BIOLOGICAL INVASIONS
IMPLICATIONS FOR BIODIVERSITY, ECOSYSTEM SERVICES AND HUMAN WELL-BEING

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Invasive species are recognised as one of the key drivers of human-induced global environmental change, along with other factors such as climate change, over-utilisation and land degradation. In fact, internationally, biological invasions result in economic losses of US$ 1.4 trillion per year (Pimentel et al. 2000). These costs arise as invasive alien species induce numerous negative impacts on biodiversity, ecosystem services and human well-being (Pejchar & Mooney, 2009). This said, a subset of invasive species are useful, which can result in conflicts of interest between the stakeholders who benefit from the invasives and those who carry the costs (Vaz et al. 2017).

WHAT ARE BIOLOGICAL INVASIONS?

Biological invasions arise from the human-mediated spread of organisms out of their native range to new areas of the world. This is done purposefully and accidently. For example, some species are intentionally introduced for forestry, ornamental use, aquaculture and as pet species. Other invasive species are introduced accidently, such as when seed is concealed in imported goods or through ballast water discharge.

Most introduced species don't become invasive, as introduced species need to overcome a number of barriers to survive and eventually spread (Blackburn et al 2011). Initially, introduced species are termed casual species. If they are able to survive and reproduce locally, they are defined as naturalised species. Only if species are able to spread naturally over large areas and cause negative impacts are they termed invasive alien species. Only a small proportion of species actually become invasive aliens, but this number is growing every year. In 2013 there were just over 750 trees and shrubs listed as invasive globally amongst thousands of introduced plant, animal and fungus species.

Various factors enable some species to become invasive. These include specific traits, such as being hardy and prolific seeders, or superior competitors. Another factor that facilitates some species to become invasive is explained by the "empty niche hypothesis". For example, cats introduced onto islands often become invasive, as there are no other predators prior to their introduction. Similarly, in the Cape Floristic region of South Africa, many introduced tree species have become invasive as there are very few trees within the fynbos shrublands. Another explanation for species becoming invasive is the "enemy release hypothesis" whereby a species is introduced into a new range where it has no natural enemies or pests allowing the species to spread rapidly.

IMPACTS OF INVASIVE SPECIES

1 IMPACTS ON BIODIVERSITY

Most studies on the impacts of invasive species focus on their impact on biodiversity and ecological functioning (Vilà et al. 2011). For example, many invasive plants displace native species, including plants, animals and insects which can reduce species richness and abundance as well as result in extinctions. Furthermore, invasive plants can alter mutualisms between species thus impacting the long term survival of native species. Mutualisms are interactions between plants and other organisms, such as plants associating with nitrogen-fixing bacteria and birds and insects that act as pollinators. Many invasive animal species have detrimental effects on native species through predation (e.g. snakes, rats and cats), through competition for food (e.g. birds and goats) and through habitat destruction (e.g. rabbits and goats). Invasive insects can have serious negative effects on native species populations as seen in North America where the emerald ash borer, an insect from Asia, is killing off trees in their thousands. Similarly, invasive micro-organisms, such as fungi and bacteria, can have negative impacts on native species, as seen with chestnut blight that has killed millions of trees in the United States. Numerous invasive species such as cats and the brown tree snake have resulted in the extinction of native organisms.

2 IMPACTS ON ECOSYSTEM SERVICES

Supporting and regulating: Many invasive species have negative impacts on ecosystem services, through reducing their supply or function (Le Maitre et al. 2011). These include impacts on regulating and supporting services, such as reductions in above and below ground water flow and changes in runoff that can affect erosion. Tree species contribute to this through increased evapotranspiration, and altering water channels. A number of invasive species, especially legumes, also alter soil chemistry and properties that affect the growth of native species and crops. Numerous introduced plant species, including grasses, shrubs and trees, alter fire regimes and soil characteristics. For example, Australian acacia (wattle) invasion in South Africa is a serious fire hazard near urban areas. Invasive water weeds can induce eutrophication, which negatively affects water chemistry and quality. Some invasive species can also alter pollination systems and micro-climates.

Provisioning: Where invasive species displace other vegetation and animals there is a loss of provisioning services, such as grazing and fishing potential and the supply of non-timber forest products such as medicinal plants (Shackleton et al. 2014). Invasive insects and pathogens like cassava mealybug and banana bunch top virus, have negative impacts on crop yield across many African countries. Similarly, invasive fish like Nile perch have had detrimental effects on native fish species stocks and have reduced subsistence fishing in Lake Victoria. In India, invasive lantana has reduced the supply of bamboos used for weaving, and in Kenya, Prosopis trees have reduced the supply of medicinal plants and palms used for weaving. Deep rooted species like Prosopis use precious underground water in arid areas.

Cultural: Several invasives also have negative implications for cultural services, which link to reductions in recreational, aesthetic and spiritual values. For example, invasive water weeds prevent recreational fishing, swimming and boating. Similarly, invasive lionfish reduce reef diversity and therefore diving experiences in the Caribbean. In some areas, invasive wattle species in South Africa hinder access to sacred pools which are important Xhosa cultural and spiritual sites. In other areas, people take issue with invasive species blocking views of the landscape and thus their aesthetic beauty.

3 IMPACTS ON HUMAN WELL-BEING

Invasive species often have negative impacts on human well-being through their impacts on ecosystem services as well as through direct impacts which can increase vulnerability (Shackleton et al. 2007; Vaz et al. 2017). This includes threats to human health through inducing allergic reactions, increasing the presence of diseases, and causing direct injuries. For example, the pollen of invasive Prosopis trees is highly allergenic and this tree has thorns that cause substantial injury to humans and livestock. Prosopis invasions also act as an alternative food source for mosquitos, thus increasing their abundance and incidence of malaria.

Many invasive species reduce economic output and land value. For example, invasive stands of trees are costly to remove and reduce grazing capacity. Herbaceous plants like parthenium invade fields and rangelands thus reducing cropping and grazing potential. This plant is also poisonous to livestock, thus increasing mortality of cattle and reducing economic output. Similarly, invasive crop pests reduce output thus reducing incomes from land.

Many invasive species displace important natural resources used by humans which can substantially increase the vulnerability of communities. Furthermore, invasive species hinder human movement and access. In arid areas, invasive species can reduce the availability of water which is often a key limiting resource for development and economic production. This is seen commonly with Prosopis and wattle trees in Africa. Some invasive species can also increase the intensity and prevalence of natural disasters such as fires, floods and droughts which can increase human vulnerability and reduce well-being. Invasive species can also negatively influence cultural, aesthetic and recreational value for humans which is also important for well-being as cultural aspects often help to build social capital.

CONFLICTS OF INTEREST

Some invasive species cause conflicts of interest because they have economic and/or intrinsic value for some people, but also induce substantial negative effects for others (Zengeya et al. 2017). For example, many invasive birds and animals cause negative effects on native biodiversity and ecosystems, but some people intrinsically value them and view efforts to reduce the numbers of these species as unethical. This has been noted for mallard ducks in Cape Town and camels in Australia. Trout are a major invasive species in many parts of the world but have conflicts of interest surrounding their management as people value them for recreational fishing. Aesthetically beautiful plants like Jacaranda trees have resulted in conflicts of interest as people value their beauty.

Many species also provide direct benefits, such as timber, fuelwood, and edible products, and are therefore economically valuable but also induce many of the costs mentioned above, making their management a highly complex issue. In southern Africa, this includes species such as guava, pine, prickly pear and trout. Therefore stakeholder engagement prior to and during the management of some invasive species is crucial, and managing invasive species has no easy solutions.

IMPLICATIONS FOR SOCIAL-ECOLOGICAL RESILIENCE

Due to their impacts on biodiversity, ecosystem services and human well-being, invasive species often reduce social-ecological resilience. A number of species have led to the crossing of tipping points in social-ecological systems, and induced regime shifts (Gaertner et al. 2014). For example, Nile perch negatively affected native fish stocks in Lake Victoria, which resulted in a loss of subsistence fisheries that triggered substantial shifts in livelihoods and social-economic conditions for local villages surrounding the lake. In the Cape of South Africa, Australian wattle tree invasions have resulted in dramatic changes to the landscape that have led to the loss of native biodiversity, water supply to local towns, and grazing potential and have increased the risk of fire hazards, thus substantially impacting livelihoods and economies in the region. Such impacts reduce the resilience of ecosystems and the communities who live in them to shocks such as droughts and floods, and the capacity of these social-ecological systems to cope with ongoing changes such as urbanisation.

It is therefore crucial to better understand the benefits, costs and social-ecological implications of biological invasions to guide their control to reduce costs for people and the environment and potentially improve benefits.

WHAT CAN BE DONE TO REDUCE THE IMPACTS OF BIOLOGICAL INVASIONS?

Various options are available to reduce the negative impacts of invasive species which will help with improving the resilience of ecosystems and reducing human vulnerability. Each option has its pros and cons and the application of different techniques depends on the specific context (van Wilgen et al. 2011). In many cases, integrated management approaches are needed. Good strategic planning and adaptive management approaches are crucial.

First of all, it is most cost effective to prevent invasions before they arise. This can be done through conducting risk assessments for purposeful introductions, as well as better managing pathways of spread to prevent accidental introductions, for instance managing ballast water and ensuring that imported equipment is sterilised. After prevention, it is then the most cost effective to try and eradicate naturalised species (small localised populations) before they become invasive and widespread. This is often termed as Early Detection, Rapid Response (EDRR).

Once invasions are well established there are various management options available including mechanical control (cutting, digging, pulling, caging, shooting); chemical control (herbicide, poison or pesticide use); cultural control (use of fire, grazing); control through utilisation (exploiting the invasive as a resource); or biological control (introducing the invasive species' native pests/pathogens).

Increasingly it is being recognised that engaging with multiple actors is key for successful control of invasive alien species (Novoa et al 2018).

1 MECHANICAL CONTROL

This is the most commonly applied management technique. It is the simplest method and requires minimal knowledge and equipment. This method involves cutting and pulling out invasive plant species. For species that coppice, herbicide is also needed. For animal species, this can involve hunting, trapping and sexual sterilisation. Mechanical control can be quite labour intensive and slow to yield results over the long term. In developing nations such as South Africa, this method is an important form of job creation and aids rural development.

2 CHEMICAL CONTROL

This technique involves the use of herbicide to kill off invasive trees and pesticides or poisons to kill insects and animals. This can vary from large scale application using aerial spraying, to localised application. This technique can be quite expensive and also requires large amounts of labour in some cases. There are also issues with non-target effects on other species, human health and contamination.

3 CULTURAL CONTROL

This technique focuses on changing and adapting land use practices that help to remove invasions and prevent their establishment. This could include factors such as burning invaded areas and adopting different grazing strategies to prevent invasive species from becoming dominant. In theory, these practices should be easy, however, it often takes a lot of engagement to change stakeholder practices. The use of fire is also controversial due to its hazardous nature and can be a risk to property and lives.

4 CONTROL THROUGH UTILISATION

This management technique can be applied to invasive species that have economic value. This approach promotes the use of invasive species to reduce their abundance and spread. It is, however, a very controversial management technique as some view it as aiding local development and the environment, while profits help cover management costs. Others feel that this approach could create dependency on the invasive species thus exacerbating conflicts of interest, and if the species becomes valuable it could lead to further introductions into new areas.

5 BIOLOGICAL CONTROL

This management approach involves releasing the natural pests and pathogens of invasive species into areas they invade. This process requires long-term research and, if done properly, is considered safe. If the biological control agent establishes, this approach is the least costly method of control, works over large spatial scales – and often in areas inaccessible for mechanical and chemical control - and requires very little labour or input costs over the long run. However, the initial research is expensive, and the agent often fails to establish. That said, there are also many success stories using this approach. For example, in South Africa and Australia, biological control of prickly pear (Opuntia ficus-indica) has been highly successful in reducing densities to a manageable level, where benefits now exceed impacts.

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