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Mitigating Water Lily Invasion: Evaluating the Efficiency of a Novel Manual Machine in Aquaculture Ponds

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Abstract

Despite being used in pond aesthetics, waterlilies can grow to such proportions that they become detrimental to pond aquaculture. A study was conducted in Liberia to establish the efficiency of a newly fabricated manually operated machine to remove the water lily in infested ponds. A baseline survey of fish farmers facing waterlily invasion was done. A total of 30 farmers (20 from Bong and 10 from Nimba) were interviewed. Half of the respondents (53.4%) have had no basic knowledge on the water lily. Of those who had identified it, 93% of them had made attempts to remove them from their ponds. Methods employed in the removal by the farmers were manual removal by uprooting after fish harvest (67%), cutting using cutlass and hoe (26.7%), and chemical control (6.7%). *Nymphaea* sp was the most dominant water lily (42.6%), followed by *Nelumbo nucifera* (35.7%), and *Salvinia auriculata* (25.3%). The newly fabricated prototype reduced the removal time by 50% and hence reduced the removal cost by the same margin for a pond measuring 1500m^2. Future tests on this device should be done on larger ponds with different types of the waterlilies.

Keywords: Water lily, aquaculture, waterlily control, novel machine

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Original Article

Introduction

White waterlily is an aquatic, perennial plant with floating leaves and branched, creeping rhizomes. They have numerous small seeds that are each up to 2 mm long (Hitchcock & Cronquist 2018. *Nymphaea nouchali,* also known as blue lotus, is a water lily of genus *Nymphaea*. It is native to southern and eastern parts of Asia, and is the national flower of Bangladesh and Sri Lanka (Guruge *et al.,* 2017). This species is usually considered to include the blue Egyptian lotus *N. nouchali var. caerulea*. In the past, taxonomic confusion has occurred, with the name *Nymphaea nouchali* incorrectly applied to *Nymphaea pubescens* (Dezhi *et al*., 2015). *Nymphaea Capensis* is native to Africa and is also known as Cape Blue Water-Lily. It is found growing abundantly in freshwater habitats in South Africa and neighboring countries. This plant's bulb can survive relatively long periods of time without rainfall in a dry riverbed. The blue lotus, *Nymphaea caerulea*, the Cape blue water lily, and *Nymphaea capensis* are no longer regarded as distinct species (Qian *et al.,* 2022).

Salvinia auriculata is a perennial floating fern with horizontally growing abundant shoots. The color of this aquatic plant varies from bright green to olive-green featuring numerous leaves that are arranged in whorls of three. The plant undergoes changes in morphology or diverse growth forms depending on environmental conditions. These are primary, secondary, and tertiary growth forms. *Salvinia auriculata* lacks true roots and depends on the hair-like projections of the submerged leaves to function as root. The submerged leaves also bear spore-producing structures known as sporocarps (Michael, 2020*).*

Sacred Lotus or the *Nelumbo nucifera* is one of the most important perennial plants with both floating and aerial orbicular leaves. Leaves which are floating have flat shape whereas the aerial leaves are cup shaped. *Nelumbo nucifera* is an aquatic rhizomatous herb consisting of elongated, slender, nodal roots with creeping stem. Lotus is popular among Asian countries as an economically important aquatic vegetable. China is considered the world's largest producer and consumer of dry seeds which represents 45,000 tons, on an area of approximately 0.5–0.7 million hectares of land (Pal & Dey, 2015).

Nymphaea odorata also known as fragrant or white-water lily has negative impacts that can affect both humans and other aquatic species. According to the Washington State Department of Ecology, the fragrant water lily is second to Eurasian water milfoil in regards to nuisance (Washington Dept. of Ecology Water Program, 2005). As far as the effect on other species, *N. odorata* can have consequences on different levels of impact including population, community, and ecosystem, hence regarded as an ecosystem engineer (Olden, 2014). High densities of water lilies in ponds reduces the amount of sunlight penetrating the water and therefore interfering with photosynthetic activities (Giri, 2020). The dispersal of macrophytes mats influences the dispersal of zooplankton and other aquatic insect and hence fish populations (Moore et al., 1994).

Nymphaea spp provides essential habitat for many frogs, fish, and invertebrates, but there is a decrease in positive influences on fish species once 40% of surface coverage is exceeded (Washington Dept. of Ecology, 2014). The mats of water lilies result in low amounts of oxygen in the water column due to less wind mixing into the water (Civille, 2014). In turn, this alters the water pH of the littoral zone where key life stages occur for other aquatic species. Also, when water lilies die, the resulting decay processes use dissolved oxygen as well as adding nutrients to the water (Nachtrieb *et al*., 2011). They are digested and decomposed by microorganisms, which require oxygen in the process (Moore *et al*, 1994). These processes further reduce the amount of dissolved oxygen in the water. Such environments become inhospitable to many fish species of commercial value. Good growing conditions for most aquatic species (with the exception of some like carp and catfish) require roughly 4-7 mg/L of dissolved oxygen (Moore *et al*, 1994). Higher nutrient and lower oxygen content trigger increased algal blooms, which decreases water quality (Yang, 2008). This decrease in oxygen content has also been seen to actually facilitate other invasive species to establish, one of which being various species of carp (Frodge *et al*., 1995). Apart from the ponds, *Nymphaea* spp have been shown to invade freshwater lakes in Africa resulting in a reduction in fish species. An example case is in L. Victoria in East Africa (Harun *et al.,* 2021).

White water lily can be controlled by cutting, harvesting, covering with bottom barrier materials, and applying aquatic herbicides (Giri, 2020; Washington Department of Ecology, 2005). Lowering the water level of an invaded area has also been used to control aquatic plants, but results have been variable. Studies show that this method of control only controls about 50% of *Nymphaea odorata*, and the plants usually recover from propagation of rhizomes (DiThomaso & Kyser 2013). Invasion control can also be done by physically removing the invasive organisms (Olden, 2014). Manually, pulling out the entire plant including the rhizomes can be successful for a small area or pond size if repeated regularly (King County, 2010). However, the amount of time and manpower required to manually eradicate established populations by pulling is usually unsuccessful. For most sub-Saharan Africa fish farmers, manual removal is the only method available to them (Zongo *et al*., 2017). This study therefore sought to put to test a newly fabricated machine. The machine helps in meeting the rigorous demands characterized by manual removal of the water lilies in ponds.

Materials and methods

Study site

This study was conducted in Bong and Nimba Counties, in the central and northern parts of Liberia. Comparatively, Bong County has the highest aquaculture activities among all the 15 Counties (Wuor & Mabon, 2022). This is because the two counties are landlocked (Figure 1). Twenty fish farms were selected in Bong while ten fish farms were selected in Nimba.

Survey

A baseline survey of fish farmers facing waterlily invasion was done. A total of 30 farmers (20 from Bong and 10 from Nimba) were interviewed. The survey was aimed at identifying the types of water lily affecting farmer's farms, effects experienced by the fish farmers, impacts on fish productivity and the control practices/methods used in removing water lily from their farms.

Prototype fabrication

One prototype of a manually operated mechanical rake was designed and fabricated. The mechanical prototype is 1.0 m wide, with several 5 inches blades and rakes mounted at both ends of the manual machine. The submersible part is 30-50 cm adjusted according to the depth of the pond. Blades are flanked on both sides of the machine. Four-20 litres containers are attached to the prototype to aid in floatation. Ropes are then attached on the opposite ends to facilitate weeding by pulling the machine on the pond.

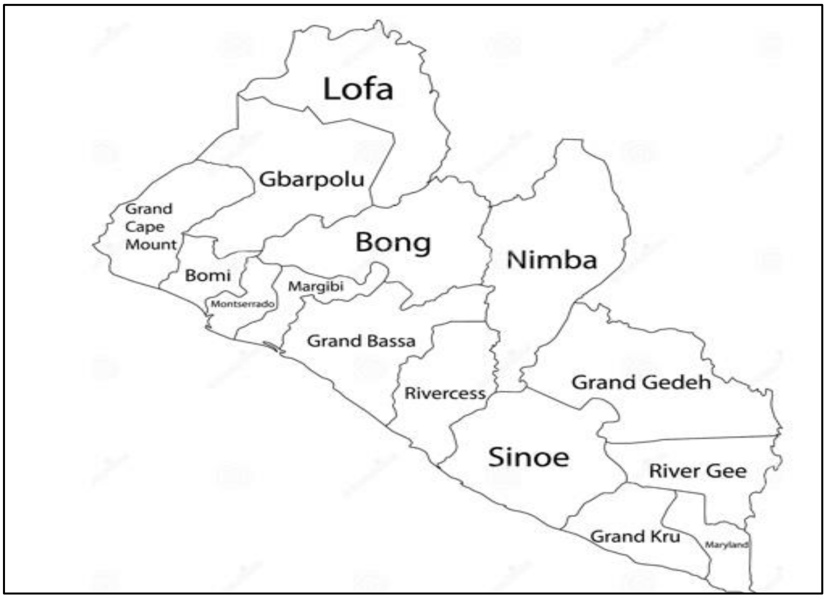

Figure 1: Map of Liberia showing all the counties (Bong and Nimba are located in the North Central part)

Evaluation of different water lily control measures

Due to its dominance, *Nymphaea* sp was used for this assessment. Each of the procedures to control the *Nymphaea* sp was conducted on three farmers' ponds over a period of six months. The six-month period allowed sufficient time to monitor and evaluate the persistence or any reemergence of the weeds following the application of the control method that was tested.

The tested methods were the manual hand-weeding method and the novel method using the fabricated manually operated prototype. The manual method was used as the positive control since it is the main method used by most farmers in Liberia. The fabricated machine was tested for its capacity to facilitate the timely removal of waterlily in ponds. This invented system was placed into the water and controlled by a manually operated pulley.

The evaluation of each method was assessed by estimating the biomass of *Nymphaea* sp removed in a specific duration of time and its implication on cost of labor per day. The newly fabricated machine requires four people to operate it. Therefore, this was compared to four individuals carrying out the manual removal.

Data analysis

Data collected was subjected to descriptive analysis in Statistical Package for Social Sciences (SPSS) 2021 version for data analysis. Tables and graphs were generated using Microsoft Excel 2016 to illustrate the results that were obtained from the experiment.

Results and discussion

Half of the respondents (53.4%) have no basic knowledge on the water lily in terms of the identification (Table 1). Of those who have identified it, 93% of them have made attempts to remove them from their ponds. Methods employed in the removal are manual removal by uprooting after fish harvest (67%), cutting using cutlass and hoe (26.7%), and chemical control (6.7%).

The dominant use of the manual means of removal of the water lily is reflected in many parts of sub-Saharan Africa (Coetzee *et al*., 2021). When biocontrol strategies have been used, other side effects like attacks on nearby crops have been experienced. Therefore, enhancing the efficiency of the manual harvesting is most viable for African fish farmers

Table 1: Effect of the water lily to the fish farmers

What knowledge/experience you have on water lily?	**Percent (%)**
Basic knowledge	46.6
No basic knowledge	53.4
Have you made any effort to remove the water lily?	
Yes	93.3
No	6.7
Most dominant species	
Nymphaea sp	42.6
Nelumbo nucifera	35.7
Salvinia auriculata	25.3
Mode of removal from the pond	
Manually after harvesting we uproot it	66.7
Manually by cutting with cutlass and hoe	26.7
Spraying with Chemical	6.7

There were three different species of water lilies identified during the experiment. They include, *Nymphaea* sp, *Nelumbo nucifera* and *Salvinia auriculata* (Figure 2). Among the three identified species, the *Nymphaea* sp was the most dominant and prevalent species found in farmers' ponds across the regions (Table 1). Any mode of removal could be employed on any of the species.

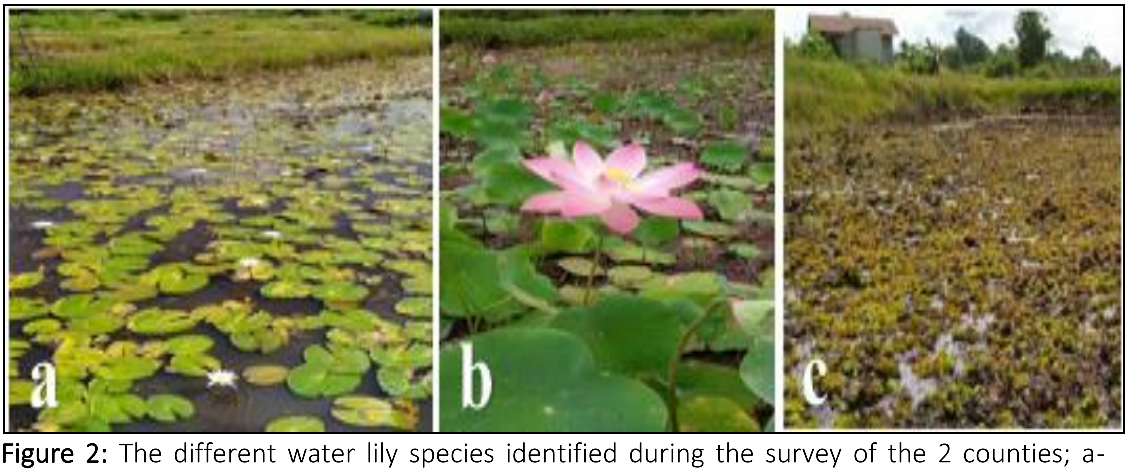

Figure 2: The different water lily species identified during the survey of the 2 counties; a- *Nymphaea* sp, b- *Nelumbo nucifera*, and c-*Salvinia auriculata*.

Effectiveness of the removal methods

Table 2 shows a comparison between manually man day works of weeding exercise to that of the new invented machine operation in farmers' pond regarding its efficiency and cost benefit analysis. From the table, a farmer hired 4 persons to operate the machine, with the payment scheme of 4.00 USD per day per person. When the pond size is $1500m^2$ and below, the machine lowers the cost by half. The efficiency increases with the size of the pond since the cost of weeding out the water lily at an $1800m^2$ pond in Zowenta was reduced by 60% (Table 2). Compared to other control methods, physical harvesting of the water weeds gives immediate relief to the water body (Helfrich, 2000). Further, chemical methods such as use of herbicides have been shown to be effective but is used selectively (Harrell & Hochheimer, J. N, nd). Biological control mainly applies the use of grass carp (*Ctenopharyngodon idella*) (Selden, 2020).

Table 2: The efficiency of the novel method compared to the conventional method of water lily removal

Community	Method	Pond size	Day (s)	Labour Cost/USD
Neingbin	Conventional	$1300m^2$	2	32.00
	Prototype		1	16
Tudin	Conventional	$1500m^2$	2	32.00
	Prototype		1	16.00
Zowenta	Conventional	$1800\ m^2$	2.5	40.00
	Prototype		1	16

The fabricated machine is more advantageous with larger ponds. However, in larger ponds, use of mechanical means to remove the water lily is complementary to other control methods like herbicide use (Shireman *et al*., 1986). Scale up of the fabrication and use of this machine would therefore encourage the use bigger ponds which will translate to more fish yield among the farmers. Manual removal method however, exposes the workers to waterborne diseases (Figure 3).

Figure 3. Both types of weeding exercises are depicted. On the left if the manual is the manual exercise while on the right, is the use of the fabricated prototype

Conclusion

- Half of the farmers of under the study have no basic knowledge on water lily.
- All the respondents have tried to remove the waterlilies in their ponds with the most popular

method being manual uprooting of the weeds.

- *Nymphaea* spp is the most dominant water lily weed in most fish ponds.
- The tested prototype increased the efficiency of pond removal of waterlily by at least 50%.

Recommendation

Future tests on this equipment should focus on larger ponds with different types of waterlilies.

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