The Entire Nation

Question	Indicator Name	Category	Section
What is the ecological condition of the entire nation?	Ecosystem extent	2	5.8
	At-risk native species	2	5.8
	Bird Community Index	2	5.8
	Terrestrial Plant Growth Index	1	5.8
	Movement of nitrogen	1	5.8
	Chemical contamination	2	5.8

Note: Italicized indicators are presented in other chapters.

5.1 Links Between Stressors and Ecological Outcome: A Framework for Measuring Ecological Condition

The primary reasons to monitor ecological condition are similar to those for monitoring air, water, and land;

- To establish baselines against which to assess the current and future condition.
- To provide a warning that action may be required.
- To track the outcomes of policies and programs, and adapt them as necessary.

Measuring ecological condition is not as straightforward as monitoring water or air to determine whether temperatures or concentrations of pollutants exceed a legal standard, however. Ecosystems are dynamic assemblages of organisms that have more or less continuously adapted to a variety of natural stresses over shorter (e.g., fire, windstorms) and longer (climate variations) periods of time, taking on new and different characteristics. This makes determination of the condition of a "natural" system difficult (Ehrenfeld, 1992). In addition, people have altered natural ecosystems to increase their productivity of food, timber, fish, and game, and to provide the infrastructure needed to support a modern society. How should the ecological condition of these altered ecosystems be measured, and against what reference points? Several recent reports by experts in the field have provided advice to guide current and future efforts.

The National Research Council (NRC) report, *Ecological Indicators for the Nation* (NRC, 2000), provides an introduction to recent national efforts to measure ecological condition and a thoughtful discussion of the rationale for choosing indicators. EPA's Science Advisory Board (SAB) also proposed a *Framework for Assessing and Reporting on Ecological Condition* (EPA, SAB, 2002). The framework identifies six "essential ecological attributes" (EEAs) of ecosystems:

- Landscape condition
- Biotic condition
- Chemical and physical characteristics
- Ecological processes
- Hydrology and geomorphology
- Natural disturbance regimes

The EEAs, along with reporting categories and examples of associated indicators, are displayed in Exhibit 5-3. Neither report identifies specific methodologies, network designs, or actual datasets corresponding to the examples.

The H. John Heinz III Center for Science, Economics, and the Environment (The Heinz Center) led a nationwide effort by government, academia, and the private sector to develop a report entitled T*he State of the Nation's Ecosystems: Measuring Lands, Waters, and Living Resources of the United States* (The Heinz Center, 2002). According to the introduction, the report "provides a prescription for 'taking the pulse' of the lands and waters. It identifies what should be measured, counted, and reported, so that decision-makers and the public can understand the changes that are occurring in the American landscape." The Heinz Center report identified 103 specific indicators, of which 33 were judged by the authors to have adequate data for national reporting.

The Heinz Center report provides an important core of indicators for this chapter. The Heinz Center report uses a somewhat different categorization of indicators than the Category 1 and 2 designations, and indicators identified by The Heinz Center that have inadequate data or need further development have not been included here. The Heinz Center indicators in this chapter are organized around the SAB framework, but given the similarities among the NRC, SAB, and Heinz Center approaches, this choice does not affect the final result. This chapter also includes, in addition to The Heinz Center national indicators, some Category 2 indicators from regional monitoring studies that

Exhibit 5-3: Essential ecological attributes and reporting categories

Landscape Condition	Chemical and Physical Characteristics (Water, Air, Soil, and Sediment)	Hydrology/Geomorphology
■ Extent of Ecological System/Habitat Types ■ Landscape Composition ■ Landscape Pattern and Structure **Biotic Condition** ■ Ecosystems and Communities - Community Extent - Community Composition - Trophic Structure - Community Dynamics - Physical Structure ■ Species and Populations - Population Size - Genetic Diversity - Population Structure - Population Dynamics - Habitat Suitability ■ Organism Condition - Physiological Status - Symptoms of Disease or Trauma	■ Nutrient Concentrations - Nitrogen - Phosphorous - Other Nutrients ■ Trace Inorganic and Organic Chemicals - Metals - Other Trace Elements - Organic Compounds ■ Other Chemical Parameters - pH - Dissolved Oxygen - Salinity - Organic Matter - Other ■ Physical Parameters **Ecological Processes** ■ Energy Flow - Primary Production - Net Ecosystem Production - Growth Efficiency ■ Material Flow - Organic Carbon Cycling - N and P Cycling - Other Nutrient Cycling	■ Surface and Ground Water Flows - Pattern of Source Flows - Hydrodynamics - Pattern of Ground Water Flows - Salinity Patterns - Water Storage ■ Dynamic Structural Characteristics - Channel/Shoreline Morphology, Complexity - Extent/Distribution of Connected Floodplain - Aquatic Physical Habitat Complexity ■ Sediment and Material Transport - Sediment Supply/Movement - Particle Size Distribution Patterns - Other Material Flux **Natural Disturbance Regimes** ■ Frequency ■ Intensity ■ Extent ■ Duration

Source: EPA, Science Advisory Board. *A Framework for Assessing and Reporting on Ecological Condition.* June 2002.

show promise for implementation on a national scale. Regardless of whether the indicators are Category 1 or 2, all indicators were drawn directly from scientifically defensible studies published in peer-reviewed reports and journals.

One of the most critical data quality objectives of monitoring for EPA is representativeness, the degree to which monitoring data accurately and precisely represent the variations of a characteristic over an entire population (e.g., all streams or forests)[3]. *Sampling design*[4] approaches the problem of representativeness and the effects of sampling and measurement error on environmental management policies and decisions. Sampling designs fall into two main categories, *probability designs and judgmental designs*. Probability designs apply sampling theory, so that any sampling unit (e.g., a stream of a stand of trees in a forest) has a known probability of selection. This important attribute allows the characteristics of the entire population of streams or forest stands to be estimated with known uncertainty, ensures that the results are reproducible within that uncertainty, and enables one to calculate the probability of decision-error based on the uncertainty in the data. Probability designs do not provide information on the precise conditions at any location where measurements are not made, or of the populations during times when measurements are not made,[5] or of populations not included in the sampling design.

Judgmental designs rely on expert knowledge or judgment to select sampling units. They can be easier and less expensive to implement than probability sampling. Monitoring sites selected at random can be difficult or even impossible to access, and some monitoring programs require sites that are easy to access repeatedly, or remote sites from which to search for faint signals such as climate change or long-range transport of pollutants. The accuracy of the results of judgment designs depends on the quality of the professional judgment, but in the best of cases quantitative estimates of uncertainty cannot be made. In this report, Category 1 indicators were required to be based on indicators collected using probability designs or "wall-to-wall" coverage by remote sensing, unless a strong case could be made that the data were representative of the population being sampled.

This chapter follows The Heinz Center (2002) in reporting on six major ecosystem types.[6] With a few exceptions, environmental and natural resource monitoring programs currently are structured to track the condition of individual natural resources (e.g., trees, crops, soil, water, or air) represented by the first six ecosystem types. Though some of this

[3]Like the U.S. Census, which strives to collect data on every person in the U.S., an ecological census could attempt to collect data on every plant, animal, stream, etc. This is generally impossible or cost-prohibitive, except for data collected on land cover or other features of the environment that can be measured by satellite.

[4]Olsen, et al., 1999, and Yoccoz, et al., 2001, provide useful discussions of sampling oriented toward ecological monitoring.

[5]For example, if estuaries are sampled only in the fall, the sample reveals nothing about estuaries in the spring or winter.

monitoring takes place on a national level, it still focuses on discrete resources or ecosystem types. For this reason, most available indicators can help answer questions about the condition of individual ecosystem types, but cannot track the overall ecological condition of an area comprising different interconnected and interacting ecosystem types. Therefore, this chapter includes a seventh category representing indicators potentially suitable for the entire nation.

A few indicators are available to help provide a more holistic assessment of ecological condition at the national level. For example, large or migratory organisms (e.g., bears or neotropical birds, respectively) depend on many ecosystem types over large areas for their continued survival. As another example, all of the terrestrial ecosystems types may contribute nitrogen, carbon, or sediment to streams and rivers in watersheds. Even the arrangement of ecosystems in the landscape and the composition of patterns of land cover and land use have been identified as critical components in the way ecosystems function (Forman and Godron, 1986; Naiman and Turner, 2000; Winter, 2001; EPA, SAB, 2002). Section 5.8 corresponds approximately to the core national indicators in The Heinz Center report.

Ideally, the indicators in this chapter would be presented in a way that spoke to the success of our efforts to protect and restore the ecological condition of the types of ecosystems considered in this chapter. Trends in biotic condition and ecological functions and in the physical, chemical, hydrological, landscape, and disturbance regimes of each ecosystem would provide keys to stories involving acid rain, or landscape fragmentation, or changing climate. The resulting "stories" would establish baselines, provide warnings, and track the effectiveness of management actions by EPA and its partners, as envisioned by the NRC (2000). Because so few reliable data exist on trends for any indicators at the national level, however, such a presentation is not yet possible. Instead, the chapter presents a disturbingly fragmentary picture of what little is known reliably and nationally based on Category 1 indicators. It also anticipates what could reasonably be known if monitoring of Category 2 indicators were to be expanded.

Sections 5.2 through 5.8 below describe the ecological condition of the seven ecosystem types. Each section begins with an introduction that summarizes data on the indicators that appear in the previous chapters of this report on air, water, and land. Indicators presented for the first time then are described in detail. Each section ends with a summary of what the available indicators, taken together, reveal about the ecological condition of that ecosystem type.

5.2 What is the Ecological Condition of Forests?

Forests, as defined by the U.S. Department of Agriculture (USDA) Forest Service (FS), are any lands that are at least 10 percent covered by trees of any size and at least 1 acre in extent (Smith, et al., 2001). Some forested ecosystems are rich sources of biodiversity and recreational opportunities, while others are managed intensively for timber production. All are important for carbon storage, hydrologic buffering, and fish and wildlife habitat. Forested ecosystems are under pressure in the U.S. from a number of non-native insects and pathogens and from deviations from natural fire regimes (The Heinz Center, 2002). They also are becoming increasingly fragmented by urbanization and other human activities (Noss and Cooperrider, 1994).

Under its statutory programs, EPA has particularly focused on the effects of air pollution on forest ecosystems, including the effects of acid rain on forests and forest streams. Such impacts might affect not only the health and productivity of trees, but also biodiversity in forest ecosystems (Barker and Tingey, 1992). Under the Clean Air Act, EPA must promulgate secondary standards for criteria air pollutants that present unreasonable risks to plants, animals, and visibility. EPA also has statutory authority to control the effects of forest management practices on aquatic communities; safe use of herbicides and pesticides in forest systems; and significant federal activities in forested ecosystems subject to EPA's review under NEPA.

Forests are possibly the best monitored of the six ecosystem types in this report. The Forest Service has long monitored standing timber volume and production, as well as damage from fire and pests, in its Forest Inventory and Analysis (FIA) program (Smith, et al., 2001). This program relies on probability sampling to ensure that the results are statistically representative, and there is complete long-term national coverage. This results in two Category 1 indicators relating to forest extent and one to biotic condition. In the early 1990s, the Forest Service in collaboration with EPA's Environmental Monitoring and Assessment Program (EMAP) developed the Forest Health Monitoring (FHM) program to monitor additional indicators of the ecological condition of forests (see Stolte, et al., 2002), also using a probability design. Over the course of the 1990s, forests in a growing number of states were sampled in the FHM program, and many of the FHM indicators were merged into the FIA program in 1999. Although data on these indicators are now being collected in 47 states, with all 50 expected to be covered by 2005, at the time this report was being prepared, coverage was not yet sufficiently complete for these to reach Category 1 status.

[6]The concept of an ecosystem, while extremely useful and relevant, is a somewhat vague classification for purposes of environmental monitoring. See O'Neill, et al. (1986); Turner (1989); Suter (1993), pp. 275-308; and Knight and Landres (1998) for highly relevant discussions.