SHORT COMMUNICATION

Potential penetration of exotic aquatic plants into natural environment through ornamental plant industry in Sri Lanka

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ABSTRACT

Aquatic plant industry has shown a rapid growth during past few decades in its export capacity and thus there are number of registered exporting companies directly involved in this business. This study was conducted to evaluate the invasion risk of exotic aquatic plant species to the natural environment through ornamental aquatic plant industry. Information of major aquatic plant nurseries in Sri Lanka were obtained from the National Plant Quarantine Service of Sri Lanka (NPQS). A field survey was performed in aquatic and semi-aquatic habitats within 1 km radius from four major nurseries selected in order to understand whether any species has escaped from the nurseries. photographs and the GPS data of the escaped species were taken. Echinodorus argentinensis, Mayaca sellowiana, Ceratophyllum demersum, Hydrilla verticillata, Hydrocotyle verticillata, Micranthemum umbrosum, Echinodorus grandiflorus, Echinodorus decumbens and Alternanthera sessilis were detected in natural habitats around some nurseries giving evidence for invasion risk from the nurseries. This finding indicates the necessity of implementing policy decisions and amending regulation on importation and cultivation of aquatic plant species in Sri Lanka.

Keywords*: Invasive risk, exotic aquatic plants, ornamental aquatic plant industry, natural environment*

INTRODUCTION

Export aquatic plant industry contribute to about 0.5% of the export earnings of Sri Lanka annually and many plant species are traded; out of which nearly about 98% are non-native species (NPQS, 2016). Therefore, the Plant Protection Regulations of Sri Lanka prohibits import of aquatic plants considering the potential threat of being invasive species. Therefore, many of the currently traded aquatic plant species are seems to be imported to the country prior to the enactment of Plant Protection Regulations by the extraordinary gazette notification 165/2 (Anon., 1981), and in addition, there may have illegal imports of plants after 1981. Hence, the Plant Protection Act No. 35 of 1999 and the regulations made thereunder regulates the importation of plant materials to the country (Anon., 1999). Import of aquatic plants as a group is prohibited by the

same act, unless they are imported for research, considering the past experience of almost all imported exotic aquatic plant species being invasive in natural habitats. However, during past few decades, large number of exotic aquatic plant species have been introduced to Sri Lanka through unrecognized means and all these species will have potential risk to be naturalized in the aquatic and semi-aquatic habitats (Marambe, 2001). Also, the exotic aquatic plants which have already been introduced are multiplied and cultivated for the ornamental plant industry and increases the risk of invasion of natural ecosystems. Many of these exotic species are utilized in this industry which brings an immense potential for further introduction of new exotics to the country (Yakandawala and Yakandawala, 2007). Also these invasions directly affect the balance of flora and fauna in the natural environment.

Management of aquatic invasive species costs a lot to the government budget in many countries. In Sri Lanka, the Department of Irrigation has bear cost of Rs. 324 million since 2008 on cleaning tanks, canals and waterways affected by such invasive species (Uduman, 2017). However, there is no any clear investigation recorded in Sri Lanka to find out the possibility of penetration of exotic aquatic plant species through ornamental aquatic plant nurseries. The inadequacy of information regarding the ornamental exotic aquatic plants is another factor which makes the process of the management of invasive aquatic plants cumbersome. Further, the study and management of invasive aquatic plants can be more challenging in the future due to the rapid changes in socioeconomic and environmental conditions in the country. Therefore, the present study was conducted to explore the aquatic plant species that have high risk of invasion in the natural habitats, introduced through the ornamental aquatic plant industry.

MATERIALS AND METHODS

Information on major exporters, exotic aquatic plant species and volumes exported (From September 2016 to August 2017) were obtained from the National Plant Quarantine Service (NPQS) of Sri Lanka (NPQS, 2016). According to the NPQS data, four major exporters at six different locations (Padukka, Ingiriya, Bope, Marawila, Moratuwa and Pugoda) were selected and visited.

Lists of plant species exported by the companies were collected and a complete aquatic plant gallery was compiled with referring information gathered from exporters and according to Hiscock (2003). A field survey was performed in aquatic and semi-aquatic habitats within 1 km radius from selected nurseries, to find out the presence of introduced exotic aquatic plant species in the natural environment. Previously prepared aquatic plant gallery and the method proposed by Hiscock (2003) were used to identify the exotic species that invaded the environment. Photographs of the escaped species were taken and the Geographical Position System (GPS) data were recorded. Finally, likelihood of invasion of exotic plants and invasion risk analysis was conducted for five species, by considering the highest volume of exports exceeding 100,000 plants

per year, using National Early Warning System developed by the Ministry of Mahaweli Development and Environment (2015). This protocol consists of 32 questions on the biology, ecology, distribution, impact and management aspects of a particular plant species. Information required to answer the questions were collected from available literature. A score of 1 was assigned for each "YES" answer and the total marks obtained for all "YES" answers were calculated as a percentage. Probability of invasion risk and categories of risk resulted from pre-entry risk analysis were given as follows.

$$\text{Invasion probability} = \frac{Total\ Marks}{32} \times 100$$

If resulted invasion probabilities are > 80, 60 – 80, 40 – 60 and < 40%, invasion risks are categorised as Very high, High, Moderate and Low risk, respectively (Ministry of Mahaweli Development and Environment, 2015)

RESULTS AND DISCUSSION

Survey on the ornamental aquatic plant industry

Survey conducted by focusing four exporting companies indicated that different products of aquatic plants are exported to Germany, South Africa, Turkey, Japan, United Kingdom, the Netherlands, United States of America, Canada, Sweden, Korea and Australia. Mainly vegetative propagation and tissue culture techniques are used to multiply the aquatic plants. Among the selected industries, three companies cultivate aquatic plants in poly tunnels and one company cultivate aquatic plants in abandoned paddy fields.

Several exotic aquatic plant species were found within the 1 km radius of the nurseries located in Ingiriya, Padukka and Bope where the open abandoned paddy fields are used for propagation of ornamental aquatics. Identified plant species are presently cultivated in respective nurseries for the purpose of exportation and some of those species are not available for local sales. Usually the expected mechanisms of species escape from nurseries to natural environment are either through waste, used water drainage, human carrying or due to production malpractices such as propagation done in open fields etc. During the survey it was evident that the highest observed escapes of species into the natural environment were from nurseries, which cultivate plants in abandoned paddy fields. Drainage channels of these paddy fields used for cultivation are directly connected with other fields, the water canals connected to those paddy fields and as well as with the natural environment. Further, it was observed that those companies have not practiced any preventive measures to avoid introduction of aquatic plants to the natural environment.

Field observations in Ingiriya

Ceratophyllum demersum, Hydrilla verticillata, Echinodorus argentinensis, *Echinodorus grandiflorus* and *Mayaca sellowiana* (Figure 1a, 1b and 1c) were found in natural

environment surveyed such as paddy fields, water streams and marshy areas. Distribution map and the photographs of discovered plants are shown in Figure 1 and 2. *Mayaca sellowiana* is a submerged plant and it was established in places with slow water movements. *Echinodorus argentinensis* and *Echinodorus grandiflorus* are emerged plants and they were established in embankments. During the flooding periods *Echinodorus argentinensis* and *Echinodorus grandiflorus* spread into neighboring environments through water and established in new areas. Further, the drainage channels of the industry are directly connected with water channels of the natural environment, since the industry has not used any preventive measures to control the introduction of aquatic plants to the natural environment. These plants grow fast suppressing the native species in the area and blocking the water streams creating conditions favourable for water pollution.

Figure 1: (a) *Ceratophyllum demersum* (6.701657° N, 80.197691° E), (b) *Hydrilla verticillata* (6.701764° N, 80.197687° E), (c) *Echinodorus argentinensis* (6.706701° N, 80.196778° E) found in Ingiriya.

Field observations in Padukka

Distribution map and the photographs of discovered plants are shown in Figures 3 and 4. *Mayaca sellowiana* and *Micranthemum umbrosum* (Figure 4a and 4b) were found in the natural ecosystem around the nursery. The investigation revealed that *Mayaca sellowiana* in water channels and *Micranthemum umbrosum* in paddy fields near the nursery. *Mayaca sellowiana* is a submerged aquatic plant and it was discovered in the places where water movement occurs with a low speed.

Field observations in Bope

Distribution map and the photographs are shown in Figures 5 and 6. Ornamental aquatic plants of *Echinodorus grandiflorus, Alternanthera sessilis*, *Echinodorus decumbens,* and *Hydrocotyle verticillata* (Figure 5a, 5b, 5c and 5d) were found in the surrounding paddy field plot near the nursery. With spreading and establishing of these exotics in surrounding paddy fields and water streams it suppresses the growth of naturals and cultivated crops and also creates unfavourable conditions in water bodies leading to the pollution.

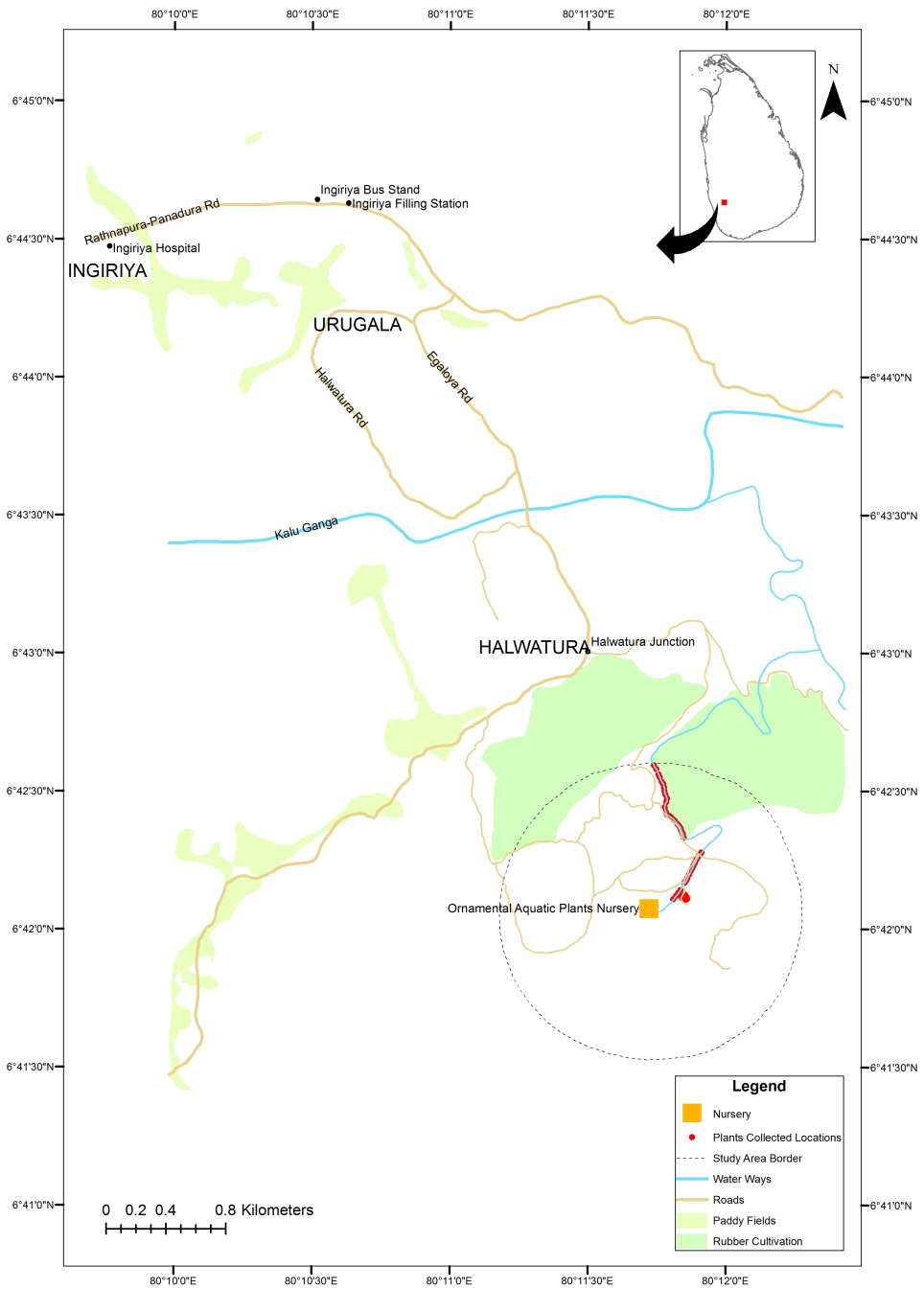

Figure 2: The distribution of the exotic aquatic plants within the surveyed area in Ingiriya.

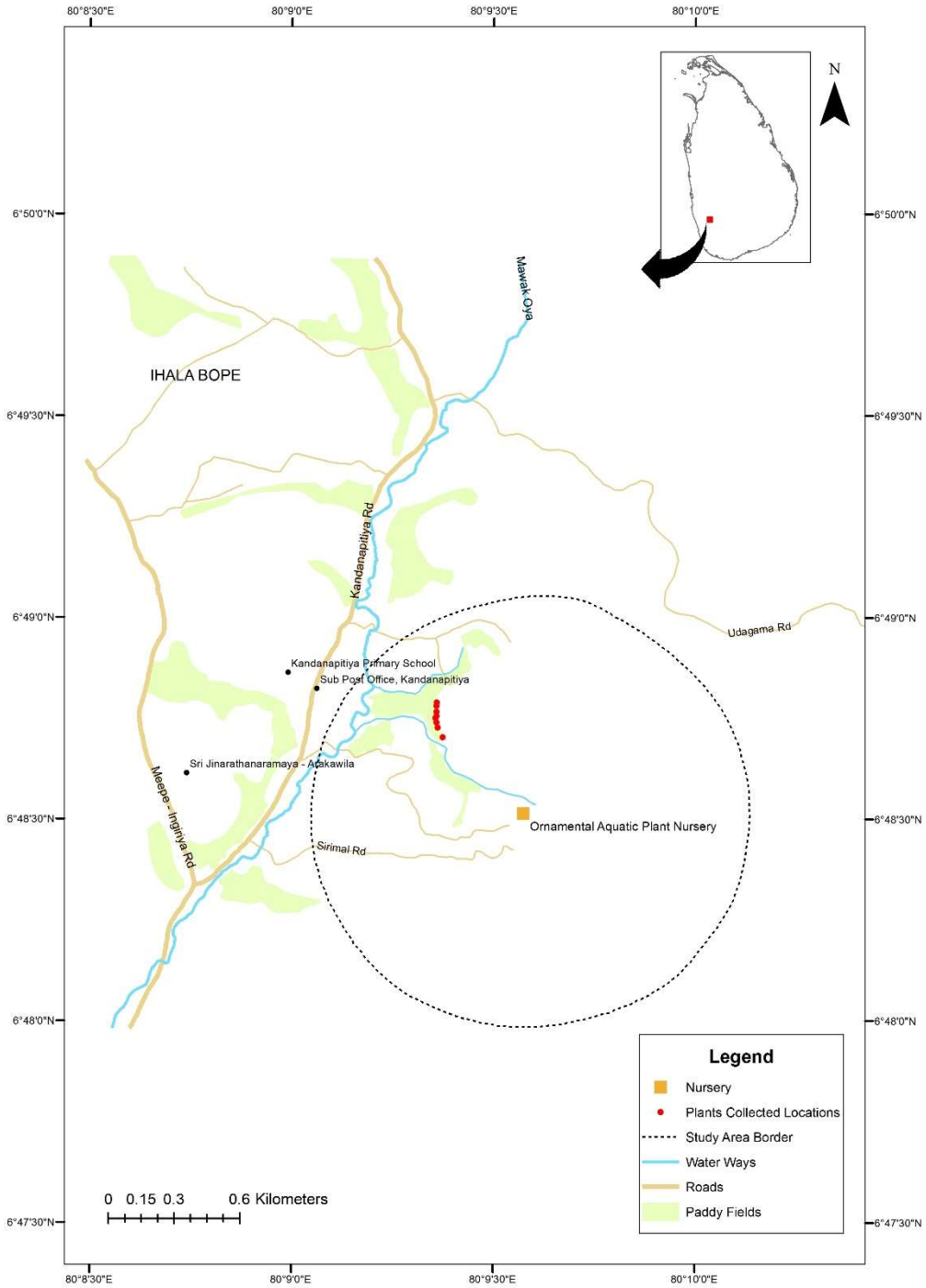

Figure 3: The distribution of the exotic aquatic plants within the surveyed area in Padukka.

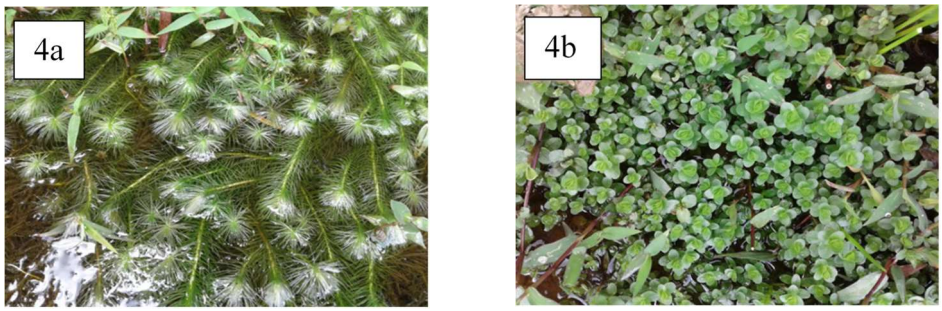

Figure 4: (a) *Mayaca sellowiana*; (6.811729° N, 80.156552° E), (b) *Micranthemum umbrosum*; (6.812443° N, 80.156312° E) found in Padukka.

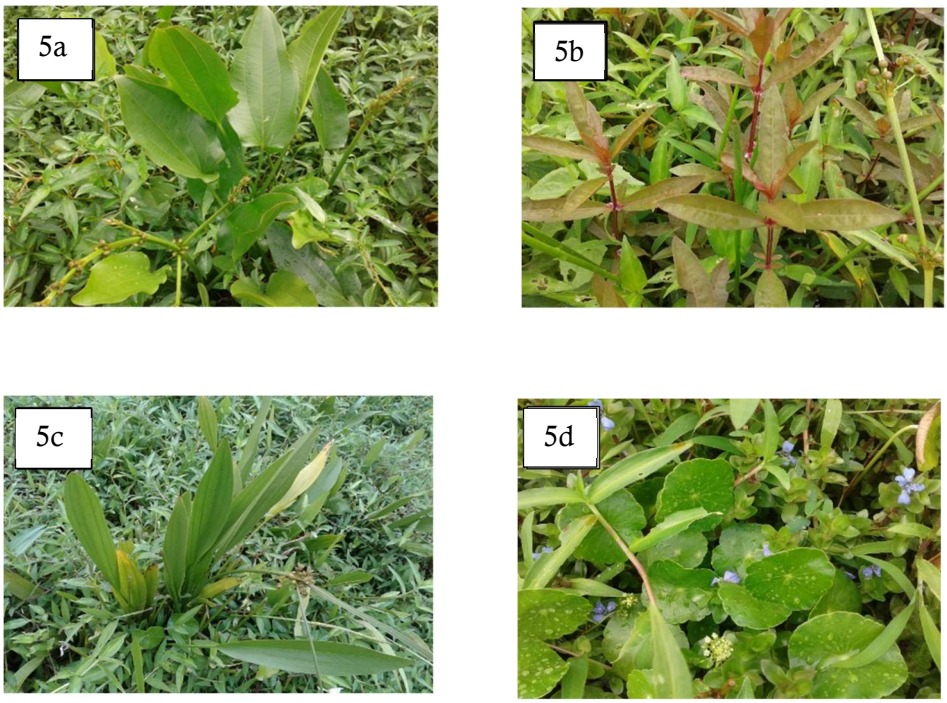

Figure 5: (a) *Echinodorus grandiflorus;* (6.830150° N, 80.137291° E), (b) *Alternanthera sessilis*; (6.830143° N, 80.137273° E), (c) *Echinodorus decumbens*; (6.830088° N, 80.137127° E), (d) *Hydrocotyle verticillata*; (6.830308° N, 80.137345° E) found in Bope.

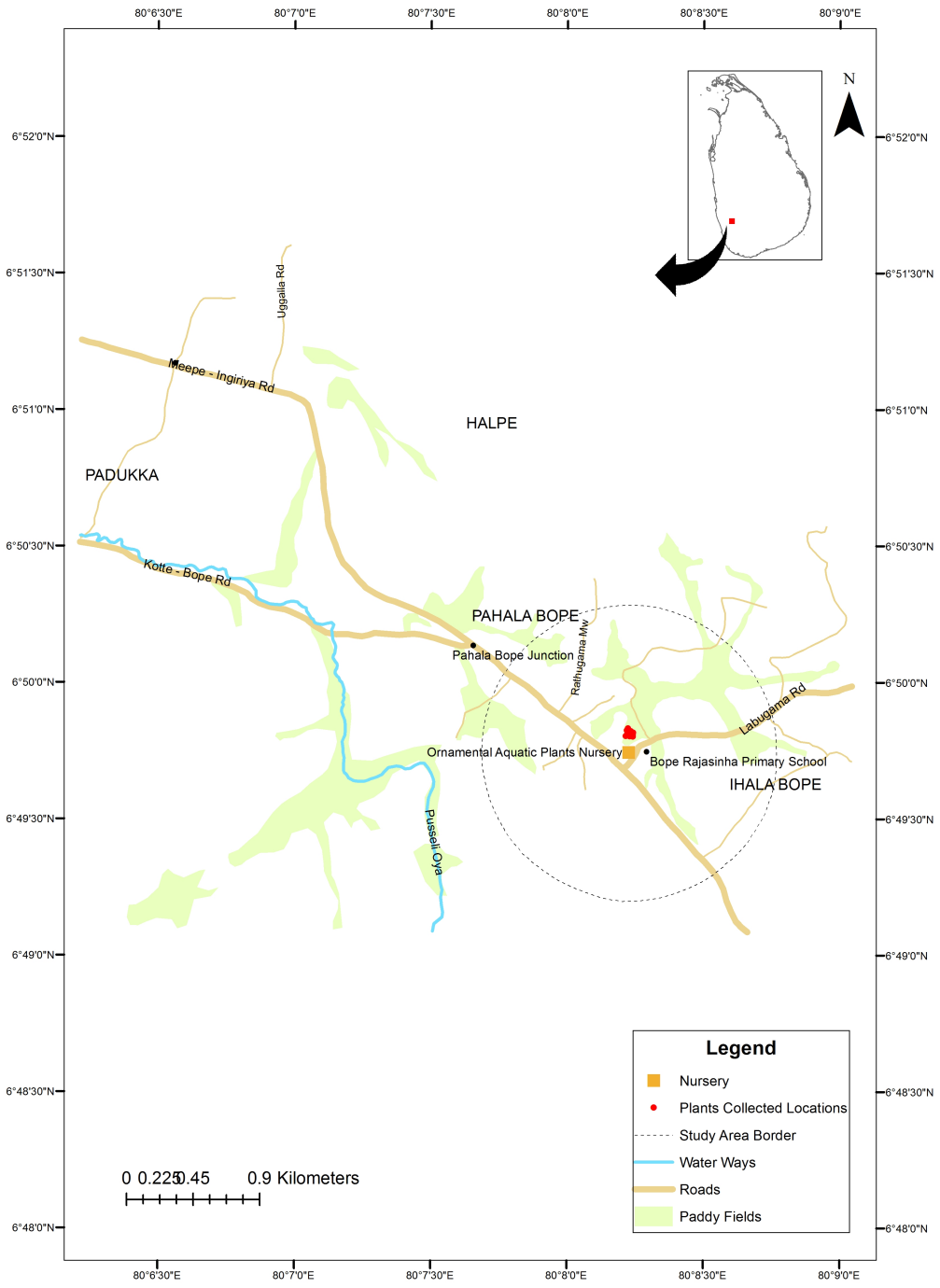

Figure 6: The distribution of the exotic aquatic plants within the surveyed area in Bope.

Likelihood of introduction of exotic aquatic plants into the natural environment

A total of 1,882,137 individual plants of 135 species were exported per year by the four companies during September, 2016 to August, 2017 (NPQS, 2016). Five species that have the highest demand in export market, based on statistics, out of the 135 species, were selected (Table 1) with the hypothesis that they could bring into the country in mass quantities without official permission and also have a potential of multiplying into large plantlet numbers. Therefore, these species may have the greatest potential to get escaped and established in the natural environment.

Table 1: Total amount of five selected species exported by selected companies in 2016 – 2017.

Aquatic Plant Species	No. of plants exported per year
Echinodorus bleheri	387270
Echinodorus argentinensis	186445
Hydrocotyle leucocephala	146750
Lilaeopsis brasiliensis	136325
Hygrophila difformis	110560

Source: National Plant Quarantine Service, Annual Report, Department of Agriculture, 2016

Invasion risk analysis

Five ornamental aquatic plant species, which were selected from likelihood analysis were subjected to an invasion risk analysis (Anon., 2017; USDA, 2015). National Early Warning System for Invasive Alien Species is the risk analysis model used in the analysis. Results of the invasion risk analysis are interpreted in Table 2.

Table 2: Invasion risk analysis for selected five species of ornamental plants.

Ornamental aquatic plant species	Invasion Probability (%)	Risk category
Echinodorus bleheri	36.36	Low risk
Echinodorus argentinensis	30.43	Low risk
Hydrocotyle leucocephala	50.00	Moderate risk
Lilaeopsis brasiliensis	47.37	Moderate risk
Hygrophila difformis	60.00	High risk

According to the results (Table 2), it is evident that *Hygrophila difformis* has a high risk of being invasive if the species is successfully established in the environment, while *Hydrocotyle leucocephala* and *Lilaeopsis brasiliensis* are having a moderate risk.

The survey conducted during this study has also revealed that *Hydrocotyle leucocephala* is already established in the environment and spreading along the water bodies to nearby natural habitats. These species may compete with indigenous plant species in natural aquatic/semi aquatic ecosystems in nearby areas threatening the survival of indigenous species. Further, these exotic aquatic plant species will be a potential source for major environmental issues like floods, limiting available water for aquatic animals, promoting eutrophication, exudation of toxic chemicals to water making it not suitable for drinking/bathing, reduce production in inland fishery industry, block irrigation systems and thereby limiting water availability for agriculture and increasing maintenance cost of such systems, block transport routes, foul industrial pipelines, accelerate filling of lakes and reservoirs and decrease property values and so forth.

The environmental cost caused by the invasive aquatic plants will be massive and ranging through social, cultural, and natural costs. In addition, managing such damaged ecosystem essentially causes an additional economic damage (Uduman, 2017) to the country in view of removing aquatic plants from water bodies and to implement preventive measures to avoid spreading of such plants in the future.

CONCLUSIONS

Survey indicated that the nurseries used open fields for the cultivation and propagation have penetrated exotic aquatic plants species to the natural environment and nurseries that cultivate under controlled conditions (Tanks/Protected houses) found to be adequately applied preventive measures to avoid penetration of exotic aquatic plants species to the natural environment. *Echinodorus argentinensis, Mayaca sellowiana, Ceratophyllum demersum, Hydrilla verticillata, Micranthemum umbrosum, Echinodorus grandiflorus, Echinodorus decumbens, Hydrocotyle verticillata* and *Alternanthera sessilis* were found within the periphery of the surveyed nurseries. Except for *Ceratophyllum demersum*, *Alternanthera sessilis* and *Hydrilla verticillata* all the other species (including their genera, except for Genus *Hydrocotyle*) recorded during the survey are not reported to be indigenous to Sri Lanka according to Senarathne (2001). Even though *Alternanthera sessilis* is recorded, the detected variety is alien to Sri Lanka.

Many of the species detected during the survey are having free floating habit, which may assist those species to spread a long distance. The species such as *Hydrocotyle* and *Echinodorus* can propagate through small stem parts, which can float with water and establish in another location (NECR, 2011). From the results, it was clearly evident that the ornamental aquatic plant industry in Sri Lanka is one of the main sources of introducing exotic aquatic plants species to the natural environment. Therefore, responsible government bodied have to consider about this situation and need to reconstitute the legislation related to exotic aquatic plant importation, cultivation and propagation. There should be proper regulations prohibiting the cultivation of any exotic aquatic plant species

in open environment and there should be operating procedures established for promoting correct protective measures to avoid accidental escape of such species. In addition, frequent supervision and surveillance of natural habitats near the nurseries conducted by responsible government bodies is necessary to monitor the status of distribution of the species, applying management measures as well as confining species into the nurseries.

The Invasive Risk Analysis conducted has explained the level of risk imposed by most demanding species in the export market. As it elucidates one of the studied species (*H. verticillata*) has already established in the environment successfully. The other species used for invasive risk analysis may be still restricted to nurseries, and explains how disastrous it will be if those species are accidentally introduced to the environment. Further, it will be worth to study the invasive risk of other species in the export trade, which will provide insights to government regulatory bodies on application of management options of such species. That will also assist development of risk management protocols in a prioritized manner in the future.

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