting the macrophytes in the selected aquatic areas; the third phase was dedicated to data compilation; and the final phase encompassed data manipulation and validation.

3. Results and Discussion

Macrophytes play an essential role in stream ecosystems, with their importance extending well beyond their mere physical presence. As primary producers, they facilitate nutrient cycling and contribute to water purification. The composition of macrophyte communities is shaped by species-specific reactions to variations in water quality, making them effective bioindicators. Their capacity to accumulate heavy metals in their tissues further enhances their value as indicators of contamination. The acknowledgment of macrophytes as biological quality elements by legislation, such as the Water Framework Directive (WFD) and the Clean Water Act (CWA) in US, has heightened scientific interest in this group, resulting in the development of numerous new indices and predictive models in recent years. Additionally, macrophytes offer diverse habitats for macroinvertebrates, zooplankton, and fish within these ecosystems. In their absence, populations of macroinvertebrates and zooplankton would likely be diminished in stream environments.

The sampling locations within the main water bodies and wetland regions displayed a varied collection of submerged macrophyte species. Over the course of the four-year study, 89 emergent macrophyte species were identified from the littoral and sub-littoral areas of chosen sampling sites in the district. This compiled inventory reflects the emergent macrophytes noted, though it is not exhaustive. A summary of the documented submerged macrophytes can be found in Table 1.

Table 1: A comprehensive inventory of submerged macrophytes identified in significant water bodies, surrounding areas, and wetlands within the Beed District study region.

Sr. No.	**Scientific Name (Family)**	**Common Name**
1	*Cabombacaroliniana* (Nymphaeaceae)	Fanwort
2	*Ceratophyllumdemmersum*(Ceratophyllaceae)	Coontail
3	*Ceratophyllumsubmersum*(Ceratophyllaceae)	Soft Hornwort
4	*Charaglobularis*(Characeae)	Green algae
5	*Elodea canadensis* (Hydrocharitaceae)	Canadian pondweed
6	*Elodea densa* (Hydrocharitaceae)	Brazilian pondweed
7	*Elodea trifoliate* (Hydrocharitaceae)	Pondweed
8	*Heterentheradubia*(Pontederiaceae)	Water stargrass
9	*Haterrautheralimosa* (Hydrocharitaceae)	Blue mud plantain
10	*Hydrillaverticillata* (Hydrocharitaceae)	Oxygen weed
11	*Myriophyllumexalbescens* (Haloragaceae)	Water milfoil
12	*Myriophyllumspicatum* (Haloragaceae)	Eurasian water milfoil
13	*Najasgraminea* (Hydrocharitaceae)	Water nymph
14	*Najasindica*(Najadaceae)	Naiads
15	*Najas minor* (Najadaceae/ Hydrocharitaceae)	Water velvet/ Najas
16	*Potamogetoncrispus* (Potamogetonaceae)	Curlyleaf pondweed
17	*Potamogetongramineous* (Potamogetonaceae)	Pondweed
18	*Ruppiamaritima* (Potamogetonaceae)	Ruppia
19	*Trifoliumfragiferum* (Fabaceae)	Strawberry clover
20	*Vallisnerianatans*(Hydrocharitaceae)	Tapegrass

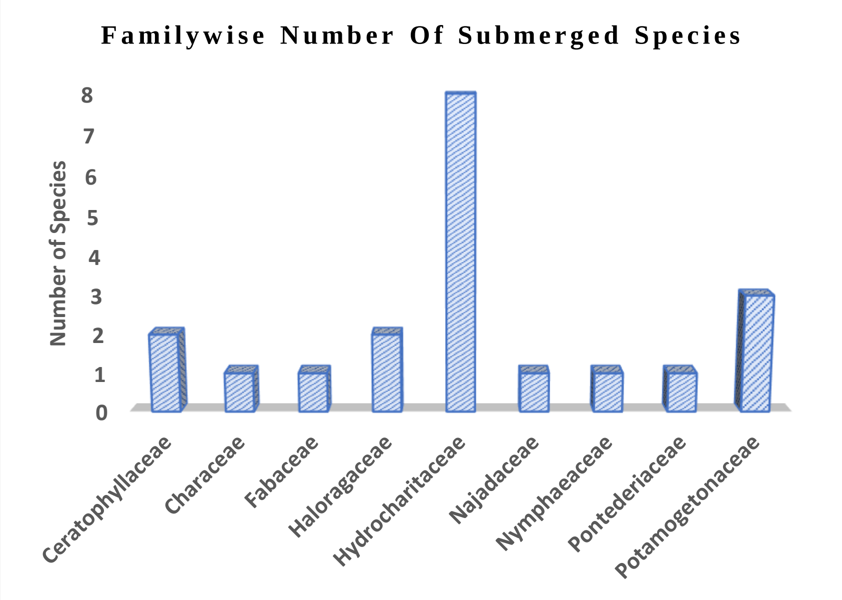
This survey of macrophytes, conducted in the rivers, tributaries, wetlands, dams, reservoirs, and watercourses of Beed District, aimed to evaluate the submerged macrophyte vegetation in various aquatic environments, including water bodies, waterlogged regions, wetlands, and marshes. The main goal of the survey was to identify ecological species of aquatic macrophytes from different families or groups and to explore their diversity within the designated area. Over the years, several researchers have undertaken 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).

Macrophyte species play a crucial role in various functions within aquatic ecosystems, including biomineralization, transpiration, sedimentation, elemental cycling, material transformation, degradation, and the release of biogenic trace gases. When utilized appropriately, these attributes and processes related to macrophytes can be effectively leveraged for the treatment of water and wastewater (Carpenter and Lodge, 1986; Daspute-Taur et al., 2018; Thete-Jadhav et al., 2018a & 2018b). In their natural habitats, the flora and fauna of aquatic ecosystems interact with one another, significantly contributing to the maintenance of ecological balance. Aquatic macrophytes encompass a variety of plant types, including macroalgae, mosses, ferns, and angiosperms. This research specifically focused on the investigation of macrophytes.

Table 2: A comprehensive classification of submerged macrophyte species by family in Beed District.

Sr. No.	Family of Submerged macrophyte	Number of Species
1	Ceratophyllaceae	2
2	Characeae	1
3	Fabaceae	1
4	Haloragaceae	2
5	Hydrocharitaceae	8
6	Najadaceae	1
7	Nymphaeaceae	1
8	Pontederiaceae	1
9	Potamogetonaceae	3
Total		20 species

In all, 20 species of submerged species of macrophytes were recorded during the present investigation. The investigation of submerged macrophytes in the Beed district indicates that the Hydrocharitaceae family is the most prevalent, comprising eight species (see Table 2). Following Hydrocharitaceae, the next most commonly observed families include Potamogetonaceae with three species, and Ceratophyllaceae and Haloragaceae, each with two species. Additionally, Characeae, Fabaceae, Najadaceae, Nymphaeaceae, and Pontederiaceae each contain one species. Prior studies (Jadhav and Babare, 2025a) have shown that the emergent macrophyte vegetation in the Chhatrapati Sambhajinagar district is similarly dominated by the Cyperaceae family, indicating its widespread presence throughout the Marathwada region. This group of researchers has conducted several studies on the survey of aquatic macrophytes and their potential for phytoremediation of metal-contaminated wastewaters and sewage (Shingadgaon and Chavan, 2018a; 2018b; 2018c; 2019; Jadhav and Babare, 2025a,b,c,d,e,f,g).



	Ceratophyllaceae	Characeae	Fabaceae	Haloragaceae	Hydrocharitaceae	Najadaceae	Nymphaeaceae	Pontederiaceae	Potamogetonaceae
Number of Species	2	1	1	2	8	1	1	1	3

Figure 2: Classification of submerged macrophyte species by family as observed in the study area.

The investigation of submerged macrophyte vegetation in Beed district indicates that the Hydrocharitaceae family is the dominant group in this region. Analyzing diversity indices within these districts allows researchers to acquire a more profound understanding of their ecological conditions and functional characteristics. This study offers essential baseline data concerning the diversity of submerged aquatic macrophytes in the significant water bodies of Beed district, which includes crucial water bodies, river systems, marshes, and wetlands. The findings will be vital for managing plant growth, tackling eutrophication, restoring aquatic ecosystems, and regulating plant species to improve pollution control through phytoremediation techniques.

Macrophytes play a significant role in the phytoremediation of wastewater contaminated with metals (Shingadgaon and Chavan, 2018a; 2018b; 2019). The variety and distribution of emergent, submerged, floating, and free-floating macrophyte species in the study area reflect a considerable diversity, which is vital for regulating the climatic conditions of Beed district in the Marathawada region of Maharashtra (Jadhav and Babare, 2025a). Submerged macrophytes generally display a simpler structural complexity, as their growth primarily occurs underwater (Singadgaon and Chavan, 2018a; 2018b; 2018c). Consequently, it is often suggested that these species establish a uniform habitat (Daspute-Taur et al., 2018). These macrophytes perform analogous ecological functions across various trophic levels within ecosystems; however, there is currently a lack of scientific evidence to support this claim. Thorough scientific research is necessary to elucidate the role of submerged macrophytes in the formation of aquatic habitats (Stahr and Kaemingk, 2017).

Conclusion

In conclusion, the Beed district, located in the Marathwada region of Maharashtra, exhibits a remarkable variety of submerged macrophytes, consisting of 20 species from 9 different families. The Hydrocharitaceae family is the most prevalent, featuring 8 species, followed by Potamogetonaceae with 3 species, and Haloragaceae and Ceratophyllaceae each with 2 species. Additionally, there is one species represented from the families of Characeae, Fabaceae, Najadaceae, Nymphaeaceae, Typhaceae, and Potamogetonaceae.

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Declaration of Conflicting Interests

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