



# Alien species: to remove or not to remove? That is the question



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## ABSTRACT

Invasive alien species (IAS) are universally known for being a controversial management issue. What makes IAS management a particularly thorny question is that although numerous studies document the negative effects of IAS, the potential benefits of IAS are generally underreported. This may result in wrong assessments on the real socio-economic and environmental impact of IAS. This study aimed to provide new insights to support the decision making of IAS management. In particular, the biased approach to IAS management seems to be a likely consequence of the lack of appropriate metrics able to assess the real IAS impact. A basic aspect of IAS management is to decide whether and when IAS removal is a suitable action. Specifically, this study supported the idea that IAS removal may be considered as a possible solution only after establishing a tipping point relying on economic, cultural and pragmatic evaluations. This analysis should include the identification of the ecosystem services damaged and provided by IAS, the attribution of an economic value to such ecosystem services, and when expressing the interaction between IAS and culture is not possible in monetary terms, then social values and cultural traditions should be incorporated in any management plan. Novel ecosystems are now a fact worldwide that should prompt to be realistic about the extent of efforts required for IAS removal. A significant step towards well-pondered decisions should consider that a change in host communities does not imply necessarily harm, and that the functional roles of a species matter more than its origins.

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## 1. Introduction

New organisms and their genetic materials are increasingly being introduced and exchanged with local species worldwide (Gritti et al., 2006; van Wilgen et al., 2008). Such species, commonly called alien species, are spread both intentionally, because of their utilitarian value, and unintentionally as a consequence of travel and trade (Kettunen et al., 2008). Invasive alien species (IAS), defined as those non-native species that threaten ecosystems, habitats and species (Convention on Biological Diversity, 2008) are considered as important drivers of the ongoing global environmental change (Pyšek and Richardson, 2010). Generally ranked as the second greatest cause of species endangerment and extinction after habitat destruction (Wilcove et al., 1998; IUCN, 2011), IAS can also affect seriously the ecosystem services that are fundamental to human survival and well-being (Millennium Ecosystem Assessment, 2005; Vilà et al., 2010; Branco et al., 2015).

The documented effects of IAS are numerous, and include direct threats to human health, and loss or alteration of goods and services regarding fishery, farming, forestry, drinking water,

hydrology, climate stabilization, pollination, culture and recreation (Le Maitre, 2004; McNeely, 2005; Lovell et al., 2006; EEA, 2012). Other impacts are subtler, and are the result of long-term transformations affecting habitat and ecosystem functioning (Hulme, 2007). These alterations include nutrient cycling (Chamier et al., 2012), soil properties (Ehrenfeld, 2003), disturbance regimes (Mack and D'Antonio, 1998), fire frequency (Brooks et al., 2004), trophic interactions (Levin et al., 2006), and biodiversity loss (Powell et al., 2011). In particular, IAS can threaten biological diversity in various ways, from reducing genetic variation and eroding gene pools to the extinction of endemic species, especially in islands and freshwater ecosystems (Sax and Gaines, 2008). The costs associated with the impacts of IAS are consequently enormous, and amount yearly to hundreds of billion dollars worldwide. Pimentel et al. (2005) estimated that the damage and management of IAS determine an economic impact of 120 billion dollars yearly in the USA alone. Similarly, in Europe, lost output due to IAS, health impacts and expenditures to repair IAS damage has cost the European Union at least 12 billion euros per year over the past 20 years (LIFE Guidelines, 2014).

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The issue of IAS is, however, highly controversial, and a wide literature claims that the alleged impacts of IAS often rely on prejudice rather than scientific evidence (Reise et al., 2006; Davis et al., 2011; Hulme et al., 2013). First, despite considerable and increasing data showing that IAS are not a top extinction threat to most species (e.g., Harrison et al., 2006; Stohlgren et al., 2008), it is generally accepted as a global fact that IAS are the second most important cause of extinction (Perrings et al., 2005; Pejchar and Mooney, 2009). Second, only a very small fraction of non-native species becomes invasive (van Kleunen and Johnson, 2007). Third, the language used to describe IAS in the scientific literature is often characterized by military and xenophobic expressions such as “biological invasions” or “war on aliens”, which inevitably contribute to convey the message that introduced species are enemies of man and nature (Larson, 2005). Fourth, also native species can become invasive and cause ecological and economic impacts even worse than IAS (Valéry et al., 2009; Simberloff, 2011). Last but not least, numerous non-native species, even invasive, provide positive economic impacts such as European honeybees (*Apis mellifera*), which are widely used to pollinate crops in North America, and offer a pollination service worth of c. 14.8 billion dollars annually in the USA (Morse and Calderone, 2000). Aliens can also provide conservation benefits such as habitat and food resources to rare species, or by acting as functional substitutes for extinct taxa, and in general by providing or enhancing desirable ecosystem services (Rodriguez, 2006; Chiba, 2010; Schlaepfer et al., 2011).

This overview shows that the impact of IAS cannot be easily generalized and that eradication is rarely the best solution. While

eradication of IAS may often be the most desired management option, accomplishing this objective once the species has become well-established is normally extremely difficult, if possible at all, and expensive (Denslow, 2007), not to mention the risk that when eradication works, empty niches may be filled by another alien invader (Ogden and Rejmanek, 2005). Practices for eradication or control of non-native species may also determine undesired effects and further environmental degradation (Rinella et al., 2009), which may prove even more damaging than the invasion itself in the long run (Smith et al., 2006).

This study investigated the main aspects that may play a role in IAS management. In particular, this study aimed to identify and analyze the rationale of the current approach to IAS management. The general goal was to provide valuable insights for a paradigm shift from focusing on the negative effects of IAS to recognizing the potential positive contribution of non-native organisms.

## 2. Materials and methods

This study analyzed the scientific literature dealing with invasive alien species, their related impacts and management issues. Specifically, this study searched for the existing literature included in Scopus, one of the largest international bibliographic databases of academic journal articles. According to current data, Scopus includes c. 21,000 peer-reviewed journals and over 57 million records in the fields of science, technology, medicine and social sciences (Scopus, 2015). Thanks to its significant availability of literature data spanning over 50 years, the database Scopus has progressively become an indispensable tool for any

**Table 1**  
Article records per phrase combination according to the bibliographic database Scopus.

Thematic group	Phrase combinations	Records
Health	Invasive alien species and health	130
	Invasive alien species and human health	81
	Invasive alien species and health impacts	71
	Invasive alien species and health factors	19
	Invasive alien species and health effects	37
	Invasive alien species and health consequences	9
	Invasive alien species and infections	51
	Invasive alien species and casualties	0
Economy	Invasive alien species and economy	71
	Invasive alien species and economic impacts	183
	Invasive alien species and economic factors	65
	Invasive alien species and economic effects	93
	Invasive alien species and economic consequences	32
	Invasive alien species and economic aspects	25
	Invasive alien species and economic assessment	73
	Invasive alien species and economic damage	61
Society and Culture	Invasive alien species and society	486
	Invasive alien species and culture	51
	Invasive alien species and social impacts	57
	Invasive alien species and social factors	41
	Invasive alien species and social effects	32
	Invasive alien species and cultural impacts	23
	Invasive alien species and cultural factors	11
	Invasive alien species and cultural effects	13
Ecology	Invasive alien species and ecology	604
	Invasive alien species and ecological impacts	480
	Invasive alien species and ecological factors	210
	Invasive alien species and ecological effects	362
	Invasive alien species and ecological consequences	85
	Invasive alien species and ecological aspects	52
	Invasive alien species and biodiversity	780
	Invasive alien species and ecosystem services	102

researcher and research team worldwide. Therefore, Scopus was considered as a reliable and exhaustive source of information for retrieving most studies on IAS and related themes.

The bibliographic investigation of this study searched for the articles of the Scopus database updated to December 2015. The specific setting for article search was:

- Document type: article and review
- Search field type: article title, abstract, keywords
- Date range: all years to present
- Subject areas: life, health, physical and social sciences, humanities

The target articles included the main issues concerning IAS management, namely health and economic harm, social and cultural factors, and ecological impacts. In particular, the article search was divided into four thematic groups according to the phrase combinations typed in the Scopus research box.

The thematic groups were as follows:

#### 1) Group “Health”

Phrase combinations entered:

- Invasive alien species and health
- Invasive alien species and human health
- Invasive alien species and health impacts
- Invasive alien species and health factors
- Invasive alien species and health effects
- Invasive alien species and health consequences
- Invasive alien species and infections
- Invasive alien species and casualties

#### 2) Group “Economy”

Phrase combinations entered:

- Invasive alien species and economy
- Invasive alien species and economic impacts
- Invasive alien species and economic factors
- Invasive alien species and economic effects
- Invasive alien species and economic consequences
- Invasive alien species and economic aspects
- Invasive alien species and economic assessment
- Invasive alien species and economic damage

#### 3) Group “Society and Culture”

Phrase combinations entered:

- Invasive alien species and society
- Invasive alien species and culture
- Invasive alien species and social impacts
- Invasive alien species and social factors
- Invasive alien species and social effects
- Invasive alien species and cultural impacts
- Invasive alien species and cultural factors
- Invasive alien species and cultural effects

#### 4) Group “Ecology”

Phrase combinations entered:

- Invasive alien species and ecology
- Invasive alien species and ecological impacts
- Invasive alien species and ecological factors

- Invasive alien species and ecological effects
- Invasive alien species and ecological consequences
- Invasive alien species and ecological aspects
- Invasive alien species and biodiversity
- Invasive alien species and ecosystem services

### 3. Results and discussion

The article search showed that the group “Ecology” included the highest mean number of records (Table 1). In particular, the search associated with IAS and biodiversity showed the highest number of scientific studies. This result may reflect the ever-increasing interest for knowing in depth biotic and abiotic correlations in the face of global environmental changes of which IAS are considered one of the most prominent drivers. The thematic groups “Health” and “Economy” showed a similar mean number of records. The combination phrase “IAS and casualties” was the only one with 0 records. These results were further discussed as follows.

#### 3.1. IAS and health factors

The effects of IAS on human health are manifold, and may cause considerable costs for prevention and treatment. Mazza et al. (2014) identified four categories of hazards to human health associated with IAS: (1) species causing diseases or infections; (2) exposing humans to wounds from bites/stings, biotoxins, allergens or toxicants; (3) favoring diseases, injuries or death; (4) and inflicting other negative effects on human livelihood. Alien pathogens are generally responsible for the most serious diseases (Bol, 2011), instead invasive plants cause mainly allergies and skin irritation (DAISIE, 2009), whereas animal species act as principal vectors of diseases and infections (Wolfe et al., 2007). The most notorious IAS pathogen is human immunodeficiency virus (HIV), spreading since the 1980s from Central Africa worldwide. The impact of HIV pandemic on human wellbeing is extremely severe, as shown by the large number of contagions and deaths amounting in 2007 to 40 million infected people, 5 million new infections, and 2 million deaths (UNAIDS, 2014), and the massive costs of health care of US\$ 100 billion per year worldwide (Pimentel et al., 2007). Regarding plant and animal invasive species, health concerns may be annoying but generally not worrying. However, the indirect effects of some IAS on health may prove very serious. For instance, the water hyacinth, *Eichhornia crassipes*, a South American freshwater ornamental plant included in the list of the top 100 invasive species worldwide, can host mosquitoes and snail species that are vectors of pathogens favoring the spread of lethal diseases such as schistosomiasis (Plummer, 2005). Apart from spreading pathogens and parasites, IAS can also impact human health through other mechanisms. Some alien plants, for example, reduce protection against natural hazards, such as fire and flooding: the former by replacing less inflammable vegetation, the latter by obstructing canals (GISD, 2015). IAS may also cause malnutrition by reducing crops yields with economic losses amounting to tens of US\$ billions (Gherardi, 2007).

IAS management is a top priority when human health is at stake, especially if we consider that IAS effects on human health are expected to exacerbate as a consequence of the increased opportunities of invasion favored by new pathways of introductions, environmental degradation and climate changes. Compared to social, cultural and ecological effects, IAS impact on human health can be identified more rapidly and assessed more directly and objectively, in particular because the main metric involved, namely the number of affected people, is well defined and measurable. The number of infections and deaths caused by IAS provides a clear idea of the magnitude of a disease. Consequently,

when it comes to deciding IAS removal, setting a tipping point beyond which eradication becomes a suitable option, results in a less complex process.

### 3.2. IAS and economic factors

The economic assessment of IAS impact considers mainly the negative consequences without including any potential positive effect as a trade-off that may make the total economic impact of IAS balanced or even positive. Relatively few researchers have indeed quantified the economic benefits obtained from IAS such as pollination by non-native bees or fees paid to hunt and fish non-native species (e.g. Ackefors, 1999; Pascual et al., 2009). The consequences of these gaps are difficult to quantify, but certainly may have favored mismanagement of economic resources when it came to IAS removal. Apart from the scarcely documented IAS benefits, studies use relatively simple methods for assessing damage costs, and failure to use systematic empirical cost estimation methods and the anecdotal nature of their estimates are also seen as major flaws (Lovell et al., 2006). Another criticism concerns the fact that IAS economic assessment often fails to incorporate impacts on ecosystem services (OTA, 2015). Assessing the impacts of IAS on ecosystem services has only recently become an explicit focus of invasion ecology (Richardson and van Wilgen, 2004), and certainly some ecosystem services are better understood than others. For example, the impacts of IAS on provisioning services (food, fiber and fuel) are usually well quantified. Impacts on other life-supporting services, such as fresh water and most regulating services (e.g., pollination, disease and pest regulation, flood and fire control, microclimatic mitigation), despite being significant, are rarely calculated. Finally, the interaction between IAS and culture is probably one of the most complex and under addressed aspects of ecosystem services (Hoagland and Jin, 2006).

Expressing IAS impact by attributing a monetary value to ecosystem services should be considered as an effective managing methodology. Applying economic criteria may not only help set tipping points but also engage the public at a level that social and ecological information on IAS impact does not, since the value of something in economic terms is more understandable by people. However, many effects of IAS on ecosystem services that are difficult to convert into monetary terms are regularly overlooked (Born et al., 2005; Hoagland and Jin, 2006). On the one hand, to capture the full impact of IAS on human well-being, evaluations that go beyond monetary aspects and benefits should be considered, such as the number of people affected positively or negatively by IAS and the magnitude of this impact on their lives (Pejchar and Mooney, 2009). On the other hand, we should remember that IAS management needs a pragmatic approach, and attributing a cost to the ecosystem services affected by IAS may provide practical indicators of the suitability of IAS removal. The future challenge is to increase our ability to identify exhaustively and assess economically the ecosystem services affected by IAS. This will contribute to fill the gap between appropriate economic assessment of IAS impact and real suitability of IAS removal.

### 3.3. IAS and socio-cultural factors

Social issues concerning IAS are mainly economic, cultural, emotional and recreational. Regarding the economic aspect, an emblematic example comes from the Galapagos Islands where an intensive goat eradication program was undertaken. Although some of the poorest inhabitants of the islands used the goats as an important source of food and income, and objected to the goal of complete eradication, from the perspective of the conservationists, the eradication program, funded by millions of dollars and carried out using helicopters, hunting dogs, and hired shooters, was largely

successful (Romero, 2007). The Galapagos case shows that socio-economic analyses should be part of any management plan of IAS removal, especially when IAS provide some material benefits to local communities. Examining how local people perceive and respond to IAS is thus important to develop effective environmental policies whose success is largely dependent on the support of local people.

Assessing the extent to which the public can think of IAS as part of their own identity is an element that makes IAS removal further problematic. As such, cultural factors may play an important role in IAS removal. An interesting example concerns the non-native honeybee *Apis mellifera*, which a dozen US States adopted as their state insect, not to mention the US State Vermont whose residents not only named the honeybee as their state insect but also named as their state flower another non-native species, namely purple clover (*Trifolium pratense*) (Davis, 2009). Similarly, emotional factors may prove decisive for IAS removal. This case is particularly evident when it comes to cull harmful but “attractive” IAS such as gray squirrels (*Sciurus carolinensis*) whose removal has found a great public opposition in Europe (Bremner and Park, 2007), whereas IAS with less appeal, such as the cane toad (*Rhinella marina*) in Australia, have been the target of millions of dollars and thousands of hours of community effort for their physical removal (Shine and Doody, 2011). An emotional approach to IAS removal may be also the consequence of using an inflammatory language characterized by unjustified ecological hyperboles such as “IAS threaten native species with extinction” (Larson, 2005; Smith et al., 2006). Emotional factors influence the way the problem of IAS removal is perceived, and may create an obstacle for scientifically based management actions. This may result in more drastic, and thus expensive, measures to remove IAS despite the insufficient evidence of their real ecological impacts.

The above examples show that IAS removal is a social issue that may have different reactions. On the one hand, decisions to remove IAS may be one-way processes where the role of local communities is largely ignored. On the other hand, local communities may oppose fiercely IAS removal for cultural, recreational or even aesthetic reasons. However, all these different reactions share a common fundamental aspect: the social consequences of IAS removal are generally described but not evaluated. As long as the approach to IAS removal lacks a scientific base, management solutions will be open to arbitrary actions with catastrophic results such as removing IAS when provide essential livelihood to local people or leaving harmful IAS only because considered “attractive” by the public. Assessing the social impact of IAS is intrinsically difficult and cannot be easily generalized because strongly linked to the history of local communities. Future studies on IAS should focus much more on the relationship between “invader” and local culture, and in particular, the following questions may provide a starting point for an appropriate socio-economic analysis:

- 1) Do IAS provide any material benefit for local communities?
- 2) Do IAS have a symbolic meaning for local communities?
- 3) Do IAS provoke a feeling of affection in local communities?
- 4) Do IAS provide a spiritual benefit for local communities?

### 3.4. IAS and ecological factors

It is undeniable that IAS determine an ecological impact on their host environments, and that impacts imply changes. But should such ecological changes be considered harmful? And if yes, to what extent? Unfortunately, most studies have failed to provide an answer. One commonly recognized criticality to IAS management is the difficult identification and quantification of the response metrics. However, the real underlying obstacle that interferes with

IAS management is that when it comes to removal, decisions are still largely supported by scarce scientific evidence. The supposed ecological effects of IAS are, indeed, often taken for granted and synthesized in the mantra “IAS are the second cause of species extinction”. IAS may, in some cases, even provide desirable functions previously relying on native species. The case of tamarisk eradication in the USA is emblematic. Salt cedar shrubs (*Tamarix* spp.) were introduced from Eurasia and Africa in the 19th century as ornamental species and later as shade trees for desert farmers. However, in the 1930s, tamarisk was blamed for impoverishing water supplies in arid lands, and since then has become the target of eradication campaigns (Chew, 2009). Later, ecologists found that not only do tamarisks use a quantity of water comparable to that of their native counterparts but also they provide nesting habitats for the native endangered southwestern willow flycatcher (*Empidonax traillii extimus*) (Stromberg et al., 2009). Moreover, tamarisks are drought-, salt- and erosion-resistant plants able to survive under common water-management regimes that destroy native vegetation, and have a crucial role in the functioning of man-modified riparian ecosystems (Aukema et al., 2010). Yet, between 2005 and 2009, the US Congress allocated 80 million dollars for tamarisk control and eradication (Davis et al., 2011). As the tamarisk case shows, prior to implementing an eradication effort, IAS should be evaluated and prioritized for management according to the extent of trophic interactions with native species, and the importance of key functional roles provided to host ecosystems. However, the impacts of most IAS have not been quantified yet and, when measured, those impacts are based on a limited number of response metrics (Barney et al., 2013). As a result, invasion ecology has been inundated with allegations and conjectures regarding the ecological consequences of IAS.

Whether or not IAS causing ecological changes should be considered harmful, and hence a problem, is not as obvious as for those species causing economic harm or human health concerns. Society needs to know whether it is in its interest to consider as harmful particular ecological impacts of IAS, and managers should actively contribute to make suitable decisions (Davis, 2009). For an exhaustive assessment of the ecological impacts of IAS, decision-making processes should consider the extent of ecosystem services affected and provided. IAS may, indeed, influence basic ecosystem functions such as pollination, water purification, pest control, natural hazards and climate mitigation, services that are both the cornerstone of fisheries, agriculture and forestry and fundamental to human well-being. Only when a scientifically supported assessment shows that the eradication or significant reduction of a target IAS will be economically sustainable without undesirable ecological consequences, should the eradication effort be considered as a feasible option.

### 3.5. Perspectives

IAS removal is a controversial issue where economic, socio-cultural and ecological factors often clash in the arena of environmental management. Probably, few would question efforts by society to control, or even eradicate, IAS causing health concerns, financial loss, and harm to essential ecosystem services. Although support would likely not be as strong, many would also encourage efforts to control or eradicate those IAS that are really threatening native species with imminent extinction. However, it may be legitimate to question the control and management efforts involving IAS that cause other undesirable ecological impacts. These would include species that alter the composition of historical communities, change disturbance regimes, and affect ecosystem processes, but that are not threatening our health, economies, ecological services, or causing other types of great ecological harm such as driving other species to extinction

(Davis, 2009). In general, by adhering tightly to a native preference, we are destined to a life of frustration and disappointment, since we will likely be surrounded by more and more non-native species. The introduced species are not going back, and like it or not, they are our new residents, no matter what we choose to call them.

IAS management is generally affected by a biased approach resulting in the common practice of implementing eradication efforts without a cost-benefit analysis supported by exhaustive scientific evidence. The inevitable consequence is several non-native organisms targeted for management with almost no impact on the invaded ecosystems (Hejda and Pyšek, 2006; Meffin et al., 2010). If health and economic concerns are primary reasons for IAS removal, it is also true that assessing the magnitude of their impact may prove easier because of the measurable parameters generally considered, such as number of infected people and money loss respectively. When it comes to assessing socio-cultural and ecological impacts, instead, IAS management struggles with ill-defined metrics and methodological limitations. As an answer to these uncertainties, pragmatism and common sense should be considered as supporting principles in any restoration effort. In particular, managers should accept some IAS as permanent members of communities, and IAS that provide important ecological services may be the most likely candidates for acceptance (Hershner and Havens, 2008). As a general principle, when non-native, and even non-native invasive, species are not causing significant harm but only change, modifying one's perspective is undoubtedly much less costly than any other sort of management action. Anyway, society has every right to try to restore or keep a portion of nature in some pristine 'pre-invasion' condition given that natural environment is integral part of a community's cultural heritage.

Not only economic parameters but also social norms and institutions are crucial for decision-making. Societies and citizens may decide to put an infinite value on certain ecological goods for cultural or spiritual reasons, be it a rare species, a sacred grove or a special landscape, and not subject it to a cost-benefit analysis. Achieving sustainable solutions requires an integrated assessment of ecological, social and economic systems, and an open debate among stakeholders (Ring et al., 2010). Managers should thus work to understand the basis of public perceptions, to anticipate possible resistance, and be proactive in developing management plans that are sensitive to community values (Larson et al., 2011). Understanding the social values and personal motivations behind the public's preferences for some IAS, should better prepare ecologists and managers for their discussions with other stakeholders (McNeely, 2005; Coates, 2006). If this knowledge helps ecologists and managers realize that people can legitimately disagree on when IAS impact is considered beneficial or harmful, then the dialogue between public, ecologists and managers will be inevitably improved.

Most human and natural communities now consist both of long-term residents and of new arrivals, and ecosystems are emerging that never existed before. It is impractical to try to restore ecosystems to some historical condition. We should accept the fact of 'novel ecosystems' and incorporate many alien species into management plans, rather than try to pursue the often impossible goal of eradicating them or drastically reducing their abundance (Davis et al., 2011). Advocates of eradication should be realistic about the extent of societal investment required. Given constraints on time and money, management efforts with goals of coexistence are certainly more feasible than ones with total eradication in mind (Davis, 2009). This study does not suggest that conservationists and land managers abandon their efforts to cope with serious problems caused by some introduced species, or that governments stop trying to prevent harmful species from arriving in their countries. Stakeholders should instead consider as

priorities whether IAS cause benefits or harm to human health, economies, cultural traditions, ecosystem services, and biodiversity. After a two-century debate on species nativeness, times are mature enough to focus much more on species roles rather than on species origins.

#### 4. Conclusions

IAS management is a discipline that still struggles with biased approach and methodological limitations when it comes to assessing the real impacts of IAS. The future effects of IAS are uncertain because biotic interactions are extremely difficult to predict, especially in a fast changing world. These uncertainties have led many to take the negative impacts of IAS for granted, and to ignore possible trade-offs or even positive impacts. Invalid assumptions and mistaken understandings may not only slow the progress of the discipline but also result in unrecoverable economic losses and irreversible ecological alterations. Although assessing IAS impacts is dramatically problematic for the lack of well-defined metrics, this study disagrees with the simplistic arguments that eradication or control are always appropriate actions. Moreover, the total restoration of native biodiversity should not be the driving principle in ecological restoration, which should instead rely on species functional roles rather than taxonomic considerations. Yet many conservationists still consider the native-versus-alien species dichotomy a core guiding principle in ecological restoration. IAS management can take a significant step forward if all stakeholders realize that IAS cause changes but not necessarily harm. IAS are actually the symptoms of natural environments that are changing forever thanks to drivers such as climate change, nitrogen eutrophication, increased urbanization and other land-use changes. The next challenge is to understand as far as these changes are acceptable. To identify these tipping points, scientists, environmental managers and policy makers should embrace a more pragmatic approach that avoids dogmatic consideration, promotes a dialogue with citizens and uses ecosystem services as metrics for assessing IAS impacts. We should finally remember that IAS management is often case-specific and influenced by economic, socio-cultural and ecological factors acting synergistically on a local scale. Only if the balance between such factors is irretrievably compromised, should IAS removal be considered as a possible solution.

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