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ALIEN INVASIVE SPECIES: A MAJOR DRIVER OF NATIVE SPECIES DECLINES AND EXTINCTIONS?

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Abstract Although there is wide consensus that biodiversity is threatened worldwide by human activities, the role that alien invasive species (AIS) play in this process is controversial. Many reports have addressed this issue, but their conclusions differ widely. Disagreements are partly due to the fact that drivers of species declines and extinctions are multiple and concurrent, and unevenly distributed among taxa and geographic regions, but con- icting interpretations of the same sources of information seem to play an important role as well. These discrepancies underscore our poor understanding of the role of AIS in the declines and extinctions of native organisms, hindering decisions associated with resource allocation for management actions.

Palabras clave
Especies exóticas invasoras
Extinciones
Especies naticas
Impactos
Mermas en la biodiversidad

Resumen Especies exóticas invasoras: ¿un causante primario de la declinación y extinción de especies nativas? Si bien existe un consenso amplio en que a nivel mundial la biodiversidad está amenazada por las actividades humanas, el rol que en este proceso desempeñan las especies exóticas invasoras es controvertido. Muchos estudios analizaron esta relación, pero sus conclusiones di eren marcadamente. Estas diferencias son en parte debidas a que los factores responsables de las mermas en las cantidades de especies y en su extinción son múltiples y concurrentes, y sus efectos varían mucho, tanto entre taxones como entre áreas geográ cas. Sin embargo, interpretaciones disímiles de las mismas fuentes de información también parecen ser muy importantes. Estos desacuerdos ponen en evidencia nuestro escaso entendimiento acerca de la importancia de las especies exóticas invasoras en los mecanismos que determinan las declinaciones en la biodiversidad y las extinciones de las especies nativas, afectando las decisiones relacionadas con la administración de los recursos destinados a acciones de manejo y mitigación.

1. Introduction

In the last decades, alien invasive species (AIS), and their environmental and economic impacts, have become a hotspot in the area of ecology and conservation, as well as an issue of numerous debates (Shackleton et al. 2022). Although information on the topic has been growing fast worldwide, opposing evidence is pervasive in the literature (Lévêque 2022). A major issue at stake is to what extent AIS are responsible for the decline and extinction of native organisms. The purpose of this this note is pointing out several con icting pieces of information which illustrate the discordances involved, and to overview their probable causes.

2. Methods

This article is based on a non-exhaustive review of the literature, centering chie y on the information produced during the last ~20 years.

3. Results

In 2016, C. Bellard and coauthors (Bellard et al. 2016) concluded that that "...alien species are the second most common threat associated with species [plants, amphibians, reptiles, birds and mammals] that have gone completely extinct... since AD 1500." According to this survey, for the species with a single extinction driver listed in the 2015 version of the IUCN (International Union for Conservation of Nature) Red List, alien species comprised from 17% (plants) to 47% (mammals). Two years later, M. A. Dueñas and coauthors (Dueñas et al. 2018) found that of the 1363 endangered and threatened species protected under the United States Endangered Species Act (plants, invertebrates, shes, amphibians, reptiles, birds and mammals), only 6.2% were backed by scienti c evidence supporting the negative impacts of AIS.

While differences in the groups, categories (extinct vs. endangered), geographic regions, and time-frames covered, and the sources of information used (Harris et al. 2012) may partially account for these disagreements, differences in the results are too large to explain them. Further, in these two surveys much higher proportions of AIS-related cases were found among the extinct (of all extinct species since AD 1500) plants and animals, than among the ones only “negatively impacted” (of all impacted species).

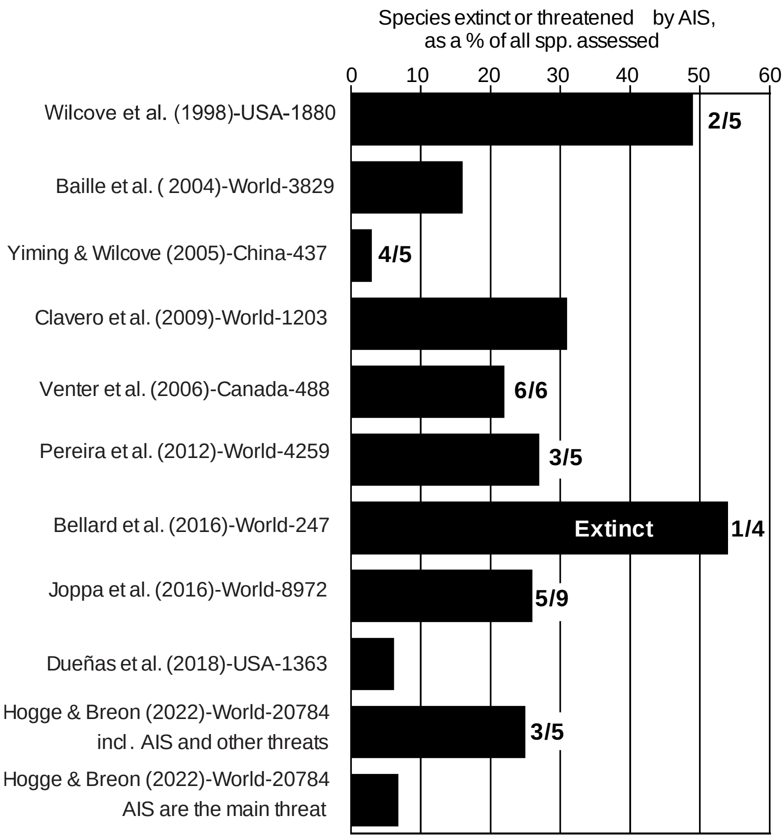

Fig. 1. Examples of proportions of extinct or endangered species for which AIS have been reported to be a driver. X-axis denotes the source of the information illustrated-geographic coverage-number of species assessed. Most values are chiefly based on plants and vertebrates. Data are sorted in ascending year of publication order. All values refer to threatened species, with the exception of Bellard et al. (2016), which refers to extinct or extinct in the wild organisms. Numbers next to bars denote rank of impact by AIS as compared with the number of all threats considered (when explicitly stated). Figures based on IUCN’s threat categories include AIS and “other problematic species, genes & diseases”.

These two examples are but a small fraction of the many widely contrasting conclusions published (Fig. 1). Several other studies arrived at different results, either in favor of the premise that AIS are among the primary drivers of biodiversity loss (Vitousek et al. 1996, Wilcove et al. 1998, Clavero and Garcia-Berthou 2005, Clavero et al. 2009); that they are much less important than other human activities, such as agriculture, resource use, urbanization, and system modification (Joppa et al. 2016, Harfoot et al. 2021, IUCN (International Union for Conservation of Nature) 2022) (Fig. 2); or that their impacts are variable and often of minor importance, are the primary threat for comparatively small numbers of native species, or the information supporting their deleterious effects is largely lacking (Gurevitch and Padilla 2004, Venter et al. 2006, Davis 2013, Thomas and Palmer 2015, Nelson et al. 2017, Hogue and Breon 2022). These discrepancies have been noticed years ago and alternative strategies for approaching this issue were proposed (Roberts et al. 2013, Ridley et al. 2022), but despite the massive growth of published information on the impacts of AIS (Boltovskoy et al. 2018) the gap does not seem to be closing.

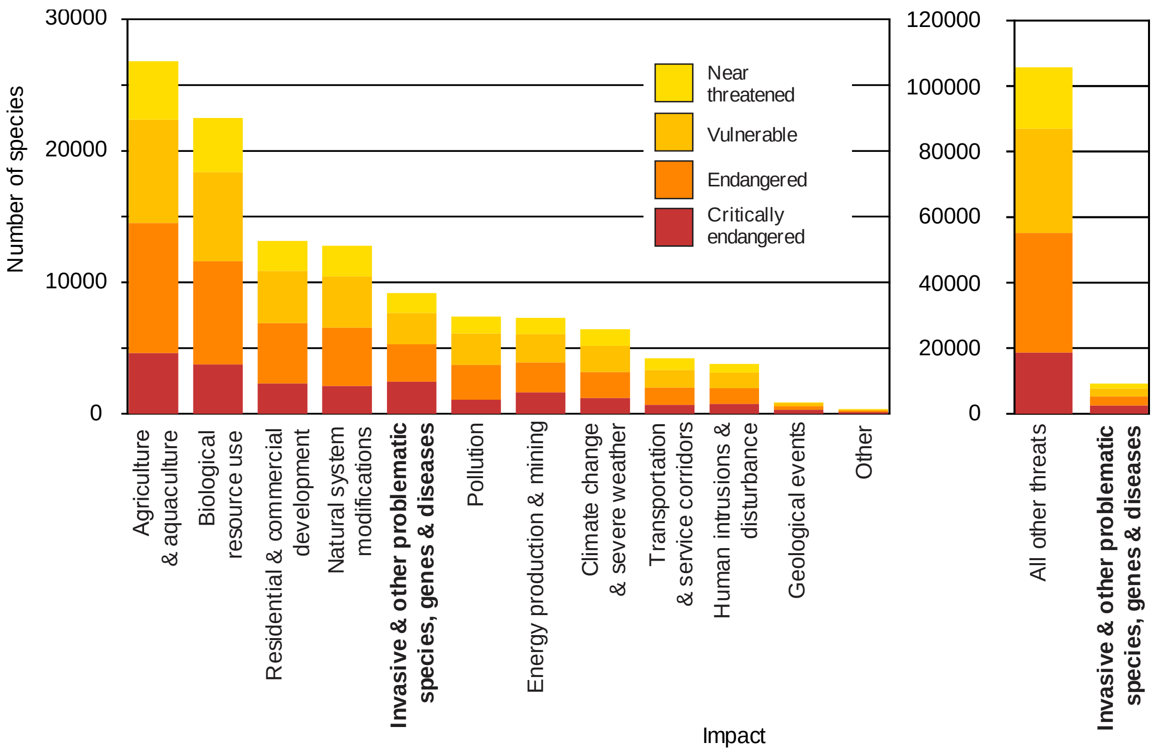

Fig. 2. Numbers of endangered, near threatened and vulnerable species in the 12 threat categories defined in the IUCN's Red List 2022 version. Left: binned by threat category; right: all other threats and threats by "Invasive & other problematic species, genes & diseases". Note that many species are included in more than one threat category [from data in (IUCN (International Union for Conservation of Nature) 2022)].

4. Discussion

Different interpretations of the data at hand, sometimes associated with adherence to a particular standpoint, are probably major reasons for these divergent conclusions (Pouteau et al. 2021, Bellard et al. 2022), as suggested by the fact that many surveys used largely the same source (the Red List of the IUCN), albeit in different versions (Clavero and Garcia-Berthou 2005, Clavero et al. 2009, Bellard et al. 2016, Howard et al. 2020, Harfoot et al. 2021, Hogue and Breon 2022, Ridley et al. 2022).

In some cases, questionable information might be responsible. For example, the report by Wilcove et al. (Wilcove et al. 1998), concluding that AIS are the second-greatest extinction threat in the world, has serious limitations and is based on biased information, as the authors themselves were careful to acknowledge (Davis 2013), yet it has been cited 2172 times (SCOPUS, August 2022). The same applies to at least some of the reports claiming that AIS are not a major threat, often due to potential biases in the information used (Venter et al. 2006; also acknowledged by the authors). Another major hindrance is that objective studies comparing the numerous threats to species survival are comparatively few; most focus on just 1-3 of the ca. 20 most frequently mentioned (Ridley et al. 2022), and the causes of species declines are often multiple, concurrent, context-dependent, and very difficult to tease apart (Didham et al. 2005, Berglund et al. 2012, Howard et al. 2020, Pouteau et al. 2021). For example, of the 8972 species identified as threatened by Joppa and coworkers (Joppa et al. 2016), only 1.3% were reported as affected only by AIS, whereas 24% were endangered by AIS and 1 to 8 (mean: 3.3) of the other 8 threats considered (not explicitly associated with AIS). Further, extinctions and declines are very unevenly distributed among taxa and geographic regions (Fig. 1), although the same sources also produced very different results for the same taxa, areas, and time-frames. For example, Venter et al. (2006) reported that AIS were involved in ~27% of threatened Canadian freshwater fish species (usually as a secondary cause). Using the same data (COSEWIC - Committee on the Status of Endangered Wildlife in Canada), the same year Dextrase and Mandrak (2006) concluded that AIS were the primary cause for the declines of 34% of freshwater fishes, and the primary or subsidiary cause for 63%.

Because of their higher visibility and charisma, as a function of their numbers of species vertebrates (in particular amphibians, reptiles, birds and mammals) have received much more attention than other organisms. According to the IUCN Red List (IUCN (International Union for Conservation of Nature) 2022), by 2022 80% of the vertebrates had been evaluated in terms of the threats for their subsistence, as opposed to only 4.3% for fungi, protists, plants and invertebrates, which comprise 97% of all described organisms. As stated by the IUCN, "For many of the incompletely evaluated groups, assessment efforts have focused on those species that are likely to be threatened; therefore any percentage of threatened species for these groups would be heavily biased (i.e., the % of threatened species would likely be an overestimate)."

Geographically, islands, which are more vulnerable to the impacts of AIS than continents (Blackburn et al. 2004, Kier et al. 2009, Russell et al. 2017, Leclerc et al. 2018), can also be over-represented in global and regional surveys (Clavero et al. 2009). Although islands account for only ~5% of the overall land surface (Weigelt et al. 2013), and relatively small proportions of species worldwide (17-19% of flowering plants, birds and rodents; Tershy et al. 2015), their fractions of extinct and threatened species due to AIS are much higher than those on continents (Tershy et al. 2015, Russell and Kueffer 2019). All the native plants endemic to islands are reported to have AIS as at least one of the factors contributing to species declines in the IUCN Red List (Pouteau et al. 2021).

On the other hand, the impacts of AIS on biodiversity loss have also been suggested to be significantly underestimated, largely because of underreporting by less developed nations (McGeoch et al. 2010).

Regardless of the reasons for such disparate estimates, these figures underscore our poor understanding of the role of AIS in the declines and extinctions of native organisms, and even the conceptual appropriateness of ranking the drivers involved. These rankings have been suggested to hinder - rather than facilitate - our understanding of the processes responsible for biodiversity declines and species extinctions (Pouteau et al. 2021, Bellard et al. 2022). However, while based on solid arguments, the solutions proposed involve holistic approaches which require much more knowledge than we presently have, and more demanding experimental and observational work than most scholars are willing or able to undertake. Further, given the high context-dependency of the impacts of AIS in general (Boltovskoy et al. 2021), including those on biodiversity declines (Didham et al. 2005, MacDougall and Turkington 2005, Pouteau et al. 2021), with few exceptions (e.g., islands vs. continents), new data are unlikely to yield generally applicable cause-effect relationships.

While many surveys coincide that worldwide biodiversity (taxonomic, functional and genetic) is being eroded at unprecedented rates (Gonzalez et al. 2016, Ceballos et al. 2017, Mimura et al. 2017, Leigh et al. 2019, Ridley et al. 2022) (but see also He and Hubbell 2011, Ellis et al. 2012, Vellend et al. 2013, Bull and Maron 2016, Briggs 2017, Blowes et al. 2019, Humphreys et al. 2019), the relative importance of the underlying drivers is still very controversial. The role of invasive species very rarely tops the rankings of the threats identified. As of 2022, in terms of numbers of organisms affected worldwide, AIS are fifth out of the 12 threat categories proposed by the IUCN (Fig. 2), even though the category in question ("Invasive and other problematic species, genes & diseases") is not restricted to AIS *sensu stricto* as it includes both native and non-native plants, animals, pathogens, microbes, and genetic materials that have or are predicted to have harmful effects on biodiversity following their introduction, spread and/or increase in abundance, or AIS are considered as a secondary effect of other forcings (Pereira et al. 2012, Bellard et al. 2022). Moreover, because these surveys center on the deleterious impacts of AIS on biodiversity, the effects of AIS that enhance biodiversity (Thomas 2013) without affecting native species

(Thomas and Palmer 2015), help the recovery of endangered natives (Bruestle et al. 2018), and restore degraded ecosystems providing valuable ecological assets (Martinez-Cillero et al. 2019, Burlakova et al. 2022) are often ignored.

These comments should not be interpreted as an attempt to downplay the negative impacts of many AIS on biodiversity, but rather as a call to improve the critical appraisal of the data available, thus aiding in the provision of more reliable information for scientists, managers, policymakers, stakeholders and society in general for a more efficient allocation of efforts and resources in the quest for culling human-driven biodiversity declines worldwide.

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