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Clarifying debates in invasion biology: A survey of invasion biologists

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ABSTRACT

Invasion biology is a relatively new field, so there are ongoing debates about foundational issues regarding terminology and assessment of the causes and consequences of invasive species. These debates largely reflect differing views about the extent to which invasion biologists should advocate on behalf of native species. We surveyed reviewers of the journal *Biological Invasions* to obtain a better sense of how invasion biologists evaluate several foundational issues. We received 422 replies, which represented a very good response rate for an online survey of 42.5% of those contacted. Responses to several debates in the field were distributed bimodally, but respondents consistently indicated that contemporary biological invasions are unprecedented. Even still, this was not seen as justification for exaggerated language (hyperbole). In contrast to prevalent claims in the literature, only 27.3% of respondents ranked invasive species as the first or second greatest threat to biodiversity. The responses also highlighted the interaction of invasive species with other threats and the role of human activity in their spread. Finally, the respondents agreed that they need to be both more objective and better at communicating their results so that those results can be effectively integrated into management.

1. Introduction

In recent years, controversies and disagreements among invasion biologists have "created an intellectually dynamic and sometimes emotionally charged atmosphere" (Davis, 2006, 2009). This in part reflects the relative youth of the field; the journal *Biological Invasions*, which was founded as an international platform for communications about invasive species, has existed for little more than a decade (Carlton, 1999). Although the first article published in the journal, in January 1999, sought to define the "impact" of non-indigenous species (Parker et al., 1999), there are still legitimate debates about the causes and consequences of these impacts and what, if anything, we should do about them.

The ecologists Brown and Sax (2004), for example, argued that biological invasions are a natural process and "nothing new," citing the bidirectional exchange initiated by the inter-American land bridge as a primary example. Cassey et al. (2005), however, counterargued for the uniqueness of modern human-caused invasions because they are so much more rapid and widespread than historical invasions. As a second example, some biologists have questioned whether the emphasis on biological invasions as a "driver" of extinctions is justified given that they may more often be "passengers" responding to concurrent environmental changes (e.g., Didham et al., 2005; MacDougall and Turkington, 2005). If this is the case, then it may be misleading to repeat the prevalent claim, attributed to Wilcove et al. (1998), that invasive species

are the "second greatest threat to biodiversity" behind habitat destruction (e.g., Mack et al., 2000; Simberloff, 2005). Recent studies have questioned the validity of this claim, partly because it is based on data for the United States that was skewed by the inclusion of Hawaii, which has a higher prevalence of invasive species than most of the continental United States, but also because recent data suggest that invasive species are less of a threat to the extinction of species in other countries, such as Canada and China (Gurevitch and Padilla, 2004; Yiming and Wilcove, 2005; Venter et al., 2006; Davis, 2009; but see Clavero and García-Berthou, 2005). These and other debates may seem to undermine the basis for responding to invasive species, but they more importantly signify a vibrant and young field going through some growing pains (see Moore et al., 2009).

Another area where invasion biologists sometimes disagree concerns the interface of their field with society (Larson, 2007). Like the cognate field of conservation biology (Barry and Oelschlaeger, 1996), invasion biology places a value on existing biodiversity and seeks to slow its decline. Accordingly, it is a value-laden science and thus one in which the appropriate degree of advocacy is debated (Davis, 2006). A more value-based approach, promoted by Charles Elton's classic 1958 book, *The Ecology of Invasions by Animals and Plants*, emphasizes applying general ecological theory to predict and manage biological

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invasions. A contrasting, relatively value-neutral approach, in the spirit of a 1964 symposium held in Asilomar, California, argues that biological invasions should be studied as natural experiments to inform ecological theory.

Different scholars have reached different conclusions about the appropriate level of advocacy in invasion biology. Brown and Sax (2004), for example, "plead for more scientific objectivity and less emotional xenophobia about invasive species." While not debating the need for scientific objectivity, Cassey et al. (2005) countered that invasion biologists have a responsibility to advocate for native biodiversity. Similarly, Simberloff (2006) denounced Brown and Sax (2004) as part of a "rearguard action to convince biologists and the lay public that the ecological threat from invasive species is overblown". And debates about the role of social values – and the appropriate level of advocacy – have increasingly spilled beyond the confines of invasion biology and attracted social scientific commentators to whom invasion biologists have felt compelled to respond (e.g., Sagoff, 2005 and Simberloff, 2005; Larson, 2007 and Colautti and Richardson, 2009; Warren, 2007 and Richardson et al., 2008; Evans et al., 2008 and Simberloff, 2009).

Here we report on a survey of invasion biologists that sought to understand their views on some foundational debates in their field, with a focus on areas where science and values intersect. Similar expert assessments have been used for other issues, such as climate change and genetic modification (e.g., Morgan and Keith, 1995; Fisher et al., 2005). Recently, Moore et al. (2009) found that a panel of expert ecologists was unable to reach consensus over such pertinent issues for invasion biology as the relation between diversity and ecosystem function, an uncertainty that suggested to them a challenge for clearly communicating with managers. Lodge and Shrader-Frechette (2003) have also observed that disagreeing scientists have created confusion both within the field and among the public: "The public is getting a mixed message, and some ecologists have contributed to the confusion."

We intend to provide current data to update the arguments presented in Lodge and Shrader-Frechette (2003), and thus a novel form of insight into prevailing areas of consensus and dissent among invasion biologists. These results will help enhance invasion biologists' self-reflection about their field and its evolution (cf. Pysek et al., 2006) and will, we hope, encourage further discussion among them to resolve tensions in the field. In some instances, for example, invasion biologists have defended their assertions about invasive species by stating that these assertions are generally accepted in the field (see below), and we provide an empirical test of such claims. Our results will also provide a more realistic view for outsiders to the field who might otherwise be given a mistaken impression when seeking to develop conservation priorities. Additionally, the results will provide insight for other environmental scholars into how invasion biologists conceptualize this dimension of global change and how they incorporate values into science in responding to it. Specifically, our survey addressed the following questions: (1) What do invasion biologists conclude about the effects of invasive species on biodiversity? (2) What do they see as their appropriate role in dealing with invasive species? and (3) What is their prognosis for biological invasions?

2. Methods

To assess how invasion biologists themselves respond to various debates in their field, we surveyed peer reviewers for the journal *Biological Invasions* both because its focus is invasion biology and because its reviewers provide a proxy for expertise in this field as determined by its editor and editorial board. The survey received approval from the Office of Research Ethics at the University of Waterloo. It was hosted by SurveyMonkey.com and followed recommended protocols for an online survey (e.g., Schonlau et al., 2001; Van Selm and Jankowski, 2006). In particular, though there are undoubtedly many interesting theoretical debates in the literature about invasive species, we focused on a few key foundational issues in order to keep the survey short, reduce respondent burden, and thus obtain a favorable response rate.

We pretested a draft version with invasion biologists and social scientists in early April 2008. On April 21 we sent an introductory e-mail to the distribution list of reviewers of *Biological Invasions* to announce our survey and describe its purpose; we also included a note of endorsement from James Drake, editor of *Biological Invasions*. Two days later we sent a second e-mail with more detailed information and a direct link to the survey. To ensure that only our target group of reviewers responded to the survey, and to prevent multiple submissions, the link sent to each individual e-mail address was programmed to allow only one submission. Nonrespondents were sent reminder e-mails on April 28 and May 6, and the survey concluded on May 10.

We asked invasion biologists to indicate their level of agreement with numerous statements on a scale from 1 to 5: strongly disagree, disagree, neutral, agree, or strongly agree. The survey included diverse statements that captured alternative perspectives on the rate of biological invasions and their impact on biodiversity, as well as the appropriate role for invasion biologists (including linguistic issues) and their prognosis. The majority of the statements were 35 direct quotes from the primary literature (see Table 1; the full survey instrument is available upon request), some of which were modified slightly for clarity. We sometimes reversed their polarity so that both positive and negative statements could be included in our design. Quoted statements were also taken out of context; as such, the quoted individual may have been arguing something different than the statement implies. The order of statements was randomized for each respondent.

We also asked respondents to evaluate invasive species alongside other commonly recognized threats to biodiversity. Wilcove et al. (1998) considered five threats, which in rank order were habitat destruction and degradation (which affected 85% of the species they considered), alien species (49%), pollution (24%), overexploitation (17%), and disease (3%). We adapted this list of threats so that it more accurately reflected the current literature on factors affecting species diversity (Table 2). We included "global climate change" because it is a major risk factor, one that Wilcove et al. (1998) did not include but predicted would become important. We included "increasing atmospheric CO_2" and "nitrogen deposition" because they are also critical elements of global climate change. We also included "the rate of human population increase" because some argue that it is a critical factor that requires greater emphasis (Meffe, 1994). We excluded "disease" from our list because it was the lowest threat in their study and recent reviews provide further evidence that it has not commonly led to extinctions (Smith et al., 2006), even though there are prominent examples of introduced diseases with substantial effects (such as the white-nose syndrome killing bats in the United States). Respondents were not explicitly asked to rank these factors, which might have biased them to affirming that invasive species are second; they were asked instead to evaluate each of them on a scale from 1 to 5, where 1 is the least serious and 5 is the most serious. From these data we calculated the mean "seriousness" of each threat as well as the percentage of respondents who ranked invasive species as the *n*th greatest threat; we ranked invasive species as the *n*th threat even if other threats were ranked equivalently. For this analysis of threats, we excluded 16 respondents who left two or more of the options blank for this question or who equally ranked all choices (though their responses were included in our calculation of overall mean response).

To assess respondents' views of the appropriate degree of advocacy in their field, we also asked them to identify their preferred role in management decisions about invasive species. We adapted a list of five generalized roles for scientists in natural resource decision making from a study by Lach et al. (2003), simply substituting "invasion biologist" for "scientist" in their answer choices (see Table 4).

3. Results and discussion

3.1. Overall survey response

Our survey received 422 responses, which represents an overall response rate of 42.5% (after subtracting undeliverable e-mail addresses from the original contact list). This response is at the upper end of that reported for previous Web and e-mail surveys (Schonlau et al., 2001), so although our results may contain unavoidable sampling bias, we assume they are about as representative as any we can obtain.

The response rate was favorable, but the trade-off was that we limited the number of questions and their detail to ensure that high response rate. Consequently, in a comment box at the end of the survey numerous respondents stated that they had

Table 1
Invasion biologists' response to statements from the literature regarding the effects of biological invasions on biodiversity, the appropriate level of advocacy in invasion biology, and invasion biologists' prognosis for the future. We report (i) their mean response (± standard deviation) on the scale from 1 (''strongly disagree'') to 5 (''strongly agree''); (ii) the percentage of respondents who disagreed (sum of percent choosing ''strongly disagree'' and ''disagree'') and agreed (sum of ''agree'' and ''strongly agree''), the remainder having chosen ''neutral''; and (iii) the original source of the quotation.

	Survey statement	Mean	% Disagree	% Agree	Source
Effects of invasions on biodiversity					
Historical precedents					
1	The current mass invasion event is without precedent and should be regarded as a unique form of global change	4.0 (0.9)	9	81	Ricciardi (2007)
2	Modern rates and consequences of non-indigenous species establishment are comparable to episodes in the geological past	2.1 (1.0)	72	10	Ricciardi (2007)
3	Terms such as ''non-native'' or ''invasive'' are arbitrary because all species have spread into new territory at some point in their evolutionary history	2.3 (1.0)	73	16	Ricciardi (2007)
Impact on native species					
4	There is strong evidence for invasive species as a direct cause of native species decline	3.7 (1.0)	14	68	Didham et al. (2005)
5	Non-native species are a highly significant factor in endangerment and extinction—indeed second only to habitat destruction	3.6 (0.9)	15	64	Simberloff (2005)
6	Invasive species are a direct and leading cause of extinctions	3.3 (1.0)	25	45	Gurevitch and Padilla (2004)
7	Available data supporting invasion as a cause of extinctions are, in many cases, anecdotal, speculative and based upon limited observation	3.1 (1.1)	34	42	Gurevich and Padilla (2004)
8	The generalization that invaders will reduce species diversity is not well founded	2.9 (1.1)	43	36	Slobodkin (2001)
9	At small scales the losses due to extinction of native species have on average been more than offset by the colonization of invading species	2.5 (1.0)	53	18	Brown and Sax (2004)
Multiple causes					
10	Extinctions of many native species cannot be attributed solely to invading aliens	4.1 (0.9)	7	88	Brown and Sax (2004)
11	Invasive species are a correlate of habitat disturbance by humans	3.7 (1.0)	15	69	Didham et al. (2005)
12	The invasive exotic that has had by far the greatest impact on biodiversity and ecosystems is our own species	4.0 (1.2)	14	68	Brown and Sax (2005)
Appropriate level of advocacy					
Language and terminology					
13	We could usefully avoid the language of natives and aliens altogether	2.5 (1.1)	57	18	Rawles (2004)
14	The term ''invasive'' should not be used to connote negative environmental impact	2.9 (1.2)	46	37	Ricciardi and Cohen (2007)
15	By using loaded language, invasion biologists may erode public trust in their objectivity	3.5 (1.0)	21	61	Larson (2005)
16	Hyperbolic language about invasive species is needed to capture the attention of policy makers and the general public	2.7 (1.1)	48	27	Davis (2006)
17	The ambiguities surrounding invasive species have been neglected or glossed over in the haste to sound the alarm of a crisis	3.1 (1.0)	30	41	Foster and Sandberg (2004)
The role of scientists					
18	There should be more scientific objectivity and less emotional xenophobia regarding invasive species	3.7 (1.1)	17	65	Brown and Sax (2004)
19	The role of scientists in studying invasive species should be to gather, interpret and communicate information as accurately and objectively as possible	4.5 (0.7)	2	94	Brown and Sax (2005)
20	Decisions to manage invasive species will require judgments to be communicated from invasion biologists to policy makers	4.4 (0.7)	3	93	Cassey et al. (2005)
The value of invasive species					
21	Non-indigenous species are inherently evil	1.6 (0.9)	88	4	Simberloff (2006)
22	Any characterization that non-indigenous species are good or bad is a value judgment, not science	3.2 (1.3)	40	49	Lodge and Shrader-Frechette (2003)
23	The identification of any species as an invader, weed, or exotic is conditioned by cultural and political circumstances	3.1 (1.2)	39	44	Robbins (2004)
24	Exotics are an unnatural, undesirable component of the biota and environment	3.1 (1.1)	34	37	Brown and Sax (2005)
Prognosis for the future					
25	Invasion biologists have recently developed methods that greatly aid prediction of which introduced species will harm the environment	2.8 (1.0)	41	28	Simberloff (2005)
26	The ecological and economic costs associated with human-caused biological invasions will continue to rise substantially over the coming decades	4.3 (0.8)	2	90	Levine and D'Antonio (2003)
27	Synergistic interactions among invaders may well lead to accelerated impacts on native ecosystems—an invasional 'meltdown' process	3.7 (0.8)	8	68	Simberloff and Von Holle (1999)
28	Exotic species invasions create almost ideal conditions for promoting evolutionary diversification	2.6 (1.0)	46	18	Vellend et al. (2007)
29	The fact that we can look forward to ecological systems recovering from invasive species in the next 10 million years or so is a great consolation	2.0 (0.9)	73	5	Cassey et al. (2005)
30	The earth and much of its biota will survive the effects of modern humans	3.0 (1.1)	34	37	Brown and Sax (2004)
31	Figuratively, globalization of Earth's biota will not lead to a world composed of zebra mussels, kudzu, and starlings	3.2 (1.1)	30	43	Davis (2003)

difficulty evaluating particular statements because they were uncomfortable making the required generalization: many impacts are taxon- or ecosystem-specific. Another uncertainty was whether the term *extinction* in our survey referred to local or global extinction. Despite these concerns, over 409 individuals responded to each of our questions. We do not report the results for all questions below; the complete survey results are available upon request.

Table 2
Invasion biologists' evaluation of eight factors affecting biodiversity. The response options ranged from 1 ("least serious") to 5 ("most serious"). Statistically different means are indicated by distinct letters (one-way ANOVA with Tukey's test, df=7, $p<0.001$). SD=standard deviation.

Factor affecting biodiversity	Mean	SD
Habitat loss/degradation/fragmentation	4.7[a]	0.6
The rate of human population increase	4.6[a]	0.8
Global climate change	4.1[b]	0.9
Invasive species	3.7[c]	0.8
Over hunting/commercial exploitation of species	3.6[c]	1.0
Increasing atmospheric carbon dioxide	3.5[c]	1.1
Atmospheric pollution	3.0[d]	1.1
Nitrogen deposition	2.9[d]	1.0

3.2. Effects of invasive species on biodiversity

In contrast to claims quoted earlier, our findings indicate that invasion biologists generally conclude that the current mass invasion event is unique and incomparable to events in the geologic past (Table 1: statements 1 and 2). Ricciardi (2007) summarizes how modern biological invasions are unprecedented, including their greater rate (especially over long distances), geographic extent, and organismal diversity. Accordingly, invasion biologists in our survey concluded that it is justified and nonarbitrary to distinguish these human-caused biological invasions from the normal spread of species during evolutionary history (Table 1: statement 3). This result affirms many invasion biologists' insistence on a clear distinction between recent human-mediated dispersal of species versus natural dispersal over evolutionary time, as mentioned above (e.g., Cassey et al., 2005; Ricciardi, 2007).

What are the effects of invasive species on biodiversity? The respondents generally agreed that invasive species are a leading contributor to the decline (reduced abundance) of native species (Table 1: statements 4 and 5), but they were less strongly convinced that this decline inevitably leads to extinction and thus to a loss of biodiversity (Table 1: statements 6–8). Not all invasive species are problematic, and in some cases non-native species have been shown to actually increase local and regional species richness, thereby compensating for species that may be lost (Sax and Gaines, 2003; Davis, 2009). While Cassey et al. (2005) agree that this may be true "in terms of pure local species numbers," they propose that "few scientists would agree" with this seemingly "positive benefit of biotic homogenization." Our data support their assertion that few scientists would agree (Table 1: statement 9) and thus highlight invasion biologists' particular concern for the loss of endemic species.

Invasion biologists agreed that invasive species contribute to extinction, but also that extinction events must be viewed in the context of other changes brought about by humans (Table 1: statements 10–12). In particular, they strongly implicate humans both as invasive species ourselves and as the cause of habitat disturbance that facilitates the spread of other invasive species.

This result was further supported by their evaluation of various threats to biodiversity, which corroborated Wilcove et al.'s (1998) conclusion that habitat loss and degradation (including fragmentation) are the greatest threats to biodiversity (Table 2). Unlike their study, our respondents rated other threats more highly. On average they did not rate habitat change significantly above the next most highly ranked threat, human population growth. Global climate change was the third greatest threat, leaving invasive species as the fourth. Furthermore, respondents considered invasive species no more of a threat than either overhunting and commercial exploitation or increasing CO_2 levels. Overall, we found that only 27.3% of the respondents rated invasive species as the greatest or the second greatest threat to biodiversity (14.5% and 12.8%, respectively). More respondents placed them as either the third or fourth greatest threat (20.0% and 20.2%, respectively), and the remainder put them lower.

Thus, the majority of invasion biologists surveyed in this study did not place invasive species as the second greatest threat to biodiversity, as the famous conclusion attributed to Wilcove et al. (1998) claims. The Wilcove et al. (1998) paper is now over a decade old, and as mentioned earlier, there has recently been considerable focus on global climate change as well as the synergistic effects of multiple human stressors. The implication is not so much that invasive species are not an important threat to biodiversity, but that claims that they are the "second greatest" threat to it must be tempered by awareness of larger causal factors. Otherwise, we will be hampered by a problematic logic of 'main effects' conservation management, where managers select and focus only on the dominant causal factor among many and thus develop partial solutions that attempt to deal with invasive species as a unitary force rather than with the other anthropogenic drivers that facilitate their invasiveness (Didham et al., 2007).

3.3. Advocacy in invasion biology

Given that invasion biologists largely agree that invasive species pose a threat to biodiversity, there still remains the question of what their role might be in addressing it. For example, invasion biologists generally believe that we need to linguistically distinguish species that humans have introduced into a new region outside their historic range (Table 1: statement 13), but there is a long-running debate about which terminology to use because some options are more loaded than others (Davis, 2006; Colautti and Richardson, 2009). We found that invasion biologists most preferred the terms *introduced* and *non-native* and least preferred *foreign* and *immigrant* (Table 3). *Non-indigenous*, *exotic*, and *alien* fell in between. Several respondents wrote that they preferred the term *introduced* because it implies that humans have been involved in some way. For example, one respondent stated that "'introduced' is the only term of the six that indicates explicit human interaction," and another commented that "introduced (by humans) is exact, precise, and value-free. Most of the other terms are either less precise (species can arrive without human agency) and/or value-laden." In short, this result provides evidence that invasion biologists lean away from more resonant terminology, notwithstanding the fact that usage will vary with context.

These introduced species may spread to new habitats, sometimes having ecological and economic impacts. There is also debate in the literature about whether spread is the primary factor that defines an invasive species, or whether it is the impact of this spread; ecologists more often adopt the former stance and policy-makers the latter (Ricciardi and Cohen, 2007). The invasion biologists we

Table 3
Invasion biologists' evaluation of seven terms for species that people have brought to a new region outside of their historic range. The response options ranged from 1 ("strongly disagree") to 5 ("strongly agree"). Statistically different means are indicated by distinct letters (one-way ANOVA with Tukey's test, df=6, $p<0.001$). SD=standard deviation.

Term	Mean	SD
Introduced	4.3[a]	0.8
Non-native	4.3[a]	0.8
Non-indigenous	4.1[b]	1.0
Exotic	3.8[c]	1.1
Alien	3.4[d]	1.2
Foreign	2.5[e]	1.1
Immigrant	2.0[f]	0.9

surveyed were uncertain. They were split about whether the term *invasive* should be used to connote negative environmental impact (Table 1: statement 14), and they agreed equally with the following two alternative definitions for invasive species: "introduced species that spread rapidly in a new region" or "introduced species that spread rapidly and have harmful environmental or socio-economic impacts" (*t*-test, mean response of 3.90 and 3.94, respectively). This suggests that both definitions are suitable, depending on the context in which invasive species are being discussed.

Davis (2006) predicted that "whether … ecologists should modify their language when advocating environmental concerns will likely be a matter of disagreement within the field." Some argue, for example, that the credibility of the field is compromised by militaristic language (Larson, 2005) and that the field requires a more neutral terminology (Colautti and MacIsaac, 2004). In contrast, others disagree that hyperbole impedes scientific credibility and communication with the public (Simberloff, 2006). We substantiated Davis's (2006) prediction with our finding that invasion biologists are more often than not uncomfortable with using loaded and exaggerated language when discussing invasive species, although a substantial proportion think that it is necessary (Table 1: statements 15–17).

In terms of their broader role, the respondents strongly agreed that the study of biological invasions should be more objective rather than full of "emotional xenophobia" (Table 1: statements 18 and 19). Yet they also strongly agreed that invasion biologists will need to communicate value judgments to facilitate management (Table 1: statement 20), and the challenge for doing so lies in the nearly equal split between those who recognize that characterizing exotic and invasive species as good or bad is a culturally conditioned value judgment and those that do not (Table 1: statements 22 and 23). While respondents do not perceive invasive species to be "inherently evil," they are also divided on whether they are uniformly unnatural and undesirable (Table 1: statements 21, 24). This creates inevitable tensions in the field; for example, one respondent replied, "I abandoned the arena of invasive plant species many years ago because I grew weary of the hype and the rush to declare ecological disaster solved only by the widespread use of herbicides."

In terms of their specific role in natural resources management, invasion biologists preferred that their results be integrated into management, a preference followed closely by their assuming a role in which they interpret their results for managers (Table 4). They wanted neither to merely report their results nor, at the other extreme, to make management decisions themselves. These results were similar to those found by Lach et al. (2003) in their study of scientists in the US Pacific Northwest, although our research indicated that invasion biologists were more open to a greater role in decision making. This result may seem contrary to their desire to be more objective, yet it shows that they recognize a way to be objective in their science while acknowledging the need to advocate (see Foote et al., 2009; Nelson and Vucetich, 2009). In short, invasion biologists appear to have very different judgments of these species and a wide range of opinions on appropriate advocacy, which suggests that the field would benefit from continued discussion of such issues and more clear differentiation of those specific species that are problematic in particular contexts (Lodge and Shrader-Frechette, 2003; Gurevitch and Padilla, 2004).

3.4. Prognosis for biological invasions

Invasion biologists are concerned enough about the impact of invasive species to seriously consider acting as advocates, but what is their prognosis? The control of these species may depend on better prediction of which introduced species will prove harmful so that their movement across borders can be restricted and early response can be more effective. Although Simberloff (2005) concluded that invasion biologists have recently developed methods that "greatly aid prediction," more of the respondents disagreed with this position than agreed (Table 1: statement 25). Their pessimism goes further: most of them predicted that the impacts of biological invasions will continue to increase and that an "invasional meltdown" is likely (Table 1: statements 26 and 27). Though some authors have suggested that evolutionary processes will recoup diversity over time, this provides little solace to most invasion biologists (Table 1: statements 28 and 29). And, finally, they hold disparate views on the overall prospects both for biotic homogenization and for the future of Earth and its biota; about one-third of the respondents hold a fairly despairing view (Table 1: statements 30 and 31).

4. Conclusion

The results presented here confirm invasion biologists' sobering view of the changes that are being wrought by species that humans transport around the globe; yet they also highlight the extent to which these species are entangled with other types of anthropogenic activity. In addition, we found that invasion biologists have differing views of the appropriate degree of advocacy in their field. Such uncertainty may create challenges for communication and policy development, so invasion biologists will benefit from further discussion of their role in the realm of management (cf. Moore et al., 2009). In the words of one of our respondents, invasive species "provide an outstanding opportunity for educating and engaging the public in discussions about how to promote a more sustainable relationship of humanity to the environment and to reflect more on our role in environmental change." Yet the task still remains to connect such a vision with the practice of science in which invasion biologists are engaged.

Table 4
Preferred role for scientists (Lach et al., 2003) and invasion biologists (this study) in natural resource decision making. We report the mean response from each study on the scale from 1 ("strongly disagree") to 5 ("strongly agree"). The survey question for Lach et al. (2003) was identical to ours except they used the term "scientist" in place of "invasion biologist." The responses to the five roles in our survey were significantly different from one another (one-way AVOVA with Tukey's test, df=4, $p<0.0001$). SD=standard deviation.

Scientist role	Scientists in Lach et al. (2003) (mean)	Invasion biologists in this study (mean)	SD
1 Invasion biologists should only *report* results and leave others to make management decisions	2.9	2.1	0.9
2 Invasion biologists should report results and then *interpret* for others involved in management decisions	4.2	4.0	0.7
3 Invasion biologists should work closely with managers and others to *integrate* scientific results into management decisions	4.1	4.5	0.6
4 Invasion biologists should actively *advocate* for specific natural resource management decisions	2.2	3.5	1.0
5 Invasion biologists should *make decisions* about natural resource management	1.7	2.8	1.0

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