Module 1

INTRODUCTION TO INVASIVE ALIEN SPECIES

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1 INTRODUCTION TO INVASIVE ALIEN SPECIES

Objectives of this module:

1. *Define invasive alien species and related concepts*
2. *Describe invasion patterns and pathways*
3. *Illustrate important differences between intentional and unintentional introductions*
4. *Give an overview of the global impacts of invasive alien species*
5. *Explain why we cannot predict species invasiveness with certainty*
6. *List some of the characteristics of invasive alien species*
7. *Identify major factors that increase IAS incursions*

Invasive Alien Species (IAS) are the second biggest threat to biodiversity (after habitat destruction) and are a major cost to the economic well being of the planet. They cause enormous and often irreversible harm to biodiversity around the world by displacing native and useful species and changing ecosystems. They are responsible for the extinction or decline of many species and continue to pose a huge threat to many more. They cost economies billions of dollars every year, in lost production, control and mitigation efforts, loss of ecosystem services and many other ways. IAS can profoundly perturb environments, and communities or societies that value these in any way are negatively affected as a result.

1.1 Introducing concepts and terms

1.1.1 Definitions

The understanding and management of invasive alien species (IAS) is an immature, emerging science and its terminology continues to evolve and change. There is currently no convenient glossary of terms that provides a comprehensive set of definitions based on fully understood processes. Terms such as *alien, invasive, weed, introduced, feral, exotic* and more are sometimes used interchangeably, or to describe the same thing. This can be confusing and can hinder understanding and progress. Some basic definitions are important, and for the purposes of this course, we will use the following:

1.1.1.1 Alien or Invasive?

Alien species – a species that has been intentionally or unintentionally introduced to a location, area, or region where it does not occur naturally.

According to the Convention on Biological Diversity (CBD) “Alien species” refers to a ‘species, subspecies or lower taxon, introduced outside its natural past or present

distribution; including any part, gametes, seeds, eggs, or propagules of such species that might survive and subsequently reproduce'.

Synonymous terms such as *non-native* species or *non-indigenous* species are more precise and should be used in preference to terms as *introduced, exotic, feral, foreign, ornamental* or *weedy* species.

Invasive species – a species that has established and spread – or has the potential to do so – outside of its natural distribution range, and which then threatens ecosystems, habitats and/or other species, potentially causing economic and/or environmental damage, or harm to human health.

The majority of invasive species are alien, but it is important to note that native species may also become invasive, usually under altered environmental conditions such as grazing, cyclones, changes in nutrient regimes, colonisation by an invasive species, or other alterations. For example, the native water plant hippo grass (*Vossia cuspidate*) and the bulrush (*Typha* sp) have become invasive in many African water bodies following an invasion of alien species such as water hyacinth (*Eichhornia crassipes*) and salvina (*Salvinia molesta*).

Invasive alien species (IAS) – an alien species that has established and spread, and which causes, or has the potential to cause, harm to the environment, economies, or human health.

There are various versions of the IAS definition. For example, the Convention on Biological Diversity (CBD) defines an IAS as an alien species whose establishment and spread threatens ecosystems, habitats or species with economic or environmental harm.

According to the IUCN an IAS is an alien species which becomes established in natural or semi-natural ecosystems or habitats, is an agent of change, and threatens native biological diversity.

An alien species is considered invasive only if it has adverse impacts on the environment, the economy or human health

Other important terms may be defined in subsequent sections and modules as appropriate. A comprehensive list of terms and definitions associated with invasive species can be found in Annex I of the course handout.

Some other terms used to refer to IAS are: *invasive species, alien invasive species, noxious species, pests, weeds,* etc. The words *pests* and *weeds* are commonly used to refer to organisms that can have adverse impacts on the primary sector of the economy (e.g. agriculture, forestry or fishing) or that affect humans (e.g. mosquitoes). However they are not necessarily alien or invasive.

Box 1.1
Definitions under Law

Under South Africa's National Environmental Management: Biodiversity Act (2004), the terms "alien" and "invasive" have legally distinct definitions. According to the act an ''alien species'' is defined as:
(a) a species that is not an indigenous species; or
(b) an indigenous species translocated or intended to be translocated to a place outside its natural distribution range in nature, but not an indigenous species that has extended its natural distribution range by natural means of migration or dispersal without human intervention;

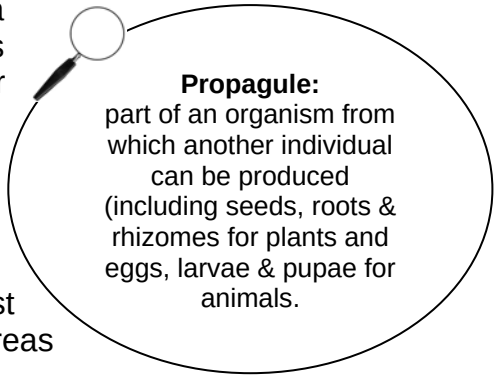
while an ''invasive species'' is any species whose establishment and spread outside of its natural distribution range:
(a) threatens ecosystems, habitats or other species or has demonstrable potential to threaten ecosystems, habitats or other species; and
(b) may result in economic or environmental harm or harm to human health.

Activity 1.1

List five alien species that are present in your country. Identify those that have become invasive.

1.1.1.2 Defining Pathways

A **pathway** is broadly defined as the means (e.g. aircraft, vessel or person), purpose or activity (e.g. farming, shipping or pet trade), or a commodity (e.g. fisheries) by which an alien species may be transported to a new location, either intentionally or unintentionally.



This differs from a **vector**, which is the actual physical means, agent or mechanism which facilitates the transfer of organisms or their propagules from one place to another. So a tourist carrying seeds in muddy boots is a vector, whereas tourism and international flights are the pathways.

Note that species can also expand their range through natural means. For example, birds can fly or be blown by storms to new locations. Some species or their propagules can be moved to new locations by wind, currents and in or on animals. This is referred to as natural dispersal and not an introduction. Natural dispersal may play a significant role in the subsequent spreading of an alien species once introduced to a new region or country.

1.1.2 Which taxa invade?

There is no group that is more or less invasive. Every species taken out of its natural environment has the potential to become invasive. This is shown by the fact that IAS are found in all taxonomic groups, including, mammals, aquatic and terrestrial plants, fish, birds, insects, amphibians, molluscs, reptiles, fungi and viruses. Below are some examples (Figures 1.1 to 1.8):

Figure 1.1. The House Sparrow (*Passer domesticus indicus*) – Bird (http://www.fnal.gov/ecology/wildlife/pics/House_Sparrow2.jpg)

The house sparrow is of Asian origin. It was introduced to Eastern Africa as a hitchhiker on trading ships about 150 years ago. It has gradually spread from port areas in eastern and southern Africa ever since. They are now found from Cairo to Cape Town and most urban areas and many rural areas in between. In East Africa it has slowly moved inland from the coast and is still spreading westwards. For example it reached Nairobi business district in the late 1980s and took another ten years to appear in the western suburbs of that city. It then moved slowly west, north and south from a suburban centre to the outlying peri-urban and farming areas of Kiambu and Ngong. As their name implies, house sparrows are closely associated with humans. They feed on grains and insects and can also feed on domestic refuse. They can cause extensive damage to crops and fruit trees and damage the eaves and roofs of houses with their nesting activities. They can also take over the nesting sites of native cavity-nesting birds. In Africa it appears that the sparrow is displacing several similar granivorous and house-nesting birds – especially the local species of sparrows such as the rufous sparrow (*P. rufocinctus*), Somali sparrow (*P. castanopterus*) and the grey-headed sparrow (*P. griseus*).

The presence of the domestic sparrow can easily be determined by its distinctive calls (the "*chirp, chirp*" and "*trit treet trit tret tret* …"). If one listens to the background noise during daylight interviews (e.g. on television and radio news) it is often possible to hear the house sparrow. This is a truly invasive species which has become so commonplace that most people do not even see or hear it as it spreads and replaces other birds.

Figure 1.2. Tilapia (*Oreochromis mossambicus*) – Fish
(www.akwafoto.pl/fotoreport/ katowice2003/inne.jpg)

Tilapia has spread worldwide through intentional releases for aquaculture or as unintentional escapes from fish farms. Tilapia tolerates a wide range of salinity, is omnivorous and feeds on almost anything, from algae to insects. However the younger fish are more carnivorous, while the adults are more herbivorous. Its impacts on lakes and estuaries is huge, to the point of driving native fish and invertebrates extinct.

Figure 1.3. The Indian house crow (*Corvus splendens*) – Bird
(www.kolkatabirds.com/housecrow8.jpg)

The Indian house crow was introduced to the east coast of Africa over a century ago, has spread to coastal towns on the Red Sea and Indian Ocean. It is still spreading inland. They form large flocks around human habitation where they negatively impact on human health, public amenities, poultry and native bird populations.

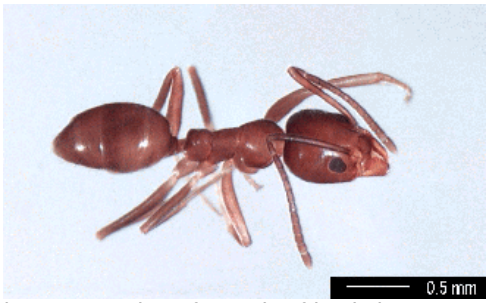


Figure 1.4. The Argentine ant (*Linepithema humile*) – Terrestrial invertebrate (Photo from Holldobler and Wilson 1990. The Ants. Cambridge University Press. Cambridge.)

The Cape region of South Africa is home to one of the worlds six Floristic Kingdoms, a major part of which is called Fynbos. Up to 30% of the plants of the Fynbos rely on native ants for their dispersal. These ants are attracted by nutrient-rich elaiosomes attached to seed. The native ants carry the seed to their underground nests where they eat the elaiosome and leave the seed intact, ready to geminate. In contrast the Argentine ants eat the elaiosomes but leave the seeds on the ground where they are vulnerable to fire or rodents.

By displacing native ant species the Argentine ant has the potential of radically changing the Fynbos plant community. Additionally, the ants can deter pollinators of protea flowers, one of the symbols of the Fynbos.

They are a pest in gardens where they protect scale insects and aphids. In orchards swarms of these ants will invade, taking over trees and destroying fruit crops. The Argentine ant is a global economic and environmental threat.

The black or ship rat, of Eurasian origin is the most significant invasive mammal species in Africa. It is an indiscriminate feeder, causing massive economic losses throughout Africa and worldwide by consuming and contaminating foodstuffs (e.g. crops, seeds and seedlings, fruits, etc.) and animal feed. The black rat can also cause structural damage to buildings by burrowing and chewing.

By preying on other species or competing with them for food, black rats have directly caused or contributed to the extinction of many species of wildlife including birds, small mammals, reptiles, invertebrates and plants, especially on islands.

Among the diseases that the black rat may transmit to humans or livestock are murine typhus, leptospirosis, trichinosis, salmonellosis (i.e. food poisoning), ratbite fever and bubonic plague. The latter disease is known to have been spread by the fleas of black rats. Where the alien invasive rats are still absent, there are often many local species of rodents which cause very little impact to humans, their crops houses and health.

Figure 1.5. Black rat (*Rattus rattus*) – Mammal

Figure 1.6. Golden apple snail (*Pomacea canaliculata*) – Aquatic mollusc (R. H. Cowie)

The golden apple snail is a freshwater snail with a voracious appetite for water plants, including lotus, water chestnut, taro, and rice. Originally from South America, it has been introduced widely by the aquarium trade and as a source of human food. It is a major crop pest in Southeast Asia (primarily in rice) and Hawaii (taro), and poses a serious threat to many wetlands around the world through habitat modification and competition with native species.

Figure 1.7. Triffid weed (*Chromolaena odorata*) – Terrestrial plant (Jim Space)

Triffid weed is an aggressive invasive shrub in much of tropical Africa, Asia, and the Pacific. It causes wildfires, skin complaints and asthma in allergy-prone people, disrupts breeding patterns, is a major weed of plantation crops such as rubber, oil palm, forestry, coffee etc.. It also invades natural areas and is becoming a problem in some national parks in South Africa, where dense stands are interfering with toursists ability to view game.

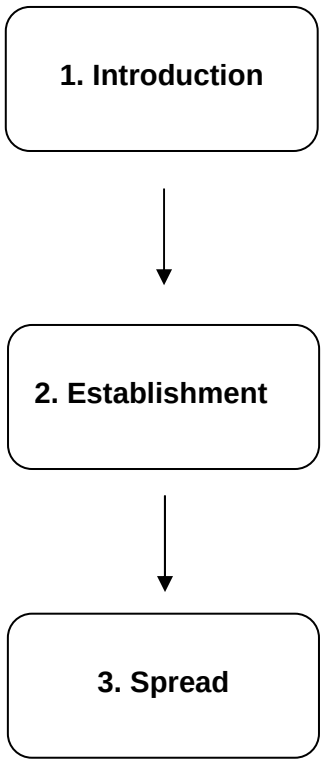
Figure 1.8. Salvinia (*Salvinia molesta*) – Aquatic plant
(C. Jacono, U. S. Geological Survey)

Salvinia is a serious aquatic weed in many countries. In Zambia and Zimbabwe it is known as Kariba weed because of its infestation of vast areas of Lake Kariba in the 1960s.

Salvinia forms thick mats that choke waterways, impeding water flow, obstructing boat traffic and fishing activity and disrupting hydroelectric generating activities. Infestations provide an ideal breeding environment for disease-carrying mosquitoes. The floating mats change the whole ecosystem. They shade out any submerged plant life and impede oxygen and carbon dioxide, making the water unsuitable for native plants, fish and other animals.

1.1.3 The process of invasion

The main phases in the invasion process are:



1. Introduction of the species
Species coming from another place must survive during and after the journey. Many species fail to survive unless they are cared for (e.g. aquarium fish). However, almost all invasive plants spread as seeds which do not require special care while being transported

2. Establishment and reproduction of the introduced species
The survivors must persist and reproduce successfully (i.e. there usually needs to be more than one individual) until they establish a self-sustaining population.

3. Spread
In certain cases, established populations will multiply rapidly and spread across the landscape. This is the explosion phase (Figure 1.9), and may only happen after a considerable lag phase.

The lag phase
Some species show no lag phase, and will begin to spread rapidly and uncontrollably as soon as they establish. On the other hand, many IAS have a **lag phase**, during which they occur at low densities and their impacts are not noticeable. The duration of this lag phase will vary depending on the species, and circumstances, and may be only a few months, or as long as centuries. Once the population starts increasing (explosion phase), the impacts will rapidly become apparent. Following the explosion phase, the growth levels out as the population reaches the carrying capacity of the environment (Figure 1.9).

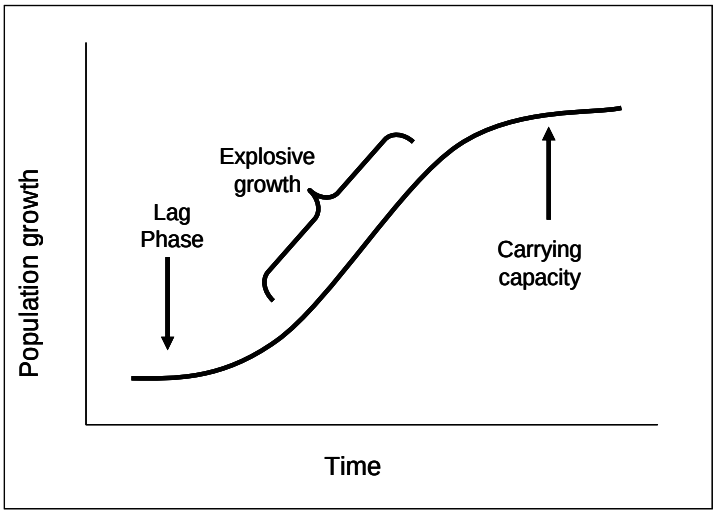


Figure 1.9. The stages of an invasion process

The variable duration of the lag phase means that one cannot assume that an apparently benign alien species is safe to ignore, as it may change. It is therefore preferable not to allow an alien species to become established, even if there is no immediate indication that it is invasive.

Many alien population undergo a lag phase after initial establishment, and may remain unobtrusive/non-invasive for a long time before suddenly changing, becoming invasive and spreading rapidly

1.2 Invasion vectors and pathways

1.2.1 Introductions: anthropogenic changes

Over the millennia, species have dispersed throughout the world by natural means. The major barriers to their spread have been the limitations of their own dispersal abilities (small terrestrial mammals cannot travel great distances, whereas many birds can) natural geological obstacles (such as rivers, mountains and oceans) and environmental factors (such as temperature, altitude, disease, lack of available niches and predators).

However, with the advent of widespread human movement, humans have aided the process of species dispersal, by, amongst other things, carrying organisms or propagules with them around the world. Humans have also created many new and very effective vectors such as grain and wood shipments, or ballast tanks in ships; as well as many new pathways such as long-distance trucking, aeroplanes and ship voyages. As a result, many species have been able to establish new populations outside of their native range. These incursions have shown a dramatic increase in frequency, extent and damage over the last half a century or so and there is every indication of this trend continuing. There is little doubt that this is due largely to the increase in “the three Ts”: Trade, Tourism and Transport.

Activity 1.2

List the pathways for introductions that you encounter in your field of work. Rank them from most dangerous to least dangerous in terms of numbers and types of species likely to be introduced via the pathway.

The rates of introductions and spread of IAS are inherently variable but they have increased substantially since the 1960s. There are many cases where species have probably been translocated for many decades, but did not establish until recent times. One probable cause is related to the concept of increased 'propagule pressure'. Propagule pressure is directly linked to the number of individuals (or propagules) of a particular species that is introduced and the frequency thereof, as this increases the likelihood of a founding population being established. Recent increases in traffic volume have therefore increased propagule pressure.

Other factors explaining the rise in the number of alien species establishing and spreading since the 1960s are the anthropogenic changes that have made many receiving environments more 'invader friendly'. Finally, selection pressures operating on IAS founder populations may also help their offspring to become better adapted to the new environments and consequentially to become better at surviving and spreading further.

Species introductions, intentional or unintentional, occur through a very long list of pathways. Knowledge and understanding of invasion pathways will enable countries to take appropriate action to prevent them from delivering harmful species to their doorsteps.

Human activities have dramatically increased opportunities for species to travel around the world and to become invasive

1.2.2 The types of introductions

The introduction of species beyond their natural range is closely linked to the historical and present day movement of humans across the globe. Wherever humans have travelled, they have introduced species to new locations for food, social or economic purposes. This type of introduction is referred to as an **intentional introduction**. Many more species have been accidentally transported around the world as the by-product of human activities such as trade, travel and transport. These are called **unintentional introductions** (Figure 1.10).

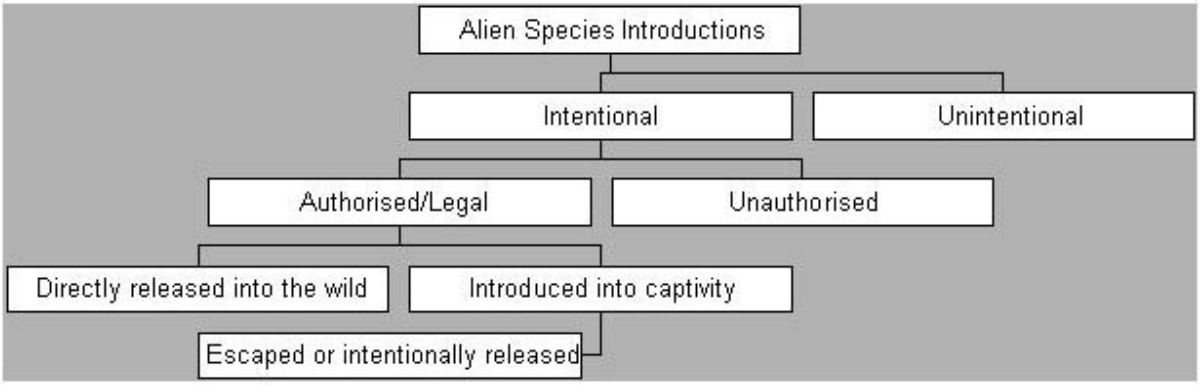


Figure 1.10. Types of alien species introductions

1.2.2.1 Intentional introductions

Intentional introductions fall into two categories: authorised and unauthorised.

a) Authorised
The introduction of species in this category is planned and (ideally) formally approved. This formal process is designed to try and ensure that the species being introduced does not become invasive. Distinction should be made between:

- Species that are directly introduced into the wild for economic reasons (e.g. crops, domestic animals, game species, biological control agents, or plants intended to improve soil condition, provide fuelwood/pasture or prevent erosion). These species are introduced with the purpose and intention of them establishing in their new ranges. They are usually cared for to ensure a greater chance of establishment.

EXAMPLE

Figure 1.11. Tall fescue (*Festuca arundinacea*)

A legal, intentional introduction that went wrong: the tall fescue (*Festuca arundinacea*) originates in Europe but was introduced into the U.S. for use as a pasture grass, for erosion control and as a turf grass. However it thrived in the warmer drier areas from Texas and Florida to Canada and is now displacing native plants, especially in the prairies of the U.S. Midwest. Fescue is also the carrier of a toxic fungus, which can cause the death of horses, cattle and possibly other ruminants.

And

- Species that are introduced into captivity (e.g. zoos, botanical gardens, private gardens, aquaculture, pets, farmed animals (including animals introduced for fur production) and scientific research). These species are not meant to be released into the wild but be kept in captivity. Nevertheless, escapes and deliberate releases of individuals do occur

EXAMPLE

Figure 1.12. Miconia (*Miconia calvescens*)

An intentional introduction into captivity that escaped and became invasive: the highly ornamental tree from South America, Miconia was introduced to a botanical garden on the island of Tahiti in 1937. From there, it spread into the wild by fruit-eating birds and today this plant heavily invades more than half of the island. It has become the dominant canopy tree over large areas of Tahiti, shading out the entire forest understorey.

b) Unauthorised (legal and illegal)

Smuggling (including the illicit trade in endangered species) of plants, animals, seeds and foodstuffs such as meat and meat products, fruits and vegetables is a serious problem worldwide. The risk of IAS introductions through this pathway is high and it is important to have measures in place to regulate this pathway.

There may also be instances where there is not an authorisation process in place for regulating alien species introductions. For example, some countries may regulate the movement of alien species across their political borders but not within the country itself. It is important to regulate the movement of alien species across both ecological and political boundaries.

1.2.2.2 Unintentional introductions

Unintentional introductions are those that occur in an unplanned, accidental manner. Species enter as hitchhikers or stowaways through pathways involving human activities such as trade, travel and transport. Many unintentional introductions occur as by-products of intentional introductions.

EXAMPLE

Figure 1.13. South African abalone (*Haliotis midae*)

An example of an unintentional introduction as a byproduct of an intentional introduction is the invasion by the sabellid polychaete worm *Terebrasabella heterouncinata* in California. The economically valuable South African abalone (*Haliotis midae*) is a subtidal gastropod. It was introduced to California for mariculture. However, the commensal sabellid polychaete worm lives inside the shell of abalones. It hitchhiked with the abalone, and became a serious pest for the indigenous black turban snail, *Tegula funebralis*.

Photo: R Wanless

The recent rapid growth of world trade, travel and transport (commonly known as the three Ts) has greatly increased the rate of unintentional introductions. The natural protection provided by oceans and mountains, that once acted as natural barriers to the movement of species, have now been breached, ending millions of years of biological isolation.

Because of their number and unplanned nature, unintentional introductions potentially pose a bigger threat to the environment and society than do intentional introductions. Stowaways in the ballast water of container ships or in the cargo of airplanes are transported from place to place with ease. For example, the Globallast Programme estimated that on any given day, between 3000 and 10000 marine species are moving around the world with ships' ballast water.

Intentional Introductions		**Unintentional Introductions**
Direct Introductions into the Environment	**Introductions into Captivity/Containment**	
▪ Agriculture ▪ Forestry ▪ Soil improvements ▪ Horticulture (*ornamentals, nursery stock, house plants, etc.*) ▪ Conservation ▪ Fishery releases ▪ Hunting and fishing ▪ Release of mammals on islands as food sources ▪ Biological control ▪ Aid trade ▪ Smuggling ▪ Aesthetics ▪ Medicinal ▪ Religious	▪ Botanical and private gardens ▪ Zoos ▪ Farmed animals ▪ Beekeeping ▪ Aquaculture ▪ Pet trade ▪ Aquarium and horticultural pond trade ▪ Research	▪ Vessels/aircrafts/vehicles/trains, etc. ▪ Ballast water ▪ Hull fouling ▪ Sea cargo ▪ Sea containers ▪ Personal baggage/equipment ▪ Agricultural produce ▪ Seed contaminants ▪ Soil, gravel, sand, etc. ▪ Timber ▪ Packaging material ▪ Dirty equipment, machinery, vehicles - including military ▪ Hitchhikers – including parasites and diseases – associated with aquaculture introductions, cut flowers, and introductions for the nursery trade

Table 1.2. Some pathways for the different types of introductions

EXAMPLE

Figure 1.13. South African abalone (*Haliotis midae*)

(www.zeestop.com/ examples.htm)

An example of a species introduced via ballast water is the zebra mussel (Dreissena polymorpha), which was introduced to North America's Great Lakes in the mid-1980s. Zebra mussels have since spread throughout the lakes and other waterways of North America, where they are having severe social, economic and ecological impacts. The sheer numbers of mussels, and their ability to stick on underwater structures such as water pipes, causes disruption to supplies of drinking, cooling, processing and irrigating water (Figure 1.14). The costs of mitigating these impacts were estimated at US$750 million to US$1 billion between 1989 and 2000 (Globallast Programme). In addition, zebra mussels compete with zooplankton for food, thus affecting natural food webs.

Pathways can be divided into primary and secondary categories. Primary pathways refer to those vectors and routes which move species to new regions or provinces across major oceanic, landmass or climatic barriers (i.e. trans-oceanic and intercontinental pathways), while secondary pathways help spread and disperse invasive species between points within or between neighbouring regions. In Figure 1.15, the primary pathway for the invasive grass was probably travel (vector: a seed on clothing) or imported animal feed. The secondary pathway into the interior is roadways and corridors of disturbed land (such as degraded farmland).

Figure 1.15. A farm road becomes a secondary pathway for invasive grasses in Mexico (Photo Angel/Wanless)

Secondary pathways include all 'within-region' activities and circumstances, which can facilitate the local spread of an invasive species after its founder population has established. These secondary range expansions may start quickly or require several years or even decades before eventual removal of some internal or external constraining factor/s provides the impetus (e.g. an improved waterway, new trading route, adaptation to local environment, etc).

Alien species enter countries through both legal and illegal routes, and introductions can be both intentional and unintentional

1.3 Impacts of IAS

The impacts of IAS can be dramatic. The number of species that have gone extinct due to IAS is high, and all major taxa are affected. For example, the island of Guam in the Pacific Ocean has lost almost **all its native forest bird species, two native mammals and nine native reptiles to one IAS**, the brown tree snake (*Boiga irregularis*). In a different example, although humans probably destroyed much of the endemic palm on Easter island, every single seed found by archaeologists had been gnawed by the introduced Kiore or Pacific rat (*Rattus exulans*), undoubtedly contributing to the palm's extinction. The introduction of the predatory Nile perch to Lake Victoria (in eastern Africa) precipitated a flood of extinctions in the endemic Cichlid fish.

The impacts of other environmental problems, like fire or pollution, tend to diminish over time. In contrast, the impacts of IAS, Instead of lessening over time, tend to increase (e.g. Figure 1.16).

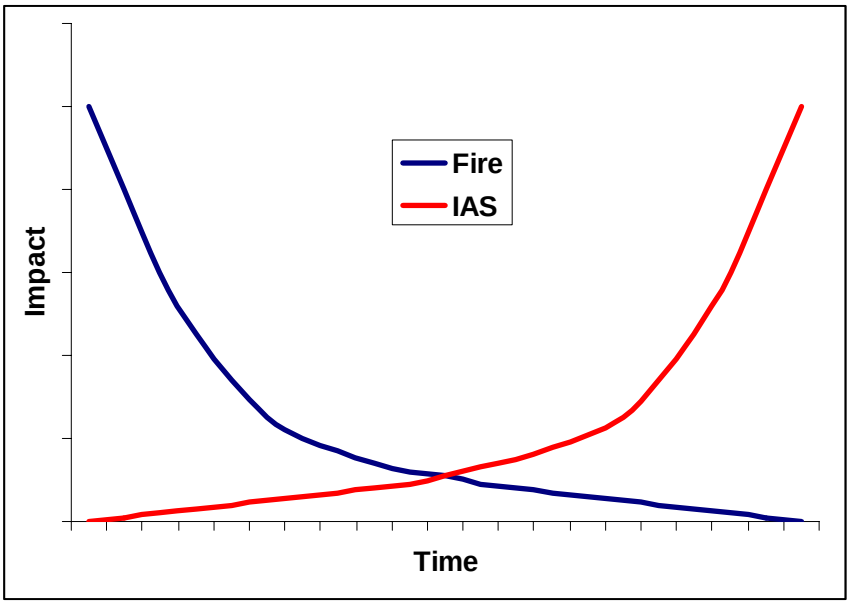


Figure 1.16. The inverse relationship between the impacts of fire and the impact of IAS on an ecosystem

The introduction of alien organisms into a new environment can have serious negative consequences for the environment and local biodiversity, for industries and users of natural resources, and also for the health and welfare of those associated with the affected systems. While impacts can be direct and indirect, the principal consequences can be grouped into three main categories - **ecological, economic** and **public health and society**.

IAS have significant negative impacts on biodiversity, the economy and public health

1.3.1 Ecological

Ecological impacts occur when the local biodiversity of the area and/or the ecological processes are altered by the invasive species. IAS affect native biodiversity through a diversity of ecological processes, such as:

- Direct predation/herbivory
- Competition for resources, such as nesting sights (for birds), light (for plants) or preferred food/nutrients
- Habitat alteration, such as shading out native species and freshwater systems, increasing erosion, changing fire regimes, permanently altering nutrient cycles or soil properties
- Spreading pathogens and parasites
- Upsetting ecological balances and interactions, such as producing more attractive flowers for pollinators, or causing native prey populations to decrease to the point that they can no longer cope with natural predation rates, even if the IAS is removed
- Synergies with other IAS, such as degrading the environment so that further invasions are facilitated

While the initial impacts may be minor and near-invisible, as the IAS population increases over time, the impacts will increase in severity. Assessing the impacts of IAS on biodiversity is not as straightforward as considering their economic impacts. While the costs of prevention, control and mitigation measures to avoid biodiversity impacts can be measured, the actual value of an extinct species or a change to the ecosystem is harder to quantify. Sometimes it is possible to quantify the costs. In the fynbos biome of South Africa, invasive plants produce excessive fuel loads and cause more frequent fires. The damage to the fynbos is measured in numbers of species that disappear after it has been repeatedly burned. Furthermore, the impacts of IAS should not be considered in isolation, as they are often exacerbated by other environmental disturbances.

The impacts of IAS on natural ecosystems are usually irreversible

EXAMPLE

Figure 1.17. Brown tree snake (*Boiga irregularis*)

The brown tree snake (*Boiga irregularis*) is an example of how direct predation by an IAS can cause species extinction.

Since its accidental introduction to Guam in early 1950s it has caused the extinction of 10 of the 13 native forest birds, 2 out of 3 native mammals, and 9 of 12 native lizards.

Guam's ecosystem is now full of vacant niches, and alien species are expected to arrive and fill the void created by the extinction of the native fauna

Photo: Gordon Rodda, USGS

Ecological impacts may include:

- Displacing native species, which causes changes in the ecosystem functioning
- Causing extinctions, which may have "cascade" effects and cause further extinctions
- Degrading ecosystem services (such as reducing river runoff volumes or water quality or destroying fisheries)
- Altering environmental conditions such as increasing erosion or changing natural fire regimes
- Disturbing ecological processes and thereby facilitating invasion by other alien species
- Altering of the food web and nutrient cycles

1.3.2 Economic

Invasive species may cause major economic losses to society, whether in the form of direct economic impacts, such as loss of agricultural or fishery production, or secondary economic impacts caused by human health issues. It has been estimated that a single IAS, the water hyacinth (*Eichhornia crassipes*), cost Uganda US$112

million in 1999. Similar examples of losses due to different IAS abound throughout the world (Table 1.2). However, IAS also have negative impacts on ecosystem services upon which humans depend. They change ecosystems in ways that affect flooding, erosion and silt accumulation, water quality and air quality. These are not so easily quantified and are often excluded from the analysis of costs associated with IAS.

Country	Cost ($US billions)
Brazil	50
India	117
South Africa	12
United Kingdom	12
United States	137

Table 1.2. Examples of annual national economic losses due to IAS in 2001

Economic impacts may include:

A) Direct costs:

- Direct loss of crops to introduced crop pests. For example it is estimated that rats consume as much as 50% or Madagascar's annual rice production.
- Spoiling of produce, rendering products unsuitable for consumption, such as fruit-fly infestations destroying fruit crops
- Loss of export earnings due to prohibitions on exporting products infected by IAS, such as bans of meat exports due to foot-and-mouth disease
- Reductions in agricultural production due to displacement of pasture by unpalatable grasses and woody species, and/or through habitat/environmental changes caused by the invading species
- Impacts on fisheries and aquaculture (including closure of fisheries or aquaculture facilities), especially from introduced harmful algal blooms, smothering plants like salvinia or the introduction of predatory species such as Nile perch
- Secondary economic impacts from human health issues associated with introduced pathogens and toxic species, including increased monitoring, testing, diagnostic and treatment costs, and loss of social productivity due to illness and death in affected people
- Loss of tourism revenues due to disease epidemics (e.g. the SARS outbreak in China in 2003)
- Costs of producing and using chemicals and machines to deal with IAS

B) Indirect costs:

- Degradation of ecosystem services, such as reduced water supplies from alien trees growing in catchments and along rivers, or siltation of dams and rivers due to increased soil erosion
- Lost human productivity due to time and resources allocated to dealing with IAS, such as clearing weeds or spraying pesticides
- Damage to infrastructure due to ecosystem changes, such as increased intensity and/or frequency of fires, floods or landslides

- The costs of responding to the problem, including research and development, monitoring, education, communication, regulation, compliance, management, mitigation and control costs and restoration activities

The costs to non-economic sectors (for instance, the natural environment and societal or cultural values) of IAS, while not easily measurable in monetary terms are also significant.

IAS cost economies billions of dollars every year in direct losses; the indirect losses to economies may equal or exceed the direct losses

Activity 1.3

List some IAS and the ways they have had an economic impact on you directly or in your country's economy

EXAMPLE

Figure 1.18. Parthenium weed (*Parthenium hysterophorus*)

Parthenium weed (*Parthenium hysterophorus*) is an annual herb that aggressively colonises disturbed sites. It has been accidentally introduced to many countries in Africa, Asia and the Pacific where it has become a serious weed of medium rainfall, semi-arid rangelands and seasonal cropping areas.

Negative impacts of parthenium weed include livestock poisoning; increased management costs; exclusion of useful plants; pasture seed, grain and hay contamination and an impact on human health: frequent contact with the plant or pollen can produce serious allergic reactions.

Photo: (Rüdiger Wittenberg, CABI)

1.3.3 Public health

Disease vector: an organism (e.g. a mosquito or a tick) that carries and transmits a disease

IAS can also have severe impacts on human health. Infectious disease agents may themselves be IAS or may be introduced by IAS vectors (e.g. introduced mosquitoes carrying malaria). West Nile Virus is an example of this. It was first described from Uganda in 1937 and causes encephalitis (inflammation of the brain) in humans and horses, as well as mortality in certain domestic and wild birds. It was introduced to the United States in 1999. According to the US Centers for Disease Control and Prevention, 9862 people in the US tested positive for the West Nile Virus in 2003, and 264 people died of the virus.

Human and animal diseases are often IAS that have huge impacts on human lives and the economy

Figure 1.19. Sign warning about the danger of SARS

Diseases can affect the movement of people and limit tourists to an area. This was demonstrated by the Severe Acute Respiratory Syndrome (SARS) outbreak in 2003 where there was a worldwide downturn in tourism. For example, the SARS outbreak cost the tourism industry in China $17 billion for that year. There was also a cost in lost exports and foreign investment.

Besides diseases, other IAS are dangerous to humans. For example, in the US, the South American red fire ant (*Solenopsis invicta*), a notoriously aggressive stinging ant, has been implicated in the death of over 80 people. When disturbed, these ants deliver multiple stings, releasing venom that can be fatal to some people. The African honey bee *Apis mellifera* has also invaded parts of southern USA, where it is so aggressive, and kills so many people and animals each year that it has earned the nickname Killer Bee.

The threat of IAS to biodiversity, economies and human health is real and need to be taken seriously by the global community. Everybody has a part to play in the fight against IAS whether at the individual, community, national or international level.

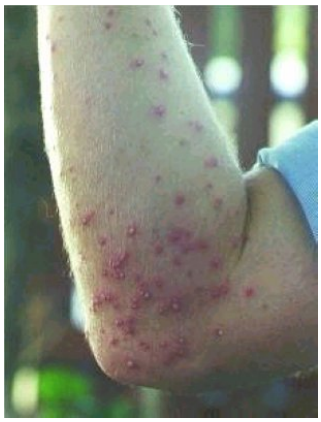


Figure 1.20. Stings of the red fire ant (*Solenopsis invicta*) can be so severe they cause anaphylactic shock and death (Queensland Department of Primary Industries)

Activity 1.4

List some recent (last 10 years) disease epidemics, describe how the disease is spread and from where it originates

1.4 Can we predict species invasiveness?

The short answer is no, not very well. It has proven especially difficult to identify the characteristics that distinguish invasive from harmless alien species. However, there are some guidelines. Current best predictors for identifying which introductions are mostly likely to establish, spread and cause harm are broken into two groups: the “potential” of the organism and the “susceptibility” of the ecosystem.

1.4.1 Species characteristics

The biology and ecology of an alien species can be determining factors of its invasiveness potential.

Activity 1.5

List some characteristics of species that would make them more (or less) likely to become invasive.

- **Invasive elsewhere –** often the best indicator for invasiveness is if a species is invasive elsewhere.
- A widespread distribution and abundance in their native range
- High adaptability to, and tolerance of, a variety of environmental conditions
- Able to grow and mature rapidly, i.e. reach reproductive age quickly
- High reproductive output, i.e. are able to build populations quickly, increasing the chance for establishment in their new range
- Ability to colonise from a single pregnant female
- Effective dispersal mechanisms
- Broad diet (animals) or tolerant of various soil types (plants)
- Aggressive behaviour and competitive ability
- Association with humans (human commensals)
- Small size, making both detection and control difficult

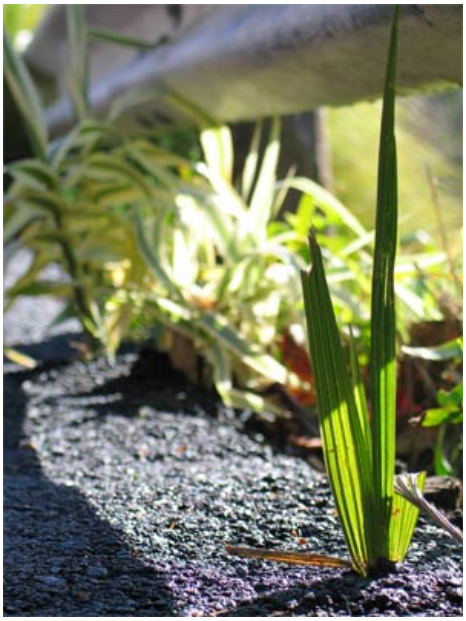


Figure 1.21. Aggressiveness is often a characteristic of IAS, to the point of sprouting through tarmac on a roadside (Photo R. Wanless)

Although predicting invasiveness is extremely difficult, one of the best indicators is invasive elsewhere

1.4.2 Characteristics of invaded environments

Some factors which may predispose certain areas to becoming invaded include:

- The degree of similarity between the climate and habitats of the receiving region and those colonised by the species of interest in its natural and other introduced ranges.
- The degree of 'invader friendliness' of the area where the invasions occur. For example:
    - The number of recently established invasive species

  - The percentage of artificial, heavily modified or disturbed habitats that offer vacant niches due to absence or immaturity of native assemblages
  - Lowered biodiversity in native communities owing to overgrazing, frequent burning, deforestation, pollution, overfishing, dams or other disruptive processes
- The range of secondary pathways available (i.e. number and frequency of local vectors and their routes that can assist regional spread)
- The presence of biogeographically isolated communities containing a high percentage of endemic taxa and/or offering naturally vacant niche space owing to relatively low biodiversity

However there is insufficient evidence to adequately quantify these trends. There are also mechanisms that influence invasiveness on a more 'case by case' basis which are difficult to predict. For example, pathogens, parasites and predators control populations in their native range by reducing fitness, fertility and/or longevity. The presence or absence of these may make a big difference to an alien species' vigour. For these reasons there remains no substitute for careful biological research on any species of concern, both in its natural and invaded habitats.

Other factors, which may help alien species to establish in new ranges, include:

- **Propagule pressure –** The likelihood of the establishment of an alien species increases with the number of individuals introduced and the frequency of introductions.
- **Lack of natural enemies** (e.g. pathogens, diseases, predators or competitors) - When a species is transferred to a new location outside its native range the predators, diseases or other species that help control it may be left behind. This is also termed "competitive release".

1.5 The need for IAS management

The impacts of human activities on the earth's environment need to be managed in a sustainable and rational way to ensure that ecosystems upon which our existence, and the existence of most life on earth, can continue to function. At present, the global economy is a very long way from achieving this ideal. Nevertheless, understanding some of the consequences and implications of actions will aid in developing systems that reduce the impacts. For IAS, three activities (or the unintended byproducts of human activities) are major driving forces shaping the ability of species to invade and the susceptibility of environments to invasions:

- Globalisation
- Land-use change
- Climate change

1.5.1 Globalisation

Trade liberalisation is a relatively recent phenomenon that has transformed the way in which the world economy operates. Exports from distant countries are now quickly and efficiently transported to almost anywhere in the world in

quantities unheard of a century ago. For example, the value of worldwide exports grew from US$192 billion in 1965 to $6.2 trillion in 2000. Similarly, people are moving in ever-increasing numbers and more remote places are coming under increasing human pressure. The rapid growth in the movement of people and their goods is facilitating the transportation of thousands of organisms (i.e. plants, animals and diseases) around the world. The increasing number of ships and planes, all of which have the potential to introduce damaging species over long distances, require strict border control and quarantine measures to be undertaken to reduce the spread of IAS.

Figure 1.22. How species move to new locations.

The rapid growth in trade, travel and transport (the "3 Ts") is causing the number of introductions to increase

1.5.2 Land-use change

The alteration of the natural environment by humans is not a recent phenomenon. However, since the industrial age the rate at which humans are transforming natural landscapes has mushroomed. Now, globalisation is opening up world markets, and economies are increasingly reliant on exports. This has had the effect of dramatically increasing the economic incentives for growth of industry and expansion of agriculture. The result is large-scale environmental change, such as urbanisation, deforestation and agribusiness, across the globe.

In many cases, the effects of these changes have provided ideal conditions for invasive species to successfully out-compete the native species that share their environment. For example, large-scale the loss of large trees to deforestation opens up the forest understorey to increased light levels and

higher soil temperatures. This creates areas that are conducive to invasion by weedy, fast-growing plants.

The expansion of human population has led to more large towns and cities, and this in turn has led to a massively increased network of road and railways interconnecting urban areas. These are highly disturbed environments and often serve as easy secondary pathways for invasive species to spread and become established deep inside undisturbed habitats.

1.5.3 Climate change

The burning of fossil fuels and production of methane and other "greenhouse gases" is causing a general warming of earth's atmosphere and resulting in climates across the globe changing. The results of this are difficult to predict. However, the ability of natural ecosystems to respond to shifting "climatic envelopes" is severely limited in a highly fragmented and intensively used landscape. Plants and animals will struggle to shift their ranges to match the shifts in rainfall, temperatures, etc. Alien species are expected to benefit from this because of more opportunities for them to expand and because natural systems will be compromised and so more prone to invasion.

Human activities are changing natural ecosystems and making them more susceptible to a great diversity of IAS

1.5.4 The way forward

Recognition of these facts, and of the impacts caused by invasive species, has led to the development of a variety of strategies for their prevention and control. These strategies will be the focus of the next modules.

1.6 Key points of this module

- An alien species is considered invasive only if it establishes and spreads in its new location, and has adverse impacts on the environment, the economy or human health
- IAS are not restricted to plants and mammals, but come from almost every major taxon of organisms
- Many alien populations undergo a lag phase after initial establishment, and may remain unobtrusive/non-invasive for a long time before suddenly changing, becoming invasive and spreading rapidly
- Human activities have dramatically increased opportunities for species to travel around the world and to become invasive

- Alien species enter countries through both legal and illegal routes, and introductions can be both intentional and unintentional

- IAS have significant negative impacts on biodiversity, the economy and public health

- IAS are a global problem, affecting every country in the world

- The impacts of IAS on natural ecosystems are usually irreversible

- IAS cost economies billions of dollars every year in direct losses; the indirect losses to economies may equal or exceed the direct losses

- Human and animal diseases are often IAS that have huge impacts on human lives and the economy

- Although predicting invasiveness is extremely difficult, one of the best indicators is invasive elsewhere

- The rapid growth in trade, travel and transport (the “3 Ts”) is causing the number of introductions to increase

- Human activities are changing natural ecosystems and making them more susceptible to a great diversity of IAS