**A review on Aquatic weeds and their management**

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**Abstract**

When aquatic weeds grow too much, they pose a threat to fish farming. An essential component of pond management is weed control. Out of over 160 aquatic weeds, *Eichhornia crrassipes, Ipomoea aquatica, Typha angustata, Ceratophyllum demersum, Salvinia molesta, Nelumbo nucifera, Alternanthera philoxeroides, Hydrilla verticillata, Vallisneria spiralis, Chara spp., Nitelia spp., Potamogeton spp*. are of main concern in India. Aquatic weeds are rapidly expanding in several irrigation and hydropower projects across the nation, including the Kakki and Idikki reservoirs in Kerala, the Tungabhadra project in Karnataka, and the Nagarjuna Sagar project in Andhra Pradesh. Weeds significantly increase evapotranspiration rates compared to open surface rates, which results in significant water loss. Eutrophication caused by water hyacinth renders water unsuitable and reduces water flow, in addition to various health-related issues. Biological, chemical, and physical strategies can all be used to control aquatic weeds. Aquatic weeds can be stopped from spreading or eliminated using a number of common control methods. Physical remedies work best for small-scale infestations, but they are expensive and prone to regrowth when used on big water bodies. Aquatic weeds have long been subject to chemical treatment, however this practise is not common in India. Herbicide control of tiny infestations has frequently been quite successful, but it significantly depends on trained operators who keep a close eye out for the appearance of regrowth or seedlings over a lengthy period of time. The amount of nutrients released into water in recent decades has significantly increased from home and industrial sources as well as from land where fertilisers are applied or where clearing has increased run-off. *Neochetina spp.* and *Cyrtobagaus salvinae,* exotic weevils, have been used successfully to manage water hyacinth and water fern in several parts of India, but suitable bio agents are not yet available for several additional aquatic weeds. With varied degrees of success, some submerged weed, particularly Hydrilla species, have been controlled using some kinds of herbivorous fish, including *Tilapia spp*. and *Ctenopharyndon idella*. This essay discusses the issues with aquatic weeds in India and the attempts taken thus far to manage them using a variety of techniques.

**Introduction**

Aquatic weeds are undesired plants that grow out of control. The principal producers in the aquatic ecosystem are aquatic plants. They assist fish by giving them food, oxygen, protection, and other things. The productive capacity of the aquatic body is undoubtedly threatened by the presence of these unwanted and undesirable aquatic plants. In reality, having some aquatic vegetation present is typically preferred in fish ponds. Any laxity in reining in their excessive growth reduces the water body's productivity by utilising the nutrients or by limiting the entrance of sunlight by shading may cause either super saturation or oxygen depletion. Aquatic weeds give predatory fish a place to hide out, and weed fish themselves become overpopulated due to their prolific breeding and voracious feeding habits. The availability of food is constrained by several variables. Fish-harming gases like H2S and CH4 are created as a result. However, the presence of a few aquatic weeds is essential since many fishes utilise them as natural sources of food. When they decompose, they produce good fertilisers in the pond. Over 140 species of plants have been reported to act as aquatic weeds both within and around various kinds of aquatic bodies in India. The states comprising West Bengal, Odisha, Bihar, Assam, Tripura and Manipur have the maximum incidence of weed infestation ranging from 40-70%, whereas in other states it may range between 20-50% (Philipose, 1968).

Ponds used for fish culture are surrounded by a wide variety of aquatic plants. These plants range in size from microscopic plankton algae that float suspended in the water to bigger plants that are rooted in the pond bottom. Certain varieties of aquatic plants are necessary for the growth of fish. However, aquatic plants that obstruct the generation of commercial fish are regarded as weeds. Inorganic fertilisers and significant quantities of commercial feed are frequently added to ponds to support intensive fish production. An excellent environment for aquatic weed development is frequently created when nutrients are added to the water through feeds and fertilisers. Because fish harvesting seines will ride up over submerged aquatic weeds and allow fish to escape, submerged aquatic weeds are particularly undesirable. Since the weight of the weeds accumulated in the seine can grow too great to be withdrawn, ponds with extensive weed infestations may be impossible to harvest. Furthermore, weeding out fish takes a long time and puts a lot of stress on the fish (Marley et al. 2017).

**Types of aquatic weeds**

**A) Floating weeds**

Floating weeds float in or on the surface of the water and obtain their nutrients from water rather than soil. Duck­weed *(Lemna minor* and *Spirodela polyrhiza)* and watermeal *(Wolffia* spp.) are examples of common floating weeds (Marley et al. 2017) as shown in table No.1 and fig No. 1 to 5)

They are not attached to the pond bottom rather float upon the surface. Sometimes they profusely grow and shade the pond, so are harmful to the fish in many ways. e.g. *Azolla, Pistia,**Wolfia, Lemna* etc. (Abhishek, 2020). Floating weeds have their foliage above surface of water with rooted hanging free underneath (Sanyal and Tanmay, 2017).

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| **Fig1.** Duck­weed (*Lemna minor*) | | **Fig2.** *Spirodela polyrhiza* (common duck weed) | |
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| **Fig3.** *Wolffiaglobose* (watermeal) | | **Fig4.** Azolla | | **Fig5.**Pistia | |

**B) Emergent weeds**

Emergent weeds, rooted in the bottom but having their foliage and flowers above the water surface (Sanyal and Tanmay, 2017). These weeds are rooted in the bottom soil but have all or some of their leaves, leaf, lamina or shoots above the water surface e.g. *Nymphaea, Myriophyllum, Vallisneria* etc. (Abhishek, 2020).Emersed weeds are rooted to the bottom, but have stems, leaves and flowers which extend above the water surface. They primarily occur on the shoreline and in shallow water up to 10 feet deep. Common emersed weeds are waterlily (Nymphaea spp.) and alligator weed (Altemanthera philoxeroides) (Marley et al. 2017) as shown in table No1 and fig No.6 to 8)

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| **Fig 6.** *Nymphaea* (water lilly) | **Fig7.** *Myriophyllum* (Alligator weed) | **Fig8.** Altemanthera philoxeroides |

**C) Submerged weeds**

Submerged weeds may or may not be rooted (Sanyal and Tanmay, 2017).Submersed aquatic weeds grow under and up to the water surface. Most submersed weeds have flowers and seed heads that extend above the surface of the water. Examples of com­mon submersed weeds include hydrilla (*Hydrilla verticillata*)and Brazilian elodea (*Egeria densa*)(Marley et al. 2017).

These weeds are classified into two groups:

i. Completely submerged weeds within the water but may be rooted in the bottom soil. e.g. *Hydrilla, Najas* etc.

ii. Free floating submerged weed floats freely under the water e.g. *Ceratophyllum, Utricularia* etc. (Abhishek, 2020) as shown in table no. 1 and fig. no 9 to 13.

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| **Fig9.** Ceratophyllum | **Fig10.** Utricularia |
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| **Fig11.** Najas | **Fig12.** Hydrilla(*Hydrilla verticillate*) |

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| **Fig13.** Brazilian elodea (*Egeria densa*) |

**D).Marginal weeds**

****These types of weeds grow on the margins or on the shore line of the water body. They are mostly rooted in water logged area. e.g. *Typha, Nymphaea, Marsilia, Ipomoea* etc. as shown in table no. 1 and fig no 14 to 17.

**Fig14**. *Typha* **Fig15**. *Nymphaea*



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| **Fig16.** *Nymphaea* | **Fig17.** *Ipomoea* |
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**Table 1.** Three types of aquatic weeds (Dissanayaka et al. 2023)

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| **Plant Type** | **Botanical Name** | **Family** |
| **Floating** | *Azolla spp.*  *Eichhornia crassipes*  *Hydrilla verticillate*  *Lemna spp.*  *Pistia stratiotes*  *Salvinia molesta* | *Azollaceae*  *Pontederiaceae*  *Hydrocharitaceae*  *Lemnacea*  *Araceae*  *Salviniaceae* |
| **Submersed** | *Cabomba caroliniana*  *Ceratophyllum demersum*  *Chara spp.*  *Crassula helmsii*  *Egeria spp.*  *Lagarosiphon major*  *Nitella spp.*  *Potamogeton spp.*  *Utricularia spp.*  *Vallisneria spp.* | *Cabombacea*  *Ceratophyllaceae*  *Characeae*  *Crassulaceae*  *Hydrocharitaceae*  *Hydrocharitacea*  *Characeae*  *Potamogetonaceae*  *Lentibulariaceae* |
| **Emersed** | *Brachiaria spp.*  *Ipomoea spp.*  *Limnocharis flava*  *Ludwigia spp.*  *Lythrum salicaria*  *Monochoria*  *Myriophyllum spp.*  *Nelumbo nucifera*  *Nuphar luteum*  *Nymphaea stellata*  *Phragmites karka*  *Polygonum spp.*  *Sagittaria spp*  *Scirpus spp.*  *Spartina spp.*  *Sphenoclea zeylanica*  *Typha spp.*  *Vossia cuspidata* | *Poaceae*  *Convolvulaceae*  *Limnocharitaceae*  *Onagraceae*  *Lythraceae*  *Pontederiaceae*  *Haloragaceae*  *Nymphaeaceae*  *Nymphaeaceae*  *Poaceae*  *Polygonaceae*  *Alismataceae*  *Cyperaceae*  *Poaceae*  *Sphenocleaceae*  *Typhaceae*  *Poaceae* |

**Effects of Aquatic weeds**

**1) Impact of weed to other species population on same ecosystem**

Submerged macrophyte modify food web interaction and stability of late littoral ecosystem (Sanyal and Tanmay, 2017). On the basis of units of collonisable Typha and Phragmites plant surface on eutrophic lakes, quantitative relationships between epiphyte and macroinvertebrate were investigated, but no direct correlations between total macroinvertebrate abundance and epiphyte on mass on the plant surface were discovered**.** (Sanyal and Tanmay, 2017). Genetic diversity, species diversity, and ecological diversity are all examples of biodiversity in a natural ecosystem. Numerous environmental weeds have the potential to have an effect at one or more of these levels, though the extent of the impact is rarely quantified (Adair and Gropves, 1998).

Growth of water hyacinth has been prolific in many lake resulting in breeding vector and causing endemic disease**.** Bats may interfere with people's activities either by this overabundance or by their sheer abundance because aquatic plants are more frequent in the warm and marshy, which is a natural element of the ecosystem and used by many different creatures as food or hiding places (Sanyal and Tanmay, 2017).

**Effects of aquatic weeds in India**

India is most concerned about the following aquatic weeds out of around 160: *Eichhornia crassipes, Salvinia molesta, Nymphaea stellata, Hydrilla verticillata, Vallisneria spiralis, Typha angustata, Chara species, Nitella species, Ipomoea species,* and others are just a few of the plants mentioned. The five most common aquatic weeds in the world- *Eichhornia crassipes, Salvinia molesta, Hydrilla verticillata, Alternanthera philoxeroides,* and *Pistia stratiotes* also rank as the worst weeds in India. But according to estimates, water hyacinth (*Eichhornia crassipes*) is currently present in 20–25% of all India's potable water, compared to 40% in Assam, West Bengal, Orissa, and Bihar (Gopal and Sharma, 1981). By the end of 20th century, *A. philoxeroides* had become a growing menace in water bodies in India, (Sushilkumar et al*.* 2009).

**(a) Aquatic weed problems in lakes and reservoirs**

Aquatic weeds may negatively impact commercial navigation, water quality, hydropower production, flood frequency, duration, and intensity, species diversity, extinction rates for rare, threatened, and endangered species, animal community interactions, recreational navigation, safe swimming, sediment chemistry, and hydropower generation, among other issues. Aquatic weeds have been identified as an increasing ecological threat (Malhotra and Ahmed, 1996). Thirunavukkarsu and Kayarkanni (1996) talked about how aquatic weeds affect the ecosystem in India.The famous Kolleru lake in the West Godavari has succumbed to invasion of *E. crassipes, Ipomoea aquatic, Typha Vallisneria*, *Nymphaea* and *Ulothrix spp.*

**b) Aquatic weeds problems in fish ponds and lakes of India**

The majority of freshwater fishes depend on aquatic plants at some point in their lives and favour particular habitats depending on their stage of development. Aquatic vegetation is used by young fish as protection from predators and as a food source, both by directly ingesting the plants and by hunting for the microfauna that the plants support. In order to improve their chances of finding food and to diversify their diets, mature fish go to more open waters. Plant type and density have an impact on the nesting, growing, and foraging success of fish that prefer plants.

About 40% of India's 8 lakh ha of freshwater that can be used for pisciculture are no longer suitable for fish production due to aquatic weed invasion. Water hyacinth has severely overtaken the majority of the fisheries tanks and ponds in and around Bangalore and neighbouring cities. Problematic weeds in fishery lakes and tanks in Andhra Pradesh, Assam, Haryana, Himachal Pradesh, Jammu & Kashmir, Maharashtra, Tamil Nadu, and Uttar Pradesh in India include *Eichhornia, Azolla, Nymphaea, Nelumbo, Nymphoides, Hydrilla, Vallisneria, Potamogeton, Najas, Ceratophyllum, Typha, and Utricularia spp*. Aquatic weeds have significantly overtaken some of the well-known fishery lakes, including Barwar, Ramgarh, and Guiar lakes in Uttar Pradesh, Ansupa lake in Orissa, Ootucmund lake in Tamil Nadu, Kollern lake in Andhra Pradesh, Loktak lake in Manipur, and the renowned Dal, Nigeen, and Walur lakes in Jammu & Kashmir. Aquatic macrophytes have taken over a significant portion of Assam's natural and artificial water bodies, rendering them unsuitable for fish farming and other commercial uses.

In Assam in beel fisheries situation, water hyacinth has been considered a major problem by National Bank for Agriculture and Rural Development (NABARD). Fish production was found drastically reduced in beels due to infestation of water hyacinth. When the environmental conditions and nutrient availability are optimal, a specific phytoplankton species will frequently grow quickly to form thick masses. Depending on the type of bloom forming algae, such dense growths, or "water blooms," give water bodies colours like green, reddish brown, yellow green, and blue-green. The Chlorophyceae (*Chlorella vulgaris, Pandorina morum, Volvox aureus*), Bacillariophyceae (*Melosira granulata, Synedra ulna*), Dinophyceae (*Peridinium inconspicuum*), and Euglenineae (*Euglena spp., Trachelomonas spp*.) families of algae are primarily responsible for transient blooms. The Myxophyceae (*Microcystis spp., Anabaena spp., Raphidiopsis spp.,* and *Oscillatoria chlorina*) make up the majority of the persistent blooms. Blooms are also produced by the widespread filamentous algae Spirogyra, Pithophora, and Oedogonium.

In Nagpur (Maharashtra) aquatic weeds are of major concern in potable waters and pisciculture. In Pune and Kolhapur water hyacinth and recently *P.stratiotes* has become problematic. Aquatic weeds cause significant economic losses in fisheries and rice cultivation in Orissa's coastal regions. Invading weeds include those that are submerged, *stratiotes* free-floating, and have emerged. Blue-green algae, particularly *Microsystis spp*., frequently cause large-scale fish mortality in nutrient-rich fish ponds. Aquatic weeds are to blame for reducing fish output in many ponds, lakes, and reservoirs in Uttar Pradesh as well. For instance, the annual fish production potential in a 300 ha Kitham lake near Agra was almost completely eliminated due to the water hyacinth's extensive cover of the lake's water surface. In the Tarai area of Uttar Pradesh and Uttarakhand consisting Pilibheet, Barielly, Rampur, Udhamsing Nagar, Nanital etc.the fishery ponds are also losing ground to aquatic weeds like *Hydrilla, Potamogeton, Vallisneria*, *Nelumbo*, *Nymphaea, Typha*, *Saccharum* and *Brachiaria* spp. (Sushilkumar et al. 2009).

**Effect of aquatic weeds on environment**

Aquatic weeds produce conditions that are perfect for the development of mosquitoes. The aquatic weed roots and leafy growth provide refuge and protection for the mosquitoes, which carry diseases like malaria, yellow fever, river blindness, and encephalitis. Snails can reproduce and play a significant part in the life cycle of parasitic worms like liver and blood flukes by finding shelter and food in the root zones. Because the floating weed transports the snails to other sites, the diseases schistosomiasis and fuscioliasis spread. Residents that live around these areas complain about mosquito issues.

The presence of aquatic weeds that are both floating and submerged has a significant impact on fish output. When weed growth is sparse and covers the entire water body, it can be fatal for fish growth. However, isolated weed beds may be tolerated because they offer fish refuge and shade. Fish can die from oxygen deprivation and suffocate. Numerous fish species fall extinct when aquatic weeds that are both floating and submerged become so abundant. For instance, the production of fish in Punjab's Harike Lake is declining, which is of concern to all.

Huge volumes of biological matter decomposing leads to conditions where carbon dioxide and carbon monoxide are created and discharged into the environment. Compared to other vegetation on land, the duration of degradation is significantly shorter. The process of decomposition releases unpleasant odours that are bad for public health. In these conditions, parasites like mosquitoes thrive and threaten the lives of nearby residents.

Aquatic weed growth has a negative impact on water bodies that are used for enjoyment and aesthetic purposes. They interfere with other water activities as well as boat movement. Silica and other insoluble salts are produced during the decomposition of weed material and settle to the bottom of the water body. In rivers, canals, and drainage ditches, dense weed growth slows water flow, allowing silt to settle out and be deposited on the water body's bed. The longevity of lakes, dams, tanks, etc. is ultimately impacted by this rise in silt deposition, which necessitates additional spending for frequent desilting through dredging.

Water quality is also impacted by aquatic weeds. These weeds have unpleasant tastes and odours, and their organic loading raises the need for biological oxygen. When used as curing and mixing water, they raise the organic matter content of the water, which may have an impact on the durability of concrete structures. It is because organic material reacts with cement to weaken the bond and can result in significant air entrapment in concrete. Aquatic weeds obstruct the free flow of water, which may lead to more seepage and raise water tables in nearby places. It could result in water logging. As a result, the soil may become saline or alkaline, which will also encourage the growth of numerous other land weeds.

Weeds that are floating and submerged spread rapidly. In this group, *Eichhornia crassipes* deserves special attention. These plants can grow up to 4,000 times in one season from a couple. Just a few sprouting or introduced plants are usually enough to cover and choke a canal or drain surface in one season. The weeds that float on the surface weave together to form dense mats that go down stream. These moving mats frequently pack up against bridges and other structures, exerting tremendous pressure that can occasionally cause significant damage. An illustration of this kind of destruction was seen on Kasur Nala in India, not far from Taran-Taaran. Over time if left unchecked the weed mats become so dense that people and animals can walk on them, although at the risk of injury or drowning.

**Management measures to control Aquatic weeds:**

**1) Physical/mechanical method**

Aquatic weeds can be removed by machines. Water hyacinth can be removed by JCB (Abhishek, 2020). In comparison to other strategies, this one requires more time and effort (Hill et al. 2017). Due to a change in the water's nutritional composition, a reduction in water levels in water bodies may have an impact on the growth of floating and submerged aquatic weeds (Thomaz et al. 2006). The common human and mechanical methods used to manage aquatic weeds include installing obstacles like booms and cables in the water channels, manually removing weeds with rakes and fine-mesh nets, and mechanically removing weeds with tractors and excavators (Cilliers et al. 2003). Modern technology has led to the development of equipment with simple handling, such as autonomous rotary-wing unmanned air vehicles (Goktogan et al. 2010). Aquatic weeds like *Hydrilla verticillata* and *Egeria spp.* that are submerged and floating should be removed manually and mechanically can result in canopy fragmentation, which will spread later and boost weed population (Dayan et al. 2005). Various types of aquatic weed cutters and harvesters have been developed for canals and large reservoirs. Use of these machines is not practical in fish ponds. Early manual removal of weeds by seining or raking can prevent some weed problems (Marley et al. 2017).Harvested weeds may have various utilities such as feed, manure, energy source etc. There are several techniques like (a) netting (b) barriers (c) chaining (d) water weed cutters to control weeds in aquatic situations. At the Central Institute of Fisheries Technology (CIFT), a portable mechanical gadget was developed which can clear both floating and submerged weeds at the rate of 1-1.5 ha area per day (Sushilkumar et al. 2009).

**2) Biological method**

The biological control through herbivorous fishes are - *Osphronemus gorannmi, Ctenopharyngodon idella* (Grass carp)*, Puntius javonicus* (Tawes)*, Tilapia mossambica, Chanos chanos* (Milk fish) have been used.

ii. Some birds have been found in controlling aquatic weeds. For example, Swans, Ducks feed on algae like *Wolffia, Lemna,* Marginal grasses etc. (Abhishek, 2020). Natural biological regulating agents cannot be identified in the current habitats since aquatic weeds make up 99% of the ecosystem's newcomers (Lovell et al. 2006). Therefore, after examining their adverse effects on the ecosystems as well, appropriate controlling chemicals for particular weeds should be found and conveyed (Sousa et al. 2011). This approach is viewed as being too sluggish and insufficient in some places to provide quick gains (Coetzee et al.2007). Fungal species like *Fusarium spp.* for *Egeria densa, Cercospora pistiae* for *Pistia stratiotes, Phaeoramularia spp.* and *Phoma spp.* for *Echinochloa polystachya* and *Paspalum repens*, insect species like *Agasicles hygrophila* and *Vogtia malloi* for *Alternanthera philoxeroides, Bagous.* (Dissanayaka et al. 2023).

The grass carp is a practical and affordable solution for pond weed control. The weeds filamentous algae and duckweed, which have soft, succulent foliage, are efficiently controlled by grass carp, whereas the weeds waterlily and cattail, which have harsh, woody vegetation, are not. Grass carp use is governed by numerous state laws. For information on state rules governing the usage of grass carp, speak with your Department of Natural Resources representative (Marley et al. 2017). Because it necessitates (a) long-term planning (b) a variety of strategies, and (c) manipulation of the cropping system to interact with the environment, biological control is more difficult than chemical control. When managing specific aquatic weeds in multi-use streams, biological management can be a long-term, ecologically safe, economically viable solution. Biological controls work best on invasive aquatic weeds that cover large regions of water bodies in monotypic stands. The total number of releases of biological agents used to combat weeds has been calculated (Julien, 1989). According to his research, the number of releases per decade climbed almost exponentially following the first decade of the 20th century saw 13 releases of agents for conventional weed control. The rate of effectiveness declined from 29% of all releases up to 1980 to 25% of all releases up to 1985 (Sushil kumar et al. 2009).

**Use of insects:**

The water hyacinth (*Eichhornia crassipes*) is still the most significant aquatic weed in the world. It is a significant issue in the Indian Subcontinent and South-East Asia and is growing at an alarming rate in Africa and Papua New Guinea. In 3 to 10 years following the installation of an agent, successful biological control can dramatically lower this weed cover, and it has produced outstanding control in a number of nations. In 1984, research into the usage of the curculionid Neochetina bruchi for water hyacinth control was conducted in Karnataka (Sanyal and Tanmay, 2017).

**Use of Snails:**

Snails Pomade canaliculata Lamer have also shown promise in the control of the aquatic weed *Anachaares alensa* in Brazil and *Marisa cornuarietis* in Florida **.** Additionally, successful management of aquatic weeds like Potamogeton illinoensis, Najas guadalupesis, and Ceratophyllum demersum has been noted. While Pistia stratoites and Alternanthera philoxeroides were partially restricted, Eichhornia crassipes growth and flowering were significantly slowed down by the snail's root trimming operation. The water plant-eating snail *Marisa cornuarietis* was once thought to have weed-controlling capability. Its capacity to consume young rice seedlings and poor tolerance for water temperatures below 10°C, however, limited its utility. On the other hand, its capacity to eradicate the bilharzia snail vector's breeding grounds would enable its introduction in locations where rice isn't the main crop. Another option for weed control is a South American snail called *Pomacea australis*. (Sanyal and Tanmay, 2017).

**3) Chemical methods**

**Chemical control of floating weeds:**

i. 2,4-D @ 4.5-6.5kg/hac. (Water hyacinth).

ii. Kerosene and Diseale @ 775-1100lit/hac. (*Pistia, Lemna).*

iii. Paraquat @ 0.02 a/hac. (*Pistia, Lemna).*

**Chemical control of marginal weeds:**

i. 2,4-D @ 5.0kg/hac, 2,2-dichloropropionic sodium @ 10- 12kg/hac, Amitrol @ 8.0kg/hac. (*Typha, Colocasia, Grasses)*.

ii. Copper sulphate with mud on the bottom soil @ 175kg/ hac. (*Nymphae)*.

**Chemical control of emergent weeds:**

i. 2,4-D @ 1.5kg/hac. (Water lilies, Lotus).

**Chemical control of submerged weeds:**

i. Sodium arsenite @ 5-6ppm.

ii. Copper sulphate or Copper sulphate with ammonium sulphate @ 50-300ppm.

iii. Ammonia @ 18ppm. (*Hydrilla, Najas, Vallisneria)*. (Abhishek, 2020)

Selecting the most suitable herbicides which are specific to aquatic weeds and applying them at the correct time with the recommended dose will control the aquatic weeds effectively without harming their ecosystems. Some components (ingredients and/or surfactants) in such herbicides can be toxic to beneficial aquatic organisms and terrestrial biological controlling agents. The toxicity of diquat, glyphosate, and glyphosate trimesium chemicals (which is used for controlling *Eichhornia crassipes*) on aquatic insects such as *Eccritotarsus catarinensis* and Neochetina eichhorniae had been proven by previous literature (Hill et al. 2012, Dissanayaka et al. 2023)**.** Chemical control is accurate identification of the problem weed. Weed identifica­tion assistance is available through county Extension and Department of Natural Resources offices. After the weed has been identified, herbicide that is labelled for commercial fish ponds may be selected. The herbicide label must be read and fully understood by the user prior to application to the pond. SRAC-361, Aquatic Weed Management Herbicides, contains information on commercial fish pond herbicides (Marley et al. 2017).

Several chemicals have been tried against water hyacinth with varying degree of success. Some notable contributions in the field are that of (Mitra 1948,Ramachandran and Ramaprabhu 1968, Misra and Das 1969, Ramachandran et al.1973, Patnaik, 1980). The herbicide 2,4-D (2,4-dichlorophen oxyacetic acid) is most effective for control of water hyacinth. The smaller floating weeds like *Spirodela, Lemina* and *Azolla* can be fully controlled with 0.1 kg/ha of 'Gramoxone' (paraquat) as reported by Patnaik (1976). Srinivasan and Chacko (1952) reported control of *Nymphaea* with 2,4-D ethyl ester while (Singh, 1962) reported control of *Nelumbo* and *Euryale* with 2,4-D sodium salt. (Mitra and Banerjee 1966) attained considerable success in controlling *Nymphaea* and *Nymphoides* by applying copper sulphate pellets. The primary submerged weeds which infest fish ponds are tap grass (*Vallisneria*), water plantain (*Ottelia*), bushy pond weed (*Najas*), coon tail (*Ceratophyllum*), bladder wort (*Utricularia*), *Hydrilla* and *Nechamandra*. Philipose (1963) found sodium arsentte at 46 ppm effective against *Hydrilla* and *Najas* without killing fish. Rooted submerged weeds like *Hydrilla, Vallisneria, Najas* and *Nechamandra* were controlled by localized application of copper sulphate pelleted with mud at the rate of 35 kg/ha as advocated (Mitra, 1977). Spraying with 2,4-D amines and esters ranging from 3.4 to 13.5 kg/ha proved effective against a number of grasses and sedges . Panchal and Sastry (1976) found application of diuron at the rate of 4 kg/ha along with 1 l/ha paraquat to clear *Typha* *angustata* at the pre-flowering stage and 2,4-D (sodium salt) at the rate of 8 kg/ha to control *Ipomoea aquatica*.

**4)Through utilisation**

**Control through utilization**

Aquatic weeds have economic value. They are used for various purposes. The removal cost of aquatic weeds by manual, mechanical and chemical methods is high and this cost can be compensated by utilizing the weeds for the following purposes (Abhishek, 2020).

i. Fertilizer

ii. Feed for animals/fishes/birds.

iii. Leaf protein.

iv. Manufacture of paper.

Despite the fact that aquatic plants have become invasive in some regions of the world, certain weeds have directly led to socioeconomic livelihood in other areas. Some aquatic weeds have a greater potential to be used as a bio-fertilizer due to their allelopathic behaviors (Fu et al. 2020). and a mulching material for supplying plant nutrients and organic matter, retaining soil moisture, and increasing soil microbial population (Tate et al.1988). Its higher cellulose, hemicellulose, and low lignin content can easily be used for making low-cost bags, paper plates, paper boards, and decorative paper (Nawaj et al. 2021). Moreover, aquatic weeds are potential raw materials for producing biogas and thereby generating electricity (Bote et al. 2020). *Azolla spp.* is considered as a feed supplement for livestock, poultry, and aquaculture farming due to its high nutritional value, especially with favorable amino acids and higher protein content (Brouwer et al. 2018, Das et al. 2018). Other than the ornamental value, free radical scavenging pigments in *Nymphaea pubescens* extract have a medicinal value that can be used for treating melanoma skin cancers (Aimvijarn et al. 2018). *Eichhornia crassipes* is an ornamental plant and is also popular as a phytoremediation plant, a source of biomass energy, and a source of raw materials for animal feed, construction, handicraft, paper, and board making (Jafari et al. 2010). *Pistia stratiotes* oil extract is good medicine, especially for worm infections, asthma, and skin disease, while leaves and roots are excellent sources of antioxidants (Wasagu, at al. 2014). Other than that, every part of *Nelumbo nucifera*, including leaves, rhizomes, seeds, and flowers, have been involved with traditional human livelihood as a part of the human diet, ayurvedic medicine, pharmaceuticals, and also landscaping (Chen et al. 2019). Controlling aquatic weeds is very difficult in developing countries such as Sri Lanka due to limited resources. As a result of that, several types of aquatic weed species have grown at an alarming rate, causing a disturbance in nature and agriculture in Sri Lanka. The ultimate aim of this work is to evaluate the feasibility of aquatic weeds to be used as a raw material for compost production to meet the requirements in sustainable plant nutrient management in the local context. Aquatic weed management will thereby be more effective in terms of the agriculture and ecosystem level (Dissanayaka et al. 2023).

**The roles of aquatic plants in phytoremediation of wastewater**

Aquatic plants are essential in biological wastewater treatment systems because they can be used for phytoremediation through rhizofiltration, phytoextraction, phytovolatilization, phytodegradation or phytotransformation techniques. The eradication of pollutants depends upon duration of exposure, concentration of pollutants, environmental factors (pH, temperature) and plant characteristics (species, root system etc.) (Irshad et al. 2013). However, it is worthy to note that different species of aquatic plants have been utilized in the phytoremediation process of wastewater with notable successes (Richard et al. 2002).

**Conclusion**

Although invasive aquatic weeds harm the pond environment and restrict use of the afflicted waters, native aquatic plants are a crucial component of the ecosystem. Exclusion or prevention should be used as the first line of defence because the majority of aquatic weeds have been intentionally introduced. Aquatic weeds can be controlled using a variety of methods, including cultural, mechanical, biological, and chemical control once a pond has been overrun. In order to prevent harm to native plants and fish, pond owners should first identify the invasive species. Then, they should choose a product labelled for that weed and for the situation. Unfavourable effects on aquatic ecosystems caused by invasive aquatic weeds have been one of the most common hazards to the global economy, ecology, and environment. The majority of the water bodies are hard to use and maintain because of its rapid growth and larger range of adaption mechanisms. One of the eco-friendliest and sustainable ways to incorporate nutrients from aquatic weeds into crop production is by composting. Their appropriateness as composting raw materials is supported by their short life cycles, increased biomass yield, higher plant nutrient contents, allopathic behaviours, and phytoremediation capabilities. Most aquatic ecosystems can be protected from soil and water contamination while being improved by using correct composting techniques and parameters after analysing the ecology and morphological characteristics of certain aquatic weeds.

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