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Investigation of Submerged aquatic macrophytes in Jalna District of Maharashtra

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Abstract

Aquatic macrophytes, often referred to as hydrophytes, are essential in providing structural habitats that significantly influence fish communities. This influence enables zooplankton and other macro-invertebrates to exercise top-down control over algal growth, a process that remains largely unaffected by the nutrient concentrations within the water body. However, these populations are under considerable threat from various factors, including eutrophication, sewage discharge, and industrial pollutants. Furthermore, seasonal changes can result in a marked reduction in the diversity of these aquatic plants. Consequently, it is imperative to establish baseline data to assess these impacts and safeguard the health of aquatic ecosystems.

A thorough survey was carried out to evaluate the presence of submerged macrophyte populations in the waterways of Jalana District, with careful documentation of the findings. The results indicate that the Jalna district is home to a rich diversity of submerged macrophytes. Notably, the district is characterized by a significant representation of an impressive variety of submerged macrophytes, encompassing 22 species across 9 families. The study reveals that the Hydrocharitaceae family is the most abundant, featuring 9 species, followed by Potamogetonaceae with 5 species, Ceratophyllaceae with 2 species, and Characeae, Fabaceae, Haloragaceae, Lentibulariaeaceae, Nymphaeaceae, and Pontederiaceae families, each represented by 1 species.

Keywords: Aquatic flora, Lake management, Wetland regions, Emergent, submerged, and floating macrophytes, Biodiversity, Water resources.

Introduction

Submerged macrophytes are essential for the proper functioning of shallow lakes and play a significant role in maintaining clear water conditions (Scheffer et al., 1993; Jeppesen et al., 2007). Aquatic macrophytes provide a safe haven for small animals from predators, modify the nutrient dynamics within the ecosystem, and prevent sediment resuspension, thus regulating water turbidity, which affects physicochemical water quality and biotic communities (Kristensen et al., 1992; Horppila and Nurminen, 2001).

One of the main ways in which macrophytes influence lake conditions is through their role in nutrient cycling. Their capacity to produce substantial biomass allows aquatic plants to effectively accumulate biogenic compounds (Clarke and Wharton, 2001; Abdo and Da Silva, 2002). Typically, the structural complexity and biomass of submerged macrophytes are affected by nutrient enrichment. The management of phosphorus and nitrogen is vital for preserving the biodiversity of lake ecosystems. Phosphorus is considered a critical element affecting primary production in lakes, particularly for phytoplankton (Kalff, 2001).

Submerged macrophytes constitute a vital functional group within lake ecosystems (Jeppesen et al., 1997). However, many submerged macrophytes in lakes have seen a decline or have even disappeared in recent years, both in China and worldwide, and significant challenges remain in restoring all submerged macrophytes in lakes due to unclear recession mechanisms (Qin et al., 2014; Zhang et al., 2017). A major factor contributing to this problem is the widespread decrease in underwater light availability, which hinders the growth of submerged macrophytes (Chen et al., 2016; Jin et al., 2020). Additionally, underwater light availability is crucial for influencing freshwater biodiversity in lakes that are dominated by submerged macrophytes (Karlsson et al., 2009; Estlander et al., 2017; Yu et al., 2021).

Submerged macrophytes play a vital role in shallow lakes. They improve water quality by absorbing nutrients from the water column (Jeppesen et al., 1998; Liu et al., 2018) and by stabilizing the sediment at the lakebed (Wu and Hua, 2014; Zhang et al., 2016). Additionally, they provide food and habitat for aquatic organisms (Blindow et al., 2014; Wood et al., 2017; Choudhury et al., 2019). However, the increase in human activities and eutrophication has resulted in a worldwide decline in the populations of submerged macrophytes in shallow lakes (Jeppesen et al., 1998; Wang et al., 2014; Yu et al., 2015). Due to their importance for the ecology of shallow lakes, submerged macrophytes have received growing attention, and their restoration is a crucial aspect of rehabilitating 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 often encounters difficulties due to several inherent constraints, such as elevated nutrient loading, artificially regulated water levels, and limited littoral zones (Guo, 2007; Van Geest et al., 2007; Mao et al., 2020). Moreover, frequent algal blooms can negatively impact the survival of submerged macrophytes (Kibria et al., 2012; Wang et al., 2021), with light deficiency being a significant factor that contributes to the decline of these plants (Schelske, 2010; Arthaud et al., 2012; Olsen et al., 2015; Zhang et al., 2016). Therefore, it is crucial to enhance underwater light availability to support the growth and reproduction of submerged macrophytes in urban lakes (O'Farrell et al., 2011; Paillisson and Marion, 2011; Zhang et al., 2016).

As a result, improving underwater light through artificial methods may be an effective strategy for restoring submerged macrophytes in urban lakes, especially in regions with low fish populations or where fish are absent. This approach would prevent the recovery of macrophytes from being hindered by fish grazing on the plants or fish predation on zooplankton, which could otherwise lead to increased phytoplankton growth and diminished light availability for macrophyte development.

Aquatic macrophytes are also employed as bioindicators of water pollution due to their sensitivity to variations in water quality. They play an essential role in mineral cycling and organic components, which subsequently affects total biomass production within aquatic ecosystems. Numerous researchers have undertaken studies related to aquatic and wetland flora across different regions of India (Mirashi, 1954; Sen and Chatterjee, 1959; Srivastva et al., 1987; Dhote and Dikxit, 2007; Chandra et al., 2008; Jadhav and Babare, 2025a to 2025i).

Research on aquatic macrophytes is of great significance to limnologists, as it aids in understanding the dynamics of aquatic ecosystems. For fisheries personnel, these studies act as a reference for fish food sources, while pollution control experts gain insights into their ability to remove nutrients. The diversity of macrophytes has been extensively studied by various researchers, including Chakraborty (2008), Vardayan (2006), Devi et al. (2004), Manorama et al. (2007), and LaishramKamla et al. (2007). Their research indicates that numerous aquatic macrophytes can become problematic when they grow excessively, resulting in their classification as aquatic weeds, which presents challenges for water management.

At present, freshwater systems are negatively impacted, experiencing a reduction in native biodiversity due to the influx of untreated sewage and pollution, which significantly alters the physicochemical parameters of water, affecting both its quality and quantity. Macrophytes encourage the growth of phytoplankton and aid in the recycling of organic matter. Moreover, submerged species at the edges serve as green manure, increasing the population of zooplankton and benthic fauna. They also provide suitable breeding and sheltering habitats for macro-invertebrates and fish (Meshram, 2003). The excessive growth of aquatic macrophytes can result in nuisance conditions, classifying them as aquatic weeds and raising concerns for water management.

Conducting surveys of aquatic macrophytes can establish a solid foundation for developing management plans. The aim of the current study was to summarize the biodiversity of submerged aquatic macrophytes in the examined area and categorize them, thereby offering essential baseline data on species diversity for the conservation of water bodies in Jalna District.

Materials and methods:

Study area:

The research on macrophytes was conducted in the Jalna district, which is situated in the central region of Marathwada, Maharashtra State. This district lies between the latitudes of 19° 15' and 20° 32' North, and the longitudes of 75° 36' and 76° 45' East. It extends 150 kilometers from north to south and 110 kilometers from east to west. Jalna district holds a prominent position on the Deccan plateau, with the majority of its area classified as plateau, except for the Ajanta and Satamala ranges and the river basins. The predominantly flat terrain of the region accommodates a high population density. The district is divided into eight tahsils, four subdivisions, and eight panchayatsamitis, covering a total geographical area of 7,726 square kilometers, which accounts for 2.47% of the state's total area. The population is primarily rural, with 98.07% residing in rural areas and only 1.93% in urban locales. The district consists of eight talukas: Jalna, Bhokardan, Jafrabad, Badnapur, Ambad, Ghansawangi, Partur, and Mantha. It is located in the eastern part of the Marathwada region and is bordered by Aurangabad district to the west, Jalgaon district to the north, Buldhana and Parbhani districts to the east, and Beed district to the south.

Climate:

The region is defined by a dry and tropical climate, which includes extremely hot summers and mild winters, as well as a humid southwest monsoon season that brings moderate rainfall. This climate can be categorized into three primary seasons: a) the hot to warm humid monsoon season from June to September, b) the cool dry winter season from October to February, and c) the hot dry summer season from March to June. During the rainy season, temperatures vary between 21 and 30°C, while winter temperatures significantly drop, ranging from 10 to 25°C. Nighttime temperatures typically range from 20 to 25°C, often accompanied by a refreshing breeze. Rainfall patterns in the district reveal two distinct areas. The first area includes the Bhokardan, Jafrabad, and Jalna talukas, which receive approximately 700 mm of rainfall. The second area consists of the Ambad and Parturtalukas, with an average rainfall of about 800 mm. Rainfall distribution is uneven across the district; Jalna and Ambadtalukas are noted for their consistent rainfall, whereas Bhokardan and Jafrabadtalukas experience moderate rainfall ranging from 625 to 700 mm. The average annual rainfall in the region is recorded at 725.80 mm, with around 83% occurring between June and September, making July the month with the highest precipitation.

Overall, the climate in the district is predominantly arid, except during the southwest monsoon when the relative humidity increases. The summer months are the driest, with afternoon humidity levels typically ranging from 20 to 25 percent. Winds are generally light to moderate, intensifying in the latter part of the hot season and throughout the monsoon. During the hot season, winds mainly come from the west and north, while during the southwest monsoon, they predominantly originate from the southwest and northwest. The district features an efficient drainage system characterized by dendritic patterns and well-defined valleys. There are two primary drainage systems: (1) the Godavari River and (2) the Purna and Dudhna Rivers. The Godavari River delineates the entire southern boundary of the district, particularly in the Ambad and Parturtalukas. It is a significant river within the Deccan Plateau, with the entire Jalna district situated within its extensive basin. The direct tributaries of the Godavari include the Shivbhadra, Yellohadrs, Galhati, and Musa Rivers, all of which originate from the Ajanta and Ellora plateaus, flowing south and eastward to merge with the Godavari. While numerous smaller streams tend to dry up during the summer months, the major rivers maintain a perennial flow. The Purna River originates near Mehun, approximately 8 km northeast of the Satmala Hills. It is the most important river after the Godavari and drains the entire regions of Jafrabad, Bhokardan, and parts of the Jalna district. Its tributaries encompass the Charna, Khelna, Jui, Dhamna, Anjan, Girja, Jivrakha, and Dudhna Rivers. The Dudhna River, the largest tributary of the Purna, is nearly as long as the main river itself. It has the longest course within the Jalna district, draining areas of Ambad, Jalna, and Parturtalukas, along with its tributaries such as Baldi, Kundilikha, Kalyan, Lahuki, and Sukna.

Climate and Rainfall:

The district's climate is marked by hot summers and a general lack of moisture throughout the year, with the exception of the southwest monsoon season, which occurs from June to September. The months of October and November represent the post-monsoon phase. The winter season begins in late November, leading to a rapid decline in temperatures. December is recognized as the coldest month, with an average maximum temperature of 30.5°C and a minimum of 10.5°C (2015). Starting in early March, daily temperatures gradually rise, peaking in May, the hottest month, with an average maximum temperature of 41°C and a minimum of 24.6°C. The southwest monsoon typically commences around the second week of June, resulting in a significant temperature drop. However, the arrival of the monsoon has increasingly been delayed to the third or fourth week of June. In the absence of the monsoon season, the district generally experiences dry air, with high relative humidity occurring only during the southwest monsoon. The summer months are particularly arid, with afternoon relative humidity levels usually between 20% and 25%. Winds are generally light to moderate, intensifying during the latter part of the hot season and throughout the monsoon. During the hot season, winds predominantly originate from the west and north, while during the southwest monsoon, they mainly come from the southwest and northwest. For the remainder of the year, winds are primarily from the northeast and southeast, shifting to southwesterly and northwesterly in January and February. The average annual rainfall in the district ranges from approximately 600 mm to 750 mm, with drought conditions arising when rainfall drops to between 400 mm and 450 mm.

Survey Methodology:

Aquatic macrophytes from major waterways and water bodies within the Jalna district study area were systematically collected over three distinct seasons: rainy, winter, and summer. Seasonal surveys, which involved multiple visits, were conducted to collect data on both littoral and submerged vegetation, as outlined by Narayana and Somashekar (2002).

Macrophytes were gathered monthly from June 2005 to May 2007 from shallow, littoral zones using the hand-picking technique. Specimens were thoroughly rinsed with water, excess moisture was absorbed using filter papers, and the specimens were stored in polythene bags prior to being transported to the laboratory in an ice box. They were preserved in 10% formalin and identified to the species level with the aid of relevant literature from Edmondson (1959), Pennack (1978), Tonapi (1980), and Fasset (2000). Over a four-year period, from June 2018 to 2022, these surveys recorded aquatic plants, particularly submerged macrophytes, through regular excursions at short intervals to collect and identify plant samples from the designated study sites. This paper specifically focuses on the submerged macrophytes identified in the Jalna district.

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

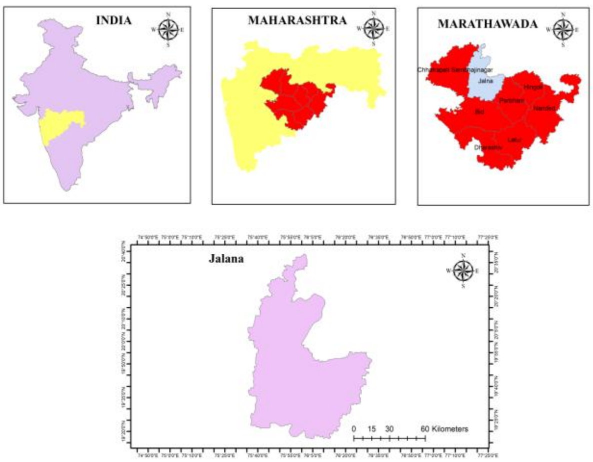

Figure 1: Map showing the location of the Jalna district within the study area.

Results and Discussion:

This survey of aquatic plants was primarily conducted to identify, document, and assess the abundance and distribution of various submerged aquatic plant species found within the waterways of the study area. Aquatic plants are species that flourish in a variety of saltwater and freshwater environments, which include small fish tanks, home aquariums, lakes, ponds, and oceans. These plants can either grow above the water, be entirely submerged, or exist in a transitional state; the key factor is that they naturally thrive in wet habitats. Aquatic plants display a range of characteristics that support their survival in these environments (Rascio, 2002). A compilation of submerged macrophytes identified in major water bodies, their adjacent areas, and wetlands within the study region (the list is representative, not exhaustive) is presented in Table 1.

Table 1: List of Submerged Macrophytes observed in major water bodies, their vicinities and wetlands in 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.	*Myriophyllumspicatum* (Haloragaceae)	Eurasian water milfoil
12.	*Najasgraminea* (Hydrocharitaceae)	Water nymph
13.	*Najasindica*(Najadaceae)	Naiads
14.	*Potamogetoncrispus* (Potamogetonaceae)	Curlyleaf pondweed
15.	*Potamogetongramineous* (Potamogetonaceae)	Pondweed
16.	*Potamogetonnodosus* (Potamogetonaceae)	Longleaf pondweed
17.	*Potamogetonpectinatus* (Potamogetonaceae)	Sago pondweed
18.	*PotamogetonPerfoliatus* (Potamogetonaceae)	Pond weed / Redhead grass
19.	*Trifoliumfragiferum* (Fabaceae)	Strawberry clover
20.	*Utricularia vulgaris* (Lentibulariaeaceae)	Bladderwort
21.	*Vallisnerianatans* (Hydrocharitaceae)	Tapegrass
22.	*Vallisneria Americana* (Hydrocharitaceae)	Eelgrass / tapegrass

The earlier research conducted by Jadhav and Babare (2025i) on emergent macrophyte vegetation in the Jalna district has indicated that the Cypereaceae family stands out as the most prevalent group among the emergent families in this region. Analyzing diversity indices within this district allows for a more profound comprehension of the ecological conditions surrounding submerged macrophytes and their functional characteristics. This study offers crucial baseline information pertaining to the diversity of submerged aquatic macrophytes found in the principal water bodies of the Jalna district, which includes important water bodies, river systems, marshes, and wetlands. The findings related to submerged macrophytes in the Jalna district of the Marathwada region in Maharashtra are vital for the management of plant growth, tackling eutrophication, rehabilitating aquatic ecosystems, and controlling plant species to improve pollution management through phytoremediation techniques in the area of study. The total count of submerged macrophyte species categorized by family in Jalna District is detailed in Table 2.

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

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

The recent survey of submerged macrophytes in the Jalna district, Maharashtra, reveals a clear dominance by the Hydrocharitaceae family, which accounts for 9 of the identified species (see Table 2 in the original study). This prevalence of Hydrocharitaceae is a significant finding, suggesting that the environmental conditions in Jalna are particularly conducive to the growth and diversification of plants within this family. Hydrocharitaceae, commonly known as the "frogbit family," includes well-known aquatic plants such as Hydrilla, Vallisneria, and Ottelia, all of which are recognized for their submerged growth forms and adaptability to various freshwater habitats (Jadhav and Babare, 2025h). Their success in the Jalna district could be attributed to factors like water quality, sediment composition, light penetration, and the presence of suitable substrates, which these species are known to favor (Jadhav and Babare, 2025d).

Following Hydrocharitaceae, the Potamogetonaceae family emerges as the second most commonly found, with 5 species reported. This family, often referred to as the "pondweed family," includes the genus Potamogeton, species of which are widespread in freshwater environments globally and are known for their ecological importance as food sources and habitat providers for aquatic organisms (Shingadgaon and Chavan, 2018a). The presence of a substantial number of Potamogetonaceae species further enriches the submerged macrophyte diversity in Jalna, indicating a relatively healthy aquatic ecosystem capable of supporting multiple families with distinct ecological requirements.

The survey also identified the Ceratophyllaceae family with 2 species. This family includes the genus Ceratophyllum, commonly known as hornworts, which are rootless, submerged plants that float freely in the water column and are highly adaptable to different water chemistries (Shingadgaon and Chavan, 2018b & 2018c). Their presence, though less numerous than the dominant families, still contributes to the overall biodiversity.

Furthermore, several other families were noted, each represented by a single species. These include Characeae, Fabaceae, Haloragaceae, Lentibulariaceae, Nymphaeaceae, and Pontederiaceae. While each of these families contributes only one species to the submerged macrophyte count in this specific survey, their individual presence adds to the ecological complexity and functional diversity of the aquatic habitats in Jalna. For instance, Characeae (stoneworts) are often indicators of good water quality, while Nymphaeaceae (water lilies) are prominent components of many aquatic ecosystems (Daspute-Tour et al, 2018a & 2018b).

The graphical representation in Fig. 2 (from the original study) would visually emphasize this percentage comparison, clearly illustrating the significant dominance of the Hydrocharitaceae family within the submerged macrophyte community of the Jalna district.

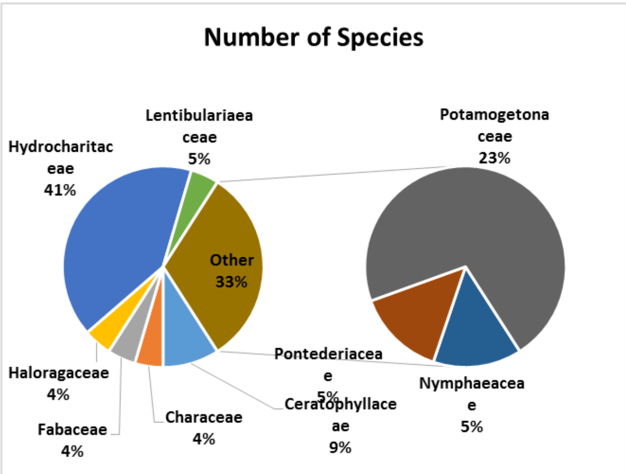

Figure 2: Categories of submerged macrophyte species classified by family as observed in the study area.

Macrophytes are crucial for the functioning of ecosystems. They act as primary producers, creating structural habitats for a variety of animal species, while also providing shelter and food for invertebrates (Castella et al., 1984) and fish (Rossier, 1995). Furthermore, they participate in ecosystem processes including biomineralization, transpiration, sedimentation, elemental cycling, material transformation, and the emission of biogenic trace gases into the atmosphere (Carpenter & Lodge, 1986). Recent studies have underscored the essential function of aquatic macrophytes in managing nutrient availability in water and improving the stability of lakeshores (Carpenter & Lodge, 1986; Blindow et al., 2014). The makeup of macrophyte assemblages can be influenced by geological factors, land use practices, and the chemical properties of water and sediment (Barko et al., 1991; Lougheed et al., 2001; del Pozo et al., 2011). Additionally, the composition and distribution of macrophyte communities differ based on climate, hydrology, substrate type, and nutrient availability.

Numerous researchers have highlighted the significance of macrophytes. Aquatic macrophytes are essential in aquatic ecosystems as they offer food and shelter for invertebrates (Rejmankova, 2011) and help stabilize sediments and shorelines, which in turn reduces turbidity in aquatic environments (Bamidele&Nyamali, 2008). Submerged macrophytes affect nutrient dynamics, light attenuation, temperature regimes, hydrodynamic cycles, and substrate characteristics (Rooney et al., 2003). These macrophytes play a crucial role in regulating and stabilizing mineral cycling in water bodies, thereby serving as indicators of potential ecosystem damage (Pieczynska&Ozimek, 1976). Aquatic plants are key drivers of ecosystem productivity and biogeochemical cycles, in part because they function as a vital interface between sediments and the overlying water column (Carpenter & Lodge, 1986). Aquatic plants are indispensable elements of aquatic ecosystems. Like all other photosynthetic organisms, they are crucial for harnessing the solar energy that sustains all other components of the ecosystem. They supply oxygen to other biota and enhance the physical habitat (Cronk&Fennessy, 2001).

Submerged macrophytes play a pivotal role in the health and functioning of aquatic ecosystems, acting as much more than just underwater plants. Their contributions span across various ecological processes, influencing everything from water quality to the diversity of aquatic life.

Firstly, these plants are primary producers within food webs, forming the base of the food chain by converting sunlight into energy. Beyond their role as a direct food source for herbivores, submerged macrophytes provide essential shelter and refuge for a wide array of organisms, including fish and invertebrates, protecting them from predators and strong currents (Nieder et al., 2004). Their presence significantly contributes to the diversity of zoobenthos (organisms living on or in the bottom sediments), offering crucial breeding grounds and additional food sources that support a thriving community of bottom-dwelling invertebrates (Ali et al., 2007).

Moreover, submerged macrophytes are instrumental in maintaining water quality. Through photosynthesis, they generate oxygen in stagnant areas, which is vital for the respiration of other aquatic organisms, especially in water bodies with limited circulation (Chambers et al., 1999). They also play a critical role in nutrient cycling and removal. By extending the hydrologic retention time, they facilitate the settling and removal of particulate nutrients from the water column, effectively "cleaning" the water (Nepf et al., 2007). This process helps to prevent the excessive buildup of nutrients that can lead to detrimental algal blooms. Additionally, the presence and health of submerged macrophytes often serve as indicators of overall water quality, with a diverse and abundant macrophyte community generally signaling a healthy aquatic environment (Nieder et al., 2004).

However, the beneficial influence of submerged macrophytes can be a double-edged sword. While their presence is desirable, the development of dense, monotypic stands—where one species dominates excessively—can have negative impacts (Buchan & Padilla, 2000). Such thick beds can outcompete other plant species, thereby reducing overall plant biodiversity. This lack of diversity can, in turn, negatively affect the diversity and abundance of invertebrates and fish that rely on a variety of habitats and food sources.

Furthermore, excessive growth of submerged macrophytes, particularly in dense stands, can contribute to eutrophication. As these plants grow and subsequently decay, they release a significant amount of organic matter into the water column (Chambers et al., 1999). This organic matter, combined with the decomposition process, can lead to increased nutrient loads and reduced dissolved oxygen, exacerbating eutrophication and potentially leading to harmful algal blooms and fish kills. Beyond ecological impacts, unchecked macrophyte growth can pose practical problems, including obstructing water flow, blocking reservoir inlets, and disrupting recreational activities such as boating, swimming, and fishing, making water bodies less accessible and enjoyable for human use (Kenneth, 1996).

In general, the growth of macrophytes is limited by a variety of factors, including the type of substrate, water depth, water clarity, nutrient concentration, and various physical disturbances. The presence and abundance of submerged macrophytes are influenced by both chemical and physical factors, such as water quality, light availability (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). Understanding how different environmental factors affect the habitats of submerged macrophytes is essential for purposes such as flow regulation, sediment transport (Jarvela, 2005), and assessments of the ecological status of rivers (Clayton and 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 and 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 and 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 Jalna 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 play a significant role in the phytoremediation of metal-contaminated wastewaters (Shingadgaon and Chavan, 2016; 2018; 2019). The occurrence and distribution of submerged macrophyte species within the study area reflect a notable diversity, which is vital for regulating the climatic conditions of the Jalna district, situated in the Marathawada region of Maharashtra. Typically, macrophytes demonstrate a simpler structural complexity, as their growth primarily takes place beneath the water's surface, making them less accessible to various aquatic organisms (Singadgaon and Chavan, 2017; 2018a; 2018b). Consequently, it is often recommended that these species create a uniform habitat (Daspute-Taur et al., 2018). The root systems of emergent macrophytes are acknowledged for their influence on the movement of solutes in the subsurface. Furthermore, it is suggested that these macrophytes perform similar ecological functions across different trophic levels within ecosystems; however, submerged macrophytes have not been thoroughly examined by researchers and necessitate increased focus from the scientific community, as there is currently inadequate scientific evidence to support this claim. Comprehensive scientific research is crucial to elucidate the role of submerged macrophytes in shaping aquatic habitats (Stahr and Kaemingk, 2017).

Conclusions:

The Jalna district, located in the Marathwada region of Maharashtra, exhibits a remarkable variety of submerged macrophytes, consisting of 22 species across 9 families. The results reveal that the Hydrocharitaceae family is the most abundant, featuring 9 species, followed by Potamogetonaceae, which includes 5 species. The Ceratophyllaceae family was observed to have 2 species, whereas Characeae, Fabaceae, Haloragaceae, Lentibulariaceae, Nymphaeaceae, and Pontederiaceae were each recorded with 1 species throughout the research.

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References:

[1] Abdo, M. S. A., & Da Silva, C. J. (2002). Nutrient stock in the aquatic macrophytes *Eichhornia crassipes* and *Pistia stratiotes* in the Pantanal–Brazil. In *Proceedings of the German-Brazilian Workshop on Neotropical Ecosystems* (pp. 875–880).

[2] Ahmadi-Nedushan, B., St-Hilaire, A., Bérubé, M., Robichaud, É., Thiémonge, N., & Bobée, B. (2006). A review of statistical methods for the evaluation of aquatic habitat suitability for instream flow assessment. *River Research and Applications*, *22*(4), 503–523.

[3] Ali, M. M., Mageed, A. A., & Heikal, M. (2007). Importance of aquatic macrophyte for invertebrate diversity in large subtropical reservoir. *Limnologica - Ecology and Management of Inland Waters*, *37*(2), 155–169.

[4] Arthaud, F., Mousset, M., Vallod, D., Robin, J., Wezel, A., & Bornette, G. (2012). Effect of light stress from phytoplankton on the relationship between aquatic vegetation and the propagule bank in shallow lakes. *Freshwater Biology*, *57*(3), 666–675.

[5] Asri, Y., & Eftekhari, T. (1999). Flora and vegetation of Siah-Keshim lagoon. *Journal of Environmental Studies*, *28*, 1–19.

[6] Bakker, E. S., Sarneel, J. M., Gulati, R. D., Liu, Z., & Donk, E. (2013). Restoring macrophyte diversity in shallow temperate lakes: Biotic versus abiotic constraints. *Hydrobiologia*, *710*(1), 23–37.

[7] Bamidele, J. F., & Nyamali, B. (2008). Ecological studies of the Ossiomo river with reference to the macrophytic vegetation. *Research Journal Botany*, *3*(1), 29–34.

[8] Barko, J. W., Gunnison, D., & Carpenter, S. R. (1991). Sediment interactions with submerged macrophyte growth and community dynamics. *Aquatic Botany*, *41*, 41–65.

[9] Blindow, I., Hargeby, A., & Hilt, S. (2014). Facilitation of clear-water conditions in shallow lakes by macrophytes: Differences between charophyte and angiosperm dominance. *Hydrobiologia*, *737*(1), 99–110.

[10] Buchan, L. A. J., & Padilla, D. K. (2000). Predicting the likelihood of Eurasian watermilfoil presence in lakes: A macrophyte monitoring tool. *Ecological Applications*, *10*(5), 1442–1455.

[11] Camporeale, C., & Ridolfi, L. (2006). Riparian vegetation distribution induced by river flow variability: A stochastic approach. *Water Resources Research*, *42*(10), W10415. https://doi.org/10.1029/2006WR004933

[12] Canfield, D., Langeland, K., Linda, S., & Haller, W. (1985). Relations between water transparency and maximum depth of macrophyte colonization in lakes. *Journal of Aquatic Plant Management*, *23*, 25–28.

[13] Carpenter, S. R., & Lodge, D. M. (1986). Effects of submerged macrophytes on ecosystem processes. *Aquatic Botany*, *26*(3-4), 341–370.

[14] Castella, E., Richardot-Coulet, M., Roux, C., & Richoux, P. (1984). Macro-invertebrates as descriptors of morphological and hydrological types of aquatic ecosystems abandoned by the Rhone River. *Hydrobiologia*, *119*(3), 219–226.

[15] Chakraborty, A., Jha, B. C., & Bhakat, R. K. (2008). Diversity and impact of macrophytes in Bandardaha Beel, Murshidabad, West Bengal. *Indian Journal of Environmental & Ecoplan*, *15*(1-2), 331–335.

[16] Chambers, P. A., DeWreede, R. E., Irlandi, E. A., & Vandermeulen, H. (1999). Management issues in aquatic macrophyte ecology: A Canadian perspective. *Canadian Journal of Botany*, *77*(3), 471–487.

[17] Chandra, G., Bhattacharji, I., Ghosh, A., & Chatterji, S. N. (2008). Mosquito control by larvivorous fishes—A review. *Indian Journal of Medical Research*, *127*(1), 13–27.

[18] Chen, J., Cao, T., Zhang, X., Xi, Y., Ni, L., & Jeppesen, E. (2016). Differential photosynthetic and morphological adaptations to low light affect depth distribution of two submerged macrophytes in lakes. *Scientific Reports*, *6*, 34028. https://doi.org/10.1038/srep34028

[19] Choudhury, M. I., Urrutia-Cordero, P., Zhang, H., Ekvall, M. K., Medeiros, L. R., & Hansson, L. A. (2019). Charophytes collapse beyond a critical warming and brownification threshold in shallow lake systems. *Science of the Total Environment*, *661*, 148–154.

[20] Clarke, S. J., & Wharton, G. (2001). Sediment nutrient characteristics and aquatic macrophytes in lowland English rivers. *Science of the Total Environment*, *266*(1-3), 103–112.

[21] Clayton, J., & Edwards, T. (2006). Aquatic plants as environmental indicators of ecological condition in New Zealand lakes. *Hydrobiologia*, *570*(1), 147–151.

[22] Cook, C. D. K., & Urmi-König, K. (1984). A revision of the genus *Hydrilla* (Hydrocharitaceae). *Aquatic Botany*, *17*(1), 1–10.

[23] Cronk, J. K., & Fennessy, M. S. (2001). *Wetland Plants: Biology and Ecology*. CRC Press/Lewis Publishers.

[24] Dai, Y., Jia, C., Liang, W., Hu, S. H., & Wu, Z. B. (2012). Effects of the submerged macrophyte *Ceratophyllum demersum* on restoration of a eutrophic waterbody and its optimal coverage. *Ecological Engineering*, *40*, 113–116.

[25] Daspute-Taur, A. B., Thete-Jadhav, R. G., Jadhav, S. L., Shingadgaon, S. S., & Chavan, B. L. (2018a). An application of floating constructed wetland reactor to phytoremediation of sewage. *International Research Journal of Natural and Applied Sciences*, *5*(2), 136–144.

[26] Daspute-Taur, A. B., Thete-Jadhav, R. G., Jadhav, S. L., Shingadgaon, S. S., & Chavan, B. L. (2018b). The use of a floating constructed wetland reactor for the phytoremediation of sewage. *International Research Journal of Natural and Applied Sciences*, *5*(2), 136–144.

[27] del Pozo, R., Fernandez-Alaez, C., & Fernandez-Alaez, M. (2011). The relative importance of natural and anthropogenic effects on community composition of aquatic macrophytes in Mediterranean ponds. *Marine and Freshwater Research*, *62*(1), 101–109.

[28] Dennison, W. C., Orth, R. J., Moore, K. A., Stevenson, J. C., Carter, V., Kollar, S., Bergstrom, P. W., & Batiuk, R. A. (1993). Assessing water quality with submersed aquatic vegetation. *BioScience*, *43*(2), 86–94.

[27] Devi Beenakumari, N., & Sharma, M. B. (2004). Life form analysis of the macrophytes of the Loktak Lake, Manipur, India. In A. Arvindkumar (Ed.), *Biodiversity and Diversity* (pp. 19–23). A.P.H. Corporation.

[28] Dhote, S., & Dixit, S. (2009). Water quality improvement through macrophytes—A review. *Environmental Monitoring and Assessment*, *152*(1-4), 149–153.

[29] Edmondson, W. T. (1959). *Fresh Water Ecology* (2nd ed.). John Wiley & Sons, Inc.

[30] Estlander, S., Horppila, J., Olin, M., & Nurminen, L. (2017). Should I stay or should I go? The diurnal behaviour of plant-attached zooplankton in lakes with different water transparency. *Journal of Limnology*, *76*(2), 253–260. https://doi.org/10.4081/jlimnol.2017.1564

[31] Fassett, N. C. (2000). *A Manual of Aquatic Plants*. Agrobios (India).

[32] Franklin, P., Dunbar, M., & Whitehead, P. (2008). Flow controls on lowland river macrophytes: A review. *Science of the Total Environment*, *400*(1-3), 369–378.

[33] Freitas, A., & Thomaz, S. M. (2011). Inorganic carbon storage may limit the development of submerged macrophytes in habitats of the Paraná River Basin. *Acta Limnologica Brasiliensia*, *23*(1), 57–62.

[34] Ghahreman, A., & Attar, F. (2003). The Anzali Wetland: A critical ecological and floristic study. *Journal of Environmental Studies (Special Issue on Anzali Lagoon)*, *28*, 1–38. (Published in Persian with an English summary).

[35] Guisan, A., Edwards, T. C., & Hastie, T. (2002). Generalized linear and generalized additive models in studies of species distributions: Setting the scene. *Ecological Modelling*, *157*(2-3), 89–100.

[36] Guo, L. (2007). Ecology—Doing battle with the green monster of Taihu Lake. *Science*, *317*(5842), 1166.

[37] Haynes, R. R., & Holm-Nielsen, L. B. (1985). A generic treatment of *Potamogeton* L. (Potamogetonaceae). *Nordic Journal of Botany*, *5*(6), 577–592.

[38] Horppila, J., & Nurminen, L. (2001). Effects of different macrophyte growth forms on sediment and P resuspension in a shallow lake. *Hydrobiologia*, *545*(1), 167–175.

[39] Jadhav, S. L., & Babare, M. G. (2025a). Investigation of emergent aquatic macrophytes in the Chhatrapati Sambhajinagar District. *International Journal of Research Publication and Reviews*, *6*(3), 7322–7329.

[40] Jadhav, S. L., & Babare, M. G. (2025b). Bioconcentration Factor (BCF), Bioaccumulation Factor (BAF), Metal Enrichment Factor (MEF) and Metal Translocation Factor (MTF) for the submerged macrophyte species *Ceratophyllum demersum*. *International Journal of Innovative Research in Technology*, *11*(11), 1903–1913.

[41] Jadhav, S. L., & Babare, M. G. (2025c). Screening of *Azolla caroliniana* for metal related bio-potential factors. *International Journal of Innovative Science and Research Technology*, *10*(4), 143–154.

[42] Jadhav, S. L., & Babare, M. G. (2025d). Survey of emergent aquatic macrophytes in the District of Dharashiv of Maharashtra. *International Journal of Recent Advances in Multidisciplinary Research*, *12*(4), 11042–11048.

[43] Jadhav, S. L., & Babare, M. G. (2025e). Bioabsorption, bioconcentration, metal enrichment and metal transfer factors of toxic metals in *Arundo donax* L. *International Journal of Novel Research and Development*, *10*(4), e619–e629.

[44] Jadhav, S. L., & Babare, M. G. (2025f). Investigation of emergent aquatic macrophytes in Jalna District of Maharashtra. *International Journal of Creative Research Thoughts*, *13*(4), 1907–1919.

[45] Jadhav, S. L., & Babare, M. G. (2025g). Bio potential factors of the aquatic plant species *Ceratophyllum submersum*: BCF, BAF, MEF, and MTF. *International Journal of Novel Research and Development*, *10*(4), f771–f785.

[46] Jadhav, S. L., & Babare, M. G. (2025h). Survey of submerged aquatic macrophytes in Beed District, Maharashtra. *International Journal of Science, Architecture, Technology and Environment*, *2*(5), 287–300.

[47] Jadhav, S. L. (2025i). Survey of submerged aquatic macrophytes in the District of Dharashiv of Maharashtra. *International Journal of Advanced Scientific and Technical Research*, *2*(1), 194–203. https://doi.org/10.26808/RS.2025.87c51a

[48] Jalili, A., Hamzehee, B., Asri, Y., Shirvani, A., Khushnivis, M., & Pak Parvar, M. (2009). Identifying dominant ecological vegetation patterns in Anzali Wetland and their significance for ecosystem management. *Journal of Sciences, University of Tehran*, *35*(1), 51–57.

[49] Jarvela, J. (2005). Effect of submerged flexible vegetation on flow structure and resistance. *Journal of Hydrology*, *307*(1-4), 233–241.

[50] Jeppesen, E., Søndergaard, M., & Christoffersen, K. (Eds.). (1997). *The structuring role of submerged macrophytes in lakes*. Springer-Verlag.

[51] Jeppesen, E., Søndergaard, M., Meerhoff, M., Lauridsen, T. L., & Jensen, J. P. (2007). Shallow lake restoration by nutrient loading reduction: Some recent findings and challenges ahead. *Hydrobiologia*, *584*(1), 239–252.

[52] Jeppesen, E., Søndergaard, M., & Christoffersen, K. (1998). *The Structuring Role of Submerged Macrophytes in Lakes*. Springer.

[53] Jin, S., Ibrahim, M., Muhammad, S., Khan, S., & Li, G. (2020). Light intensity effects on the growth and biomass production of submerged macrophytes in different water strata. *Arabian Journal of Geosciences*, *13*, 1–7. https://doi.org/10.1007/s12517-020-05924-4

[54] Kalff, J. (2001). *Limnology*. Prentice Hall.

[55] Karlsson, J., Byström, P., Ask, J., Ask, P., Persson, L., & Jansson, M. (2009). Light limitation of nutrient-poor lake ecosystems. *Nature*, *460*(7254), 506–509. https://doi.org/10.1038/nature08179

[56] Kenneth, A. L. (1996). *Hydrilla verticillata* (L.F.) Royle (Hydrocharitaceae), "The perfect aquatic weed". *Castanea*, *61*(3), 293–304.

[57] Kibria, G., Lau, T. C., & Wu, R. (2012). Innovative 'Artificial Mussels' technology for assessing spatial and temporal distribution of metals in Goulburn-Murray catchments waterways, Victoria, Australia: Effects of climate variability (dry vs. wet years). *Environmental International*, *50*, 38–46.

[58] Kristensen, P., Søndergaard, M., & Jeppesen, E. (1992). Resuspension in a shallow eutrophic lake. *Hydrobiologia*, *228*(2), 101–109.

[59] Lacoul, P., & Freedman, B. (2006). Environmental influences on aquatic plants in freshwater ecosystems. *Environmental Reviews*, *14*(2), 89–136. https://doi.org/10.1139/a06-001

[60] Laishram, K. D., & Sharma, M. (2007). Life form analysis and biological spectrum of the macrophytes of the Laisoipat lake, Manipur. *Indian Journal of Environmental & Ecoplan*, *14*(1-2), 153–159.

[61] Les, D. H. (1988). The origin and affinities of the Ceratophyllaceae. *Taxon*, *37*(2), 345–367.

[62] Liu, H., Zhou, W., Li, X. W., Chu, Q. S., Tang, N., Shu, B. Z., Liu, G. H., & Xing, W. (2020). How many submerged macrophyte species are needed to improve water clarity and quality in Yangtze floodplain lakes? *Science of the Total Environment*, *724*, 138267.

[63] Liu, Z. W., Hu, J. R., Zhong, P., Zhang, X. F., Ning, J. J., Larsen, S. E., Chen, D. Y., Gao, Y. M., He, H., & Jeppesen, E. (2018). Successful restoration of a tropical shallow eutrophic lake: Strong bottom-up but weak top-down effects recorded. *Water Research*, *146*, 88–97.

[64] Lougheed, V. L., Crosbie, B., & Chow-Fraser, P. (2001). Primary determinants of macrophyte community structure in 62 marshes across the Great Lakes basin: Latitude, land use, and water quality effects. *Canadian Journal of Fisheries and Aquatic Sciences*, *58*(8), 1603–1612.

[65] Manorama, T. D., & Sharma, M. (2007). Studies on the distribution of macrophytes of Yenapat Lake, Bishnupur, Manipur. *Indian Journal of Environmental & Ecoplan*, *14*(1-2), 311–318.

[66] Mao, Z., Gu, X., Cao, Y., Luo, J. H., Zeng, Q. F., Chen, H. H., & Jeppesen, E. (2020). Pelagic energy flow supports the food web of a shallow lake following a dramatic regime shift driven by water level changes. *Science of the Total Environment*, *756*, 143642.

[67] Meshram, C. B. (2003). Macro-invertebrate fauna of Lake Wadali, Amravati, Maharashtra. *Journal of Aquatic Biology*, *18*(2), 47–50.

[68] Middelboe, A. L., & Markager, S. (1997). Depth limits and minimum light requirements of freshwater macrophytes. *Freshwater Biology*, *37*(3), 553–568.

[69] Mirishi, M. V. (1954). Studies on the hydrophytes of Nagpur. *Journal of the Indian Botanical Society*, *33*, 298–308.

[70] Naqinezhad, A. R., & Hosseinzadeh, F. (2014). Plant diversity of Fereydoonkenar International wetland, Mazandaran. *Journal of Plant Researches (Iranian Journal of Biology)*, *27*(2), 320–335.

[71] Narasimha, R. K., & Banargee, G. (2016). The diversity and distribution of macrophytes in Nagaramtank, situated in the Warangal district of Telangana state. *International Journal of Fisheries and Aquatic Studies*, *4*(1), 270–275.

[72] Narayana, J., & Somashekhar, R. K. (2002). Macrophytes diversity in relation to water quality investigation on river Cauvery. In A. Kumar (Ed.), *Ecology and conservation of lakes, reservoirs and rivers* (pp. 86–113). A.B.D. Publishers.

[73] Nepf, H., Ghisalberti, M., White, B., & Murphy, E. (2007). Retention time and dispersion associated with submerged aquatic canopies. *Water Resources Research*, *43*(4), W04422.

[74] Nieder, W. C., Barnaba, E., Findlay, S. E. G., Hoskins, S., Holochuck, N., & Blair, E. A. (2004). Distribution and abundance of submerged aquatic vegetation and *Trapa natans* in the Hudson River Estuary. *Journal of Coastal Research*, *20*(Special Issue 41), 150–161.

[75] O'Farrell, I., Izaguirre, I., Chaparro, G., Unrein, F., Sinistro, R., Pizarro, H., Rodriguez, P., Pinto, P. D., Lombardo, R., & Tell, G. (2011). Water level as the main driver of the alternation between a free-floating plant and a phytoplankton dominated state: A long-term study in a floodplain lake. *Aquatic Sciences*, *73*(2), 275–287.

[76] O'Hare, J. M., O'Hare, M. T., Gurnell, A. M., Dunbar, M. J., Scarlett, P. M., & Laizé, C. (2011). Physical constraints on the distribution of macrophytes linked with flow and sediment dynamics in British rivers. *River Research and Applications*, *27*(6), 671–683.

[77] Olsen, S., Chan, F., Li, W., Zhao, S. T., Søndergaard, M., & Jeppesen, E. (2015). Strong impact of nitrogen loading on submerged macrophytes and algae: A long-term mesocosm experiment in a shallow Chinese lake. *Freshwater Biology*, *60*(7), 1525–1536.

[78] Paillisson, J. M., & Marion, L. (2011). Water level fluctuations for managing excessive plant biomass in shallow lakes. *Ecological Engineering*, *37*(2), 241–247.

[79] Pennak, R. W. (1978). *Fresh Water Invertebrates of the United States* (2nd ed.). Wiley Interscience Publishers, John Wiley & Sons.

[80] Pieczynska, F., & Ozimek, T. (1976). Ecological significance of lake macrophytes. *International Journal of Ecology and Environmental Sciences*, *2*, 115–128.

[81] Qin, B., Zhang, Y., Gao, G., Zhu, G., Gong, Z., & Dong, B. (2014). Key factors affecting lake ecological restoration. *Progress in Geography*, *33*(7), 918–924. https://doi.org/10.1007-6301(2014)33:7& lt;918:HPSTHF>2.0.TX;2-9

[82] Rascio, N. (2002). The underwater life of secondarily aquatic plants: Challenges and solutions. *Critical Reviews in Plant Sciences*, *21*(5), 401–427.

[83] Rejmankova, E. (2011). The role of macrophytes in wetland ecosystems. *Journal of Ecology and Field Biology*, *34*(4), 333–345.

[84] Riazi, B. (1996). *Siah-Keshim, The Protected Area of Anzali Wetland*. Department of the Environment Press.

[85] Rooney, V. J. N., Girwat, M. W., & Savin, M. C. (2005). Links between phytoplankton and bacterial community dynamics in a coastal marine environment. *Microbial Ecology*, *49*(1), 163–175.

[86] Rossier, O. (1995). Spatial and temporal separation of littoral zone fishes of Lake Geneva (Switzerland–France). *Hydrobiologia*, *300-301*(1), 321–327.

[87] Scheffer, M., Hosper, S. H., Meijer, M. L., Moss, B., & Jeppesen, E. (1993). Alternative equilibria in shallow lakes. *Trends in Ecology & Evolution*, *8*(8), 275–279.

[88] Schelske, C. L., Lowe, E. F., Kenney, W. F., Battoe, L. E., Brenner, M., & Coveney, M. F. (2010). How anthropogenic darkening of Lake Apopka induced benthic light limitation and forced the shift from macrophyte to phytoplankton dominance. *Limnology and Oceanography*, *55*(3), 1201–1212.

[89] Sculthorpe, C. D. (1967). *The Biology of Aquatic Vascular Plants*. Edward Arnold.

[90] Sen, D. N., & Chetterjee, U. N. (1959). Ecological studies on aquatic and swampy vegetation of Gorakhpur. A survey. *Agra University Journal of Research (Science)*, *8*(1), 17–27.

[91] Shingadgaon, S. S., & Chavan, B. L. (2018a). The potential for zinc absorption in Water Lettuce (*Pistia Stratiotes*, Linn). *International Journal of Science and Research*, *7*(3), 1497–1504.

[92] Shingadgaon, S. S., & Chavan, B. L. (2018b). Zinc uptake potential of *Eichhornia crassipes* at various concentrations. *International Journal for Research in Applied Science & Engineering Technology*, *6*(3), 3472–3476.

[93] Shingadgaon, S. S., & Chavan, B. L. (2018c). Zinc uptake potential in *Cyperus esculentus* L. *International Journal of Application or Innovation in Engineering & Management*, *7*(6), 47–58.

[94] Shingadgaon, S. S., & Chavan, B. L. (2019). Assessment of Bioaccumulation Factor (BAF), Bioconcentration Factor (BCF), Translocation Factor (TF), and Metal Enrichment Factor (MEF) capabilities of aquatic macrophyte species exposed to metal-contaminated wastewater. *International Journal of Innovative Research in Science, Engineering and Technology*, *8*(1), 329–347.

[95] Short, F. T., & Coles, R. G. (1999). Global seagrass research: an update. *Aquatic Botany*, *63*(3-4), 185-191.

[96] Sondergaard, M., Johansson, L. S., Lauridsen, T. L., Jørgensen, T. B., Liboriussen, L., & Jeppesen, E. (2010). Submerged macrophytes as indicators of the ecological quality of lakes. *Freshwater Biology*, *55*(5), 893–908.

[97] Son, D., Cho, K.-H., & Lee, E. J. (2017). The potential habitats of two submerged macrophytes, *Myriophyllum spicatum* and *Hydrilla verticillata* in the river ecosystems, South Korea. *Knowledge and Management of Aquatic Ecosystems*, *418*, 58.

[98] Sousa, W. (2011). *Hydrilla verticillata* (Hydrocharitaceae), a recent invader threatening Brazil's freshwater environments: A review of the extent of the problem. *Hydrobiologia*, *669*(1), 1–20.

[99] Srivastava, A. K., Dixit, S. N., & Singh, S. K. (1987). Aquatic angiosperm of Gorakhpur. *Indian Journal of Forestry*, *10*(1), 46–57.

[100] Stahr, K. J., & Kaemingk, M. A. (2017). An evaluation of emergent macrophytes and their role in supporting various aquatic species. *Lake and Reservoir Management*, *33*(3), 314–323.

[101] Thete-Jadhav, R. G., Daspute, A. B., Jadhav, S. L., Shingadgaon, S. S., & Chavan, B. L. (2018a). Sewage treatment by Floating Constructed Wetland Reactor System. *Journal of Emerging Technologies and Innovative Research*, *5*(12), 406–413.

[102] Thete-Jadhav, R. B., Daspute-Taur, A. B., Jadhav, S. L., Shingadgaon, S. S., & Chavan, B. L. (2018b). Performance of Floating Constructed Wetland Reactor with *Cyperus esculentus* L. macrophyte at different concentrations of sewage. *International Journal of Application or Innovation in Engineering & Management*, *7*(2), 6–11.

[103] Tonapi, G. T. (1980). *Fresh Water Animals of India, An Ecological Approach*. Oxford and IBH Publishing Co.

[104] Van Geest, G. J., Coops, H., Scheffer, M., & Nes, E. (2007). Long transients near the ghost of a stable state in eutrophic shallow lakes with fluctuating water levels. *Ecosystems*, *10*(1), 36–46.

[105] Vardayan, L., & Ingole, B. S. (2006). Studies on heavy metal accumulation in aquatic macrophytes from seven lakes: Armenia and Caranbolim. *Internet Collection*, 1–27.

[106] Wang, H. J., Wang, H. Z., Liang, X. M., & Wu, S. K. (2014). Total phosphorus thresholds for regime shifts are nearly equal in subtropical and temperate shallow lakes with moderate depths and areas. *Freshwater Biology*, *59*(12), 1659–1671.

[107] Wang, Y., Pedersen, M. W., Alsos, I. G., De Sanctis, B., Racimo, F., Prohaska, A., Coissac, E., Owens, H. L., Merkel, M. K. F., Fernandez-Guerra, A., Rouillard, A., Lammers, Y., Alberti, A., Denoeud, F., Money, D., Ruter, A. H., McColl, H., Larsen, N. K., Cherezova, A. A., & Willerslev, E. (2021). Late Quaternary dynamics of Arctic biota from ancient environmental genomics. *Nature*, *600*(7887), 86–92. https://doi.org/10.1038/s41586-021-04016-x

[108] Wood, K. A., O'Hare, M. T., McDonald, C., Searle, K. R., Daunt, F., & Stillman, R. A. (2017). Herbivore regulation of plant abundance in aquatic ecosystems. *Biological Reviews*, *92*(2), 1128–1141.

[109] Wu, D., & Hua, Z. (2014). The effect of vegetation on sediment resuspension and phosphorus release under hydrodynamic disturbance in shallow lakes. *Ecological Engineering*, *69*, 55–62.

[110] Yu, Q., Wang, H. Z., Li, Y., Shao, J. C., Liang, X. M., Jeppesen, E., & Wang, H. J. (2015). Effects of high nitrogen concentrations on the growth of submerged macrophytes at moderate phosphorus concentrations. *Water Research*, *83*, 385–395.

[111] Yu, Y. X., Li, Y., Wang, H. J., Wu, X. D., Zhang, M., Wang, H. Z., Hamilton, D. P., & Jeppesen, E. (2021). Submerged macrophyte restoration with artificial light-emitting diodes: A mesocosm experiment. *Ecotoxicology and Environmental Safety*, *228*, 113044. https://doi.org/10.1016/j.ecoenv.2021.113044

[112] Zahed, S., Asri, Y., Yousefi, M., & Moradi, A. (2013). The flora, life forms, and chorotypes of plants in Selkeh Lagoon, Northern Iran. *Journal of Plant Researches (Iranian Journal of Biology)*, *26*(3), 301–310.

[113] Zhang, Y. L., Liu, X. H., Qin, B. Q., Shi, K., Deng, J. M., & Zhou, Y. Q. (2016). Aquatic vegetation in response to increased eutrophication and degraded light climate in eastern Lake Taihu: Implications for lake ecological restoration. *Scientific Reports*, *6*, 23867.

[114] Zhang, Y., Jeppesen, E., Liu, X., Qin, B., Shi, K., Zhou, Y., Thomaz, S. M., & Deng, J. M. (2017). Global loss of aquatic vegetation in lakes. *Earth-Science Reviews*, *173*, 259–265. https://doi.org/10.1016/j.earscirev.2017.08.013