Status of Research on Invasive Alien Species in Sri Lanka

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ABSTRACT

Invasive Alien Species (IAS) has not been a popular topic of research in Sri Lanka in the past. The existing published information is widely scattered in the literature and has become a major obstacle for information sharing among stakeholders. This paper presents, published research on IAS. The oldest publications on IAS of flora and fauna in Sri Lanka date back to 1923 and 1948 respectively, although the term IAS was not used, then. Out of a total 470 records, 161 had been published between the years 2005-2010. Among the topics covered in these publications, other than the topics, flora and fauna, 'IAS in Sri Lanka' was the most popular topic followed by 'impacts of IAS'. Only a few IAS have been subjected to in- depth investigations. Among them, fish species have received more attention than any other groups of fauna, where both *Oreochromis mosambicus,* and *O. niloticus*, Cichlids, *Poecilia reticulate* and *Cyprinus carpio* have been widely addressed compared to other species. Published research was not available for the Invasive Alien Plant Species; *Ulex europaeus, Parkinsonia aculeate, Pennisetum polystachyon, Mimosa invisa, Colocasia esculenta, Aristea ecklonii.* Of the 15 potential invasive alien plant species identified, research publications were limited to 08 species. Similarly of the 10 potential invasive animal species, only 05 species had published research information. A wide range of topics including socio economic impacts, biotic interactions of IAS and their impacts on ecosystem services and effects of climate change on IAS need urgent attention of researchers. There is also a lack of publications on case studies of good IAS management practices and of successes and failures in adaptive management. The need for more governmental attention and financial assistance, to raise the research capacity of an island nation to minimize the spread and impact of IAS, cannot be overlooked any longer.

Key Words: Invasive Alien Species research, impacts of IAS, fish species, alien plant species, Sri Lanka

INTRODUCTION

The scientific term 'Invasive Alien Species (IAS)' appears to have been added to scientific literature in Sri Lanka in the late 1990s and has become a popular research topic thereafter. Until then, all problematic and unwanted species in irrigation, agriculture, plantation and other related sectors were commonly known as environmental weeds and pests. Lately, IAS in Sri Lanka have received considerable attention from a variety of sectors and have been subjected to research at different scales. Findings of these research studies have been disseminated in a

variety of forms in the print and digital media. Nevertheless, sharing of research findings on IAS has been difficult as published records are not in any one location and many publications on IAS authored by local scientists are available only as printed copies in libraries of a few institutions. In compilation of this bibliography on IAS, the publications were arranged into a few categories, key aspects of IAS covered in published research records were noted and data gaps that should be addressed in the future were identified.

MATERIALS AND METHODS

Published research records on IAS of priority and potential categories (as declared as published lists by The Ministry of Mahaweli Development and Environment in 2015), were collected from libraries of universities and other institutions, personal communications and through web search. These were categorized according to the type of publications, such as full papers, abstracts, plenary lectures/keynote/presidential addresses and books and of the subject areas covered. The trends in research studies from past to present were recognized. The already investigated aspects and existing data gaps were identified.

RESULTS

The 470 published research entries on IAS that were examined included 210 full papers, 242 abstracts,14 plenary lectures/keynote/presidential addresses and 04 local books.

The earliest publications on IAS were on eradication of *Eichhornia crassipes* by A.T. Reeve (1923) and Lester Smith (1927) on *Salvinia auriculata*, by J.E. Senaratne (1943) and R. A. William (1956), control of *Lantana* in Eucalyptus plantations by W. E. S. Goonewardene (1953) and investigations on *Eupatorium riparium* (presently known as *Agertina ripraria*) by F. H Kehl and E. S Rajiah (1954). The very first publication on invasive alien fauna in Sri Lanka, was 'Observation on the mouth breeding cichlid fish *Tilapia mossambica'* by E.R.A De Zylva (1948). Until the1980s, research publications on IAS and/or related species were few in number. Research publications on IAS have increased to a maximum of 161 between 2005-2010 (Figure 1).

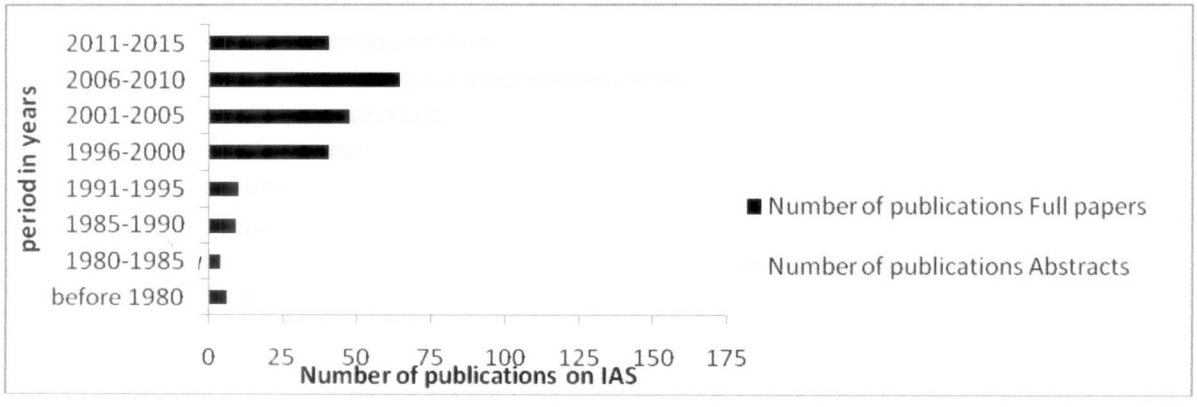

Figure 1: Research publications on IAS from 1980 -2015

Of the total 470 publications, 209 were on flora while 137 publications were on fauna. This shows that information available for invasive alien plants is much higher than that for invasive alien animals. Among the flora, *Lantana camara* had the highest number of publications and among the fauna, *Tilapia* spp. had the highest number of publications (Figures 2a & b). The information on Tilapia focused mainly on its uses in the inland fishery industry and its products. The unavailability of information on aspects related to the potential invasiveness of this species and its distribution was a common feature and hampered the evaluation of its invasiveness and the decision making process in the declaration of IAS.

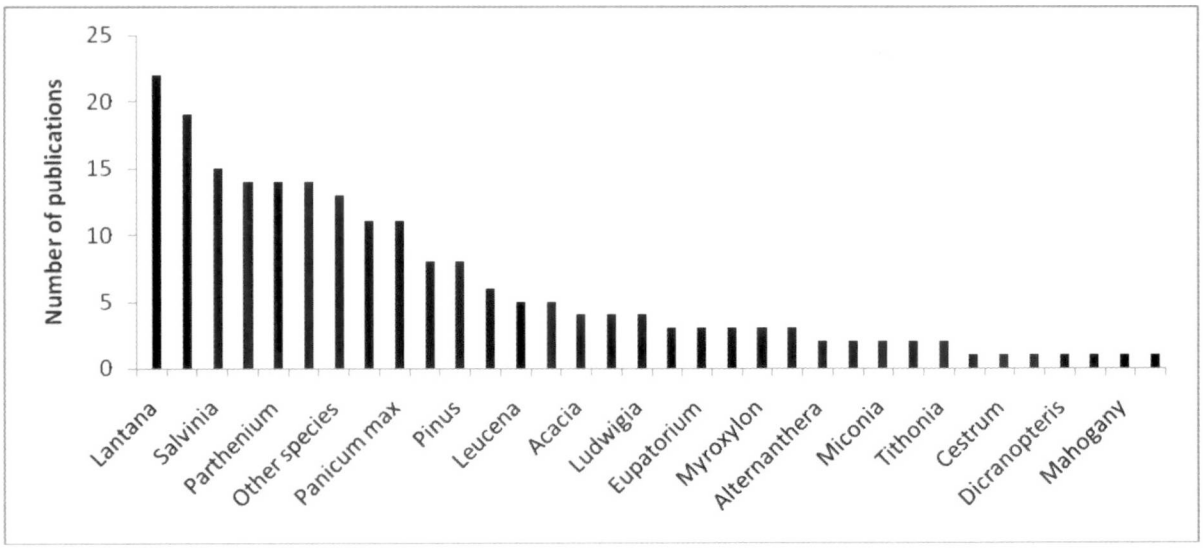

Figure 2a: Research publications on invasive alien plants arranged according to their numbers

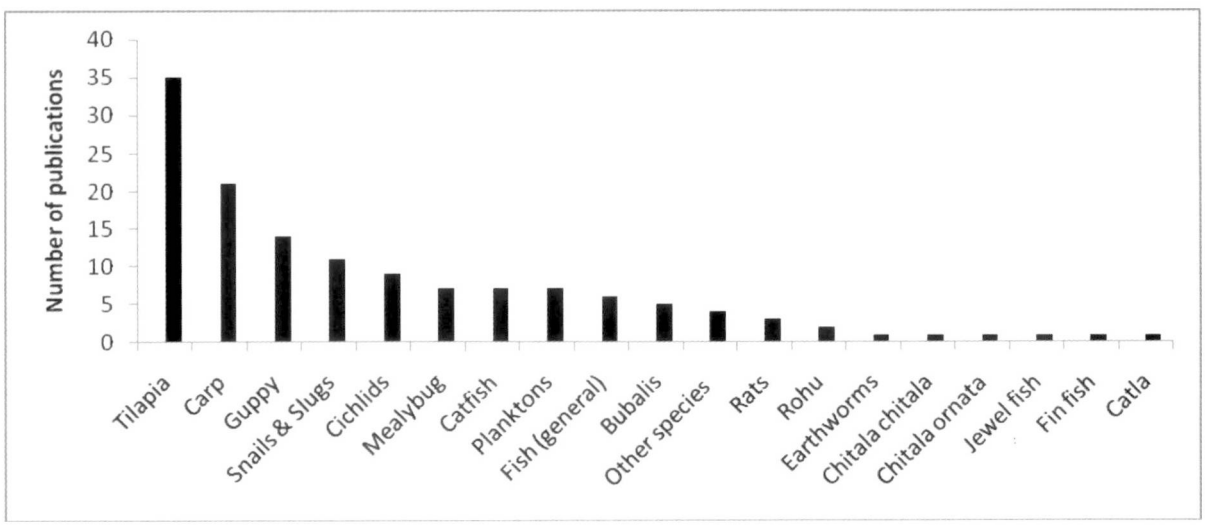

Figure 2b: Research publications on invasive alien animals arranged according to their numbers

Among the total entries on IAS, common topics covered such as 'IAS in Sri Lanka' and 'impacts of IAS' had a higher number of publications.There were only very few publications on communication and hybridization aspects of IAS (Figure 3).

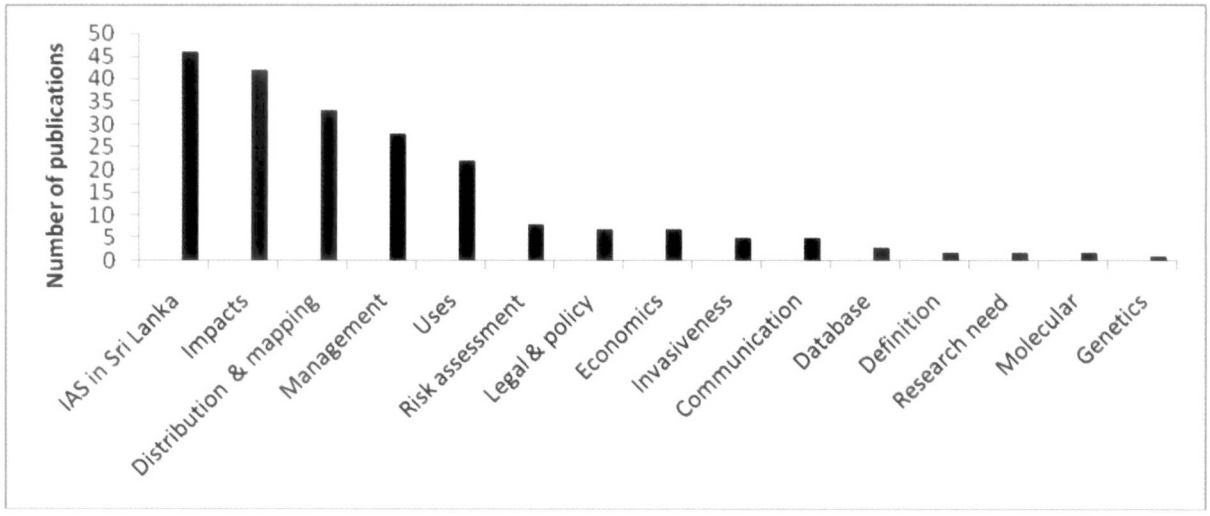

Figure 3: Research publications on topic areas of IAS other than the topics of flora and fauna

A detailed analysis of research on different aspects of each IAS (Table 1) indicated that few species have been subjected to in depth research. There was very limited research information on species listed under IAS non-priority category, such as *Clusia rosea*, *Annona glabra, Dillenia suffructicosa, Alstonia macrophylla, Leucaena leucocephala, Pteridium revolutum, Opuntia dillenii.* Among animals, fish species have received the most attention. Among the fish, *Tilapia* spp. (both *Oreochromis mosambicus,* and *Oreochromis niloticus*), Cichlids, *Poecilia reticulate* and *Cyprinus carpio* have been widely studied.

Of the 07 invasive animal species prioritized for control, only 03 had research records, indicating that very limited species targeted research had been conducted in Sri Lanka (Table 2). No research records were available for *Chitala ornata, Clarias batrachus, Oncorhynchus mykiss,* included in the priority list of IAS.

Table 1-Aspects of IAS addressed in research studies conducted in Sri Lanka. (Priority species are in bold font)

Invasive alien plant Species		Aspects addressed
1	***Prosopis juliflora***	Factors affecting infestation; soil nutrients, seed dispersal agents; allelopathy on forest species, impacts on other species (eg: *Araecerus faciculatus*), distribution in Puttalam and Hambanthota, possible control using pathogenic fungi in seeds
2	***Salvinia molesta***	Eradication, management (in rice fields) biocontrol, impacts on vertebrates and water quality, post control impacts such as succession by other macrophytes, biology and growth, economics, ecological aspects (morphological plasticity, intra and inter specific competition), uses as a feed for pigs and fertilizer substitute
3	***Eichhornia crassipes***	Favourable growth conditions, control suspects bio-control agents, use as a compost for paddy, in water purification
4	***Panicum maximum***	First record in Sri Lanka, growth performance of cultivars , effects of fertilizer application on growth and yield, interspecific interactions, improving fodder (use), seed production, germination of seeds, chemical composition, uses in aquaculture
5	***Clusia rosea***	Regeneration
6	***Lantana camara***	Inter-specific competition , varieties and their allelopathic strength, heavy metal uptake, as a photo-sensilizing agent, organic application for paddy, phytotoxic and herbicidal effects, distribution in national parks, control in Eucalyptus plantations, use of native grass to control *Lantana,* vulnerability to diseases
7	***Annona glabra***	Use as a grafting material
8	***Austroeupatorium inulifolium***	Morphology & competitive ability, ecophysiology, distribution (in Knuckles), bioactivity, phytotoxicity, cytotoxicity & antioxidant activity, Impacts on tea lands, forest borders
9	***Dillenia suffructicosa***	Effects on below and above ground flora
10	***Cuscuta campestris***	Host range, growth & development, impacts on crops, control with hot water

11	***Alstonia macrophylla***	Use for pulp
12	***Leucaena leucocephala***	As an alternative host for coconut pest, uses as mulch for rice
13	***Clidemia hirta***	Factors affecting invasion, growth and competitive responses under different soil nutrients
14	***Parthenium hysterophorus***	Discovery as a new weed, allelopathy and effect on crops and neighboring species, control: media campaign, actions for awareness, bio-control agents
15	***Mimosa pigra***	Discovery as a new weed, distribution in Mahaweli riverine areas, studies on growth and development, invasive behavior, management, pilot testing for control, natural enemies
16	***Pteridium revolutum***	Taxonomy and misidentification aspects
17	***Opuntia dillenii***	Effect of nutrients
18	***Sphagneticola trilobata (Wedelia trilobata)***	Role as an invader and impacts on rubber plantation, heavy metal uptake, reproductive biology
19	*Cestrum aurantiacum*	Distribution in Hakgala
20	*Myroxylon balsamum*	Impacts, spread and invasive behavior in Udawatta-kele,
21	*Miconia calvescens*	Status, ecology and management
22	*Alternanthera philoxeroides*	Effect of salinity on growth, pests of the species
23	*Tithonia diversifolia*	As a multi purpose shrub, for extraction of pigments in green leaf
24	*Ageratina riparia*	An up- country weed

Table 2-Aspects of invasive alien animal species addressed in research in Sri Lanka

Priority Invasive Alien Animal Species		Aspects addressed in research publications in Sri Lanka
1	*Pterygoplichthys disjunctivus*	Ecology, biology & impacts at Mahaweli middle catchment, food resource partitioning among others, impacts at Polgolla reservoir and fishcatch
2	*Pterygoplichthys pardalis*	Population biology in Polgolla Reservoir
3	*Pomacea spp*	Distribution in Jaela- Dalugama areas, food quality and body size *P. canaliculata* in paddy fields
4	*Lissachatina fulica*	Food sources & favourable environment, Invasive risk at Kurudana village, community based control

Several publications on IAS have focused on general topics on IAS such as genetics/germplasm studies, reproductive biology, germination and propagation methods, distribution and spread, potential uses, allelopathy related research.

Information is lacking for the following invasive alien plant species listed in the invasive alien flora: *Ulex europaeus, Parkinsonia aculeate, Pennisetum polystachyon, Mimosa invisa Colocasiae sculenta, Aristea ecklonii.* Furthermor ,it is important to note that among the potential IAS, research records are not available for *Millingtonia hortensis, Manihot glaziovii, Acacia auriculiformis, Myriophyllum aquaticum, Tibouchin aurvilleana, Muntingia calabura, Psidium littorale, Ludwigia peruviana, Panicum trichocladum, Setaria barbata, Aconogonon molle (Pollygonum molle), Clerodendrum quadriloculare, Cissus rotundifolia.*

Similarly, the following species included in the priority list of IAS and as potential invaders, for *Chitala ornata, Clarias batrachus, Oncorhynchus mykiss, Trachemys scripta, Trichopodus pectoralis, Osphronemus goramy, Felis catus, Canis familiar is* have no research records. Of the 15 potential invasive alien plant species identified, research publications are available only for 08 species (Table 3) and similarly of the 10 potential invasive animals only 50% of the animals (5 species) have published research information (Table 4).

Table 3- Aspects addressed in research of potential invasive alien plant species in Sri Lanka

Potential Invasive Alien Plant Species		**Aspects addressed**
1	*Mayaca fluviatilis*	Competitive ability, a potential invasive ornamental plant
2	*Ludwigia sedoides*	Regeneration ability, invasive potential, bio-accumulation of heavy metals
Other species	*Sweitenia macrophylla*	Natural regeneration in forests
	Pinus spp	Invasive behavior impacts on growth of other invaders, mapping using remote sensing, management aspects
	Chromaleana odorata/ Eupatorium odoratum	Distribution in Hurulu, bio-control
	Oclandra stridula	Dominance in understory in Meethirigala forest
	Pistia stratiotus	Potential bio-control agents
	Acacia nilotica	Chemical control & salinity tolerance

Table 4- Aspects addressed in research of potential and other invasive alien animal species in Sri Lanka

	Potential Invasive Alien Animal Species	**Aspects addressed**
1	*Tilapia* spp (*Oreochromus mossambicus, Oreochromus niloticus*)	Whether invasive, taxonomy & hybridization, *T. nilotica* variation of hybrids, morphological variation in populations, Recruitment of *Tilapia mossambica* in man made lakes, food aspects, nesting aspects, feeding patterns in Kotmale reservoir, effect of Abate on fingerlings, toxicity to Fenthion on growth, heavy metal accumulation, effect of water quality & metals on haematological parameters, reproduction *O. niloticus*, performance in culture based fisheries in perennial waters, Tilapia and indigenous fish biodiversity, Pollution response of *T. nilotica,* as a biomarker/pollution indicator, value added products from Thilapia, fermented Thilapia fish, shelf life evaluation of Thilapia marinades, Thilapia fish sausage and its quality, *T. nilotica* fish nuggets
2	*Poecilia reticulata*	Feed, growth spawning performance & survival, anesthetizing material for females, fatty acid composition in eggs & embryos in female guppy, resistance in development, effect of *Spirullina* on growth, predators, toxicity on un-ionied ammonia, feeder guppies as unsaturated fatty acid food source, use as a mosquito control agent
3	*Labeo rohita*	Stocking In open waters Kandalama and Udawalawa, performance in perennial an seasonal waters
4	*Bubalus bubalis*	Effect of nitrogenous fodder on growth & reproduction of indigenous sp., protein nutrition
OTHER SP.	*Rattus ratus*	Zoonotic importance in Western Province, parasites of rats
	Other snails	Snails in vegetable growing areas, Occurrence of cestodes from alternative carplets in Sri Lanka

OTHER SP.	Other fish	Habitat Characteristics of invasive fish Kotte- Kolonnnawa, Kandy, Pollgolla , IAS fish & impacts, predicting invasiveness of fish, alien Finfish; impact on aquatic culture, reproductive biology of *Catla catla* in Udawalawa reservoir
	Chitala chitala	Dietary shifts and impacts on fauna
	Carp *(Cyprinus carpio)*	Fecundity and breeding aspects, collecting eggs, parasites, acquired immunity, spawning, catchanility in Victoria Reservoir, bioaccumulation of heavy metals and effect of pesticides
	Cichlids	Abundance in lakes, endemic and exotic species in Batticaloa lagoon, effect on native species, reproductive biology of different species and diurnal pattern of feeding in Victoria Reservoir, role of non-cichlids exotics in Victoria reservoir
	Jewel fish	Whether invasive
	Birds	Red vented Bulbul- Impact on other birds, logistic growth and carrying capacity of house crow- Colombo City

DISCUSSION AND RECOMMENDATIONS

This study revealed that published research on IAS reached a peak during years 2006-2010. This is largely due to the opportunity provided to disseminate research findings at two IAS symposia organized during this period. This paper therefore, highlights the national need for an IAS research forum to be held on a regular basis. Furthermore, the study stresses the need to encourage better stakeholder involvement on IAS research.

Good IAS management begins with prevention, which often eliminates the problem at very early stages. It is also considered as the best solution and a cost-effective strategy. Prevention of IAS threats begins with identification of potential invaders at the national borders. Although some preliminary work has been carried out on pre-border risk assessment, research on application of scientific and practical knowledge at screening of potential IAS has to be strengthened. Case studies highlighting repeated introductions of the same species and/or multiple pathways of introduction of species are lacking. The necessity to maintain proper records at national borders needs much attention. More information from research is needed to manage potential invaders following introduction to the country and to block their dispersal pathways, i.e. the vectors of introduction and contamination processes. Biotic interactions of IAS and their impacts on ecosystem services should also be given attention as these aspects have been poorly represented in past research. Moreover the economic and social impacts, distribution, biogeography, effects of climate change, restoration of degraded ecosystems in relation to IAS also need urgent attention of the researchers. IAS research in Sri Lanka also lack of publications on case studies of good IAS management practices, stories of success and

failures in adaptive management and stakeholder involvement. As future practices of IAS also need to be directed towards an ecosystem approach, research pertaining to field applications of IAS management is strongly recommended.

Methods of dissemination of research findings needs further support from relevant authorities. Scientific journals and conference proceedings are the traditional mechanisms for dissemination of research, but it is crucial to disseminate IAS information more widely and rapidly among stakeholders using mechanisms that link researchers directly with potential end users. This could be achieved through networking with the Provincial level units that are established by the Ministry of Mahaweli Development and Environment.

CONCLUSION

The paper highlights the shortcomings in present research on IAS in Sri Lanka and the need for a shift in the pattern of future research in order to address the core areas of great importance towards better prevention and management of IAS.

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