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**Viewpoint**

# Systematic and persistent bias against invasion science: Framing conservation scientists

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Pereyra and colleagues (2024) accused conservation scientists of bias against nonnative species and asserted that this bias casts doubt on the findings of the entire field of invasion biology. They based this argument on a subjective review of the introduction sections of 300 publications on the ecological effects of nonnative species, which they scored in terms of how they thought these introductions were framed: positive if framed as a conservation opportunity, neutral if framed as an ecological phenomenon, and negative if framed only as a conservation problem. They scored 66% of the articles as negative, 33% as neutral, and 1% as positive. Furthermore, they found no notable differences in the degree of negative framing across taxonomic groups, habitat types, and geographic regions, leading to their assertion of an overall bias pervading all published research on nonnative species. Pereyra and colleagues (2024) also speculated that the zebra mussel invasion in North America strongly influenced the early establishment of the bias and that the greatest percentage of negatively framed publications was from North America. However, in their view, the bias is universal.

Their explanation for the perceived bias is that "the diversity of views found across society is not allowed to express itself freely in academic spaces" and that "there is evidence that there is a concerted effort to stifle divergent voices." They were ambivalent about whether a scientific consensus on the ecological impacts of nonnative species exists but claimed that, if it does, it is based on ideology rather than research. Similar accusations of bias have been leveled against climate change research and reporting (e.g., Michaels 2008, Brimicombe 2022, but see Harlos et al. 2017). Surely, ideology (e.g., economic libertarianism, conservation ethics, or animal rights philosophy) can motivate investigations and critiques, but the degree of scientific rigor required to cast doubt on an entire field of research that has informed ecology and management for decades would be very high indeed, as it would be for climate science, immunological research, and other fields subjected to accusations of bias.

Fortuitously, we can quickly establish that there is, in fact, a formidable international scientific consensus that nonnative species in general pose ecological, economic, public health, and other threats (Schwindt et al. 2023). The report of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) on invasive alien species and their control (Roy et al. 2023) was recently approved by 143 member states representing all world regions. The report presented compelling evidence that people and ecosystems all over the world suffer adverse impacts from nonnative species. The negative impacts include global economic costs of hundreds of billions of dollars annually, costs projected to quadruple every decade and likely to worsen existing global inequities. Native species population extirpations owing to nonnative species erode diversity at all biological levels in a time of unprecedented global change and affect ecosystem function—for example, through the loss of pollinators, seed dispersers, and foundation species. Of the documented impacts of nonnative species, 85% were negative. The thoroughly documented information in this report removes any uncertainty about the negative consequences of nonnative species (Roy et al. 2023).

Pereyra and colleagues (2024) defined bias against nonnative species as the view that "all introduced species are regarded as invasive," and this is the bias they claim their framing study establishes. In fact, this bias has never been a pillar of invasion biology from Elton's early popular book (1958) through the initiation of the modern field with the SCOPE program of the 1980s and through to the present. Rather, as research on invasions has burgeoned, an initial belief that very few nonnative species were problematic gradually shifted to the view that substantial numbers are problematic, that research for most nonnative species is still insufficient to yield a good sense of their

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impacts, that an increasing number of nonnative species initially seen as innocuous are impactful, and that many of these impacts are harmful. This evolution is captured well by ongoing discussion of the tens rule (Williamson and Brown 1986, Williamson and Fitter 1996), proposed as part of the SCOPE program. The tens rule stated that 1% of nonnative species become pests. As research with diverse taxa suggested higher numbers, the continued citing of the tens rule, largely but not only in popular literature, frustrated many invasion scientists, who viewed it as a highly misleading low estimate (Jarić and Cvijanović 2012) and a zombie idea, a notion that survives despite abundant contrary evidence (Jeschke and Pyšek 2018). Mainstream invasion scientists today hesitate to estimate just what fraction of nonnative species leads to harm, but they agree it far exceeds 1%. For instance, for vertebrates, one recent rough estimate is 50% (Jeschke and Pyšek 2018). The claim of Pereyra and colleagues (2024) that "all introduced species are regarded as invasive" is particularly off base in light of a longstanding convention of invasion scientists and managers that distinguishes a subset of nonnative species as invasive, however defined (e.g., Colautti and MacIsaac 2004). We note two caveats: Most nonnative species in all major habitats have never been assessed for impacts of any kind, and in some habitats, such as the world's oceans, a vast number of nonnative species simply go unreported (Carlton and Schwindt 2024).

The impact estimates keep rising with the explosion of research on invasions. Multiple reasons, none acknowledged by Pereyra and colleagues (2024), account for the rise. One reason is simply the greatly increased amount of detailed research on more species. A second is that this research has revealed a wealth of examples in which an invasion previously assumed to be innocuous has proven harmful. Many invasions for which negative consequences were suspected early had striking visible impacts, such as vertebrate predators attacking seabirds on islands or zebra mussels smothering and killing native mussels. The scope and nature of the impact—and especially the population, community, and ecosystem consequences for the affected native biota—have required more detailed research, but at least the possibility of harm was obvious. Many other impacts are subtle, so even an initial suspicion would require unusual insight; the paradigmatic example is soil fertilization by a nonnative nitrogen-fixing plant (Vitousek 1986). As more types of subtle effects are documented, more scientists studying invasions are alert to their possibility. A third reason estimates of the percentage of introductions with harmful impacts keep rising is the phenomenon of the lag effect—that is, a situation in which an introduced population establishes but remains small or highly localized for an extended period then abruptly explodes and spreads, greatly increasing the severity and numbers of types of potential impacts. Many examples of such lags have been documented (e.g., Spear et al. 2021). A fourth reason is that an increasing number of species previously misinterpreted as native are recognized as overlooked or cryptic invasions. An example is the belated recognition that an iconic ecological engineer, smooth cordgrass (*Spartina alterniflora*), is a nonnative species along the entire Atlantic coast of South America (Bortolus et al. 2015).

These facts—the frequency of negative impacts, the difficulty of predicting and easily detecting many of them, and the challenges of management to minimize them—shape the prevailing attitude of conservation scientists toward biological invasions. It is not that all nonnative species are regarded as harmful. It is that they are all, to some extent, potentially harmful. This is why the IPBES report calls for enforcing biosecurity management strategies. Pereyra and colleagues (2024) mischaracterized the IPBES report, which did not oppose all nonnative species; it recognized that some are ultimately beneficial from particular perspectives. What it did urge is thorough consideration of possible impacts, vigilance against introductions that have not been subject to such consideration, and recognition of the variety of possible harmful impacts and difficulty of foreseeing them.

Pereyra and colleagues (2024) erred in attributing the prevailing perspective to ideology rather than to research. They assigned transcendent value to their own moral judgments, asserting, for instance, that those undertaking eradication programs for sentient invaders are callous and cruel, absent any knowledge of the considerations underlying the decision to undertake such programs, such as harm to individuals and threats to populations of native species. Of course, it is true that different stakeholders have different values (Bortolus and Schwindt 2022, Shackleton et al. 2022), as witness instances in which certain individuals prize particular nonnative species and others deplore them. However, simply asserting the primacy of one's views will not advance the understanding of invasion impacts or agreement on whether or how to manage them.

Pereyra and colleagues (2024) were also extremely selective in their statements about the status and impacts of invasions and the management of them. Their descriptions are general and give little or no indication of the entire context of phenomena. Therefore, for instance, they asserted, correctly, that "eradication programs of introduced species have had deleterious outcomes," citing one example. They did not provide references or context to the larger picture, that many more eradication programs have had strikingly beneficial conservation outcomes, including preventing native species extinctions, and that the technology to undertake such efforts is rapidly improving (Jones et al. 2016, Simberloff et al. 2018). Similarly, they stated that no nonnative plants are known to have caused extinction, citing a study (Downey and Richardson 2016) without noting that its authors studied impacts only on native plants, not other organisms, and that these authors pointed to numerous instances in which nonnative plants have lowered population sizes and spatial extents of native plants to the point where their existence is threatened and their ecological function is muted. Nor did Pereyra and colleagues (2024) acknowledge an enormous literature on inimical ecological effects of nonnative plants other than extinction, such as their well-known frequent impacts on fire regimes (e.g., D'Antonio and Vitousek 1992, Underwood et al. 2019).

Finally, we are concerned with aspects of how Pereyra and colleagues (2024) conducted their survey. First is the issue of who judges the framing. Although the criteria stated by Pereyra and colleagues (2024) seem reasonable, "conservation opportunity" and "conservation problem" can be interpreted variably, and their results rest on assignments by two of the authors or three when the initial two disagreed. The fact that disagreements occur makes the point that different observers, all acting honestly, can interpret the key message of a paragraph differently. A second concern is that the assignments rested entirely on the introduction sections of the surveyed publications. Discussion and conclusion sections often provide different and more nuanced perspectives or results than an introduction does. Introduction sections are partly designed to provide the rationale for conducting a research project in the first place and to suggest the importance of the topic. To both the scientific community and the larger public, the importance of the topic is often primarily a concern for potential damage; therefore, introduction sections tend to voice this concern.

In summary, it is appropriate that the prevailing attitude be to view all invasions as potentially harmful and unsurprising that a majority of publications, especially in their introduction sections, reflect this view. Although knowledge gaps exist, there is

consensus that this gap does not justify inaction. Furthermore, the metaphor of guilty until proven innocent, although imprecise as all metaphors are and vague about how such an approach should be implemented, is not facially inappropriate as Pereyra and colleagues (2024) suggested. Consider another metaphor. Actinic keratoses are premalignant dermatological lesions. A small fraction of them become invasive, potentially lethal squamous cell carcinomas (one estimate of yearly progression rates is 0.6%), and regression of actinic keratoses is believed to exceed 50% (Siegel et al. 2017). Nevertheless, the overwhelming prevailing medical advice is to survey skin frequently and to treat keratoses immediately, because carcinomas, should they arise, can threaten lives (Siegel et al. 2017, Marques and Chen 2023). This consensus is in spite of the fact that all treatments entail the risk of adverse side effects, such as pain, inflammation, difficulty healing, and scarring (Marques and Chen 2023). Nevertheless, despite the existence of a strong scientific consensus, a small minority of physicians do not advise prompt treatment but instead recommend waiting to see if a keratosis progresses toward a melanoma before treatment (Petrou 2008), just as some critics of the scientific consensus on invasions advocate waiting until an adverse impact is noted before attempting management (e.g., Davis et al. 2011). The great majority of dermatologists believe the risk of failed management is too great to allow delay of this sort before treatment. This metaphor exemplifies the precautionary principle that most scientists and managers apply to apparently benign nonnative populations, which can similarly irrupt into invasion problems (Spear et al. 2021), but, unlike for invasions, no one claims keratoses have benefits. Benefits are claimed for anthropogenic climate change (e.g., longer growing seasons or larger suitable areas for some crop plants), but, as with invasions, the overwhelming scientific consensus is that harm will greatly exceed benefits and that humankind should act now to minimize impacts (IPCC 2023). This is precisely the scientific consensus on the analogous case of biological invasions, and the framing of publications would be expected to reflect this view.

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