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LETTER TO THE EDITOR

Current understanding of invasive species impacts cannot be ignored: potential publication biases do not invalidate findings

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To the Editor,

Guerin et al. (2017) believe many nonnative species do not cause ecological harm and, therefore, underlying biases towards studying harmful species render meta-analysis unhelpful for designing effective management strategies. Invasion biologists already recognize this bias (Pyšek et al. 2008; Hulme et al. 2013). We argue that meta-analyses are indeed useful for managers for three reasons. First, most meta-analyses explicitly and honestly address bias. Second, for our meta-analysis (Kuebbing and Nuñez 2016), it is unlikely that more even sampling across types of nonnative species would lead to a different conclusion. Finally, and perhaps most importantly, the bias of studying nonnatives with suspected or known impacts focuses research on the exact subset of nonnatives most relevant to managers.

It is important to clarify terminology to understand the nature and implications of bias. Ecologists classify nonnative species into three categories: (1) *casual nonnatives* that do not form self-sustaining populations; (2) *naturalized nonnatives* that do form self-sustaining populations; (3) *invasive nonnatives* that form self-sustaining populations and spread beyond their original introduction point (Richardson et al. 2000). There is disagreement whether the definition of *invasive* should include a negative impact (Young and Larson 2011), but the best available evidence suggests that impacts increase with increasing spread and abundance (Simberloff et al. 2013; Hulme et al. 2013).

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Biased sampling of predominantly invasive nonnatives, assumed to have the largest impacts, could lead to misrepresentation of the average impact of all nonnatives. However, misrepresentation exists only if researchers do not explicitly state the types of nonnatives included in a study. The meta-analyses Guerin et al. criticize (Vilà et al. 2011; Kuebbing and Nuñez 2016) and others (Liao et al. 2008; van Kleunen et al. 2010; Paolucci et al. 2013; Castro-Díez et al. 2013; Twardochleb et al. 2013; Kuebbing and Nuñez 2015; Jackson 2015; Gallardo et al. 2016) include in their titles or text that the majority of data focusd on *invasive* nonnatives that are expected to have, on average, greater impacts than naturalized nonnatives (Fig. 1a).

Our meta-analysis considered the competitive impacts of nonnative plants on native and nonnative neighbors (Kuebbing and Nuñez 2016). Guerin et al. argue our results are misleading because of the underlying bias towards invasive nonnatives in the literature from which we drew our data. They propose that if there were more even sampling across types of nonnatives, the average impact of nonnatives would be neutral, or potentially even positive. We disagree for three reasons.

First, our results should not mislead because we were explicit that our study primarily considered invasive nonnatives. Furthermore, approximately 20% of our data observations that included nonnative species represented naturalized nonnatives and we found no difference in competitive effects of naturalized and invasive nonnatives (Fig. 1b). This supports the generalization that, on average, nonnatives have negative competitive impacts.

Second, our findings are resilient to an influx of data on nonnatives with neutral impacts. Because of the well-known bias against publishing null results, tools such as the fail-safe number assess the severity of this "file-drawer problem" (Rosenthal 1979). Using this tool, we see that an additional 235,294 neutral observations—or a 19,400% increase—would be necessary to shift the negative mean effect to zero. An estimated 13,168 plant species are naturalized outside of their native range (van Kleunen et al. 2015). Our findings are robust even if we knew that all these nonnatives had a neutral—not negative—competitive impact.

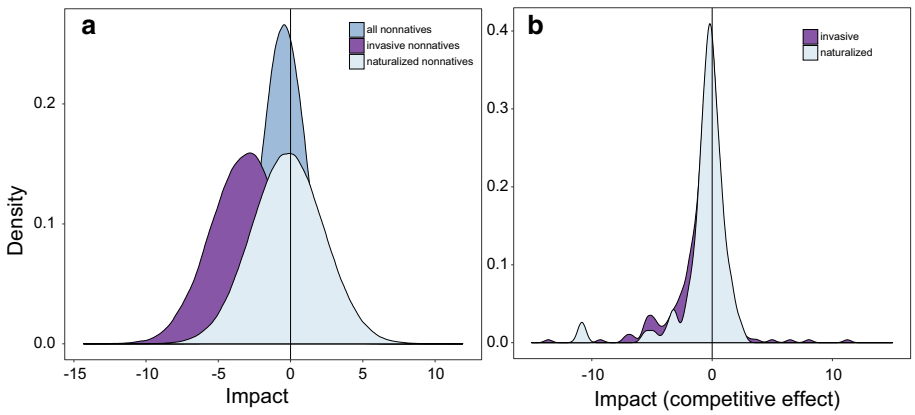

Fig. 1 Invasive and naturalized nonnative species are expected to have a different distribution of impacts, and therefore biased sampling of studies considering only invasive species may misrepresent the distribution of impacts for all nonnatives (**a**). However, empirical evidence demonstrates that the competitive impacts of invasive and naturalized nonnatives are similar, and that although the mean effect of nonnatives is negative the data captures many neutral and positive effects (**b**, data from Kuebbing and Nuñez 2016 Supplementary Information)

Third, if many more nonnatives had beneficial impacts then the true distribution of impact may shift to the right. However, the derth of evidence on the benefits of nonnatives suggests this is unlikely. As with negative impacts, positive impacts should be more common for more widespread and abundant nonnatives (Parker et al. 1999), which is exactly the subset of nonnatives that is most studied. Contrasting the small handful of studies cited by Guerin et al. with the hundreds of studies on impacts of invasive species (Vilà et al. 2011; Pyšek et al. 2012; Hulme et al. 2013) suggests that the authors are too confident in their belief that we are underestimating positive effects of nonnatives. Furthermore, it is likely that impacts will continue to rise owing to "invasion debts" (Essl et al. 2011) and that more studies on rarer nonnatives will show that even low-density nonnatives can have large impacts (Peltzer et al. 2009).

Science is built upon discourse, but it is imperative that disagreement does not venture into the realm of denialism (Simberloff et al. 2013; Richardson and Ricciardi 2013; Ricciardi and Ryan 2017). Many of Guerin et al.'s arguments fit within the set of common criticisms of invasion biology (Richardson and Ricciardi 2013) and inaccurately represent the broad scientific consensus on the frequency and potential severity of nonnative impacts (Simberloff et al. 2013; Richardson and Ricciardi 2013; Ricciardi and Ryan 2017). As conservation biologists, we surely wish that nonnatives—as with other forms of anthropogenic global change—were not problematic, but the vast majority of available evidence suggests that the environmental risks posed by invasive nonnatives are severe and lasting (Pyšek et al. 2012; Simberloff et al. 2013). While in rare instances nonnatives may provide benefits, most nonnatives will not (Simberloff et al. 2013). Although scientific paradigms change through time, paradigm shifts should be based on accumulating evidence. Instead of asserting that over three decades of research is misleading, critics should direct their own research programs towards providing this evidence.

Finally, and most importantly, because conservation practicioners overwhelmingly prioritize managing invasive, rather than naturalized, nonnatives (Kuebbing and Simberloff 2015), these meta-analyses focus on the subset of nonnatives most relevant to management. Calls to halt all syntheses of the best available data are unwise and irresponsible in a rapidly changing world. If the weight of the evidence changes, then it will be time to revisit these calls. For now, meta-analyses are important guides for conservation decisions.

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