Conservation Biology

Comment

Beyond species counts for assessing, valuing, and conserving biodiversity: response to Wallach et al. 2019

Ninon F. V. Meyer,[1,2] Niko Balkenhol,[2] Trishna Dutta,[2] Maarten Hofman,[3] Jean-Yves Meyer,[4] Euan G. Ritchie,[5] Charlotte Alley,[1] Chad Beranek,[1] Cassandra K. Bugir,[1] Alex Callen,[1] Simon Clulow,[6] Michael V. Cove,[7] Kaya Klop-Toker,[1] Omar R. Lopez,[8,9] Michael Mahony,[1] Robert Scanlon,[1] Sandeep Sharma,[10] Elen Shute,[11] Rose Upton,[1] Emy Guilbault,[12] Andrea S. Griffin,[1,13] Edwin Hernández Pérez,[14] Lachlan G. Howell,[1] John-Paul King,[1] Dean Lenga,[1] Patrick O Donoghue,[1] and Matt W. Hayward[1]

[1]Conservation Science Research Group, School of Environmental and Life Sciences, University of Newcastle, University Drive, Callaghan, NSW, 2308, Australia
[2]Wildlife Sciences, Faculty of Forest Sciences, University of Göttingen, Büsgenweg 3, Göttingen 37077, Germany
[3]Regional Office for Eastern Europe and Central Asia, International Union for Conservation of Nature, Belgrade, 11073, Serbia
[4]Délégation à la Recherche, Gouvernement de la Polynésie française, B.P. 20981, Papeete, Tahiti, 98713, French Polynesia
[5]Centre for Integrative Ecology, School of Life and Environmental Sciences, Deakin University, 221 Burwood Highway, Burwood Campus, Melbourne, VIC 3125, Australia
[6]Department of Biological Sciences, Macquarie University, Sydney, NSW 2109, Australia
[7]Department of Applied Ecology, North Carolina State University, Raleigh, NC 27607, U.S.A.
[8]Instituto de Investigaciones Científicas y Servicios de Alta Tecnología, Edificio 219, Ciudad del Saber, Clayton, Panama, Postal 0843-01103, Panama
[9]Smithonian Tropical Research Institute, Ancon, Balboa, Panama, Postal 0843-03092, Panama
[10]Department of Conservation Biology, J.F. Blumenbach Institute of Zoology, University of Göttingen, Göttingen, 37073, Germany
[11]College of Science & Engineering, Flinders University, Bedford Park, Adelaide, SA, 5042, Australia
[12]School of Mathematical and Physical Sciences, University of Newcastle, University Drive, Callaghan, NSW, 2308, Australia
[13]School of Psychology, University of Newcastle, University Drive, Callaghan, NSW, 2308, Australia
[14]Department of Biodiversity Conservation, El Colegio de la Frontera Sur, Av. Rancho Poligono 2-A, Lerma, Campeche 24500, Mexico

Introduction

Wallach et al. (2019) propose including all non-native species when determining species richness, distribution, and threat status for biodiversity management and conservation purposes. Although contesting prevailing conservation paradigms is a useful way to critically examine and refine practice and policy, we argue that their proposal would lead to an artificial inflation in species counts and downplay the harm some non-native species cause to native species, human livelihoods, culture, and safety. Their approach, therefore, risks poor outcomes for conservation and society.

Importance of Terminology

Despite well-established terminology defined by the International Union for Conservation of Nature, Wallach et al. avoid using *invasive* and *alien* and apply the term *migrant* instead of *non-native*. *Migrant* is a well-accepted ecological term denoting seasonal or annual movement of animals, but Wallach et al. used it to

email ninon.meyer@newcastle.edu.au
***Article impact statement**: Combining native and non-native species to evaluate biodiversity is overly simplistic and may undermine the conservation of ecosystems.*
Paper submitted January 8, 2020; revised manuscript accepted July 3, 2020.

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Conservation Biology, Volume 35, No. 1, 369–372
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DOI: 10.1111/cobi.13665

anthropomorphize biotic interactions, thereby distracting from the empirical ecological considerations underpinning invasive species control. Wallach et al. (p. X) refer to *native animals* when mentioning the "historical wrongs enacted against Australia's original inhabitants," invoking and conflating language typically used to respectfully address Aboriginal and Torres Straight Islander People.

Non-native species are species moved to new areas by humans (e.g., rats [*Rattus* spp.]) or species naturally expanding or shifting their ranges, often in response to human-induced environmental change (e.g., tropical rabbitfishes [*Siganis* spp.]). Many climate-displaced species are increasingly relying on shifting range for their survival, usually moving within contiguous areas higher in latitude or elevation (Chen et al. 2011). The term *neonative* describes non-native species that were not deliberately moved by humans over large distances into new ecosystems (Essl et al. 2019), acknowledging that ecosystems are inherently dynamic (Lambertini et al. 2011).

Regardless of their origin, species are considered invasive when they sustain self-replacing populations, spread considerable distances, reach large numbers, and, most importantly, cause harm to biodiversity, agriculture, and human livelihoods (Simberloff et al. 2011). Only a small portion of the many non-native species worldwide are invasive (Lambertini et al. 2011), but this number is increasing along with their harmful impacts on local biodiversity (Seebens et al. 2017). Yet, management decisions are not made on the sole basis of terminology (Simberloff et al. 2011). For example, native wild boars (*Sus scrofa*) are managed across Europe, whereas widely distributed around the world non-native honey bees (*Apis mellifera*) are not subject to control. Instead, it is the magnitude of a species' impact on ecosystems that underpins its regulation, thereby often prevailing over the native versus non-native distinction. Because the effects of many neonative species are unknown, conservationists need to monitor their impacts closely and apply adaptive management when necessary.

Inequality of Species in Local Contexts

Wallach et al.'s recommendation to count all species equally, regardless of their origins or effects on ecosystems, can inflate the total number of species in an environment, thereby allowing "flourishing" of biodiversity. However, higher species counts resulting from biological invasion rarely translate to well-functioning ecosystems and do not address the fundamental biodiversity crisis, including habitat degradation, which is often exacerbated by non-native invasive species (Didham et al. 2007). Introduced species can disrupt interaction webs and functional diversity in communities, with dramatic consequences for ecosystem processes, and reduce biodiversity over time (Spotswood et al. 2012; Matsuzaki et al. 2013). For example, feral horses (*Equus caballus*) alter vegetation structure resulting in degraded habitat for many Australian threatened species (e.g., broad-toothed rat [*Mastacomys fuscus*]) (Driscoll et al. 2019). Equalizing all species irrespective of their effects would essentially create a conservation fata morgana, where relying on species counts as an index of ecosystem function risks adverse land-use decisions and resource allocation (e.g., for reserve selection or prioritization).

Ecosystem functioning and stability are not primarily influenced by species richness, but rather by variation in species composition and their relative abundances (Tilman et al. 2014). Species differ in their resource use, functional equivalency, environmental tolerances, and interspecific interactions (Saul & Jeschke 2015). Species that have coevolved often show intricate coadaptations and symbiotic relationships that non-native species can rarely replace (Saul & Jeschke 2015). Consequently, one cannot expect that the loss of a native species will always be functionally compensated by introduced, widespread species. For example, invasive European rabbits (*Oryctolagus cuniculus*) in Australia do not replace the soil engineering role of locally extinct native bilbies (*Macrotis lagotis*) (James et al. 2011), and rats are not as effective at dispersing seeds as native flying foxes *(Pteropus* spp.*)* of New Caledonian rainforests (Duron et al. 2017).

Replacing native species with widespread, generalist, invasive species promotes species homogenization and is akin to replacing Van Gogh's *Sunflowers* with a mass-produced print. Many native species hold deep cultural and spiritual values (Woinarski et al. 2015), whereas some introduced species imperil lives and livelihoods (e.g., hippopotamuses [*Hippopotamus amphibius*] in Colombia threaten water resources and humans who rely on waterways [Shurin et al. 2020]). Finally, the indirect effects of species introductions on human health are only starting to be examined. Mosquitoes (*Culex cedecei*) in the Florida Everglades are now feeding more on rodents that host zoonotic pathogens due to the collapse of native mammals caused by the introduced Burmese python (*Python bivittatus*) (Hoyer et al. 2017).

Nature is essentially in a constant state of flux (e.g., Pickett 2013), but we stress that humans have an ethical obligation to be accountable for and minimize the damage they cause to environments and native species by introducing, spreading, or poorly managing invasive species (Driscoll et al. 2019). Rapid environmental changes caused by invasive species often outpace resident species' abilities to adapt to these changes, and although some native species have overcome their naiveté relative to invasive predators, most cannot (Banks et al. 2018). Invasive species have caused major environmental degradation in native

ecosystems, including the displacement, decline, and extinction of native species, especially in island ecosystems (Meyer & Florence 1996; Doherty et al. 2016). In Australia alone, the extinction of at least 29 mammalian species is associated with the impacts of 4 non-native animals (e.g., red fox [*Vulpus vulpus*], European rabbit, domestic cat, and sheep [Lunney 2001; Woinarski et al. 2015]), which were deliberately introduced from Europe a few hundred years ago. Viewing this dynamic as a standard flux of nature is irrational because anthropogenic relocation of species often takes place over greater distances and shorter periods than natural movement of species. The catastrophic toll non-native invasive species exert on Australian native fauna provides clear evidence of how the negative impacts of some invasive species outweigh any ecosystem benefits. Assuming that nature itself heals every injury caused by humans means humanity avoids accountability and misrepresents the realities of species interactions, ecosystems, and evolution. Conserving native species and ecosystems may, therefore, sometimes require active suppression or removal of non-native invasive species (Lambertini et al. 2011). This said, the widespread and increasing creation of novel ecosystems (Hobbs et al. 2009) resulting from introduced species requires a greater understanding and adaptive management to achieve the best conservation outcomes.

Inadequacy of Using Out-of-Range Regions as Zoos to Safeguard Threatened Species

Safeguarding threatened species in regions outside their native ranges may have some merit depending on context (e.g., assisted migration, Hoegh-Guldberg et al. 2008). However, it does not justify widespread, assisted invasion at the potential expense of native biota. Worldwide, zoos and other facilities (e.g., botanical gardens) strive to maintain viable populations of species to ensure their long-term persistence by participating in coordinated captive breeding programs (Conde et al. 2011). Although such programs do not always succeed in preventing extinction, many cases illustrate the benefits to species of reintroducing them in situ (e.g., recovery of Przewalski's horse [*Equus ferus przewalskii*] after being declared extinct in the wild) or of restocking populations in the wild. Importantly, these programs succeed without negatively affecting native species and ecosystems.

The local conservation status of a species is often more meaningful than its global status. Downlisting species by pooling all populations worldwide could remove a driver of in situ conservation in their native range, where they may be at much greater risk of extinction. For example, including Australia's non-native population of banteng (*Bos javanicus)* in conservation assessments could cause government funding or conservation action in its native range to be withheld on the grounds that it is secure elsewhere. This would further divert funds from conservation programs in native ecosystems. Similarly, management of species in their introduced ranges should not be driven by their status in native ranges (e.g., Burmese pythons are vulnerable in their native range but must be managed in the Florida Everglades).

Conclusion

Combining native and non-native species in evaluations of biodiversity is overly simplistic and would undermine the conservation of functional ecosystems and their native species assemblages. We stress the severe potential harm to ecosystems and native species that could arise from implementing such an approach. It risks confusing policy makers and diverting limited resources. Instead, conservation should ideally focus on determining the full range of functions and impacts (positive and negative) of introduced species; predicting and assessing risks on a case-by-case basis for native, resident species (Banks et al. 2018); and developing practical, evidence-based approaches to control species if the environmental, economic, or cultural harm they cause outweighs benefits (Doherty & Ritchie 2017; Driscoll et al. 2019).

Acknowledgment

The basis of this paper arose on the land of the Awabakal people in which the Callaghan campus resides. NM is a fellow of the PRIME program of the German Academic Exchange Service (DAAD). We are grateful to K. Smith for valuable insights, B. Callicott and 2 anonymous reviewers for improving a previous version of this manuscript. We acknowledge support by the German Research Foundation and the Open Access Publication Funds of the University of Göttingen.

Open access funding enabled and organized by Projekt DEAL.

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