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United States Department of Agriculture
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Integrating Invasive Species Prevention and Control Policies

Michael Livingston and Craig Osteen

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Invasive species have been associated with billions of dollars in economic and environmental losses in the United States, including yield and quality losses for farmers and ranchers. Particularly problematic invasive species include insects (Mediterranean fruit fly, Emerald ash borer, Asian longhorned beetle), aquatic invertebrates (zebra mussel), weeds (kudzu, yellow starthistle, purple loosestrife), plant diseases (Asian soybean rust, citrus canker, sudden oak death), animal diseases (exotic Newcastle disease), and zoonotic diseases (West Nile virus). Invasive species clog and foul waterways, impair the productivity of pastures, reduce property values and environmental amenities associated with parks and natural ecosystems, and threaten the survival of indigenous wildlife. Moreover, some invasive pathogens pose health risks to humans.

Programs and policies to minimize the threat of, or mitigate the damages from, invasive species work best if designed in concert with each other. Whether program emphasis should be on prevention or control depends on the biological characteristics and size of the invasive species population, ecological characteristics of invaded ecosystems, the cost and efficacy of prevention measures relative to control measures, and the level of prevention costs borne abroad. Because all of these factors are highly variable, data needs are constant if intervention is to be both effective and economical.

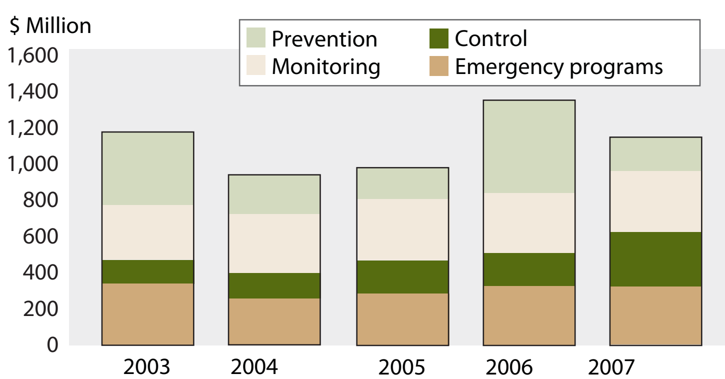
The Invasive Species Management Problem

The value of U.S. agricultural imports grew 7 percent per year between 1995 and 2004. Over the same period, foreign travel expenditures in the United States and domestic travel expenditures abroad increased 3 and 4 percent annually. The economic benefits of trade and travel, however, have brought with them a heightened risk of invasive species, like the Mediterranean fruit fly, becoming established within our borders (Hlasny and Livingston, 2008). Although most introductions of invasive species are believed to be facilitated by humans (National Research Council, 2002), harmful organisms like Asian soybean rust also enter the United States via wind and water currents. Once established, pests often move between agricultural fields and other domestic areas naturally and via the movement of contaminated vehicles, packaging materials, and commodities.

Because agricultural pests are difficult to detect and eliminate, and because many are highly mobile, population control in one area may affect population levels, damage, and control costs in nearby areas. If the pest control decisions made in one area are based solely on the benefits to individuals making those decisions, the level of prevention and control effort is likely to be less than desirable from society's perspective. When the prevention and control efforts in one area affect pest population levels in other areas, coordination of decisions by all of those affected often requires government intervention. For this reason, government agencies around the world regularly devise and implement prevention and control policies.

Figure 1

APHIS expenditures during fiscal years 2003-2007



Source: U.S. Department of Agriculture fiscal year budget summaries.

Limiting new invasions, controlling outbreaks of established populations, and restoring native ecosystems in the U.S. occupies 21 Federal departments and agencies, with USDA's Animal and Plant Health Inspection Service (APHIS) taking the lead for pests of agricultural significance, forest pests, and zoonotic diseases. Figure 1 shows how APHIS budget expenditures are divided among prevention, control, and other activities. Monitoring activities encompass both prevention and control, while emergency spending is for rapid-response eradication (control) programs. Designing programs that work together to deal with invasive species problems requires economic as well as biological and ecological research.

The Invasive Species Solution—Creating Synergy

Previous research recognizes the interdependence of policies designed to limit the introduction of invasive species (prevention) and those designed to reduce or eradicate domestic populations of invasive species (control), as well as the practicality of designing such policies simultaneously and harmoniously. This report synthesizes recent research highlighting the information and data required when developing policies (for government decisionmakers) or deciding on a course of action (for agricultural producers). Especially important to consider are the biological characteristics of the invasive species, ecological characteristics of the invaded environment, the costs and benefits of prevention and control policies, the ways in which the actions of decisionmakers in the public and private sectors combine to influence management outcomes, and whether the costs of prevention are borne domestically or abroad.

For some invasive species, domestic regulatory authorities and agricultural producers directly influence the rate of introduction through preventive efforts. The cost of these efforts is borne domestically, by U.S. taxpayers who fund public prevention and control programs and by agricultural producers and other landowners who implement prevention and control practices to protect their operations, businesses, or property. For example, ships and airplanes leaving Guam for Hawaii are routinely inspected for brown tree snakes. The State of Hawaii pays the Government of Guam for canine inspections at civilian ports and airports, as well as for the maintenance of snake detection traps along fences surrounding ports and airports in Guam. Similarly, livestock and broiler producers can reduce the likelihood of an animal disease outbreak by constructing borders that separate cultivated animals from wild animals, maintaining sanitary working conditions, and vaccinating animals against specific diseases (Hennessy, 2007). Research examining this type of invasive species management has offered a number of policy options.

Prevention and Control Programs Are Substitute Instruments in Invasive Species Management.

If a prevention program—such as inspecting ships, airplanes, and cargo in Guam headed to Hawaii for brown tree snakes—is more effective and less costly than alternative control programs—such as searching the difficult Hawaiian terrain for brown tree snakes and eliminating them—devoting more resources to prevention than control makes economic sense (Burnett et al., 2006; Kim et al., 2006; Olson and Roy, 2005). In the case of a windborne fungus like Asian soybean rust, which entered the United States in 2004, the only way to have prevented entry would have been to eliminate the pathogen from all areas linked atmospherically to the country. Such a program would be extremely costly and ineffective because the fungus is highly fecund and can live on over 95 plant hosts (Livingston et al., 2004). APHIS' response to the threat, therefore, focused on educating U.S. farmers on appropriate control techniques, viewing the introduction of the pathogen as inevitable (Roberts et al., 2006).

The relative allocation of resources devoted to prevention and control programs will depend on biological characteristics of the invasive species, including its population size and rate of growth (Kim et al., 2006; Olson and Roy, 2005), the minimum number of organisms required to establish a self-sustaining population (Burnett et al., 2007a), the carrying capacity of potential host areas (Kim et al., 2006), and the cost and efficacy of prevention relative to control. For example, when the rate at which an invasive species outbreak occurs is high, or varies widely from year to year, it may be more efficient to focus additional funds on control programs rather than prevention programs (Keohane, Roy and Zeckhauser, 2000, 2007).

Invasive Species Research at ERS

While drawn from the economics literature dealing with the prevention and control of invasive species, much of the information presented here was from studies funded by the Program of Research on the Economics of Invasive Species Management (PREISM). Under this program, the Economic Research Service conducts research and funds extramural research to support the economic basis of decision making concerning invasive species of significance to agriculture or USDA. For more information on PREISM, including detailed activities reports and published research, visit http://www.ers.usda.gov/Briefing/InvasiveSpecies/.

Figure 2

Cost of controlling *Miconia calvescens* in Oahu by population size versus level of control

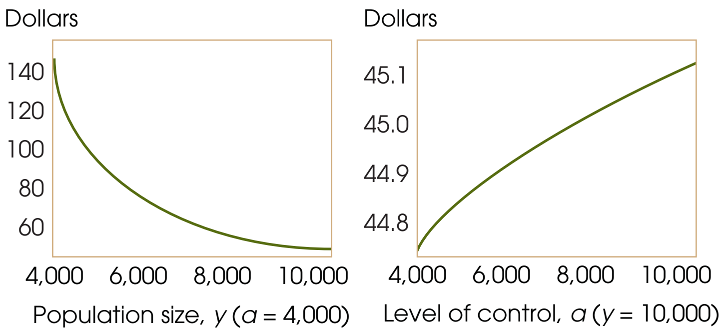
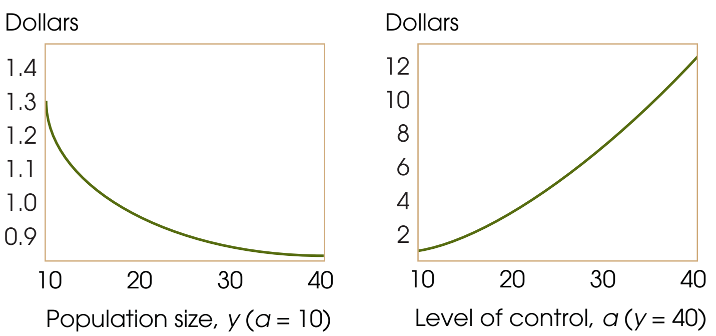


Figure 3

Cost of controlling a hypothetical insect infestation, by population size versus level of control



Level of Control Needed Is Higher for Larger Initial Outbreaks. Not surprisingly, the level of resources needed to control an invasive species outbreak tends to be higher when the initial size of the pest population is high (Olson and Roy, 2005). On the other hand, the cost of removing an additional organism is smaller for larger pest populations because it is less costly to find and deal with invasive organisms in dense pockets of infestation. The cost of removing an additional organism generally grows as more organisms are removed because the cost of finding and targeting the remaining organisms increases. Figure 2 demonstrates that the cost of removing an additional amount of the invasive weed *Miconia calvescens* on the island of Oahu (Burnett et al., 2007a) is much more sensitive to changes in the population size than to changes in the level of control (i.e., the number of organisms removed). Figure 3 demonstrates the opposite case—the additional cost of control increases more rapidly with the level of control than it decreases with the population size. For example, pesticide expenditures increase with the percentage of insects removed from a given field, especially if a fraction of the population is resistant to the pesticide.

These results have important implications for the tradeoff between spending additional funds on prevention or control. For the *M. calvescens* case, the level of spending on prevention declines for larger initial outbreaks. This occurs because the cost of control decreases relative to the cost of prevention, highlighting again the way in which prevention and control measures are substitute policy instruments. However, in the insect management case, the reverse is true: the level of spending on prevention should increase because the cost of control increases relative to the cost of prevention.

Olson and Roy (2005) examine a static environment; however, their basic idea—that it is important to understand how the additional cost of control depends on both the level of control and the population size—is relevant under dynamic management settings. Because the additional cost of eliminating a single organism is smaller for larger populations, costs per organism increase as a control program reduces the invasive population over time. If incremental control costs increase enough as the population declines, rather than eliminating the pest, it may be less expensive to maintain a small target population level, using control measures to remove new growth and new entrants from a particular region and prevention measures to reduce the rate of new introductions (Burnett et al. 2006, 2007a; Kaiser, 2006). Indeed, in many cases, allowing low populations of an invasive species to survive may be economical because of the difficulty and extreme cost of finding and eliminating each organism (Burnett et al. 2006, 2007b).

Optimal Spending Increases with More Rapid Infestations and More Conducive Habitats. Resources needed to control invasive species will be larger if they can grow and spread rapidly (Kim et al., 2006; Olson and Roy, 2005). Similarly, spending on prevention (before an invasive species is discovered) will need to be larger for areas that may allow larger populations to develop—areas lacking biological and environmental constraints (like natural predators or unfavorable climate) on the growth of invasive populations. For example, forests with large numbers of dense ash tree stands would receive larger allocations under an economical Emerald ash borer management program, not only because those stands are valuable and vulnerable to attack, but also because, if left unprotected, the stands would harbor the pest and allow it to spread more quickly.

Economical Policies Depend on the Stage of an Invasion and Growth Rates. Because pest invasions are dynamic processes, policies designed to ameliorate their impacts must be dynamic as well. As the level of a (controlled) invasive population changes, the control cost changes too, so prevention and control policies must be fluid. Simply recognizing the dynamic nature of the invasion process has important policy implications. For example, immediate eradication may be economical for smaller invasions, such as the periodic, contained outbreaks of the Mediterranean fruit fly (medfly) that have occurred in California and Florida since 1929. However, achieving and maintaining a reduced population level may be economically efficient for larger, less contained infestations, such as the *M. calvescens* weed outbreak in Hawaii. Moreover, if eradication is feasible, total damages are likely to be minimized if control efforts are implemented early, when the population is small. Underfunded control efforts may be wasteful, having little effect on population growth and related damages. Higher initial expenditures may reduce long-term damages and control costs, even if the species is not eradicated.

Accounting for the Intertwining Effects of Private and Public Actions Is Essential. It is important for public decisionmakers to understand how agricultural producers and/or homeowners may respond to outbreaks of invasive species, and how private sector responses may be affected by government policies (Finnoff et al., 2005a, 2005b). Otherwise, it is unlikely that the benefits and costs associated with proposed policies will be estimated accurately. For example, pest control in one area serves as a preventive measure for areas linked via a pathway. However, individuals typically control pests in accord with their own costs and benefits and not society's. In these settings, public monitoring and control programs, such as APHIS' Fruit Fly Cooperative Control Program, may help to improve social welfare by coordinating population management across regions (Baumol and Oates, 1988).

Uncertainty and Risk Perception Can Complicate Decisions. While quick and decisive action can be cost effective, when the rate of outbreaks varies considerably over time or space, there may be value in delaying implementation of control measures. It is rare that decisionmakers enjoy perfect information about the extent of an outbreak. But once committed, control efforts are irreversible (i.e., the expenditures cannot be recouped), so until the full extent of the problem is understood, rapid response may be wasteful (Dixit and Pindyck, 1994).

In addition, the benefits and costs of prevention and control programs are generally uncertain upon and even during implementation. If individual decisionmakers view the risk of an outbreak differently (that is, some are more risk averse than others), then the levels of prevention and control provided are likely to differ depending on who is making the decisions. For example, if the benefits associated with control are perceived to be more certain than those associated with prevention, decisionmakers will tend to focus more resources on the control of invasive species (Finnoff et al., 2005a, 2005b; Olson and Roy, 2005).

When Prevention Costs Are Borne Abroad, Higher Infestation Rates Call for Heightened Restrictions. Sanitary and phytosanitary (SPS) import regulations can affect U.S. infestation rates only indirectly, and foreign parties generally bear most of the direct costs associated with U.S. prevention programs. Therefore, understanding how agricultural producers abroad react to U.S. SPS import regulations is essential to the effective design of the overall invasive species management package (Peterson and Orden, 2006). For example, because the medfly is known to exist in 65 countries that export fresh produce to the United States, USDA regulates the process by which it is imported. Among the approved and commonly applied ways to eliminate larvae inside infested produce is cold treatment: refrigeration at a mandatory average temperature for a specific duration. Livingston (2007) examines cold-treatment schedules that maximize the net benefits of U.S. producers and consumers of produce using a simulation model, wherein foreign producers control medflies to maximize their profit. If medflies survive pesticide sprays, cold treatment, and domestic monitoring/control programs, an outbreak can cause U.S. produce growers to suffer yield losses and increased production costs.

The efficient number of days to treat imports increases with the severity of medfly outbreaks abroad. When medfly populations abroad are unusually high, the share of exported commodities infested with medfly eggs and larvae is higher, requiring heightened population control abroad and more stringent SPS import restrictions. The appropriate level of prevention—both the stringency of the SPS regulations and the effort and direct costs incurred abroad—increases with higher risks of infestation. When pest pressure is at or below historic levels abroad, economic incentives of foreign producers may be consistent with U.S. policy; this is less likely when pest pressure is above average. This finding demonstrates the importance of monitoring compliance with international cold-treatment regulations, and provides some justification for USDA's practice of doing so.

Conclusion

This report synthesizes the implications of a series of studies that describe the information and data needed by public and private decisionmakers. Keeping detailed records about the estimated size of an invasion, control costs, and the numbers of organisms removed—or acreage cleared—will enable decisionmakers to modify control programs as needed to improve program efficacy and economic efficiency. Information about an organism's ability to spread and a potentially invaded ecosystem's carrying capacity is also important. Understanding how agricultural producers and homeowners, both at home and abroad, will respond to outbreaks and public prevention/control policies is important, especially when the decisionmaker can affect the risk of infestation only indirectly.

This brief is drawn from . . .

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* Citations preceded with an asterisk are PREISM-funded studies (see box, “Invasive Species Research at ERS” on p. 3).

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