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Biosecurity: Moving toward a Comprehensive Approach

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Biosecurity: Moving toward a Comprehensive Approach

LAURA A. MEYERSON AND JAMIE K. REASER

> Biosecurity itself is more than a buzzword; it is the vital work of strategy, efforts, and planning to protect human, animal, and environmental health against biological threats. The primary goal of biosecurity is to protect against the risk posed by disease and organisms; the primary tools of biosecurity are exclusion, eradication, and control, supported by expert system management, practical protocols, and the rapid and efficient securing and sharing of vital information. Biosecurity is therefore the sum of risk management practices in defense against biological threats. (NASDA 2001, p. 1)

A COMPREHENSIVE APPROACH TO BIOSECURITY IS NECESSARY TO MINIMIZE THE RISK OF HARM CAUSED BY NON-NATIVE ORGANISMS TO AGRICULTURE, THE ECONOMY, THE ENVIRONMENT, AND HUMAN HEALTH

The events of September 11 and subsequent anthrax assaults have made US policymakers and the public more aware of our vulnerability to organisms released with the intent to cause significant harm. Such acts are generally labeled "bioterrorism," which has been defined as "the threat or use of biological agents [to cause harm] by individuals or groups motivated by political, religious, ecological, or other ideological objectives" (Carus 2001, p. 3). Bioterrorism differs from other forms of terrorism in three important ways: (1) In addition to intimidation of governments and societies, mass destruction of life (humans, animals, or plants) is a major goal; (2) the onset of an attack may not be readily apparent until the biological agent has spread significantly (among populations or species), depending on the length of incubation periods and detection of visible symptoms; and (3) it may be impossible to establish whether release of the organisms was intentional, in large part because sources and vectors of biological agents, such as wind-borne diseases or food contaminants, can be extremely hard to trace (Chyba 1998, Casagrande 2000, Carus 2001). This last point (i.e., difficulty in establishing intentionality) could prove to be particularly true of bioterrorist acts launched in natural systems, with the ultimate intent that biological agents will spread to livestock, crops, or humans.

Although bioterrorism is a rare event, it has understandably captured the attention of the media and public. To protect human health and agriculture, the government has called for substantial financial and technical resources to combat bioterrorism (Wheelis 2000, Malakoff 2002). Given this laudable response to acts of terrorism, it is interesting to note that nonterrorist, accidental or intentional introductions of harmful biological agents that daily harm the US economy, public health, and environment—at a cost of more than $100 billion annually (Pimentel et al. 2000)—receive substantially less attention. It is our contention that efforts to secure national biosecurity must encompass all introduced harmful organisms, whether or not intent to harm can be established.

The purpose of this article is to illustrate the need for the United States and other governments to adopt a comprehensive approach (termed *biosecurity*) to minimize the risk of harm caused by foreign (nonnative) organisms to the economy (which encompasses all market-related activities and

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infrastructures), to the environment (including the geophysical environment, biodiversity, and their interrelationships), or to human health. To do this, we first discuss approaches to biosecurity in the United States and elsewhere and review aspects of the environment, agriculture, and human health that affect US biosecurity. We then summarize recommendations cited in numerous reports as relevant to a unified approach to biosecurity. Finally, because this article is a contribution to a specific *BioScience* section on agricultural terrorism, we focus on the role of the US Department of Agriculture (USDA) in implementing a national biosecurity strategy. We recognize, however, that the risks of biological harm extend to a wide variety of sectors and agencies that must be considered a critical part of biosecurity in a collective and integrated fashion (Meyerson and Reaser 2002).

Biosecurity defined

Until recently, the term *biosecurity* was used in the United States primarily to describe an approach designed to prevent or decrease the transmission of infectious diseases in crops and livestock. Examples include karnal bunt fungus (a disease that infects wheat), soybean rust, and foot-and-mouth disease (FMD, a pathogen of cattle and other ungulates), all of which have also been identified as potential biological weapons against US agriculture (Ban 2000, Casagrande 2000). Increasingly, however, the term *biosecurity* has been applied more broadly to encompass efforts to prevent harm from both intentional and unintentional introductions of organisms to human health and infrastructure and the environment, as well as to the agricultural crop and livestock industries (NPB 1999, Chyba 2001, McNeely et al. 2001, Meyerson and Reaser 2002).

Comprehensive approaches to biosecurity are under way in Australia and New Zealand. At a recent conference in western Australia on biosecurity, issues identified as relevant to Australian biosecurity included harmful biological introductions to agricultural systems and the effects of invasive pathogens (e.g., FMD) on tourism (Nairn 2001). Also cited were animal and plant pathogens present in neighboring countries, genetically modified organisms, the effects of climate change on the establishment and spread of exotic pests and diseases, and increases in illegal immigration (Nairn 2001). Successful partnerships have been forged between the Department of Agriculture in Australia and industry organizations (the Grainguard, Hortguard, Stockguard, and Beeguard initiatives) (Delane 2001). These have provided a cost-effective approach to addressing known and anticipated invaders and effective precautionary measures for enabling rapid response to rare and unexpected events of a disease outbreak or incursion (Delane 2001).

New Zealand has adopted what is perhaps the most comprehensive biosecurity approach, based on its Biosecurity Act of 1993. This act essentially unifies all pest management legislation in New Zealand into a single, comprehensive law; creates a central authority to deal with harmful organisms; and, together with subsequent legislation, covers biological threats to agriculture, horticulture, and forestry, as well as the country's unique biota (Bright 1998, Parliamentary Commissioner for the Environment 2000).

A review of New Zealand's biosecurity system highlighted its many strengths and weaknesses (Parliamentary Commissioner for the Environment 2000). Among its strengths are a central coordinating body, economic advantages associated with pest-free exports, international recognition of success for managing risks to agriculture and trade, eradication of a pest species (e.g., the white spotted tussock moth in 1997), and a reduction of biosecurity risks detected at international airports (Parliamentary Commissioner for the Environment 2000). Weaknesses included difficulties in implementing appropriate risk management strategies because of limits in predicting new invasive alien species (IAS), slow progress in developing strategic directions for biosecurity policy, political and financial constraints, and lack of recognition of the significance of biosecurity to national security (Parliamentary Commissioner for the Environment 2000).

New Zealand's national biosecurity plan is only one model. Because of its size, shared borders, and high volume of trade, tourism, and immigration, the United States faces many biosecurity challenges that New Zealand and other island nations do not, and therefore the United States will have to tailor its approach accordingly.

Invasive alien species: The silent assault

At no time in history has the US rate of invasion of harmful organisms, or diversity and volume of invaders, been as great as it is today (Bright 1998, McNeely et al. 2001). Invasive alien species are nonnative organisms that cause, or have the potential to cause, harm to the environment, economy, or human health (NISC 2001). Under this definition, pests of agricultural or natural systems, infectious diseases, and even agents used for bioterrorism that originated outside the United States are termed IAS. Scientists, industry leaders, and land managers increasingly recognize that IAS are one of the most serious ecological and economic problems of the 21st century for this country (Pimentel et al. 2000), as well as one of the top drivers of environmental change and economic hardship worldwide (McNeely et al. 2001). For example, introduced human and agricultural (livestock and crop) diseases alone are estimated to cost $41 billion dollars annually, and invasive plants are estimated to infest more than 100 million acres of US land (Daszak et al. 2000, Pimentel et al. 2000). Furthermore, globalization, climate and land use changes, and advances in certain technologies (e.g., rapid transportation and genetic modification) may increase the risks of biological harm from IAS. Harmful organisms may be intentionally traded or "hitchhike" on other commodities and thus have opportunities to become established and spread.

Although few principles concerning the reliable prediction of the invasive potential of nonindigenous organisms have emerged, much of the conceptual groundwork for developing such principles has already been laid (NAS 2002). In addition, existing data could be better utilized. For instance, pre-

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dictive capability could be enhanced if government agencies that currently collect data on IAS (e.g., as does APHIS through the Port Information Network) used standardized methods and made their data widely available to researchers outside the agencies (NAS 2002). Another recommendation of the National Academy of Sciences (2002) report was that risk assessments conducted before species introductions be "transparent, repeatable, peer-reviewed, and updated to capture new information and enhance expert judgement." Globalization and global change are two among many complex factors that complicate predictions of the invasiveness of introduced species.

Globalization

In December 2001, the Millennium Project for the American Council for the United Nations University issued a draft report stating that IAS will become a significant issue for US security in the next 20 years as IAS spreads like a global epidemic, because of "human movement and unbridled trade" (Glenn and Gordon 2002). According to the US Customs Service, during fiscal year 2000, 489 million passengers and pedestrians crossed US borders using 140 million vehicles for travel and transportation of commercial goods, and 38,000 animals were imported daily (Glenn and Gordon 2002). Imported goods and animals can harbor undetected species such as microbial pathogens, arthropods, or plant seeds with the potential to become invasive and cause significant harm in the United States. A case in point is the Asian long-horned beetle, thought to have been introduced into the United States via packing materials (Casagrande 2000).

Globally, tourism has become the world's largest industry ($476 billion), with the fastest growing sector occurring in nature travel and ecotourism (USDA 2001). Travelers (and their possessions) can become contaminated with pathogens (e.g., the FMD virus), seeds, or insect pests, or travellers may intentionally smuggle harmful biota into the country, which then escapes to the environment (Wilson 1995, USDA 2001). The volume of travel and trade is expected to double by 2009 (NASDA 2001) and continue to rise, making IAS a growing problem that will have to be managed in perpetuity.

Global change

Increases in the size and density of human populations and rising consumption are changing the landscape and global climate in unprecedented ways. Atmospheric concentrations of carbon dioxide (CO_2) have increased because of the burning of fossil fuels and the destruction of forests, and nitrogen levels have significantly risen in the atmosphere because of industrial pollution, automobile emissions, and agricultural fertilizers. Global trends in land use change include increasing urbanization, deforestation, and ecosystem fragmentation, as well as agricultural intensification in some areas and the abandonment of agricultural land in others (Meyerson 1999).

Preventing and controlling invasions of harmful organisms will become an even greater challenge in the future, because alterations of CO_2 concentrations, temperature, moisture, and nutrient status may modify habitats and change the competitive relationships among plant species (Mooney and Hobbs 2000a). For example, increasing CO_2 concentrations may enable some plants, particularly annual grasses, to more efficiently use water and extend their ranges into more arid landscapes (Dukes 2000, D'Antonio et al. 2001). In naturally nutrient-poor soils, nitrogen deposition can modify habitats by accelerating the spread of fast-growing grasses and other species. For example, the addition of an invasive grass to a system could increase fire frequency, putting native species at a disadvantage. Elevated levels of nitrogen deposition have already been implicated in the invasion of ecosystems in Hawaii (e.g., *Psidium cattleianum* [strawberry guava tree], facilitated by the invasive nitrogen-fixing *Myrica faya* [fire tree]) and California (e.g., nonnative grass invasion, facilitated by the nitrogen-fixing *Lupinus arboreus)* (Vitousek and Walker 1989, Hobbs et al. 1998). Land use changes can themselves be brought about by the purposeful introduction of nonnative organisms—new forage or plantation species may utilize resources differently than native species or change disturbance regimes (D'Antonio and Vitousek 1992, Richardson et al. 2000). For example, invading trees can transform grassland into forest and thus greatly reduce the supply of surface water available for drinking and irrigation (Dukes 2000).

Environmental changes will benefit some, but not all, species. Typically, anthropogenic disturbance increases the opportunities for invasion because IAS often can tolerate a wide range of conditions, and some are particularly adept at colonizing or expanding their populations after habitat disturbances. Therefore, global change scenarios must be included in biosecurity strategies when assessing future risks, pathways, and vectors.

The case of emerging infectious diseases. Emerging infectious diseases (EIDs) are products of both globalization and changes in land use and climate (McMichael and Bouma 2000) that pose a particular challenge for biosecurity (Chyba 1998, Daszak et al. 2000). Some of these diseases are zoonotics (i.e., transmittable to humans via vertebrate animals), which means that contact with wildlife species can result in the emergence of previously unknown human pathogens (Daszak et al. 2000). Infectious diseases are an increasing threat, responsible for 170,000 deaths annually in the United States; they account for approximately 15% of US health care costs (NIC 2000). Many EIDs, such as West Nile virus and HIV/AIDS, are introduced from outside the United States by travelers, returning military personnel, immigrants, and imported food and animals (NIC 2000). Epizootic EIDs (diseases that affect many animals of one kind) transmitted between livestock and wildlife populations can have devastating economic consequences and potentially lead to losses of wildlife populations (Daszak et al. 2000).

Recently, concern has grown in both the health and agricultural sectors over the use of EID agents as biological weapons. Although smallpox is not considered an EID, the US

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government has dramatically increased reservoirs of smallpox vaccines (Chyba 2002), and stockpiling vaccines for other diseases may soon follow. In particular, EIDs merit careful attention because of their potential to cause significant harm. For example, the recent spate of West Nile virus cases in the United States has provoked suspicions of bioterrorism in some quarters, but all available evidence points to an accidental introduction (NIC 2000).

Genetic modification

Advances in transport technologies enable unintentional introductions to be moved rapidly around the world and thus provide opportunities for harmful organisms to spread rapidly. The media and the health, agricultural, and ecological literature, however, give more attention to the technologies of genetic modification. These new technologies, which enable rapid genetic modification of specific traits, could provide opportunities for addressing problems with IAS (e.g., their greater resistance to herbivores) (Paoletti and Pimentel 1996); such technologies could also enable more effective means for mitigating the effects of IAS (by increasing the sterility of introduced species, e.g.) (Cho 2002). On the other hand, new technologies could increase the risk of infestions by enhancing organisms' competitive ability or hybridization with native species (D'Antonio et al. 2001).

Studies of plants suggest that whether the potential risks (costs) of genetically modified organisms (GMOs) outweigh their potential benefits largely depends on what organisms are genetically engineered, which traits are modified, and what environment the organisms occupy (Wolfenbarger and Phifer 2000). Traits such as hardiness and large reproductive output can be attractive to agricultural and aquaculture industries but may also increase the likelihood that the modified organism will become invasive. Several ecologists have advocated that the release of GMOs be considered analogous to the introduction of nonnative species (Levin 1988, Colwell 1997). An important question is whether GMOs released into agricultural systems will invade natural ecosystems and hybridize with related species or in some other way threaten native populations and communities (Levin et al. 1996, Parker and Kareiva 1996, Simberloff and Stiling 1996). Unfortunately, the complexity of natural and human-modified systems presents considerable experimental challenges to gauging the uncertainties and assessing the risks of GMO invasiveness (Wolfenbarger and Phifer 2000).

USDA addresses the risks of genetic modification in its report *Safeguarding American Plant Resources,* in which it states that GMOs "may pose new problems in environments where the organisms were neither tested nor produced. Some of these problems can be anticipated, others cannot" (NPB 1999). The report cautions that the field of GMOs is new and the number of GMO crops and the amount of land devoted to them have thus far been limited. However, both crops and the land they occupy are increasing in the United States and abroad, "and so the timeframe for potential problems to arise is fast approaching" (NPB 1999).

Biosecurity measures

Even before September 11, it was clear that the risks (and uncertainties) of significant impacts from harmful organisms were increasing as a result of the globalization of trade, travel, and transport; climate and land use change; technological advancements; political instability; and crime (bioterrorism itself and other crimes, such as smuggling, that involve living, potentially harmful organisms) (Kennedy et al. 1998, Mooney and Hobbs 2000b, Wolfenbarger and Phifer 2000, McNeely et al. 2001). Indeed, on 18 January 2001, the National Invasive Species Council, a body mandated under Executive Order 13112 and comprising ten federal government departments, adopted the first US National Invasive Species Management Plan (see *www.invasivespecies.gov).* This plan sets out 57 action items to minimize the effects and spread of IAS in the United States and overseas. The federal government is currently implementing it in cooperation with other stakeholders (e.g., nongovernmental organizations and trade associations). Despite differences in approach and emphases among agencies, there is clearly momentum toward initiating a more holistic approach that will strengthen US biosecurity against IAS and biological weapons.

Numerous other papers and reports have recommended actions to prevent the movement and establishment of harmful organisms (Chyba 1998, Daszak et al. 2000, Kohnen 2000, Wheelis 2000, Casagrande 2001, NASDA 2001, NISC 2001, USDA 2001, Glenn and Gordon 2002). Although most of these reports have tended to focus on individual sectors (i.e., health, agriculture, and environment), without a vision for building a comprehensive, integrated biosecurity system, it is encouraging that their recommendations typically touched on the same themes (i.e., an emphasis on prevention, early detection, and rapid response) and in some cases specific actions. We believe these commonalties can provide the foundation upon which to build a comprehensive approach to biosecurity and that such an approach is not untenable technically, financially, or politically. Opportunities for enacting a comprehensive biosecurity approach exist because the most harmful organisms are, in fact, IAS; minimizing the risk of any foreign organism requires the same initial lines of defense (prevention, early detection, and rapid response); and in all cases, coordination must be established across governments and other institutions at all levels (Meyerson and Reaser 2002). The following section includes a general discussion of prevention, early detection, and rapid alert and response measures, as well as a synthesis of the commonly stated recommendations to enhance biosecurity. While not an exhaustive list, these recommendations can be viewed as the basis for further discussion of the steps necessary to develop a comprehensive biosecurity strategy.

Prevention. Once a harmful organism becomes established, it is difficult to eradicate it for both technical and financial reasons. For example, it may be impossible to ensure that all affected individuals or populations have been detected, and multiple treatments associated with long-term

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monitoring may be required to guarantee success. Prevention, thus, is the first and often most cost-effective line of defense against harmful organisms. It requires exclusionary policies and apparatuses (technologies, facilities, and personnel; McNeely et al. 2001, NISC 2001, Wittenberg and Cock 2001). Prevention programs necessarily include an integrated process of risk and impact assessment, regulatory permitting, and quarantine. Although these processes may be set by international standards, they do not adequately guarantee successful outcomes. Significant weaknesses in prevention programs often exist because we lack the necessary taxonomic, behavioral, and ecological information to reduce uncertainties sufficiently to make well-informed decisions (McNeely et al. 2001). Furthermore, prevention efforts to ensure safe, uncontaminated shipments need to expand beyond border control to include responsibility at points of origin by governments and the private sector. Some industries already utilize technology that allows for real-time tracking of shipments during transportation (Flynn 2000).

On a global scale, assessments indicate that many of the biological invasions that have caused the most economic and environmental damage were intentional (e.g., the introduction of the golden apple snail in the Philippines; Naylor 1996, Bright 1998, NISC 2001, Wittenberg and Cock 2001). Organisms that have been intentionally imported without plans for release into the environment have escaped and caused significant damage (e.g., the European gypsy moth, *Lymatria dispar,* in the northeastern United States; Bright 1998, Cox 1999). Furthermore, there is an increasing trend toward the importation of new invasive species through methods that intentionally bypass prevention measures (e.g., smuggling or ordering commodities through the Internet and having them delivered by postal services); moreover, increasing international trade, travel, and transport allow unintentional introduction of "hitchhiking" organisms (McNeely et al. 2001).

Thus, the following recommendations are in order:

- Develop rigorous, risk-based screening systems for evaluating new, intentional introductions of potentially harmful organisms.
- Modify existing screening systems and other prevention measures (e.g., codes of conduct, preclearance or compliance agreements) to effectively evaluate the risk of potentially harmful organisms already moving into the United States.
- Identify the pathways by which harmful organisms are moved, rank them according to their potential for economic, ecological, agricultural, and human health effects, and develop mechanisms to minimize the movement of harmful and potentially harmful organisms.
- Build basic border control, risk and impact assessment, and quarantine capacity by enhancing the numbers and capabilities of personnel, employing more effective technologies, and improving scientific methods.

Early detection. Once a nonnative organism transgresses prevention measures, time becomes one of the most important predictors for the significance of its effects. The longer the organism goes undetected, the greater the costs for management and the fewer the opportunities and options for eradication. Because all prevention systems have gaps and the possibility of eradication or effective control is time sensitive, substantial investments in early detection programs are warranted. Effective early detection systems consist of inventory and monitoring programs (general and site and species specific) conducted by knowledgeable surveyors, as well as by an international network of taxonomic experts (NISC 2001, Wittenberg and Cock 2001).

Recommendations for effective early detection are as follows:

- Increase capacities for taxonomic identification of harmful and potentially harmful organisms, employing available new technologies for molecular analysis where appropriate.
- Establish inventory and monitoring programs (general and site and species specific) to detect organisms of concern, giving high priority to pathways and sites of potential invasion that are particularly high risk.

Rapid alert and response. Once a harmful organism has been detected, mechanisms must be in place to quickly alert the appropriate managers to the identity of the organism and the options for eradication, containment, or control of it. To rapidly implement the most effective measures, the managers must have technical expertise, adequate information for decisionmaking, and immediate access to adequate technologies and financial resources (NISC 2001, Wittenberg and Cock 2001).

Therefore,

- Develop a rapid response program, in close cooperation with state and local efforts, to respond immediately to the presence of potentially harmful organisms as soon as they are detected. This requires governments and other bodies to
  - establish an easily accessible funding mechanism for emergency action;
  - establish or modify policies and regulations to support rapid response; and
  - develop and improve environmentally sound techniques to eradicate and control harmful organisms.

Cross-cutting issues. Prevention, early detection, and rapid response measures all depend upon multidisciplinary teams of well-trained personnel, the support of rigorous policy and legislative frameworks, coordination and partnerships among key stakeholders, public support, and up-to-date, easily accessible information. Information systems should integrate research and management findings, curated spec-

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imen collections, and standardized databases that are accessible on the Internet (NISC 2001, Wittenberg and Cock 2001).

Personnel. Expand the staffing and training for personnel dedicated to prevention, early detection, and rapid response activities and enable them to fully develop specific competencies and engage in cross-sectoral and cross-jurisdictional actions.

Coordination and cooperation. Establish mechanisms for interdepartmental information exchange, coordination, and cooperation between all levels of government and the private sector; and establish mechanisms for building partnerships and exchanging relevant information among governments, especially between neighboring countries and trading partners.

Policy and regulation. Review at all levels relevant policies, legislation, and institutions; identify conflicts, gaps, and inconsistencies; and take action to coordinate and harmonize these approaches.

Also, establish policies that enable agencies to coordinate and share authority to respond rapidly.

Information management. Build an information system of linked national and regional databases that contains information of harmful and potentially harmful organisms and can provide rapid alerts on the detection of harmful organisms.

Research. Improve understanding of how and why harmful organisms become established and spread, which species are most likely to be harmful, and how the biological and socioeconomic consequences of harmful organisms can be determined and evaluated.

Develop new, environmentally sound techniques that allow for rapid response to and eradication of harmful organisms.

Education and outreach. Establish programs to build public support for prevention, eradication, and control programs.

Laying the foundation on the agricultural front

> A global marketplace is the future, and that future has arrived. In this marketplace, international travel and trade have not only made borders irrelevant, but also dramatically increased the risk of invasive plant pest introductions. The challenge to the United States Department of Agriculture, Animal and Plant Health Inspection Service, Plant Protection and Quarantine (APHIS-PPQ) is defining its role in this environment, today and far into the future. (NPB 1999, p. i)

USDA has significant responsibilities for improving biosecurity within the United States and at its borders. While biosecurity measures have historically benefited agriculture by reducing crop and livestock losses, as well as costs associated with control programs, there have also been benefits to human health and the environment through the reduced use of pesticides and the exclusion of some invasive alien species (NPB 1999). Some of the policies and activities undertaken by USDA suggest that the department is willing and able to move toward a comprehensive biosecurity approach.

USDA uses the term *safeguarding* to refer to activities intended to protect livestock and plant resources (i.e., agricultural food and fiber crops, horticultural crops, forestry resources, and natural resources, including native species and ecosystems; NPB 1999, NASDA 2001). Safeguarding focuses on preventing the entry and establishment of pests, such as plant pathogens, noxious weeds, and other injurious organisms (NPB 1999). It typically includes a continuum of interrelated and interdependent activities aimed at organisms that are potentially harmful to US agricultural interests, beginning in the country of origin and ending in the eradication of harmful organism that enter the United States. Activities include pest exclusion, pest detection and response, gathering and use of international pest information, and managing the movement of pests through a permitting system (NPB 1999). For example, USDA routinely employs onsite inspection and sanitation measures, primarily at farms and livestock concentration points. The program is based on levels of perceived risk: At level one, for example, there is no animal contact and thus only minimal precautionary action, such as ensuring that vehicle tires are free of dirt before leaving a site, while at level three, when direct animal contact has occurred, complete disinfection is required. (See *www.aphis.usda.gov:80/oa/fmd/fmdbiose.html.)*

A safeguarding report issued in 2001 recognizes that the threat of agroterrorism and recent outbreaks of animal diseases in other countries increase the risk that devastating animal diseases such as FMD, bovine spongiform encephalopathy, and classical swine fever will enter the United States (NASDA 2001). In this same report, the authors recommend that a national surveillance system be "comprehensive, coordinated, [and] integrated" as the basis for "animal health, public health, food safety, and environmental health" (NASDA 2001).

USDA recently commissioned a study from the National Academy of Sciences to examine US preparedness to deter, prevent, and respond to a biological attack on agriculture. This report is expected to be available to the public in the summer of 2002. Other recent reports from USDA discuss the roles of bioterrorism in the spread of harmful exotic organisms (NPB 1999, NASDA 2001, USDA 2001).

The biggest hurdles to implementing a national biosecurity system are perhaps the different mandates and lack of coordination among federal agencies, particularly among those that share jurisdiction for wildlife and natural ecosystems. In 1999, USDA clearly indicated its willingness to engage in interagency coordination by agreeing to cochair, with the Departments of Commerce and the Interior, the National Invasive Species Council. USDA is also working on biosecurity issues through the Department of State's Technical Support Working Group (TSWG 2000) and the newly established office of Homeland Security.

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Close coordination between the federal government and other sectors must be in place to assure a comprehensive approach to biosecurity. Within its safeguarding framework, the USDA acknowledges that protecting US plant and animal resources is the shared responsibility of federal and state governments, industry, and the general public (NPB 1999, NASDA 2001). Furthermore, the USDA acknowledges that, to establish effective standards, cooperation must extend beyond US borders to international partners in all parts of the world (NPB 1999, NASDA 2001). Such an inclusive approach is one requisite for implementing a successful biosecurity strategy in the United States.

Conclusions

The events of September 11 and subsequent anthrax attacks could evoke enactment of reactive policies that, while addressing immediate needs, fail to meet long-term challenges. As the United States moves to dedicate substantial financial and technical resources to combat bioterrorism, we hope that policymakers and the public will recognize that protecting the country against harmful biological agents requires a biosecurity infrastructure and approach that minimizes and responds not only to the rare events of bioterrorism but also to the everyday biological assaults of invasive alien species. Leveraging the new resources that are directed at bioterrorism and improving coordination through a comprehensive approach to biosecurity could streamline US programs, reduce redundancy in efforts, and ensure that homeland security is without gaps (Meyerson and Reaser 2002).

The risks of breaches in biosecurity will continue to rise, and the consequences may become more frequent and severe as environmental change, globalization, technological developments, and social stresses increase. To maintain biosecurity, significant attention should be paid to strategies for the prevention and early detection of, as well as rapid response to, harmful and potentially harmful organisms. Undoubtedly, policymakers will seek to weigh the costs (facilities, technologies, personnel, and potential negative public opinion concerning regulatory control) against the benefits (economic savings from losses and favorable public opinion regarding protected values). In doing so, they must keep in mind that synergistic and indirect effects also accrue costs and that the value of some outcomes—preservation of biodiversity, for example—transcends a price tag.

All aspects of human and environmental well-being are vulnerable to violations of biosecurity. To afford true protection, policies, regulations, and management strategies must be implemented through a comprehensive approach—fragmented efforts, undertaken without cooperation and coordination among agencies, will not suffice.

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