INVASIVE ALIEN SPECIES AND THEIR IMPACTS ON NATURAL RESOURCES

16 CHAPTER

D.S.A. Wijesundara

Abstract

Invasions are a basic characteristic of nature and have occurred ever since life first appeared on Earth. Invasion can be considered as an integral part of evolution as any other mechanism or process. However, the unprecedented and accelerating rate of species invasions caused by the removal of natural impediments to dispersal, deliberate introductions and ecosystem changes caused by man have devastated ecosystems and caused enormous ecological and economic damage to natural resources.

Invasiveness of a species is generally defined as the ability to spread beyond its introduction site and become established in new locations where it may cause a deleterious effect on organisms already existing there. An invasive alien species is also defined as an alien species whose establishment and spread threatens ecosystems, habitats or species causing economic or environmental harm (McNeely, 2001).

However, there are various definitions to invasive species (Wijesundara, 2010). Davis and Thompson (2000) introduced a rather novel framework for the definition of biological invaders based on the concept of Rabinowitz's (1981) classification of species rarity based on dispersal distance, novelty to the region, and impact. The Davis and Thompson model identifies 'invaders' as both a) native species that colonize naturally and b) species introduced by man to areas where they have no evolutionary history.

HISTORY OF PLANT INTRODUCTIONS

Deliberate plant introductions date back from the early days of human civilization, from ages so distant that the origin of some of the most useful crops of the world is unknown. For example, according to historical information, nuts of the coconut palm (*Cocos nucifera*) have been used even in the 2nd century. The botanic gardens and the Agricultural Departments have played a major role in early plant introductions. It would be impossible to estimate what Sri Lanka owes to plants that have been introduced from other countries and successfully acclimatized. Our principal economic crops, tastiest fruits, best shade trees, most beautiful flowering trees, major vegetables and our best fodders have all been introduced from other countries. Our most venerated tree, the sacred *Ficus religios* (Sacred Sri Maha Bodhi) at Anuradhapura, was also introduced to Sri Lanka 2,300 years ago from India (MacMillan, 1908).

However, some of the plants introduced have become invasive or noxious weeds. The Royal Botanic Gardens, Peradeniya played a major role in many such introductions. A well-known example is Water hyacinth *(Eichhornia crassipes)*. This aquatic plant species was first introduced in 1905 to the Royal Botanic gardens, Peradeniya by Lady Blake, the wife of the Governor, from Hong Kong as an ornamental plant. By June 1912 it was reported from Wattegama and in 1914 it appeared near Tangalle in the south and in Chilaw two years after. By 1917 it was found in

Table 1 - Some notable invasive alien flora introduced through botanic gardens

Family	Species	Common name	Country of origin	Year of introduction
Asteraceae	*Ageratina riparia*	*meedum mal*	Mexico	1905
Asteraceae	*Tithonia diversifolia*	*naththa suriya*	Mexico	1851
Clusiaceae	*Clusia rosea*	*gal goraka*	West Indies	1866
Dilleniaceae	*Dillenia suffruticosa*	*kaha para*	Borneo	1882
Fabaceae	*Myroxylon balsamum*	*sambrani*	Venezuela	1870
Fabaceae	*Prosopis juliflora*	*kalapu andara*	Tropical America	1880
Fabaceae	*Ulex europaeus*	*kaha katu*	Europe	1888
Iridaceae	*Aristea ecklonii*		Guatemala	1889
Melastomataceae	*Clidemia hirta*	*kata kalu bowitiya*	Tropical America	1894
Melastomataceae	*Miconia calvescens*	*yoda bowitiya*	Mexico	1888
Polygonaceae	*Antigonon leptopus*		Tropical America	1870
Pontederiaceae	*Eichhornia crassipes*	*japan jabara*	Hong Kong	1905
Solanaceae	*Cestrum aurantiacum*		Cape of Good Hope	1889
Verbenaceae	*Lantana camara*	*lantana*	Tropical America	1826

Source: Wijesundara, S. (2010)

Sabaragamuwa Province. By 1930, four ordinances were in action to control this weed, namely Water Hyacinth Ordinance No. 4 of 1909, Plant Protection Ordinance No. 10 of 1924, Village Communities Ordinance No. 9 of 1914 and Irrigation Ordinance No. 45 of 1917 (Wijesundara, 1999). Table 1 gives some of the notable invasive species introduced to Sri Lanka through the botanic gardens.

TYPES OF INVASIVE FLORA

Invasive alien plants can be herbs (*e.g. Alternanthera philoxeroides*), shrubs (*e.g. Cestrum aurantiacum*), creepers *(e.g.Wedelia trilobata)* or trees *(e.g. Prosopis juliflora)*. They may invade terrestrial or aquatic ecosystems. Some of these species such as *Cuscuta* are parasitic (Wijesundara *et al.*, 2001). According to current knowledge almost all invasive alien plants reported from Sri Lanka are vascular plants (Angiosperms or Pteridophytes). Although a green alga, *Caulerpa taxifolia* has been reported as an invasive sea weed, data on invasive lower plants are scanty in Sri Lanka.

INVASIVE ALIEN PLANTS IN SRI LANKA AND THEIR EXTENT OF SPREAD

A few researchers have previously attempted to compile lists of invasive alien flora in Sri Lanka (Marambe *et al.*, 2002; Bambaradeniya, 2002; Wijesundara, 1999). Others have either documented the spread of several invasive alien plants in a specific locality (Ratnayake, 2008), or the spread of a single invasive alien plant species in different localities (Jayasuriya, 2001; Marambe *et al.*, 2000; Medawatte *et al.*, 2008; Hitinayake *et al.*, 2000; Pushpakumara *et al.*, 2001). The main drawback of these attempts is the lack of proper criteria to determine the invasive nature of the listed species. Ranwala (2010) has prepared a set of Post and Pre Entry Risk Assessment Criteria for IAS and the Biodiversity Secretariat of the Ministry of Mahaweli Development and Environment is involved in using these criteria to assess the degree of invasiveness of the listed species.

Even though there is no accurate information on the degree of infestation, Amarasinghe and Ekneligoda

Table 2 - Common invasive alien flora found in Sri Lanka and their distribution

	Family	Species	Common name	Distribution	Affected habitats/ ecosystems
1	Amaranthaceae	*Alternanthera philoxeroides*	*rata mukunuwenna*	up- / low-country Wet Zones	fallow fields, marshy/ riparian areas
2	Annonaceae	*Annona glabra*	*wel aatha*	lowland Wet Zone	marshes in Wet Zone, coastal lagoons
3	Apocynaceae	*Alstonia macrophylla*	*hawari nnuga*	sub-montane zone	degraded Wet Zone forests, lowland Wet Zone forest edge
4	Araceae	*Colocasia esculenta*	*gahala*	island-wide	wetlands, marshes in Wet Zone
5	Asteraceae	*Ageratina riparia*	*meedum mal*	montane zone	open areas in montane forests, roadsides
6	Asteraceae	*Austroeupatorium inulifolium*	*pathan paalu*	montane zone	montane grassland/ forest ecotone
7	Fabaceae	*Mimosa invisa*	*gas nidikumba*	island-wide	wastelands, agricultural lands in mid-country
8	Fabaceae	*Mimosa pigra*	*yoda nidikumba*	Dry and Intermediate Zones	river banks, fallow fields, irrigation canals
9	Asteraceae	*Parthenium hysterophorus*	*parthenium*	Dry and Intermediate Zones	open wastelands, in the Dry Zone and Intermediate Zone
10	Asteraceae	*Sphagneticola trilobata (Wedelia trilobata)*	*aruna devi*	Wet and Intermediate Zones	wastelands, roadsides, abandoned paddy fields in Wet Zone
11	Asteraceae	*Tithonia diversifolia*	*naththa suriya*	Wet, sub montane and Intermediate Zones	wastelands, roadsides in the Wet Zone and sub-montane area
12	Cactaceae	*Opuntia dillenii*	*katu pathok*	arid zone	thorn scrublands in the Dry Zone, coastal areas
13	Clusiaceae	*Clusia rosea*	*gal goraka*	sub-montane zone	rock outcrops/ sub-montane forest edges
14	Convolvulaceae	*Cuscuta campestris*	*aga mula nethi wel*	island-wide except in upper montane zone	wastelands, agricultural land in low country
15	Dilleniaceae	*Dillenia suffructicosa*	*kaha para*	low-country Wet Zone	wet zone forest edges, open scrublands in Wet Zone near water
16	Fabaceae	*Leucaena leucocephala*	*ipil ipil*	Dry and Intermediate Zones	dry-mixed evergreen forests
17	Fabaceae	*Myroxylon balsamum*	*sambrani*	Wet and Intermediate Zones	mid country Wet Zone forests
18	Fabaceae	*Parkinsonia aculeata*	*bath karal gas*	Dry Zone	thorn scrub, degraded areas in dry evergreen forest

19	Fabaceae	*Prosopis juliflora*	*kalapu andara*	arid zone	thorn scrublands, edges of dry mixed evergreen forest, sea shore
20	Fabaceae	*Ulex europaeus*	*kaha katu*	montane zone	montane grasslands
21	Hydrocharitaceae	*Hydrilla verticillata*	hydrilla	island-wide	streams, canals, marshes in Dry Zone
22	Iridaceae	*Aristea ecklonii*		montane zone	montane grasslands, open areas of montane forest and wastelands
23	Melastomataceae	*Clidemia hirta*	*kata kalu bowitiya*	sub-montane wet zone	open areas in Wet Zone, lowland rain forest edges
24	Melastomataceae	*Miconia calvescens*	*yoda bowitiya*	sub-montane zone	edges of the sub-montane forest
25	Poaceae	*Panicum maximum*	*ali thanakola*, guinea grass	island-wide	wastelands, dry patana grassland, savannah, agricultural lands
26	Poaceae	*Pennisetum polystachyon*	*rila thana*, fox tail grass	dry and intermediate zones	wastelands, dry patana grassland
27	Poaceae	*Pennisetum clandestinum*	Kikiyu grass	montane zone	montane grasslands
28	Polygonaceae	*Aconogonon molle (Polygonum molle)*		montane Zone	degraded areas in montane forest, wastelands.
29	Pontederiaceae	*Eichhornia crassipes*	*Japan jabara*	island-wide	reservoirs, ponds, marshes, streams
30	Salviniaceae	*Salvinia molesta*	salvinia	island-wide	reservoirs, ponds, marshes, streams, paddy fields
31	Solanaceae	*Cestrum aurantiacum*		montane zone	open areas in montane forests, forest/grassland ecotone
32	Verbenaceae	*Lantana camara*	Lantana	island-wide	scrubland, degraded open scrub mainly in Dry and Intermediate Zone

Source: Wijesundara, S. (2010)

(1997) reported that about 8,000 ha of rice fields were infested with *Salvinia* in 1988. The area invaded by *Alternanthera philoxeroides* was reported to be more than 200 ha of land in the Southern Province of Sri Lanka (Marambe *et al.*, 2002). Now this infestation has been reported in the montane areas of the island as well.

Sri Lanka is blessed with a wide array of vegetation types distributed in diverse climatic zones. Some IAS are specific to certain ecosystems or climatic zones while others are widely distributed. Some of the common invasive alien species and their current distribution are given in the table 2.

MODE OF INTRODUCTION AND SPREAD OF INVASIVE PLANTS

Introduction of invasive alien plant species may be deliberate or accidental. Deliberate introduction of an alien species applies to a collection of plants, useful, interesting or ornamental, which are imported (through institutions such as botanic gardens), and have to be treated with special care, being propagated by artificial aid. A plant is said to be naturalized when, having become independent of artificial aid of any kind, escaped from cultivation and thrives in a wild state. Some plants deliberately introduced for a specific purpose have escaped from cultivation and become invasive.

For example, salvinia (*Salvinia molesta*), was introduced to Sri Lanka in the late 1930s as educational material, but appears to have escaped and is currently one of the most troublesome aquatic invasive plants, blocking irrigation canals and water bodies and also invading aquatic ecosystems and rice fields in the Dry and Intermediate Zones of Sri Lanka (Marambe *et al*., 2002).

It is believed that giant mimosa (*Mimosa pigra*) was introduced to Sri Lanka in the early 1980s to strengthen the river banks in the Mahaweli areas. This species has now spread to other parts of the country through irrigation water, machinery, river sand used for construction purposes, and lopping branches with mature pods for use as fuel wood by people (Marambe, 2000).

Many other invasive species are spread by irrigation water. In some instances even the control measures can cause further spread of the plant meant to be controlled. For example, mechanical removal of water hyacinth has resulted in its spread due to contamination of the machinery used for this purpose (Marambe, 1999). According to Jayasinghe (2004) the spread of the parasitic invasive plant, *Cuscuta campestris* is facilitated by irrigation water in the Mahaweli areas.

Mesquite (*Prosopis juliflora*) was first introduced by the Royal Botanic Gardens, Peradeniya in 1880. It is reported that it was introduced to the Hambantota District in the Southern Province of Sri Lanka in the early 1950s to improve its saline soils, and as a form of ground cover. *Prosopis juliflora* has become a very serious invasive plant threatening the ecosystems in Bundala National Park, a Ramsar wetland site. The seeds of this plant are dispersed by cattle as well as by elephants that eat the pods.

One of the best examples for accidental or non-deliberate introductions of an invasive plant is the congress weed *(Parthenium hysterophorus)* which was first reported by Jayasuriya (2001). This plant was believed to have entered the northeast of the country in the late 1980s, through goats imported from India by the Indian Peace-Keeping Force (IPKF). Seeds of *P. hysterophorus* have also entered the island along with seeds of onion and chilli imported from India as a contaminant.

Since colonial times many plant species introduced into the island have become invasive. Several invasive alien species have been reported during the last few decades. Some plants show invasive characteristics long after the first introduction. For example, the Guinea grass *(Panicum maximum)* was not considered a weed in 1908 (MacMillan, 1908) even though it is believed to have been introduced around 1801-1802 (Wisumperuma, 2008). Similarly, there may be some species which may become invasive in the future. A list of such species with invasive potential is given in table 3.

It has been reported elsewhere that climate change could result in both range expansion and contraction of invasive plants (Bethany *et al.*, 2009; Kriticos *et al.*, 2003; Dukes *et al.*, 1999). Although there are no quantitative ecological studies comparing the population sizes at different intervals, some invasive species such as *Austroeupatorum inulifolium, Clidemia hirta* and *Dillenia suffruticosa* have shown a marked increase in population sizes during the last

Table 3 - A list of potential invasive plant species in sri Lanka

No	Family	Species	Common name	Remarks
1	Bignoniaceae	*Millingtonia hortensis*	Indian cork tree	Dry Zone degraded areas. Open areas, wastelands.
2	Euphorbiaceae	*Manihot glaziovii*	sierra rubber, hevan maiyokka	Mid country Wet Zone, Sub-montane areas bordering degraded tea lands
3	Fabaceae	*Acacia auriculiformis*		Wet Zone, open areas near plantations.
4	Haloragaceae	*Myriophyllum aquaticum*	parrot feather	Invasive in many countries. Including USA, Pacific Islands, Japan, New Zealand, South Africa and European countries. Montane zone. native of the Amazon River in South America. Only reported in Nuwara Eliya Lake. (Sujith Ratnayake. Personal communication)
5	Mayacaceae	*Mayaca fluviatilis*	stream bogmoss	Invasive in several countries (Yakandawala, 2009). Wet Zone Ornamental aquatic. Escaped into some water bodies in the Western Province near Gampaha
6	Melastomataceae	*Tibouchina urvilleana*	glory bush	Invasive in Hawaii and some pacific Islands. Montane zone. Native to Southern Brazil. Small population in Horton Plans near Anderson Bungalow
7	Muntingiaceae	*Muntingia calabura*		Now spreading along Mahaweli areas in the mid-country and North Central Province, and Western Province degraded areas specially near water
8	Myrtaceae	*Psidium littorale*		Mostly in the edges of sub-montane forest, sometimes in the disturbed areas of the wet zone forest at higher altitudes
9	Onagraceae	*Ludwigia sedoides*	false loosestrife, mosaic plant	Invasive in other countries. (Yakandawala, 2009). Wet Zone. Native to South America. Ornamental aquatic. Escaped into some water bodies in the western Province near Gampaha
10	Onagraceae	*Ludwigia peruviana*	water primrose	Aquatic ecosystems and marshy areas mostly in the Wet Zone.
11	Poaceae	*Panicum trichocladum*	donkey grass, creeping guinea grass	Wet Zone. Native to Africa. Probably imported as a pasture grass or as a contaminant with tobacco seeds. Spreading in Hanguranketha area. Observed around 2002
12	Poaceae	*Setaria barbata*	bristly foxtail grass	Wet Zone. Native to Africa Spreading in the mid country
13	Typhaceae	*Typha angustifolia*	cat tail	Dry Zone water bodies, mostly coastal saline habitats
14	Verbenaceae	*Clerodendrum quadriloculare*	philippine fireworks, valentine plant	Invasive in the Pacific. All zones. Native to Philippines . Ornamental plant grown in many parts of the country
15	Vitaceae	*Cissus rotundifolia*	Arabian wax cissus	Dry Zone. Native to Africa. Cultivated ornamental. Invasive in some countries

Source: Wijesundara, S. (2010)

three decades in Sri Lanka (Iqbal *et al.*, 2014). It was also observed that *Pinus caribaea*, a plantation tree species, which did not regenerate naturally before, has shown invasive behaviour (Medawatte *et al.*, 2008) in the Knuckles Forest region. Whether these are due to the changes in climate needs to be investigated.

HISTORY OF ANIMAL INTRODUCTIONS

Except for a few species such as Giant African snail *(Lissachatina fulica)*, introduced in the nineteenth century, the majority of our invasive alien fauna were introduced during the last few decades. As in the case of plants, introductions of animals that have become invasive were both intentional and unintentional.

Many of our invasive fauna are fish species introduced into Sri Lanka as food, sport or aquarium fish. One species *(Poecilia reticulata)* was introduced for bio-control of mosquito larvae in 1930s. Mammal species such as feral dogs, cats and buffaloes are escapees from domestication while the invasive rats may have come through marine cargo. Except for the fish species introduced for food, many of the recently

Table 4 - List of invasive alien species of fauna recorded in Sri Lanka

No	Scientific name	Common name	Year and reason for introduction
1	*Bubalus bubalis*	feral buffalo	escape
2	*Canis familiaris*	feral dog	Abandonment or escape
3	*Chitala ornata*	clown knife fish	1990s, escaped from aquariums
4	*Clarias batrachus*	walking cat fish	unknown, escaped from aquariums
5	*Felis catus*	feral cat	abandonment or escape
6	*Labeo rohita*	rohu	1981, food fish
7	*Lissachatina fulica*	giant african snail	1900s, deliberate
8	*Onchorhynchus mykiss*	rainbow Trout	1889, sport fish
9	*Oreochromis mossambicus*	Mosambique tilapia	1951, food fish
10	*Oreochromis niloticus*	Nile tilapia	unknown, food fish
11	*Poecilia reticulata*	guppy	1930s, mosquito control
12	*Pomacea diffusa*	apple snail	1970s, aquarium industry
13	*Pterygoplichthys multiradiatus*	plecostomus catfish	1990s, escaped from aquariums
14	*Rattus rattus alexandrines*	Egyptian rat ships from Middle East	
15	*Rattus rattus rattus*	ship rat	ships from Europe
16	*Rattus rattus rufescens*	Indian house rat	ships from India
17	*Trachemys scripta*	red eared slider turtle	1980s, accidental though the pet trade
18	*Trichopodus pectoralis*	snakeskin gouramy	1951, food fish

Source: Biodiversity Secretariat, Ministry of Mahaweli Development & Environment (2015)

introduced invasive alien fauna are escapees from pet trade or aquaria.

TYPES OF INVASIVE FAUNA

According to the IUCN Invasive Species Specialist Group's (ISSG) Global Invasive Species Database, there are 82 potentially invasive species in Sri Lanka. Of these more than 60 species have become invasive (40 plants and 20 animals) and these include 23 of "100 of the world's worst".

According to Bambaradeniya (2002) there are 20 species of invasive alien fauna recorded in Sri Lanka. His list includes nine species of freshwater fish, a reptile, five mammals, and five molluscs. Ten of these species are included in the list of 100 of the world's worst IAS (IUCN-ISSG 2001). Marambe *et al.*, (2011) list 12 invasive alien fauna and the latest list prepared by the Biodiversity Secretariat of the Ministry of Mahaweli Development and Environment after several stakeholder consultations is given in table 4.

NATURE OF THREATS

Invasive alien species (IAS) can cause significant changes in ecosystems, upset the ecological balance, and cause economic harm to agricultural and recreational sectors. These invasive alien species compete with native species for space, resources and disturb plant-animal interactions. Only a few researchers have documented the harmful impacts of invasive alien flora on native biodiversity in Sri Lanka.

The flowers of *Cestrum aurantiacum* are pollinated by an endemic bird, the Sri Lanka white eye, and the fruits of this species are dispersed by another endemic bird, the yellow eared bulbul. Due to the abundance of *cestrum* plants in the forest fringe, these two bird species are now found mostly in those areas, and the pollination and dispersal of native species in the montane forest may be affected by the altered feeding habits of them.

The spread of mesquite *(Prosopis juliflora)* in the Bundala area has deprived large mammals such as elephants in their usual habitats. It is now spreading in the lagoon shore areas of Bundala National Park, reducing the feeding area for wading birds (Bambaradeniya *et al.,* 2002).

As documented by Bambaradeniya *et al.* (2006), a rapid increase in the spread of thorny cactus *(Opuntia dillennii)* in the coastal scrubland and seashore habitats in Tangalle and Ambalanthota areas subsequent to December 2004 tsunami has resulted in the loss and/or deterioration of nesting habitats of globally threatened marine turtles that visit these areas annually. The spread of the invasive cactus has also hindered the regeneration of coastal vegetation destroyed by the tsunami, such as *Pandanus odoratissimus, Scaevola taccada,* and *Spinifex littoreus (*Bambaradeniya *et al*., 2006).

As stated in the 2007 National Red List of Threatened Species, the spread of invasive alien plants such as *Annona glabra, Dillenia suffruticosa,* and *Eichhornia crassipes* has led to further degradation of the remaining marshy habitats of threatened blind eels *(Monopterus desilvai* and *Ophisternon bengalense)* in the Western Province of Sri Lanka (IUCN SL and MOENR, 2007).

According to the research findings of Gunaratne *et al*. (2008), the preferred habitat types of native aquatic birds such as the little grebe and the pheasant-tailed jacana are adversely affected by the spread of *Salvinia* molesta and *Eichhornia crassipes* in tanks and reservoirs. Similarly, Weerakoon and Athukorala (2008) have stated that the feeding habitats of globally threatened spot-billed pelicans in Sri Lanka are adversely affected by these aquatic invasive plants.

A large area in the natural montane grassland in Horton Plains was cultivated with potato during 1961 to 1978. This cultivation was abandoned in late1970s. These areas were later invaded by exotic, pasture grasses such as *Pennisetum clandestinum,*

Figure 1 - ***Prosopis juliflora*** **invading dry zone scrub land**

Pennisetum thunbergii and *Vulpia bromoides* escaped from the nearby cattle farm in Ambewela.

The original montane grassland vegetation in the Horton Plans comprised tussock grasses such as *Chrysopogon, Cymbopogon* and *Andropogon.* The change in physiognomy and composition due to potato cultivation followed by invasive alien grass species benefited the local population of sambur. The presence of nutritious pasture grasses and the increased safety due to absence of tussock grass cover for predators (leopards) may have caused the apparent increase in sambur populations in Horton Plains (Wijesundara, 1997). On the other hand, lack of tussock grasses may have negatively affected the leopards who use them for cover in hunting sambur.

On a recent visit to Bundala International Man and Biosphere (MAB) Reserve in the Hambantota District it was observed that the local communities in the peripheral area of the reserve are affected by *Typha angustifolia,* an aquatic invasive plant found in the wetlands of the reserve. The airborne cottony material (wind-dispersed seeds covered with hair) are considered a health hazard especially for little children.

As Sri Lanka is an island with sensitive ecosystems consisting of a unique biodiversity it is very important to mitigate factors affecting regeneration of species. Impact of IAS on pollination and dispersal of native species is worth studying.

The clown knifefish (*Chitala ornata*), introduced in 1994 has become a serious predator. affecting the populations of native fish species such as *Aplochielus dayi, A. parvus, Horadandiya athukorali, P. vittatus, P. bimaculatus, R. daniconius* and *Amblypharyngodon melettinus* (Gunawardena, 2002).

Other exotic species of fish affecting the biodiversity of aquatic ecosystems include the guppy *(Poecilia reticulata)*, walking catfish *(Clarias batrachus),* Mosambique tilapia *(Oreochromis mossambicus)* and the tank cleaner *(Hypostomus plecostomus)* (Bambaradeniya, 1999; Weerawardane and Dissanayake, 2005; Pethiyagoda, 1999; Wijethunga and Epa, 2008). The guppy was introduced to control

mosquito larvae, but Shirantha *et al.,* (2008) showed that the feeding habits of that species have become more carnivorous. This species is also reported to be feeding on the amphibians eggs (Bambaradeniya, 1999). Pethiyagoda (1999) reports that Mosambique tilapia is displacing native inhabitants such as *Labeo porcellus* and *L. dussumieri,* and the endemic red-fin labeo *(L. lankae)* has been driven to near extinction, possibly due to competition by this prolifically breeding fish species. Amarasinghe *et al*., (2006) predicts that the scrape feeding habits of the tank cleaner could change habitat quality, leading to detrimental effects on co-occurring species.

Adverse impacts on wild reptiles, birds, small animals and marine turtle by feral cats *(Felis catus)* and dogs *(Canis familiaris)* in natural ecosystems and home gardens have been reported (de Silva, 1999; Ilangakone, 2000; Bambaradeniya, *et al.,* 2002; de Silva, 2007). Feral buffalo populations in the Dry Zone on the other hand are competing with other herbivores such as sambur *(Rusa unicolor)* and elephants *(Elephas maximus)* in the ecosystem for food (Bambaradeniya, 2000). Populations of endemic rodent, *Srilankamys ohiensis,* in Sinharaja Tropical Rain Forest is reported to be suppressed by exotic ship rats *(Rattus rattus*) due to competition between the two species (Bambaradeniya, 2000). According to Bambaradeniya (2002) domestic buffaloes have interbred with the native wild water buffaloes *(Bubalus arnee)* and formed a hybrid feral population.

Data on the statistics of distribution or economics of the damages due to IAS in Sri Lanka is scarce. The goat weed or white weed *(Ageratum conyzoides)* is said to have cost the planters ₤ 250,000 a year to control it during the time of the coffee cultivation (MacMillan, 1908). Currently, many government departments including Irrigation Department, Department of Wildlife Conservation, Forest Department and the Department of Agriculture are spending millions of rupees in controlling IAS. However, as these expenditures are included in several vote heads under maintenance the total amount spent cannot be calculated easily.

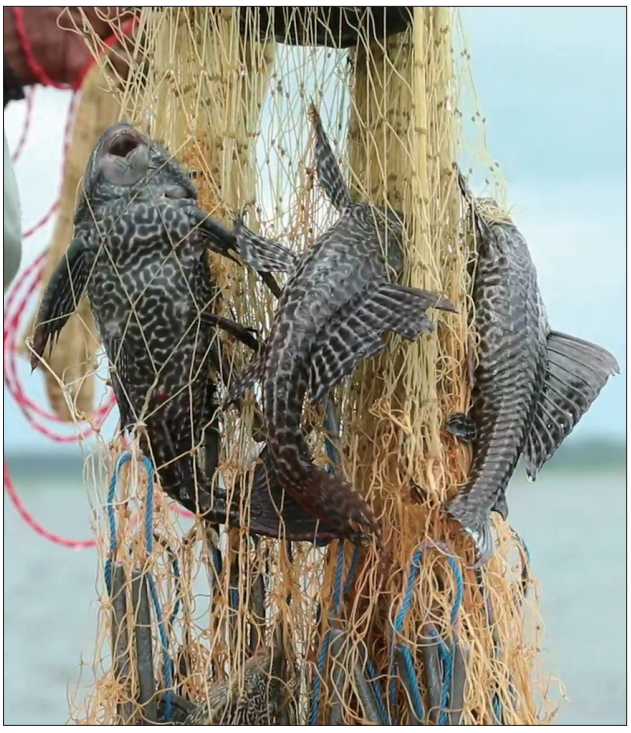

Figure 2 - ***Pterygoplichthys pardalis***

INSTITUTIONAL RESPONSIBILITY FOR THE CONTROL OF IAS

A coordinated strategy based on cooperation among all land managers is essential for managing IAS (Marambe, 2001). The absence of a National Strategy and an Action Plan has become a serious obstacle.

In Sri Lanka several organizations are actively involved in or conduct research on IAS related activities. The most prominent agencies are: Department of Wildlife Conservation, Forest Department, Department of Agriculture, Department of National Botanic Gardens, Irrigation Department, Mahaweli Authority, Department of Fisheries, Department of Animal Production and Health, Central Environment Authority, Marine Pollution Prevention Authority, National Aquatic Resources Research and Development Agency, World Conservation Union – Sri Lanka (IUCN-Sri Lanka), National Universities, and several non-governmental organizations (NGOs) and community-based organizations (CBOs).

Figure 3 - ***Anona glabra***

The Ministry of Mahaweli Development and Environment has recently established a National Invasive Species Specialist Group to oversee and coordinate IAS related activities.

The involvement of the private sector in IAS related activities has not been given due recognition in the country. Since they are a key sector involved in international trade, tourism and transport, involvement of the private sector organizations in IAS management activities is imperative in achieving the targets and goals in IAS control and management (Marambe *et al.*, 2011). The role played by NGOs and CBOs in IAS management is also vital in relation to awareness building, preventing introduction and spread, and management of IAS in the country. However, there should be proper guidance and coordination of the activities of these NGOs and CBOs to direct them to meaningful and appropriate IAS management programmes.

MANAGEMENT STRATEGIES FOR THE CONTROL OF IAS

Control and management of IAS need a strategic approach that encompasses prevention, eradication, control and containment. Several legislative provisions have been enacted in Sri Lanka (Marambe *et al.,* 2002). These include;

- Water hyacinth ordinance No 4 of 1909 makes provisions to prevent introduction into and dissemination in Sri Lanka of this weed. This act could be expected to expand further to control other noxious species as well.
- The Plant Protection Ordinance 1924 provides provisions against the introduction into Sri Lanka and against therein of weeds, pests and diseases injurious or destructive to plants and for the sanitation of plants in Sri Lanka. This ordinance was amended several times (1956, 1981 and 1999).
- Fauna and Flora Protection Ordinance (No. 02 of 1937, as amended) provides provisions for removal and transport of plants within and exporting.
- Fisheries and Aquatic Resources Act (No. 02 of 1996, as amended) provides provisions to manage, regu++late, conserve and develop the fisheries and aquatic resources.

Figure 4 - ***Typha angustifolia***

- Seed Act of the Department of Agriculture 1999 and 2003 provides provisions to control activities of plant nurseries and seed production.
- Marine Pollution Prevention Act (No. 35 of 2008) provides provisions to prevent, control and reduce pollution in the territorial waters.

The above legislative acts and ordinances can be used to prevent and control introduction of IAS to a considerable extent. However, there are many areas to be improved in accordance with the current needs.

ACTION PLANS

As a part of the Addendum to the Biodiversity Conservation in Sri Lanka, a framework for action, the Ministry of Environment and Natural Resources of Sri Lanka has formulated a "National Action Plan for the Control of IAS in protected areas". A "National Experts' Committee on IAS" has also been appointed to deal with the threats of the alien invasions. The Biodiversity Secretariat of the Ministry of Environment and Natural Resources has conducted many awareness programmes to educate the general public on the adverse impacts of IAS. Research on biology, impact and control of IAS is also receiving attention.

About four national level workshops and symposia have been conducted on IAS in Sri Lanka. The first workshop was conducted by the Ministry of Environment in 1999 (Marambe, 1999). In 2000 a symposium was conducted by the National Agricultural Society of Sri Lanka in collaboration with the Ministry of Environment (Marambe, 2000). The third symposium was conducted by the National Botanic Gardens Division of the Department of Agriculture in 2001 (Kotagama *et al.,* 2001) and the fourth symposium on IAS was conducted by the Sri Lanka Association for the Advancement of Science in 2008.

A National Symposium on IAS was held in 2014, organized by GEF/UNDP IAS Project, Ministry of Environment and Renewable Energy and University of Kelaniya. The proceedings of this National Symposium were published in 2014.

Useful information related to management and control of IAS was presented in the above symposia. Marambe *et al.* (2002) presented a draft national

list of IAS at a workshop titled "Prevention and Management of Invasive Alien Species: Forging Cooperation throughout South and Southeast Asia", convened by the Global Invasive Species Programme (GISP) in Bangkok, Thailand.

SPECIFIC ACTIONS TO MANAGE IAS

The Ministry of Environment and Natural Resources, together with the Department of Agriculture, implemented a one year project on management of aquatic weeds in 2005/2006, with funding from the FAO. This project involved awareness raising activities and pilot scale control programmes targeting *Salvinia molesta, Eichhornia crassipes* and *Pistia stratiotes.*

The Department of Agriculture was engaged in a biological control programme for *Salvinia molesta* using the weevil *Cyrtobagus salviniae*. This has been successful and it was introduced into many parts of the country, especially in the low-country Wet Zone. This species has been declared as a serious pest under the Plant Protection Ordinance. Doeleman (1989) carried out an assessment of cost and benefits related to the biological control of *Salvinia molesta* in Sri Lanka.

The Department of Agriculture is also rearing the bio-control agent *Neochetina eichhorniae*. Unfortunately this organism does not seem to feed effectively on the invasive aquatic weed. The Department of Agriculture also launched a chemical control programme for *E. crassipes* in the northwestern province in collaboration with the Irrigation Department.

The Department of Agriculture, together with Ministry of Environment and Natural Resources, universities and other governmental, non-governmental and private organizations, is actively involved in programmes to control *Parthenium hysterophorus.* An extraordinary gazette notification was released by the government of Sri Lanka in December 2000, prohibiting the movement of materials contaminated with any part of *P. hysterophorus* from the infested areas (Marambe *et al.,* 2002).

The Department of Wildlife Conservation, in collaboration with the private corporate sector has implemented a programme to manage the spread of *Prosopis juliflora* and *Opuntia dillennii* in Bundala National Park. That department is also spending a considerable amount of money for eradication of *Lantana camara* in the protected areas in the Dry Zone.

The Irrigation Department spends over Rs. 15 million annually to control *Eichhornia crassipes* and *Salvinia molesta.* (Although these funds are not specifically allocated for control of invasive plants, they are meant for cleaning waterways blocked with these two species.)

Marambe *et al.* (2000, 2003) attempted to control *Mimosa pigra* using glyphosate and enhanced community awareness.

Many NGOs, in collaboration with the Ministry of Environment and Natural Resources, are actively involved in campaigns to eradicate IAS. Some of the programmes conducted to eradicate IAS have become complicated due to the interactions with wildlife. For example, the eradication programmes on *Ulex europaeus*, were aborted due to the fact that endemic lizards and amphibians seek protection from their natural enemies in this thorny plant (Bambaradeniya *et al.*, 2001). Programmes conducted by the Department of Wildlife Conservation to remove *Lantana* from Uda Walawe national Park were also not successful due to various practical difficulties.

In some instances the control measures are affected by conflicts in the policies. For example, the Forest Department is reported to promote planting *Clusia rosea* in the Knuckles reserve as a fire prevention measure (as a biological barrier). Similarly the Department of Wildlife Conservation has been promoting the planting of *Panicum maximum* as a food source for elephants.

During the last 2-3 years several projects have been funded by the Ministry of Environment to eradicate IAS at local level. The species selected were mainly *Eichorrnia crassipes, Mimosa pigra, Annona glabra, Prosopis juliflora* and *Lantana camara.*

INVASIVE ALIEN SPECIES AS A RESOURCE

It is clear from the preceding sections that the IAS are seriously affecting the natural resources of Sri Lanka. However, since any plant or animal has some use, IAS could also be made into valuable commodities if the proper uses are found. Already some common IAS are being used directly or indirectly for various purposes. In fact, one of the main reasons for a species to become invasive is the absence of a population controlling mechanism in its habitat. For such species the use by man can be the best mechanism to control the spread. As human use comes with an economic gain, the IAS populations could become a resource under such situations.

One of the direct uses of invasive plants such as *Eichorrnia crassipes* is the use of dried plants as raw material for making handicrafts. There are several CBOs engaged in this as a commercial venture in Matale area. Another popular use of this species and other aquatic plants, such as *Salvinia molesta*, is converting them into green manure.

Prosopis juliflora, which has become a very serious invasive plant in Sri Lanka, is considered as a useful multipurpose tree in India and Africa (Mwangi and Wallow, 2005; Pasiecznik, 1999). This species is used in dryland agroforestry systems in several countries for controlling soil erosion, stabilizing sand dunes, improving soil fertility, reducing soil salinity, providing fuel energy resources, supplying feed and forage for grazing animals, furnishing construction timber and furniture wood, supplementing food for humans, and promoting honey production (Mwangi and Wallow, 2005). In India this species is used for production of charcoal (Mwangi and Wallow, 2005) and in Sri Lanka too some NGOs are involved in this activity.

Lantana camara is used for making furniture in India (Kannan *et al.,* 2014). Invasive trees such as *Alstonia macrophylla* and *Millingtonia hortensis* can be used for timber. High biomass producing invasive grasses such as *Panicum maximum* could be exploited for the production of third generation biofuel.

Phytochemical research done on several invasive plants in Sri Lanka have shown that they are rich in natural products. Some invasive plants in the montane zone such as *Cestrum aurantiacum* (Hewage *et al.,* 1997) and *Ageratina riparia* (Bandara *et al.,* 1992) have shown insecticidal and antifungal properties respectively. *Aristea ecklonii* which is rich in Quinonoids (Kumar *et al.*, 1985) also has potential to be used as a pesticide.

ACKNOWLEDGEMENTS

Much of the information used in this manuscript was compiled during the Global Environment Facility (GEF) funded project on "Strengthening capacity to control the introduction and spread of invasive alien species in Sri Lanka", through the United Nations Development Programme (UNDP) - Sri Lanka. Author acknowledges the support extended by Prof. Budhdi Marambe, Prof. Pradeepa Silva, Dr Sudheera Ranwala, Mr Jagath Gunawardena, Prof. Devaka Weerakoon, Prof. Lasantha Manawadu, Dr Nihal Atapattu, Mr Gamini Gamage, Mr Ajith Silva, Dr Ananda Mallawatantri and Mrs Padma Abeykoon.

REFERENCES

1. Amarasinghe, L. & Ekneligoda, I.A. (1997). Some recent observations on the biological control of *Salvinia*. *Krushi* **16**: 44-50.
2. Amarasinghe, U.S., Shirantha, R.R.A.R. & Wijeyaratne, M.J.S. (2006). Some aspects of ecology of endemic freshwater fishes of Sri Lanka. *The Fauna of Sri Lanka: Status of Taxonomy, Research and Conservation*, (ed. C.N.B. Bambaradeniya), pp. 113-124. The World Conservation Union (IUCN), Colombo, Sri Lanka and Government of Sri Lanka.
3. Bambaradeniya, C.N.B. (1999). Alien invasive fauna in natural habitats and their impact on indigenous biota. *Proceedings of the The First National Workshop on Alien Invasive Species in Sri Lanka,* (ed. B. Marambe), pp. 45-51. Ministry of Forestry and Environment, Sri Lanka.

4. Bambaradeniya, C.N.B. (2002). The status and implications of invasive alien species in Sri Lanka. *Zoos' Print Journal* **17** (11): 930-935.

5. Bambaradeniya, C.N.B., Ekanayake, S.P. & Gunawardena, J. (2001). Preliminary observations on the status of alien invasive biota in natural ecosystems of Sri Lanka. *Report of the Workshop on Alien Invasive Species*. (ed. P. Balakrishna), Global Biodiversity Forum, South and Southeast Asia Session, October 1999, Colombo, Sri Lanka. IUCN Sri Lanka. pp. 67-76.

6. Bambaradeniya, C.N.B., Ekanayake, S.P., Fernando, R.H.S.S., Perera, N. & Somaweera, R. (2002). A biodiversity status profile of Bundala National Park - A Ramsar wetland in Sri Lanka. *Occasional Paper of IUCN Sri Lanka.* No. 2, pp. iii + 37

7. Bambaradeniya, C.N.B., Perera, M.S.J. & Samarawickrama, V.A.M.P.K. (2006). A rapid assessment of post-tsunami environmental dynamics in relation to coastal zone rehabilitation and development activities in the Hambantota District of Southerm Sri Lanka. *Occasional Paper of IUCN Sri Lanka.*, No.10 pp. iv+ 27

8. Bandara, B.M.R, Chandralal, M. H., Karunaratne V., Wannigama, G.P. & Adikaram, N.K.B. (1992). An antifungal chromene from *Eupatorium riparium* 1992 *Phytochemistry* **31** (6): 1983-1985.

9. Bradley, B., Oppenheimer, M. & Wilcove, D. (2009). Climate change and plant invasions: restoration opportunities ahead? *Global Change Biology* **15** (6): 1511-1521.

10. Davis, M.A. & Thompson, K. (2000). Eight ways to be a colonizer; two ways to be an invader: a proposed nomenclature scheme for invasion ecology. *Bulletin of the Ecological Society of America* **81**: 226–230.

11. De Silva, A. (1999). Turtles, terrapins and tortoises of Sri Lanka. *Sri Lanka Nature* **2**(3): 4-9.

12. De Silva, A. (2007). *The Diversity of Horton Plains*. pp. 275. Vijitha Yapa Publications.

13. Doeleman, J.A. (1989). Biological control of *Salvinia molesta* in Sri Lanka. An assessment of cost and benefits. *ACIAR Technical Report*. pp. 14. Canberra, Australia.

14. Dukes, Jeffrey S. & Mooney, H.A. (1999). Does global change increase the success of biological invaders? TREE **14** (4):135-139.

15. Gunaratne, A.M., Jayakody, S. & Bambaradeniya, C.N.B. (2008). Spatial distribution of aquatic birds in Anawilundawa Ramsar wetland sanctuary in Sri Lanka. *Biological Invasions*, **11**: 951-958.

16. Gunawardena, J. (2002). Occurrence of *Chitala chitala* (Syn. *Chitala ornata*) in native freshwater habitats. *Sri Lanka Naturalist* **5**(1): 6-7.

17. Hitinayake, H.M.G.S.B., de Costa, W.A.J.M. Dharamawardena, M.I.U.D.S. & Wedathanthri, H.P. (2000). Key ecological features and distribution of plant species showing apparent invasive behavior at Udawattakele forest reserve. *Proceeding of the Symposium on Alien Invasive Species in Sri Lanka: Impact on Ecosystems and Management* September, 2000. National Agricultural Society of Sri Lanka (NASSL) and Ministry of Forestry and Environment

18. Ilangakone, A. (2000). Marine turtles: Imperiled ancient ocean wanderers. *Loris* **22**(3): 18-21.

19. Iqbal, M.C.M., Wijesundera, D.S.A. & Ranwala, S. M.W. (2014). Climate Change, Invasive Alien Flora and Concerns for their Management in Sri Lanka. *Ceylon Journal of Science* (Biol. Sci.). **43** (2): 1-15

20. IUCN Sri Lanka and the Ministry of Environment and Natural Resources (2007). *The 2007 Red List of Threatened Fauna and Flora of Sri Lanka.* Colombo, Sri Lanka. Xiii+148pp.

21. IUCN-ISSG (2001). *100 of the world's worst invasive alien species*. pp. 11. The World Conservation Union (IUCN), Sri Lanka.

22. Jayasinghe, J.L.D.H. (2004). Identification, distribution and host specificity of lowland *Cuscuta* in Sri Lanka. *M.Phil Thesis,* University of Peradeniya, Sri Lanka.

23. Jayasuriya, A. H. M. (2001). New invasive weed in Sri Lanka: *Parthenium hysterophorus* L. (Asteraceae) *Proceeding of the Silver Jubilee Seminar Series of the Postgraduate Institute of Agriculture,* University of Peradeniya, Sri Lanka. (ed. HPM Gunasena) pp. 14.

24. Kannan, R., Shackleton, C. M. & Shaanker, R. Uma (2014). Invasive alien species as drivers in socio-ecological systems: local adaptations towards use of *Lantana* in Southern India. *Environment, Development and Sustainability* **16**:649–669.

25. Kotagama, H. B., Wijesekara, A. & Wijesundara, D.S.A. (2001). *Sri Lankan Biodiversity Review*. Vol. 1, Department of Agriculture, Sri Lanka.

26. Kriticos, D. J., Sutherst, R. W., Brown, J. R., Adkins, S. W. & Maywald, G. F. (2003). Climate Change and the Potential Distribution of an Invasive Alien Plant: *Acacia nilotica* ssp. *indica* in Australia *Journal of Applied Ecology* **40**: (1) : 111-124

27. Kumar, V., Meepagala, K.M., Balasubramaniam, S. (1985). Quinonoid and other constituents of *Aristea ecklonii. Phytochemistry* **24**: 1118-1119.

28. MacMillan, H.F. (1908). Acclimatization of Plants. *Circulars and Agricultural Journal of the Royal Botanic Gardens*, *Ceylon*: **IV**, (9) : 55-73.

29. Marambe, B. (ed.) (1999). *Proceedings of the First National Workshop on Alien Invasive Species*. Ministry of Forestry and Environment, Sri Lanka.

30. Marambe, B.(1999). Factors affecting the spread of alien invasive plants in Sri Lanka. *Proceedings of the First National Workshop on Alien Invasive Species*. (ed. B. Marambe), Ministry of Forestry and Environment, Sri Lanka. pp. 29-34.

31. Marambe, B. (ed.). (2000). *Proceedings of the Symposium on Alien Invasive Species in Sri Lanka:* Joint Publication of the Ministry of Forestry and Environment and the National Agricultural Society of Sri Lanka, Peradeniya, Sri Lanka.

32. Marambe, B. (2000). The need for a coordinated strategy to control alien invasive plants in Sri Lanka. *Proceedings of the Symposium on Alien Invasive Species in Sri Lanka: Impact of Ecosystems and Management*. (ed. B. Marambe), Joint Publication of the Ministry of Forestry and Environment and the National Agricultural Society of Sri Lanka, Peradeniya, Sri Lanka. pp. 13-23.

33. Marambe, B., Amarasinghe L., Dissanayake, S. & Balasooriya, A.H.K. (2000). Distribution of the alien invasive plant *Mimosa pigra* L. in Sri Lanka. *Proceedings of the Symposium on Alien Invasive Species of Sri Lanka: Impact on Ecosystems and Management* (ed. B. Marambe), Ministry of Forestry and Environment of Sri Lanka and the National Agricultural Society of Sri Lanka. pp. 69-63.

34. Marambe, B. (2001). National action plan for alien invasive plants. (ed. H.P.M. Gunasena), *Silver Jubilee Commemorative Volume*, pp. 93-104. Postgraduate Institute of Agriculture, University of Peradeniya, Sri Lanka.

35. Marambe, B., Bambaradeniya, C., Pushpakumara, D.K.N.G. & Pallewatta, N. (2001). Human dimensions of invasive alien species in Sri Lanka. *The Great Reshuffling, Human Dimensions of Invasive Alien Species,* (ed. J.A. MacNeely), pp. 135-142. The World Conservation Union (IUCN), Gland, Switzerland and Cambridge, UK.

36. Marambe, B., Amarasinghe, L., & Gamage, G. (2002). (eds. N., Pallewatta, J.K. Reaser, & A.T. Gutierrez), Invasive Alien Species in South-Southeast Asia: National Reports & Directory of Resources. Global Invasive Species Programme, Cape Town, South Africa.

37. Marambe, B., Amarasinghe, L, Silva, A., Gamage, G., Dissanayake, S. & Seneviratne, A. (2003). Distribution, biology and management of *Mimosa pigra* L. in Sri Lanka. Manual on Biology and Management of *Mimosa pigra* (eds. M. Julien, G. Glanagan, T. Heard, Q. Paynter & C. Wilson), CISIRO, Australia. pp. 85-90.

38. Marambe, B., Amarasinghe, L. & Gamage, G. (2003). Sri Lanka. (eds. N. Pallewatta, J.K. Reaser & A.T. Gutierrez), Invasive Alien species in South-Southeast Asia: *National Reports and Directory of Resources,* pp. 91-100. The Global Invasive Species Programme (GISP), Cape Town, South Africa.

39. Marambe, B. (2008). Research priorities on invasive alien species in Sri Lanka. *Proceedings of the National Symposium on Invasive Alien Species*, (ed. S. Ranwala), pp. 7-12. Sri Lanka Association for the Advancement of Science.

40. Marambe, B., Silva, P., Ranwala, S., Gunawardena, J., Weerakoon, D., Wijesundara, S., Manawadu, L., Atapattu, N. & Kurukulasuriya, M. (2011). (eds. C. R. Veitch, M.N. Clout & D. R. Towns), Island Invasives: Eradication and Management. pp. 445-450. IUCN, Gland, Switzerland.

41. McNeely, J. A. (Ed.). (2001). *The Great Reshuffling: Human Dimensions of Invasive Alien Species.* pp. vi + 242. IUCN, Gland, Switzerland and Cambridge, UK.

42. Medawatte, W.W.M.A.B., Tennakoon, K.U., Hulme, P.E., & Gunatilleke. I.A.U.N. (2008). Spread of Caribbean pine into the grasslands of the Knuckles range, Sri Lanka. *Proceedings of the National Symposium on Invasive Alien Species*, 11 November 2008, Colombo 07, p.5.

43. MOENR (2007). *Biodiversity conservation in Sri Lanka – A framework for action (Addendum)*. pp. 52. Biodiversity Secretariat, Ministry of Environment and Natural Resources, Sri Lanka.

44. Mwangi, Esther & Swallow, B. (2005). Invasion of *Prosopis juliflora* and local livelihoods: Case study from lake Baringo area of Kenya. *ICRAF Working Paper No. 3.* Nairobi World Agro Forestry Center, Kenya.

45. Pasiecznik, Nick. (1999). Prosopis - pest or providence, weed or wonder tree? *European Tropical Forest Research Network Newsletter.* **28**: pp. 12-14.

46. Pethiyagoda, R. (1999). Fishes in trouble: The decline and fall of Sri Lanka's fresh water fish fauna. *Loris, Journal of Wildlife and Nature Protection Society of Sri Lanka* **22**(2): 56-64.

47. Pushpakumara, D.K.N.G. & Hitinayake, H.M.G.S.B. (2001). Invasive tree species in Udawattakele forest reserve. *Sri Lankan Biodiversity Review* **1**:53-63.

48. Rabinowitz, D. (1981). Seven forms of rarity. *The biological aspects of rare plant conservation*. (ed. H. Synge), pp. 205-218. Wiley, New York, USA.

49. Ranwala, S. (2009). Risk assessment protocol for IAS in Sri Lanka. (eds. B. Marambe, P. Silva, S. Wijesundara & N. Atapattu), *Invasive alien species in Sri Lanka – Strengthening Capacity to Prevent Introduction and Spread,* pp. 15-26. Ministry of Environment and Natural Resources, Sri Lanka and United Nations Development Programme, Sri Lanka.

50. Ratnayake, R.M.C.S. (2008). Dominant alien invasive plants of Hantana ecosystem. *Proceedings of the National Symposium on Invasive Alien Species*, 11 November 2008, Colombo 07. p.21.

51. Shirantha R.R.A.R., Amarathunga, A.A.D. & Weerasekara, K.A.W.S. (2008). Do feral populations of *Poecilia reticulata* ready to bring its overall efficacy as a mosquito bio-control agent or pose threats to aquatic biodiversity in Sri Lanka. *National Symposium on Invasive Alien Species*, 11 November 2008, Colombo, Sri Lanka.

52. Weerakone, K., & Athukorala, H. (2008). Invasive plant species: Is it a threat to the existence of globally threatened spot-billed pelicans in Sri Lanka? *Proceedings of the National Symposium on Invasive Alien Species*, 11 November 2008, Colombo 07. p.24.

53. Weerawardane, N.D.R. & Dissanayake, J. (2005). Status of forest invasive species in Sri Lanka. (eds. P. McKenzie, C. Brown, S. Jianghua & W. Jian), The unwelcome guests. *Proceedings of the Asia-Pacific Forest Invasive Species Conference*, FAO Regional Office for Asia and the Pacific, Bangkok, Thailand, RAP Publication, pp. 114-120.

54. Wijesekera, G.A.W. & Bambaradeniya, C.N.B. (2007). Invasive Alien Species. *The National Atlas of Sri Lanka*, 2nd Edition, pp. 95-97. Survey Department, Colombo, Sri Lanka.

55. Wijesundara, S. (1997). Leopards in Horton Plains (long). Available at https://lists.princeton.edu/cgi-bin/wa?A2=ind9705&L=NATHISTORY-INDIA&P=R3788. Accessed.

56. Wijesundara, S. (1999). Alien invasive species in Sri Lanka and their history of introduction. *Proceedings of the First National Workshop on Alien Invasive Species*. (ed. B. Marambe), Ministry of Forestry and Environment, Sri Lanka. pp. 25-27.

57. Wijesundara, D.S.A., Jayasinghe, C., Marambe, B. & Tennakoon, K.U. (2001). Host-parasitic association of *Cuscuta chinensis* Lam. in Sri Lanka. *Annals of the Sri Lanka Department of Agriculture* **3**: 343-351.

58. Wijesundara, S. (2010). Defining invasive alien species. (eds. B. Marambe, P. Silva, S. Wijesundara, & N. Atapattu), *Invasive Alien Species in Sri Lanka – Strengthening Capacity to Control Their Introduction and Spread.*

59. Wijethunga, M.U.I. & Epa, U.P.K. (2008). Food resource partitioning of introduced alien sucker mouth catfish, *Pterygoplychthys multiradiatus* with some of the alien and indigenous fish species in Sri Lanka. (ed. S. Ranwala), *National Symposium on Invasive Alien Species*, Sri Lanka Association for the Advancement of Science, pp. 103-119.

60. Wisumperuma, D. (2008). First known record of guinea grass cultivation in Sri Lanka, 1801-1802. *Journal of the Royal Asiatic Society of Sri Lanka*, Colombo. **LIII,** (New Series): 219-226.

61. Yakandawla, K. (2009). Long term observations on escaped ornamental aquatics in the wet zone of Sri Lanka. *Paper presented at the National Symposium on IAS in Sri Lanka*, 21-22. May 2009. Pegasus Beach Hotel, Negombo, Sri Lanka.