The Application of Decisionmaking Methods 4

Before the early 1900s, private individuals usually made decisions about whether to introduce non-indigenous species (NIS) with little, if any, government oversight. Even when government was involved, the decision processes were informal and often lenient. Ad hoc judgments and decisions based on precedent predominated. Since then, a trend toward more formal methods has emerged, including risk analysis, legally mandated environmental impact assessment, and economic benefit/cost analysis (table 4-1). Still, these formal approaches rely heavily on judgment and precedent, which in turn are based on the values of the public and its governmental representatives. Whatever the approach, factual gaps and uncertainty complicate the analysis of many existing and potential NIS problems. This chapter examines the prominent decisionmaking methods in use, the role of uncertainty, and the tradeoffs that decisionmakers must face.

Decisions about MS are made at various levels in Federal and State governments. The flexibility that agency personnel have in making management level decisions depends on their governing statutes, regulations, or policies. A National Park Service (NPS) manager, for example, has very little discretion when deciding whether to introduce a new plant species—in most situations it is prohibited outright by current NPS policies, which seek to preserve the indigenous flora. By contrast, most State and Federal legislation gives broad discretion to managers in dealing with NIS. Agency personnel face two kinds of decisions regarding NIS: which species to allow to be imported and released, and which species to control.

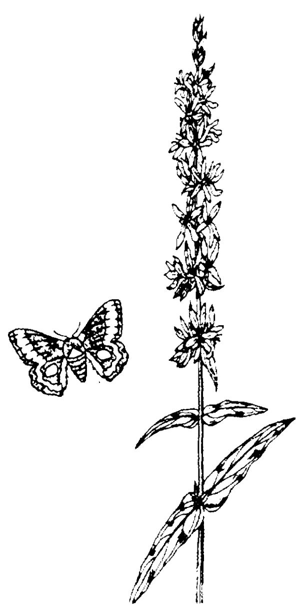

Table 4-I—General Approaches to Making Decisions About Non-Indigenous Species

	Approaches		
	Judgment	**Precedent**	**Formal analysis**
Features	Based on relatively undefined procedures Often undocumented	Done according to previous decisions Usually documented	Decisions made according to well-defined procedures Contains explicit documentation
Examples	Judgments by: . General public . Policy makers . Interest groups . Experts	Legal precedent Status quo Tradition	Risk analysis Environmental assessment Economic analysis

SOURCE: P. Kareiva et al., "Risk Analysis as Tool for Making Decisions About the Introduction of Non-Indigenous Species Into the United States," contractor report prepared for the Office of Technology Assessment, July 1991.

WHICH SPECIES ARE IMPORTED AND RELEASED?

Finding:

Most government regulatory approaches to importation and release of NIS use variations of "clean" (allowed) and "dirty" (prohibited) lists of species or groups, with heavy reliance on the dirty list approach. An effective way to reduce risks of harmful invasions is to employ, where practical, a system of both clean and dirty lists, and a "gray" category of unanalyzed species that are prohibited until analyzed and approved.

"Clean" and "Dirty" Lists[1]

The use of 'clean" and "dirty" lists reveals a fundamental dichotomy in government decision-making on NIS importation and release. Generally, the clean list approach presumes that all species should be prohibited unless they have been officially listed as allowed, or 'clean. ' The species on the list offer net positive consequences. The dirty list approach presumes that all species may be allowed unless they have been listed as prohibited. Listed species pose net negative consequences. The dirty list method dominates Federal and State decisiomnaking, although several examples of clean lists exist (table 4-2).

Numerous variations of the clean and dirty approaches are employed. These include using a different system for the two phases of introduction, i.e., importation versus release. Also, different methods are used for the major taxonomic groups, e.g., plants, fish, and mammals. Regulators can use a variety of listing criteria, permit requirements, and exemptions; some even adopt total bans on importation or release of major taxonomic groups. Neither clean nor dirty lists per se eliminate the need for inspections and other regulatory compliance measures (25).

Three main factors appear to influence the selection and use of a clean or dirty list approach. These are:

1. technical feasibility, that is, whether the potentially threatening NIS in a large taxonomic group, such as non-indigenous plants, are sufficiently limited in number, scientifically understood, and capable of detection so that a comprehensive and accurate clean list can be constructed with reasonable confidence (table 4-3) (25);
2. requirements for scientific expertise in fields such as taxonomy, ecology, and risk analysis; these needs are greater to imple-

[1] The Federal interagency Aquatic Nuisance Species Task Force has abandoned the terms ''clean" and "dirty" due to public objections. Instead, they plan to use the more neutral-sounding "approved," "restricted," and "prohibited." Note that these terms are used by a number of States as well (34).

Table 4-2—Examples of Clean and Dirty Lists in Statutes or Regulations

	Summary
Clean Ilst	
USDA Quarantine 56 (7 CFR 319.56)	Allows import of only listed fruits and vegetables from specified countries
Hawaii Revised Statutes sec. 150A.6	Allows import of only animals and microorganisms on "conditionally approved" list
Dirty Ilst	
Lacey Act	Restricts import of two taxonomic families, 13 genera, and 6 species of fish and wildlife
Federal Noxious Weed Act	Prohibits import of 93 listed weeds

SOURCE: Office of Technology Assessment, 1993.

ment a comprehensive clean list approach and not always available; and

3. willingness to accept risks of unanticipated invasions by harmful NIS; a clean list approach can reduce risks, however, decisionmakers may be willing to accept the higher risks of a dirty list approach, especially if control or eradication is feasible.

Several experts have argued for treating NIS under a clean list approach whenever practical; that is, prohibiting all species that are not on a clean list until they have been satisfactorily analyzed and determined to offer net benefits (26,74). This would be comparable to the Food and Drug Administration's general regulatory system for approving a new drug for human use: prohibited until proven net beneficial.

Moving to a clean list approach would require substantial changes in the regulation of *importation* (that is, the act of bringing an NIS across a border into the country or a particular State). Allowing importation only of species on a clean list would place greater restrictions on international trade.

For some groups of organisms, only *release* into a free-living condition has been this strictly regulated. However, importation of some NIS is likely to lead eventually to their release, whether intentional or by their escape. Imported aquarium fish are a good example. Those that have established free-living populations after being discarded by their owners have often had negative effects, especially in Florida and in the Southwest (11). For such taxonomic groups composed of organisms that readily escape, the regulation of importation in effect *is the* regulation of release. The more restrictive clean list approach would be more effective in preventing harm although this approach is more burdensome in the short run.

Even for those groups in table 4-3 for which clean lists appear technically feasible, the political feasibility of such an approach is questionable. The U.S. Fish and Wildlife Service (FWS) made three politically unsuccessful attempts in the mid-1970s to change the Lacey Act[2] process for regulating importation of 'injurious' fish and wildlife from a dirty to a clean list, or to substantially lengthen the dirty list (box 4-A). The available information on environmental and economic consequences of harmful NIS was far less complete than it is today (76,82). whether the political obstacles remain is unclear.

The Lacey Act was interpreted by FWS to be legally broad enough to allow for a clean list approach without amendment (76). No court has ruled on this interpretation. Apart from this legal issue, the question remains of how to best regulate potentially risky fish and wildlife. One method being considered is a three-part system with an intermediate "gray" category.

"Gray" Category

In any given' jurisdiction (e.g., country, State, or county) the vast majority of potentially introduced NIS belong to a "gray" category. This consists of all species not already listed as clean or dirty because decisionmakers lack detailed analyses of the likely consequences should they

[2] Lacey Act (1900), as amended (16 U.S.C.A. 667, *et seq.*, 18 U.S.C.A. 42 *et seq.*)

Table 4-3-Relative Technical Feasibility of Comprehensive Clean Lists for Regulating importation of Major Groups of Non-indigenous Species

Group	Clean list feasibility	Reasons
Fish and other vertebrate animals	High	Well known; fewer species; moderate commercial trade; easily detected
Plants	Medium	Well known; many species; high commercial trade; easily detected
Insects	Low	Poorly known; very many species; low commercial trade; difficult to detect
Other invertebrate animals	Low	Poorly known; very many species; low commercial trade; ease of detection varies
Micro-organisms	Low	Poorly known; very many species; low commercial trade; very difficult to detect

NOTE: These are general ratings. Taxonomic subgroups within each major group may justify different ratings. For example, within the major category of invertebrate animals it would be more feasible to adopt a dean list for the relatively small sub-group of freshwater mollusks.

SOURCE: Office of Technology Assessment, 1993 and R.P. Kahn, letter to P.N. Windle, Office of Technology Assessment, Dec. 2, 1991.

become established. Combining this gray category with the clean and dirty list approaches forms a classtification scheme that can be adjusted to suit particular regulatory circumstances (26).

Hawaii, for example, recently amended its laws on importing animals and micro-organisms, creating the most restrictive State laws on the subject (ch. 7). This change responded to the perceived urgency of Hawaii's NIS problems (ch. 8). State law now provides for three lists and a gray category.[3] Species on the *conditionally approved* list require a permit for importation, while those on the *restricted* list require a permit for both importation and possession. Those on *the prohibited* list may not be imported or possessed except in very limited cases. Species not on any list (the gray category) are prohibited without official permission. The State now handles requests for permission as follows (50):

> If the request is for a species that is on an animal or micro-organism list and has received prior approval by BOA [Board of Agriculture] or is a plant that has received such approval, PQ [Plant Quarantine Branch] can issue the permit. If, however, an applicant is requesting a permit for a species that has not received prior BOA approval, PQ will conduct a three-tiered review process to bring the request before the board.
>
> First, the application is submitted to the BOA's Technical Advisory Subcommittees. The five subcommittees (Land Vertebrates, Invertebrates and Aquatic Biota, Entomology, Micro-organisms and Plants) are composed of researchers, industry representatives and government officials. The subcommittees evaluate the application along technical/scientific lines, particularly for the organism's potential impact. The subcommittees then pass their analyses to the Plant and Animals Advisory Committees which considers the application and the subcommittee findings from a broad perspective, weighing the potential harmful impacts against the potential benefits. BOA then reviews the Advisory Committees' recommendation and issues the final decision on the application.

Much of the rest of this chapter discusses general methods for making the type of listing and approval decisions referred to above, such as how to weigh the potential harmful impacts against the potential benefits.

WHICH SPECIES ARE CONTROLLED OR ERADICATED?

Sometimes greater difficulty can arise in deciding which damaging NIS to control or eradicate,

[3] Hawaii Revised Statutes, section 150A-6.

Box 4-A–History of Fish and Wildlife Service Attempts To Implement Clean Lists Under the Lacey Act

The Lacey Act of 1900 and 50 CFR, part 16, enable the Secretary of Interior to restrict fish and wildlife imports beyond those species listed as prohibited in the Act itself. Pursuant to this authority, in December 1973, FWS proposed regulations that concluded all non-indigenous fish and wildlife species had the potential to be injurious and should be prohibited, except for a list of several hundred species and larger taxonomic groups that were believed to pose little risk. FWS prepared this "clean" list after soliciting input from user groups and scientific experts, and it made provisions for future additions.

However, the more than 4,300 comments on the proposal were mostly negative, especially those from people involved with the pet trade, zoos, game ranches, agriculture, and aquiculture. After preparing an environmental impact statement and taking part in a congressional hearing, the agency published a revised proposal to lengthen the dean list, in February 1975.[2] That also received a negative reception, with nearly 1,200comments. Opponents claimed evidence was insufficient that importation of any particular species would cause harm. The pet industry claimed it would be particularly affected by excluding rare or poorly studied species that were not on the clean list, because they would command the highest prices. After extensive controversy, FWS withdrew the clean list proposal.

As a final effort, in *1977, FWS* proposed a rule[3] containing a much longer dirty list. This approach failed as well, with the primary resistance from the hobby fish industry. No major constituency weighed in favoring the concept and further formal attempts to change the regulations were abandoned.

1 38 *Federal Register* 34970, (Dec. 20, 1973).

2 40 *Federal Register* 7935, (Feb. 24, 1975).

3 42 *Federal Register* 12972, (Mar. 7, 1977).

SOURCES: R.A. Peoples, Jr., J.A. McCann, and L.B. Starnes, "Introduced Organisms: Policies and Activities of the U.S. Fish and Wildlife Service," *Dispersal of Living Organisms into Aquatic Ecosystems*, A. Rosenfield and R. Mann (eds.) (College Park, MD: Maryland Sea Grant, 1992), pp. 325-352; J.G. Stanley, R.A. Peoples, Jr., and J.A. McCann, "Legislation and Responsibilities Related to Importation of Exotic Fishes and Other Aquatic Organisms," *Canadian Journal of Fisheries and Aquatic Sciences*, vol. 48, suppl. 1, 1991, pp. 162-166.

and how to do it, than in deciding which species to allow to be imported or released. If a manager has 10 existing problem species and a control budget that allows elimination of only 3, which ones should he or she choose? Should the goal be complete eradication, or control at some point less than 100 percent eradication? What methods should the manager use?

To complicate matters, eradicating or controlling NIS with chemical pesticides often arouses public opposition. So does killing popular non-indigenous animals, like feral horses (Equus *caballus)*, by any method. Both cases involve weighing the potential damage caused by the NIS against other factors. In the pesticide case, the factors are potential human health and environmental impacts; the popular animal case involves mainly ethical values. For both, costs of the available methods may be a major factor. As with decisions about importation and introduction, the formal approaches discussed below may aid these weighing processes.

COMMON DECISIONMAKING APPROACHES

Decisionmakers commonly employ three tools in analyzing NIS: risk analysis, environmental impact assessment, and economic analysis.

Risk Analysis

Finding:

Scientists generally cannot make quantitative predictions of the invasiveness or impact of a new, untested species with high degrees of confidence. Nevertheless, useful qualitative predictions often can be made. Expert judgment based on careful research and diverse input is the most broadly feasible predictive approach. Controlled, realistic-setting experimentation reduces uncertainty but requires more resources.

THE ROLE OF RISK ANALYSIS

A strictly empirical, or after-the-fact, approach to NIS introductions would be clearly inadequate. Always waiting to see if a species causes harm before deciding whether to prohibit it would lead to multiple disasters and huge control costs. Conversely, barming *all* importation and release of NIS would be an effective, but obviously impractical, risk reducer. The most realistic way to prevent human-caused harmful invasions by NIS is to develop better scientific methods to accurately predict them and to act based on these predictions. The field of risk analysis encompasses these predictive methods. Risk analysis looks at the chances that an unwanted event will occur and the consequences if it should occur.

Risk analysis can inform decisionmakers on everything from building nuclear power plants to anticipating oil spills to keeping zebra mussels *(Dreissena polymorpha)* out of the Missouri River. The subfields most relevant here are "pest risk analysis, " undertaken to protect agriculture (including forestry) and "ecological risk analysis, ' which looks at threats to non-agricultural areas and their occupants. The goal is understanding and ordering different degrees of risk, from those as obvious as introducing a mammal that has rabies to those as subtle as introducing an insect that slightly raises the probability that an indigenous insect will go extinct (26).

The ideal risk analysis should specify the likelihood of possible outcomes from a particular activity, estimate the risks associated with the various outcomes, and identify effective means to mitigate the risks. Although much of this follows common sense, as a discipline it forces analytical accounting for uncertainty, that is, when the data do not permit the ideal analysis. And the process can make the tradeoffs between competing factors clear to the observer.

Clarity regarding tradeoffs in the face of uncertainty is important. A hypothetical example: if current scientific knowledge cannot predict whether a potentially damaging Australian tree fungus will invade valuable redwood stands in northern California, then on what basis can a decision be made to allow Australian logs into northern California? How much would the decisionmaker be willing to spend to reduce that scientific uncertainty? Given the uncertainty, and thus the chance of deciding mistakenly, how does one balance being too restrictive against being too lenient? What numerical chance of being wrong is acceptable? Risk analysis alone does not answer these questions. Nevertheless, a risk analysis process should display the potential tradeoffs clearly, that is, it "must not cloak what should be societal decisions in the mantle of scientific objectivity when the determinations are not purely scientific" (39).

Even the best risk analysis methods cannot eliminate all uncertainty. With enough resources, imperfect or incomplete knowledge and human errors-two important sources of uncertainty—can be reduced or eliminated. However, the inherent randomness of the world adds uncertainty that cannot be reduced (71). Also, the ability of NIS and their receiving ecosystems to adapt and evolve means that risk analysis done at the time of introduction maybe rapidly obsolete; this adds another source of uncertainty to predictions (70).

In making tradeoffs on the national scale, policymakers must decide the most fundamental question of NIS policy: how much risk of damage will we accept? No formulaic answer exists. Hundreds of harmful NIS are already in the country. Early warnings were available for several recent additions: the zebra mussel, the Asian tiger mosquito ***(Aedes** albopictus)*, and the Asian gypsy moth *(Lymantria dispar). In* each case, a


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Controlled scientific studies, such as this study of a biological control organism, can boost the reliability of risk assessment.

fair degree of risk was tolerated. So far, at least, most governmental decisionmakers have not been highly risk averse where potentially damaging NIS were concerned.

THE PROCESS OF RISK ANALYSIS

The frost step in risk analysis for *planned* releases is predicting the likelihood that the species to be released will survive and establish one or more self-sustaining populations (27). Then one must assess the probable resulting impacts on the ecosystems and/or agricultural systems involved. The combination of the characteristics of the new organism and the new environment determines the risks associated with the release.

Greater difficulty in prediction arises when one considers *unplanned* introductions. These are NIS that escape from confinement or are unknowingly released. Risk analysis in these cases requires initial determination of the probability that a release will, in fact, occur. The same determination applies to NIS that are knowingly, but illegally released, though some classify these as planned releases (see ch. 3). Probability of release must then be factored into the likelihood of survival, establishment, and environmental impact, as determined for planned releases, also. The Federal interagency Aquatic Nuisance Species Task Force, formed to respond to the invasion of the zebra mussel and other NIS in the Great Lakes, has adopted a pathways-oriented approach to risk analysis for unplanned releases (75). The Task Force intends to assess all potential pathways for harmful, unintentional releases, ranging from cargo ships dumping their ballast water to pathogens inadvertently transported with fishery stock.

Several models have been developed that generalize about the risks of NIS invasions. Current applications of these models are limited because they do not quantitatively predict with high degrees of confidence either the likelihood that a new species will become established or its impacts (26).

Useful generalities about risks can be drawn, however, some of these lack clear scientific validation. In general, the species most likely to be successful invaders have large natural ranges, a high intrinsic population growth rate, and a large founding population in the new environment (12). The environments most likely to be invaded are those with few species present, a high degree of habitat disturbance, and an absence of species closely related and morphologically similar to the potential invaders (48).

The risk analysis process has relied largely on professional judgments based on "impressionistic syntheses of case studies and anecdotes" (27) rather than rigorous statistical studies or experimental analyses. Formal risk analysis methods for NIS have not been developed or applied (70). This qualitative rather than quantitative approach may be satisfactory in most cases, particularly if a diverse panel of scientists and other experts has input into the analysis. Some expect that more reliable quantitative predictions will be available as data accumulate and computer models are refined (24,57).

The intense commercial interest in risk analysis for the controlled release of new genetically engineered organisms (GEOs) (ch. 9) has helped advance both theoretical and experimental appreaches to NIS risks generally (26), as have the research and testing of new biological control agents (ch. 5). The standard paradigm for analyzing risks of these specialized releases relies much more heavily on experimentation, including controlled, small-scale trial releases, than is normally done for other proposed NIS releases.

Recent technological advances have made some experimental releases safer. For certain species, scientists can ensure that released NIS are infertile through sterilization, birth control, or other manipulations such that no more than one generation will survive (ch. 5). Fisheries biologists have used these techniques to assess new introductions of fish and shellfish (51). Some advocate the use of these reproductive control techniques as a precondition for all experimental releases (67).

Experimentation can provide data critical for linking mathematical models to ecosystem behavior, especially for generalized theories of ecosystem response to stress (39). Experimentation also informs the optimal design of monitoring systems and the apportionment of containment or control efforts according to the risks involved. In one facility in England, experiments on invasions are conducted in a large laboratory with 16 connecting microcosm chambers (38). It allows the assembly of a wide variety of plant and animal communities in computer-controlled environments. Still, organisms can behave quite differently in the real world than they do in experimental settings because of untested, often unanticipated, influences. The possibility of chaos in ecological systems suggests that making accurate predictions may be more complex than anticipated (19,60) and not a matter necessarily solved by accumulating more data for better models.

Experimental analyses for NIS (other than GEOs and biological control agents) are not consistently done or required by Federal or State laws. Despite difficulties in interpreting results from small-scale trial releases, experts have called for more use of these and other experimental approaches as providing better predictions than the largely anecdotal "paper" studies that dominate now (40). An experimental approach would require more personnel, funding, and time.

RISK ANALYSIS BY FEDERAL AGENCIES

Finding:

Within the Animal and Plant Health Inspection Service (APHIS) of the U.S. Department of Agriculture (USDA), there is great variation as far as the stringency of its risk analysis procedures for different types of NIS importation. Internal proposals to improve and standardize risk analysis procedures have not been broadly implemented. Two existing policies hamper the agency's effectiveness at keeping new, harmful NIS from entering the country: its lack of explicit focus on risks to non-agricultural areas, and its general operation under the presumption that unanalyzed imports will be admitted unless risks are proven. Still, APHIS is more analytical than FWS. FWS has implemented very little scientific risk analysis for potentially harmful fish and wildlife.

The primary Federal responsibility for regulating NIS lies with USDA's APHIS and the Department of Interior's FWS (see ch. 6). APHIS can regulate both private and governmental actions that pose risks of introducing agricultural and forestry pests, including weeds. FWS is responsible for "injurious" fish and wildlife under the Lacey Act, which, as applied, primarily means species that threaten interests outside agriculture.

Animal and Plant Health Inspection Service-Much of current APHIS risk analysis consists of preparing a "decision sheet, ' which often includes only a paragraph or two on the biology of a prospective plant pest (80). Great variation exists within APHIS as far as the stringency of analysis (26). Comprehensive assessments of probabilities and risks are rarely undertaken. The agency is revising a number of its regulatory quarantines and considering adoption of new quarantines, and in the process has sought to improve and standardize its procedures.

The main foundation for this standardization with respect to plants and plant products is the "Generic Pest Risk Assessment Process" developed by the Policy and Program Development office (53). This process has not been finalized yet[4] or broadly adopted within the agency. Once adopted, the process can be tailored to decisions about particular types of proposed new commodity importations, such as cut flowers, nursery stock, and logs (figure 4-l). Since a commodity can carry more than one potential pest, conducting Individual Pest Risk Assessments on each pest will be necessary in addition to the analysis of the risk of the commodity itself (e.g., for its potential weediness). An analyst will make qualitative ratings (low, medium, high) for various factors and assign an uncertainty level. The combination of these will result in an overall Commodity Risk Potential rating and a recommendation by the analyst. APHIS regulatory and operational personnel will make the final decision.

The Agricultural Research Service assists APHIS on risk analysis questions requiring research. ARS conducts experiments on a few potentially serious pests like soybean rust *(Phakopsora pachyrhizi) (87). This* method, in which a small number of samples are imported under controlled conditions and tested in small-scale trials, would be impractical for analyzing risks from all potential pests.

While APHIS has kept thousands of potential agricultural pests from becoming established, it has done little explicit analysis of risks to natural areas. Critics have also pointed to insufficient scientific input, especially from the field of ecology, in its analyses (25,26,36). Long-term risks, such as the potential for pests to evolve more harmful characteristics, are under-analyzed because of lack of input from evolutionary biologists (26).

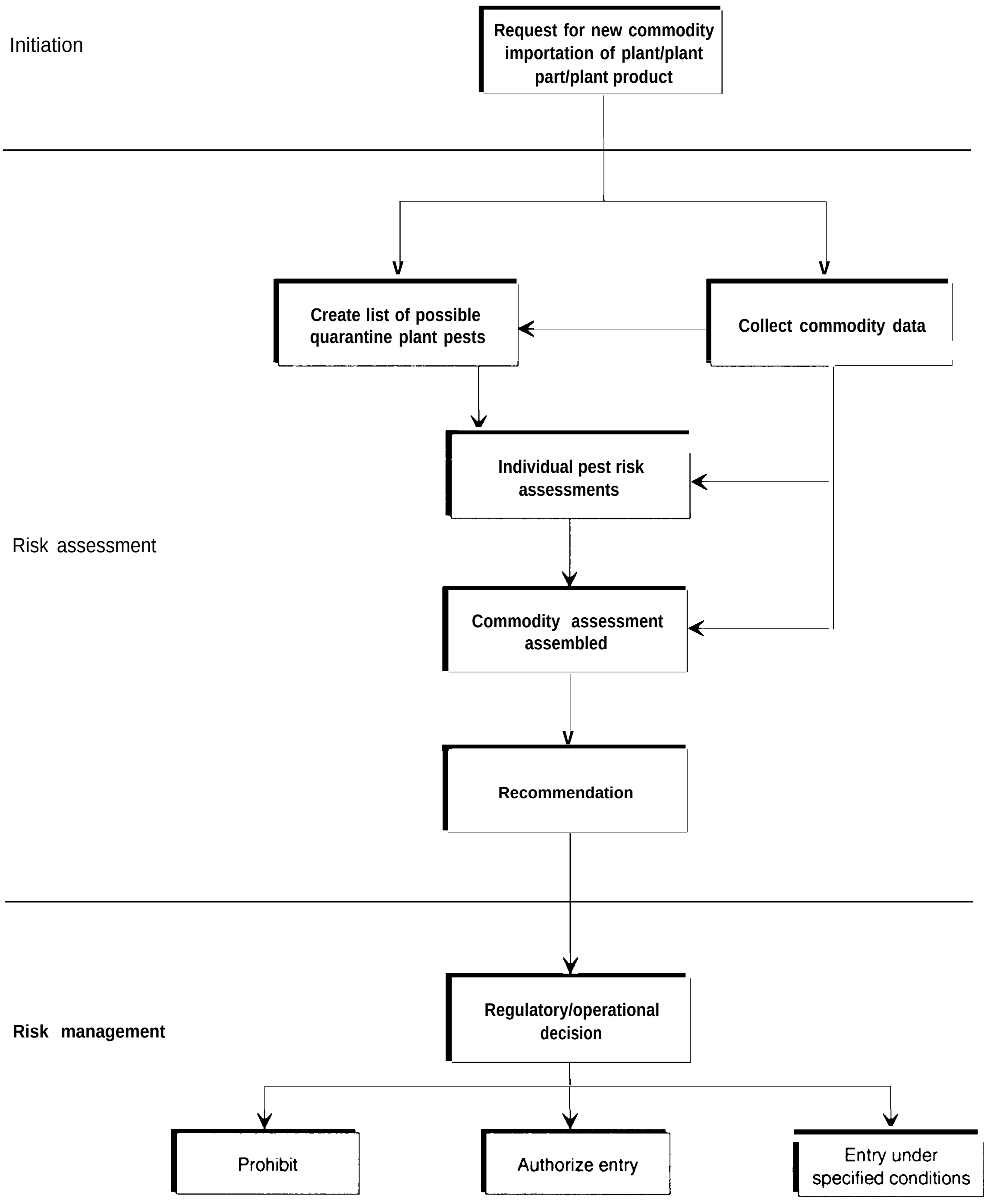
APHIS lacks sufficient in-house expertise to fully address the questions posed by the regular flow of new potential pests (26). Outside experts are sometimes consulted, but they often lack training or experience in quarantine problems. Further, in the past many risk analyses were not adequately documented to be of use in future decisions (26). The agency is considering several proposals to implement more explicit procedures that are sensitive to natural ecosystems, embrace more diverse input, and provide useful data for the future.

Implementation of these improvements is important. However, a basic policy hampers APHIS's success at keeping out pests-that is, its Willingness to allow many types of imports that pose unanalyzed, or incompletely analyzed, risks. Examples of this include virtually all unprocessed wood and wood products, including packing and shipping materials;[5] and potential pests on or in containers and ships that have been in high-risk areas. The agency generally treats unregulated imports under the presumption ''that everything is enterable until we [APHIS] determine it should not be' (53). Implicit in this is APHIS's accepting the burden of proving a proposed new import's potential for harm, rather than putting the burden on the importer to demonstrate its safety. This policy relies on inspection at ports-of-entry to interdict potentially harmful organisms despite the fact that many are very difficult to detect or present unknown risks.

[4] The final version is anticipated in December, 1993.

[5] APHIS recently published an Advance Notice of Proposed Rulemaking regarding importation of logs, lumber, and certain other wood products, 57 *Federal Register, 43628-31* (Sept. 22,1992). At this writing it is unclear whether a rule will be issued, or what it will provide, but the Notice indicates that the agency may more proactively address risks from logs and wood products in the future. The Notice did not cover wooden packing or shipping materials.

Figure 4-l—Application of the APHIS Generic Pest Risk Assessment Process



SOURCE: R.L. Orr, Entomologist, and S.D. Cohen, Plant Pathologist, Animal and Plant Health Inspection Service, U.S. Department of Agriculture, "Generic Pest Risk Assessment Process—For Estimating the Pest Risk Associated With Importation of Foreign Plants and Plant Products (draft)," Nov. 20, 1991.

This "presumption of enterability" is not mandated by the Plant Pest Act[6] or by other controlling legislation; it is apparently a policy choice to favor unburdened trade. That choice may itself be the result of weighing the overall risks and benefits of a more restrictive presumption of exclusion. However, OTA has not discovered any evident national weighing of these risks and benefits. The weighing process appears to occur in difficult new cases, one at a time, at high levels of the Department of Agriculture.

> [I]n controversial trade matters, top management outside of APHIS may 'weigh' the biological position against the economic or other positions, and the short-term decision made by non-biologists may in some instances prevail regardless of the probability of long-term adverse consequences. (25)

The presumption of enterability has real consequences. In the recently proposed importation of Siberian timber to West Coast sawmills (box 4-B), for example, several critics pointed out that APHIS's starting assumption was that the importation would occur. The agency initially stressed the rights of the importers to proceed rather than the biological issues (7). Indeed, it allowed them to bring in a small shipment of logs, without a formal pest risk analysis or environmental assessment, that was found later to carry pests. It took pressure from academic scientists and members of Congress to stop APHIS from allowing further shipments without a comprehensive risk analysis (14).

For a proposed importation of pine *(Pinus* spp.) wood chips from Honduras into Oregon, APHIS did not require a formal assessment of the potential risk, despite serious warnings from an Oregon State University entomologist (37). The agency would not delay the imports unless risk was first proven; expert opinion was insufficient to overcome the presumption of enterability (66).

The agency's willingness to accept unanalyzed risks is compounded by the low level of effort USDA devotes to researching where risky species are likely to come from and to proactively regulate so as to prevent problems before they arise. The relatively short list of foreign weeds prohibited under the Federal Noxious Weed Act represents one example (ch. 6) (41). Another is the recent Asian gypsy moth infestation in Pacific Northwest ports, which necessitated a $14 million to $20 million emergency eradication program (box 4-B). The moth arrived via cargo ships on which eggs had been laid while in Far East ports. Ships are one of the most obvious pathways for new pest introductions because of their size and frequency of arrival. Yet APHIS had not proactively analyzed the Asian gypsy moth risks nor taken steps to prevent the infestations. In the words of a former California Department of Agriculture official discussing overall U.S. quarantine policy, ''ignorance is viewed as a relatively low-level risk compared to the benefits of open trade and other societal needs" (62).

For the items discussed above-unprocessed wood, packing materials, containers from high risk areas, etc.—APHIS lacks specific regulations. The agency assumes the items are suitable for import unless agricultural port inspectors detect a problem. APHIS treats all plants in a similar manner, including nursery stock, seeds, and bulbs, under regulations known as Quarantine 37. Such foreign plants are enterable with a permit if they are *no?* listed in these regulations, that is, on the 'dirty' list of plants known to carry important pests or diseases in their countries of origin. Quarantine 56, which covers imported fruits and vegetables for consumption, is an exception to APHIS' overall assumption of enterability (25). Under this quarantine, pest risk assessments have judged listed articles ''clean' and, thus, able to be imported with a permit.

[6] Federal Plant Pest Act (1957), as amended (7 U. S.C.A. 147a *et seq.*)

Box 4-B--Siberian Timber Imports: A Potentially High-Risk Pathway

Siberia has almost half of the world's softwood timber supply. Since the late 1980s a few U.S. timber brokers and lumber companies, short on domestic supplies, have been negotiating for the Importation of raw logs from Far East ports to West Coast sawmills. This may create a pathway for non-indigenous forest pests that are adapted to many North American climate zones and tree types. In the past 100 years raw wood or nursery stock imports have provided entry for a number of devastating pathogens, such as chestnut blight (Cryphonectria parasitica), Dutch elm disease (Ceratocystis *ulml),* and white pine blister rust *(Cronartium rlblcola).*

In early 1990, the private importers voluntarily notified APHIS and the California Department of Agriculture that they would be shipping two containers of logs representing four Siberian tree spades into the northern California port of Eureka. The logs were fumigated, handled, sawn, and disposed of pursuant to agreed upon guidelines. The California officials had sought more time to develop the guidelines before shipment but were unable to obtain a voluntary delay and lacked regulatory authority to require a delay. According to the program supervisor of the Pest Exclusion Branch, APHIS's California approach to the State's biological concerns was to stress the importers' rights to proceed.

Dead insects were recovered off three of the tree species; the fourth carried a nematode. The agencies concluded that no further shipments should come in until personnel could identify the species and do a pest risk analysis. APHIS arranged a voluntary embargo with the importers. Two of the species were later identified as potentially harmful new pests.

Participation by APHIS in the early phases (April through September 1990) was criticized as "chaotic" by the California official in charge. The agency's Preliminary Pest Risk Analysis was completed in September; it was generally regarded as inadequate, failing to list many known Siberian pests and lacking investigation into the many unresearched potential pest species. Worried California and Oregon officials sought independent scientific advice. several State university professors warned of potentially disastrous consequences from the organisms that were Iikely to be introduced, even if the logs were fumigated.

Communication among these academics and the State officials in fall 1990 eventually led to congressional pressure in the form of a letter from three members of the Oregon delegation to the Secretary of Agriculture inquiring about APHIS's handling of the matter and requesting a delay pending resolution of the pest issues. At the same time, the importers were negotiating with APHIS to allow large-scale shipments to mills in Humboldt Bay, California However, "to honor the congressional request," the agency suspended the discussions on December 13. APHIS announced it had imposed a "temporary prohibition" on future imports. Without the congressional pressure, it appears the shipments would have gone ahead without comprehensive analysis.

A joint U.S. Forest Service/APHIS Task Force was convened and worked for almost a year on adetailed risk assessment focusing on larch (Larix spp.) from Siberia The project cost of approximately $500,000 was paid out of a Forest Service contingency fund. APHIS lacked a flexible fund to pay for the unanticipated, unbudgeted work

The assessment found serious risks posed by several pests. A worst-case scenario examined the economic impacts should they successfully invade Northwest forests. it produced astoundingly high figures for the cumulative potential losses from the Asian gypsy moth *(Lymantria dispar)* and the nun moth *(Lymantria monacha)* between 1990 and 204&in the range of $35 billion to $58 billion (net present value in 1991 dollars). Still, the assessment did not resolve all the issues about mitigating the risks. Ultimately, APHIS put the burden back on the importers to propose new pest treatment methods and protocols with "evidenced complete effectiveness". some experts said the logs would need sawing and kiln-drying to exterminate all risky species, which would probably be prohibitively expensive. The assessment concluded: "if technical efficacy issues can be resolved, APHIS will work with the timber industry to develop operationally feasible Import procedures." To date the industry has identified no feasible procedures that APHIS has deemed completely effective.

(continued next page)

Box 4-B-Continued

A recent discovery may render the timber import risk mitigation efforts moot, at least for the Asian gypsy moth. While APHIS and the Forest Service were looking at the chances it would arrive on logs, the Asian gypsy moth arrived in the Pacific Northwest clinging to grain ships. The risk of this pathway had been overlooked.A$14 million to $20 million program of broadcast biopesticide spraying, trapping, and monitoring has been implemented by Federal and State officials to stop what the Deputy Director of the Washington Department of Agriculture said "has the potential to be the most serious exotic insect ever to enter the U. S." An information program was also initiated to keep shippers that trade in high-risk Far Eastern ports from inadvertently transporting more moths. While officials have found no more Asian gypsy moths in the Pacific Northwest to date, their ultimate success in eradicating this pest remains uncertain.

SOURCES: Associated Press, "Forest Bugaboo—Alarm Over Discovery of Asian Gypsy Moths," *Seattle T/mewPost Intelligencer, Nov.* 24,1991, p. B-S; A. Clark, Program Supervisor, Pest Exclusion Branch, California Department of Agriculture, Sacramento, CA, personal communication to P. Jenkins, Office of Technology Assessment, Feb. 14, 1991; P. DeFazio, U.S. House of Representatives et al., letter to C.K. Yeutter, Secretary, U.S. Department of Agriculture, Washington, DC, Dec. 5, 1990; J.D. Lattin, Professor of Entomology, Oregon State University, personal communication to P. Jenkins, Office of Technology Assessment, Jan. 31, 1991; J.D. Lattin, Professor of Entomology, Oregon State University, memorandum to B. Wright, Administrator, Piant Division, Oregon Department of Agriculture, Salem, OR, Nov. 1, 1990; R. Morals, Division Resources Manager, Louisiana-Pacific Corp., Samoa, CA, internal memorandum to B. Phillips, Dec. 19, 1990; M. Shannon, Chief Operating Officer for Planning and Design, Animal and Plant Health Inspection Service, U.S. Department of Agriculture, Hyattsville, MD, personal communications to P. Jenkins, Office of Technology Assessment, Feb. 5,1991 and Mar. 2, 1992; U.S. Department of Agriculture, Animal and Plant Health Inspection Service, Hyattsville, MD, "USDA Places Temporary Prohibition on Entry of Siberian Logs Because of Pests," press release, Dec. 20,1990; U.S. Department of Agriculture, "An Efficacy Review of Control Measures for Potential Pests of Imported Soviet Timber," Miscellaneous Publication No. 1496 (Hyattsville, MD: Animal and Plant Health Inspection Service, September 1991); U.S. Department of Agriculture, Forest Service, "PestRiskAssessment of the Importation of Larch From Siberia and the Soviet Far East," Miscellaneous Publication No. 1495 (Washington, DC, September 1991); D.L. Wood, Professor of Entomology, and F.W. Cobb, Jr., Professor of Plant Pathology, Univ. of California, Berkeley, letter to Dean Cromwell, California State Board of Forestry et al., Sacramento, CA, Dec. 11, 1990.

Fish and Wildlife Service-FWS does far less than APHIS in analyzing risks from injurious fish and wildlife (26). The current Lacey Act dirty list is short (prohibiting 2 families, 13 genera, and 6 species), and FWS uses no checklist or other standardized procedure to analyze risks from other imported species. While APHIS inspects incoming agricultural livestock for diseases, FWS has no procedure for refusing entry to the remaining unlisted and non-agricultural fish and wildlife.

Service officials acknowledge the need for better evaluation of risks from unlisted NIS: "it would be desirable to improve internal Service procedures for modifying the list of injurious wildlife . . . by establishing listing criteria and procedures' (54). The Intentional Introductions Policy Review conducted by the Federal interagency Aquatic Nuisance Species Task Force represents one attempt to do so for aquatic species (see ch. 6) (17). Much of the responsibility in this area rests with State agencies, many of which lack the necessary regulatory authority and/or resources to adequately address these risks (ch. 7).

ANALYSIS OF CONTROL OR ERADICATION EFFORTS

Although risk analysis primarily focuses on preventing harmful invasions, it also assists in setting priorities for control of established, unwanted NIS. In agricultural applications this tactical decisionmaking is part of Integrated Pest Management programs (ch. 5). Farmers use a variety of systems based on factors like pest population size (determinedly sampling); weather; and crop stage for efficient allocation of pesticides, cultivation practices, and other control measures. Some systems have been developed for area-wide agriculture and forestry control projects, These systems, in large part computerized, guide responses to important pests such as the European gypsy moth *(Lymantria dispar).*

Outside agriculture and forestry almost no formal systems for pest control decisionmaking existed until recently. Yet, like farmers and foresters, natural area managers must evaluate new NIS and respond if the risks are high, or they may face a major infestation. Recently developed models and ranking systems can help maximize the impact of limited NIS control budgets for natural areas. These models can help a manager determine, for example, whether it is better to first destroy large concentrated populations of an invasive plant or the outlying "satellite" populations (usually the latter (47)).

Ronald Hiebert, Chief Scientist with the National Park Service, Midwest Region, developed such a system for ranking control efforts for the more than 250 non-indigenous plant species growing at Indiana Dunes National Lake Shore (23). The system uses a flexible point scale to weigh the current impact of an introduced plant, its potential for harm, control feasibility, and the consequences of delay. The goal is to allow trained ecologists to rank different NIS. New data and theoretical advances may require continual revision of the ranking system. It is undergoing further testing for broader use and has been used by the State of Minnesota Exotic Species Task Force to classify benign, neutral, and threatening plants (46). The Task Force also adapted it to rank animals.

A simpler ranking system using four categories was developed in 1989 for management of 221 species of non-indigenous plants in and around Everglades National Park (85). The National Park Service has also developed a *Handbook for the Removal of Non-Native Animals* which lays out criteria for ranking species for eradication or control projects (15).

Environmental Impact Assessment

Environmental impact assessment refers to a governmental decisionmaking process mandated under the National Environmental Policy Act[7] (NEPA) or under analogous State environmental policy acts (SEPAs), adopted in 18 States (ch. 7). The laws generally require assessments for both government-initiated actions (including funding of private actions) and issuing governmental permits for private actions. Using a standardized environmental assessment check list, the responsible agency makes a "threshold decision" as to whether a particular action poses potentially significant environmental impacts, which can include impacts on both the natural and the human-built environment. If so, the agency must prepare a detailed environmental impact statement (EIS) analyzing the potential impacts and alternatives to the action before undertaking or permitting it. The laws also provide opportunities for public comment and for legal appeals on the adequacy of these assessments, including the threshold decision.

NEPA and SEPAs generally do not impose the precise methods of analysis required either for the threshold decision or the EIS, but they do provide some standards.[8] Environmental impact assessments tend to be more qualitative than formal risk analyses (26), although some EISs include quantitative risk analysis.

NEPA has received broad recognition for compelling more analytical decisionrnaking (although critics say many ways exist to make the information generated more useful (21)). A recent EIS evaluated the introduction of chinook salmon *(Oncorhynchus tshawytscha)* into the Delaware Bay. However, few detailed EISs have been prepared on other decisions related to NIS except

[7] National Environmental Policy Act of 1969, as amended (42 U.S.C.A. 4321 *et seq.*)

[8] 42 U.S.C.A. 4332 generally requires Federal agencies to: "(A) utilize a systematic interdisciplinary approach which will insure the integrated use of the natural and social sciences and the environmental design arts in planning and in decisionmaking . . .; (B) identify and develop methods and procedures. . . which will insure that presently unquantified environmental amenities and values maybe given appropriate consideration in decisionmaking along with economic and technical considerations; . . . [and] (H) initiate and utilize ecological information in the planning and development of resource-oriented projects."

for control programs involving widespread pesticide spraying. For example, APHIS has never required an EIS for any new plant or wood imports (16). Some observers claim that NEPA is an adequate mechanism to analyze these potential impacts at the Federal level (65). However, existing regulations lack a clear definition of when NEPA should be triggered for government approval of new imports. Thus, neither APHIS nor any other agency has a clear obligation to follow the NEPA process before allowing the increase of agricultural, horticultural, or wood imports from potentially risky sources such as Mexico, South Africa, and Russia.

Various avenues exist to increase consideration of NIS under environmental impact assessment laws. These include:

- Current NEPA regulations do not cover all governmental actions likely to contribute to NIS problems, such as approving major trade agreements like the North American Free Trade Agreement (this is being litigated; see ch. 10).
- Agencies' existing ''categorical exclusions' —regulations that excuse NEPA compliance for certain activities--can result in unanalyzed importations or releases. An example is the categorical exclusion for the landscaping of Federal highway projects, including those either federally approved or funded, which have historically involved extensive use of non-indigenous plants.[9]
- Detailed questions specific to NIS are not required in the standardized check lists used for preliminary environmental assessments and for making threshold decisions as to whether an EIS is called for (2).
- Most agency regulations and internal policies do not mandate the integration of risk analysis or other formal decisionmaking tools into the NEPA process.[10]
- The laws vary widely in the 18 States that have SEPA review processes, and 32 States lack them altogether (ch. 7, table 7-5) (18).

The potential for wood imports to carry non-indigenous pests has prompted reconsideration of risk and environmental impact assessment procedures.

The most rigorous application of NEPA and SEPAS would be to require an EIS for all new releases that are not already on a clean list—in other words to declare by law that new, unanalyzed releases are per se potentially significant environmental impacts and require detailed analy -

[9] 23 CFR 771.1 17(7), as amended (Aug. 28, 1987).

[10] To some extent this is happening, however, in analysis of the risks of noxious weeds on Federal lands in accordance with the 1990 Farm Bill's amendment to the Federal Noxious Weed Act, 7 U. S.C.A. sec. 28 14; see, Forest Service Manual Interim Directive 208092-1, dated Aug. 3, 1992.

sis. Montana already does this for all new fish releases.[11] However, biological control advocates concerned about potential costs and delays caused by NEPA have argued strongly against a proposal to require an EIS for all releases of new biocontrol agents (10).

Some concern exists that NEPA and SEPAS can hinder the responsiveness of NIS regulation and control (63). However, emergency control measures can be excused from environmental impact assessment requirements.[12] For less urgent, broader control measures, such as long-term weed management, Federal and State agencies have already written many EISs. Little support is evident for reducing the role of NEPA and SEPAs in this regard because of the potential health and environmental impacts of the pesticides used.

Environmental impact assessment laws could affect the adoption of new clean and dirty lists for regulating importation and release. FWS prepared the only known EIS for a new listing approach when the agency proposed its clean list regulation under the Lacey Act, in 1974 (box 4-A). The EIS was fairly basic and general, having been prepared in the early years of NEPA. Because FWS withdrew the regulation, the adequacy of that EIS remains untested.

An EIS for adopting a new regulatory clean list of NIS would address the potential impacts of allowing those listed species into the country, or State. Conversely, an EIS for a new dirty list regulation would need to focus on the potential impacts of allowing in the *unlisted* species. Such a task would be quite difficult to do because the number of unlisted, and mostly unanalyzed, species would presumably be quite large.

I Economic Analysis

Economic analysis of *past* introductions is feasible through careful research, although relatively little has been done and the studies that exist are of highly uneven quality (see economic consequences section of ch. 2). Even less has been done in the way of future projections that attempt to predict economic scenarios with and without a particular introduction. To date no "standard accounting practice' exists for NIS benefits and costs, whether past or projected.

Projecting future economic effects necessarily follows detailed scientific analysis, such as a pest risk analysis or EIS. That is, economists are data hungry-they cannot assess likely effects of a particular NIS until they understand biological baselines and the likely outcomes of an introduction. Projections of future economic effects are available for about a dozen prominent damaging NIS (ch. 10, table 10-2). In these projections uncertainty about biological outcomes compounds the uncertainty about economic outcomes.

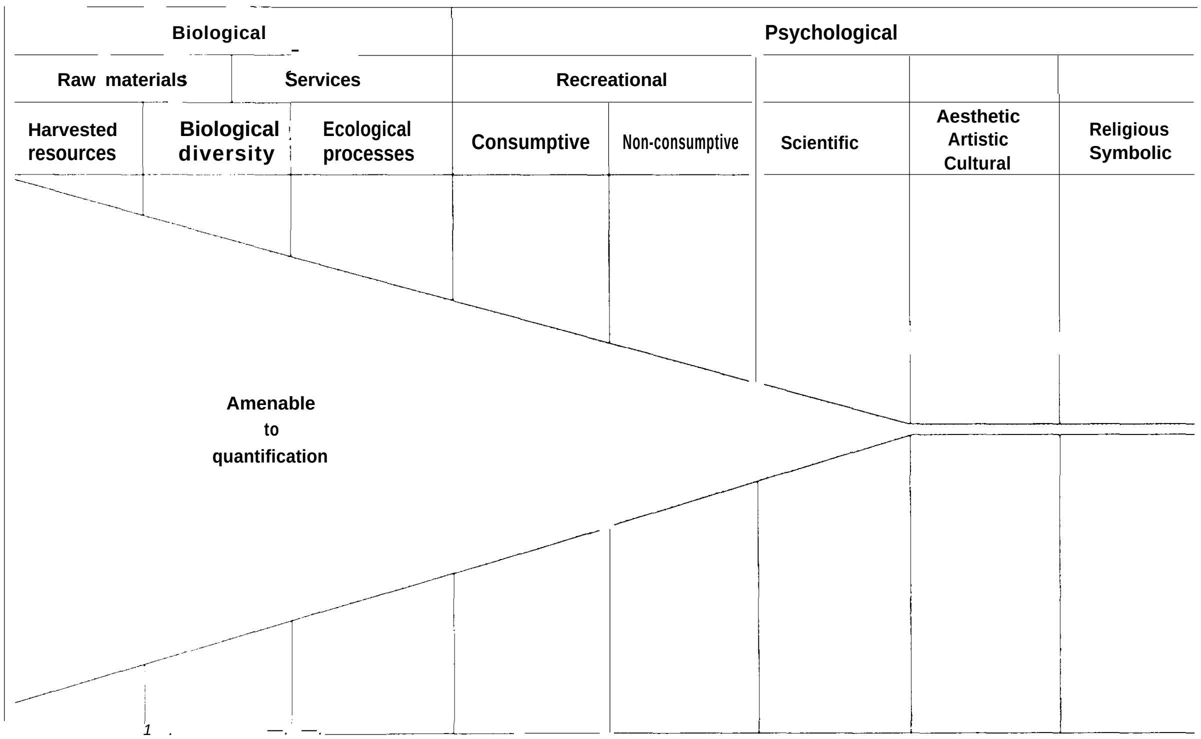
Some question the validity of economic analysis as an aid to public policy decisionmaking because of its heavy reliance on market effects—based on things bought and sold in markets-and lesser emphasis on hard-to-quantify non-market effects. Since the mid-1970s, natural resource economists have made major advances in both the theory and methods of valuing non-market effects (56). (Shadow pricing and contingent valuation are the economic terms for this.) Still, a lively debate continues as to whether these methods adequately account for the way people develop and hold different attitudes toward the value of the natural world or its components (58), aspects of which do not seem amenable to quantification (figure 4-2).

Economic projections do not account well for those future events that have a low probability of occurring but will cause high impact if they do occur (9,56). Unfortunately, many potential NIS problems fit this description. Scientific ignorance, long time lags, and cumulative, sometimes irreversible, effects confound the accounting. For example, highly questionable analyses would

11 Montana Code Annotated 87-5-71 1(2).

12 40 CFR 1506.11, as amended (Nov. 28, 1978).

Figure 4-2—Relative Extents to Which Effects of Indigenous and Non-Indigenous Species are Amenable to Economic Quantification



SOURCE: C. Prescott-Allen and R. Prescott-Allen, *The First Resource—Wild Species in the North American Economy* (New Haven, CT: Yale Univ. Press, 1986).

derive from estimating the benefits and costs of releasing a sport fish that could, but might not, drive an indigenous, non-harvested fish species to extinction several decades later. Some economists propose assigning rights or entitlements to future generations as an additional way of valuing uncertain future effects (52). However, this ''intergenerational equity" has not received wide acceptance in economic accounting to date (56).

Despite these limitations, economic analysis provides a useful rigorous structure to guide decisionmakers who might not otherwise consider all the relevant factors. If the analytical process is accessible to the public and outside experts, it can highlight the areas of debate and uncertainty, making decisionmakers more accountable. This positive effect of economic analysis must be weighed against its costs: personnel, funding, and time. Incurring these costs may only be justified for cases above a certain threshold of risk that cannot be resolved using other accepted methods.

Economics has utility for broader aspects of NIS decisionmaking than whether a particular NIS should be imported, introduced, or controlled (box 4-C). Well-documented economic analysis can help in designing the most efficient regulatory approaches as well as appropriate incentives (e.g., rewards, bounties) and disincentives (e.g., taxes) to respond to existing problems (56). It can determine effective levels of frees and penalties for violations, that is, disincentives that will keep importers and purchasers of potentially harmful NIS from imposing externalized costs on society.

Economics also serves to ensure that both private and government resources are expended

Box 4-C-Macroeconomics and Non-indigenous Species

Macroeconomics is the study of whale systems and the relationships among different economic sectors. Examination of the increasingly linked global economic system, in which relationships are largely expressed through international trade, illuminates the larger forces behind NIS problems. Some important trends:

- As developing countries pursue export markets for cash crops, traditional agroecosystems are increasingly converted to large monoculture. Global homogenization of crops can reduce biological diversity and increase the crops' vulnerability to pests.
- in the last several years, economic and political changes have resulted in several new significant U.S. trading partners, from Chile to China These shifts in NIS pathways could lead to new pest problems.
- The North American Free Trade Agreement if implemented, will increase certain imports from Mexico that pose pest risks, such as fruits and vegetables (see ch. 10).

Economic analysis could also highlight the role NIS play indifferent sectors of the U.S. national economy and the potential impact of more, or fewer, import restrictions. For example, to what extent do profits of the nursery industry depend on continued infusion of new imported species or varieties? Could an indigenous plant industry substitute for imports in a way that would satisfy consumer preferences and maintain industry profitability? Little analysis of such questions has been done by either government or industry. They represent areas of fruitful inquiry on the relationship between economics and the environment.

SOURCES: R.B. Norgaard, "Economics as Mechanics and the Demise of Biological Diversity:' *Ecological Modelling, vol. 38,1987,* pp. 107-121; T. Dudley, Research Botanist and Project Leader, National Arboretum, personal communication to Office of Technology Assessment, Oct. 4,1991; C. Regelbrugge, Director of Regulatory Affairs, American Association of Nurserymen, personal communication to Office of Technology Assessment, Oct. 8,1991.

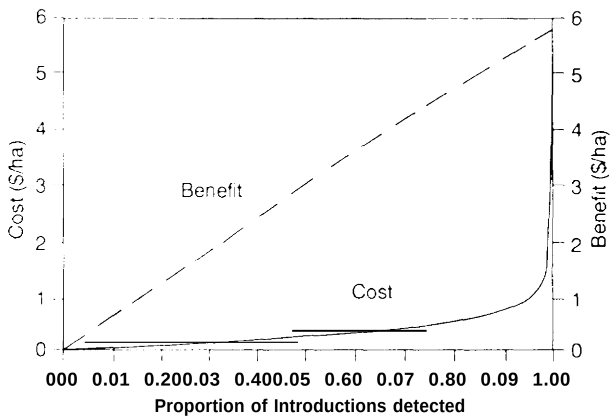
wisely on broad programs. For example, New Zealand's forest industries recently undertook a detailed benefit/cost analysis on conducting forest pest detection surveys at various levels of intensity (6). They found the maximum national net benefit from these surveys resulted at levels that detect 95 percent of new introductions (figure 4-3). The costs of detecting the last 5 percent sharply exceed the marginal benefits. This exemplifies the case that seeking 100 percent success is not always the optimal allocation of resources. However, optimal resource allocation depends entirely on the context, and relatively few detailed studies exist for U.S. NIS programs. In other environmental areas a clear trend exists toward incorporating more economic analysis in designing new policies (13).

BENEFIT/COST ANALYSIS

Where enough is known about the probabilities of future effects from NIS, one can calculate the different expected values of resulting benefits and costs. Benefit/cost analysis (BCA) is a method of weighing particular decisions (box 4-D), such as allowing an NIS to be imported or introduced, or controlling or eradicating it if already present (9). The resulting ratio compares the cumulative potential economic benefits to the costs of the decision, expressing them in 1991 dollars (present value).

Calculating a benefit/cost ratio does not automatically determine a decision. Even when the benefits are greater, the magnitude of the costs may be so high as to make the action unacceptable or unfeasible. Costs and benefits that are unevenly distributed socially, geographically, or generationally can present fairness questions. For example, crop losses from pests can be highly regional-some farmers may lose while others profit from increased market prices (32). Excessive uncertainty or questionable valuation techniques may undercut the analysis. BCA is most useful for ranking a comparable group of desira-

Figure 4-3-National Costs and Benefits of Detecting Forest Pest Introductions in New Zealand



SOURCE: P.C.S. Carter, "Risk Assessment and Pest Detection Surveys for Exotic Pests and Diseases which Threaten Commercial Forestry in New Zealand," New *Zealand Journal of Forestry Science,* vol. 19, Nos. 2/3, 1989, pp. 353-374.

ble actions when budget constraints prevent undertaking them all (9).

In fact, benefit/cost ratios have been calculated for only a few NIS decisions. Most existing studies have focused on the economic justification for eradicating or controlling established infestations. Benefit/cost ratios have been developed for past or potential effects of 12 prominent NIS (table 4-4), In almost all the studies (of highly variable rigor) the ratios are high (median 17.2/1; range 0.23/1 to 1,666/1). That is, the management actions are well justified economically because the overall benefits of eradicating, controlling, or preventing the potential infestations far exceed the costs of the actions. However, these ratios do not give detailed accounting for the uneven distribution of the effects. Also, several of the ''potential impacts' represent worst-case scenarios. The analyses did not weigh the likelihood that the worst potential impacts would actually occur. Thus, those resulting ratios are probably too high.

As with risk analysis, future theoretical and technical improvements are likely to make BCA's more comprehensive (56). BCA for NIS will benefit from the development of standardized practices, such as those proposed in box 4-D and table 4-4, to make results more consistent and comparable. The ability of economists to provide useful analyses will depend to a large extent on whether scientists can estimate probabilities of future effects of NIS in a consistent, comparable way. Economic models provide little assistance, regardless of their sophistication, where they rest on vague or equivocal predictions of biological events ("garbage in, garbage out").

DECISIONMAKING PROTOCOLS

Protocols are written codes used in diplomatic, military, and scientific affairs to guide adherence to a prescribed course of action. In the NIS context, decisionmaking protocols consist of criteria developed by experts to guide the determination of whether a proposed activity involving MS is appropriate. Some protocols also prescribe precautions to minimize risks. They can be focused narrowly, such as to guide procedures for federally funded research on non-indigenous aquatic species, or broadly on policy-level decisions, such as the model national approach proposed by the International Union for Conservation of Nature and Natural Resources (box 4-E). The broader protocols have the distinctive feature of going beyond scientific or risk-based criteria to encompass value-based considerations and to guide the weighing of benefits and costs.

Protocols lack enforceability except when adopted by law, which has rarely happened (5,84). For example, the American Fisheries Society protocol on new fish introductions has existed for more than 20 years, but no Federal or State laws mandate its use, despite calls for its adoption (33). Few documented cases of its voluntary use exist (1 1,51). Congress considered, but did not pass, a bill[13] in 1991 requiring agencies to follow a detailed protocol for aquatic introductions (77). Several experts have supported greater use of

13 The Species Introduction and Control Act of 1991, H.R. 5852.

Table 4-4-Documented Benefit/Cost Ratios for Eradication, Control, or Prevention of Selected Non-Indigenous Species

Notes: dollar figures are in millions; totals columns give Net Present Values in 1991 dollars, calculated as indicated in box 4-D to the extent that the information was provided in the original studies; letters after species names refer to references for table 4-4 at end of this table. Note numbers refer to notes at bottom of page. The ratios given compare the benefits to the rests of eradicating, controlling, or preventing the NIS invasion under the circumstances that were studied. (Check index for scientific names.)

	Direct effects		Indirect effects		costs						
	Market goods	Nonmarket goods	Multiplier effects	Related goods	Direct control costs	Opportunity costs	Distribution rests considered	Year of study	1991 total benefits	1991 total costs	Benefit/ cost ratio
Past impacts-Plants											
Hydrilla and water hyacinth[a]	0.497			0.016			N	1974	1.260	0.041	31/1
Hydrilla and water hyacinth[a]		0.023			0.100		N	1977	0.047	0.203	0.23/1
Hydrilla and water hyacinth[a]		0.567			0.003		N	1978	1.075	0.006	179/1
Hydrilla and water hyacinth[a]		0.869			0.019		N	1979	1.514	0.033	45.9/1
Hydrilla and water hyacinth[a]		0.468			0.089		N	1982	0.641	0.122	5.25/1
Melaleuca[b]	160[1]				12.3[1]		N	1991	160[1]	12.3[1]	13/1
Melaleuca[c]	8.4		15.2	145.0		15.0	Y	1989	182.75	16.259	11.241
Leafy spurge[d]							N	1984			10/1[2]
Pest impacts-Fish											
Sea lamprey[e]		219,748		42.898	8.681		N	1988	296.421	9.797	30.25/1
Sea lamprey[f]		5503			40		N	1980	878.588	63.897	13.7511
Past impacts-insects											
Alfalfa blotch leafminer[g]	13				1.1		N	1983	17.128	2.0864	
Potential impacts--Plants											
Purple loosestrife[h]	6.54	39.32			0.100	1.6	N	1987	53.477	1.982	27/1
Witchweed[1]	389.55				57.4		N	1976	845.6	124.53	6.78/1
Witchweed[1]	997.17				57.4		N	1976	2,163.43	124.53	17.3711
Witchweed[1]	389.55				52.1		N	1976	845.16	113.03	7.47/1
Witchweed[1]	997.17				52.1		N	1976	2,163.43	113.03	19.1/1
Potential impacts-insects											
Cotton boll weevil[J]	3.755			-0.84	0.16		Y	1979	5.068	0.279	18.1/1
Cotton boll weevil[J]	5.50[5]			-1.37	0.24		Y	1979	7.193	0.418	17.2/1
Mediterranean fruit fly[k]	1,2566				64		Y	1981	1,829.22	93.21	19.62/1
Mediterranean fruit fly[k]	816s				64		Y	1981	1,188.41	93.21	12.75/1
Mediterranean fruit fly[1]	3,078				62.76		N	1981	4,482.49	91.40	49/1
Potential impacts-Pathogens											
Foot and mouth disease[m]	11,6507				467		N	1976	25,275.51	1,013.19	24.95/1
Foot and mouth disease"	11,6507				690		N	1976	25,275.51	1,497	16.88/1
Potential impacts-Other											
Pests of:											
Siberian log imports[no]	62,152[8]					37.4	Y	1990	64,704.21	38.94	1,661/1
Siberian log imports[n,o]	35,390.35[8]					37.4	Y	1990	36.843.62	38.94	946/1

NOTES:

1. Direct effects and costs were reported without further classifications, therefore, these figures are listed here under their general headings.
2. Only benefit/cost ratio was reported for this study, without supporting figures.
3. These estimates are the value of all sport and commercial fishers in the Great Lakes. This study used "all or none" valuation technique and hence overstates benefits to sea lamprey control.
4. Costs converted to 1991 dollars by assuming that midpoint of time series was appropriate index year. Assumption was made due to lack of information on the flow of funds through the time series.
5. Two scenarios were examined-the first is for current insect control with boll weevil eradication and the second is for optimum pest management with no government incentives but with a boll weevil eradication program. The analysis is for a 15-year period starting in 1979.
6. High and low cost scenarios were used to estimate the impacts of severe infestations of the Mediterranean fruit fly in California. These were contrasted against only 2 years of current to control costs ($64 million), generating benefit/cost ratios which may be high.
7. High and low control costs were employed as contrasted to the benefits estimated from 1976 to 1990.
8. High and low scenarios for the economic impacts assuming accidental introduction and unmitigated infestations of defoliators (i.e., Asian gypsy moth and Nun moth), nemotodes, larch canker, spruce bark beetles, and annosus root disease resulting from the import of Siberian logs as contrasted to the estimated net welfare gains from the log imports,

REFERENCES FOR TABLE 4-4

a D.E. Cone, J.V. Shireman, W.T. Halter, J.C. Joyce, and D.E. Canfield, Jr., "influence of Hydrilla on Harvestable Sport-fish Populations, Angler Expenditures at Orange Lake, Florida," *North American Journal of Fisheries Management* vol. 7, 1987, pp. 410417.

b *Federal Register*, "Noxious Weeds: Additions to List," VOl. 56, No. 201, Oct. 17, 1991, pp. 52,005-52,007.

c C. Diamond, D. Davis, and D.C. Schmitz, "Economic Impact Statement: The Addition of *Melaleuca quinquenervia* to the Florida Prohibited Aquatic Plant List," unpublished paper for the Joint Center for Environmental and Urban Problems, Ft. Lauderdale, Florida.

d U.S. Department of Agriculture, Animal and Plant Health Inspection Service, "Biological Control of Leafy Spurge," program aid #1435, 1988, p. 2.

e W.M. Spaulding, Jr. and R.J. McPhee, "An Analysis of the Economic Contribution of the Great Lakes Sea Lamprey Control Program," *The Report of the Great Lakes Fishery Commission by the Bi-National Evaluation Team, vol. 2, Nov. 28, 1989,* pp. 1-27.

f D.R. Talhelm and R.C. Bishop, "Benefits and Costs of Sea Lamprey *(Petromyzon marinus)* Control in the Great Lakes: Some preliminary Results," *Canadian Journal of Fishery and Aquatic Science,* vol. 37, 1980, pp. 2,169-2,174.

g J.J. Drea and R.M. Hendrickson, Jr., "Analysis of a Successful Classical Biological Control Project: the Alfalfa Blotch Leafminer (Diptera: Agromyzidae) in the Northeastern United States," *Environmental Entomology, vol. 15, No. 3,* June 1986, pp. 448453.

h D.Q. Thompson, "Spread, Impact, and Control of Purple Loosestrife (*Lythrum salicaria*) in North America Wetlands," U.S. Fish and Wildlife Service, 1987.

i P.M. Emerson and G.E. Plato, 'Social Returns to Disease and Parasite Control in Agriculture: Witchweed in the United Stat=, " *Agricultural Economic Research*, vol. 30, No. 1,1978, pp. 15-22.

j C.R. Taylor et al., "Aggregate Economic Effects of Alternative Boll Weevil Management Strategies,"' *Agricultural Economics Research, vol. 35, No. 2,* April 1983, pp. 19-28.

k R.K. Conway, "An Economic Perspective of the California Mediterranean Fruit Fly Infestation," National Economics Division, Economic Research Service, U.S. Department of Agriculture, ERS Staff Report #AGES820414, 1982.

l T.T. Vn,(Economic Analysis of the Mediterranean Fruit Fly Program in Guatemala," Animal and Plant Health Inspection Service, U.S. Department of Agriculture, August 1989.

m National Research Council, "Long-Term Planning for Research and Diagnosis to Protect U.S. Agriculture from Foreign Animal Diseases and Ectoparasites," Subcommittee on Research and Diagnosis on Foreign Animal Disease, Committee on Animal Health, Board on Agriculture, NRC paper #PB84-165141, 1984.

n U.S. Department of Agriculture, Forest Service, "Pest Risk Assessment of the Importation of Larch from Siberia and the soviet Far East," Misc. Publ. No. 1495, September 1991, pp. S-I-K-1 5.

o U.S. Department of Agriculture, "Economic Benefits from the Importation of Soviet Logs," unpublished draft (1991).

SOURCE: M. Cochran, "Non-Indigenous Species in the United States: Economic Consequences," contractor report prepared for the Office of Technology Assessment, March 1992.

Box 4-D-Outline of Steps for Benefit/Cost Analysis of Non-Indigenous Species

1. Effect estimation
   - A. Identify relevant input and output categories
     1. Inputs-(e.g., wetland invasion by non-indigenous melaleuca)
     2. Outputs-(e.g., tourism; honey production)
   - 6. Define units of measurement for input and output categories
     1. Inputs-(e.g., acres invaded)
     2. Outputs-(e.g., tourist expenditures; quantity of **honey sold)**
   - **C.** Establish a base of values for input and output categories without the introduction of the NIS
   - D. Identify production process relating to introduction of the NIS to a series of outputs, expressed probabilistically
     1. Expected units of invasion-(e.g., acres of distinct environs where NIS would be established and distributed)
   - E. Quantify expected magnitude of each output for the relevant magnitudes of each input category
   - F. Estimate changes in input and output categories for with introduction versus without introduction scenarios

ii. Valuation of direct effects
   - A. Market goods
     1. Marginal changes in production
        a. Market price x change in output quantity
     2. Non-marginal change in product in product
        a. Identify market price changes
        b. Measure consumer and producer surplus
   - B. Non-market goods
     1. Contingent valuation

Ill. Calculate indirect effects
   - A. Multiplier income and employment effects
     1. Opportunity costs
     2. Unemployed resources
   - B. Related goods
     1. Changes in production
     2. Changes in market price
     3. Calculate consumer and producer surplus

IV. Calculate annual benefits and costs

V. Accounting for time
   - A. Select **appropriate discount rate**
     1. Use real (deflated) rate (e.g., riskless rate; Water Resources Council rate)
   - B. **Convert annual benefits and costs to real terms (e.g., using CPI, GNP Deflator)**
   - **C. Calculate** present value
     1. Present value of benefits = $\sum_{n=0}^{N} \frac{B_n}{(1+r)^n}$
     2. Present value of costs = $\sum_{n=0}^{N} \frac{C_n}{(1+r)^n}$

n. number of the year in time series, N = last year of time series, **r = discount rate, B = benefits, C = costs**

SOURCE: M. Cochran, "Non-Indigenous Species in the United States: Economic Conse quences," contractor report prepared for the Office of Technology Assessment, March 1992.

Box 4-E-The IUCN Position Statement on Translocation of Living Organisms

A broad protocol covering the whole field of NIS releases was developed by the International Union for Conservation of Nature and Natural ***Resources*** (IUCN), a body comprised of scientific experts and government officials involved in conservation from around the world. The lengthy IUCN Position Statement on Translocation of Living Organisms, approved in 1987, lays out many questions to answer and steps to follow when considering future releases. In summary it provides that:

- Release of a NIS should be considered only if dear and well-defined benefits to humans or natural communities can be foreseen.
- Releases should be considered only if no indigenous species is suitable.
- No NIS should be deliberately released into any natural area; releases into seminatural areas should not occur absent exceptional reasons.
- Planned releases, including those for biological control, entail three critical phases: rigorous assessment of desirability; controlled experimental release; and extensive release accompanied by careful monitoring and pre-arrangement for control or eradication measures, if necessary.
- Special consideration should be given to eradicating existing introductions in ecologically vulnerable areas.

This approach represents the most broadly applicable model national law on NIS. Indeed, the position statement calls on national governments to provide the “legal authority and administrative support” to implement IUCN’s approach. This has not occurred. The statement did substantively influence the initial version of the Convention on Biological Diversity, which was drafted by IUCN’s legal branch. However, by the time the convention was opened for signing in Rio de Janeiro the negotiation process had greatly diluted the strong principles summarized above (see ch. 10).

SOURCE: International Union for Conservation of Nature and Natural Resources, Species Survival Commission, ‘he IUCN Position Statement on Translocation of Living Organisms: Introductions, Reintroductions, and Restocking” (Gland, Switzerland, 1987).

protocols; some suggest that they be implemented federally by grafting their use into NEPA when agencies assess potential environment impacts of proposed releases (74).

Adhering to a decisionmaking protocol can require data that are more difficult or expensive to obtain than the information traditionally considered by managers. Even so, protocols often do not eliminate subjectivity and scientific uncertainty—some of the needed data may be unobtainable. Few protocols have been validated by way of follow-up evaluations of decisions based on them (83). Of course, if they are used more broadly greater opportunities for evaluation will exist.

Some prominent decisionmaking protocols do exist or have been proposed (box 4-F), Others could be developed to cover additional NIS groups and situations. Biological control specialists in particular have proposed codifying more comprehensive protocols: 1) to preempt overly restrictive regulations constructed by non-experts and 2) to protect the public from amateur introductions (10). Their emphasis is on flexibility within a reasonable, non-regulatory framework: “the protocols must be dynamic, i.e., capable of being updated in response to ever increasing knowledge and changing conditions’ (10). Fisheries specialists have also stressed voluntary compliance with protocols or guidelines, especially combined with education regarding it importance, as a way to avoid the litigation that might accompany overly strict regulations (31).

VALUES IN DECISIONMAKING

Many NIS issues may not be resolvable using risk analysis, environmental impact assessment, or economic analysis, because of lack of necessary information or disagreement over the appro-

Box 4-F-Prominent Decisionmaking Protocols

Codes of Practice and Manual of Procedures for Considration of Introductions and Tranfers of Marine and Freshwater Organisms, European Inland Fisheries Advisory Commission, Food and Agriculture Organization, United Nations, Rome, Italy, and International Council for the Exploration of the Sea, Copenhagen, Denmark; revision published in 1988.

Guidelines for Introducing Foreign Organisms into the United States for the Biological Control of Weeds, Working Group on Biological Control of Weeds, joint Weed Committees of the U.S. Departments of Agriculture and Interior; revised in 1960. (The U.S. Department of Agriculture has developed several other guidelines for the importation, interstate movement, and field release of various types of organisms for biological control.)

Guidelines *for Re-Introductions-Draft,* Re-introduction Specialist Group, Species Survival Commission, International Union for Conservation of Nature and Natural Resources, Gland, Switzerland; proposed in 1992.

IUCN Position Statement on Translocation of Living Organisms, International Union for Conservation of Nature and Natural Resources, Gland, Switzerland; approved in 1967.

Position Statement on Exotic Aquatic Organisms' Introductions, American Fisheries Society, United States; revision adopted in 1966.

Protocol for Translocation of Organisms to Islands, New Zealand; proposed in 1990.

Research Protocol for Handling Nonindigenous Aquatic Species, U.S. Fish and Wildlife Service, National Fisheries Research Center, Gainesville, Florida, adopted by the Federal interagency Aquatic Nuisance Species Task Force in 1992.

The Planned Introduction of Genetically Engineered Organisms: Ecological Considerations and Recornmendations, Ecological Society of America; proposed in 1969.

SOURCES: J.T. Carlton, "Man's Role In Changing the Face of the Ocean," Conservation *Biology,* vol. 3, No. 3, September 19S9, pp. 270-272; D.L. Klingman and J.R. Coulson, "Guidelines for Introducing Foreign Organisms into the United States for the Biological Control of Weeds," *Bulletin of the Entomological Society of America,* vol. 19, No. *3,* 1983, pp. 55-S1; J.M. Tiedje et al., "The Planned Introduction of Genetically Engineered Organisms: Ecological Considerations and Recommendations," *Ecology,* vol. 70, No. 2, 19S9, pp. 29$315; D.R. Towns et af., "Protocols for Translocation of Organisms to Islands," *Ecological Restoration of New Zealand Islands,* D.R. Towns et al. (eds.) (Wellington, New Zealand: Department of Conservation, 1990).

priate method. Decisionmakers may prefer, or be compelled, to decide on the basis of fundamental values. As used in this section, ''values" has no monetary connotation, rather, it refers to overarching criteria that people use to make decisions (3). Values, although they are critical, often receive little explicit acknowledgment in studies of decisionmaking because of the focus on science-based models.

For most non-native Americans, being of relatively recent stock in North America and Hawaii, little of their cultural identity revolves around a relationship with indigenous species. Indeed, much pioneer history is the story of clearing the land of threatening or competing indigenous species in favor of tame, familiar, introduced ones. Not surprisingly, preserving indigeneity, both biological and cultural, has only risen as a public value in the last few decades. The Endangered Species Act[14] represents the strongest national law embodying this biological *preservation value.* It is also reflected in native plant societies and similar manifestations of a growing emphasis on using indigenous species for landscaping and other applications (45).

Americans also place strong emphasis on liberty as a value, here encompassing the liberty to sell, purchase, catch, hunt, possess, and use

[14] Endangered Species Act of 1973, as amended (16 U. S.C.A. 1531 *et seq.*)

NIS. Most people own pets and/or keep house or garden plants, which are virtually all non-indigenous. This *liberty value* is so strong that at the 1974 congressional hearing on the FWS attempt to implement a clean list decisionmaking approach (box 4-A, above), the successful opponents-largely the pet trade-argued that it usurped their civil rights to import MS (76). This liberty is not limited to dogs, cats, and poinsettias. Many people want to own novel species because of their novelty (4).

Values can conflict at social or personal levels. The use of non-indigenous fish for recreational fishing, such as hybrid bass *(Morone chrysops x M. saxatilis)*, represents a social conflict (59). Anathema to fishing purists, these "put and take' fisheries enjoy broad popularity-some have clubs devoted to their furtherance. Preserving indigeneity in U.S. waters conflicts with the liberty to use the new fish. However, a limited opinion poll (Arizona only) suggests that the public opposes the release of non-indigenous fish that threaten the existence of indigenous fish (22).

No broad public survey data exist on the prevalence of concerns about NIS problems. Surveys do show the public to be very concerned about the health risks of pesticides, however (8). A person who supports preservation of indigenous species may also oppose the use of chemical pesticides because of their health risks. In situations where chemical pesticides offer the only control for NIS that threaten indigenous species, that person has a personal conflict. He or she must decide which carries the most weight, the *preservation or the health value.*

Many NIS choices boil down to *humane values,* rooted in basic moral principles. Monkeys may be low-risk invaders, but many people object to their being imported and possessed as pets for ethical reasons. Feral horses and burros *(Equus asinus)* have been successful and often damaging invaders, but vocal citizen groups object to their being killed on ethical grounds. However, few object on ethical grounds to the killing of the less attractive feral hog *(Sus scrofa*)-advocates for their preservation are the hunters who want to shoot them. (Indeed, a survey has shown that if a decisionmaker is a hunter he or she is more likely to view non-indigenous animals, like feral hogs, as a beneficial resource than if he or she does not hunt (61)). Almost no one objects *on* ethical grounds to highly deleterious rats or sea lampreys *(Petromyzon marinus)* being killed.

Clearly the attitudes of the public vary with the perceived attractiveness and usefulness of the species involved, indigenous or non-indigenous (28). Nevertheless, most people would probably support the following ethical position: regardless of the species being controlled, if other factors such as costs and risks are equal, managers should use the most humane methods. When applied in the field, though, "humane" methods of control elude easy definition (69).

OTA makes no findings as to which values deserve the greatest weight. Their role in past decisions, however, has tended to lack clarity. Future policy and management decisionmaking would benefit from explicitly separating factual questions from questions of values. Nevertheless, cultural, religious, and historical factors will inevitably color a decisionmaker's perspective.

NEW SYNTHESES OF DIVERSE APPROACHES

Difficulties abound in generalizing about NIS decisionmaking. An approach that holds for one taxonomic group may not hold for another-one size does not fit all. Potential impacts (harmful and beneficial) vary with the species and the environments involved. Different areas of the country often have different interests. A new NIS may favor one group in society and burden another.

Numerous interests can influence NIS decisionmaking (figure 4-4). Each interest is not monolithic; as much contention can occur within an identified group as between them. Not all these interests are brought to bear in all cases nor do all carry equivalent weight. For example, a large or politically influential constituency that favors a particular decision regarding NIS may far outweigh the positions of a small number of expert scientists who caution against the decision (44).

Are methods available to reconcile these diverse interests and to resolve disputes that may otherwise end in expensive and burdensome litigation? If decisionmakers attempt to reconcile these interests, which of the approaches discussed above should they rely on—risk analysis, environmental impact assessment, economic analysis, and/or protocols? None of them alone is currently broadly applied to NIS. And how should diverse values factor in?

Two proposals for synthesis allow incorporation of diverse societal interests and capitalize on the strengths of the various decisionmaking approaches without according any of them trump status. These proposals are outlined here with the caveat that their application in particular contexts may require modifications.

Benefit/Cost Analysis Subject to a Safe Minimum Standard

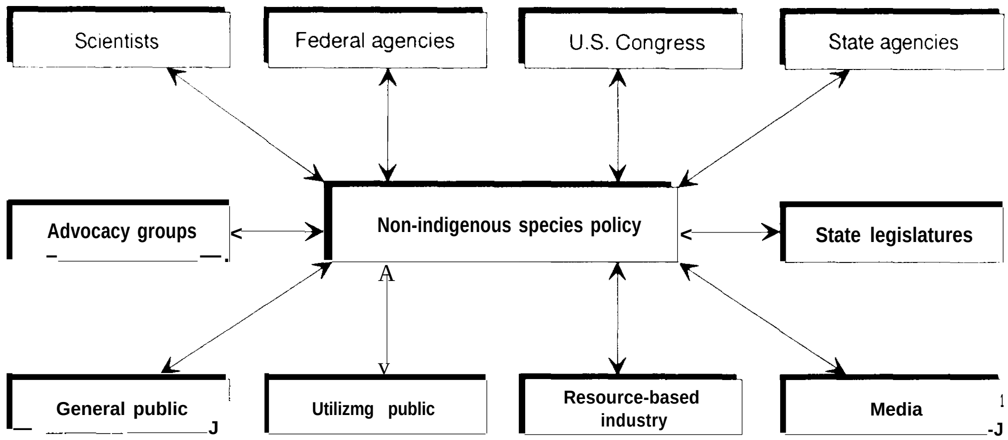
Economist Alan Randall of Ohio State University proposes that current natural resources economics theory justifies this rule: Decide on the basis of maximizing net benefits to society subject to the constraint of a Safe Minimum Standard (56). A "safe minimum standard' is a level of environmental quality that society should not go below, except in extraordinary cases. The rule applies in deciding whether to prevent, support, or take no action on a particular introduction, or whether an existing NIS should be controlled or eradicated. It can be applied to intentional releases and in preparing for or responding to accidental releases. Generic application of the Randall approach by a manager would follow six steps, with the underlying premise that each step involves an open, pluralistic process (56):

Step 1: The manager obtains the judgment of scientists who use risk analysis, experimentation, and/or other methods to predict the likely spread and effects of a particular NIS. They determine likely future scenarios of resulting ecological situations under both baseline conditions, i.e., no introduction or further spread, and ''with introduction" (or further spread) conditions. The scientists then determine whether a real possibility exists of a *harmful* invasion. If so, the manager proceeds to Step 2. If no such possibility exists, then the introduction can proceed, providing for further consideration if and when new evidence arises.

Step 2: The manager obtains the judgment of scientists as to whether a possibility exists of ecologically *disastrous-as* opposed to harmful but manageable-consequences. If ecologically disastrous consequences are not a real possibility, the manager proceeds to Step 3. If ecologically disastrous consequences are a real possibility, the manager omits Steps 3, 4, and 5, and proceeds to Step 2a.

Step 2a: If a real possibility of ecologically disastrous consequences exists, the manager invokes a Safe Minimum Standard rule. This is a presumption based on preservation and other values that actions will not be taken that cause ecologically disastrous consequences even if substantially greater potential benefits are lost. The introduction would be prevented or reversed except for extraordinary cases in which the value of these foregone benefits would be intolerably high. To make that decision, the manager first obtains economic calculations of the foregone benefits, then engages in a public decision process to determine whether these are socially intolerable. If the decision is made to proceed, mitigation of the potentially disastrous consequences would be pursued.

Figure 4-4-The Major Interests Involved in Shaping Non-indigenous Species Policy



SOURCE: Adapted from S.R. Kellert and T.W. Clark, "The Theory and Application of a Wildlife Policy Framework," *Public Policy Issues in Wildlife Management*, W.R. Mangun (cd.) (New York, NY: Greenwood Press, 1991), pp. 17-38.

Step 3: (from Step 2) Starting with the baseline and "with introduction' scenarios (predicted in Step 1), the manager employs economists to develop accounts of the resulting flows of goods and services. They per-form benefit/cost analyses based on these accounts, with appropriate market and non-market valuation methods to measure total value, including use and ''existence' values. The manager determines whether the prospective introduction (or spread) is expected to have a net benefit.

Step 4: If Step 3 reveals that the introduction (or spread) will not have a net benefit, the manager develops alternative scenarios to prevent it. If Step 3 reveals positive net benefits, but also significant harmful effects (ecological or economic), alternative scenarios to mitigate the harmful effects are developed. Then the economists perform further benefit/cost analyses based on accountings under these new scenarios that incorporate the prevention or mitigation alternatives. (If positive net benefits result with no significant harmful effects, then no further accounting is needed.)

Step 5: The manager gives full public consideration to the benefits and costs of the alternatives resulting from Step 4. Absent compelling input to the contrary, the alternative with the maximum net benefits is chosen.

The Randall approach represents a compromise between the liberty value and the preservation and humane values discussed in the values section, above. That is, traditional benefit/cost analysis assumes the decisionmaker has the freedom to choose the maximum net benefit alternative, regardless of associated costs, whereas the Safe Minimum Standard (Step 2a) constrains that liberty based on a socially accepted higher good. The constraint also acts as a check on the problem, discussed above, of relying on economic analysis to value effects of low-probability future events that may be irreversible (i.e., disastrous), like extinction.

Decision Analysis Combined With Alternative Dispute Resolution

Professor Lynn Maguire of the Duke University School of the Environment proposes a different way to synthesize decisionmaking approaches. It combines decision analysis with alternative dispute resolution. This method has more participation by ‘‘stakeholder’ groups than does the Randall approach, but fewer pre-selected analytical methods (42).

Decision analysis is a framework that ensures that the components common to any decision are recognized and addressed explicitly. Those decision components are: objectives, criteria, alternative actions, sources of uncertainty, and values associated with possible outcomes. The concurrent use of alternative dispute resolution recognizes that leaving difficult decisions to government officials or experts can result in continued conflict among the interest groups involved. The process creates a forum for addressing the decision components, making tradeoffs, recognizing common ground, and making the needed decision. A similar framework has been proposed for decisionmaking for releases of genetically engineered organisms (20). The Maguire approach proceeds through four steps:

Step ***1:*** Identify and convene, in a neutral setting, representatives of stakeholder interest groups in a particular NIS decision (e.g., release, control, eradication, or regulatory changes).

Step 2: Undertake preliminary negotiations to achieve, where possible, joint acceptance of major objectives and sub-objectives, and criteria for judging whether alternative outcomes from the decision to be made meet the objectives (i.e., the ‘utility’ of the outcome). To the extent possible, separate technical questions from value-based questions and obtain technical expertise to address the former. When agreed, engage in joint fact-finding efforts.

Step *3: The* parties flesh out the sub-components of their views of the probable effects of the alternative outcomes, including factual and value-based effects. These are graphically represented on a “decision tree” in which the parties, with expert assistance if needed, assign perceived probabilities to different outcomes (the “branches” of the tree), accounting for uncertainties. The ‘‘utility” (identified in Step 2) of each identified outcome is weighted with the perceived probability of the outcome occurring to calculate the “expected utility” of each outcome for each party.

Step 4; All parties identify actions with “maximum expected utility. ” Other jointly accepted rules, such as minimizing the largest costs, are also possible. Identify and negotiate options to reduce uncertainty by obtaining additional information. If agreed, obtain this additional information. Then discuss creative tradeoff alternatives in view of the maximum expected utilities of all parties or other accepted decision rule. Attempt to negotiate tradeoffs with the aim of achieving a consensus decision.

The Maguire approach, unlike the Randall approach, neither makes presumptions based on values nor prescribes analytical methods. It mandates less input from scientists and economists than the Randall approach. Consequently, the outcomes may reflect less ‘‘good science” and rely more on the subjective probabilities assigned by the participants. Indeed, the absence of scientific answers may be why the dispute among the stakeholders exists in the first place. The approaches are not mutually exclusive, however. Participants in the Maguire process could ‘jointly accept” that benefit/cost analysis subject to a Safe Minimum Standard embodies the appropriate Step 2 criteria to judge the utility of alternative outcomes. They could choose to obtain more “good science” to the extent possible.

OTA finds three common hurdles to implementing these two approaches:

1. Lack of clear guidance as to what should trigger the significant commitment of personnel, expertise, and time necessary to implement formal approaches. Various trigger options exist, however: for preparation of any new clean or dirty list; pursuant to a petition process (similar to listing decisions under the Endangered Species Act); under

NEPA for controversial environmental impact statements (21); and pursuant to the Federal Negotiated Rulemaking Act,[15] discussed below.

2. Lack of convincing treatment of uncertainty, because of their emphases on negotiating, quantifying, or developing scenarios based on unknowns. Admittedly, it is hard to envision *any* convincing treatment of uncertainty in a decisionmaking model.
3. Lack of evaluation of their adaptability to NIS decisionmaking in the real world. Randall's Safe Minimum Standard very roughly resembles the restrained benefit/ cost weighing allowed under the Endangered Species Act (55). (The act's Safe Minimum Standard is no further human-caused extinctions unless the 'God Squad' determines the costs to be intolerably high in a particular case.) The Maguire approach has been utilized successfully in other natural resource contexts, such as reintroducing the endangered grizzly bear *(Ursus arctos horribilis) in the* Northern Rockies, which is comparable in some ways to introducing potentially harmful NIS (43). Obviously, neither model can be evaluated in the NIS context unless a commitment is made to try them.


ANIMAL AND PLANT HEALTH INSPECTION SERVICE

Agencies' implementation of decisions should be evaluated if new decision making methods are tried. Also, the ***quality*** *of decisions reached must be assessed, i.e., whether new approaches ultimately improve management of harmful NIS.*

As far as strengths, both models can incorporate the various decisionmaking approaches discussed in this chapter. In doing so, they organize and structure information from diverse sources but are not overly rigid. Both proposals also call for full documentation of the process. They force methods, assumptions, comparisons, and tradeoffs to be explicit, which facilitates their communication, review, and appraisal (20,68).

The question remains how these or comparable decisionmaking approaches could be integrated into a regulatory process. One existing avenue is the Federal Negotiated Rulemaking Act. It provides a process whereby the head of a Federal agency makes a threshold decision about whether an issue would benefit from negotiations. He or she bases this on the need for a new Federal regulation and the feasibility of convening a representative committee likely to achieve consensus. Public notice of the process is required. The agency may hire professional facilitators to run the negotiations. Under the act, the agency commits to using the consensus agreement, if the parties reach one, as the basis for the proposed regulation "to the maximum extent possible

[15] Negotiated Rulemaking Act of 1990 (5 U. S.C.A. section 561 *et seq.*)

consistent with the legal obligations of the agency. ''16 Although it apparently has never been applied before in the NIS context, negotiated rulemaking has successfully resolved disputes in other environmental areas.

Even if these model approaches are used, and consensus achieved, positive improvements in regulation and control of damaging NIS will not necessarily follow. Regular feedback based on monitoring of ultimate results would aid in improving the models. Follow-up evaluation of agency implementation of resulting decisions should be an integral part of any changes in decisionmaking processes (29).

CHAPTER REVIEW

This chapter has examined the means by which decisions about potentially harmful NIS are made: clean and dirty lists, risk analysis, environmental impact assessment, economic analysis, values, and protocols. This chapter also looked at two methods to synthesize the different approaches. Explicitly addressing three interrelated issues would contribute to clearer decisions in the future: 1) determining the level of risk that is acceptable; 2) setting thresholds of risk at which decisionmakers should invoke formal, more costly, approaches; and 3) clarifying the tradeoffs when deciding in the face of uncertainty. The benefits of taking these issues seriously would be better NIS decisions in many cases or, at least, decisions that take better account of the diverse societal interests involved.

Even under the best of circumstances, some mistaken decisions will be made because of the inherent unpredictability of NIS. Technology provides the means to counter such mistakes. Methods to prevent and control problems due to NIS are the subject of the next chapter.

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16 5 U.S.C.A. 583(a)(7).