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Commentary

Can Ecologists Heat Up the Discussion on Invasive Species Risk?

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Ecologists predict that invasive species and global climate change will be two of the leading drivers of global biodiversity loss over the next century (Sala *et al*., 2000). Society, however, has responded to these two threats in a very uneven way; global climate change has become a major focus of public policy, while problems from invasive species remain poorly addressed. This discrepancy is emphasized by the Kyoto Protocol, which brought 160 nations together in 1997 to create a program for worldwide reductions in greenhouse gas emissions. Despite the fact that ecologists have recognized invasive species as a serious problem since the 1950s (Elton, 1958), there has been no international effort comparable to the Kyoto Protocol to reduce their impacts. This discrepancy is also reflected at the national scale—this fiscal year the United States will spend close to $2 billion on climate change research (CCSP, 2004), while only $227 million is budgeted for invasive species research (NISC, 2005). In this editorial, we ask why ecologists have had so little success communicating the problems of invasive species to society, and offer some suggestions for how ecologists can be more effective at this in the future.

Communicating the risks from invasive species is complicated. Each invasive species has different impacts, and there are many diverse vectors of introduction. In our experience, members of the general public are aware of a few specific examples of invasive species, but few people understand the global scale of vectors and impacts. In contrast, ecologists are increasingly coming to see invasive species as byproducts of globalization and ecosystem disturbance, and are especially beginning to recognize that, because eradication is usually difficult or impossible unless done early in the invasion process (Simberloff, 2003), attempting to prevent the arrival of new species is the most efficient way to reduce future impacts. Policy and funding responses remain, however, focused on local examples of already invasive species, rather than widespread prevention. Consider three examples of invasive species that are current foci of policy and funding. The states of Indiana, Michigan, and Ohio have launched massive ash tree cutting programs to restrict the spread of the emerald ash borer, a beetle ravaging ash trees throughout the Midwest. The western states of the United States, through the U.S. Fish and Wildlife Service, have instituted a wide-ranging education program to prevent the spread of zebra mussels to western rivers in order to prevent the costly fouling of hydropower dams, fish ladders, and intake pipes for irrigation and water supply. Finally, individual homeowners and lake associations are attempting to eradicate Eurasian watermilfoil, which is choking lakes across the United States and Canada. While these invasive species need to be controlled, we are concerned that considerably less energy is being spent on identifying and managing the vectors that introduced these species in the first place. As long as those vectors remain active, the risk of new invasions, and new impacts, is undiminished. Ecologists need to communicate a more integrated message about invasive species to give policymakers and society the perspective required to most efficiently reduce the risks of future invasions.

In order for ecologists to communicate an integrated message about invasive species, they will need to put more effort into understanding the basic

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biology of invasions. Ecologists have been quite effective at studying and reporting the impacts that invasive species have on society and the environment, but considerably less effort has been aimed at research that would help to predict the likely identity and location of future invaders. A quick survey of the Sea Grant Nonindigenous Species Site (www.signis.org) database found 369 articles on "Environmental Impacts," 22 on "Dispersal Mechanism," 20 on "Prevention," and 3 on "Economic Impacts" in the peer-reviewed literature section. Understanding the risk of future invasions requires theoretical and applied research that looks at, for example, rates of introduction, establishment success, and seasonality of both the vectors of introduction and the lifecycle of organisms. Better knowledge about these factors would allow much more effective actions to prevent invasions, but to date ecologists have given relatively little attention to such questions.

As well as addressing basic biological questions, ecologists need to provide guidance for public policy by generating information about the likely outcomes of different policies. In the case of invasive species, very little information of this type has ever been produced. For example, although it is known that unrestricted trade in ornamental plants inevitably leads to the establishment of economically and environmentally costly invasive species (Virtue *et al*., 2004), to our knowledge there are no assessments available that would help a government to quantitatively evaluate the risks posed by different policies. Without this information, policymakers cannot make informed decisions, and thus invasive species are given lower priority than other concerns. To address this lack of knowledge, we believe that more effort should be spent investigating the intersection of invasive species biology and policy. For example, it would be possible to determine the average rate at which introduced plants from the ornamental trade become invasive. Given this invasion rate, predictions of the number of new invaders could be made based on different policy options regarding the nursery industry. These data could be combined with the average cost of an invasive plant in terms of lost agricultural production; thus a quantitative prediction of the likely economic damages could be calculated for different policy prescriptions. Although any such predictions would have large uncertainty, they would enable policymakers to quantitatively incorporate the costs of invasive species into their decisions.

We believe that one of the primary reasons ecologists have tended not to work toward predictions of future invasions, or toward prescribing realistic prevention methods, is the lack of communication with economists and policymakers. Economists and policymakers understand the reality of costs, benefits, and the allocation of limited resources far better than ecologists. Communication among these groups is essential for effective ecological risk assessments (Landis, 2003), but very few collaborative efforts have been undertaken to integrate the science and economics of invasive species, let alone the development of public policy. When these collaborations do occur, however, they are generally effective, as shown by a recent special issue of the journal *Ecological Economics* (see Shogren & Tschirhart, 2005) that published a set of tools to cost-effectively prevent and control invasive species. Another collaborative effort, the Integrated Systems for Invasive Species (ISIS; http://www.math.ualberta.ca/~mathbio/ISIS/), of which we are a part, is uniting ecologists, mathematical modelers, and economists to address the bioeconomic framework of invasive species. Collaborative efforts such as these are rare, but offer the best hopes for generating information that will enable society and policymakers to make informed decisions about invasive species.

Increasingly, scientists must conduct outreach as part of research funding. Ecologists studying invasions can, and should, use outreach to push a cohesive message about invasive species issues into the mainstream. Avenues for outreach include formal education settings (e.g., schools), informal education venues for the general public (e.g., public displays), media, resource managers, and policymakers. For example, we and other colleagues from the ISIS project are developing communication with the general public, resource managers, and policymakers as a central part of our work. The flagship of these efforts is a partnership with the Shedd Aquarium in Chicago, where we are helping to develop displays that will inform some of the 1.8 million annual visitors about invasive species. With the staff of the Shedd Aquarium we are developing a message that accurately reflects the latest in science and that is comprehensible and relatable to the public. In addition, we meet directly with resource managers from state and federal agencies to inform them of the latest in research on risk assessment and to discuss how this might influence management. Interaction with the public and resource managers allows us to both present our results, and to learn how our future research can best address prevention and management of invasive species.

An illustration of how ecologists' concerns about the risks of invasive species have been poorly incorporated into public policy is the introduction of zebra mussels to the Laurentian Great Lakes via ballast water. The potential damage that zebra mussels could have on the waters of North America were predicted several times as far back as 1921, including a report for the Environmental Protection Service of Canada in 1981 (see Carlton, 2001, for a list of predictions). Despite these warnings there was no significant effort to prevent invasion, and in 1988 zebra mussels were found in Lake St. Clair. Zebra mussels now occur throughout the Great Lakes, many eastern U.S. river systems, and several hundred inland lakes, costing the U.S. industry an estimated $1 billion per year (Pimentel *et al*., 2005). In addition, they have caused the local extinction of many native mollusks (Strayer & Smith, 1996), and have been implicated in the demise of valuable sport fish populations (Dermott, 2001). Given that this invasion was predicted and that measures could have been taken to reduce the chance of it occurring, it is worth considering what an appropriate response to this risk would have been.

First, it would have been possible for a collaboration of ecologists and economists to predict the scale of impacts. Zebra mussels have caused serious damage to infrastructure in Europe for many years (Ricciardi, 2003), and these impacts could have been projected onto the U.S. landscape. Likewise, ecologists could have investigated the likely impacts on native species. Given that native mussels are particularly vulnerable to being overgrown by aggressive colonizing species, such as zebra mussels, and that the United States has the highest diversity of pearly mussel species in the world, the predicted impacts would have been large. While any estimates of economic and environmental impacts would have been approximate, these estimates would have offered society an appropriate scale on which to base efforts to reduce the risk of zebra mussels becoming established.

In order for action to be taken by policymakers the public needs to be convinced that significant funds should be expended to reduce the risk of an invasion. Because of the expense and difficulty of eradicating invasive species, proactive policy and research are necessary. For action to be proactive, the general public has to be better educated about the mechanisms by which invasive species arrive, and the damages caused when they do. To remedy this situation, we hope that ecologists will make more effort to engage the public in discussions about invasive species, and suggest that the outreach component required by funding agencies will be an effective avenue for this. Likewise, just as policy should be proactive so should the research conducted by ecologists. Understanding the impacts of invasive species is an essential component of the invasive species issue, but more attention needs to be focused on quantifying and predicting future impacts and methods of prevention. If the public and policymakers had been better informed about the risks from invasive species before the warnings about zebra mussels were made, and if those warnings had been accompanied by quantitative predictions of the losses that would occur, then society would have been in a better position to manage the risk of invasion. We hope that this will be the case in the future.

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