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EDITORIAL

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The economic costs of biological invasions around the world

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A large and increasing number of ecosystems of the planet are now invaded by alien species, resulting in detrimental impacts on biodiversity, human health, and ecosystem services (IPBES 2019). Many of these impacts can be defined and quantified as economic costs; expenditures to prevent, reduce or mitigate the losses caused by invasive alien species (IAS). Reports on the global economic costs over the last 50 years estimate that IAS are responsible for a minimum of US$1.288 trillion (2017 US dollars) in damages, a number that is steadily rising over time (Diagne et al. 2021a). Understanding and estimating economic damages caused by IAS is particularly important given that new introductions of alien species and impacts are increasing globally with no sign of slowing down (Seebens et al. 2017; Essl et al. 2020). In addition, just as current and future projections of numbers and types of IAS vary across ecosystems (van Kleunen et al. 2015; Essl et al. 2020), impacts and costs of biological invasions differ widely across space and time (Angulo et al. 2021b; Diagne et al. 2021a). Improving economic cost estimates of biological invasions across regions helps scientists, managers, and stakeholders to develop and inform benefit-cost analyses and policies for dealing with invasive alien species. Previous studies have modelled and estimated the economic costs of biological invasions for specific countries (e.g., Pimentel et al. 2005; Hoffmann and Broadhurst 2016) or globally (e.g., Diagne et al. 2021a), but a standardized assessment of costs of biological invasions with detailed information for countries and regions was lacking for most regions of the world. In this special issue on the "The economic costs of biological invasions around the world," 63 authors address this issue by bringing together 19 papers from 13 countries and 6 supra-national regions that report on the economic cost-dimension of biological invasions (Fig. 1, Table 1). Collectively, they provide a global, innovative perspective detailing the economic costs of biological invasions while also providing regional information to help raise public awareness, and support efficient and cost-effective decision-making.

All papers in this special issue are based on the InvaCost database (Diagne et al. 2020). InvaCost is a global database built from a systematic review on reported economic costs of biological invasions in peer-reviewed articles, official reports and gray literature; it considers impacts caused by any alien species that result in economic costs on any human activities (Diagne et al. 2020; Angulo et al. 2021b). With observations obtained from sources across 16 languages, the resulting database is considered the most comprehensive, harmonized and robust global-scale data compilation and description of economic cost estimates associated with alien species reported in the literature (Diagne et al. 2020; Angulo et al. 2021b). Yet, cost accounts of alien species are unavailable or undocumented for many parts of the globe. When costs were available, they were generally concentrated in specific regions and were mainly attributed to agriculture, human health, and terrestrial habitats. Here, we outline some of the key messages from the papers in this special issue and synthesize the main findings.

Despite being widely recognized as a major threat to biodiversity and ecosystem services, reported economic costs of prevention, control, and damage of biological invasions on biodiversity and conservation are surprisingly rare. Perhaps just as perplexing, alien species are rarely identified as a leading threat to global agriculture and human health (but see Nuñez et al. 2020; Eschen et al. 2021; Vilà et al. 2021), but many of the papers in this special issue found some of the largest costs impact these sectors. For instance, agricultural losses and damage were the main component of reported costs for Africa (Diagne et al. 2021b), the Americas (Crystal-Ornelas et al. 2021; Heringer et al. 2021), and Asia (Kirichenko et al. 2021; Liu et al. 2021; Watari et al. 2021). Human health costs were strongly related to mosquitoes of the genus *Aedes* and were a main component of reported costs for Brazil (Adelino et al. 2021), Central America (Heringer et al. 2021) and Singapore (Haubrock et al. 2021b). Conversely, economic costs of preventing or mitigating alien species impacts on biodiversity and ecosystem services were virtually non-existent, with a few exceptions. In Ecuador, most cost reports were from one region only, the Galapagos Islands – a biodiversity hotspot –, aimed at controlling alien species impacting natural habitats (Ballesteros-Mejia et al. 2021). Similarly, Japan intensively invested in alien species management on small islands with high conservation value (Watari et al. 2021).

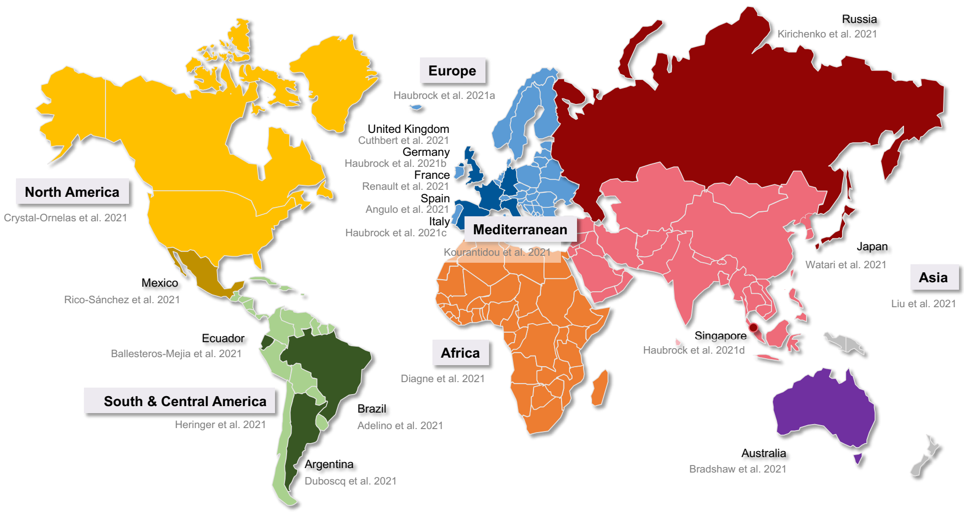

Figure 1. Distribution of studies on economic costs of biological invasions. Lighter tones represent continents and regions covered by the special issue "The Economic Costs of Biological Invasions Around the World." Delineation of countries does not imply data availability for every country depicted in that region or continent. Darker tones represented countries with assessments at national levels. Gray represents regions not included in the special issue.

Table 1. Reported economic cost of invasive alien species for 13 countries and 6 supra-national regions, main type of expenditure reported (realized and expected), ecosystem with most cost reporting, main biological group for which economic cost was reported, number of invasive alien species for which economic cost was found and reference. Expenditure values are not directly comparable as studies have used different analytical approaches. We strongly suggest readers refer to the original papers cited in the table for detailed explanations on data gathering, analytical approach, potential limitations and recommendations.

Region	Expenditure (US$ million)	Main expenditure	Main system	Main group	Number of IAS with cost data	Reference
Africa	**78,900.00**	**Damage**	**Terrestrial**	**Animal**	**62**	**Diagne et al. (2021b)**
Asia	**432,600.00**	**Damage**	**Terrestrial**	**Animal**	**88**	**Liu et al. (2021)**
Japan	728.00	Management	Terrestrial	Animal	54	Watari et al. (2021)
Russia	51,520.00	Damage	Terrestrial	Animal	72	Kirichenko et al. (2021)
Singapore	1,720.00	Damage	Terrestrial	Animal	3	Haubrock et al. (2021b)
Australia	**298,580.00**	**Damage**	**Terrestrial**	**Plants**	**172**	**Bradshaw et al. (2021)**
Central and South America	**146,500.00**	**Damage**	**Terrestrial**	**Animal**	**81**	**Heringer et al. (2021)**
Argentina	6,908	Damage	Terrestrial	Plants	15	Duboscq-Carra et al. (2021)
Brazil	105,530.00	Damage	Terrestrial	Animal	16	Adelino et al. (2021)
Ecuador	626.00	Management	Terrestrial	Animal	37	Ballesteros-Mejia et al. (2021)
Europe	**140,200.00**	**Damage**	**Terrestrial**	**Animal**	**381**	**Haubrock et al. (2021c)**
France	11.535	Damage	Terrestrial	Animal	98	Renault et al. (2021)
Germany	9,800.00	Management	Terrestrial	Animal	28	Haubrock et al. (2021a)
Italy	819.76	Damage	Terrestrial	Animal	15	Haubrock et al. (2021d)
Spain	261.00	Management	Terrestrial	Plants	174	Angulo et al. (2021a)
United Kingdom	17,600.00	Damage	Terrestrial	Animal	42	Cuthbert et al. (2021)
Mediterranean	**27,300.00**	**Damage**	**Terrestrial**	**Animal**	**218**	**Kourantidou et al. (2021)**
North America	**1,260,000.00**	**Damage**	**Terrestrial**	**Animal**	**164**	**Crystal-Ornelas et al. (2021)**
Mexico	5,330.00	Damage	Aquatic	Animal	35	Rico-Sanchez et al. (2021)

We can only speculate why most cost data come from agricultural and health sectors and rarely from the environmental sector. One reason might be that agriculture and human health are more commonly viewed as economic activities, whereas the economic value of biodiversity and ecosystem services preservation is often not recognized (i.e., crops and drugs are economic products, but biodiversity is not). Further, quantifiable economic impacts attributed to biodiversity loss and the environment tend to be indirect, making them more challenging to collect and estimate. Another reason might be that alien species are managed in conservation areas to maximize biodiversity protection, whereas, on farms, they are managed to optimize crop yield and revenue, making it easier to monetize gains and losses in agricultural systems. Overall, many of the papers in this issue encourage people engaged with biodiversity and natural resources management to document and report the costs associated with IAS.

Just like cost data were only available for a select few territories and industries, economic cost estimates were only available for a limited number of alien species (at most, 10% of known IAS in a given region). Europe reported costs for the largest number of species: 381 for the continent (Haubrock et al. 2021c), 174 for Spain (Angulo et al. 2021a), 98 for France (about 10% of known IAS in the region) (Renault et al. 2021), 42 for the United Kingdom (about 8% of known IAS in the region) (Cuthbert et al. 2021), 28 for Germany (Haubrock et al. 2021a), and 15 for Italy (Haubrock et al. 2021d). However, besides Europe, numbers of alien species with cost reports were smaller. For instance, all North America reported costs for 164 species (Crystal-Ornelas et al. 2021), Australia had costs for 172 species (Bradshaw et al. 2021) and South and Central America had costs for 80 species (Heringer et al. 2021). Fungi and microbes were rarely mentioned.

Aside from alien insects, which were frequently reported in the papers of the special issue, data were unavailable for a large number of alien species (Pagad et al. 2018). Thus, it is not possible to compare patterns of costly species across countries and regions. However, Heringer et al. (2021) suggest a promising approach for comparing economic impacts of biological invasions across countries or regions – the concept of hyper-costly species. Comparisons of costs of alien species broken down by control and damage costs, may allow governments, practitioners, and stakeholders to evaluate the pros and cons of different management strategies and actions.

The papers in this special issue also highlight the challenge of comparing economic costs and damages over time. Most of the reported cost estimates are recent, so long-term trends on economic costs of biological invasions are not available in most publications, with the exception of the UK (Cuthbert et al. 2021). It is also important to note that a lag exists between observed and reported impacts, which is why most papers showed a decrease in costs in recent years. For the UK, where long-term trends were examined, authors show that species with longer resident times had higher costs (Cuthbert et al. 2021). Despite reporting mostly recent cost estimates and the observed lag between expenditure and cost reporting, none of the publications in the special issue conclude that economic costs will flatten or decrease in the future. As more alien species become introduced into new regions, and alien species that are already present in a region often spread further, we can only expect that damage and management costs will continue increasing.

Taken together, all publications in this special issue “The Economic Cost of Biological Invasions Around the World” estimate global realized and potential economic impacts of biological invasions around US$2.3 trillion (2017 US dollars) (Table 1, excluding overlapping costs between countries and supra-national regions). However, at the same time, one of the most common themes across all the publications in this special issue is that the true economic costs are underreported, as cost data were unavailable for many groups (e.g., microorganisms), systems (e.g., marine) and regions (e.g., Central America). This special issue highlights the need to publicly document the high economic impact that alien species can have on people’s lives, especially since the number of biological invasions is projected to increase (Seebens et al. 2017; Essl et al. 2020). To achieve this, it is imperative that researchers and practitioners collaborate on the assessment and reporting of economic costs of biological invasions. More and better data are needed to evaluate the costs and benefits of IAS management actions, and these costs need improved documentation.

In conclusion, the global map of expenditures with alien species shows that societies have been paying for the post-introduction management of alien species impacts with very little reported investment in prevention of biological invasions. While prevention might not necessarily be cheaper than control and impact mitigation efforts, in many cases it can help diminish the costly environmental, agricultural, and health impacts observed throughout this special issue. As a result, reducing globally the damage costs of biological invasions likely requires spending more money and effort undertaking prevention, early detection, and rapid response. Finding ways to minimize damage is essential because as the articles in this special issue highlight, the economic costs of biological invasions are only likely to increase in the future.

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