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.

Exhibit 5-4: Forest Indicators

Essential Ecological Attribute	Indicators	Category 1	Category 2	Source
Landscape Condition		1	2	
Extent of Ecological System/ Habitat Types	Extent of forest area, ownership, and management	■		USDA
	Extent of area by forest type	■		USDA
Landscape Composition	Forest age class		■	USDA
Landscape Pattern/Structure	Forest pattern and fragmentation		■	USDA
Biotic Condition				
Ecosystems and Communities	At-risk native forest species		■	NatureServe
Species and Populations	Populations of representative forest species		■	NatureServe
Organism Condition	Forest disturbance: fire, insects, and disease	■		USDA
	Tree condition		■	USDA
	Ozone injury to trees		■	USDA
Ecological Processes				
Energy Flow				
Material Flow	Carbon storage		■	USDA
Chemical & Physical Characteristics				
Nutrient Concentrations	Nitrate in farmlands, forested, and urban streams and ground water		■	DOI
Other Chemical Parameters	Wet sulfate deposition		■	EPA
	Wet nitrogen deposition		■	EPA
Trace Organic and Inorganic Chemicals				
Physical Parameters	Soil compaction		■	USDA
Hydrology and Geomorphology				
Surface and Ground Water Flows	Changing streamflows	■		DOI
Dynamic Structural Conditions				
Sediment and Material Transport	Soil erosion		■	USDA
Natural Disturbance Regimes				
Frequency	Processes beyond the range of historic variation		■	USDA
Extent				
Duration				

Many of the indicators monitored by the FIA and FHM (Smith, et al., 2001) were included in the Heinz report (2002) and formed the original core of this chapter. As this chapter was being completed, however, the Forest Service published its *Final Draft National Report on Sustainable Forests–2003* (USDA, FS, 2002) under the Montreal Process. Several of the indicators contained in this 2002 report (all Category 2) were included in this chapter to demonstrate the kinds of data that will be available nationwide for a range of the forest EEAs as the FIA achieves data collection and analysis on a national basis. Data for several of these indicators (e.g., air quality, atmospheric deposition, and the chemistry and biology of forest streams) are contributed by national monitoring programs operated by other government and private sector organizations.

The forest indicators used in this report are displayed in Exhibit 5-4, grouped according to the EEAs. Some indicators relating to the EEAs of forest landscape condition, the chemical and physical attributes of forest streams, and the hydrology of forest watersheds are discussed in the chapters on Cleaner Air, Purer Water, and Better Protected Land, because they also relate to questions about those media. This section briefly summarizes the data for these indicators as they relate to the ecological condition of forests. This section then introduces additional indicators that relate to the EEAs of forest landscape condition, biotic condition, ecological processes, physical condition of forest soils, and natural disturbances in forests.

The following indicators presented in the previous chapters relate to the ecological condition of forests:

- The indicator *Extent of Forest Area, Ownership, and Management* (Chapter 3, Better Protected Land), is important for assessing trends in how forests are managed and protected. Forested ecosystems cover some 749 million acres in the U.S., or about one-third of the total land area. While approximately 25 percent lower than the pre-settlement acreage in the 1600s, the total acreage has held steady for the past century, although regional and local patterns have changed (USDA, FS, April 2001). Since the 1950s, forest land has increased by 10 million acres in the Northeast and North Central states, and decreased by 11 million acres in the Southeast (USDA, FS, April 2001).

  About 55 percent of all U.S. forests are in private ownership, with 83 percent of forests in the East being privately held (USDA, FS, 2002). About 9 percent of forest lands are managed by private industry to produce timber. Although 503 million acres of forests are classified as "timberland," the rest receive less intensive management. Harvest on public lands declined nearly 50 percent from 1986 to 2 billion cubic feet per year in 2001, but increased on private land by 1 billion cubic feet per year, to 14 billion cubic feet per year during the same period (USDA, FS, 2002). About 38 percent of harvesting is by clearcut, mostly in the South (USDA, FS, 2002). About 76 million acres of forests are "reserved" and managed as national parks or wilderness areas, an almost threefold increase since 1953 (USDA, FS, 2002). Much of the protected forest in the West is in stands more than 100 years old.

- The indicator *Nitrate in Farmland, Forested, and Urban Streams and Ground Water* (Chapter 2, Purer Water) is important for tracking the loss of nitrate from forested watersheds, which often indicates the effects of acid rain or insect infestation. In 36 forested streams monitored by the National Water Quality Assessment (NAWQA) program, almost 50 percent had concentrations of nitrate less than 0.1 parts per million; 75 percent had concentration of less than 0.5 ppm; and only one had a concentration of more than 1.0 ppm. By comparison, of 107 agricultural watersheds, almost half of the streams had nitrate concentrations greater than 2.0 ppm.

- According to the indicator *Deposition–Wet Sulfate and Wet Nitrogen* (Chapter 1, Cleaner Air), wet sulfate deposition decreased substantially throughout the Midwest and Northeast between 1989-1991 and 1999-2001 (Chapter 1, Cleaner Air). By 2001, wet sulfate deposition had decreased by more than 8 kilograms per hectare per year (kg/ha/yr) from 30-40 kg/ha/yr in 1990 in much of the Ohio River Valley and northeastern U.S. The greatest reductions occurred in the mid-Appalachian region. Wet nitrate deposition levels remained relatively unchanged in most areas during the same period and even increased up to 3 kg/ha in the Plains, eastern North Carolina, and southern California.

  Using National Atmospheric Deposition Program data, a USDA report on sustainable forests observed that annual wet sulfate deposition decreased significantly between 1994 and 2000, especially in the North and South Resource Planning Act (RPA) regions, where deposition was the highest. Nitrate deposition rates were lowest in the Pacific and Rocky Mountain RPAs, where approximately 84 percent of the regions experienced deposition rates of less than 4.7 kg/ha/yr (4.2 pounds per acre per year). Only 2 percent of the sites in the eastern U.S. received less than that amount (USDA, FS, 2002).

- The indicator *Changing Stream Flows* (Chapter 2, Purer Water) addresses altered stream flow and timing, which are critical aspects of hydrology in forest streams. Low flows define the smallest area available to stream biota during the year, and high flows shape the stream channel and clear silt and debris from the stream. Some fish depend on high flows for spawning, and the timing of the high and low flows also can influence many ecological processes. Changes in flow can be caused by dams, water withdrawal, and changes in land use and climate. This indicator reveals that 10 percent of predominantly forested watersheds showed decreased minimum flow rates during the period 1940 through 2000 compared to the period before 1940, while 25 percent had increased minimum flow rates (USDA, FS, 2002). Five percent of the watersheds had lower maximum flow rates, and 25 percent had higher maximum flow rates compared to the earlier period. There were no obvious trends in maximum flow rates in the decades since 1940, but minimum flow rates increased over the period. Increased flows were generally found in the East, but decreased flows were found in the West.

The other 12 forest indicators in Exhibit 5-4, described on the following pages, appear for the first time in this report in this chapter. Most of these indicators are from the *Final Draft National Report on Sustainable Forests-2003* (USDA, FS,2002) which became available after The Heinz Center report went to press. All are Category 2 indicators because the data are not yet available for the entire country.

Indicator

Extent of area by forest type - Category I

Trends in the distribution of forest types ultimately control the different types of communities that they support. The data for this indicator were collected by the FIA program, which currently updates the assessment data every 5 years. This indicator compares current conditions to those in 1977.

What the Data Show

Oak-hickory forest is the most common forest type in the U.S., covering 132 million acres—an increase of 18 percent since 1977 (Exhibit 5-5). Maple-beech-birch forest covers 55 million acres and has increased 42 percent since 1977. Pine forest of various types covers 115 million acres; spruce-birch forests cover 61 million acres (mostly in Alaska); and Douglas fir covers 40 million acres, mostly in the Pacific Northwest. Mixed forests (e.g., oak-pine and oak-gum-cypress) cover 64 million acres, mostly in the South (USDA, FS, 2002).

In the East, longleaf-slash pine and lowland hardwoods (elm-ash-cottonwood and oak-gum-cypress) had the largest decreases in acreage (12 million and 17 million acres, respectively). In the West, hemlock-sitka spruce, ponderosa pine, and lodgepole pine decreased the most (by 9 million, 8 million, and 6 million acres, respectively). In both regions, "non-stocked" land, on which trees have been cut but that has not yet regrown as forest, has declined steadily.

Indicator Gaps and Limitations

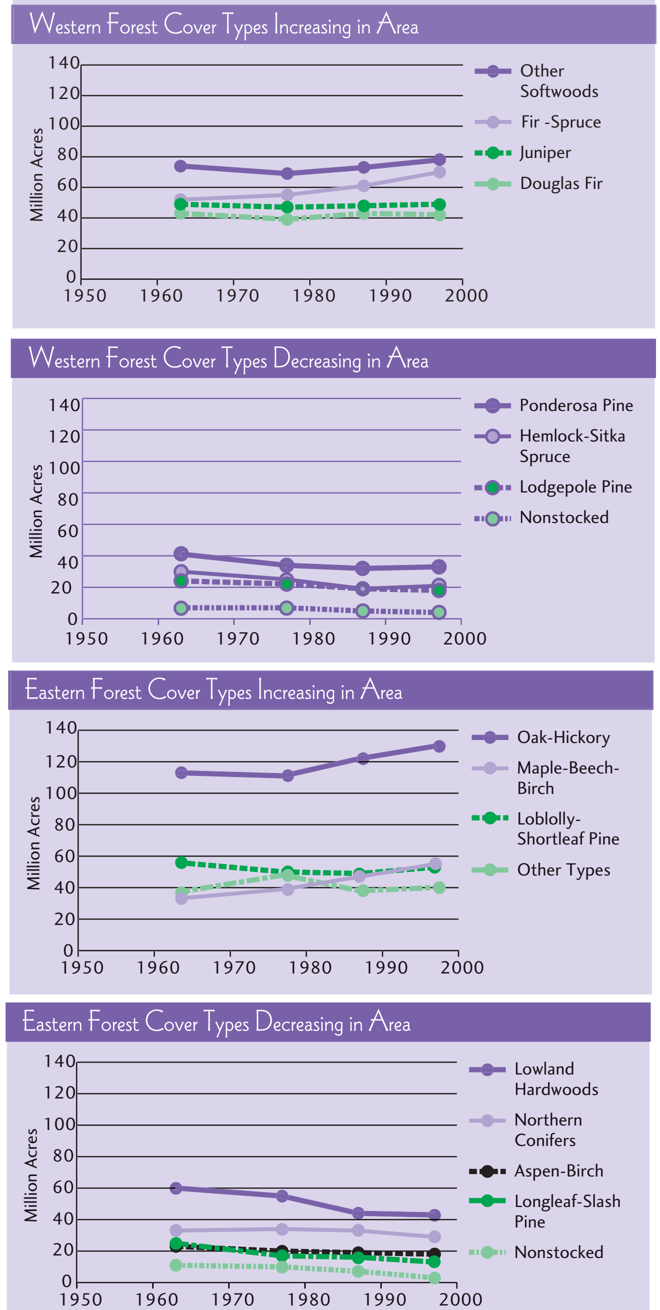
Limitations of this indicator include the following:

- Since the late 1940s, field data on species composition have been collected on a probability sample of 450,000 sites, nationwide (Smith, et al., 2001). The resulting estimates of area by forest type have an uncertainty of 3 to 10 percent per million acres of area sampled (The Heinz Center, 2002).
- The data do not include information on private lands that are legally reserved from harvest, such as lands held by private groups for conservation purposes. Other forest lands are at times reserved from harvest because of administrative or other restrictions. Data on these lands would provide a more complete picture of U.S. forest lands.

Data Source

The data source for this indicator was *Forest Resources of the United States*, 1997, Smith, et al., 2001. (See Appendix B, page B-36, for more information.)

Exhibit 5-5: Forest types in the United States, 1963-1997



Coverage: All 50 states.

Source: The Heinz Center. *The State of the Nations Ecosystems.* 2002. Data from the USDA, Forest Service.

Indicator | Forest age class - Category 2

Maintaining forest cover with a wide age range and a variety of successional stages sustains habitats for a variety of forest-dependent species and provides for the sustainable yield of a range of forest products. This indicator reports the percentage of forest area, with stands in each of several age classes.[7]

What the Data Show

In the eastern U.S., 35 percent of forests classified as "timberlands" are more than 60 years old, and 10 percent are more than 100 years old; in the West, the corresponding numbers are 70 percent and 35 percent, respectively (Exhibit 5-6). Softwood age distributions are skewed slightly toward younger age classes due to their management for timber. Hardwoods have a more normal distribution, with a peak in the 40 to 79 year age class, reflecting maturing second and third growth forests in the East. Stands averaging 0 to 5 inches and those over 11 inches are increasing, while intermediate stands in the 6 to 10 inch range are decreasing, indicating a rise in selective harvesting in the U.S. (USDA, FS, 2002).

Indicator Gaps and Limitations

Data for national parks and wilderness areas and other forested land are not available at this time, but will be in the future (The Heinz Center, 2002).

Data Source

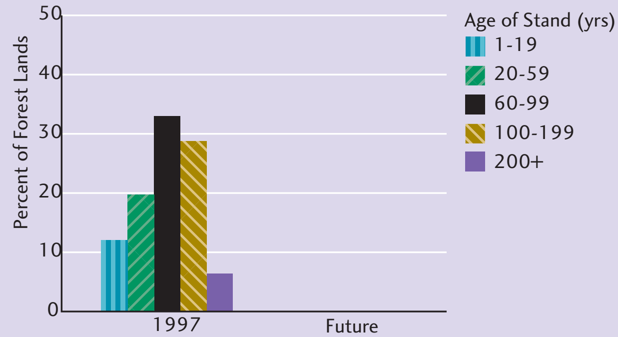
The data source for this indicator was *Forest Resources of the United States, 1997,* Smith, et al., 2001. (See Appendix B, page B-36, for more information.)

[7]Age class is defined by the mean age of the dominant or codominant crowns in the upper layer of the tree canopy.

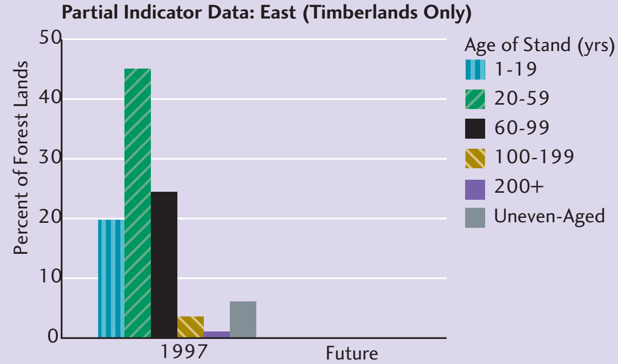
Exhibit 5-6: Forest age class, 1997

Data Not Adequate for Reporting on Forest Lands Other Than Those Classified as Timberlands

Partial Indicator Data: West (Timberlands Only)



Partial Indicator Data: East (Timberlands Only)



Coverage: all 50 states (timberlands only.)

Note: "Timberlands" is a USDA Forest Service designation for lands that grow at least 20 cubic feet of wood per acre per year, which is considered be sufficient to support commercial harvest under current economic conditions. Lands on which harvest is prohibited by statute are not included as "timberlands." Note also that the term "uneven-age" is being phased out; such stands are composed of intermingled trees that differ considerably in age.

Source: The Heinz Center. *The State of the Nation's Ecosystems.* 2002. Data from the USDA, Forest Service.

Indicator

Forest pattern and fragmentation - Category 2

Forest pattern and fragmentation affect the plant and animal species that live in forests. Large blocks of contiguous forest support interior forest species. Partial forest cover creates forest edge habitat, which supports birds and other animals that nest in forests but forage in nearby fields (Ritters, et al., 2002). Fragmentation also creates areas that concentrate airborne nutrients and pollutants by increasing the amount of unprotected forest edge (Weathers, et al., 2001). This indicator captures some of these features.

What the Data Show

Fragmentation in forests in the U.S. is significant. Based on 1992 data (The Heinz Center, 2002), two-thirds of all points within forests were surrounded by land that was at least 90 percent forest in their "immediate neighborhood" (i.e., a radius of 250 feet) (Exhibit 5-7). However, only one-fourth of the points within forests were surrounded by land that was at least 90 percent forest within their "larger neighborhood" (i.e., to a radius of 2.5 miles) (The Heinz Center, 2002). Approximately half of the fragmentation consists of "holes" in otherwise continuous forest cover. About three-quarters of all forest land is found in or near the boundaries of these large (greater than 5,000 hectares), but heavily fragmented, forest patches (Ritters, et al., 2002). In short, most forest is near other forest, and "holes" in forest cover caused by development, agriculture, harvesting, etc., tend to be isolated from each other.

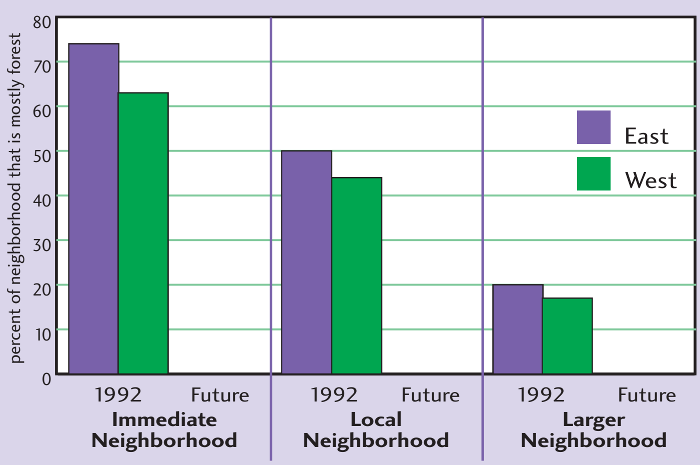
Indicator Gaps and Limitations

Although this indicator was calculated for the conterminous U.S., it has been categorized as a Category 2 indicator because it is only one of many potentially important fragmentation indicators. The exact impact of the amount and type of fragmentation on biotic structure and ecological processes is poorly known, and is likely to vary from one species and process to another (Ritters, et al., 2002). The FHM program is developing additional landscape fragmentation indicators, but the data have not been fully evaluated as this report was being finalized.

Data Sources

The data source for this indicator was *Forest Health Monitoring National Technical Report, 1991 to 1999*, U.S. Department of Agriculture, Forest Service, Southern Research Station, 2002; and *Fragmentation of Continental United States Forests*, Ritters, et al., 2002. (See Appendix B, page B-37, for more information.)

Exhibit 5-7: Forest cover and neighborhood size, 1992



Immediate neighborhood: land within a radius of about 250 ft from each forest point.
Local neighborhood: land within a radius of about 1/4 mile from each forest point.
Larger neighborhood: land within a radius of about 2 1/2 miles from each forest point
Mostly forest: land that is at least 90% forested (less than 10% nonforest)

Coverage: lower 48 states
Source: The Heinz Center. *The State of the Nation's Ecosystems.* 2002. Data from the Multi-Resolution Characterization Consortium and the USDA, Forest Service.

Indicator At-risk native forest species - Category 2

Species richness is considered to be an important indicator of ecological condition by both the National Research Council (2000) and the Science Advisory Board (2002). Although the role of species richness in maintaining a stable ecosystem is debated, greater species richness (i.e., greater number of species) is generally accepted as desirable. Species richness could be altered by air pollution, fragmentation, and forest disturbance by fire, insects, or disease.

What the Data Show

Based on an assessment of 12 factors, NatureServe and its member programs in the Natural Heritage program determined that 5 percent of forest animal species are imperiled, 3.5 percent are critically imperiled, and 1.5 percent are or might be extinct (The Heinz Center, 2002) (Exhibit 5-8). This indicator includes reports on mammals, amphibians, grasshoppers, and butterflies; too little is known about other groups, including plants, to assign risk categories. NatureServe data reveal that of the 1,642 species of terrestrial animals associated with forests, 88 percent still occupy their full historical geographic range on a state-by-state basis (USDA, FS, 2002).

The Natural Heritage Program uses standard ranking criteria and definitions, making the ranks comparable across groups. This means that "imperiled" has the same basic meaning whether applied to a salamander, a moss, or a forest community. Ranking is a qualitative process, however, taking into account several factors that function as guidelines rather than arithmetic rules. The ranker's overall knowledge of the element allows him or her to weigh each factor in relation to the others and to consider all pertinent information for a particular element. The factors considered in ranking species include population size, range extent and area of occupancy, short- and long-term trends in the foregoing factors, threats, and fragility (Stein, 2002).

The information gathered by Natural Heritage data centers also provides support for official designations of endangered or threatened species. However, because Natural Heritage lists of vulnerable species and official lists of endangered or threatened species have different criteria, evidence requirements, purposes, and taxonomic coverage, they normally do not coincide completely with the official designations of "rare and endangered" species.

Indicator Gaps and Limitations

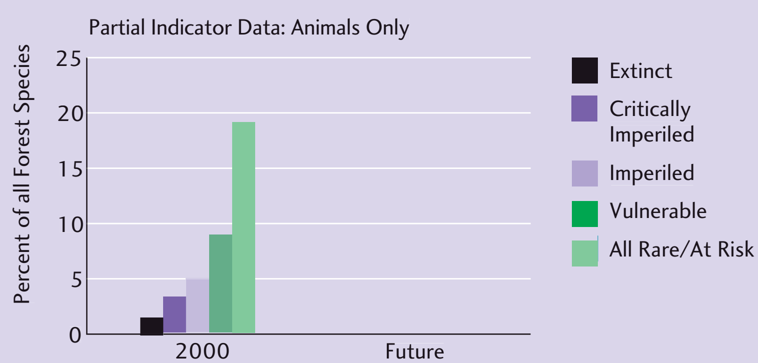
The data for this indicator are not from a site-based monitoring program, but rather from a census approach that focuses on the location and distribution of at-risk species. Determining whether species are naturally rare or have been depleted is currently not possible. It is not clear that trends can be quantified with any precision.

Data Source

The data source for this indicator was *The State of the Nation's Ecosystems,* The Heinz Center, 2002, using data from the NatureServe Explorer Database. (See Appendix B, page B-37, for more information.)

Exhibit 5-8: At-risk native forest species, by risk category, 2000

Data Not Adequate for National Reporting on Forest Plants



Coverage: all 50 states.

Source: The Heinz Center. *The State of the Nation's Ecosystems.* 2002. Data from NatureServe and its Natural Heritage member programs.

Indicator Populations of representative species - Category 2

The abundance of species representative of particular forest types is a more sensitive and less dramatic measure of ecological condition than species richness alone. Species richness reflects the net number of species invading an area and species going extinct, whereas species abundance also includes the numbers of individuals in each species (USDA, FS, 2002). The FHM program has collected abundance data on bird and tree species.

What the Data Show

Between 1966 and 1979, 21 percent of bird species associated with forests experienced population declines. This figure rose to 26 percent between 1980 and 2000 (USDA, FS, 2002). Areas with the greatest population declines were along the coasts and in the Appalachians. Between 1966 and 2000, 26 percent of bird species associated with forests showed population increases.

In the majority of tree species groups, the number of trees with trunk diameters greater than 1 foot increased by more than 50 percent between 1970 and 2002, indicating a more abundant community of older trees (USDA, FS, 2002) (Exhibit 5-9).

Indicator Gaps and Limitations

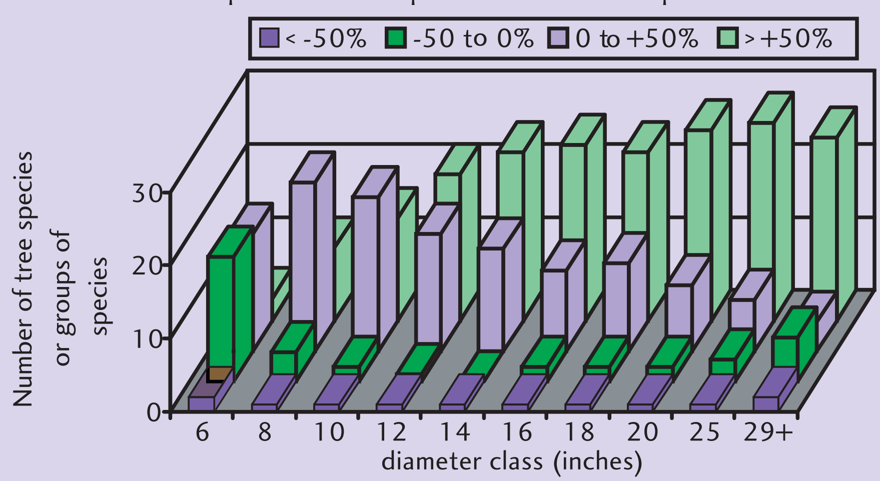
Several limitations are associated with this indicator:

- Population data are available only for birds and trees. Data for big game are reported by the states, but generally very few systematic measures of animal population density exist.
- The data from the Breeding Bird Survey (BBS) are based on a volunteer observer program and might not be statistically reliable.

Data Sources

The data sources for this indicator were the Breeding Bird Survey, U.S. Geologic Survey (1966-2000); and U.S. Department of Agriculture, Forest Service. *Draft Resource Planning and Assessment Tables*, 2002; and *National Report on Sustainable Forests-2003, Final Draft*, U.S. Department of Agriculture, Forest Service, 2002. (See Appendix B, page B-38, for more information.)

Exhibit 5-9: Populations of representative forest species, 1970-2002



Coverage: 37 states.

Source: USDA, Forest Service. Draft Resource Planning Act Assessment Tables. May 3, 2002 (updated August 12, 2002). (September 2002; *http://www.ncrs.fs.fed.us/4801/FIADB/rpa_tabler/Draft_RPA_2002_Forest_Resource_Tables.pdf.*)

Indicator Forest disturbance: fire, insects, and disease - Category 1

Fires, insects, and disease often occur naturally in forests. Their impact on forest ecosystems can be influenced by their interaction with other variables such as management decisions, air pollutants, and variations in climate. For example, trees weakened by pollutants might be more susceptible to attack by pathogens. When ecological processes are altered beyond a critical threshold, significant changes to forest conditions might result.

What the Data Show

Wildfire acreage has declined from a peak of more than 50 million acres per year in the 1930s to 2 to 7 million acres per year, largely due to fire suppression policies (The Heinz Center, 2002).[8] However, there has been a slight increase in fires in national forests in recent decades, with 8.4 million acres burned in 2000 (Exhibit 5-10).

Insect damage fluctuates from year to year, mostly as a result of population cycles of the gypsy moth and southern pine beetle, affecting between 8 and 46 million acres per year. Data for two major parasites, fusiform rust and mistletoe, are available only for the past several years, but the total acreage affected is 43 to 44 million acres (The Heinz Center, 2002).

Indicator Gaps and Limitations

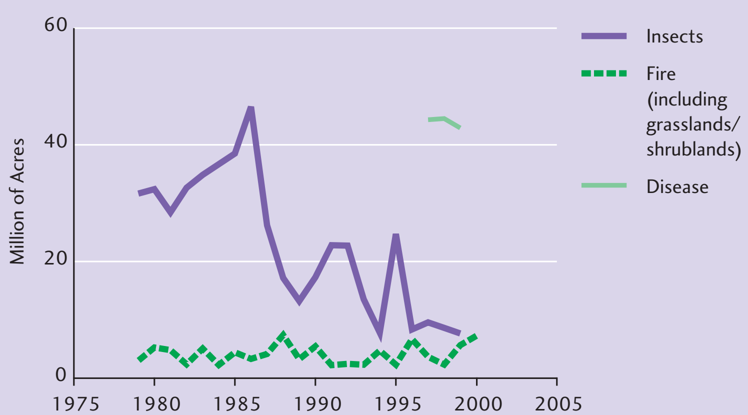
Limitations of this indicator include the following:

- This indicator does not distinguish between forest fires, other wildfires, and prescribed burns. It also does not track the intensity of the fires.
- Data are not available on forests affected by diseases other than those listed above.
- Some insects can cause widespread damage before it is apparent from aerial surveys.

Data Sources

The data sources for this indicator were *The State of the Nation's Ecosystems,* The Heinz Center, 2002, using data from *Western National Forests: Nearby communities are increasingly threatened by catastrophic wildfires,* U.S. General Accounting Office, 1999; *Forest Health Monitoring National Technical Report, 1991-1999,* U.S. Department of Agriculture, Forest Service, Southern Research Station, 2002; and National Fire Statistics, the National Interagency Fire Center, (See Appendix B, page B-38, for more information.)

Exhibit 5-10: Forest disturbance: fire, insects, and disease, 1979-2000



Insects: gypsy moth, spruce budworm, southern pine beetle, mountain pine beetle, western spruce budworm (all but the gypsy moth are native to the United States.)

Diseases: fusiform rust, dwarf mistletoe

Coverage: all 50 states

Note: Data are not limited to national forests.

Source: The Heinz Center. *The State of the Nation's Ecosystems.* 2002. Data from the USDA, Forest Service Health Protection/Forest Health Monitoring Program (insects, disease) and the National Forest System (fire).

[8]These data include wildfires in grasslands and shrublands.

Indicator Tree condition - Category 2

Changes in tree condition reflect the sum total of factors acting on the tree, including stress due to pollutants, climate, nutrient status, soil condition, and disease. This indicator (called "diminished biological components" in USDA, FS, 2002), reports on the percentage of trees in each region of the conterminous U.S. states that exhibit significant changes in three measures: mortality volume, crown condition, and the area in fire Current Condition Class 3. A Resource Planning Act region (shown in Exhibit 5-11) was considered to have poor tree condition (designated as diminished biological components in the exhibit) if (1) average annual mortality volume was more than 60 percent of gross annual growth volume, or (2) the ZB-index, an indicator of crown condition, was increasing at a rate of 0.015 or more per year, or (3) more than half of the forest area was in fire Current Condition Class 3. Fire condition Class 3 represents a major deviation from the ecological conditions compatible with historic fire regimes and might require management activities such as harvesting and replanting to restore the historic fire regime.

What the Data Show

According to the data for this indicator, 20 percent of forests in the U.S. were observed to exhibit poor tree condition, 40.9 percent were in fair or good condition, and 38.8 percent had no or insufficient data (USDA, FS, 2002) (Exhibit 5-11). Mortality was highest in the Pacific Northwest and northern Minnesota, and a large portion of these forests was in fire Current Condition Class 3, indicating that mortality might be producing a high fuel load. The South and Rocky Mountain regions had the smallest areas of poor tree condition, but more than half of those areas had insufficient data or no data at all.

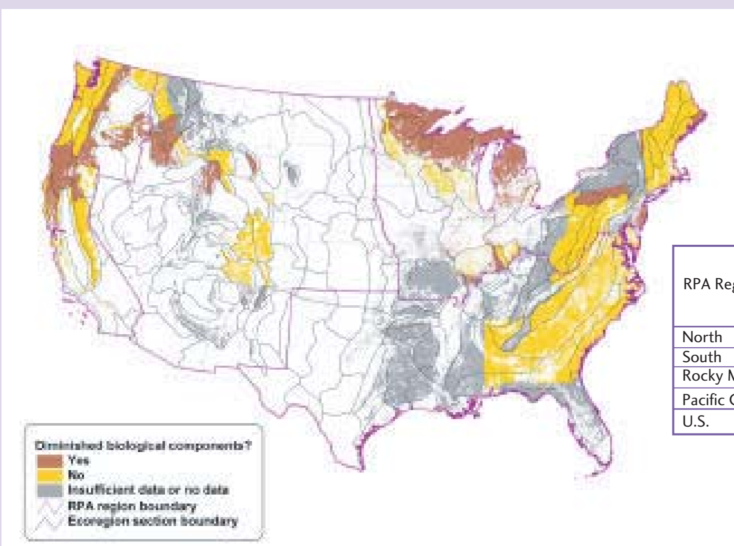
Indicator Gaps and Limitations

The data used to calculate this indicator were available at the time for only 32 states; more than half of the South and Rocky Mountain regions had insufficient or no data at all.

Data Sources

The data sources for this indicator were *Forest Health Monitoring National Technical Report,* 1991-1999, U.S. Department of Agriculture, Forest Service, Southern Research Station, 2002, and *National Report on Sustainable Forests-2003, Final Draft*, U.S. Department of Agriculture, Forest Service, 2002. (See Appendix B, page B-39, for more information.)

Exhibit 5-11: Tree condition, 1990-1999



RPA Region	Diminished Biological Components? Yes	No	No or Insufficient Data
	percent		
North	33.1	37.1	29.8
South	0.0	43.1	56.9
Rocky Mtn.	18.5	29.2	52.3
Pacific Coast	40.5	59.5	0.0
U.S.	20.3	40.9	38.8

Coverage: 32 states.

Forest area having diminished biological components that may indicate changes in fundamental ecological processes and/or ecological continuity. Percentages based on forest area in conterminus 48 States.

Source: Conkling, B., et al. *Forest Health Monitoring National Technical Report 1991-1999*. 2002.

Indicator

Ozone injury to trees - Category 2

Ozone injury to trees can be diagnosed by examination of plant leaves (Skelly, et al., 1987; Bennet, et al., 1994). Foliar injury is the first visible sign of injury of plants from ozone exposure and indicates impairment of physiological processes in the leaves.

What the Data Show

Little or no ozone injury was reported at 97 percent of Pacific Coast sites and 100 percent of Rocky Mountain sites (Exhibit 5-12). In the North and South regions, however, 23 percent of biomonitoring sites showed at least low levels of injury, with severe levels observed at about 5 percent of the plots (USDA, FS, 2002).

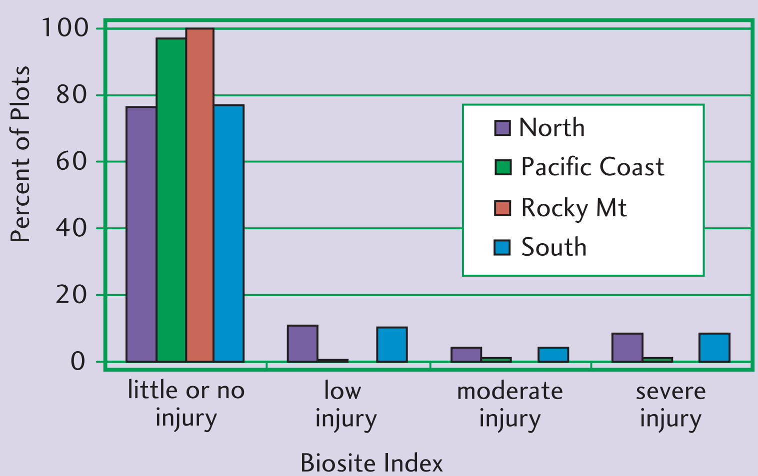
Indicator Gaps and Limitations

- Any further injury to the plant (beyond injury to the leaves) requires that ozone penetrate through the stomata into the leaf interior, which is regulated by a variety of environmental processes; some plants that show foliar damage show no further damage, and some plants show damage without concurrent signs of leaf damage (EPA, ORD, July 1996).
- Biomonitoring site data were available for only 32 states at the time the data for this indicator were analyzed.

Data Sources

The data sources for this indicator were the Forest Health Monitoring Program, U.S. Department of Agriculture (1991-2000) and *National Report on Sustainable Forests-2003, Final Draft*, U.S. Department of Agriculture, Forest Service, 2002. (See Appendix B, page B-39, for more information.)

Exhibit 5-12: Ozone injury to trees, 1994-2000



Coverage: 32 states.

Source: USDA, Forest Service. *National Report on Sustainable Forests - 2003. Final Draft.* 2002.

Indicator Carbon storage - Category 2

As a result of photosynthesis, carbon is stored in forests for a period of time in a variety of forms before it is ultimately returned to the atmosphere through the respiration and decomposition of plants and animals. A substantial pool of carbon is stored in woody biomass (roots, trunks, and branches). Another portion eventually ends up as dead organic matter in the upper soil horizons. Carbon storage in forest biomass and forest soils is essential for stable forest ecosystems, and it reduces atmospheric concentrations of a carbon dioxide, a greenhouse gas (see Chapter 1, Cleaner Air).

What the Data Show

For the period 1953 to 1996, the average annual net storage of non-soil forest carbon pools was 175 million tonnes of carbon per year (MtC/yr). The rate of storage for the last period of record (1987-1996) declined to 135 MtC/yr (Exhibit 5-13). The decrease in sequestration in the last period is thought to be due to more accurate data, increased harvests relative to growth, and better accounting of emissions from dead wood. The Northern region is sequestering the greatest amount of carbon, followed by the Rocky Mountain region. The trend of decreasing sequestration in the South is due to the increase in harvesting relative to growth. Some of the harvested carbon is sequestered in wood products (USDA, FS, 2002).

Indicator Gaps and Limitations

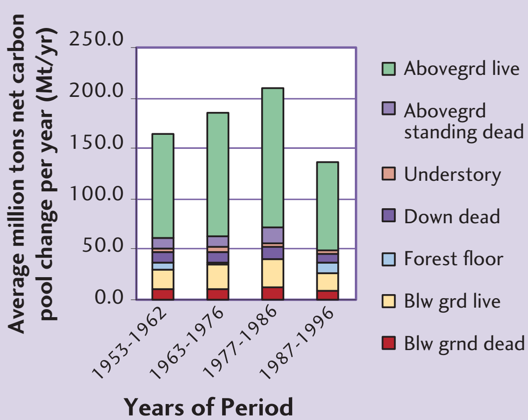
Limitations of this indicator include the following:

- The data only cover forest classified as "timberland," which excludes about one-third of U.S. forests.
- Carbon stored in soil is not included.
- Several of the carbon pools are not measured, but are estimated based on inventory-to-carbon relationships developed with information from ecological studies.

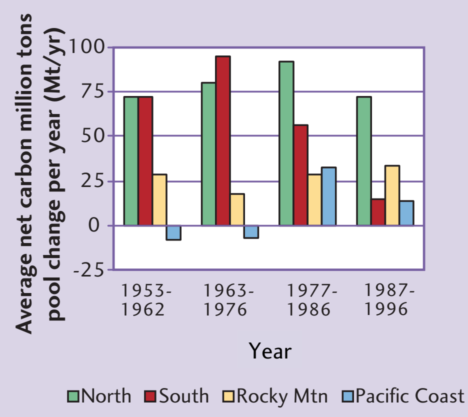
Data Sources

The data sources for this indicator were the Forest Inventory and Analysis, U.S. Department of Agriculture (1979-1995); and *National Report on Sustainable Forests, 2003, Final Draft*, U.S. Department of Agriculture, Forest Service, 2002.
(See Appendix B, page B-39, for more information.)

Exhibit 5-13: Contribution of forest ecosystems to the total global carbon budget, 1953-1996



Average annual net forest carbon change (Mt/yr), 1953-1996



Average annual net forest carbon change (Mt/yr) by region, 1953-1996

Coverage: lower 48 states.

Source: USDA, Forest Service. *National Report on Sustainable Forests - 2003. Final Draft.* 2002.

Indicator Soil compaction - Category 2

This indicator measures the extent of changes to the physical properties of forested soils resulting from forest harvesting, road construction, or other human impacts that are of sufficient magnitude to lower soil fertility or cause significant reductions in site productivity. Compaction can have a variety of negative effects on soil fertility by causing changes in both physical and chemical properties (Sutton, 1991; Fisher and Binkley, 2000). Reduction in pore space makes the soil more dense and difficult to penetrate and thus can constrain the size, reach, and extent of root systems. Reduction in soil aeration and water movement can reduce the ability of roots to absorb water, nutrients, and oxygen, resulting in shallow rooting and stunted trees. Destruction of soil structure can limit water infiltration and increase rates of runoff and soil loss from erosion.

What the Data Show

Soil compaction is primarily a local phenomenon. More than 86 percent of the plots measured showed less than 5 percent of the plot area exhibitng of soil compaction (Exhibit 5-14) (USDA, FS, 2003). Only a small fraction of plots (1.6 percent) showed compaction on more than 50 percent of the plot.

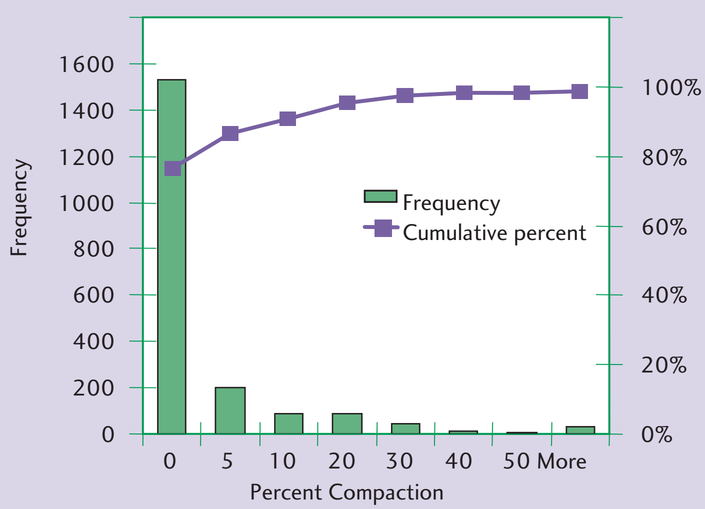
Indicator Gaps and Limitations

Soil physical properties (e.g., bulk density) are not conventionally monitored in a way that facilitates national reporting, and the current approach relies heavily on visual inspection and the State Soil Geographic Database (STATSGO) state soil maps (USDA, FS, 2003). No measurements were made of the degree or intensity of compaction. Physical disturbances that are not readily visible from the surface might be under-reported. Therefore the national maps thus far are only indicative of the *potential* for soil compaction on a regional basis. The FIA program has begun monitoring actual soil physical properties at the FIA sites, to be used in conjunction with the current method, but the data were not available nationally for development of the indicator in 2002 (USDA, FS, 2003).

Data Source

The data sources for this indicator were the Forest Health Monitoring Program, U.S. Department of Agriculture (1999-2000); and State Soil Geographic Database (STATSGO) state soil maps. (See Appendix B, page B-40, for more information.)

Exhibit 5-14: Frequency distribution of percent of plot area exhibiting evidence of surface compaction reported on Forest Health Monitoring (FHM) Program plots, 1999-2000



Coverage: 37 states.

Source: USDA, Forest Service. *National Report on Sustainable Forests-2003*. 2003.

Indicator Soil erosion - Category 2

Erosion is a term used to describe various mechanisms that wear away the land surface. Soil erosion is caused naturally by running water, wind, ice, and other geologic processes, but forest harvesting and road construction can increase erosion beyond natural levels. Erosion in excess of soil formation decreases the long-term productivity of forest systems and contributes to siltation of streams, lakes, and reservoirs. The Water Erosion Prediction Project (WEPP) model is commonly used in conjunction with the STATSGO state soil maps to estimate and predict the amount of soil loss based on several factors influencing erosion (Liu, et al., 1997).

What the Data Show

Modeled erosion rates on undisturbed forest lands were less than 0.05 ton per acre per year, on nearly 90 percent of the measured plots, compared to 3.1 tons per acre per year in agricultural ecosystems (USDA, FS, 2003) (Exhibit 5-15). Exposed mineral soil is a substantial contributor to erosion in the regions of the country sampled, and about 65 percent of the measured forest plots showed bare soil on less than five percent of the plot.

Indicator Gaps and Limitations

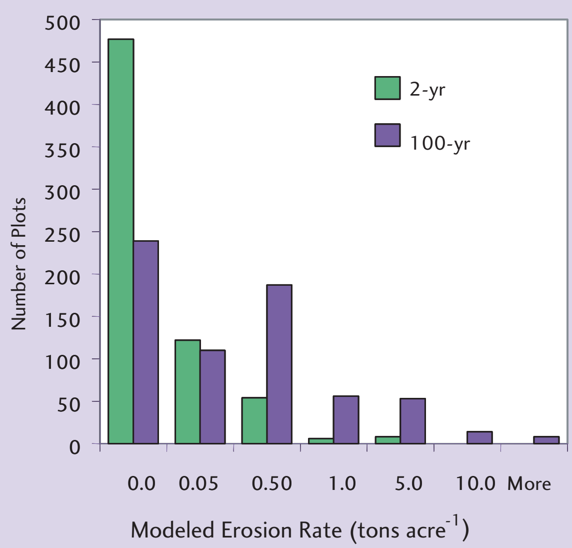
Limitations of this indicator include the following:

- The modeling approach (WEPP) was originally designed for agricultural systems. It might overestimate erosion from well-managed forest plots and underestimate erosion on plots that have been harvested and mechanically prepared (USDA, FS, 2003).
- The erosion indicator was calculated for only 37 states by 2002.

Data Sources

The data sources for this indicator were the Forest Health Monitoring Program, U.S. Department of Agriculture (1991-2000); and State Soil Geographic Database (STATSGO) state soil maps. (See Appendix B, page B-40, for more information.)

Exhibit 5-15: Frequency distribution for modeled erosion rates on Forest Health Monitoring (FHM) Program plots (1999-2000) following a 2-year (average) and 100-year storm event



Coverage: 23 states, excluding Alaska and Hawaii

Note: As an initial step in this analysis, model runs assume an undisturbed forest.

Source: USDA, Forest Service. *National Report on Sustainable Forests-2003*. 2003.

Indicator Processes beyond the range of historic variation - Category 2

The Forest Health Monitoring (FHM) program (USDA, FS, 2002) provided one of the few examples of an indicator that considers the essential ecological attribute of natural disturbance. The FHM program analyzed Forest Inventory and Analysis (FIA) data on climatic events, fire frequency, and insect and disease outbreaks between 1996 and 2000. These data were compared to anecdotal data from 1800 to 1850 to determine whether recent patterns in such incidents were beyond the range of historic variation. The FIA data were also compared to data from between 1978 and 1995 to determine if they were beyond the range of "recent" variation.

What the Data Show

A number of incidents were determined to be outside the range of recent variation in natural disturbance:

- El Niño during 1997 to 2000.
- A 1998 ice storm in the Northeast.
- Total area burned in the West during 1996, 1998, and 2000, and the total area burned nationwide in 2000.
- Outbreaks of spruce beetle in 1996, spruce budworm in 1997, and southern pine beetle in 2000.

Indicator Gaps and Limitations

Several limitations are associated with this indicator:

- This analysis was limited by the lack of metric data (actual measurements) available to describe conditions from 1800 to 1850.
- A relatively complete data set for major forest insects and diseases exists for the period 1979 to 2000, but these data are too recent for establishing a historical baseline.

Data Sources

The data sources for this indicator were the Forest Inventory and Analysis, U.S. Department of Agriculture (1979-1995); and *National Report on Sustainable Forests-2003-Final Draft,* U.S. Department of Agriculture, Forest Service, 2002. (See Appendix B, page B-41, for more information.)

Summary: The Ecological Condition of Forests

The available data are not, at this point, sufficient to track the progress of EPA's programs as they relate to the ecological condition of forest ecosystems. When the FHM/FIA program indicators are measured nationwide and repeatedly, they will form an important baseline against which to monitor the response of forests and their associated fauna to air pollutants, climate change, and management practices that impact forest ecosystems. At this point, the results of the leaf injury indicator suggest that research and assessment of the actual effects of ozone on forest ecosystems should be continued. The increasing acreage of older forests stands and changes in forest stream hydrology might bear watching inasmuch as these factors alter responses of forest systems to air and water pollutants.

Landscape condition

The total acreage of forests has remained steady over the past century and, although the acreage of some of the types of forests have changed, none are currently at risk of being lost. Over the past 50 years, the amount of non-stocked forest has decreased, while the amount of forest with older trees has increased. Forests are highly fragmented, but most forest land exists in or near the boundaries of large tracts of forest land.

Biotic condition

Most forest-related species continue to occupy a large portion of their original range. Eleven percent of species dependent on forest land are imperiled (5.7 percent are mammals, 2.3 percent are amphibians, and 1.4 percent are birds). Twenty-five percent of forest bird species have declined since 1975 (mostly in the Southeast), 25 percent have increased (mostly in the North), and 50 percent have stayed approximately the same. These results indicate that some forest habitats may not be supporting all the species they did historically. Currently no reliable data exist on the condition of biota in forest streams nationally or regionally. Our understanding of the relationship between indicators and biological conservation strategies remains weak (Lindenmeyer, et al., 2000).

According to available data, 20 percent of forests monitored in the U.S. were observed to exhibit poor tree condition, and 23 percent of biomonitoring plots in the eastern U.S. showed more than a small amount of ozone impact on plant leaves. Severe ozone damage to leaves was observed at 5 percent of the plots.

Ecological Processes

Annual rates of carbon storage in timberland increased over the three decades between 1953 and 1986 due to increasing age of timber stands and growth of woodlots on what was once farmland. However, annual storage declined in the decade 1987 to 1996, in part because of harvesting in Southeastern forests.

Chemical and physical characteristics

Nitrate loss from most forests does not appear to be resulting in high nitrate concentrations in forest streams, but few streams are monitored in areas where nitrate deposition is high (the East), and the baseline is too short to determine whether there are trends in the data.

Hydrology and geomorphology

With respect to forest streams, there has been a tendency toward decreased minimum flow rates in 10 percent of forest streams during the period 1940 through 2000 compared to pre-1940, while 25 percent of forest streams had increased minimum flow rates. Five percent of the watersheds had lower maximum flow rates and 25 percent had higher maximum flow rates. There were no obvious trends in maximum flow rates in the decades since 1940, but there was an increase in the minimum flow rates during that period. Increased flows were generally found in the East, and decreased flows were found in the West. Soil compaction is a problem on more than 10 percent of the plots in only 10 percent of monitored forest land.

Natural disturbance regimes

A number of events were determined to be outside the range of recent variation in natural disturbance, including two El Niño events, a severe ice storm in the Northeast, total area burned in the West during three years and the total area burned nationwide in 2000, and several tree pest outbreaks. The ecological consequences of these events are undoubtedly significant, but have not been systematically analyzed.

Many indicators currently being evaluated by the FIA and FHM programs are not included in this section because the results were not included in the Forest Service's most recent report on sustainable forests (USDA, FS, 2002). Because most of these measurements are made in a way that allows unbiased estimates and known uncertainty bounds, the ecological condition of forests will be even better known in the coming years.