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Role of Macrophytes: A Review

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Abstract Macrophytes are large aquatic plants belonging to taxonomically diverse groups. They are adapted morphologically, anatomically and physiologically to grow in aquatic habitats of fresh water, brackish water or sea water. This review is based on the rigorous study of literature and papers based on work done on wetlands and macrophytes. Surveys show that macrophytes form an important component in the structure and functioning of an aquatic ecosystem. They play a vital role in the sustenance of life by providing habitat, food, fodder, fiber, green manure, medicines and other useful products. They act as a bioindicator, influence water quality, perform nutrient cycling and reduce shore erosion. The work concluded that knowledge of floral diversity in any aquatic habitat is essential as each and every plant has its role in food chain and they must be documented and conserved before they become extinct without being acknowledged. Researches must be undertaken to scientifically study and extract the important constituents from unknown flora by identifying them with the help of indigenous people so that it can be further flourished for the welfare of mankind. The aim of this paper is to review the diverse roles of macrophytes and to focus on the conservation of aquatic resources and the biodiversity within them, as they not only provide various ecosystem services but are important for the livelihood and ecological balance.

Keywords Macrophytes, Aquatic Plants, Aquatic Ecosystem, Water Quality

1. Introduction

Macrophytes are macroscopic plants adapted to grow in aquatic environment. They include permanently or periodically submerged, floating or emergent aquatic plants and filamentous algae [1]. Cronk and Fennessy [2] divided macrophytes in to four ecological groups of emergent (E), rooted emergent (RE**)**, submerged (S) and free-floating hydrophytes (F). Chambers *et al.* [3] analyzed the diversity and distribution of aquatic macrophytes and represented them in seven plant groups. These are Chlorophyta, Cyanophyta, Xanthophyta, Rhodophyta, Bryophyta, Pteridophyta and Spermatophyta.

Macrophytes grow in aquatic habitat of fresh water, brackish water and sea water and are adapted according to the physical and chemical parameters of their surroundings. Nutrient condition, salinity, dissolved oxygen, temperature, light, water level, water flow velocity, transparency, concentration of suspended particles, gas saturation and other limnological parameters determine the community composition of macrophytes. They are influenced by their surroundings and in turn influence the surrounding affecting growth of different life forms [4-7].

Macrophytes are of diverse values in the form of food, fodder, medicine, oxygen, protection and habitat to different organisms. They are an important source of livelihood for local people. As macrophytes respond to a variety of environmental conditions they are important bioindicators. Their role in controlling water eutrophication and its purification has also been well established [8-9]. Systematic investigation of macrophyte diversity and their ecosystem services have been conducted at different places in India and abroad [2, 10-15]. This article reviews diverse roles of macrophytes.

2. Different Roles of Macrophytes in Aquatic Ecosystem

2.1. As Primary Producers

Macrophytes being primary producers are an important component of any ecosystem. As green plants, they play an important role in conversion of light energy into chemical energy in aquatic habitat. By the process of photosynthesis, they not only produce organic matter but also provide oxygen for respiration and decomposition of organic matter [16,17].

2.2. As Biological Indicators of Water Quality

An appropriate proportion of plants are required for the fitness and health of any ecosystem. In aquatic habitat, water body health is represented by the density and diversity of macrophytes. Their absence or overabundance, both are an indicator of water quality problem. Their absence represents the occurrence of factors that inhibit plant growth like water salinization, land cover changes, herbivory or presence of inhospitable bottom sediments while their excessive growth may be an indicator of high nutrient condition that causes eutrophication threatening aquatic life [18,19]. Macrophytes maintain oxygen balance, metabolism and nutrient cycle of waterbodies [17, 20]. Thus maintenance of their balanced growth is essential.

Harmful algal blooms are a threat to any water reservoir consumed for household, industrial or recreational purposes. These algal blooms produce a harmful effect on various aquatic organisms, birds and human beings as they gradually deplete oxygen concentration from the water body and produce cyanotoxins. The allelochemicals secreted by the macrophytes are natural algaecides. They can be used as an inhibitor in the proliferation of cyanobacterial blooms and stabilize the clear water condition in shallow lakes [21].

2.3. In Phytoremediation

Continuous increase in population and industrial activity is polluting the aquatic system. Heavy metal removal experiments using different macrophytes showed that several aquatic plants act as natural biological filters that carry out purification of water. Macrophytes are hyperaccumulators and have an enormous ability to absorb and accumulate excessive nutrients and toxic metals from the water in their tissues. They also slow down the flow of water to allow sedimentation of suspended particles. Thus they are suggested as one of the best alternative to mitigatethe problem of water pollution. Various studies have been conducted to identify the bioaccumulation potential of macrophytes and utilize them as phytoremediators in control of heavy metal pollution in lake ecosystem [22-24]. Efforts have been done to identify and utilize the specific nutrient uptake ability of different plants for phytoremediation [25-26]. Darr *et al.* [27] explored the possibility of use of water hyacinth in degradation of water pollutants. Tang *et al.* [28] compared the nutrient uptake rates of *Azolla filiculoides, Ceratophyllum demersum* and *Myriophyllum spicatum*.

Macrophytes are also capable of detoxifying the absorbed chemicals from the surrounding aquatic environment. An experiment with water hyacinth, duckweed and lettuce for municipal waste water treatment suggests that the use of macrophytes has low operational and maintenance cost and can be preferred over conventional methods as a waste water treatment system [29].

2.4. In Fish Farming

The macrophytes are utilized in fish farming either in the form of food, breeding ground or sheltering places. Macrophytes having high nutritional profile have been suggested as an inexpensive alternative to costly fish feed in order to reduce the cost of fish production. This will not only allure fish farmers towards aquaculture but also meet the demand of high quality and easily digestible animal protein for growing population [30].

Comparative analysis of different macrophytes such as *Azolla*, *Lemna*, *Ipomoea*, *Nelumbo*, *Wolffia*, etc. has established their nutritional value as fish feed [31-32]. Herbivorous fishes prefer those macrophytes as feed that are fleshy and have high energy and protein content and avoid those that have chemical deterrents and calcareous or encrusting material [33]. Macrophyte complexity provides protection to larvae, juvenile and minute species against predation. They are also used for laying eggs by fishes like *Heterotis niloticus*, *Clarias* and *Tilapia zilli* [34].Aquatic macrophytes had socio-economic importance to fishing communities in the Northern region of Ghana [12]. Macrophytes when evaluated for ecological intensification of small scale fish farming on multi-parameter matrix *Azolla filiculoides* showed the best overall score [35]. Although feeding rate of fishes is maximised at intermediate density of macrophytes, it is reduced at its further increase. Thus timely harvesting of macrophytes is necessary for integrated fish management.

2.5. As Medicine

Among the multipurpose traditional use, medicinal properties of macrophytes have been well documented. The ethnomedicinally important aquatic macrophytes used by the rural people have been explored at various regions. They are used for various ailments like skin diseases, throat disorders, inflammation, muscular pain, jaundice, dysentery, chest pain, small pox, yellow fever, flu, improving immunity, etc. [10,11,13]. The macrophytes used as nesting material at Alwara Lake had anti-viral, anti-fungal, anti-bacterial and anti-oxidant properties [36]. A report on ethnomedicinally aquatic and semi-aquatic plants in wetlands of Western Assam showed a decline in population of *Nelumbo nucifera, Euryale ferox,* and *Trapa natans* due to huge exploitation and excessive growth of invasive species [14].

2.6. Macrophytes in Nest Building

The abundance of macrophytes affects the diversity of nesting bird species. Many macrophytes are used by the birds as sheltering material. The quality of nest is determined by the material used in building nest. The large biomass of plants helps in faster building of nests and provides camouflage to their chicks from intruders in their territory. Whiskered tern builds large nests on large floating plants for its stability and security [37]. Study conducted on Saras crane showed that the bird uses locally available macrophytes as the common and main material for nest building [36,38].

2.7. Macrophytes as Food and Fodder

A large number of aquatic and semi-aquatic plants have potential for being used as food due to their nutritional value. The emergent macrophyte rice *Oryza sativa* forms a staple diet for more than 50% of world's population [39]. In India, the seeds of *Euryale ferox* and *Echinochloa colona* are eaten for their nutritional value [40-41]. *Nelumbo nucifera, Alternanthera sessilis, Ipomoea aquatica, Nymphaea pubescens, Neptunia oleracea, Ceratopteris thalictriodes,* etc. are reported to be consumed as food in different parts of the world. Macrophytes like, *Ceratophyllum demersum, Eragrostis unioloides, Fimbristylis miliacea, Hygroryza aristata, Ipomoea aquatica, Kyllinga brevifolia, Leersia hexandra,* etc. have been mentioned for use as livestock fodder [13,42,43].

2.8. Macrophytes as Fertilizer

Macrophytes have been suggested as an innovative solution to the problem created by the use of chemical fertilizers. As biofertilizer, it not only reduces pollution but also increases soil fertility. A literature survey compiled the work on application of various macrophytes on different plants as biofertilizers [44]. Baweja *et al.* [45] proposed that macroalgae and microalgae are rich in macronutrients, micronutrients, growth regulators, etc. and can be used as an ecofriendly and cost-effective alternative in the form of organic fertilizer to increase crop production.

A study showed that application of decaying macrophyes as fertilizer on maize crop not only increased its productivity but also provided resistance against phyto-pathogens as it contained phenolics and flavonoids that are known for their anti-microbial activity [46].

2.9. Macrophytes and Species Richness

Macrophytes provide food, habitat, egg laying area, refuge, etc, for various invertebrates, zooplanktons, epiphytic algae, fishes and other animals. Thus they support and nurture the biodiversity [47-48].

2.10. Miscellaneous Uses

A rigorous survey of literature shows the miscellaneous uses of aquatic plants. These are based on survey, questionnaire and conversation with the inhabitants living in vicinity of wetlands or other aquatic habitats. Miscellaneous uses include the use of macrophytes for water gardening (Eg. *Nymphaea* spp., *Nymphoides* spp., *Eichhornia* spp., *Pistia stratiotes,* etc.); religious offerings (Eg., *Nelumbo nucifera, Nymphaea pubescens, Nymphaea lotus, Nymphaea stellata, Utricularia aurea*); weaving (Eg., *Cyperus* spp., *Typha angustifolia*); fencing (Eg., *Ipomoea carnea*); firewood (Eg., *Ipomoea fistulosa*); vegetables (eg., *Monochoria hastata, Ipomoea aquatica*) and adorns (*Nymphaea* spp.) [42,43,49,50].

The work conducted by Mayala *et al.* [51] focused on the use of aquatic biomass of *Ledermanniella schlechteri* and *Ulva lactuca* as a potential source of bioenergy with an added benefit of reduction in usage of firewood and charcoal, reduction of harmful emissions and availability of organic fertilizer.

2.11. Chemistry of Macrophytes

As a process of evolution, organisms develop certain features to ensure their survival. In this sequence macrophytes have evolved chemical deterrents besides structural development of spines, thorns and tough leaves to prevent herbivory. Defensive features of macrophytes against herbivory by non-native species have been utilized in Lake restoration as it ensures structural refugia for larval fishes and invertebrates and recovery of endangered species [52]. Habenariol from *Harbenaria,* the glucosinolate-myro-sinase system in watercress, phlorotannins in brown alga; halogenated methanes, haloketones, phenolics and complex terpenes in red alga; diterpenes and sesquiterpenes in green alga; sulfate esters, phenolic acids and sulphated flavonoids in sea grasses are

some of the antifeedant chemicals found in plants of aquatic habitat. However the chemical defences vary with species, habitat and ecological conditions [53].

Increase in population has created a pressure of survival resulting in an increased demand of commodities and in turn a rise in industrial, agricultural and other anthropogenic activities. These activities, when increase the density of elements above 5 gm/cm^3,it causes heavy metal pollution. Heavy metals are taken up by the plants through roots which create stress in plants. This stress is mitigated by them through certain chemicals called phytohormones. Phytohormones such as auxins, cytokinins (CK), gibberellins (GA), ethylene (ETH), abscisic acid (ABA), brassinosteroids (BR), salicylic acid (SA), and jasmonates are the chemical messengers produced by the plants for growth and development. These messengers also guide some signalling pathways in heavy metal stress mitigation in plants. This potential of macrophytes have made them be used in alleviation of heavy metals in water bodies [54, 55].

2.12. Future Prospects

Sustainable use of water, protected ecosystem, pollution-free environment, green and clean energy are some of the core areas of sustainable development goals. Macrophytes can contribute to this by being employed in treatment of swine waste water and electricity generation through a constructed wetland system. These plants provide physical conditions that help in the treatment of waste water. Besides this, the oxygen that is released from the roots enhances aerobic degradation of organic matter [56]. A research was conducted to study the effect of macrophytes, *Canna indica*, *Acorus calamus* and *Ipomoea aquatica* on waste water treatment and electricity production in a coupled system of constructed wetland and microbial fuel cell. In this study, *Canna indica* system showed better decontamination capability while *Ipomoea aquatica* had better results in the promotion of bioelectricity generation [57].

Harilal [58] conducted a research and compared the detoxication potential of three floating macrophyte species *Eichhornia crassipes*, *Salvinia molesta*, *Pistia stratiotes* in water bodies contaminated with effluent from milk processing factory and latex factory. Water hyacinth (*Eichhornia crassipes*) comparatively gave better results in treatment of effluent from milk factory while *Salvinia molesta* showed better effluent treatment efficiency from latex factory.

3. Conclusions

On the basis of above studies, it can be concluded that intermittent documentation of macrophytes in different areas is essential for the identification of any invasive species as well as for the conservation of ecologically and economically important plants as overexplotation or slight change in physico-chemical parameter of water may result in huge loss of aquatic biodiversity. This is intolerable as macrophytes are not only the source of livelihood for local people living in the vicinity of aquatic habitat but provide various other ecosystem services necessary for ecological balance.

Studies conducted on macrophytes showed that a large part of our biodiversity having enormous value is still unexplored. Efforts must be done to retrieve and store the traditional knowledge about the importance of locally available plants from indigenous local people as this knowledge is orally transmitted and may get diminished along with time. Further the study on potential of macrophytes in decontamination of environment and electricity generation is the need of hour.

Though macrophytes are boon for the living communities near wetland but they become bane if their excessive growth is not checked from time to time. Their overabundance creates problems in maintenance and decreases the aesthetic value and recreational use of water body. Therefore proper monitoring and integrated management approach is needed on one hand to maintain proper diversity and density and on the other hand for sustainable utilization of these valuable aquatic resources.

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