

Invasive Alien Species (IAS) spread, impact, and management

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Abstract. Invasive Alien Species (IAS) have been an increasing subject of concern with their growing speed of spread and increasing impacts on the invaded areas. The sustainability of IAS control, that is, how to make managing IAS most economical, human, and environmentally efficient is currently an issue under discussion. This review catalogs the general aspects of invasive species, from their natural spread to human-induced causes such as how it is spread through cross-sea and cross-border trades, affected by artificial constructions such as dams and reservoirs, agriculture, climate change, and deliberate introduction. The review also analyzed how IAS causes harm to the ecosystem and human community, what harm it causes, and how humans manage these invaders. Thus, providing a foundation for future research regarding the sustainability of the management of invasive alien species.

Keywords: invasive species, ecosystem, invasive species management.

1. Introduction

Facilitated by the increased transportation means human-invented, invasive species have been a subject of increasing concern. Transportation vessels such as ships bring along organisms from the source to the destination through ballast water and biofouling on hulls, propellers, sea chests, and other niche areas. The effects non-native species bring to the destination environment and ecosystem could be drastic. Positive impacts of non-native species might include acting as a control for other invasive species, such as *Crepidula fornicata* which controls phytoplankton blooms. Yet, due to the detrimental threats invasive species pose on native environment quality, biodiversity, the ecosystem as a whole, and the local economy, the negative effects of non-native species have been the main focus of researchers and most studies.

Non-indigenous species introduced by human activities are at levels that do not adversely alter the ecosystem. Invasive species are consistently identified as the most prevalent threat to Australian fauna and are a primary cause of extinction by 2021 independent State of Environment Report. In Australia, the introduction of cats threatens the survival of over 100 native species and causes the endangerment of many. On 15 July 2015, Ministers endorsed the National declaration of feral cats as pests. Many other countries also take measures in an attempt to control the growth of the invasive species population in the country, such as the US, which values prevention as the most prominent way of invasive species management. Since 1977, the US government had released Executive Order 19117, dealing with Invasive Species Issues [1]. Many attempts have been done to try and control the spread of IAS and to counter the effects brought by invasive alien species and to diminish the species from the destination

area. However, due to the lack of natural predator, management methods such as culling has been rather ineffective.

The past review papers about this topic are mostly targeted toward specific invasive species or specific aspects that IAS brings and are less generalized. Thus, this paper summarized the cause of the spread of IAS, the environmental and human effects that IAS brings, and the current management methods for treating the IAS to provide an overview of this research field.

2. Spread of invasive alien species (IAS)

2.1. Invasive alien species

In recent years, the types of IAS discovered show an increasing trend. The drive for the relocation or invasion of these non-native species is the breaking of barriers or balances among organically individual ecosystems. The species performing the invasion varies, ranging from aquatic species to land species, from multicellular eukaryotes to prokaryotic microorganisms. Among the Aquatic Invasive Species (AIS), the most prominent types include marine organisms, and freshwater organisms in lakes and streams, affecting the local ecosystem and human economy. In the case of Terrestrial Invasive Species (TIA), economic and social human impacts can both be caused. Invasive Microorganisms appear in both the aquatic ecosystem and terrestrial ecosystem, disrupting the ecosystem and human life. Unlike macro-organisms, microbiomes are less easily detected, and thus often overlooked.

2.2. Causes of IAS spread

2.2.1. Natural spread. Some of the IAS are spread naturally as physical barriers disappear—such as when 2 lakes of water are joined together by flood or when water retreats and exposes the land, connecting 2 islands. Normally, these species could adapt to the local ecosystem over time, since the distance between the now-connected habitats would not be too far apart, meaning that they would have similar ecological niches, resources, and environments.

2.2.2. Cross-sea and cross-border transportation. The increasing human activity of long-distance trading and traveling has brought intensive transportation of alien species from areas located far apart from each other, meaning that the ISA would be likely to disrupt the local ecosystem, unaffected by predators and environment suppression, occupying natural resources. Aquatic ecosystems are predominantly affected by AIS. The means of spread for marine invasive species mostly rely on transportation vessels such as trade ships and canals. Methods of transportation include Biofouling and ballast water tanks.

Seatrades not only bring Marine invasive species, but it also brings land animals and plants to other pieces of continents too, whether as pets, crops for agriculture, or domesticated farm animals. The stray cat is a damaging invasive species in Australia in recent days and can be a good example. These animals are brought to the land along with humans who colonized Australia in the early 1800s. After years of reproduction, the Australian feral cat population has grown enough to cause the extinction of at least 22 Australian endemic mammals, and the numbers are still growing since feral cats are still out of the hands of the Australian government [2]. It has further threatened more than 75 local endangered mammals, as well as 40 birds, 21 reptiles, and four frog species up till 2015 [2, 3].

While cross-sea transportation shows a significant effect in causing the dispersal of alien species, cross-border transportation brought along the same problem. Cross-border transportation of IAS is often done as small animals or seeds of plants got accidentally transported along with the human, crossing the physical barriers that separate organisms into different ecosystems.

2.2.3. Artificial constructions. Humans can also accelerate the spread of IAS by constructing artificial sites, such as wind farms and reservoirs. Wind farms aid the spread of marine IAS by providing an alternate habitat that non-native species can colonize and grow in number [4]. Dams and reservoirs could

alter the natural habitat to the favor of invasive species, and could also provide pathways for aquatic invasive species to uninvaded areas. Early constructed dams often lack biodiversity, making the habitat less resistant to invasion, thus aiding the spread of invasive species.

2.2.4. Agriculture. Watershed agriculture can aid the invasion of aquatic non-native species by physically and chemically degrading the environment. Research has shown that the risk of invasive interference increases as the environment degrades. Monoculture agriculture, which covers 80% of the arable land, also homogenizes ecosystems, thus decreasing the biotic resistance against invasive species as the biodiversity in the ecosystem decreases [5]. Moreover, agriculture requires flat, plain lands for effectiveness, thus wild vegetation would be required to be cleared out, causing deforestation and the potential extinction of plant species.

2.2.5. Climate change. Climate change could alter the habitats by affecting the moisture level, temperature, and pressure of the area. An example of habitat change due to global warming is the El Niño and La Niña wind circulations, which, due to global warming, change the direction of the flow of the wind. Extreme weather, such as drought and intensive rainfall, have been caused, thus modifying the habitat to favor the Invasive species, as they are generally more resilient to extreme weather. Research has also shown that the transmission of bacteria and microorganisms in the sea could be driven by climate change, driven by the change in the nitrogen fixation cycle due to ocean acidification, ocean warming, and nutrient enrichment [6].

2.2.6. Deliberate introduction. Alien species can also be deliberately introduced by humans. They could be introduced for their economic values as more favorable domesticated animals or better-yielding crops for their resilience and more prosperous nature. They could also be introduced with attempts to act as biological control agents to other invasive species, or simply as ornaments and pets. The introduced species range from aquatic animals, terrestrial animals, plants, and even bacteria to improve soil richness.

3. Impacts of invasive alien species to invaded area

3.1. Impacts on the local ecosystem

3.1.1. Environmental impacts. The impact on the local ecosystem by IAS is a subject of great concern with a heavy research focus. These impacts vary in intensity and vary from positive to negative. IAS could chemically and physically change the environment of the habitat, such as increasing the water turbidity and increasing the organic matter level for marine ecosystems. On a wider scale, IAS could physically alter landscapes. Such as for *Castor canadensis*, a global IAS, which alters the water regime by blocking river channels and building dams.

3.1.2. Other impacts. IAS can also cause a regime shift of invasive meltdown. A regime shift is a Long-Term persistent change in the ecosystem. These changes could include species loss, homogenization, decreased genetic variation, reconstruction of food webs, and a decrease in food web stability. The process of regimen shift is often difficult to reverse. Most of these changes are negative, as it is caused when IAS disrupts the food web, causing the extinction of native species as IAS is more favored in competing for resources, thus decreasing the reticulation (food web pathway) and biodiversity. The decrease in biodiversity lowers the productivity of the ecosystem, while also making the ecosystem more vulnerable to changes. Similar effects can be found in the case of disruption of the food web, decreased genetic variation, and ecosystem homogenization, which is when 2 or more ecosystems increase in genetic similarity over time. These effects mean that the ecosystem would be less resilient against the

invasion of new IAS, thus causing an invasive meltdown. An invasive meltdown occurs with positive feedback among invasions when the number of successful invasions cumulates.

Albeit some of the most well-heard and well-known effects that IAS brings to local ecosystems are negative, according to research, they can also bring neutral and even positive effects to the area too. In a 2014 review, 87 marine IAS were classified as having “high impacts”, the majority (63 IAS) have both positive and negative impacts [7]. A 2018 research investigated the interactions between 116 local endangered species and IAS, reporting 85 cases of negative interaction, but also 31 neutral interactions [8]. In some cases, IAS might act as a control over other invasive species, provide resources and habitat for rare local species, and replace current extinct species to fill the gap in the food web. Some researchers believe that ultimately, IAS would achieve conservation goals due to their stronger persistence and resilience to changing environments [9].

3.2. Impacts on human

3.2.1. Human health. As IAS gets induced to a new area, alien diseases, viruses, and parasites might be spread by these IAS as vectors to residents, causing health problems for humans. Invasive mammals could facilitate the spread of diseases via close contact with humans, contaminating food and water resources or causing wounds and injuries to the human body. Also, many invasive plants are allergenic, their pollens causing severe allergies which could harm human lives. The growth of the invasive mammal population could also increase the risk of injuries caused to residents, due to their distinct behavioral traits. Among the Invasive wild mammals, carnivores are the group with the highest rate of animals causing problems to human health, according to 2018 research. Rats and mice are the most widespread invasive mammals causing health problems for humans, acting as a vector to spread plagues and diseases. Figure 1 is the proportion of mammals with an impact on human health (red) out of the total number of Invasive mammals (orange) from D. Capizzi et al [9].

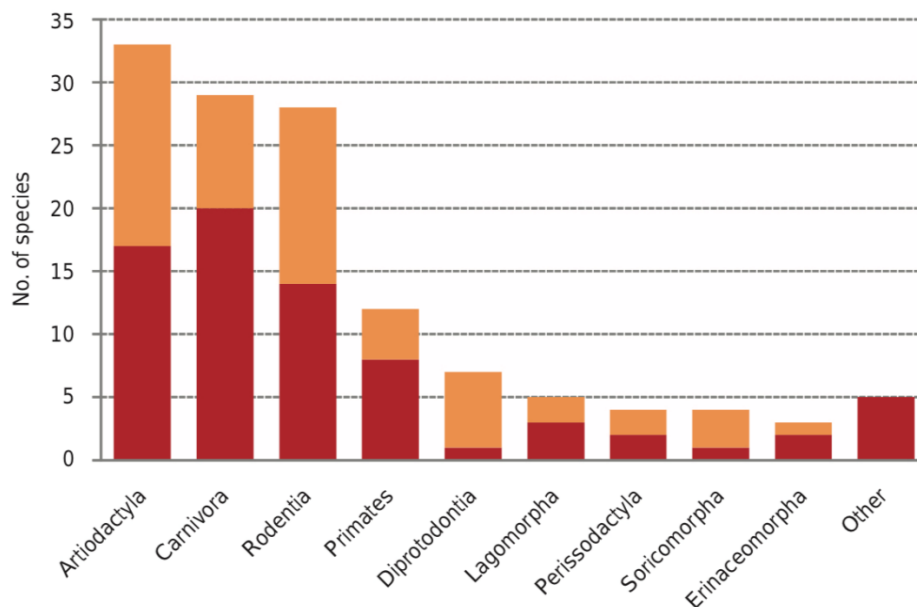


Figure 1. The proportion of mammals with impacts on human health (red) out of the total number of invasive mammals (orange). <https://www.sprep.org/attachments/VirLib/Global/cabi-health-ias.pdf>.

Invasive species could also threaten human health and human life by causing damage to human construction. River ditches had been found in Europe in 2007 to be damaged by *M. coypus* and *O. zibethicus*, both species alien to Europe, which are suspected to have caused flooding events and thus harm human lives. Damage to the electrical wires by rodents has also been reported, causing fire due to

short circuits. Invasive Giant African Land Snails are also reported to damage bridges, causing them to collapse and harming the lives of humans.

3.2.2. Economic impacts. IAS could affect the human economy by either costing the government for management or ruining resources with economic values. Cost of management includes prevention of the introduction of IAS, invasive species control within a country, and making up for the consequences caused by IAS. To protect the crops, pest control is necessary and requires great expenditure. From 2000 to 2001, pesticide consumption cost over USD 30 billion globally, including for both native and invasive pests [8]. To prevent the introduction of IAS, half of the U.S. federal expenditures were spent in 2001. Disease control is also a significant part of invasive species control, as IAS can act as effective vectors for the spread of detrimental diseases. The control requires the expenditure for the construction of hospitals, training of medical personnel, provision of medical resources, and education of the general public.

Economical values of local resources, such as forests and fields for the tourist industry, or lakes and other water resources for the recreational industry, could also be damaged by IAS. Invasive aquatic microorganisms could decrease the water quality of lakes and streams by endangering local species that consume algae [9]. Thus, it can decrease the value of the areas to be constructed as tourist attractions or to be used by water fountains. Crops might also get lost and affected by invasive alien weeds. The U.S., had an annual crop loss to weed of \$20 billion in 1991, with 50-75% of the weed Invasive.

4. Phases of management and problems facing

4.1. Pre-border actions

The management of IAS can often be concluded in the following phases: Pre-border actions, Border actions, and Post-border emergency actions [10]. Pre-border actions are the actions taken before the IAS intruded the borderline of a country or an ecosystem, it can be also addressed as preventions of the entry of IAS. Prevention is often the most resource-saving and economical measure of all, meaning that it would be the most effective method when managing the impacts caused by IAS [10]. Prevention methods include setting up federal law restricting imports of alien farm species, risk assessing of different alien species, and inspecting for any IAS brought to the border in portals or along borders.

4.2. Border actions

Border actions for managing invasive species are often taken when IAS has been spotted to be unsuccessfully prevented from entering the border. Actions taken are usually containment or eradication, aided by effective detection and early warning systems. Actions are needed to be taken early, before the invasive species become fully naturalized (self-sustainable in the wild), and reproduce at great speed to form a threatening population of invasive species [10]. Once the invasive species became fully naturalized, eradication of such species would be likely impossible, thus increasing the cost of IAS management.

4.3. Post-border emergency actions

4.3.1. Eradication. Once the IAS started to accumulate in number, it starts to get out of control and cause problems to the ecosystem and human society. During this phase of treatment, eradication would be more challenging and requires careful planning. Sometimes eradication would be unable to achieve under the “vacuum effect”. Since IAS is not confined by the environment and not threatened by any predators, they can exploit all resources available. When a portion of IAS has been eradicated, the remaining population would soon reproduce to fill the blank in population, filling the gaps in resource consumption. An example is the 2020 investigation on the rapid recolonization of feral cats after the

massive culling of 44% of the feral cats on the New Caledonian archipelago [12]. Re-invasion of the same species could also add to the difficulty in complete eradication of the invasive species.

Containment. Containment methods are generally used when eradication becomes hard to practice. Containment is the control of the IAS population under a number that would not cause as much damage to the ecosystem and human society. Methods of containment could be done using biological control agents such as other introduced species that are predators to the invaded species causing harm, chemical controls such as pesticides or herbicides, as well as other practices. An example is the Trap- Neuter-Return programs in managing the feral cat population, which research has estimated to face the difficulty of having a slow responding effect on the population, not until the population responds to natural death [13]. Other problems are such that the TNR campaign might also be inappropriate to be applied in ecologically sensitive areas, and would get affected by immigration. Figure 2 is the Invasive Curve from USDA Forest Service 2005 Invasive Plant Environmental Impact Statement.

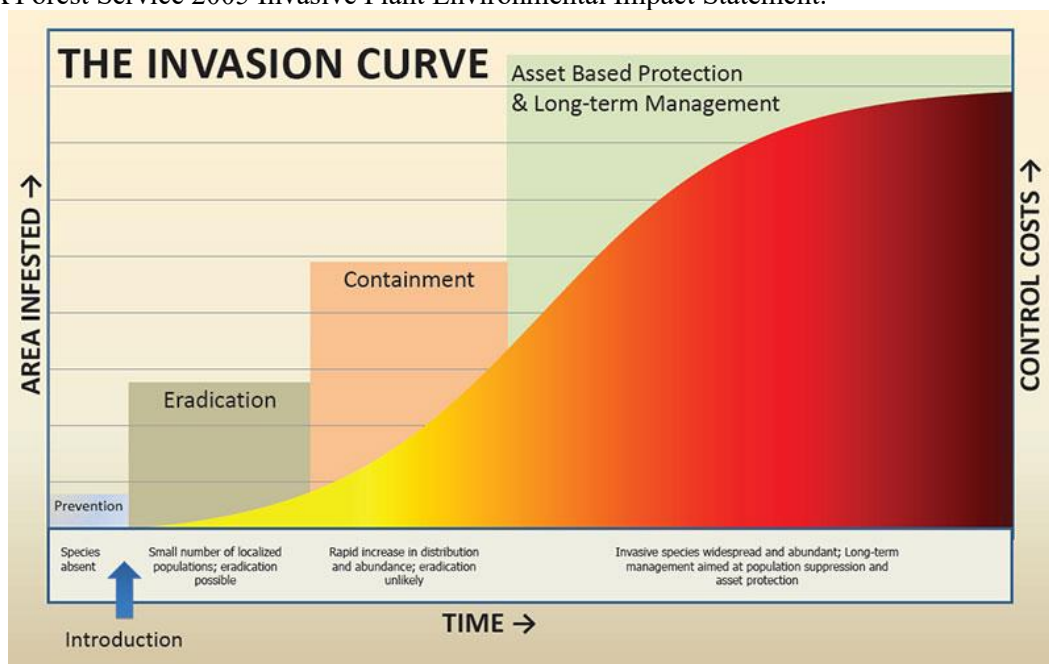


Figure 2. The invasive curve from USDA forest service 2005 invasive plant environmental impact statement. https://nri.tamu.edu/media/1132/evaluation_of_euthanasia_and_trap_neuter_return_tnr_programs_in_managing_free-roaming_cat_populations.pdf.

5. Conclusion

In conclusion, this passage summarizes the origin of Invasive Alien Species, the causes for their spread, and their impacts on both the local ecosystems and humans. The passage summarizes the major causes of the spread of IAS, from natural spread to human-induced factors, from direct causes such as the construction of dams and agriculture to indirect causes such as climate change and change in wind and water circulation. The passage also concluded the possible effects of IAS on the local ecosystem, from inanimate matters to organisms, and human society, highlighting its effect on the human economy and human health, which raised the most awareness and alarm. In the end, this piece provided a brief overview of the management mechanisms that countries have taken to protect the land from the impacts of Invasive Alien Species. However, the limitations of each management method are still somewhat under-discussed, thus making it difficult to include more details in this passage. Thus, the paper provides a thorough evaluation of the topic of invasive alien species based on past research, aiding future studies and investigations in similar fields and making the management methods sustainable.

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