

Invasive Species Indicators in *The State of the Nation's Ecosystems*: Background and General Charge to a Non-Native Species Task Group

I. Introduction

In September 2002, the Heinz Center released *The State of the Nation's Ecosystems*, which lays the foundation for periodic, high-quality, non-partisan reporting on the condition and use of our nation's ecosystems.

This report was developed over a five-year period by experts from business, environmental, academic, and federal, state, and local government institutions. The goal was to select a set of indicators that would provide a strategic view of key aspects of ecosystem condition, to serve as the basis for periodic reporting to decision makers and the public.

The report includes indicators for each of the six principal ecosystem types in the U.S. (coasts and oceans, farmlands, forests, fresh waters, grasslands and shrublands, and urban and suburban areas), and for the nation as a whole. These 103 indicators describe 10 major characteristics, which can be grouped into four broad categories: the basic dimensions of the system, chemical and physical conditions, biological components, and human uses. (See Table 1).

“Biological components” indicators were divided into two major groups: *plants and animals* and *biological communities*¹. The former group focuses on species-level indicators, and includes at-risk native species, unusual mortality events, and non-native species. Seven indicators that address “non-native” or “invasive” species were included. These seven indicators are described briefly in Table 2, and more fully in the Appendix (please refer to the *State of the Nation's Ecosystems* for a complete treatment of each of these indicators).

A review of Table 2 shows that there are some similarities among the indicators, but their diversity—or lack of consistency—is obvious as well. These indicators were selected by work groups focused on specific ecosystems (e.g., forests) rather than by a group of experts on invasive species trying to develop a coherent suite of indicators. No attempt was made to force uniformity across systems, and the result is that—even if data were available—it would not be possible to describe broad trends in the non-native situation across the various ecosystem types.

From a reader's perspective, and to communicate broad trends clearly to policymakers and the public, it would be very beneficial to increase the consistency and coherence of this group of indicators. We recognize, however, that there may remain important reasons to measure and report different aspects of non-native species status and trends in different media (i.e., aquatic, terrestrial systems), different systems (farmlands, forests), or for different taxonomic groups (animals, plants).

¹ Note also that there were two indicators of “ecological productivity” in the 2002 *State of the Nation's Ecosystems* report: a terrestrial plant growth index and an indicator of chlorophyll concentrations in the coastal ocean.

Table 1: Ecosystem characteristics and indicator focus in *The State of the Nation's Ecosystems*

| Ecosystem Characteristic | What Do The Indicators Measure? |
|---|--|
| System Dimensions | |
| Extent | How much area does an ecosystem or land cover type occupy? |
| Fragmentation and Landscape Pattern | What are the shapes and sizes of patches of an ecosystem type, and how are they intermingled with one another? |
| Chemical and Physical Conditions | |
| Nutrients, Carbon, Oxygen | How much nitrogen, phosphorus, oxygen and carbon are found in different systems? |
| Chemical Contaminants | How many synthetic compounds and heavy metals are found in ecosystems, and how often do these compounds exceed regulatory or advisory thresholds? (For urban / suburban areas, we also include air pollution from ozone in this category.) |
| Physical Conditions | What is the condition of key aspects of the physical makeup of an ecosystem, such as the temperature of the water or the amount of salt in the soil? |
| Biological Components | |
| Plants and Animals | What is the status of native and non-native plant and animal species? |
| Biological Communities | What is the condition of the plant and animal communities that make up an ecosystem? |
| Ecological Productivity | What are the trends in plant growth on land and in the water? |
| Human Use | |
| Food, Fiber, and Water | How is the amount and quality of key ecosystem products changing over time? |
| Other Services, Including Recreation | How often do people take part in outdoor recreation activities, and what other services, such as soil building and flood protection, are provided by natural ecosystems? |

II. Creating a Non-Native “Task Group”

We plan to convene a “task group” of between 8 and 15 experts knowledgeable about issues related to the design of indicators for tracking the extent and spread of non-native species. The key objective of this task group will be to determine whether it is possible to identify a suite of indicators that is more consistent and uniform than the present suite, while still retaining important ecological distinctions. If such a suite is possible and desirable, the group will also to recommend the specific indicators that should be tracked in each ecosystem.

Beyond this main goal, the group will work to strengthen the conceptual basis of some of the indicators, improve the consistency of terminology, and provide a knowledge base to help identify emerging data sets applicable to these indicators.

Creating a coherent and easily accessible set of these indicators is a key objective of the Heinz Center’s *State of the Nation’s Ecosystems* project, and a key component of work underway to develop a second edition of the report, scheduled for completion in 2007.

However, the work of this task group will also further a key objective outlined in Executive Order (EO) 13112, signed February 3, 1999:

The Invasive Species Council ...shall facilitate development of a coordinated network among Federal agencies to document ... impacts from invasive species ... [and] facilitate establishment of a coordinated, up-to-date information system...

In addition, success in this work will also fulfill a key recommendation of a recent National Research Council committee (NRC, 2002), which recommended that:

A consensus on procedures to measure the impact of invasive species should be forged in the scientific and regulatory communities, and there should be more reporting of impacts of invasive species with standardized measures. (Recommendation 7)

In addition, and perhaps most importantly, creation of a coherent set of indicators that will enable tracking of the spread of non-native species will provide the nation with a tool to understand and evaluate the success of efforts undertaken by a variety of public and private entities to reduce the impacts these species have on ecological resources and economic systems.

| Table 2: Non-Native Species Indicators in <i>The State of the Nation's Ecosystems</i> | | |
|--|--|---|
| Indicator Title | Description | <i>Page in State of the Nation's Ecosystems</i> |
| Coasts and Oceans | | |
| Non-native Species | percentage of major estuaries with high, medium, or low influence by non-native species. "Influence" is defined by both percentage of species and degree to which they occupy available habitat | Indicator: 76 Tech. Note: 222 |
| Farmlands | | |
| Native Vegetation in Areas Dominated by Croplands | In areas with large amounts of croplands, proportion of remaining "natural" areas that are covered by native plants | Indicator: 104 Tech. Note: 237 |
| Forests | | |
| Area Covered by Non-native Plants | percentage of understory and overstory covered by non-native plants | Indicator: 125 Tech. Note: 242 |
| Fresh Waters | | |
| Non-native Species | percentage of watersheds having different numbers of non-native species with established breeding populations; the preferred indicator would distinguish invasive from non-invasive, and perhaps focus on a defined list of species of particular concern. | Indicator: 145 Tech. Note: 251 |
| Grasslands and Shrublands | | |
| Non-native Plant Cover | percentage of plant cover that is made up of non-native species. Will report on both invasive non-natives and all non-natives. | Indicator: 169 Tech. Note: 261 |
| Population Trends in Invasive and Non-invasive Grassland/ Shrubland Birds | comparison of population trends of native, non-invasive bird species to invasive birds species (can be both non-native and native) | Indicator: 170 Tech. Note: 262 |
| Urban and Suburban Areas | | |
| Disruptive Species | the number and type of disruptive species found in metropolitan areas. Disruptive species can be both non-native and native and are defined as those that have negative effects on natural areas and native species or cause damage to people or property. | Indicator: 192 No tech. note |

Task Group Outcomes and Timetable

The specific goals of this Task Group are:

1. Identify a suite of indicators of non-native species status, as a refinement of the suite included in the 2002 State of the Nation's Ecosystems report. This suite will be described in sufficient detail to allow a determination as to whether specific data sources are appropriate for reporting on the various indicators. (As noted above, this objective will not be one of achieving mindless consistency, but rather achieving as much consistency as makes sense.)

As part of this element, the Task Group should endeavor to address all relevant issues of definition, terminology, and indicator coverage in as consistent a fashion as possible. These issues are discussed in Section III, Terminology and Section IV, Major Challenges.

2. Identify and evaluate the appropriateness of available data sources for reporting on the new / revised suite of indicators. If, as is unfortunately likely to be the case, adequate data for national reporting are not available, the Task Group should provide sufficient guidance to the Heinz Center to enable assessments to be made concerning what monitoring / data collection activities would be required for adequate reporting.

We expect that the product of this Task Group will be a summary report or paper to be published by the Heinz Center or submitted to a journal or other outlet (or both).

We expect this Task Group to be in existence for approximately 18 months, and to have three two-day meetings over that period. This Task Group will probably have its first meeting in early February 2003. The Heinz Center and Task Group Chair will facilitate email dialogues between meetings, and some or all members will participate in drafting the Task Group's final report.

III. Terminology

The State of the Nation's Ecosystems generally uses the term "non-native," instead of "nonindigenous" or "alien," to refer to species that find themselves in new habitats. We have pointed out in the report that the terminology to describe such species is evolving. The task group will have to navigate within this changing, and at times highly charged, environment.

Executive Order 13112 defines as "alien" any species, including its seeds, eggs, spores, or other biological material capable of propagating that species, that is not native to a particular ecosystem. It also defines as "invasive" any alien species whose introduction does or is likely to cause economic or environmental harm or harm to human health.

Adopting the terminology of the EO 13112 is a non-trivial step because the definitions leave much room for interpretation. For example, defining alien relative to an "ecosystem" begs the question of what delineates an ecosystem, and clearly, such a definition is to some extent dependent on the scale at which an evaluation is made. In addition, such definitions pose

significant challenges to those who must operate monitoring programs. Further, defining invasive as a species whose introduction “does or is likely to cause...harm...” imposes a requirement of good predictive capability—which the scientific community does not presently have.

Note that, in some cases, what might have traditionally been thought of—and which large segments of our audience consider as— “native” species have been included in the bundle of “non-native” indicators. This includes species that may be native to North America, but which have shifted their range to included areas in which they have not previously been found. We have also included a category of *disruptive* species— those that have negative effects on natural areas and native species or cause damage to people or property, irrespective of whether they are “native” or “non-native” by other definitions. Whitetail deer on the east coast are a classic case; our Urban/Suburban Work Group felt that a definition that focused on outcomes and effects (i.e., whether the species causes problems or not) was more appropriate than one that focuses on the species origins.

In addition, “noxious weeds” are defined by federal and state agencies as nonindigenous invasive plants. The Animal and Plant Health Inspection Service (APHIS) federal noxious weed program is designed to prevent the introduction into the United States of nonindigenous invasive plants and to prevent the spread of newly introduced invasive plants within the United States. This terminology is acknowledged in the *State of the Nation’s Ecosystems*, but it was not incorporated it into any of the indicators.

There is a need for the new task group to articulate these terms and associated issues more clearly as we prepare to draft material for the 2007 volume of this report. Some background on the process of invasions is included in the Appendix to serve as a seed for future discussions.

IV. Major Challenges for the Task Group

The following issues all deal with the perceived need to have more commonality within the suite of non-native indicators, as well as the need to strengthen the conceptual basis of the indicators. These issues will have to be addressed, head on, by the new task group.

Defining the Universe

There are a variety of perspectives that one could take in defining what is non-native and what is not. Spatially, it could be logical to decide that only species originally from areas outside of North America are non-native to the nation’s ecosystems. However, it is clear that, in some cases, species whose range becomes broader, or otherwise shifted, should be considered non-native in their new habitat. For example, bull frogs are native to the eastern United States, but are believed to be causing significant ecological damage in western aquatic systems.

Clearly, Executive Order 13112 attempts to combine these aspects together by defining “alien” from the perspective of a given ecosystem, rather than some sort of geopolitical boundary—it does not, however, give explicit instructions for what should constitute an ecosystem beyond “the complex of a community of organisms and its environment.”

The Issue of Time

A complication is added when time is entered into the equation: How long—if ever—must a species be in a new habitat before it is considered “native”? That is, should a bird species, such as the starling, that was introduced over 100 years ago, still be considered non-native? Is the arrival of Europeans the appropriate dividing line? The retreat of the last ice sheet? This is certainly a difficult question, and the answer may differ by species or other dimension. Yet, it is just this type of unresolved issue that prevents us from communicating a clear message.

One approach—albeit probably quite difficult to implement in practice, and potentially controversial—might be to consider species “non-native” and to track them as such, until there is a determination that the species is not (or is no longer) significantly invasive; that is, that the species has become a more or less stable element of the North American landscape.

Non-native versus Invasive

Why do we care about non-native species? The primary reason appears to be that they have the potential to become invasive, and thereby displace native species, disrupt ecosystem function, and alter the benefits humans derive from the ecosystem². One could argue—and many do—that society should not be seriously concerned about introduced species that are present in a few small pockets of habitat, but that do not transition from “established” to “invasive.”

Thus, there is a powerful logic to the distinction between non-native and invasive species, and several of the indicators make this distinction. However, this distinction is problematic.

Clearly, in hindsight, it is possible to determine which species are invasive, but our ability to predict which species will be invasive, or perhaps to identify those that are invasive at a very early point on the continuum from *introduced* to *established* to *invasive* is quite limited. This seems to be a fundamental obstacle for indicators that are framed in terms of tracking invasive species only. Nonetheless the value to decision makers and opinion leaders of the suite of non-native indicators is reduced if increasing (or decreasing) trends have minimal correlation with the impact that these species have on our nation’s ecosystems.

There are practical challenges in designing monitoring systems that distinguish between “all non-natives” and “invasives”, and similar problems if one wishes to track species that may be native to North America, but have shifted range. Some species may be invasive in some habitats or ecoregions, and not in others. Some species may be considered native in one state and non-native in another. Implementing broad-scale monitoring programs that are able to maintain and apply these distinctions across many different ecosystem types and for many different species may be quite challenging.

Plants, Animals, or Both?

Some of the indicators in *The State of the Nation’s Ecosystems* focus on plants, some on animals, some on both. Clearly, the primary objective is to focus on those taxa posing the greatest threat

² In fact, we are similarly concerned about invasive species that happen to be native to an area, but have, for example, been released from predation pressures.

to native species and ecosystems. In some cases, Work Groups made a judgment that one (usually plants) should be the sole focus, but the task group should examine this judgment.

Perhaps it was convenient that none of the indicators that proposed to deal with both plants and animals had adequate data available. It is our belief that it will be a challenge to present data for both plants and animals in a single, easily understood indicator, particularly because of the different metrics proposed for the plant and animal components of the indicators.

Indicators that incorporate animals do so in a variety of manners. One of the factors to be included in the coasts and oceans indicator is the degree to which non-natives occupy available habitat. For animals, this might be measured as the percent of the biomass of all animals sharing the habitat that is attributable to non-native species. The freshwater indicator simply tallies the number of non-native fish in the nation's watersheds, and it is not clear how non-native plants would fit into this framework. The grassland and shrubland birds indicator deals with population trends of invasive species—regardless of whether or not they are technically “non-native.”

Serious consideration needs to be given to the structure of indicators that include both plants and animals. While it appears feasible to construct easily-understood indicators that include either plants or animals, it is less clear if it will be possible to do so for an indicator that combines plants and animals.

APPENDIX: DESCRIPTION OF THE INDICATORS

Coasts and Oceans: Non-native Species

Indicator: Page 76, Technical Note: Page 222

Percentage of major estuaries with high, medium, or low influence by non-native species; “influence” should incorporate both the number of species present, and the degree to which they occupy the available habitat. This indicator is limited in focus to estuarine areas.

The indicator does not attempt to evaluate the significance of non-native species to economic or ecological condition—it simply evaluates the amount of the system that is “occupied” by non-natives. Non-natives include at least: fishes, mollusks, crustaceans, higher aquatic plants, and macroalgae. The term “occupied” is meant to represent somewhat different things for motile versus non-motile organisms. For example, for higher aquatic plants, mollusks, and macroalgae, the actual percentage of the estuary that is covered by these should be reported. However, for motile species such as fish and crabs, it would be difficult to assess the proportion on any one area covered by these species. Instead, it is suggested that the percentage of all biomass (fish or crab, in these cases) be reported. The table below outlines a possible approach for structuring the indicator.

| % of Area Inhabited or % of Total Biomass | % of Non-native Species | | |
|--|-------------------------|------------|------------|
| | <25 | 25-75 | 75-100 |
| <25 | 1 (low) | 2 (low) | 3 (medium) |
| 25-75 | 2 (low) | 3 (medium) | 4 (high) |
| 75-100 | 3 (medium) | 4 (high) | 5 (high) |
| Possible ranking system: 1,2 = low; 3 = medium; 4,5 = high | | | |

Farmlands: Native Vegetation in Areas Dominated by Croplands

Indicator: Page 104, Technical Note: Page 237

This indicator would report, for areas where croplands account for a large percentage of the land cover, how much of the remaining vegetation (outside of croplands) is native to the area. Note: this is simply an inverse of several of the non-native indicators discussed here in that it reports the fraction that is native rather than the fraction that is non-native.

Clearly, several questions must be answered before this indicator can be implemented. These include the scale at which it should be reported (i.e., county, state, or region?); the threshold for including an area in the indicator (i.e., should the indicator include only areas with more than 50% croplands, or more than 75%?); and the proportion of non-native species that should be

used to categorize areas as “dominated” by non-native rather than native species. As noted above, a complete definition of this indicator would require a decision as to whether “non-native” means only species that are not native to North America, or whether species with expanded ranges would be included, and if so, for how long they would be considered “non-native” in their new range.

Forests: Area Covered by Non-native Plants

Indicator: Page 125, Technical Note; Page 251

Percentage of understory and overstory covered by non-native plants.

Data are not currently available for national reporting, but the USDA Forest Service is incorporating such measurements into their Forest Inventory and Analysis (FIA) program. We believe the Forest Service is including all non-native species; that is, we believe they are not making a distinction between non-native and invasive, but we are not certain whether their definition of non-native covers species native to North America that have shifted in range.

Fresh Waters: Non-native Species

Indicator: Page 145, Technical Note; Page 251

Percentage (and number) of watersheds having different numbers of non-native species with established breeding populations.

The Freshwater Work Group recommended that “[I]deally, this indicator would track only invasive species, perhaps by reporting on a selected group of problematic or potentially problematic species, as identified by recognized experts.” The Work Group further recognized, however, that “it is not now possible to identify potentially problematic species, and thus we have chosen to report on all non-native species.”

The indicator currently has data for fish only. For remaining animals and all plants, USGS’s Biological Resources Division’s (BRD) Nonindigenous Aquatic Species (NAS) program collects these data and, hopefully, it should just be a matter of time before the data are mature enough for national reporting.

Grasslands and Shrublands: Non-native Plant Cover

Indicator: Page 125, Technical Note; Page 261

Percentage of plant cover that is made up of non-native species.

Invasive non-natives will be reported separately from all non-natives, however, the report recognizes that work needs to be done on defining the difference between “invasives” and other non-native species.

Grasslands and Shrublands: Population Trends in Invasive and Non-invasive
Grassland/Shrubland Birds.

Indicator: Page 169, Technical Note; Page 262

Comparison of the percent of species with increasing population trends (in five-year intervals) for a group of native, non-invasive bird species and a group of invasive birds species (which includes both non-native and native species). Indicator focuses on Midwestern and Western grasslands and shrublands.

This indicator attempts to capture the degree to which invasive birds are spreading aggressively, by measuring whether they are expanding at a greater rate or in periods when non-invasive birds are declining. The invasive group includes both species that are “Old World natives” such as cattle egrets, gray partridge, European starling, and ring necked pheasant, as well as those that are native to North America but considered problematic, such as American robin, brown headed cowbird, and house finch.

Urban and Suburban Areas: Disruptive Species

The number and type of disruptive species found in metropolitan areas. Disruptive species are those that have negative effects on natural areas and native species or cause damage to people and property. The data would be reported in four categories: native plants, non-native plants, native animals, and non-native animals.

This indicator uses the term *disruptive species* to refer to species with deleterious effects, primarily related to rapid population increase, irrespective of whether they are native or not. The Urban/Suburban Work Group identified significant problems with a metric that focused simply on non-native species—however defined. These included the ubiquitous nature of intentionally introduced non-native plants in developed areas, many of which are both desired by residents and not invasive or otherwise problematic, and the fact that many of the most disruptive species, such as whitetail deer, are native to North America.

APPENDIX: *Background: Immigration, Establishment, and Invasion*

While not “on the radar” twenty years ago, there is heightened concern about non-natives, because people readily transfer them from one location to another by our global transportation network and by deliberate actions (e.g., the desire to incorporate exotics in our landscaping), and because a small percentage of those introduced have seriously altered the ecosystems in which they thrive—they are often, among other terms, called “invasive” species.

As described at length in a recent National Academy study (NRC, 2002), colonization by nonindigenous species can be categorized into three steps: immigration, establishment, and biotic invasion. Immigration does occur naturally for some species (e.g., windborne transport of fungal spores), however, it is thought to be minor compared to the transport that is facilitated by humans—either directly (e.g., introducing fish for sport fishing reasons, or plants for landscaping) or indirectly (the transport of larvae and other organisms in ship ballast water).

To become established, a species need not be abundant or growing rapidly, yet it (or its descendents) must be able to withstand challenges to their survival. That is, they must not succumb to the various causes of extinction at low numbers (e.g., stochastic events, including unfavorable genetic mutations) in their new environment.

To mount an effective biotic invasion, a species must increase in abundance and spread beyond the original point of introduction. As the species spreads, it must be able to successfully compete for resources so that new populations grow in abundance. Genetic diversity of the invading population may play an important role, although it is not entirely clear what is necessary from an evolutionary standpoint for a species to be a good invader. Soon after introduction, a species must overcome unfavorable mutations and other genetic events that can lead to stochastic extinction. Established species that jump to being invasive do not necessarily need high genetic diversity within the population. However, as multiple populations become established, new genotypes will emerge and some of these will have a better chance of being invaders due to their higher fitness for the new environment.

The dominance of various species that are native to an area tends naturally to vary over time—especially in situations where natural disturbances, such as forest fires, create major changes in habitat. In contrast, invasive species cause concern, because they capitalize on a favorable environment, in turn displacing native species, disrupting ecosystem function, and altering the benefits humans derive from the ecosystem. In general, the advance of an invasive species is not fleeting, but rather a long-term change.

As noted above, native species, in some cases, can also be “invasive” (in the sense of moving into new habitats) and “disruptive” (in the sense of increasing in population to the point of causing ecological and economic damage). If, for example, predatory pressures are relieved, populations of species such as whitetail deer tend to explode unchecked.

Reference:

National Research Council, Committee on the Scientific Basis for Predicting the Invasive Potential of Nonindigenous Plants and Plant Pests in the United States. 2002. Predicting Invasions of Nonindigenous Plants and Plant Pests. Washington, DC. National Academy Press.