

International Journal of Scientific Research and Reviews

Challenges in the Management of Invasive Exotic Organisms in India

¹Kamala Dhasan N, ¹Soundararajan N, ¹Indhar Saidanyan R, ¹Mohan Raj R, ¹Nobin Raja M, ²Saravanan S, ¹Manikandan P, ¹B. Parthiban ³Sugato Dutt and ^{*}¹S. Chandrasekaran

¹Department of Plant Sciences, School of Biological Sciences, Madurai Kamaraj University, Madurai, 625 021, India.

²Department of Botany (DDE), Alagappa University, Karaikudi – 630 003, Tamil Nadu, India.

³Tamil Nadu State Land Use Research Board, State Planning Commission, Chennai, 600 005, India.

ABSTRACT

Invasive species possess serious menace to ecosystem and economy in the introduced regions. Moreover all countries now encounter the problems of biological invasions and devising effective strategies and control measures for curtailing the new invasion episodes and for mitigating the negative impacts posed by these exotic invaders. Understanding the behavior of exotic species, their invasive potential, ecological and economic impacts are the points usually pondered when planning for any effective control measures and legal laws globally. In India, Invasive Alien species (IAS) has havoed serious impacts which have even significant in threatening the livelihood of many local people. Though we are facing new invasive episodes day by day, still least awareness about invasive species, their management and actions plans are in naïve condition in Indian scenario. Our case study about *Achatina fulica* and *Pterygoplichthys pardalis* is evidence that how these species are tackled unscientifically by the local people and their dilemma in approaching the right officials for reporting regarding these problems. The lack of laws and regulations, non-availability of clear cut methods in managing IAS and lack of public awareness about invasive species are apparently visible in Indian context. Our case study reveals also about the gap between the public, scientific community and government organization in addressing the management of invasive species. Herewith we also propose few policy level changes which can affiliate public/ victims, scientific communities and government organizations in managing these invasive species.

KEYWORDS: *Achatina fulica*, control measures, Invasive Alien species, *Pterygoplichthys pardalis*, sucker mouth cat fish.

***Corresponding Author:-**

S. Chandrasekaran

Associate Professor, Department of Plant Sciences,
School of Biological Sciences, Madurai Kamaraj University,
Madurai, 625 021

E-mail- invasioneecology@gmail.com

INTRODUCTION

Invasive species are exotics establishing their population in an introduced range, wreaking a serious ecological and economical loss in the invaded ecosystems¹. India is one of the world's fastest developing countries in economy² with continued stake in the trade of agricultural and horticultural products, which has substantially led to the increase of invasive alien species³. Among various pathways for exotic species introduction, online trade has become a prominent vector for the introduction of non-native species globally³⁻⁵. According to global invasive species database, totally 126 invasive species were reported in India, which includes plants, animals and micro-organisms⁶. These invasive species have caused serious ecological menaces resulting in a huge environmental and economic loss estimated between 25,000 and 91.02 billion dollars per year in India respectively⁷. In the recent past, numerous research articles and reports regarding the species introduction, invasion episodes, their potential ill effects and control measures are suggested by the invasion ecologists. Though these control measures are valuable, it does not reach the victims (public affected by invasion) effectively due to the limitation in executing it at the local fields without the help of government organization. In India, the legislation for monitoring and controlling Invasive Alien Species (IAS) exists along with National Biodiversity Action Plan with other Government Agencies/ Programs/ Ministries, whereas there are no specific legislations for invasive species^{8, 9}. But in developed countries like U.S¹⁰ and U.K¹¹, there are specific legislations for invasive species to control their entry through separate federal, quarantine agencies, special institutions and separate rescue departments. India, being a biodiversity rich country, with increased participation in the global economy it is imperative that sound control measures are introduced to remedy the existing situation. This study illustrates the despondency of the local people and highlights the need for an comprehensive strategy to manage invasive alien species in the Indian context.

The African Giant Snail (AGS), being one of the 100 worst invasive species by the International Union for Conservation of Nature and Natural resources (IUCN)¹², had been first reported in West Bengal, India, which was introduced by Mauritius in 1847¹³. The terrible devastation of various crops caused by this species, resulting in a severe menace to the agricultural ecosystems in various parts of India were well documented¹⁴⁻¹⁸. An incursive invasion of African Giant Snail (Figure 1a) was recently observed in Muthalagupatti at Dindigul district of Tamil Nadu, which has approximately infested 700 to 800 acres of agricultural lands. This notorious species was conspicuously found everywhere in the field utilizing vegetation and non-vegetation habitats. The following plants (herb, shrub and tree) species viz., *Sesbania grandiflora*, *Leucaena leucocephala*, *Cocos nucifera*, *Casuarina equisetifolia*, *Thespesia populnea*, *Tectona grandis*, *Musa paradisiaca*,

Acalypha indica, *Ipomea aquatica*, *Cyperus rotundus*, fodder grass and *Alternanthera sessalis* were found to be occupied by AGS. Other habitats such as well, electric post, cement tank, gunny bags were also occupied by these AGS.

The herbaceous vegetation was rendering an ideal habitat for egg laying (Figure 1b) and protection from direct sun light, since the density of different age classes (young, intermediate and adult) of AGS was observed high (56.58 ± 10.98 per m^2) under herbaceous vegetation. Among tree species, *Musa paradisiaca* and *Sesbania grandiflora* had higher number of adult population of AGS of about 29.4 ± 8.8 and 26.2 ± 6.69 per tree respectively (Figure 1c).

LAYMAN CONTROL MEASURES AGAINST AGS

On hearing the news about the invasion of AGS, our team made a field survey to assess the impacts of AGS in the infested site. During the visit, we could hear a heap of grievances faced day by day due to the snail invasion from the farmers. The fodder needs are met from *Ipomea aquatica* and *Alternanthera sessalis* by the farmers; whereas this snail's voracious consumption of leaves makes them to suffer in maintaining their cattle. Their economy is directly stumbled due to this snail's vigorous invasion. Though the farmers are not aware about any other control measures, they go for handpick up (manual removal) (Figure 1d) to control these snail population. They are in need of spending nearly three to four hours to collect the adult snails from their agricultural land daily. Approximately, 140 kg wet weight of snails was collected from five cent of land in alternative days. This manual removal was found to be inefficient because the farmers could not collect the juvenile snails under the thick vegetation of *Ipomea aquatica*, *Alternanthera sessalis* and *Cyperus rotundus*. This makes the issue more complicated in eradicating this notorious species. Apart from the manual removal of adult snails, the eggs are crushed whenever observed in the fields by the farmers. These collected adult snails were tied in gunny bags (Figure 1e) and discarded as such in the wells (Figure 1g), local pond (Figure 1f) and pond banks to prevent their further escape. This causes a stink in and around the discarded locations and affects the peoples who are passing by the way. The collected snails were burned by local people (Figure 1h). Their shells are another annoyance due to its hard nature as they cause scratches in foot of local public and tire puncture of two wheelers. It even hurts the farmers leading to physical injuries when working in the field. The farmers were using pesticides such as Monocros 36% SL, Lancet 505 and Superkiller-10 to resist insect attacks to which these snails are found to be insensitive. Though urea fertilizers and other pesticides are used for crop growth, the farmers are not benefited due to these voracious species. The farmers also used edible salt crystals on the margin of their land to kill and avoid the migration of snail from one field to another whilst this measures does not give any significant results on curtailing the snail. The farmers

have eventually given up this activity due to increase in the salinity of soil which inhibit the growth of the crops. The serious economic concerns of the agricultural community as well as the threat posed to food security thus necessitate a sound strategy to control the AGS invasion and eventually eradicate this alien species.

IMPACTS OF *PTERYGOPLICHTHYS PARDALIS* TO ECOSYSTEM

Pterygoplichthys species are commonly known as sucker mouth armored cat fish which belongs to family loricariidae and widely used as tank cleaners in aquariums. *Pterygoplichthys* species such as *P. anisitsi*, *P. multiradiatus*, *P. disjunctivus* and *P. pardalis* has invaded into fresh water ecosystems in various parts of India such as Bihar¹⁹, Kerala²⁰, West Bengal, Andhra Pradesh²¹ and Tamil Nadu². Our team made an extensive field visit and found that *Pterygoplichthys pardalis* (Figure 2a) has invaded in Vandiyur Lake at Madurai, Tamil Nadu where aquarium trade would be an important pathway for its invasion. *P. pardalis* is a nocturnal bottom feeder and consumes all the algal debris present in the lake which ultimately ends up in a competition with the native fish population for food source. *P. pardalis* also creates burrows for laying eggs on the shoreline of lake which leads to soil erosion and disruption of shoreline. On an average, *P. pardalis* lays about 2500 to 3500 eggs²². During our study period starting from 9th January to 20th February 2010, in all the fish catches made by fishermen, the abundance and biomass of *P. pardalis* was consistently higher than the native fish population and exclusively in the last fish catch more than two tons of *P. pardalis* fishes were obtained together with only 70 kg of edible fishes². Thus, the incursive invasion of *P. pardalis* is wreaking havoc to native edible fish population and to the ecosystem.

MANUAL CONTROL OF *PTERYGOPLICHTHYS PARDALIS* BY LOCAL FISHERMAN

The Vandiyur Lake was auctioned for fish culture by local fisherman. The fishermen used to place the net, a day before and the fishes were caught on the early morning in alternative days. The collected edible fishes were sold at fish market during 4-5 am. But after the invasion of *P. pardalis* in this lake, the edible fish population was consequently decreased. The adults of edible fish species are even killed by the vigorous movement of *P. pardalis* during the escape from the net during fishing. It is also a time consuming process (2-4 hours) for the fishermen to separate these invaded fishes from the net from other edible fishes which consequently require them to repair their damaged nets for hours (Figure 2b and c). An allergy is also caused by the mucus of this invasive fish to the hands of the fisherman while continuously removing it from the net (Figure 2h). This affects the life of fishermen economically leading to the drastic reduction in fish culture. These non-edible *P. pardalis* fish species were thrown along the lake and pond banks (Figure 2d). About 10-15 volunteers were involved in eradicating this fish population (Figure 2f), and small pore sized nets were used by them

to catch even the juvenile population of *P. pardalis* (Figure 2g). In addition to fishes, several other native species including tortoise, snails and crabs were also caught during the mass eradication eventually getting affected (Figure 2g). Approximately 2 tons of *P. pardalis* was caught against 70 kg of edible fishes during the eradication (Figure 2e). These activities were failed to curtail the population of *P. pardalis* from the lake. The invasive fish was able to maintain its population in successive years during rainy season whereas the lessee was victimized to abandon his pond lease.

CONTROL OF INVASIVE SPECIES BY LAWS AND REGULATIONS IN COUNTRIES OTHER THAN INDIA

Across the globe, both developed and developing nations are attempting to solve the problems caused by the invasive species at various stages *viz.*, introduction, and establishment and spreading into newer habitats. Responding to this global problem, governments of various nations are framing specific laws and regulations for controlling invasive species at every stage. To control the alien species at its introduction stage, laws and regulations for prohibiting the import of alien species is crucial and it is being carried out in several countries (Table 1). For instance, in Greece, Commission Regulation (EC) No 1497/2003 governed by European Commission has been established for banning the import of alien species such as Red-eared slider, Painted Turtle, American Bullfrog and Ruddy duck. Similarly, in UK, a list of six aquatic invasive plants has been prohibited from sale in England by the Wildlife and Countryside Act 1981 (Prohibition on sale etc. of Invasive Non-native Plants) (England) Order 2014. Even though, several control measures governed by government agencies under specific laws are present for controlling invasive species at the introduction stage, some alien species are escaping and getting established their population in new ecosystems. Hence, these circumstances are being overcome by several activities such as awareness/ eradication programs and competitions like bow fishing tournament²³ and Python hunting challenge²⁴ are in US for minimizing the established invasive population of Asian Carp and Burmese python respectively. However, also under some laws and regulations, the established alien species are being eradicated. For instance, in UK, public and private agencies were ordered to remove the Japanese Knotweed in their premises unless penalty of £100 or prosecution will be posed to the alleged person by Anti-social Behavior, Crime and Policing Act 2014 (Under Community Protection Notice) (Table 1). Some alien species at the same time override these eradication activities and spread in to new habitats. So, it is important for countries to have separate agencies under specific laws for controlling the spread of invasive species. In developed countries like the United States, the brown tree snake is controlled by U.S. Department of Agriculture, Animal and Plant Health Inspection Service through the Animal Damage Control Act 1931. Similarly, in developing countries

like South Africa, an act governed by Department of Defense has been dedicated for the eradication of invasive species in military sites by preventing their introduction into new regions through military vehicles (Table 1). From the data, it is clear that developed countries are having more specific laws and regulations for controlling specific alien species compared to the developing countries like India.

CONTROL OF INVASIVE SPECIES BY LAWS AND REGULATIONS IN INDIAN SCENARIO

Even though, India is a well organized country with several laws and regulations for various aspects, there are no specific laws and regulations for the control of available 126 invasive species⁶ and awaiting exotic species for invasion. The threat of invasive pests has only been addressed under the Plant Quarantine (Regulation of Import into India) Order 2003 by Ministry of Agriculture and Indian Council for Agriculture. Hence, specific laws and policies have to be developed in near future by Indian government for controlling specific invasive species.

DISCUSSION

In India, unlike the countries state above, there are no specific laws and regulations for curtailing invasive species in invaded ecosystem. Even though several invasion ecologists have suggested suitable control measures for invasive species, the control measures have not reached the local people who are facing the problem of invasive species. The local people are trying to control these invasive species with their understanding and knowledge rather than knowing its ecological behaviors, proper advice from scientific communities and coordinated action by agencies of government. In the case of *Achatina fulica*, it acts as vector for *Angiostrongylus cantonensis* causing Eosinophilic meningitis and *Phytophthora* sp. causing black pod disease for humans and plants respectively²⁵. The infected snails can directly affect humans by direct touching and handling. The farmers who are involved in removing these infested snails from their lands are using bare hands without any precautionary measures and will directly prone to the microbial infection.

The farmers are using pesticides for enhancing the growth of crop species such as *Alternanthera sessalis* and *Ipomea aquatica*. But, under this vegetation only, *Achatina fulica* breeds and this makes them to get exposed to the pesticides. Hence, to escape from the pesticide exposure, *Achatina fulica* hides their body surface in to the shell and also by the over secretion of mucus, they are washing away the exposed pesticides from the body surface. This activity may develop pesticides resistance mechanism to AGS which may leads to became more vigorous species. These control measures adopted by the people are even not producing any fruitful results for them in curtailing the invasive species which has infested their agricultural lands. Similarly, in the case of *P. pardalis*

fishermen were eradicating the invasive population with their own knowledge, but it did not help them to completely remove the invasive *P. pardalis* from lake. This made the victimized lessee of that lake to abandon the place in the successive year. Our case study also reveals that the people are naïve about the officials to whom they can launch a complaint/ responsible to rectify the problem of such invaders. Their hope for the recovery from these invasions seems to be not taken care properly at any level by any government or non-governmental organizations. We could hear grudges from people regarding these invasions during our field visits and we are even unable to stop them from getting involved in controlling these species by their inadvertent practices, since, there are no government nodal agencies, lack of laws, regulations and separate departments for monitoring invasive species in India. Our case study is also a strong vindication that there is huge gap in addressing the management of invasive species in India. The following factors has to be considered for the effective management of invasive alien species in India,

- i. Specific laws and quarantine programs for monitoring the import and export of alien species, checking the possibility of spread in future. Then strict rules and regulations should be framed for the people who are releasing the exotic species into wild.
- ii. National level rescue department for continuous monitoring of the mode of introductions of exotic species, migration of invasive species and for the removal of Invasive alien species with public if found infested anywhere.
- iii. Coordinated action by agencies of government at various levels from national to state to local self-government and scientific bodies for continuous monitoring and risk assessment of invasive species for maintaining all the details about the local ecosystems infestation by invasive species.
- iv. Separate toll free helpline numbers for informing the infestation of invasive species in new ecosystems and government should reward who are informing about the new invasion.
- v. Creating awareness to the local people through conducting programs such as seminars and discussion forums about ecology of invasive species and their negative impacts.
- vi. Including the concept and impacts of biological invasions at school syllabus level to enlighten the young minds about this global problem.
- vii. Involvement of National voluntary schemes such as NSS and NCC in the eradication and creating awareness about invasive alien species and also conducting competitions in eradicating invasive species.
- viii. Making of advertisements and thematic short movies about ecological problems caused by invasive species and public telecast in television channels by government.

ACKNOWLEDGEMENT:

We thank Tamil Nadu State Land Use Research Board (TNSLURB) for providing financial assistance.

REFERENCES:

1. Chandrasekaran S, Swamy PS. Growth patterns of *Chromolaena odorata* in varied ecosystems at Kodayar in the Western Ghats, India. *Acta Oecol.* 2010; 36: 383-392.
2. Gillespie S, Harris J, Kadiyala S. The Agriculture-Nutrition Disconnect in India What Do We Know? International Food Policy Research Institute, Washington, 2012.
3. Soundararajan N, Mohan Raj R, Kamaladhasan N, Indhar Saidanyan R, Chandrasekaran S. On-line trade of aesthetic exotic organisms: sword of Damocles? *Curr. Sci.* 2015; 109: 1404-1410.
4. Humair F, Humair L, Kuhn F, Kueffer C. E-commerce trade in invasive plants. *Conserv. Biol.* 2015; 29: 1658–1665.
5. Mazza G, Aquiloni L, Inghilesi AF, Giuliani C, Lazzaro L, Ferretti G, Lastrucci L, Foggi B, Tricarico E. Aliens just a click away: the online aquarium trade in Italy. *Manag. Biol. Invasion.* 2015; 6: 253–261.
6. <http://issg.org/database/species/search.asp?sts=sss&st=sss&fr=1&x=0&y=0&sn=&rn=India&hci=-1&ei=-1&lang=EN>.
7. Pimentel D et al. Economic and environmental threats of alien plant, animal, and microbe invasions. *Agric. Ecosyst. Environ.* 2001; 84: 1–20.
8. Kannan R, Shackleton CM, Shaanker UR. Playing with the forest: invasive alien plants, policy and protected areas in India. *Curr. Sci.* 2013; 104: 1159-1165.
9. The Ministry of Environment Forests, *National Biodiversity Action Plan, 2008*; available at <http://nbaindia.org/uploaded/Biodiversityindia/NBAP.pdf>
10. <https://www.invasivespeciesinfo.gov/laws/publiclaws.shtml>.
11. <http://www.nonnativespecies.org/index.cfm?pageid=67>.
12. Lowe S, Browne SM, Boudjrlas S, de Poorter M. 100 of the world's worst invasive alien species, Holland Printing, New Zealand, 2000.
13. Mead AR. The giant African snail: a problem in economic malacology, University of Chicago Press, Chicago, 1961.
14. Javaregowda. Incidence of the giant African snail, *Achatina fulica* (Bowdich), on horticultural crops. *Pest Manag. Econ. Zool.* 2004; 12: 221-222.

15. Thakur S. Food consumption and growth potential of giant African snail, *Achatina fulica*. J. Ecobiol. 2004; 16: 455-461.
16. Reddy K, Sreedharan K. Record of giant African snail, *Achatina fulica* Bowdich on Coffee in Visakha agency areas, Andhra Pradesh. Indian Coffee. 2006; 70: 17-19.
17. Vanitha K, Karuppuchamy P, Sivasubramanian P. Comparative efficacy of bait traps against giant African snail, *Achatina fulica* attacking vanilla. Ann. Plant Prot. Sci. 2008; 16: 203-267.
18. Sridhar V, Jayashankar M, Vinesh LS, Verghese A. Severe occurrence of the giant African snail, *Achatina fulica* (Bowdich) (Stylommatophora: Achatinidae) in Kolar District, Karnataka. Pest Manag. Hort. Ecosyst. 2012; 18: 228-230.
19. Sinha RK, Sinha RK, Sarkar UK, Lakra WS. First record of the southern sailfin catfish, *Pterygoplichthys anisitsi*, Eigenmann and Kennedy, 1903 (Teleostei: Loricariidae), in India. J. Appl. Ichthyol. 2010; 26: 606–608.
20. Krishnakumar K, Raghavan R, Prasad G, Bijukumar A, Sekharan M, Pereira B, Ali A. When pets become pests-exotic aquarium fishes and biological invasions in Kerala, India. Curr. Sci. 2009; 97: 474-476.
21. Singh AK. Emerging alien species in Indian aquaculture: prospects and threats. J. Aquat. Biol. Fish. 2014; 2: 32-41.
22. Kamaladhasan N, Chandrasekaran S. Studies on various threats to urban wetland ecosystems at Madurai, Tamil Nadu. M.Phil. Thesis. Thiagarajar College, Madurai, India, 2010.
23. <http://www.pjstar.com/article/20140710/Business/140719848?page=1>.
24. <http://www.dailymail.co.uk/news/article-3448405/Month-long-Burmese-Python-hunt-Florida-brings-102-snakes-state-tries-control-reptile-s-population.html>.
25. Cowie RH. Pathways for transmission of angiostrongyliasis and the risk of disease associated with them. Hawaii J. Med. Public Health. 2013; 72: 70–74.

Table 1: Laws and Regulations for controlling invasive alien species across the world

S. No.	Country	Regulation & Year	Regulated species	Nodal Agencies involved	Constituting Measures
1.	Greece	Commission Regulation (EC) No 1497/2003	Red-eared slider (<i>Trachemys scripta elegans</i>), Painted Turtle (<i>Chrysemys picta</i>) American Bullfrog (<i>Rana catesbeiana</i>) and Ruddy duck (<i>Oxyura jamaicensis</i>)	European Commission	The import of these four species were banned by the European Commission regulation ^a
2.	Japan	Invasive Alien Species Act, Law No. 78 2004	Invasive Alien species	Minister of Environment & Minister of Agriculture, Forestry and Fisheries	This law prevents the deleterious effects caused by invasive alien species through regulating raising, planting, storing, carrying, importing and other handling of IAS ^b
3.	Netherland	Flora and Fauna Act 1998	Alien species	Ministry of Economic Affairs, Agriculture and Innovation ^c	It prevents the import and release of specific alien mammal and bird species ^d
4.	UK	Anti-social Behavior, Crime and Policing Act 2014 (Under Community Protection Notice)	Japanese Knotweed (<i>Fallopia japonica</i>), and other invasive plants	Local Council & Police	Public and Private agencies were ordered to remove the weeds in their premises unless penalty of £100 or prosecution will be posed to the alleged person ^e
		The Wildlife and Countryside Act 1981 (Prohibition on Sale etc. of Invasive Non-native Plants) (England) Order 2014	Floating Pennywort (<i>Hydrocotyle ranunculoides</i>), Floating Primrose-willow (<i>Ludwigia peploides</i>), Parrot's Feather (<i>Myriophyllum aquaticum</i>), Uruguay Water primrose (<i>Ludwigia uruguayensis</i>), Water Fern (<i>Azolla filiculoides</i>) and Water	Department for Environment, Food and Rural Affairs ^f	This order prohibits the sale of listed plants in England due to their deleterious effects to biodiversity and economy

			Primrose (<i>Ludwigia grandiflora</i>)		
		The Destructive Imported Animals Act 1932	Coypu (<i>Myocastor coypus</i>), Grey Squirrel (<i>Sciurus carolinensis</i>), Mink (<i>Mustela vison</i>) and 'non-indigenous' rabbits	Natural England & Natural Resources Body for Wales	The import and keeping these invasive organisms are restricted by this act ^g
		The Prohibition of Keeping of Live Fish (Crayfish) Order 1996	Non-native Crayfish	Minister of Agriculture, Fisheries and Food, Secretary of State for Wales, Nature Conservancy Council & Countryside Council	This act aims to prevent and prohibit the spread and unlicensed keeping of exotic crayfish ^g
5.	US	Non-indigenous Aquatic Nuisance Prevention and Control Act 1990	Zebra mussel (<i>Dreissena polymorpha</i>) and other aquatic nuisance species	U.S. Department of the Interior, Fish and Wildlife Service, U.S. Department of Transportation, Coast Guard, U.S. Environmental Protection Agency, U.S. Department of Defense, Army Corps of Engineers & U.S. Department of Commerce (National Oceanic And Atmospheric Administration-NOAA)	Aquatic Nuisance Species Task Force has been established by this act to identify, access, issue regulations and developing technology to control the aquatic nuisance species especially Zebra mussels ^h
		Asian Carp Prevention and Control Act 2010	Bighead carp (<i>Hypophthalmichthys nobilis</i>), Black carp (<i>Mylopharyngodon piceus</i>) and Silver carp	U.S. Department of the Interior, Fish and Wildlife Service	Asian Carp Species has been federally regulated by this act by including the species in injurious wildlife list under the Federal

		(<i>Hypophthalmichthys molitrix</i>)		Lacey Act ^h
	Water Resources Development Act 2007	Asian Carp	US Army	Asian carp dispersal barrier project in Upper Mississippi River has been demonstrated ^h
	Brown Tree Snake Control and Eradication Act 2004	Brown Tree Snake (<i>Boiga irregularis</i>)	U.S. Department of the Interior, U.S. Department of Agriculture, Animal and Plant Health Inspection Service ^h	This act directing the involved agencies to carry out eradication, control programs and also providing research fund ⁱ
	Nutria Eradication and Control Act 2003	Nutria (<i>Myocastor coypus</i>)	U.S. Department of the Interior, State of Maryland & State of Louisiana	This act Authorizes Secretary of the Interior to fund the State of Maryland and the State of Louisiana for the control and eradication measures against nutria ^h
	Animal Damage Control Act 1931	Blackbirds, Brown Tree Snake (<i>Boiga irregularis</i>), European Starlings (<i>Sturnus vulgaris</i>), Monk parakeets (<i>Myiopsitta monachus</i>) and Nutria (<i>Myocastor coypus</i>)	U.S. Department of Agriculture, Animal and Plant Health Inspection Service ^h	This act aims to prohibit the introduction of brown tree snakes from the invaded regions to uninvaded regions ^j
	National Defense Authorization Act (NDAA) for Fiscal Year (FY) 2008	Brown Tree Snake (<i>Boiga irregularis</i>)	U.S. Department of Defense	This act involves in preventing the introduction of brown tree snake into various parts of US ^h
	Great Lakes Fish and Wildlife Restoration Act 2006	Sea Lamprey (<i>Petromyzon marinus</i>)	U.S. Fish and Wildlife Service	This act aims to developing and implementing eradication program for the control of sea lamprey population in Great Lakes basin ^h
	Salt Cedar and Russian Olive Control Demonstration Act 2006	Salt Cedar (<i>Tamarix</i> sp.) and Russian Olive (<i>Elaeagnus angustifolia</i>)	U.S. Department of the Interior	This act directs to carry out an assessment and demonstration program for the control of Salt

					Cedar and Russian Olive invasion ^h
6.	Argentina	Resolution no. 376/1997	Introduced Alien species	Department of Fish and Wildlife	All introduced alien species are initially liable to environmental impact assessment ^k
		Resolution no. 974/1998	European Starlings (<i>Sturnus vulgaris</i>), Crested Myna (<i>Acridotheres cristatellus</i>)	Department of Fish and Wildlife & Health and Agricultural Quality	These organisms are declared as harmful and aimed for eradication ^k
7.	Brazil	PORTARIA IAP n°095 2007	Invasive species	Instituto Ambiental do Paraná (State of Paraná)	This state law listed the invasive species and recognizes the criminality of introducing the invasive species ^l
8.	China	People's Republic of China (PRC) Animal and Plant Quarantine Law 1992	Animal infection, verminosis and dangerous diseases, pests, weeds and other threatening plants	Ministry of Agriculture	This law compiles a list of dangerous diseases from the imported animals, insects and weeds and a forbidden goods but not specifically for invasive species
9.	India	The Plant Quarantine (Regulation of Import into India) Order 2003	Invasive pest species	Ministry of Agriculture Indian Council for Agricultur	This order addressed the threat of invasive species entering in India ⁿ
10.	Malaysia	The Quarantine Act and Plant Quarantine Regulation 1976 and 1981	Khapra Beetle (<i>Trogoderma granarium</i>), Golden Snail (<i>Pomacea canaliculata</i>), Papaya Ringspot Virus, Banana Bunchy Top Virus, Nile grass (<i>Cyperus papyrus</i>) and Itch grass (<i>Rottboellia cochinchinesis</i>)	Ministry of Agriculture	Preventive measures and eradication programs are being undertaken to control these organisms ^o
11.	South Africa	Environmental Implementation Plans and Environmental Management Plans Under	Invasive Alien species	Department of Defense	This is mainly to eradicate IAS on military sites and their chance introducing them into South Africa by military vehicles ^p

		Section 15(1) of the National Environmental Management Act 1998			
12.	Vietnam	Government Decree No. 58/2002/ND-CP 2002	Alien species	Minister of Agriculture and Rural Development	This law strictly prohibits the entry of quarantined plants and alien species ⁹

- a. <https://www.cbd.int/invasive/doc/legislation/Greece.pdf>.
- b. <https://www.cbd.int/invasive/doc/legislation/Japan.pdf>.
- c. <https://hub.globalccsinstitute.com/publications/permitting-process-report/63-list-required-permissions-and-permits>.
- d. <https://www.cbd.int/invasive/doc/legislation/Netherland.pdf>.
- e. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/364846/Japanese_Knotweed_information_notepad.pdf.
- f. <http://www.legislation.gov.uk/uksi/2014/538/made>.
- g. <http://www.nonnativespecies.org/index.cfm?pageid=67>.
- h. <http://www.invasivespeciesinfo.gov/laws/publiclaws.shtml#waterres2007>.
- i. <https://www.gpo.gov/fdsys/pkg/PLAW-108publ384/pdf/PLAW-108publ384.pdf>.
- j. <https://www.animallaw.info/statute/us-agriculture-animal-damage-control-act-chapter-17-miscellaneous-matters>.
- k. <https://www.cbd.int/invasive/doc/legislation/Argentina.pdf>.
- l. http://www.institutohorus.org.br/download/marcos_legais/PORTARIA_IAP_N_095_DE_22_DE_MAIO_DE_2007.pdf.
- m. <http://www.cciced.net/encciced/policyresearch/report/201205/P020120529356009805557.pdf>.
- n. <https://www.cbd.int/invasive/doc/legislation/India.pdf>.
- o. <https://www.cbd.int/invasive/doc/legislation/Malaysia.pdf>.
- p. <https://www.cbd.int/invasive/doc/legislation/South-Africa.pdf>.
- q. <https://www.cbd.int/invasive/doc/legislation/Vietnam.pdf>.



Fig. 1: Layman control measures against African Giant Snail (AGS). a, African giant snail (*Achatina fulica*). b, Eggs of *A. fulica*. c, *A. fulica* infested in *Sesbania grandiflora* tree. d, A farmer collecting *A. fulica* with bare hands. e, Collected snails in gunny bag. f, Gunny bags containing snails discarded in the pond. g, Collected snails discarded into the well. h, Burnt *A. fulica*.



Fig. 2: Manual Control of *Pterygoplichthys pardalis* by local fisherman. *a*, *P. pardalis* caught in Vandiyur Lake. *b*, Catching of *P. pardalis* in fishing net. *c*, Difficulty in removal of *P. pardalis* from the nets. *e*, Non-edible *P. pardalis* fish species were thrown along the lake banks. *f*, Mass eradication of *P. pardalis*. *g*, People involvement in *P. pardalis* eradication. *h*, Allergy caused by the mucus of *P. pardalis* in fisherman's hand.