Benefits do not balance costs of biological invasions

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Abstract

Biological invasions have profound impacts on biodiversity and ecosystem functioning and services, resulting in substantial economic and health costs estimated in the trillions of dollars. Preventing and managing biological invasions are vital for sustainable development, aligning with the goals of the United Nations Biodiversity Conference. However, some invasive species also offer occasional benefits, leading to divergent perceptions among stakeholders and sectors. Claims that invasion science overlooks positive contributions threaten to hinder proper impact assessment and undermine management. Balancing benefits and costs quantitatively is misleading because they coexist without offsetting each other. Any benefits also come at a price, affecting communities and regions differently over time. A considered, integrated approach considering both costs and benefits is necessary for understanding and effective management of biological invasions.

Keywords: invasive species, economic costs, socio-ecological impacts, ethical management.

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1. Introduction

Biological invasions negatively affect biodiversity, ecosystem functioning, and ecosystem services (Simberloff et al. 2013, Pyšek et al. 2020, IPBES 2023). Although not all alien species have reported negative impacts (Bacher et al. 2023), the subset that becomes invasive negatively affects social well-being, reduces cultural diversity, and burdens human well-being and the economy with large costs (Diagne et al. 2021; Stoett et al. 2019). Minimum estimates of the monetary cost of biological invasions are in the order of trillions of dollars (Diagne et al. 2021), comparable to the losses incurred due to natural hazards (Turbelin et al. 2023). Preventing and managing invasions is therefore integral to the sustainable development agenda, as reflected in Target 6 of the Kunming-Montreal Biodiversity Framework Convention on Biological Diversity (2022) and through the recent Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) assessment on invasive alien species and their control (IPBES 2023).

However, some invasive species can occasionally bring benefits to some sectors of society, such as monetary gains (Shackleton et al. 2019a). Thus, actors from different sectors, practitioners, and scientists often have contrasting perceptions about the net sign of their effects on ecosystems or recipient communities and management actions (Jeschke et al. 2014, Shackleton et al. 2022). These perceptions of benefits have led to claims that the field of invasion science focuses exclusively on the negative effects of invasive species, and overlooks positive contributions to economies and ecosystems (Boltovskoy et al. 2022, Sax et al. 2022, 2023). Although these arguments are flawed because they conflate 'alien' with 'invasive alien species', the fact that some invasive species have benefits is undisputed (Vimercati et al. 2020, Kourantidou et al. 2022, IPBES 2023). Consequently, considering the occurrence and relationships between costs and benefits is necessary to contextualise the management of invasive species. In this regard, we explain that this must be done with caution because a direct, quantitative balance of benefits and costs is overly simplistic and misleading for three main reasons we describe in detail in the following sections of this forum paper: (*i*) benefits of invasive species as a collective have never been demonstrated to be as high as their massive documented costs, (*ii*) benefits do not offset costs (they only exist in parallel to costs), and (*iii*) benefits always come at a price, because they are context-dependent and affect different stakeholders or regions at different times. Emphasising economic benefits over negative impacts, drawing from ambiguities, and uncertain or unpredictable effects can be risky to conservation goals, because it can bias and hinder the proper assessment of all impacts, ultimately undermining the management of biological invasions.

2. Benefits are rarer than costs

Invasive species are plants, animals, pathogens, and other organisms that have evolved outside of a recipient ecosystem, and that can cause economic or environmental harm or adversely affect human health (Convention on Biological Diversity 2021, IPBES 2023). Importantly, non-native species or populations that are farmed or cultivated are generally not included in this category when they do not spread outside human-controlled environments. This means that the economic benefits of agriculture, aquaculture, and forestry are, for the most part, unrelated to biological invasions and therefore, many of these benefits are extraneous and irrelevant to the invasions discourse. In addition, because invasive species are associated with negative impacts, they inherently imply the presence of costs, whether as a direct result of their negative consequences on ecosystems, or indirectly through expenditure on their control. Documented benefits of invasive species are therefore typically by-products. In fact, any benefits are exceptions or special cases in the face of the massive ecological impacts of invasive species (Simberloff et al. 2013, IPBES 2023), or the result of management seeking their control or removal. While systematic comparisons of costs and benefits are sparse, a recent systematic review analysing the number of cases of costs and benefits (labelled as 'undesirable' and 'desirable' effects, respectively) of biological invasions confirmed the expectation that the presence of costs is more frequent and affects more sectors than benefits (Kelsch et al. 2020, IPBES 2023) (Fig. 1). Similarly, the recent IPBES assessment on invasive species highlights that reports from some Indigenous Peoples and local communities documented that 92% of the impacts on nature from invasive alien species were negative, with only 8% being positive (IPBES 2023). More broadly, of 3783 documented impacts of invasive alien species on quality of life in the IPBES report, more than 85% are negative and far fewer (15%) are positive for good quality of life (Bacher et al. 2023). In addition, the overall benefits of invasive species have never been demonstrated to be anything other than small compared to quantified costs. The more than US$2 trillion (2017 currency value) costs of biological invasions already recorded in the (still expanding; Ahmed et al. 2023) *InvaCost* database represent a massive, and yet conservative estimate, which could conceal a much higher true cost (Diagne et al. 2021, Leroy et al. 2021, Ahmed et al. 2023).

Moreover, benefits related to financial gains can often be easily quantifiable for some stakeholders, such as those in fisheries and tourism (Kerr 2019), but the costs are typically not as straightforward to assess and quantify. These difficulties are particularly large when pertaining to the ecological damages to recipient ecosystems (IPBES 2023). Figure 1 shows that the greatest costs of biological invasions are those that affect the environment, while most of their economic benefits are present in local communities (e.g., businesses), fisheries, and livestock farming — more visible, anthropocentric, and quantifiable sectors.

The temporal scale at which benefits and costs are generated is also necessary for comparison. The magnitude and range of social and environmental impacts (and potential associated economic costs) typically manifest over longer durations than any associated economic benefits, thereby presenting an immense challenge to management and policy. Indeed, ecological effects are often undetectable when invasive populations are first introduced (Daly et al. 2023), and while evidence for monetary impacts alone should not underpin conservation actions, assigning monetary values to their negative impacts can be challenging or impossible in these early stages. For example, the short-term economic gains from commercial fisheries targeting the Nile perch (*Lates niloticus*) in Lake Victoria have ultimately come at the vastly larger, long-term expense of the ecological and socio-economic integrity of large lake areas, driving one of the greatest extinction events of hundreds of native and endemic fish species in modern history (Aloo et al. 2017).

Finally, while monetary metrics allow for the quantification of some benefits and costs, the effects of biological invasions are often complex and difficult to value in monetary terms, with invasions sometimes benefitting certain taxa or ecosystem services while concurrently affecting others negatively.

3. Benefits do not negate costs

Even when generated by the same invasive population, the costs *versus* benefits of invasive species should not be compared to the expenditures *versus* revenue in a simple accounting framework (IPBES 2023), particularly because they usually target different sectors (Figure 1) that can be affected over different periods. Benefits can stem from (*i*) exploiting the invasive species directly, and (*ii*) profitable activities indirectly leading to an introduction. In the first case, intentional introductions of species such as the red swamp crayfish (*Procambarus clarkii*) in Europe and Atlantic salmon (*Salmo salar*) in Chilean Patagonia for aquaculture have indeed brought economic benefits for the companies commercially exploiting them (Souty-Grosset et al. 2016, Figueroa-Muñoz et al. 2022). However, these species have had substantial negative impacts in the wild across multiple sectors, including costs to agriculture, water management, and fishing livelihoods. In the second case of trade-driven accidental introductions, examples include profitable timber imports or agricultural products that can precipitate unintended insect invasions. There can also be unintentional escapes of species used from fur farming, insect farming, ornamental horticulture, or as pets (Hulme et al. 2021, Carpio et al. 2020, Bang and Courchamp 2021). Therefore, the resultant economic costs are generally borne by other industries than those responsible for the introductions or end-consumers who are faced with higher prices, which account for the invasion externality of yield losses, damage to infrastructure, or other types of costs (Diagne et al. 2021, Kourantidou et al. 2022). When economic profits are generated by the invasive species, costs of invasions continue to exist even if implicit.

4. Benefits to some are costly to others

Despite biological invasions being one of the five major direct drivers of biodiversity loss (e.g., IPBES 2019, 2023) and damage costs analogous to those of natural disasters (Turbelin et al. 2023), the emphasis on benefits, either ecosystem, social or monetary, makes them an oddity in the fields of global change research. As a parallel, it is possible to think of the economic benefits of climate change (e.g., for sectors involved in climate-change adaptation), of habitat destruction (e.g., for real-estate developers and, more generally, any industry benefiting from urban populations or agriculture), and of overexploitation (e.g., for recreation or commerce). It is doubtful that researchers studying these benefits would assign biases to the collation of costs, or present global change as desirable because of such restricted benefits. Such is, however, the status quo in critiques of invasion science. An undue emphasis on the benefits of biological invasions can also prevent or delay their management, ultimately leading to higher long-term economic costs and negative ecological and health impacts (Leung et al. 2002). Indeed, recent estimates for delayed management, even of a single species, are tens of millions of dollars per year (Ahmed et al. 2022).

In a world where economic growth is still prioritised over nature conservation, promoting such sporadic and short-term benefits might also create dependencies within affected communities, undermining management and ultimately disrupting ecosystem structure and function (Vitule and Pelicice 2023). For example, the development of the charcoal industry and bio-power plants around invasive species like the shrub mesquite (*Prosopis juliflora*) was intended to improve livelihoods, generate energy, and manage the species sustainably in low- to middle-income Asian and African nations (Mwangi and Swallow 2008, Walter and Armstrong 2014). Nevertheless, the introduced shrub outcompeted native plants and disrupted an entire ecosystem, threatening local community resources and cultural values. The perceptions can be also influenced by other context dependencies (Kourantidou et al. 2022) e.g., previous land use and features of landscapes where invasive trees in barren grasslands (*Acacia dealbata* in South Africa) are perceived as valuable assets for soil erosion regulation and resource provision, but cause damage to households, reduce crop production, and serve as hideouts for criminals (Ngorima and Shackleton 2019). However, treating an invasive species as a resource is often not the preference of local communities (IPBES 2023) and has shifted the focus to perpetuating the benefit instead of eradicating the problem, often leading to privatisation of the benefits and socialisation of the costs.

5. Ethical management must integrate all positive and negative effects

Despite the three major shortcomings detailed above, managing biological invasions does require accounting for any potentially positive effects and the implications to community members who will be affected one way or another. In general, non-monetary evaluation methods such as qualitative assessments, social impact analyses, and environmental impact assessments could be used to infer environmental and other costs across invaded systems. This can be done by combining semi-quantitative approaches integrating the positive and beneficial effects of biological invasions in existing frameworks (Shackleton et al. 2019a, Vimercati et al. 2020), such as the *Environmental Impact Classification for Alien Taxa* (IUCN 2020, EICAT+; Vimercati et al. 2022) and the *Socio-Economic Impact Classification for Alien Taxa* (Bacher et al. 2018), with quantitative approaches through databases like *InvaCost* (Diagne et al. 2020; Ahmed et al. 2023).

Decision-makers should strive to communicate the risks and impacts, negative and positive, of biological invasions across different sectors of the communities directly affected, and involve affected community members in decision-making processes (Reed et al. 2023, IPBES 2023). Equally, they should identify and raise awareness of alternative native resources that could provide similar benefits. The *Nature's Contributions to People* framework (Diáz et al. 2018) acknowledges that nature has a plurality of values, including intrinsic, instrumental, and relational values, and that decision-making and policy design should be informed by these different and complementary perspectives (IPBES 2019). For example, Indigenous Peoples and local communities might perceive the introduction of a non-native fish as an opportunity for fishing (Lima et al. 2010), or a non-native tree species as a source of shade and timber (Kull et al. 2019) without being immediately aware of the negative impacts on native species populations, on loss of arable land or health issues (Shackleton et al. 2019b). Differences in perspectives between regions can be due to differences in socio-economic development and access to natural resources (Meyer and Fourdrigniez 2019). That the public is sometimes more aware of direct, positive effects than indirect, negative ones (Sax et al. 2022) is not a good reason to abandon the management of biological invasions.

Conclusion

Positive effects of biological invasions do occasionally exist and should not be ignored by policymakers (Shackleton et al. 2019a, Vimercati et al. 2020). However, acknowledging these benefits does not negate the necessity of evaluating the overall impact (IPBES 2023). Moreover, global efforts to create evidence for the benefits of biological invasions are lacking, and do not match the recently collated evidence for its costs. In the absence of such matching evidence, it is incorrect to propose a comparability of the benefits and costs of biological invasions. While benefits, unlike costs, lack a monetary synthesis, it is important to recognise that benefits and costs often affect different stakeholders, operate over divergent time scales, and are viewed through diverse socio-ecological perspectives. Promoting the benefits of biological invasions can also hinder management and thus increase costs in the long term. The evidence and arguments we provide here demonstrate that it is ethically and scientifically dubious to argue for prioritising the limited economic benefits of biological invasions in the face of their overwhelming negative ecological, economic, and social impacts. Calls for shifting focus to the monetary benefits of biological invasions risks undermining the much-needed awareness and support to mitigate them.

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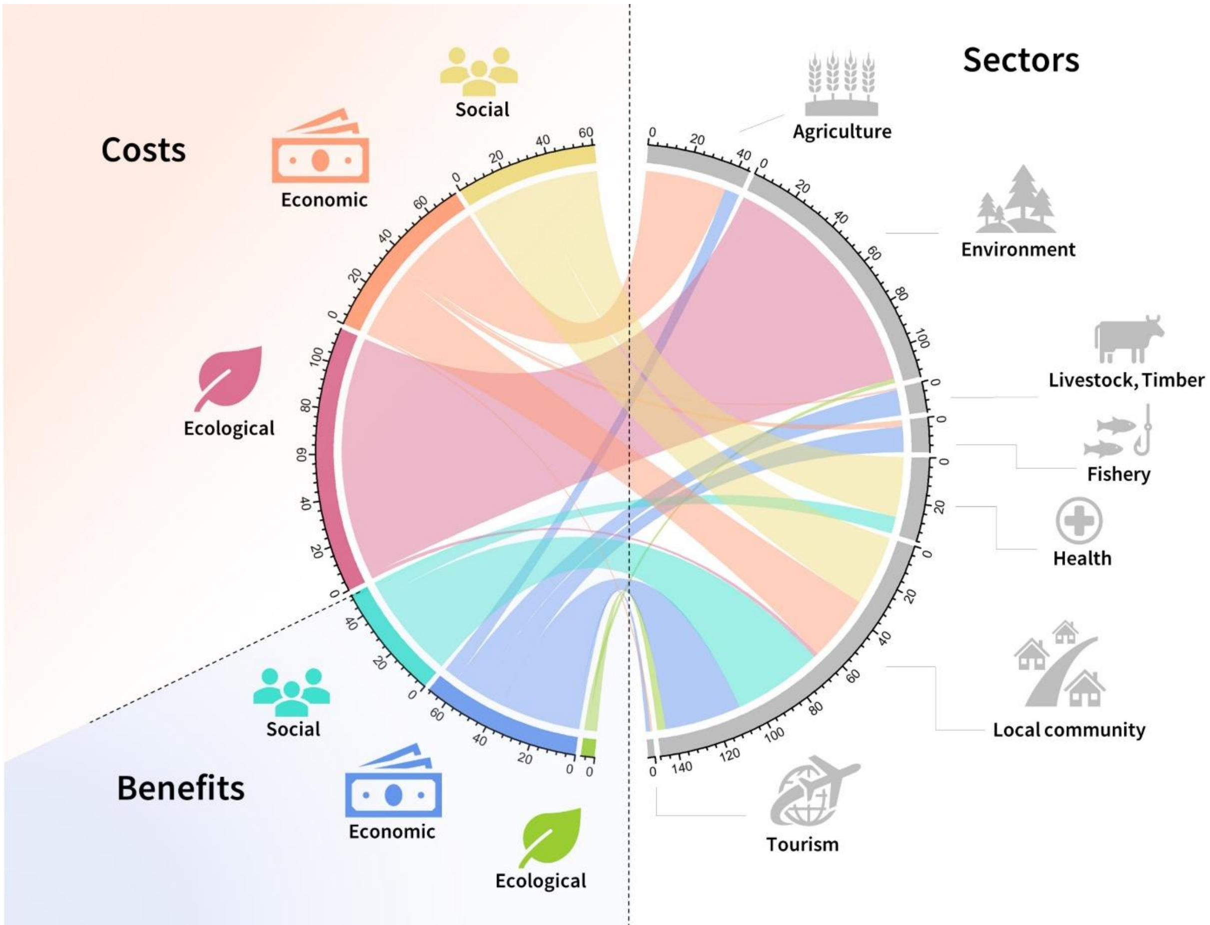

Fig. 1. Number of cases of costs and benefits of invasive species as indicated by respondents from local communities and recorded in the database of Kelsch et al. (2020), and flows towards the sector(s) they affect. We have labelled the 'desirable' positive effects as beneficial, while those effects described as 'undesirable' as costs. There are more cases of costs than benefits, and different sectors are implicated. The database, which separates the desirable and undesirable effects of invasive species, was reclassified as benefits and costs (economic, social, ecological) related to sectors (local community, health, tourism, fishery, farmers, environment, agriculture). Social costs are non-monetisable, such as impediments to movement, health problems, and cultural practices. Ecological costs include biodiversity loss and environmental

degradation. Economic costs include loss of arable lands, production (e.g., crops, fisheries, livestock), primary resources, and water supply. Social benefits include cultural practices, resource provisioning (e.g., food and fuel), and medicinal uses. Economic benefits include commercial use of resources (e.g., fuel, fishery, timber), and tourism. Ecological benefits are reported for increasing water supply, soil fertility, and control of other invasive species, although they are secondary to previous impacts reported (e.g., drought, ecosystem degradation, introduction of invasive species).