



On the Garden Path: An Economic Perspective on Prevention and Control Policies for an Invasive Species

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Economists currently use the term invasive species to denote species that arrive in a new ecological setting and spread, creating ecological and economic damages. The problem facing invasive policy managers is to select strategies that minimize the overall invasive species-related costs over time, including prevention and control expenditures and damages. This article aims to highlight the connection between prevention and control in decisions to best utilize scarce resources to fight invasive species and arises from a more extensive literature involving this author and others (Burnett et al., 2006; Olson & Roy, 2005).

Definitions and the Policy Environment

An invasive species generally causes more harm than good through its aggressive spread. Prevention efforts, however, cannot always identify distinctions between harmful, beneficial, or benign introductions, nor intercept all introductions, and are thus more risky policies compared to controlling a known invader. Thus, risk-averse managers often prevent too little (Finnoff et al., 2006, in press).

Opportunities for efficient management of invasive species from arrival to adaptation are missed in a web of overlapping mandates and complex biological and economic pathways for the introduction and spread of species. Historically, the many different avenues for invasive species propagation and intervention have led to piecemeal policy approaches to invasive species. Twenty federal agencies, from the Department of Homeland Security to NASA, administer over a dozen major congressional acts pertaining to invasive species. Executive Order 13112 (Feb. 3, 1999) acknowledged the difficulties presented by this piecemeal policy and established a coordinating inter-

departmental National Invasive Species Council (NISC), but the agency has no authoritative powers, and policy conflicts and gaps remain.

Consider the differences in legislative policy:

- There are acts targeting individual species (Sudden Oak Death, Pub. L. 108-488, Dec. 23, 2004; Brown tree snake, Pub. L. 108-384, Oct. 30, 2004; Nutria, Pub. L. 108-016, Apr. 30, 2003). These exist despite the fact that there is no definitive reason to believe that these invaders are worse threats than all others; however, the targeted legislation may limit attention toward other equally damaging prospects.
- There are direct, broad mandates to reduce harm from non-native species (Plant Protection Act, Pub. L. 106-224, Jun. 20, 2000; National Invasive Species Act, Pub. L. 104-332, Oct. 26, 1996; Lacey Act, 18 USC §42). Most of these focus on preventing the introduction of new invasive species that are likely to harm agriculture or other markets or quantifiable resources.
- There are statutes that indirectly target invasive species prevention and control for the preservation of specific assets (Public Lands Corp Healthy Forest Restoration Act, Pub. L. 109-154, Dec 30, 2005; Endangered Species Act, 16 USC §1531-1539). These statutes generally apply control measures after invasion as indirect intervention for the protection of non-market amenities such as biodiversity.

As such, the biological and economic consequences of individual species *and our awareness of these species and their consequences* may generate poor allocation of resources among species. The net benefits or damages of an introduced species may vary significantly depending on

the state of the existing ecosystem. For example, using exotic plant species for quick stabilization of denuded hillsides might bring significant benefits by mitigating massive flooding in one location, whereas introduction of the same species in another location may reduce biodiversity or water supply. Intertemporal considerations abound; today's quick fix may be tomorrow's bane.

Economic and Biological Considerations in Invasive Species Control

The problem facing invasive policy management is to minimize the expected net damages and prevention and control costs of new and existing invasions over time. This problem is also subject to the biological constraints of the species. Figure 1 illustrates how a species whose minimum viable population (E_i) is low and that grows rapidly to a large carrying capacity population (K_i) is most likely to invade successfully. One whose initial population threshold (E_n) is higher, requiring a higher initial volume of arrivals, whose growth rate is slower, allowing for more time to eradicate, control, or contain a spreading population, and whose carrying capacity population is lower (K_n), does not present the same biological threat. Furthermore, a lower initial population threshold, such as (E_i), makes eradication considerably more costly as a smaller population must be located and removed. Research and prevention policies might therefore focus on identifying and stopping species from entering based solely on their biological parameters.

However, biologically driven policies may not always target the correct species with the most efficient efforts. The biological potential of a

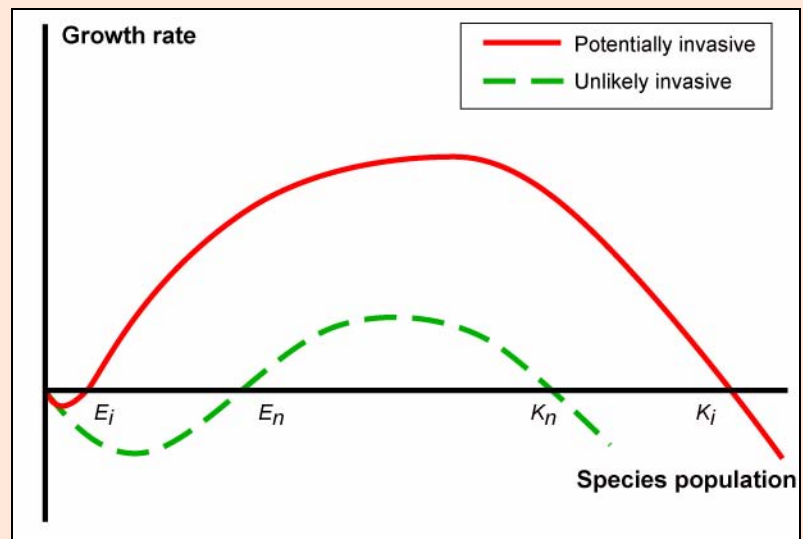


Figure 1. Role of biological growth.

species must be combined with economic theory and the expected damages and costs of control for the species. We discuss how the characteristics of damages and costs impact prevention and control decisions.

Damages may be economic or ecological. Economic damages are generally in the forms of direct damages to facilities, human health, natural resources, and indirect damages from ecological change. Ecological change may commonly include losses in water or soil quality or quantity, biodiversity and resiliency losses, and productive resource losses. The expected damages are a function of the invasion size. In many cases, ecological damages may outweigh economic ones. This is likely when the value of the threatened assets is generated from biodiversity, tourism, aesthetics, and the like. Non-market valuation techniques may be necessary to establish these damages (See Loomis, 2005). We can use information on these characteristics to determine the expected damages from taking no action, or accommodating the invasion, and the benefits from control across a spectrum of invasion

sizes corresponding to policy choices and expenditures.

Economic Conclusions Related to Invasive Species

Though similar to the harvest problem of any renewable natural resource (Clark, 2005), in which management weighs the net benefits of harvest (removals) today against the net benefits of future harvests, invasive species problems are more likely to involve cases where extinction is optimal policy or where accommodation of the damages, without control efforts, is the best choice. Determining the appropriate policy is particularly complicated when there are significant biological uncertainties surrounding the invasive species' capabilities in a new ecosystem and when there are difficulties in measuring resource values, such as with many non-market amenities. It is useful, therefore, to determine some rules of thumb regarding these parameters.

- Control policy must consider the overall cost of controlling an invasion.

If the net benefits from the invasive species removal (harvest) outweigh current control costs, conserving the species for tomorrow does not generate a net economic benefit, and biological extinction, or eradication, may well be the optimal policy. If the costs of harvest outweigh the damages of the population, it may be optimal to allow the species to invade unchecked. All other factors equal, lower levels of damages or high costs relative to the damages will decrease control activities, as will time-delayed damages.

- Control policy must consider the cost of controlling an invasion as a function of the size of the invasion so that the benefits of controlling or preventing the invasion may be weighed against the costs of doing so.

Once a species is established, we expect that the per pest cost of control will generally increase as the size of the population decreases. This is due to increased difficulty in detecting and removing fewer and fewer specimens from any given area. All other factors equal, the higher the costs of removal, the larger the population that will be accommodated, once present.

- The degree of rise in cost as control efforts increase also plays an important part in control policy.

A relatively flat cost structure is more likely to result in accommodation than a cost relation that drops off to lower levels at higher populations. On the other hand, fast increasing costs may favor eradication followed up by prevention of re-introduction.

- Policy should also weigh the intertemporal advantages, in terms of present discounted value, of preventing or removing an additional invasive specimen

today against those of leaving the problem for tomorrow.

The role of prevention, either before an initial arrival or after a successful eradication, should also be integrated into policy formation. Prevention efforts should be based on the expected outcome if prevention fails. Since prevention is imperfect, over time the cumulative probability that a new species will evade detection and establish itself is nearly one. Prevention expenditures delay this establishment, but cannot eliminate it altogether. When prevention fails, the species will establish and begin to grow and cause damages. Thus, prevention expenditures for a given species should continue until the point where the cost of preventing the next specimen from entering is equal to the cost of controlling another specimen on the ground.

- A species' ability to spread will significantly impact the costs of control.

For example, if the species needs a relatively large population to maintain itself, as visualized by E_n in Figure 1, reducing the population to this extinction level, rather than to zero, negates further control costs, though the population is not eradicated. Optimal policy determining effort allocations between prevention and control at small population levels may involve only prevention, only control, or a combination of prevention and control, and are quite sensitive to the biological and economic parameters of the system.

- Across species, the marginal benefits of prevention and the costs of control activities should also be equal.

The relationship between prevention and control, therefore, may be quite complicated. For example, it is not clear whether prevention should be high or low for a species whose

optimal control policy after establishment is accommodation; if this is the case due to control costs that are always higher than damages, in spite of high damages, then prevention should be high, in order to delay the damages. If, however, accommodation is the policy because the present value of damages is quite low, then optimal prevention might also be low.

A Case Study: Brown Tree Snake Prevention in Hawaii

The economic reasoning described here has been applied to the cases of the Brown tree snake in Hawaii with interesting results (Burnett et al., 2006). The Brown tree snake is a significant concern to the Hawaiian Islands because of its behavior on Guam over the past 50 years. Both Guam and Hawaii were snake-free islands until the Brown tree snake arrived in Guam sometime in the 1950s. Since that time, its unchecked predation has led to some of the highest snake densities known in the world, caused extirpation of 10 of 13 native bird species and caused significant economic damage to power supply and human health. Eight specimens have been intercepted in Hawaii in transported materials from Guam. A small but uncertain number may have escaped detection in Hawaii already. The carrying capacity for Hawaii is estimated at almost 39 million snakes and the damages are conservatively estimated at an average of \$122 per snake per year from losses in biodiversity, power supply, and medical expenditures (Burnett et al., 2006).

It might seem that almost no amount of prevention expenditures could be too high to avoid these damages. The old adage that "an ounce of prevention is worth a

pound of cure” comes to mind, but unfortunately, it may not be true. In cases like this where prevention is focused on a small number of expected pathways, while control of a small population might require searching over a large area at high cost, lavish prevention expenditures will not successfully minimize the threat from invasion. If one is not actively searching the broader habitat for the specimens that avoid detection through prevention mechanisms, these may rapidly reproduce and grow beyond a stage where they are eradicable or easily contained.

In the case of the Brown tree snake, such oversight could be extremely expensive. If, for instance, the current mix of prevention and control is pursued without change, \$2.6 million per year will be spent on preventing the species from reaching Hawaii, but about \$76,000 will be spent on searching for snakes that evade prevention efforts. Since these have proved to be insufficient funds to catch a snake from a very small population, under status quo efforts, the existing population will continue to grow until there are enough snakes that this limited annual expenditure results in catching a snake, imposing perhaps billions of dollars of silent damages in the meantime. Instead, if there indeed is an existing population in Hawaii, it would be preferable to spend much more of the prevention

money on ferreting out that population and limiting damages directly. An additional avenue for reallocating the prevention money might be toward joint production of snake removals with other conservation activities, should such a possibility exist.

Concluding Comments

In sum, prevention and control decisions must be integrated thoroughly to best utilize scarce resources to fight invasive species. Policy must consider that invasive species are a function of human trade and discourse, which is increasing in even the most remote corners of the globe. Optimal strategies will vary by anticipated biological growth, economic cost of prevention and control activities, and economic valuation of potential damages as a function of invasion level. Assessment of these parameters may require creative and iterative interdisciplinary processes. Closed ecosystems like Hawaii provide excellent natural labs for study and are important purveyors of irreversible assets, particularly biodiversity, that deserve particular attention in the battle against invasive species.

For More Information:

Burnett, K.M., Kaiser, B.A., Pitafi, B.A., & Roumasset, J.A. (2006). Prevention, eradication, and containment of invasive species:

Illustrations from Hawaii. *Agricultural and Resource Economics Review* 35(1), 63-77.

Clark, C. (2005). *Mathematical bioeconomics: The optimal management of renewable resources, 2nd Ed.* Hoboken, NJ: Wiley-Interscience.

Finnoff, D., Shogren, J.F., Leung, B. & Lodge, D.M. (in press). Take a risk-preferring prevention over control of biological invaders. *Ecological Economics*. Available online: <http://www.elsevier.com/locate/ecocon>.

Loomis, J. ed. (2005). Valuing the Quality of the Environment and Human Health, *Choices* 20(3). Available online: <http://www.choicesmagazine.org/2005-3/index.htm>.

National Invasive Species Information Center (2006). Available online: <http://www.invasivespeciesinfo.gov/>.

Olson, L., & Roy, S. (2005). On prevention and control of an uncertain biological invasion. *Review of Agricultural Economics*, 27(3), 491-97.

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