**Eichhornia crassipes** aquatic plant management technology for water resources enhancement

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**Abstract.** Degradation of inland waters, rivers, lakes, reservoirs, swamps, and other fish feeding areas for fish farming are increasing, resulting in the impact of fish production and the environmental health of the waters. **Eichhornia crassipes** is a floating aquatic that is highly invasive in hypertrophic water. The proliferation of water hyacinth closure from the surface water column by decreasing the concentration of dissolved oxygen in the bottom water column, causing disturbance to the growth of aquaculture fish, so it is necessary to control/eradicate the water hyacinth weed. The technology to control/eliminate water hyacinth is physical, biological, and chemical or a combination of the three. Technology to control/eradicate water hyacinth must consider the negative impact on the environment. Some technologies to eradicate water hyacinth are positive and significant using filled Chinese carp (*Ctenopharyngodon idella*) or confined in cages depending on the body of water. The caged system in lake waters considers fish and native/endemic plants while in reservoir water with a stocking system. In the lake waters, aquaculture is carried out with a floating net cage system measuring 5 × 5 × 5 m³ with a total of 100 plots, each plot filled with 500 Chinese carp (100 g/fish) fed 50 kg of water hyacinth on day-1. The maintenance period is 3 months per season for 3 seasons (1 year). The results show that water hyacinth is reduced by 300 ha. The adoption of technology to improve water quality is one of the management of water bodies to increase fish production.

**Keywords:** **Eichhornia crassipes**, management, technology, water resources enhancement

1. **Introduction**

Indonesian mainland waters have an area of 13.85 million hectares consist of 12.0 million hectares of rivers and flood plains, 1.8 million hectares of natural lakes, and 0.05 million hectares of artificial lakes (human-made lakes) or reservoirs [1]. The inland public water ecosystems, rivers, lakes, reservoirs, swamps, and other standing water have high economic value and play an important role in supporting the industrialization of fisheries in Indonesia. In terms of the fisheries sector, the waters of rivers, lakes, reservoirs, swamps, and other standing water are the fisheries management areas of the Republic of Indonesia that play an essential role in the following matters: (1) sources of protein and food security; (2) community economic resources; (3) sources of employment; (4) genetic and genetic sources, (5) sources of foreign exchange and local original income, and (6) eco-tourism. Lake and
reservoir waters in Indonesia covering 50,000 hectares when used for fish farming in mini floating nets (1 × 1 × 1 m³) can produce fish production of 292,000 tons per year-1 as material for industry [2]. Currently, public waters have experienced habitat degradation resulting in a decline in fish populations. Habitat degradation that often occurs and disturbs the public waters of the mainland is the abundance of water hyacinth weeds (Eichhornia crassipes), which cover almost the entire surface of the water. Biologically, water hyacinth has a good reproductive rate in a short time and has a high or adaptive environmental tolerance [3] states that in the waters can reach two million water hyacinth plants per hectares and double its time within five days. A water hyacinth mass covers the entire surface of eutrophic and relatively shallow waters such as Rawa Pening in a short time. Ecologically, socially and economically, this condition is more dangerous/detrimental than the benefits. The reduction of the water surface area due to the abundance of water hyacinth is the cause of the decline in aquaculture fish production caused by the reduced number of aquaculture pond plots compared to waters not covered with water hyacinth. Aquatic biodiversity has decreased, phytoplankton growth is hampered as well as zooplankton, subsurface water columns will experience deoxygenation, which results in mass fish mortality in public waters. Physically will accelerate siltation and reduce the target age of water bodies, disrupt the function of water bodies.

Based on these conditions, it is crucial to immediately manage terrestrial public waters to optimize terrestrial public waters for fisheries through habitat rehabilitation or conservation of fish species that are experiencing a decline in population. This paper aims to provide technology to control or eradicate water hyacinth that is effective both biologically or physically or a combination of biological and physical.

2. Ecology and distribution of Eichhornia crassipes

2.1. Ecology of Eichhornia crassipes

Eichhornia crassipes (Mart.) Solms-Laub is known as the common hyacinth, including the family Pontederiaceae originating from South America is a taxonomic problem because it is considered as an important weed in the world [4]. Water hyacinth was imported to Indonesia in 1894 from Brazil for the collection of the Bogor Botanical Gardens[5]. Eichhornia crassipes is a free-floating macrophyte of water that displays two different morphologies with intermediates, depending on their growth conditions in Figure. 1.

Figure 1. Eichhornia crassipes with purple flowers

Eichhornia crassipes are bluish-purple, large, look fresh, and lush. Eichhornia crassipes are part of plants that produce large amounts of seeds in capsules, each capsule containing up to 300 long-lived seeds that can remain alive for 5-20 years in sediments [4, 6]. Sexual reproduction is limited by the scarcity of suitable pollinators and the lack of appropriate sites for germination and seedling formation [4]. Vegetative reproduction is the main capital of increasing population, through ramet (child plants) formed from axillary buds on stolons produced through the extension of the segment [4]. After ramets have developed roots, stolons can decay or break, separating from the parent plant, thus the population of E. crassipes increases rapidly, doubling in suitable conditions every 11-18 days [4]. Growth of E.
E. crassipes is very rapid and forms a large population of interconnected buds like impenetrable woven mats. Plants can also reproduce vegetatively through horizontal stolon production. According to Rakotoarisoa et al. [3], because of their high reproductive rate, complex root structures and the formation of dense mats up to two million plants per hectare can be found. Under favorable conditions, water hyacinth can multiply the mass every five days and also grows from seed, which can last for 20 years or longer [7, 8]. Stems densely erect, elongated leaf stalks (up to 1 m long) short round leaves (<30 cm) kidney-shaped (4) arranged in 6-10 leaves in basal flowers, each leaf surviving until 6-8 weeks before aging. Rhizome roots and fibrous, feathered submerged in water. Root morphology is very plastic and plasticity is related to nutrients, especially phosphorus (P) available in the water column. Lateral roots are generally longer and denser at low P concentrations than at high P [4]. The root-shoot ratio varies inversely with nutrition, especially the availability of nitrogen.

2.2. Distribution of Eichhornia crassipes.

The spatial and temporal distribution of Eichhornia crassipes is extensive in tropical regions and even throughout the world, both biotic and abiotic. Biotics, distributed through seeds carried by birds suspected of being transported long distances (e.g., waterfowl and shorebirds) and if the seeds are coated in mud, can stick to mammals and birds [6]. Abiotic through the wind, it will be easy to move plants and leaves upright in lakes and canals. Along the river, water flow is the primary driver of vegetative material, but strong winds can sometimes blow plants upstream. Water hyacinth takes all nutrients directly from the water. As happened in the Juanda-Jatiluhur reservoir, water hyacinth distribution with the strength of the wind migrated from the inlet of the Citarum River to the Dam. The entire surface of the water was covered in Figure 2.

![Figure 2. Eichhornia crassipes cover the waters of the Juanda Dam Jatiluhur, July 2019](image-url)

The distribution of water hyacinth is influenced by the physical-chemical conditions of the waters, including nutrients, light, water depth, salinity, pH, and other biotic factors. Optimum growth of water hyacinth requires adequate sunlight and optimum temperatures ranging from 25 - 30°C. According to [9] reports that at pH 7.0 - 7.5, water hyacinth has better growth than those that grow at low or high pH. According to [9] stated that in the subtropical area the biomass from water hyacinth could reach a maximum of 1,500 gm raised from the total initial biomass of 5000 gm raised. At the same time, the average daily production is 7.4-22 gm raised. The production of water hyacinth is very dependent on the presence of sunlight, which is vital in the process of photosynthesis. A nutrient is an essential substance needed for the growth of water hyacinth. Nitrate (NO₃) has a significant influence on the growth of water
hyacinth wet biomass, which is around 91% - 98%. Phosphate (PO₄) does not have a substantial effect on the growth of water hyacinth wet biomass, only about 34% - 68% [10]. According to [5], water hyacinth cannot grow well on media that are treated with salinity 0.5%, 1%, 1.5%, 2%, and 2.5%. The level of salinity that most inhibits growth is the treatment of 2.5% salt levels where the water hyacinth dies at five days after treatment.

3. Impact of *Eichhornia crassipes* distribution in waters

The abundance of *Eichhornia crassipes* in stagnant and closed waters such as reservoirs, lakes, impacts in several aspects including:

3.1. Bioecology

1. Floating plants are free to monopolize light and absorb nutrients from the water column, preventing phytoplankton and submerged vegetation from getting adequate resources for photosynthesis [11]. This condition is a major factor in the growth of water hyacinth in addition to nutrients N and P.

2. The allelopathic nature of *Eichhornia crassipes* reduces the abundance and richness of native species and decreases the genetic diversity of ecosystems [12] and the number of other biotas such as phytoplankton and zooplankton as natural fish feed, which means reducing capture fisheries production [13].

3. Water hyacinth as an invasive species is considered a significant threat to aquatic biodiversity. The great effect of water hyacinth is on water quality dissolved oxygen concentration in the water column below the surface covered by the water hyacinth mass is very low even undetectable and the quantity of water (evapotranspiration) [4].

4. As a phytoremediation agent in waste treatment, the results of the research show that water hyacinth (*Eichhornia crassipes* (Mart) Solm) can act as a biological and environmental recovery agent; *E. crassipes* can reduce pH, BOD₅, and COD very significantly (P <0.01) from wastewater Slaughterhouse, Pesanggaran, Denpasar, Bali, in accordance with the wastewater quality standards for slaughterhouse activities (Appendix B Minister of the Environment Regulation No. 02 of 2006 dated April 20, 2006). The highest decrease in pH, BOD₅, and COD parameters were obtained from the treatment with the density of water hyacinth 90%. The pH value decreased 24.30% from the initial value of 8.52 to 6.45, the BOD₅ value decreased 55.50% from the initial value of 158.1 to 70.35 mg/L, and the COD value of 48.67% from the initial value of 300 to 154 mg/L [15]. The abundance of *Eichhornia crassipes* in sewage treatment ponds has a positive impact. Absorbs heavy metals [6], organic contaminants [8], and nutrients from the water column [6] consist of 95% water and 5% dry matter, of which 50% is silica, 30% potassium, 15% nitrogen, and 5% protein [6]. According to [6] reported that the absorption of nitrogen by water hyacinth is five to ten times faster than phosphorus. Phytoremediation is a plant-based technology that is engineered to clean up polluted environments. Phytoremediation is also called green-remediation or bonato-remediation, or agro-remediation water hyacinth can use the remission of Pb pollution because of the ability of the roots to absorb and accumulate it and can reduce the Pb content of the growing media up to 80%, reducing Cd [16, 17]. The roots of the water hyacinth plant naturally absorb toxic elements such as lead, mercury, and strontium [18]. Water hyacinth can absorb heavy metals, organic contaminants, and nutrients from the water column [19]. The results of Indrasti et al. [20] show that water hyacinth can absorb 88.10% of Pb heavy metal and 85.83% of Cd. As a natural cleaning agent, water hyacinth can reduce COD and BOD, deodorizing, reducing the turbidity of tofu waste. Water hyacinth can reduce pollution by organic substances [21]. *Eichhornia sp.*, from the results of [22], can reduce TSS pollutants 53.03%; BOD 64.41%; nitrate-nitrogen 47.22%; cadmium 94.67% and iron 30.30%. *Eichhornia crassipes* root functions as a regulator of nitrogen and phosphorus absorption from water [4]. According to [23], aquatic plants have benefits as a phytoremediator for the improvement of the aquatic environment. The ability of water lettuce (*Pistia sp.*) and Water hyacinth (*Eichhornia crassipes*) to reduce the total organic matter respectively by 55.52% and 23.38% and the reduction of P-PO₄ by 60.62% and 92.68%. The ability of *Pistia* sp. is higher than *Salvinia sp.*, *Lemna sp.*, and *Spirodela* sp. The study results of the floating bed phytoremediation application showed that water quality in the plant location was better than the location without
plant treatment, which was characterized by a decrease in NH$_3$-N by 46%, total phosphorus by 63.3% and COD by 20%. Plants planted on pipes can be made of bamboo or PVC with holes. Aquatic plants are transplanted into the hole. For water hyacinth, plants are harvested every 5-7 days. Installation of floating bed phytoremediation can be made in zig zag to keep the water flow not obstructed. Aquatic plants are very much needed in waters as a place for spawning, pasting eggs, foraging locations, care for fish and other aquatic animals. As a raw material for biogas, water hyacinth with the right treatment can be biogas, which is a gas fuel because it contains high cellulose and hemicelluloses but low lignin. To produce 1 MW of electricity, 50 tons of water hyacinth are needed. Fresh water hyacinths contain 95.5% water; 0.04% N; 0.06% P$_2$O$_5$; 1% ash; 0.2% K$_2$O; 3.5% organic matter. And if in dry conditions (zero moisture), water hyacinth contains 75.8% organic matter; 1.5% N and 24.2% ash. Ash contains 28.7% K$_2$O; 1.8% Na$_2$O; 12.8% CaO; 21% Cl and 7% P$_2$O$_5$ [18]. The water hyacinth composting technology can produce fine organic material and perfectly decomposed. The composting process is carried out with the help of microorganisms into organic growing media [24] and also liquid compost fertilizer [25] and able to increase the growth of mustard plants [24, 26]. As a mixture for animal feed [25]. The high content of organic matter, crude protein and amino acids is the reason why water hyacinth can be used as ingredients for ruminant and non ruminant animal feeds [27]. The result of proximate analysis of water hyacinth in Lake Limboto shows that the protein content of the roots is 17.76%; leaf 19.83; petiole 4.86% and root fat content 3.46%; 1.2% leaves and 1.56% petiole [28]. This shows that water hyacinth is can be used as alternative feed ingredients.

4. Control/eradication of water hyacinth (Eichhornia crassipes)

4.1. Control of water hyacinth

In the management of inland public waters, it is necessary to determine first whether they want to be controlled because many functions can be utilized or eradicated because the management objective requires no water hyacinth. Water hyacinth plants in aquatic ecosystems will be beneficial if <20% of the area covered [28]. Control of water hyacinth weeds can be done physically (harvesting), chemical (herbicide), and biological as well as a mixture of the three.

1. Biological control can be conducted using the Neochetina eichhornia and N. bruchi [33] or Ctenopharyngodon idella. For the use of insects, the impact can not be controlled.

2. Good and effective control of water hyacinth in lake waters is by physical and biological control that is using koan fish (Ctenopharyngodon idella) [4] because physical-biological control is environmentally friendly management and could raise the income of fishers to 20 billion fishers year$^{-1}$ [35]. Examples of physical-biological control of water hyacinth in the Limboto lake with koan fish begin with knowing the vertical distribution of several water quality parameters [34], water quality characteristics in Limboto Lake [35] and the relationship between water quality with chlorophyll-a and its effect on fish population in the waters of Lake Limboto. The speed of reduction of water hyacinth to reduce the surface area covered by water hyacinth in Lake Limboto is influenced by the rate of koan fish crawling to water hyacinth and stocking density of the stocked koan fish [36]. The flow rate of water hyacinth in Lake Limboto by koan fish influences water fertility (N, P) and phytoplankton abundance in Lake Limboto [37].

3. China carp or koan fish (Ctenopharyngodon idella) browsing rate and growth rate of water hyacinth (Eichhormia crassipes) can be used as a basis for controlling water hyacinth in Lake Limboto, Gorontalo [28]. Control of water hyacinth physically and biologically [38] presented in Figure 3.
Technological superiority: feasible and straightforward, environmentally friendly, all components originate domestically, provide added value, and the length of time the control can be known (novelty) and can be integrated with the craft industry.

4.2. Eradication of water
1. Physically, eradication of water hyacinth in Sunter Lake using dredgers, for a body of water that is not extensive (smaller than 100 ha) in Figure 4.

2. River flow, according to [5] eradication of water hyacinth in watersheds, can be done by allowing it to drift into estuaries with saline levels ranging from 0.5%.

3. The eradication of biological water hyacinth using koan fish has also been successfully carried out in Kerinci Lake. But the impact of other types of fish indirectly come to disappear because koan fish eat all the aquatic plants in the Kerinci Lake. So that the food chain of other fish is broken and eventually other fish do not survive because the food is no more in Figure 5.
5. Review
It is crucial to eradicate or control water hyacinth to support the growth of fish culture production in floating net cages in reservoir and lake waters in Indonesia.

6. Conclusion
To improve water quality and water production, it is necessary to do: (1) Water hyacinth weed eradication if the need for the use of water bodies requires clean and clear water, for example, water tourism, baths, which do not require ecological functions, (2) Water hyacinth weed control if the body of water is large enough and still requires ecological functions (fisheries, irrigation, etc), and (3) Effective control using physical and biological methods, namely with koan fish, if in the lake koan fish are confined/ floating net cages and if in the reservoir can be stocked directly.

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