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The Review on Impacts of Invasive Plants on The Physico-chemical Characteristic of Water Body Quality

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Abstract: Invasive aquatic plants may lead to local loss of diversity across the globe and deterioration in water quality. The significant contribution of the spreading of the invasive aquatic plant is their sexual reproduction and dispersal mechanisms. The management should be following three phases: prevention, early detection, and fundamental knowledge about invasive aquatic plant behaviour. The management of invasive aquatic plants is vital to sustaining our water quality resources from being contaminated and polluted by the invasive aquatic plant. This review provided useful information for the management on removal and controlled the spreading of invasive aquatic plants, which also helped decrease the negative impacts on the environment. This review is prepared to summarize 1) to categories the type of invasive aquatic plant., 2) to identify the factors for invasive aquatic plant growth, 3) to explain the impacts of invasive aquatic plants towards water quality, ecosystem and community., 4) to relate the water characteristic with the presence of invasive aquatic plant, 5) to categorize the method for invasive aquatic plant removal, and 6) to differentiate the control methods to maintain water body ecosystem. This review can be a significant reference for understanding invasive aquatic plants.

Keywords: Aquatic Plant, Water Characteristic, Removal

1. Introduction

An invasive plant is a non-native species that affect the ecosystems and tends to grow faster than native species, even in low resource habitats. Moreover, the fast growth of the invasive plant is associated with a suite of plant traits that can increase photosynthetic capacity and nutrient uptake [1]. Most invasive aquatic plants were introduced from South America, North America, and other parts of Asia [2].

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According to [3], four factors that contribute to the invasiveness of the invasive plants are 1) the lack of competition due to paucity of native floating macrophytes, 2) the lack of co-evolved natural enemies in the adventive range, 3) disturbance and the alteration of hydrological flows through the impoundment of streams and rivers, and 4) creating permanent water bodies that are no longer prone to flooding or drought. The invasion impacts associated with the new suite of aquatic invasive species are yet to be manifest themselves, and this invasion is assumed to be the results of unintentional introductions via dumping of fish tank contents, and intentional planting for a particular fish (trout)

Invasive aquatic plants can cause local losses of species diversity throughout the world, and they can also contribute to water quality deterioration [2]. Other than that, the aquatic invasive plant may give advantages and disadvantages to the ecosystem and aquatic living things. For example, the massive growth of invasive plants may affect the agricultural and industrial activities for humans, while the plant will give shelters and sources of nutrients to the aquatic life [2], [3]. The dense population of invasive floating and submerged plants form large continuous mats that crucially diminish the potential to utilize water bodies and reduce aquatic biodiversity and ecosystem functioning [2]–[4]. Such impacts will harm the economies of communities, which is dependent upon fishing, tourism and water sports for revenue.[3], [4] stated that the dense mats of floating invasive plants such as *Alternanthera Philoxeroides, Eichhornia Crassipes (water Hyacinth)* reduce the light to submerged plants in depleting of dissolved oxygen in aquatic communities. [3] stated that the water hyacinth mats significantly had reduced the diversity and abundance of benthic invertebrates in a temperate and subtropical region of South Africa.

The cleaning or maintenance work for a stream may consume high costing [3], [4]. The controlling choices for invasive aquatic plants include mechanical, physical, chemical, and biological methods [2]. For example, in South Africa, mechanical and manual removal uses a rake to remove the water weeds [5].

The objectives of this review are as follows; (1) to categories the type of invasive aquatic plant, (2) to identify the factors for invasive aquatic plant growth, (3) to study the impacts of invasive aquatic plants on water quality, ecosystem and community, (4) to relate the water characteristic with the presence of invasive aquatic plant, (5) to categorize the method for invasive aquatic plant removal and, (6) to differentiate the control methods to maintain water body ecosystem.

2. Invasive Aquatic Plant Categories

The invasive aquatic plant was categorized into four (4) categories, including 1) rooted Emergent plant, 2) free-floating emergent plant', 3) rooted submerged plant, and 4) the rooted floating leaved plant

2.1 Rooted emergent plant

The rooted emergent plant is rooted under the water and emerges on the water surface [2], [3]. The example is *Myriophyllum Aquaticum* (Parrot's Feather)(Figure 1), *Pontederia Cordata* (pickerelweed), *Sagittaria Platyphylla* (Delta Arrowhead), *Iris Pseudacorus* (Yellow Flag) (Figure 2), *Lythrum Salicaria* (Purple Loosestrife)(Figure 3), *Nasturtium Officinale* (Watercress), *Sagittaria Latifolia* (Broadleaf Arrowhead), *Alternanthera Philoxeroides* (Alligator weeds), and *Stratiotes Alcides* (Water soldier)[3].

Figure 1: *Lythrum Salicaria* (Purple Loosestrife) [6]

Figure 2: *Myriophyllum Aquaticum (*Parrot's Feather) [7]

Figure 3: *Pseudacorus* (Yellow Flag) [8]

2.2 Free-Floating Emergent Plant

The free-floating emergent plant prefers a shallow water habitat because they are good water colonizers and flourish under seasonal water level fluctuation. [2], [3], [9][2], [3], [9]. Many invasive emergent species thrive well in most shallow lakes in subtropical regions [9]. The example of a free-floating emergent plant that has been identified is *Eichhornia Crassipes* (water hyacinth) (Figure 4), *Pistia stratiotes* (water lettuce) (Figure 5), *Salvinia Molesta* and *Salvinia Minima* (Kariba Weed) (Figure 6), *Azolla Filiculoides and Azolla Cristata* (Redwater fern), *Limnobium Laevigatum* (Amazon Frogbit) [3]. The free-floating species spread fast and had strong growth, double the size covered only a week [9]. The most important factor affecting the growth reproduction of free-floating, the emergent plant is pH concentration and temperature [5]. Water hyacinth can die when the salinity in the water is more than 2% [9].

Figure 4: *Eichhornia Crassipes* (Water Hyacinth) [10]

Figure 5: *Pistia Stratiotes* (Water Lettuce) [11]

Figure 6: *Salvinia Molesta* (Kariba Weed) [12]

2.3 Rooted Submerged Plant

The invasive submerged plant thrives well in urban shallow lakes, creeds, and wetlands spreading asexually by propagules or clonally [2]. Moreover, many shallow lakes provide a suitable substrate and sufficient light for invasive submerged plants to become established and develop large populations. Such examples of submerged species are *Egeria Densa Planch* (waterweed), *Hydrilla Verticillata* (hydrilla) (Figure 7), *Lagarosiphon* (Figure 8) and *Cabombaceae* (Fanwort) [3].

Figure 7: Hydrilla Verticillata[13]

Figure 8: Lagarosiphon[14]

Submerged species are colonizing species that occupy gaps created by other aquatic plants that die in the area. Moreover, it also has higher reproduction and growth, same with other species of rooted emergent plant. [15].

2.4 Rooted Floating leaved plant

The rooted floating leaved plant shares the typical habitats with free-floating species and is rooted on the water bed. The rooted floating leaved species that have been identified are *Nymphaea Lotus* (Water Lily) (Figure 9), *Hydrocleys Nymphoides* (Water poppy)(Figure 10), and *Nymphoides Peltata* (Floating heart)(Figure 11) [3]. In any tropical region, *Nymphaea Lotus* (Water Lily) was found abundantly [16]. Water Lily usually found in the coastal environment where it is dispersed and seen floating over water bodies and also been listed among the earliest aquatic macrophytes found in Nigerian freshwater [17]

Figure 9: Nymphaea Lotus (Water Lily) [18]

Figure 10: Hydrocleys Nymphoides (Water poppy) [19]

Figure 11: Nymphoides Peltata (Floating heart) [20]

3. Factors For Invasive Aquatic Plant Growth

Humans have had tremendous impacts on the environment and its biological diversity [5], [21], and many of these effects are causing problems to our natural ecosystem around the globe. Thus, in this case, the primary factor in resulting the uncontrollable growth of invasive plants, specifically the aquatic invasive plants, came from human's activities around the globe that deteriorates the health of our environment

[21] stated that the comprehensive transportation services worldwide had caused the invasion of these aquatic invasive plants or the alien species in the native plants' region. Unconditionally, the spread of invasive aquatic plants that rapidly took over a specific territory in the habitat or ecosystem has significantly impacted other life forms such as animals and native plants.

The absence of natural adversaries co-evolved in their adventive scope, lack of disturbance in eutrophication, and a change in hydrological flows by impounding streams that create permanent water bodies that are no longer vulnerable to flooding or drought are factors that contribute to the biology of freshwater aquatic plants to their invasiveness, as they can rapidly reproduce asexually [5].

4. Impacts Of Invasive Aquatic Plants Towards Water Quality, Ecosystem And Community

The invasion of the invasive aquatic plant brings negative impacts on water quality, ecosystem and community.

4.1 Impact of Invasive Aquatic Plants on water quality

The dense mat of floating macrophytes will reduce the light to submerged plants. Thus the depleting of dissolved oxygen will happen in aquatic communities [2], [3], [5], [21]. The depleting of oxygen happens when the oxygen is unable to be transferred into the water because of the dense floating mat, while the plant does not release oxygen in the water. Thus, the floating invasive aquatic plant such as water hyacinth negatively affects the water quality and gives a high reading of turbidity and affects the water [9]. In addition, the thick mats of these weeds can interrupt the flow of water, which increases the level of siltation in water bodies, and inhibit the diffusion of air into water, leading to lower concentrations of dissolved oxygen. [22]

Lower oxygen concentrations, combined with increased volumes of organic detritus produced below these floating mats, will increase sediment formation and intensify eutrophication processes. Moreover, water decaying biomass in the water may affect the salinity of the water, resulting in unpleasant taste, foul odour and poses human health risks [22].

4.2 Impact of Invasive Aquatic Plants Towards Ecosystem

[21] stated that the dense floating mat of Invasive aquatic plants is a suitable habitat for invader fish types such as peacock bass, catfish, and Asian carps. Moreover, introducing the invader species in the existing ecosystem will simplify the food web, extending to zooplankton and insects. Due to that, the reduction of mosquitofish may increase the mosquito population and mosquito-borne illness. When the mosquitos breed, they will harm the surrounding community by spreading viruses [23].

Dense mats of floating plants reduce light penetration and prevent planktonic algal blooms, a typical result of eutrophication. The uncleared, dead or decaying weeds soon develop into rotting biomass that can contribute to localized de-oxygenation, increased nitrogen contribute to eutrophication and other harmful effects on the water body. The accumulation of eutrophication can result in hazardous algal blooms [22].

4.3 Impact of Invasive Aquatic Plants Towards Communities

The invasive aquatic plant population blocks access for sports, recreational areas and a deficit in waterfront property values. Those impacts may also impact community economies, depending on fishing activities, tourism, and water sports for revenue. Moreover, the losses towards the agricultural community will contribute to the cost of replacing irrigation pumps that clog and burn out and drowning the livestock and water losses [3].

Water with high salinity has an unpleasant taste and odour, poses a threat to human health, reduces crop yields and induces corrosion in industrial pipes. High concentrations of point-source contaminants such as heavy metals can be harmful to human health and appear to bioaccumulate in riparian vegetation [22].

5. Water Characteristic With The Presence Of Invasive Aquatic Plant

Table 1 tabulated the water quality of a water body with the presence of the invasive aquatic plant. The most common water quality measured is pH, DO, suspended solids and turbidity regardless of invasive aquatic plant types. [24] observed the lower DO of 1.0 mg/L. In another study, turbidity higher than 40 NTU was also observed [25].

Table 1 Water characteristics due to the presence of the invasive aquatic plant

Parameters	Types of invaded IAP	Reference
• pH = 7.9 • DO = 9.09 mg.L^{-1} • Oxygen Saturation = 117.82 % • Turbidity (FTU)= 5.32 • Conductivity = 89 μS.cm-1	Eichhornia Crassipes (Water Hyacinth)	[9]
• pH = 6.1, • DO = 1 mg.L^{-1} • Suspended solid= 26 mg L-1 • Conductivity = 51.7 μS.cm-1	• *Salvinia auriculate,* • *Ricciocarpos natansa, &* • *Hymenachne amplexicaulis*	[24]
• Temperature = 25°C , • pH = 8.1, • DO = 6.8 mg L-1, • Turbidity = 42 NTU, • BOD = 3.0 mg L-1,	• Hydrilla verticillata, • Vallisneria spiralis, • Typha species, • Potamogeton crispus, • Zannichellia palustris	[25]
• Temperature = (29.3 - 32.8°C), • pH = (6.02 - 8.07), • DO = (2.76 - 4.7mg L-1), • Conductivity = (0.805-96.1 µS cm-1), • TSS = (0.00119-0.4361 mg L-1), • Turbidity = (10.2-15.3 NTU), • BOD = (5.21-6.66 mg L-1), • COD (7.5-25) • ammoniacal nitrogen (0.1-0.31 mg L-1).	Mangrove Tree (overgrowth resulting in biological pollutants)	[26]

Most papers reviewed on water hyacinth. This is because water hyacinth is categorized as the famous invasive species in South Africa and other tropical country[24],[5], [6],[16].This species

became famous due to its behaviour and negative impacts that it can bring to the ecosystem and community [24]. [6] found out that only turbidity is highly affected between the sampling sites with and without water hyacinth. [13] reported that the composition of species of aquatic plants was mainly correlated with the analyzed parameters of physico-chemical depth. With the frequency of occurrence, it is clear that the various species only occur at a lower depth than a depth of 0.25m. Such example, Species such *as Oryza Glumaepatula Steud, Salvania Auriculata*, and *Ludwigia Helminthorrhiza* occurred in waters with higher conductivity, pH, and more dissolved solids. Some species such as *Eichhornia crassipes*, *Eichhornia Azurea*, *Victoria Amazonica* and *Pistia stratiotes* occurred in waters with low values of conductivity, pH, dissolved O2, and dissolved solids, in Oxbow Lakes.

6. Method For Invasive Aquatic Plant Removal

The removal of invasive plants from the water body is necessary to prevent pollution and any unwanted incidents. Some examples of pollution and incident are, the stream can be clogging which will be affecting area surrounding when a flash flood occurs [15], may disturb the natural habitats of the plant and animals that can be found in an area, affecting the water quality and physicochemical properties [27], and may lead to high maintenance cost for removing the plants from the stream [5]. Several methods have been used to remove the invasive aquatic plant from the stream through mechanical, biological, and integrated control [28].

Small invasions of an aquatic plant can be eliminated manually or mechanically using specific harvesters, but this method uses manpower to conduct it. This method also requires frequent follow-up treatments because not all plants are removed and allowing the population to be regenerated through vegetative reproduction [5]. Due to the reason above, the automated deployments in controlling the aquatic plant invasion usually can be seen particularly from canals in the city [5]. These attempts were mostly inefficient due to the rapid growth in biomass and the high costs of the elimination [29].

In contrast, the effective way to manage the invasion of invasive aquatic plants is by combining biological and integrated control. Broad populations of floating macrophytes can be effectively managed by biological control, which is economically and environmentally friendly [3]. For example, using herbicide control using glyphosate is most commonly used to control water hyacinth in South Africa. However, it is restricted in its effectiveness as it is temporary. The approach of integrated and biological control and controlled herbicide applications can minimize plant coverage and casualties to native vegetation [5]. Hence, the long-term effectiveness of floating macrophyte management involves combining several approaches, focusing on reducing nitrate and phosphate contamination in aquatic environments [5].

7. Control Methods To Maintain Water Body Ecosystem

The invasive aquatic plant has been completed, risk assessments in various countries, and extreme species are now under management and control due to their potential for significant adverse effects [28], due to that the management and control can be conduct by applying the study on prevention, early detection, and biology of invasive aquatic plants.

7.1 Prevention of Invasive Aquatic Plants Spreading

The most straightforward approach to minimize current and potential negative impacts and cost control associated with invasive aquatic plants appears to discourage the introduction and further spread of invasive aquatic plants. Aquarium trade, including the shipping of mail and internet, constitutes the most critical route for introducing invasive aquatic plants [2], [30]. But less regulated routes and national and international legislation, and voluntary codes of conduct can help avoid expected and unintended new aquatic plant introductions and also reduce the risk of invasive plants [2]. The lists of possible invasive water plants for each area must be focused on established knowledge of current or

potential impacts, invasive aquatic plant biology, habitat and climate requirements of the invasive aquatic plants, and their ability to handle incursions [28].

7.2 Early Detection and Rapid Response

Response Early Detection and Rapid Response (EDRR) and Early Warning and Rapid Response (EWRR) systems should significantly reduce the negative impact of plant invasions and essential to efficient management and effective eradication [31]. Monitoring sensitive areas, mapping and reporting, citizen engagement and mapping Applications are all main steps in many national strategies [32]. However, species identification is often tricky, making early detection methods imprecise. Some classes of aquatic plants, including invasive and non-invasive species, are not sufficiently resolved taxonomically; such examples are *Sibthorpioides Hydrocotyle* and *Myriophyllum Spicatum* [33]. New identification approaches include genetic markers and other molecular instruments that can be used in combination with accurately identified reference material to assist in the accurate identification of new incursions. Many applications for identifying and reporting geolocated sites of invasive plants have also been developed, making fast responses and mapping invaded areas more quickly [32].

7.3 Understanding of the Invasive Aquatic Plant Biology

After an invasive aquatic plant is identified in a new aquatic body, its possible ecological impacts need to be studied promptly so that an effective and species-selective management policy can be established and implemented [34]. The study should concentrate on the delimitation of invasive water plants, the evaluation of their ecological, reproductive ability, and dispersal mechanisms [5], and the documentation of the indigenous flora and associated fauna that can be affected by the invasive aquatic plant and use of the infested site [2]. This latter knowledge is relevant to accurately evaluate the benefits and implications of potential management tools on native species and ecosystem function in the invasive aquatic plant. In addition, an assessment must be made of the native seed bank to understand the chances of a successful re-establishment of native vegetation from local propagules following the management of invasive aquatic plants [35]. These data have to be considered when designing an invasive aquatic plant management plan for a particular ecosystem [28].

The effective management of invasive aquatic plants requires a thorough understanding of aquatic plant biology. The following biological attributes, plant fragments regeneration capability, the development timing and potential dispersal of storage bodies, the timing and development of seeding production and seed germination requirements are beneficial for effective management. Typically, invasive aquatic plants have a high regenerative capacity as they grow from tiny plant fragments [5], [36]. Seed development has rarely been observed or examined for invasive aquatic plants and maybe almost absent in submerged invasive aquatic plants. However, some are floating and emerging invasive aquatic plant seed development and germination have been recorded [30]. Progress of management action depends on the probability of any growth and unintended spread of controlled invasive aquatic plant from reproduction or sexual plant organs. It is essential to have sufficient knowledge of the life of storage organs and seeds before creating a suitable management plan. The emergence of aquatic plant seeds and overgrown organs makes it more challenging to succeed at eradicating aquatic plant species [2]

Waterflow disperses plant fragments and seeds into the aquatic system. Inappropriate management strategies can improve the spread and growth of invasive aquatic plant species in an aquatic environment [5]. The main concern with propagules and seeds can be placed on machinery boats and diggers and can potentially spread invasive plants into un-infested waters [5], [37]. The same crops, storages and seeds may also cause recolonization of the controlled waters. However, certain types of ecosystems, such as stabilization and wave energy, can affect the successful establishment of the species. Certain types of ecosystems, such as stabilization and wave energy, can affect the successful establishment of

the species. The reproduction organ of at least some invasive aquatic plant will last in sediment for years that may entail the development of a long-term management program [28].

Invasive aquatic plants occur in multiple types of growth, taking into account while management strategies are being pursued. Floating plants like *Eichhornia Crassipes* (water hyacinth) can be scooped out of the water as a whole, either by vessels or by land-based vehicles when the stream is narrow or shallow [3]. Biomass reduction of some free-floating organisms using host-specific biological control agents has been achieved, but similar results have not been achieved for submerged plants [38]. To minimize the biomass of aquatic plants, mowing vessels, harvesters and even blade cutters are commonly used. However, eradicating sediment-rooted invasive aquatic plants by such mechanical means is impossible, as both shoots and roots must be eliminated for successful removal[5], [39]. Moreover, a large number of plant fragments can be created by mechanical harvesting, which risks a more unintended spread of the species [5].

8. Conclusion

All the invasive aquatic plants lived in the same habitats. The category of the invasive aquatic plant can be categorized according to their natural behaviour of living. The invasive aquatic plant was categorized into four (4) categories, including 1) rooted Emergent plant, which this type of species has its roots emerge to the soil in the water and its body structure were above the water. Its growth in the shallow water habitat such as the riverbank, 2) free-floating emergent plant, which the most famous species category due to massive reproductive in a short matter of time. This species has short roots floating with their body structure emerge above the water surface. This species is very famous because it quickly invades other places and can create a dense mat on the water surface, 3) rooted aquatic plant where its body structure and roots were in the water. This species can be suitable habitats for small animals in the water for shelter, but in cons, it is not suitable for human water activities and 4) the rooted floating leaved plant, which has the same behaviour with the 'rooted floating emergent'. But to differentiate those species, the 'rooted floating leaved plant, species have long roots rooted in the soil under the water and its body structure (broadleaves) floating on the water surface.

The invasive aquatic plant quickly develops at new places due to its sexual reproduction. It has a storage organ that can store seeds and travel to other places through intentional or un-intentional human involvement. The main factors that contribute to its growth are sexual production and the carrier mechanism.

The invasion of the invasive aquatic plant brings negative impacts on water quality, ecosystem and community. Such example, impacts that happen toward water quality, the dense floating mat of the invasive aquatic plant can block the sunlight and oxygen from getting diffused in the water, and the thick mats of the submerged plants can cause the disturbance of the water flow in the stream. Next, the dense floating mat is a suitable habitat for invader fish species, simplifying the food web in the ecosystem extending to zooplankton and insects. Moreover, the dense mat floating reduces light penetration and thereby prevents the development of planktonic algal blooms, a typical result of eutrophication in the ecosystem. Lastly, the impacts on the community can be seen when the presence of the invasive aquatic plant in the area disturbed human activities such as water sport (fishing, rowing, etc.), water transportation and agriculture activities.

Most papers reviewed on water hyacinth. This is because water hyacinth is a famous invasive species in South Africa and other tropical countries. The only turbidity is positively affected between the sampling sites with and without water hyacinth. The composition of species of aquatic plants was mainly correlated with the analyzed parameters of physicochemical depth. With the frequency of occurrence, it is clear that the various species only occur at a lower depth than a depth of 0.25 m. Some invasive aquatic plants grow in waters with higher conductivity, pH, and more dissolved solids.

Meanwhile some species grow in waters with low values of conductivity, pH, dissolved O_2, and dissolved solids

The standard solution is removing the invasive aquatic plant from the water body involving biological, mechanical, and manual methods. The biological control will involve the usage of chemical substances, which can also negatively impact water bodies if it is overused. The mechanical and manual methods will use machinery and hand tools. The most effective ways for invasive aquatic plant removal are by using the integrated method. This method will apply biological and mechanical methods for the removal of the plant from water bodies and control the invasion of the plants.

The control methods to maintaining the water body ecosystem can be done using prevention, early detection and knowing the biology of invasive aquatic plants. The prevention mentioned is the method where the community needs to do the preventive action such as monitoring the aquarium trade activities, constitutes the most important route for the introduction of invasive aquatic plants and listing all the knowledge about potential impacts, the plant biology, habitat and climate requirements. Next, the early detection method that monitors the sensitive areas, mapping and reporting, citizen engagement, and mapping application are the main steps that need to be taken to detect invasion of aquatic plant species. Lastly, the understanding of invasive aquatic plant biology. Through the understanding, the community can be more aware of the invasion and impacts of invasive aquatic plants.

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