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Diverse role of Macrophytes in aquatic ecosystems: A brief review

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Abstract

The aquatic ecosystem is composed of aquatic flora and fauna which interact together in maintaining the aquatic ecosystem. Aquatic macrophytes are macroscopic forms of aquatic vegetation, including macro algae, mosses, ferns and angiosperms found in aquatic habitat. Macrophytes of freshwater ecosystems have diverse roles to play in the structure and functioning of these aquatic ecosystems. The depth, density, diversity and types of macrophytes present in a system are indicators of water body health. Aquatic vegetation can influence the water quality too. Macrophytes are considered as an important component of the aquatic ecosystem as the habitat and food source for aquatic life. Of all the biological treatments for controlling eutrophication, submerged macrophytes, has been recognized as being the most effective. This paper is a brief review of the diverse role of macrophytes in an aquatic ecosystem.

Keywords: Aquatic ecosystem, macrophytes, structuring communities.

Introduction

The aquatic ecosystem is composed of aquatic flora and fauna which interact together in maintaining the aquatic ecosystem. Submerged macrophytes represent the major component in aquatic ecosystems and help shape the physical and chemical environment, as well as the biota (Jeppesen & Søndergaard, 1999). These hydrophytes provide a considerable number of ecological niches and sustain food chains (McAbendroth et al., 2005). Aquatic macrophytes are aquatic photosynthetic organisms, large enough to see with the naked eye, that actively grow permanently or periodically submerged below, floating on, or growing up through the water surface. Aquatic macrophytes are represented in seven plant divisions: Cyanobacteria, Chlorophyta, Rhodophyta, Xanthophyta, Bryophyta, Pteridophyta and Spermatophyta (Chambers et al., 2007).

Aquatic macrophytes are macroscopic forms of aquatic vegetation, including macro algae, mosses, ferns and angiosperms found in aquatic habitat. Macrophytes of freshwater ecosystems have many roles to play in the structure and functioning of these aquatic ecosystems.

Diverse role of macrophytes in freshwater ecosystems

Macrophytes play an important role in the freshwater ecosystem functioning of many shallow water bodies: as primary producers, by providing structure in the habitat of many animal species, and provide shelter and food to invertebrates (Castella et al., 1984) and fish (Rossier, 1995). Macrophytes, which are major primary producers in shallow freshwater systems, have been reported to contribute substantially to biodiversity at the ecosystem level (Zeng et al., 2012).

Macrophytes are also involved in ecosystem processes such as biomineralization, transpiration, sedimentation, elemental cycling, materials transformation, and release of biogenic trace gases into the atmosphere (Carpenter & Lodge, 1986). Recent studies have established the importance of aquatic macrophytes in regulating the nutrient availability in the water and enhancing the stability of lakeshores (Carpenter & Lodge, 1986; Blindow et al., 2014). Macrophyte assemblage can be influenced by geology, land use, and water and sediment chemistry (Barko et al., 1991; Lougheed et al., 2001; del Pozo et al., 2011). Macrophyte community composition and distribution varies with climate, hydrology, substrate type, and nutrient availability.

Growth forms of aquatic macrophytes given below: (Chambers et al., 2007).

1. emergent macrophytes (plants that are rooted in submersed soils or soils that are periodically inundated, with foliage extending into the air (e.g., *Phragmites australis, Typha latifolia*),
2. floating-leaved macrophytes (plants rooted to the lake or stream bottom with leaves that float on the surface of the water (e.g., *Nuphar luteum*),
3. free-floating macrophytes (plants that typically float on or under the water surface (e.g., *Eichhornia crassipes*) and
4. submerged macrophytes (plants that grow completely submerged under the water, with roots or root-analogues closely associated with the substrate (e.g., *Myriophyllum spicatum*).

In theory, their distribution in lentic systems occurs in organized zones. Starting from the edge with emerged plants, followed by plants with floating leaves until we found rooted submerged species. However, abiotic factors (i.e., depth, water temperature, light incidence, input of nutrients, and interspecific competition) may facilitate heterogeneous distribution (Middelboe & Markager, 1997; Freitas & Thomaz, 2011).

Most submerged aquatic macrophytes belong to the families Ceratophyllaceae, Haloragaceae, Hydrocharitaceae, Nymphaeaceae and Potamogetonaceae. Submerged macrophytes are found in various types of water bodies, including estuaries, rivers, lakes, ponds, natural depressions, ditches, swamps and floodplains. They compete with phytoplankton for nutrients, decreasing the productivity of the water and causing hindrance to the movement of fish, irrigation and navigation.

Role of Macrophytes as primary producers

Aquatic macrophytes play a significant role in freshwater ecosystems as they provide food and shelter to invertebrates (Rejmankova, 2011) and stabilize sediments & shorelines thus reducing turbidity of aquatic systems (Bamidele & Nyamali, 2008). Submerged macrophytes affect nutrient dynamics, light attenuation, temperature regimes, hydrodynamic cycles, and substrate characteristics (Rooney et al., 2003).The macrophytes are responsible for the regulation and stabilization of mineral cycling in the water bodies and hence they serve as indicators for the possible degree of damage in the ecosystem (Pieczynska & Ozimek, 1976). The aquatic plants are the drivers of ecosystem productivity and biogeochemical cycles, in part because they serve as a critical interface between the sediments and the overlying water column (Carpenter & Lodge, 1986). Aquatic plants are an essential part of the aquatic ecosystems. They, like all other photosynthetic organisms, are crucial in fixing the solar energy that powers all other components of the ecosystem. They supply oxygen to the other biota and contribute to the physical habitat (Cronk & Fennessy, 2001).

The productivity of any water body is determined by the amount of plankton it contains as they are the major primary and secondary producers (Davies et al., 2009). As primary producers, macrophytes are among the most productive on the planet (Barrón et al., 2003; Abdullah & Fredriksen, 2004). In the aquatic ecosystem, the phytoplankton are the foundation of the food web, in providing a nutritional base for zooplankton and subsequently to other invertebrates, shell fish and finfish (Emmanuel & Onyema, 2007). Macrophytes are primary producers which are at the base of herbivorous and detritivorous food chains, providing food to invertebrates, fish and birds, and organic carbon for bacteria. Their stems, roots and leaves serve as a substrate for periphyton and a shelter for numerous invertebrates and different stages of fish, amphibians and reptiles (Timms & Moss, 1984; Dvořák, 1996).

Macrophytes and Faunal diversity

The presence of macrophytes and aquatic invertebrates in these places enhances the local species richness (Williams et al., 2008). Macrophytes play a central role in the control of phytoplankton and sustain a high faunal diversity. Diversity and abundance of invertebrates in lentic ecosystems are often influenced by the presence of aquatic macrophytes (Thomaz & Cunha, 2010). The macrophytes support epiphytic algae and animals as well as a variety of associated mobile animals, including zooplankton, macrofauna and fish (Albertoni et al., 2007; Christie *et al* 2009). Macrophytes provide habitat and refuge for zooplanktonic filter feeders to maintain top-down control on the phytoplankton (Sandilands & Hann, 1997). Wetlands with their macrophyte assemblages can also contribute to the wellbeing of the community by acting as urban green spaces which provide aesthetic appeal, landscape diversity and recreational opportunities (De et al., 2018). However macrophytes are also becoming a nuisance to the aquatic ecosystem, human health and economy when they turn out to be invasive.

Different macrophyte communities provide habitats with different structure, cover, and food for aquatic fauna, with much of the difference in quality dependent on species diversity, density, and structural aspects of the plants (Engel 1985). Macrophytes are colonized by epiphytes, which provide food for invertebrate grazers. Invertebrates also find refuge from predation and sites for oviposition in macrophyte areas. Dead macrophytes and their associated bacteria are a food source for detritivores. Living macrophytes are a direct food source for aquatic herbivores, including invertebrates, fish, waterfowl, and muskrat, and they also provide (Carpenter & Lodge, 1986).

Macrophytes and structuring communities in aquatic ecosystems

Aquatic macrophytes play an important role in structuring communities in aquatic environments. These plants provide physical structure, increase habitat complexity and heterogeneity and affect various organisms like invertebrates, fishes and waterbirds (Thomaz et al., 2010). Macrophytes generally colonize shallow ecosystems where they become important components, influencing ecological processes (e.g., nutrient cycling) and attributes of other aquatic attached assemblages (e.g., species diversity). The role of macrophytes as physical structures that increase habitat complexity or heterogeneity in aquatic ecosystems is widely recognized.

The effect of macrophytes on populations and communities has been widely demonstrated for a variety of organisms, such as micro- and macro-invertebrates (e.g., Bergström et al., 2000), fish (Araújo-Lima et al., 1986; Meschiatti et al., 2000; Vono and Barbosa, 2001; Theel et al., 2008) and waterbirds (Guadagnin et al., 2009; Klaassen & Nolet, 2007).

Role of macrophytes in fish assemblages

The absence of physical structures in the littoral zone of created ecosystems (like reservoirs) implies a lack of suitable habitats and the instability of biotic relationships, which may limit the resources available. This lack of structure can be identified as a limiting factor for population growth. Thus, the presence of an intermediate level of cover of macrophytes may maintain populations and communities, ensuring support for a larger number of organisms (Dibble et al., 1996). Aquatic macrophytes may have a strong influence on the population dynamics of these fish assemblages through structuring habitats. The important role of macrophytes to fish assemblages is considered in techniques aimed at fisheries resource management.

Macrophytes as bio-indictors

Plants are sensitive tools for prediction and recognition of environmental stresses. Ecological health can be viewed in terms of ecosystems, in which structural and functional characteristics are maintained. Ecological health has an effect on human health and well-being. (Samiyappan, 2019). The depth, density, diversity and types of macrophytes present in a system are indicators of water body health. Aquatic vegetation can influence the water quality too.

The presence or absence of certain plant or other vegetative life in an ecosystem can provide important clues about the health of the environment (Samiyappan et al., 2019). Phytoplanktons are of great importance in bio-monitoring of pollution (Davies et al., 2009). The distributions, abundance, species diversity, species composition of the phytoplankton are used to assess the biological integrity of the water body (Townsend et al., 2000). Aquatic macrophytes in the littoral zones of lakes have two fundamental properties, which make them useful as limnological indicators:

1) they react slowly and progressively to changes in nutrient conditions (Melzer, 1999)

2) the littoral zone may experience patterns of nutrient (and pollutant) concentrations caused by natural or artificial inflows as well as by diffuse, non-point sources (Melzer, 1999) and rooted submerged macrophytes may reflect this patchiness. Among the water chemical parameters Ca^{2+}, COD, NO_2, Mg^{2+}, Cl^- were important in differentiating the communities. Macrophytes are important structural components and sensitive

bioindicators of the long-term trophic state of freshwater lakes (Melzer, 1999).

Macrophytes as invasive species

Aquatic and wetland habitats are especially vulnerable to plant invasions due to high disturbance and often high nutrients that facilitate rapid expansion of invading species. Wetlands cover < 6% of the earth's land area and shallow waters cover < 9% of global area yet the proportion of invasive aquatic and wetland plant species is large (30%) (Zedler, 2011). Macrophytes affect nutrient cycling, for example through transference of chemical elements from sediment to water, by both active and passive processes (Carignan & Kalff, 1980).

Macrophytes have adaptations that enable their rapid spread and growth (Santamaria, 2002) and increase their invasive potential. Aquatic macrophytes are often dispersed and introduced around the world for ornamental objectives and other anthropogenic interests. Effects due to invasion could affect habitat heterogeneity provided to associated organisms. Other effects of macrophytes invasion include changes in the composition of the macrophytes assemblage itself (Mack et al., 2000; Michelan et al., 2010). Considering that aquatic macrophytes exert an important role in structuring habitats, their invasion could change the waterscape, impacting other taxonomic groups. Freshwater ecosystems are highly impacted by human beings (e.g., through eutrophication), which increases the invisibility of these systems by macrophytes (Engelhardt, 2011). Invasive macrophytes can cause serious ecological and economic damage worldwide (e.g., Pieterse & Murphy, 1990).

The most problematic free-floating species are *Azolla pinnata, Eichhornia crassipes, Pistia stratioites,* and *Salvinia molesta*, widespread in tropical and sub-tropical regions. Other global-scale invasives are *Lythrum salicaria, Myriophyllum spicatum, Potamogeton crispus*, and *Trapa natans* (Rejmankova, 2011). The aquatic biomass can, however, cause problems for the maintenance and leisure use of water bodies in the case of overgrowth. For this reason, the aquatic biomass has to be regularly removed and disposed away.

Role of Macrophytes in the treatment of eutrophic water

Surface water eutrophication can lead to algal and cyanobacterial blooms, die-off of indigenous vegetation, and a serious decrease in biodiversity (Pretty et al., 2003; Conley et al., 2009). Recovery of water quality and the repair of ecosystems damaged by increased nutrient runoff is a research area of importance (Song et al., 2006). Excess loading of phosphorus (P) and nitrogen (N) from domestic, agricultural and industrial wastewaters is the main cause of eutrophication of aquatic ecosystems, damaging their ecological quality and functioning (Kronvang et al., 2005; Kantawanichkul et al., 2009). Of all the biological treatments for controlling lake eutrophication, aquatic vegetation, especially submerged macrophytes, has been recognized as being the most effective. The establishment of macrophytes stands in shallow systems can increase nutrient retention and recycling (Jones et al., 1993). During the growing season, macrophytes act as a sink by accumulating nutrients in developing tissues (Engel, 1998). Aquatic floating macrophytes take up inorganic nutrients mainly by the roots, although uptake through the leaves may also be significant. Members of free floating duckweeds (Lemnaceae), namely *Lemna minor*, *L. gibba, Wolffia arrhiza,* and

Azolla pinnata have shown potential usefulness in the treatment of eutrophicated water system (Sutton & Ornes, 1975). Aquatic macrophytes are unchangeable biological filters and they carry out purification of the water bodies by accumulating dissolved metals and toxins in their tissue (Lilit & Baban, 2006). Many of the macrophytes found to be the potential scavengers of heavy metals from aquatic environment and are being used in wastewater renovation systems (Abida, 2009).

Conclusion

Macrophytes are considered as an important component of the aquatic ecosystem not only as the habitat and food source for aquatic life, but also act as an efficient accumulator of heavy metals and as an important participant in the natural processes of water self-purification of water. Macrophytes grow in aquatic environments and are well adapted to their surroundings. Presence of excessive nutrients in any water body is the root cause of eutrophication which can be checked by macrophytes as they have the potential to eliminate these excessive nutrients. Thus they have capability to improve the quality of water by absorbing nutrients with their effective root systems and hence function as powerful bio-filters.

Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this work.

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