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Overview: Designing and Implementing Invasive Species Prevention, Eradication, and Control Policies: Economics, Biology, and Uncertainty

Rachael E. Goodhue and Gregory McKee, Guest Editors

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As discussed in the other contributions to this themed set of articles, invasive species may disrupt trade flows, management of natural resources, and agricultural production. An invader may be used as the justification for erecting a barrier to trade. Fishery stocks can be decimated by an invader, requiring the recalibration of quotas, seasons, and other policy instruments. Agricultural yields or output quality may be reduced by an invader. Because of the potential for deliberate introduction, invasive species policy is even a relevant issue for policymakers addressing terrorism.

Invasive species represent a unique challenge for policymakers and for economists analyzing optimal pest control policies because of the uncertainty regarding the effects of an invasive species on pre-existing biological and economic relationships. By definition, an invasive species problem involves the invader's biological and economic interactions with the invaded ecosystem and economic agents involved in that ecosystem. The primary theme unifying these articles is that critical mistakes regarding policy choices can be made if relevant economic and biological relationships are not incorporated into analyses of policy options. Each article identifies a key lesson for invasive species policy analysis.

Articles in this Theme:

Modeling the Depth of Bioeconomic Integration

Finnoff et al. explore the importance of choosing the correct degree of integration within a bioeconomic model. As in McKee et al., in order to address a bioeconomic policy question, feedback between the two systems must be incorporated into the model. Finnoff et al. introduce a bioeconomic model with multiple feedback loops. They examine the effect of imposing quotas on pollock harvests in the Bering Sea in order to increase populations of the endangered Steller sea lion. Fishing quotas affect the market for pollock; in order to estimate the net welfare impacts in this market, the demand for pollock must be included in the bioeconomic model.

Limiting the analysis to this set of bioeconomic relationships would distort the overall welfare analysis in an important way; it does not place any value on the sea lion population, but simply takes it as the source of an exogenous biological constraint on the system, which requires the imposition of fishing quotas. The authors incorporate a second set of bioeconomic relationships that address this problem: the market for wildlife tourism in the Bering Sea, which benefits from increased populations of the Steller sea lion and other marine mammals. Ignoring these relationships would have two effects: first, the sea lion population would either be exogenously specified or chosen as a function of biological relationships alone, and second, the benefits of quotas would be underestimated since the value to marine tourism would be ignored.

The primary lesson from this analysis is that all relevant markets must be included in the bioeconomic model. A further implication is that all relevant biological relationships must be included in the model.

Integrating Prevention and Control Policies for an Invasive Species

Kaiser discusses problems stemming in part from the structure of U.S. invasive species policy. First, responsibility for invasive species policy is divided among a large number of agencies, which discourages the development of an integrated approach to prevention and control. Conceptually, this problem is driven in part by the tendency for prevention efforts to be targeted at preventing the anticipated economic and ecological losses that a given potentially invasive species may cause, while management and eradication efforts tend to be driven by the irreversible changes to ecological systems that are realized after the successful establishment of an invader. One result of this fragmentation is that resources are not allocated efficiently across species, or across prevention and control efforts for a given species. Coordinating policy across agencies, or consolidating mandates within fewer agencies, could increase the benefit of funds currently allocated to prevention and control efforts.

The economic and ecological costliness of the fragmentation of policy responsibility can be represented fully only in a bioeconomic framework. Kaiser illustrates this using the case of an invader to a closed ecosystem: the brown tree snake in the Hawaiian Islands. Limiting attention to biological factors might result in research and policy efforts directed only at preventing an invasion, in part because an earlier brown tree snake invasion on Guam has proven to be ecologically catastrophic. In the case of the brown tree snake, such efforts focus on preventing the introduction of additional specimens through materials transported from Guam. Given that prevention is by nature imperfect, however, some brown tree snakes will escape detection and enter the Hawaiian ecosystem.

Once introduced, the species requires control efforts. Because the marginal cost of control increases as the population declines, optimal policy requires the net benefit of preventing an additional snake from entering the population equals the net benefit of removing an additional snake from the existing population. Hawaiian expenditures on prevention and control are significantly distorted, relative to the point where this relationship would hold.

Hawaiian efforts regarding the brown tree snake approximate the case where only biological parameters are considered. Current annual expenditures on prevention are about $2.6 million, while expenditures on control are about $76,000. These limited control expenditures have proved insufficient to identify and reduce the existing population to optimal levels; instead, snakes that have escaped prevention efforts are able to reproduce and increase the population. (Of course, the alternative possibility is that prevention efforts have proven perfectly effective and there is no existing population. However, this seems statistically and scientifically unlikely.) The distortion in prevention and control expenditures will ultimately result in a larger Hawaiian brown tree snake population than would be the case if the same total expenditure was optimally allocated.

Value of Information and Methodological Choices in Bioeconomic Modeling

McKee et al. address one manifestation of the heightened uncertainty facing policymakers regarding an invasive species problem, relative to an established pest problem. Often, policy decisions must be made when relatively little information is available, be it in the form of experimental data regarding the specific invasive species problem or otherwise. In this event, methodological choices become critical because the role of method-driven assumptions cannot be limited by data. Often, due to data limitation, analysts construct simple reduced-form population models where current population levels are estimated based on past population levels. The authors illustrate the cost of this specific methodological choice in the context of a specific invasion: the greenhouse whitefly in California strawberries.

The authors construct two bioeconomic models of the greenhouse whitefly-strawberry relationship. The economic components of the models are identical, as is the relationship governing the effect of the whitefly population on strawberry yield. Only the models of the whitefly population differ. One is a reduced-form autoregressive model that relies only on experimental data to predict the development of the whitefly population as a function of its previously observed levels. The second is a structural simulation model that incorporates information regarding determinants of the whitefly's life cycle from the scientific literature, as well as the experimental data regarding observed population levels.

The two models are compared to the observed data. While both describe the overall pattern of population peaks and troughs reasonably well, the structural simulation model does a more accurate job of representing the magnitudes of the peaks and troughs. This suggests that incorporating data from other sources and constructing a structural simulation model can improve the descriptive power of bioeconomic models, at least in some circumstances. More critically, the authors demonstrate that this difference in the models causes growers to respond differently to regulations regarding pesticide use for whitefly control in strawberries. Using the reduced-form model, the cost per acre to a grower of the regulation limiting the number of applications of a specific pesticide to two per season is $2,500, while under the structural simulation model it is $2,100, a difference of $400 dollars per acre. This difference in the estimate of the cost is substantial, equaling about 10% of profits under the grower's unregulated profit-maximizing choice. When balancing the costs of the regulation against its benefits in terms of reducing the development of resistance, the cost will be overstated.

Institutional Uncertainty and Bioeconomic Systems

One motivation for the erection of agricultural trade barriers is the possibility of an invasion of a pest or disease that may negatively affect production in the importing country. Romano and Thornsbury examine a specific case: a U.S. ban on the importation of Argentine lemons due to diseases not present in the United States. In efforts to get the ban removed, Argentina's citrus producers developed a set of institutions to develop and implement a systems approach to phytosanitary regulation.

A systems approach to invasive species policy involves multiple control steps at different stages of production and marketing. The use of multiple, sometimes independent, control steps is intended to reduce the risk of an invasion. Successful implementation of a systems approach can be technically and politically difficult. Technically, a systems approach requires an understanding of the production and marketing chain, as well as the biology of the crop and pest in question. Institutions must be capable of mastering these technical elements and be able to undertake multiple control steps. Politically, the feasibility of implementing a systems approach in order to enable the removal of a trade barrier depends on the credibility of the institutions regarding their ability to master these technical requirements, as well as on the political influence of competing interest groups and the parameters set by international trade rules.

Such political considerations are made more powerful by uncertainty. When information regarding a bioeconomic system is incomplete, then a systems approach to regulation must be implemented based on the information available. Different stakeholders may assess the costs of the resulting risks, or even the risks themselves, very differently. Romano and Thornsbury identify U.S. growers' reluctance to allow imports based on information provided by U.S. and Argentinian institutions as "institutional uncertainty." Concerns regarding the quality and quantity of the provided information have played an important role in the still ongoing trade dispute. Clearly, when deciding how much information to obtain prior to choosing a policy, the information collection decision should be guided by the economic consequences of making a mistake, and the cost and likelihood of doing so as a function of the amount of information collected.

Lessons for Policy Analysis

Bioeconomic modeling provides a means of incorporating known information into a single decisionmaking framework. There is a great deal of uncertainty regarding the bioeconomic relationships determining the optimal policy response. The analyses in this set of articles derive four specific lessons regarding the use of bioeconomic models in invasive species policy analysis: First, all relevant economic and biological relationships must be included in the model in order to get a full picture of the benefits and costs of potential policies. Second, a complete analysis of policy choices regarding potential invasions should include not only the optimal management, eradication, or prevention policy, but a comparison of these optimal solutions that balances the marginal benefits of funds allocated to each activity. Third, methodological choices will affect estimates of these marginal benefits; alternatives to statistical methods that can incorporate additional information should be considered. Simulation models provide a means of identifying the unknown parameters that are most likely to affect the choice of the optimal policy solution. Finally, information collection efforts should be guided in part by the projected costs and probability of making policy mistakes in the absence of this information.

In sum, invasive species policymaking is a process, rather than a single decision. Bioeconomic modeling can play a role at every stage of the process, from representing the context for choosing the initial policy, identifying missing information that's important for assessing the impacts of that policy, assessing post-implementation impacts, and providing information for revising existing policies. This set of themed articles has identified guidelines for using bioeconomic models effectively in the policymaking process.

Rachael Goodhue is Associate Professor, Department of Agricultural and Resource Economics, University of California, Davis, and a member of the Giannini Foundation of Agricultural Economics. Gregory McKee is Assistant Professor and Director of the Quentin Burdick Center of Cooperatives, Department of Agribusiness and Applied Economics, North Dakota State University, Fargo, ND. *This research was supported by the Program of Research on the Economics of Invasive Species Management (PREISM), Economic Research Service, U.S. Department of Agriculture, under Cooperative Agreement 43-3AEM-3-80081. Seniority is shared equally between authors.*