We thank Vitule et al. (2012) for responding to our review “The Potential Conservation Value of Non-Native Species for Conservation.” Although scientists have long known that non-native species could be benign or beneficial in some regards, in practice most scientists and managers have treated all non-native species by definition as problematic. Gross inefficiencies and misguided programs have arisen in cases where policy was driven by such dogmatic views on non-native species (Stromberg et al. 2009). We are happy to read that Vitule et al. are in agreement with us that such biases should be actively eliminated, and we whole-heartedly agree with the last sentence in their reply, which reads: “The issue of species’ invasions is complex and necessitates a cautious, balanced view, including consideration of short-term and long-term introduction effects, both positive and negative.” We look forward to such assertions being put into practice. Indeed, we maintain that the vast majority of studies on non-native species conducted to date fail to properly consider any potential positive effects.

We disagree with Vitule et al. on numerous other points. For example, we believe they erroneously interpreted our primary message when they stated: “Their main message is clear: non-native species should be used for conservation given their potential desirable contributions.” We do not believe all non-native species should be used for conservation, and we do not even imply such a notion in our paper. In fact, we argued that the desirable and undesirable aspects of any non-native species must be evaluated carefully when deciding whether (and how) it should be managed. We further argued that it is important to do so for the sake of scientific objectivity and effective policy. It may well be that many non-native species have a sum negative effect, but this cannot be asserted until both potential positive and negative effects have been estimated. Our main point is clearly summed up in the last sentences of our paper: “In the past, risk analyses focused on negative events associated with non-native species, and a species was termed invasive if any significant negative effect was documented. Here, we suggest that both negative and positive potential effects of non-native species should be tallied. We also suggest that a more meaningful definition of an invasive species would be one for which there is a net negative effect. A dynamic view of nature that recognizes that species characteristics and human valuations thereof change over time, not only reflects ongoing evolutionary processes, but also leads to a more balanced and objective approach to the management of non-native species.” We, therefore, disagree with Vitule et al.’s interpretation of our main message.

We further believe that Vitule et al. misrepresent or misinterpret several points we raised in our article. We never discussed (explicitly or implicitly) the issue of intentional introductions. It is, therefore, a misrepresentation of our work to say that we put forth a “proposal to encourage introductions when predicted net effects are positive.” In fact, we believe that novel introductions—intentional and unintentional—are associated with great uncertainty and risk and that priority should, therefore, be given to preventing such introductions under most circumstances, with exceptions being granted, for example, to prevent extinction of certain species.

The authors also state we did not consider the uncertainty surrounding the long-term effects of non-native species, when they write: “... they do not acknowledge uncertainty - many effects are difficult to predict or occur only in the long term (Strayer et al. 2006).” In fact, in our abstract we state, “A fraction of non-native species will continue to cause biological and economic damage, and substantial uncertainty surrounds the potential future effects of all non-native species.” We also wrote, “The future effects of a non-native species are uncertain.
because biotic interactions are notoriously difficult to predict and because current and future environmental conditions may differ substantially (Walther et al. 2009).” We, therefore, fail to understand how the authors reached the conclusion that this perspective was missing in our paper.

Finally, we disagree with their statement that “introductions have much more frequently caused loss of biological diversity, ecosystem functions, and ecosystem services . . . ” They base these claims on the Millennium Ecosystem Assessment (2005), but much data has become available over the last decade that shows that these statements are not generally true. First, any discussion of loss or gain of biodiversity must be related to the spatial scale of interest (Sax & Gaines 2003). Although species diversity is declining globally, in part because of non-native species, the net effect of regional species introductions is generally an increase in diversity. Such an increase has occurred with plants, mammals, birds, fishes, and many other groups on both islands and continents worldwide (Sax et al. 2002; Sax & Gaines 2003). Locally the effects of non-native species on alpha diversity are likely to be more idiosyncratic, but net increases are still the expectation in most cases because of the positive association between local and regional species richness (Sax & Gaines 2003).

Second, introduced species typically lead to an increase, not a decrease, in ecosystem function (Ehrenfeld 2010). Results of two recent meta-analyses show this to be the general case for most ecosystem functions that have been measured (Liao et al. 2008; Vila et al. 2011). Third, non-native species can provide many ecosystem services that are desirable to humans (e.g., clean water, erosion control, food provisioning). Although we are unaware of any study that has tallied the number of services provided versus amount of harm associated with introduced species (clearly not a small task), the provision of ecosystem services by such species certainly occurs and may be more frequent than is appreciated. Non-native species may produce many different undesirable effects, but it is important to use the existing data to distinguish between disproven assumptions and real consequences.

Vitule et al. criticize us on issues we did not address in our paper. For example, they claim we misrepresented the frequency of positive effects of non-native species. In our paper, we reviewed the numerous ways in which non-native species can potentially contribute to conservation efforts. We never wrote or implied that we quantitatively measured the number of studies documenting positive versus negative effects. We concede that a reader could come away with an incomplete picture of the field if our article was the first they ever read on the topic of non-native species. But our target audience was conservation professionals who read Conservation Biology and who, by contrast, have been hearing almost exclusively about the negative effects of non-native species for years or even decades. We even clarified that our aim was “to catalog the possible ways in which non-native species can help achieve conservation objectives. We did not review all the known negative effects of non-native species because these have been described exhaustively (e.g., Mooney & Hobbs 2000; Lodge et al. 2006).” We are, therefore, uncertain how the authors concluded that our aim was to provide a quantitative measure of the number of each type of study. Such a comparison would be difficult given the historical bias in the literature that favors descriptions of negative effects of non-native species.

Vitule et al. also state that we “downplay reports of invasion effects in developing countries.” Given that we sought examples for our review indiscriminately and that our paper had no geographic or sociopolitical focus, we fail to understand the origin of this criticism. Nevertheless, the question of whether the nature and magnitude of positive and negative effects differ according to a country’s development path is an interesting one that should be pursued.

The world is rapidly changing, as are the ways we view non-native species. How we manage these species and whether we even chose to maintain a distinction between native and non-native species in the future is a wide-open question. One the one hand, the distinction may sometimes prove to be distracting from the larger issue of the positive and negative effects that both native and non-native species can have relative to any particular conservation goal (e.g., Davis et al. 2011; Carey et al. 2012). On the other hand, information on a species’ origin may provide useful information in some cases, for example, on islands and in other insular settings where non-native species regularly have negative effects on native biota (Sax & Gaines 2008). We look forward to future work by Vitule et al. and others as they carefully document both the positive and negative potential effects of non-native species, and we thank them for their contributions to this interesting debate.

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Revisiting the Potential Conservation Value of Non-Native Species

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Human travel and transportation of goods are increasingly changing species distributions (Ricciardi 2007). Non-native species—those introduced beyond their natural ranges—often have undesirable effects at levels from genes to landscapes (Ehrenfeld 2011). However, as has long been acknowledged, not all introduced species have negative effects (Williamson 1996).

Although Schlaepfer et al. (2011) recognize much evidence of undesirable effects of species introductions, they synthesize information on contributions of non-native species to conservation goals. Schlaepfer et al. contend that non-native species may catalyze restoration of native species and ecosystems, especially if they substitute for extirpated ecosystem engineers (organisms that modulate availability of resources to other species by changing ecosystem components; Jones et al. 1994), and may thus provide ecosystem services. Schlaepfer et al. predict that non-native species will increasingly aid conservation because they are more likely than native species to persist despite changing climate and land use. They further argue that non-native species may evolve into new taxa and thus increase species diversity. Their main message is clear: non-native species should be used for conservation given their potential desirable contributions.

We disagree with Schlaepfer et al.’s main message. It is challenging to understand a species’ ecological effects, and current evidence shows that desirable (i.e., positive) effects of non-native species are much less frequent than undesirable (i.e., negative) effects. Even for species Schlaepfer et al. use as examples of the positive effects of non-native species (e.g., gorse [Ulex europaeus], African honey bee [Apis mellifera], zebra mussel [Dreissena polymorpha]), most published effects are negative (Clements et al. 2001; Goulson 2003; Strayer et al. 2004). Schlaepfer et al. do not accurately represent the extent of desirable and undesirable effects of non-native species with respect to conservation. This misrepresentation can suggest that effects of non-native species are mostly positive.

When a non-native species becomes abundant, even when it is highly detrimental to the ecosystem, some native species will likely benefit because it provides an additional resource. One thus expects some positive effects. However, these effects are frequently transient, and calling them desirable or undesirable is often a consequence of subjective analyses (e.g., Rodewald 2011; Lapointe et al. 2012). Schlaepfer et al.’s examples highlight positive effects of some introduced species. They state, “[w]e did not review all the known negative effects . . . because they have been exhaustively described.” Furthermore, they do not acknowledge uncertainty—many effects are difficult to predict or occur only in the long term (Strayer et al. 2006). An example is the phenomenon of time lags (Crooks 2011), in which species do not immediately become problematic. Many effects cannot be detected without extensive, long-term studies (Strayer et al. 2006; Traveset & Richardson 2006; Arbačiauskas et al. 2010). Of course, subtle and delayed effects can be positive, although the catalog so far is heavily weighted toward negative effects.
Although we disagree with some views of Schlaepfer et al., we agree that some invasions can aid conservation, as when they functionally replace an extinct species. Ship rats (Rattus rattus) have multiple undesirable effects (Pascal 2011). Yet ship rats pollinate some native species in New Zealand, where native pollinators have been extirpated (Pattemore & Wilcove 2012). Thus, even highly detrimental species can have some desirable local effects. The irony is that rats contributed greatly to extirpating pollinators in the first place (Pattemore & Wilcove 2012), so the net invasion effect was not beneficial.

In addition, Schlaepfer et al. overestimate ecologists’ ability to forecast risks and benefits of non-native species. Prediction in ecology is difficult (Lawton 1999). Surprises emerge even in well-studied systems (Lindenmayer et al. 2010). For example, kokanee salmon (Oncorhynchus nerka) and lake trout (Salvelinus namaycush) were introduced into Flathead Lake, Montana, in the early 20th century, and 50 years later, opossum shrimp (Mysis diluviana) were introduced into part of the catchment to increase kokanee production (Ellis et al. 2011). By 1981 shrimp floated downstream into Flathead Lake, causing population crashes of cladoceran and copepod prey. Kokanee, competing with shrimp for prey, declined from 1 to 2 fish per standardized gill net set before shrimp were present to <0.5 fish per net. This decline caused the abundances of Bald Eagles (Haliaeetus leucocephalus), grizzly bears (Ursus arctos), and other predators to decline. Eagle abundance at one monitored site fell from 639 to 25 (Spencer et al. 1991). Lake trout became the dominant species of fish. Owing to changes in the food web associated with the increase in abundance of lake trout, the lake’s population of bull trout (Salvelinus confluentus) may be extirpated (Ellis et al. 2011). Such indirect effects of a non-native species are common and difficult to predict, so Schlaepfer et al.’s confidence in recognizing positive effects is unwarranted.

Schlaepfer et al. suggest quantifying net effects of non-native species to define when they become invasive. They also suggest that one should not try to control species with positive net effects and instead should consider them conservation resources. However, the aforementioned difficulties—especially that species have many effects and that these effects may be hard to measure or predict—make quantifying net effects extremely challenging, especially when management action is urgent (e.g., when an introduced species spreads rapidly).

Another point of contention is that Schlaepfer et al. downplay reports of invasion effects from developing countries. In developing countries, Schlaepfer et al.’s thesis might be used to support practices that promote introductions of non-native species that have highly undesirable effects. In many developing countries, introductions of species are promoted on economic grounds and no studies of potential undesirable long-term effects are conducted (e.g., Vitule et al. 2009; Lövei et al. 2012). There are more developing than developed countries, yet most research dealing with invasions is restricted to developed countries (Vázquez & Aragón 2002). Also, in general, economic development accelerates invasions (Lin et al. 2007). Invasions are therefore likely to become more frequent and to generate greater net undesirable effects in developing nations with rapidly growing economies. Such countries are generally located where species diversity is high and less information is available on effects of introductions (Lin et al. 2007; Lövei et al. 2012). These considerations lead us to disagree with Schlaepfer et al.’s prediction that an increasing proportion of non-native species will be benign or even desirable for conservation.

Finally, Schlaepfer et al. (p. 434) say they “question how human actions differ from those of other species. In other words, why is a dispersal event that is facilitated by, say, a migratory bird or storm event considered natural, whereas a human-transported species is non-native and thus undesirable?” Although migration of species is facilitated by the removal of natural barriers (e.g., the opening of the Panamanian corridor between North and South America during the Great American Interchange), these events cannot be compared with the current wave of human-assisted invasions. The rate of human-assisted invasions is orders of magnitude higher than natural or prehistoric rates (Ricciardi 2007). For instance, over the last century mammal genera have been exchanged between North and South America 10,000 times more frequently than during the Great American Interchange (Ricciardi 2007). Furthermore, human-mediated dispersal often carries species between sites that would never have been sites of species exchanges facilitated through tectonic movement or aerial or aquatic transport (Ricciardi 2007; Wilson et al. 2009), and human-mediated dispersal frequently moves more individuals and individuals from multiple sources (Wilson et al. 2009). Human-assisted dispersals are a distinct global change (Ricciardi 2007; Wilson et al. 2009).

Schlaepfer et al. downplay the danger of species introductions, and the absence of a perspective that accounts for the issues we raise here could encourage decision makers, who typically focus on short-term benefits of introductions without concern for potential long-term consequences, to approve introductions that carry a high risk of adverse consequences. The Millennium Ecosystem Assessment is more prudent. It notes that some introductions will be beneficial, but it nevertheless emphasizes that introductions have much more frequently caused loss of biological diversity, ecosystem functions, and ecosystem services (Millennium Ecosystem Assessment 2005). The Convention on Biological Diversity (UNEP 1992) also advocates a precautionary approach to species introduction when information about its effects is highly uncertain; thus, the risk of negative effects puts the burden of proof on those wishing to introduce species. We
believe a more sensible alternative to Schlaepfer et al.’s proposal to encourage introductions when predicted net effects are positive is to use the best available knowledge to increase vigilance and to improve management. The issue of species’ invasions is complex and necessitates a cautious, balanced view, including consideration of short-term and long-term introduction effects, both positive and negative.

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