An Overview of Macrophytes in The Tropical Wetland Ecosystem

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Abstract
Macrophytes are plants that adapted to wet environment and easily be found all over the world. Macrophytes have structures that are more complex, interdependent and physically substantial; make them one of the important components of rivers, lakes and any other wetland ecosystems. Macrophytes can be categorized into four different types; emergent, floating-leaved, submerged and free-floating plants based on their structure and life form. Light, water current and wind flow are among the most important limiting factors of macrophytes occurrence in the water system. Environmental conditions such as lotic and lentic environment influence the limiting factors and would be the key for successful macrophytes distribution. Each macrophyte species could respond differently to different environmental circumstances. It also has been widely used as subject for biological indicator of ecosystem health. This paper aimed to describe the general environmental condition for macrophytes distribution, discuss their role and impact of excessive growth.

Keywords: lentic, lotic, macrophytes, wetland.

INTRODUCTION

Aquatic ecosystem is an ecosystem surrounded by water. This water body plays crucial environmental functions such as recycles the nutrient through water cycle, purifies the water source, debilitate floods, revitalize the ground water and equip the habitat for wildlife (Solan *et al*., 2004). In addition, this water-based environment is also important as human recreation and spot for tourism. Two main types of aquatic ecosystems are marine ecosystems and freshwater ecosystems (David and Rhodes, 1999). In particular, there are three main types of freshwater ecosystems; wetlands, lentic and lotic. Wetlands are areas where the soil is saturated or inundated for at least part of time. Lentic ecosystem is a slow-moving water body including pools, ponds, and lakes, whereas lotic ecosystem is a faster-moving water body, such as streams and rivers (Wetzel, 2001).

Wetlands

Wetlands are the most productive natural ecosystems in the world due to their contiguity between water and soil. Hence, they support a huge number of flora and fauna species. Generally, vascular plants dominate the wetland areas as they are well-adapted to saturated soil. There are four main types of wetlands; swamp, marsh, fen and bog (David *et al*., 2005). Due to their productivity, wetlands are often used for agriculture by converting it into dry land with dykes and drains. In addition, their close distance to the main lakes and rivers make them preferable for human settlement. Unfortunately, once settlements are constructed and protected by ditches, it will become vulnerable to land subsidence and would increase the risk of a flash flood. Rice agriculture areas are considered as a temporary human-made wetland. For national food security purpose, Malaysia has allocated huge lands to be used as rice cultivation sites. Up to date, there is 674,548 hectares of land used for rice planting (Selamat and Ismail, 2009).

Lentic

Lentic or lake ecosystems are divided into three zones or sub-habitats; littoral, photic and aphotic zones. Littoral is a shallow zone near to the shore, whereas photic (or euphotic – open water zone) and aphotic (or profundal – deep water zone) zones are found at the limnetic zone (pelagic or offshore) (Figure 1). The littoral zone is dominated by rooted plants. *Mimosa pigra* is one of the examples of the rooted plant which successfully grow in the littoral zone (Karim and Mansor, 2013). In the open water zone, sunlight benefits the photosynthetic algae and species that feed upon them. This is different with the deepwater zone where sunlight is absence and the food web is based on detritus which come from the littoral zone and photic zone (Kalff, 2002). The results of production from plants which grow in the littoral zone, combined with production from plankton growing in the open water were contributed to the net production of a lake ecosystem as a whole.

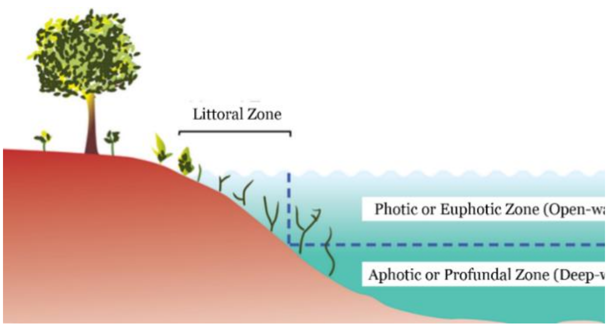

Figure 1: The three zones of a lentic ecosystem; Littoral, photic and aphotic zones

Wetlands also can be a part of the lentic ecosystem, as they are formed naturally along most of the lakeshores. The width of the wetland and littoral zone being dependent upon the slope of the shoreline. The dead trees accumulate in this zone, either from windfalls on the shore or logs transported to the site during floods. This wood debris provides important habitat for fish and nesting birds, as well as protecting shorelines from erosion.

Two important subclasses of lakes are ponds and reservoirs. Ponds typically are small lakes that support living organism such as plant and animals. Over long periods of time, a succession occur, where a pond becomes enriched by nutrients and slowly filled in with organic sediments. The increasing volumes of sediment flow into the lake can accelerate the succession process when there is humans' exploitation on the watershed. The addition or enrichment of an ecosystem with chemical nutrients or natural substances such as phosphorus and/or nitrogen into a lake is known as eutrophication. Ponds are small and shallow water bodies with still water. The depth and size of ponds often varies greatly. The fours zones of ponds are; riparian vegetation, open water, bottom mud and surface film. Usually, the food webs in a pond are based upon free floating algae, phytoplankton and aquatic plants. Normally, it has a diverse array of aquatic life, such as algae, snails, small fish, beetles, water bugs, frogs and turtle. Top predators may include large fish, herons and humans. Since fish are the major predator on amphibian larvae, ponds that dry up each year provide an important refuge for amphibian breeding thereby killing the resident fish (Keddy, 2010). Some ponds are produced by animal activity, including alligator holes and beaver ponds. These can add an important biodiversity to the landscapes.

Lotic

Lotic ecosystem is also known as a river ecosystem. The velocity of the current or the river bed's gradient determines the classification of the river ecosystem. Water turbulent with a faster moving typically contains greater dissolved oxygen concentrations, supporting a greater biodiversity rather than the slow moving water pools. With this distinction, it forms the basis for the division of rivers into upstream and downstream. The food source of a wider streams and those that lack of canopy were derived from algae, but streams with riparian forest is most likely derive their food from the trees. Anadromous fish or migrating fish such as *Devario regina* and *Poropuntius smedleyi* can be found in this type of water body (Hashim *et al*., 2012). Introduced species, chemical pollution, damming and loss of water are included in the environmental threats to the rivers. A dam construction affects the ecological balances that continued down the river system, but the most important unfavourable effects are the sediment retention, which leads to loss of deltaic wetland and the reduction of spring flooding in four seasons country which damages wetlands (Keddy *et al*., 2007).

Aquatic Plant

Aquatic plants can be found in both the littoral and the photic zones. These various forms of macrophytes generally occur in different areas of the littoral zone, with emergent vegetation nearest the shoreline such as knot grass *Persicaria barbata* then floating-leaved macrophytes like nelumbo *Nelumbo nucifera*, followed by submersed vegetation, water thyme *Hydrilla verticillata* and free-floating macrophytes such as water hyacinth *Eichhornia crassipes.* Free-floating macrophytes can grow anywhere on the system's surface (Brönmark and Hansson, 2005). Generally, aquatic weed especially *Eichhornia crassipes* was frequently observed to float in the river, stick on the riverside substrate and colonize the riverbank area (Ismail *et al.*, 2018)

Aquatic plants are crucial in each aquatic ecosystem as they providing food and habitat to aquatic organisms such as fish and wildlife. Plants stabilise sediments, improve water clarity and add diversity to the shallow areas of lakes (Madsen, 2009). Aquatic plants grow completely or partially in water. Also known as macrophytes or hydrophytes, they can be found in the littoral zone, a zone which receives sufficient light penetrations to the bottom to support the growth of plants.

There are three groups of plants that grow in littoral zones. Emergent plants inhabit the shallowest water with their roots in the sediment and their leaves are extending above the water surface. Common reed, spike rush and cattail are the representative species of emergent plants (Mashhor *et al*., 2002). Floating-leaved plants grow at intermediate depths and some of this species are rooted in the sediment. Water lily is in this group. While others are free floating with roots that hang unanchored in the water column. Water lettuce and water hyacinth are the two examples of free floating aquatic plants (Haller, 2009). Plants that grow their stems and leaves entirely underwater are known as submerged plants**.** Submerged plants display a wide range of plant shapes and grow from near shore to the deepest part of the littoral zone. Submerged plant species are including *Hydrilla*, *Cabomba* and *Egeria* (Haller, 2009). Figure 2 and Figure 3 showed macrophytes population in Chenderoh Reservoir, Perak.

Figure 2: The colony of submerged aquatic plant, water thyme *Hydrilla* sp. at Chenderoh Reservoir, Perak

Figure 3: The population of macrophyte, *Salvinia* sp. (left) and *Persicaria* sp. (right) that can be found at the lakes

The Benefits of Aquatic Plant

Aquatic plants are essentials components of healthy aquatic ecosystems. Plants, whether on land or in or around water photosynthesize using sunlight, carbon dioxide and water to grow, produce new plant tissue and grant us with oxygen through this process. Aquatic plants also play important roles in the aquatic environment (Madsen, 2000). Microscopic plants (algae) or phytoplanktons are essential elements which form the base of aquatic food chain. Aquatic macrophytes provide ideal habitats for big fish and shelter for juvenile fish, organisms as fish food and also provide food for insects, waterfowl and other wildlife. Since all plants, including those that grow underwater produce oxygen after photosynthesis process occur, they are the major source of oxygen for aquatic animal life (Bonvechio and Bonvenchio, 2006; Ismail *et al*., 2018).

Rooted plants stabilize shorelines and bottom sediments. They absorb nutrients and filter pollutant from runoff, which gradually improve water purity. A diverse aquatic plant population adds beauty to the water body. Many people recognize and appreciate the aesthetic value of aquatic vegetation, whether in the backyard fishpond, around the retention pond, or along the shoreline of a lake (Lembi, 2009). Furthermore, the developing technology in producing bio-fuel from the aquatic plant biomass is becoming a major concern nowadays. With the consideration that crude material comprises 40-80% of biofuel production costs, therefore the production of biofuel that made from volatile fatty acids (VFAs) obtained from waste biomass of aquatic plant, has therefore offers important economic benefits (Chang *et al*., 2010).

Ecological Issues related to Excessive Aquatic Plant

Although the benefit of aquatic plant is well acknowledged, the associated negative impacts due to invasive status and uncontrolled growth were also reported. The non-native plants that are introduced to new habitats often become a nuisance by hindering human uses of water and threaten the structure and function of diverse native aquatic ecosystems. Simply characterized, invasive plants are those species that easily to prevail over geographic and environmental barriers, fast self establishment, and then expand their numbers and ranges rapidly in the new habitat (Richardson *et al.*, 2000). They are often extirpating or displacing populations of indigenous species in this invasion process. Those that have been introduced into new regions, either deliberately or inadvertently, by human activities are the highly successful plant invaders (Mack and Lonsdale, 2000). For example, at least 128 of the approximately 5,800 crops or ornamental plants introduced intentionally into the United States have become noxious weeds (Pimentel *et al.*, 1989). The most commonly found commercial species was Indian hygrophila *Hygrophila polysperma* (Roxb.) T. Anderson, later followed by water hyacinth and branched bur-reed *Sparganium erectum*.

There is a possibility of plants' misidentification or inability to recognize the invasive species that will eventually become the major problem. Therefore, it is well recommended that related authorities such as wetland managers, aquatic plant nursery representatives and dealerships should have fundamental knowledge on the ecology of the aquatic plants to avoid the problems that these plants may create later on. Several aquatic plantsthat should be highlighted are the floating weeds *Eichhornia crassipes, Pistia stratiotes,* and *Salvinia* sp.; submerged weeds *Ceratophyllum demersum, Egeria* sp., *Hydrilla verticillata*, *Myriophyllum* sp., and *Potamogeton pectinatus*; rooted, shallow-water plants such as *Ludwigia* sp., *Persicaria* sp., *Typha* sp.; several grass species, and some wetland shrubs and trees (Charudattan, 2001).

There are various significant resources being expended in order to manage these infestations of aquatic weeds, because uncontrolled growth of these invasive species often interferes with the use of water. This aquatic vegetation could be considered as harmful when its notable growth causes problems for the use of ecosystems, such as navigation, water sports, and fishing activities. The invasive aquatic plant species which affecting the native aquatic plant species and fish populationresulting in the need for the controlling methods implementation or management (Ismail *et al.,* 2018). This marked growth of aquatic vegetation also increases exposure to flash flooding and result in threatened public health conditions (Kay and Hoyle, 2001).

The three most notorious weeds, *Eichhornia crassipes* (water hyacinth), *Pistia stratiotes* (water lettuce) and *Salvinia molesta* (giant salvinia) cause serious problem in nearly all countries, affecting almost all uses of water bodies such as for aquaculture, commercial and subsistence fishing, drinking and household consumption, hydropower generation, irrigation, transport and recreation (Charudattan, 2001). By replacing the native flora and fauna, these weeds would affect the biodiversity and often causing irreversible changes to habitats. With the increase of mosquitoes breeding sites, it would also increase in the insect-borne human diseases count. Another important concern which potential to affect the recreation and tourism is the loss of aesthetic value of waterfront communities due to weed growth. Sedimentation and eutrophication rates will be increased from the dead biomass of large weed and reduces water depth. Floating weeds cause problems by partially or completely forming a thick blanket in large and small water bodies, interfering with the normal access of water. They increase water loss from any water body through the dual actions of evaporation and transpiration (Janes *et al.*, 1996). With the evapotraspiration process two times faster than normal, the lake will quickly become shallow. If not treated and managed properly, the man-made lake will not function anymore (Mansor, 1994). Dense mats of aquatic macrophytes, both canopies of free floating species and the sub-canopy species distinct the littoral zone with lower DO concentrations and pH (Frodge *et al.*, 1990).

Intensive fisheries industry often involves the large amounts of commercial feeds and inorganic fertilizers into ponds. Nutrients introduced into the water through feeds and fertilizers often create an ideal environment for aquatic weed growth. Submerged aquatic weeds are particularly undesirable because fish harvesting nets will ride up over the weeds and allow fishes to escape. It is impossible can be impossible to harvest at the pond with highly weed infestations since the weight of the weeds accumulating in the seine are difficult and massive to be pulled (Shelton and Murphy, 1989). In their impact on human society, invasive plants charge economic, social, and medical costs in a number of ways. They compete with food and fibre crops, ornamentals, and other aquatic plants for nutrients and sunlight. They also interfere with water management in agriculture by infesting irrigation ditches and other waterways; reduce incomes from recreational hunting and fishing, and from tourism; restrict access to foreign markets (Culliney, 2005).

For example, *Salvinia molesta* is a free floating aquatic fern native to South America, spreading throughout the tropics and subtropics over half of the twentieth century. The ability to grow very quickly and a dense mats forming over lakes and slow moving rivers could cause wide range of ecological problems and devastating economic loss (Ali *et al*., 2011). For examples, mats of *Salvinia* could block the use of waterways from the commercial and recreational purposes and degrade the aesthetics value of waterside (Johnson *et al*., 2001). Mats of *Salvinia* reduce habitats for some birds' species, limit the access way to a fishing area and probably revise with fisheries, all with negative economic impacts. It also interfere by clogging the water intakes of agriculture irrigation, water stock and electrical generation dam (Bravo *et al*., 2012). In some reports, it provides habitats for human diseases vector with serious socioeconomic consequences (Hussner *et al*., 2010). *Salvinia molesta* dense mats provide ideal habitats for *Mansonia* mosquitoes, rural elephantiasis principal vector and other mosquitos' species which is responsible for the transmission of encephalitis, dengue, and malaria (Kweka *et al*., 2012). In developing countries, the mats of *Salvinia* could cause a devastating impact on the use of waterways for transportation, farm lands, and towards communities which depends on fish for local consumption. This species is also known as a weed of paddy field that alters the production by competing for nutrient, water and space (Sinhababu *et al*., 2013).

In addition to *Salvinia molesta*, a dense mat of *Eichhornia crassipes* could reduce the light penetration to submerged plants, thus diminishing oxygen supply in the aquatic community (Cilliers *et al*., 2003; Martins *et al*., 2008). Consequently, the limited sun penetration and oxygen concentration may inhibit the photosynthesis of submerge plant, make the water body high in the carbon dioxide and hydrogen sulphide concentration which will choke out other living organism in the water ecosystems (Richardson and Wilgen, 2004). In addition, the low concentration of dissolved oxygen may result in the lacking of phytoplankton densities, hence affecting the fisheries industry by altering the invertebrate community's composition (Turpie *et al*., 2003).

Water hyacinth often disturbing and destroy native flora and fauna habitats by competes with the native plants, displacing wildlife habitat and forage (Henderson, 2001). Hanging roots of water hyacinth also traps moving sediment, combine with detrital production and siltation under water hyacinth mats results in higher sedimentation loading (Nel *et al*., 2004). Furthermore, water hyacinth infestation management through mechanical harvesting or herbicidal treatment will cause damages to nearby desirable vegetation such as ornamental plants (Higgins *et al*., 2001).

Figure 4: The infestation of water hyacinth, *Eichhornia crassipes* at the edge of the water body

Figure 5: The blooming violet flower of *Eichhornia crassipes*

According to Stuckey and Les (1984) in Florida, water lettuce *Pistia stratiotes* is one of the invasive floating aquatic weed. Infestation of water lettuce mats able to block navigational channels, impedes water flow in flood control canals and irrigation canals, and disrupting submerge flora and fauna, recorded since 18th century. Similar to water hyacinth, roots of water lettuce, composed of long adventitious roots aligned with extensive lateral rootlets. These extensive infestations accelerate siltation rates as they begun to slow the water velocities in rivers or streams. Consequently, benthic substrates degradation under water lettuce mats resulted in creating unsuitable habitats and nesting sites for many kind of fish species, as well as macroinvertebrate (Görgens and Wilgen, 2004). Likewise, water lettuce has the ability to bioaccumulate noticeable amounts of heavy metals, so the detritus under the water lettuce mats could be highly toxic (Sridhar, 1986).

The total cost imposed solely by invasive aquatic weeds in the United States was estimated to range from $900 million to $14 billion annually (Rockwell, 2003). The Economic Cost of Invasive Non-Native Species to the British Economy suggests that invasive species cost £1.7 billion every year, which includes £251 million in Scotland. For example, it is estimated that the eradication cost of water primrose that grow rapidly and block waterways is £73,000 which is significantly less than the estimated £242 million that it would cost if the plant was to become widely established as it has on the continent in countries like France and Belgium (Williams *et al*., 2010). They have badly degraded more than 15 million ha of grazing lands and natural ecosystems in Australia (Glanzing, 2003). Noxious weeds have invaded an estimated 10 million ha in South Africa (van Wilgen *et al*., 2001). This is a critical loss of a resource vital for economic growth. Clearly, invasive plants take an unacceptable toll on agriculture and other sectors of the economy.

CONCLUSION

The distributions of macrophytes in wetland ecosystem were determined by their life form and environmental conditions. The significant role of macrophytes as shelter, food and oxygen supplier for aquatic organisms make it one of the important component in aquatic environment. However, excessive growth of macrophytes caused ecological and environmental imbalance as well as economic loss. Lotic and lentic ecosystem should be managed wisely to sustain the ecological services and function of macrophytes.

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