National Reporting on Ecosystem Condition:

Priority Data Needs and Key Management Challenges

Volume II: Appendices

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The Heinz Center
State of the Nation's Ecosystems Project

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About The Heinz Center

Established in December 1995 in honor of Senator John Heinz, The H. John Heinz III Center for Science, Economics and the Environment is a nonprofit, nonpartisan institution dedicated to improving the scientific and economic foundation for environmental policy through multisectoral collaboration. Focusing on issues that are likely to confront policymakers within two to five years, the Center fosters collaboration among industry, environmental organizations, academia, and government in each of its program areas and projects. It uses the best scientific and economic analyses to develop viable options to solving problems, and its findings and recommendations are widely disseminated to public and private sector decision makers, the scientific community, and the public.

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Introduction to the Appendices

Details on Cost Estimation

To address concern over comparability of the cost estimates provided in this report, the table in **Appendix A** shows the elements of data reporting that were included by the agency or institution making the estimate as well as whether the estimate is for startup costs, ongoing monitoring or both.

Descriptions of Data Gaps

Appendixes B and C provide further information on all the data gaps identified in the 2002 *State of the Nation's Ecosystems* report. Appendix B focuses on the high-priority gaps that are the subject of this report, and Appendix C offers brief descriptions of the remaining gaps.

It should be kept in mind that all the indicators in the 2002 *State of the Nation's Ecosystems* report were identified as vital to a broad and comprehensive understanding of conditions and trends in the nation's ecosystems and thus worthy of future action. Clearly, it would be inappropriate to assume that gaps not included here in the *highest priority* category are irrelevant or unimportant.

Appendix B offers detail on the high-priority gaps identified in the body of this report—those that demand action in the near term. For each gap or cluster of gaps, a summary is followed by detailed descriptions of such individual elements as cost, feasibility rating, and options for filling the gap.

In Appendix C, the remaining data gaps are listed, by ecosystem, and the indicator and data gap briefly described. As the 2002 report makes clear, and as emphasized above, these gaps are not insignificant or trivial—to the contrary, all the gaps identified in the 2002 report represent important elements of the condition or use of U.S. ecosystems and thus should be filled as resources are available.

Appendix A
Elements included in Cost Estimates

Agencies and experts familiar with the requirements for filling the gaps described in this report provided estimates of the costs to completely report these data. The table below shows which elements of data reporting the agencies included in the estimate they provided to the Heinz Center. The ✓ or **X** mark in the first two columns indicates whether the estimate included start-up costs for a new data reporting effort and/or yearly estimates for ongoing reporting. The next four columns describe how the estimate incorporated costs for i) development and testing of methods, ii) data collection, iii) data archiving and distribution and iv) data processing and analyis. We describe each element of data reporting as either not applicable (NA), assumed (A) to be covered by established channels and not requiring additional funds, or explicitly (E) incorporated in the cost estimate.

Data Gap		Does estimate include both startup and ongoing (long term) costs?		Does estimate cover all major elements of monitoring / reporting?			
		Initial / Startup	Ongoing	Methods Development (If needed)	Data Collection	Archiving & Distribution	Processing & Analysis
Landscape Pattern (remote sensing analysis)							
Core National	Landscape pattern	✓	✓	NA	A	A	E
Farmland	Fragmentation by development	✓	✓	NA	A	A	E
Forests	Forest pattern & fragmentation	✓	✓	NA	A	A	E
Fresh Waters	Riparian vegetation	X	X	NA	A	A	E
Grass/shrublands	Area and size of patches	✓	✓	NA	A	A	E
Urban / Suburban	Suburban/rural land use change	✓	✓	NA	A	A	E
Urban / Suburban	Total impervious area	✓	✓	NA	A	A	E
Extent of Specific Habitat Elements							
Coasts & Oceans	Coastal wetlands (west coast)	✓	✓	E	E	A	E
Coasts & Oceans	Coral reef extent	X	✓	NA	E	A	E
Coasts & Oceans	Seagrass extent	✓	✓	E	E	E	E
Fresh Waters	Impounded stream area	✓	X	NA	NA	NA	E (partial)
Fresh Waters	Altered wetlands	X	X	NA	E	A	E
Fresh Waters	Channelized or leveed streams	X	X	—	—	—	—
Urban / Suburban & Fresh Waters	Riparian vegetation	X	X	NA	A	A	E
Urban / Suburban	Total impervious area	✓	✓	NA	A	A	E
Contaminants Related to Human Exposure							
Core National	Chemical contaminants (freshwater fish, edible)	X	✓	NA	E	A	E
Core National	Chemical contaminants (saltwater, edible)	X	✓		E	A	E
Coasts & Oceans	Selected contaminants in fish and shellfish (for human consumption)	X	✓	—	—	—	—
Urban / Suburban	Contaminated soils	X	X	—	—	—	—

		Does estimate include both startup and ongoing (long term) costs?		Does estimate cover all major elements of monitoring / reporting?			
Nitrogen Loading in Major Rivers, Nitrogen Yield		**X**	✓		**E**	**A**	**E**
Carbon Storage in Ecosystems (including soil organic matter)							
Farmlands	Soil organic matter	**X**	✓	**NA**	**E**	**A**	**E**
Forests	Forest carbon storage	**X**	✓		**E**	**A**	**E**
Grass/shrublands	Grass/shrub carbon storage	✓	✓		**E**	**A**	**E**
At Risk Species and Communities							
Core National	At risk species (overarching gaps)	✓	✓				
Forests	At risk forest plants	✓	✓				
Forests	Forest communities – significantly reduced area	✓	✓	**E**	**A**	**A**	**E**
Fresh Waters	At risk plants	✓	✓				
Fresh Waters	At risk riparian communities	✓	✓	**E**	**E**	**A**	**E**
Grass/Shrublands	At risk grass/shrub plants	✓	✓	**NA**	**A**	**A**	**E**
Coasts & Oceans	At risk plants and animals	✓	✓	**NA**	**A**	**A**	**E**
Non-native Species							
Forests	Non-native plant cover	**X**	**X**		**E**	**A**	**A**
Grass/shrublands	Non-native plant cover	**X**	✓	**E**	**E**	**A**	**E**
Farmland	Non-native vegetation	**X**	✓	**—**	**—**	**—**	**—**
Fresh Waters	Non-native freshwater species	✓	✓	**NA**	**E**	**A**	**E**
Coasts & Oceans	Non-native species	**X**	**X**	**—**	**—**	**—**	**—**
Biological Community Condition							
Core National	Condition of Plant and Animal Communities	**X**	**X**	**—**	**—**	**—**	**—**
Fresh Waters	Status of animal communities	**X**	✓		**E**	**A**	**E**
Stream Habitat and Riparian Condition							
Farmlands	Stream habitat quality	✓	✓	**E**	**E**	**A**	**E**
Fresh Waters	Stream habitat quality	✓	✓	**E**	**E**	**A**	**E**
Grass/shrublands	Riparian condition	✓	✓	**E**	**E**	**A**	**E**
Groundwater levels		✓	✓	**E**	**E**	**A**	**E**

Appendix B
Descriptions of Highest-Priority Gaps and Clusters

PAGE LISTING OF SPECIFIC DATA GAP DESCRIPTIONS

Gap or Cluster Definition

This cluster consists of seven gaps related to reporting on the extent and arrangement of land cover. Overall, the gap involves the processing of large amounts of remote sensing–based land cover data and/or the merging of these data with related data (stream locations).

- Five of these gaps relate to reporting on various aspects of landscape pattern: farmland fragmentation by development, forest pattern and fragmentation, area and size of grassland and shrubland patches, suburban and rural land use change, and a national-scale landscape pattern indicator. These gaps require processing of an existing land cover data set (National Land Cover Dataset, NLCD).
- One gap relates to reporting on natural vegetation along stream and riverbanks and naturally occurring ponds and lake shores. For coarse-scale, marginally acceptable national reporting, improvements are needed to the National Hydrography Dataset (NHD) to enable distinctions to be made between natural lands and ponds and those created by dams, plus the integration of lake/pond and stream/river data (NHD) and land cover data (NLCD). For urban and suburban reporting, finer-resolution land cover data are required.
- One gap relates to the extent of impervious cover, and would require detailed analyses of existing land cover data. (This gap is also included in "habitat elements"; see below, p. 35.)

A Heinz Center review of all landscape pattern indicators, now under way, will likely result in modifications to the 2007 indicator set, but the scale or nature of the work needed is not expected to change substantially.

Costs To Address This Gap

Estimates provided by USGS and a group of land cover data experts suggest that initial investments of as much as $1.5 million and ongoing annual costs of about $100,000 or less would be required to fill some portions of this gap. Including urban/suburban reporting would incur additional costs.

Gap Description	Initial Costs	Ongoing Costs
Landscape pattern (national, farmlands, forests, grass/shrub, urban / suburban land use)	~ $500,000	~$500,000 per reporting cycle
Riparian (stream and lakeside) vegetation • Coarse resolution (currently most cost-effective / practical) • Fine scale (needed for urban / suburban reporting)	$750,000 to $1.0 million Cost Not Available	$30,000 to $50,000 per reporting cycle Cost Not Available
Urban/suburban impervious area	Not Available	$0-$1.65 million per reporting cycle
Total	**$1.2-$1.5 million**	**~ $500,000 to $2.2 million** per reporting cycle
NOTE: Assumes a 10-year reporting cycle, based on historic land cover data acquisition schedules.		

However, these estimates presume continuing, basically cost-free availability of coarse-scale (30-meter) remote-sensing information that has been processed to appropriate land cover classes. The National Land Cover Dataset is one such dataset, and many of the analyses in the 2002 *State of the Nation's Ecosystems* report relied upon it. However, this dataset has been developed through a relatively *ad hoc* interagency collaboration, and funding and management are not assured. Thus, it is quite clear that the figures reported here do not represent the full cost of this type of reporting.

Feasibility Issues
All these gaps are rated as "highly and immediately feasible" because the required analyses are relatively straightforward.

ABOUT THE GAPS

Core National	**Landscape Pattern**
Farmland	**Farmland fragmentation by development**
Forest	**Forest pattern and fragmentation**
Grassland/Shrubland	**Area and size of grassland and shrubland patches**
Urban / Suburban	**Suburban/rural land use change**
Fresh Waters	**Riparian vegetation (Altered lake and pond shoreline)**
Urban/Suburban	**Riparian vegetation (Stream bank vegetation)**
Urban/Suburban	**Total impervious area (also included in the Habitat Extent cluster, p.** 35**)**

All the estimates below are based on the costs of processing available remote sensing imagery that has been classified to an appropriate land cover scheme. Thus, these costs do not represent the full cost of acquiring and processing the basic remote sensing data; they are thus marginal costs, dependent upon funding for the base land cover data.

These indicators are currently under review by a group of experts convened by The Heinz Center to improve the full suite of landscape pattern indicators presented in the 2002 *State of the Nation's Ecosystems* report. Early indications are that this Task Group will recommend significant changes to this suite. Such changes might require other or additional data.

System: Core National Indicators
Indicator: Landscape pattern
Data Gap: Analysis of existing data (indicator definition required)

Estimated Cost To Fill Data Gap

Initial costs:	Less than $100,000
Ongoing costs:	Less than $100,000 per reporting cycle

This indicator was undefined in the 2002 report, and work is under way to provide a definition and data source evaluation. It is likely that costs will be consistent with the above estimate, however.

Indicator
Undefined in 2002. Will be defined by ongoing effort.

The Data Gap
The satellite land cover data that will almost certainly form the basis for this indicator are available, but the data have not yet been analyzed.

Feasibility Rating
Filling this data gap is rated as "highly and immediately feasible" because the data for this indicator are likely to be available from a single, central location (i.e. the National Land Cover Dataset) and relatively small amounts of resources are required to undertake the require analyses. If additional data sources are needed (e.g., roads), they are available and there are staff in several agencies with the capability of working with both datasets.

Options for Filling This Data Gap
This indicator is currently under review by a group of experts convened by The Heinz Center to improve the full suite of landscape pattern indicators across all the ecosystems presented in the 2002 *State of the Nation's Ecosystems* report. Early indications are that this Task Group will recommend significant changes to this indicator. Such changes would produce a new set of data requirements for other or additional data.

That said, before convening the Task Group, The Heinz Center convened a small group of experts to discuss the possible costs of filling the data gap as it is described above. The group's opinion was that less than $100,000 would be required to do so, with ongoing costs of $100,000 per reporting cycle.

System: Farmlands
Indicator: Fragmentation of farmland landscapes by development

Data Gap: Analysis of existing data

Estimated Cost To Fill Data Gap

Initial costs:	Less than $100,000
Ongoing costs:	Less than $100,000 per reporting cycle

Note that that this indicator is expected to change substantially for the 2007 *State of the Nation's Ecosystems* report; any data gaps associated with this new indicator will have to be evaluated at a later date.

Indicator
This indicator would report the degree to which suburban development and other built-up areas break up (fragment) the farmland landscape (croplands plus intermingled "natural" areas such as forests, wetlands, and grasslands and shrublands). Areas with a mosaic of cropland and intermingled natural areas—but little or no development—would be rated as "low" on the "fragmentation index" used for this indicator, while those in which small patches of cropland are mixed into a backdrop of suburban development would be rated as "high." These data would be presented nationally, and by region for the most current year.

The Data Gap
The satellite land cover data necessary to report this index are available, but the data have not yet been analyzed. At the time of production of the 2002 report, the technical approaches for analyzing the available land cover data were not well developed. We believe that these obstacles are no longer relevant.

Calculating this index requires digital data and specialized software designed to analyze landscape spatial patterns. The most commonly used software for analyzing landscape spatial patterns (Fragstats) is not capable of processing the very large file sizes that would be required to calculate this index for the entire nation. It may be possible to carry out this analysis using a statistical sampling technique, analytical approaches relying on GIS software, or other analytical approaches; however, the details of this were not resolved in time for the 2002 *State of the Nation's Ecosystems* report.

Feasibility Rating
Filling this data gap is rated as "highly and immediately feasible" because the data for this indicator are likely to be available from a single, central location (i.e., the National Land Cover Dataset), and relatively small amounts of resources are required to undertake the require analyses.

Options for Filling This Data Gap
This indicator is currently under review by a group of experts convened by The Heinz Center to improve the full suite of landscape pattern indicators across all of the ecosystems presented in the 2002 *State of the Nation's Ecosystems* report. Early indications are that this Task Group will recommend significant changes to this indicator. Such changes would produce a new set of data requirements for other or additional data.

That said, before convening the Task Group, The Heinz Center convened a small group of experts to discuss the possible costs of filling the data gap as it is described above. The group's opinion was that less than $100,000 would be required to do so, with ongoing costs of $100,000 per reporting cycle.

System: Forests
Indicator: Forest pattern and fragmentation
Data Gap: Coverage for linear features (roads, railroads) and other small nonforest elements

Estimated Cost to Fill Data Gap

Initial costs:	Less than $100,000
Ongoing costs:	Less than $100,000 per reporting cycle

This indicator is expected to change substantially for the 2007 *State of the Nation's Ecosystems* report; any data gaps associated with this new indicator will have to be evaluated at a later date.

Indicator
This indicator describes a tree's local neighborhood according to the degree of forest cover within various distances. Thus, the "immediate neighborhood" of a particular tree is everything within about 250 feet in all directions. This immediate neighborhood is "mostly forest" if the land is at least 90% forested. A tree's "local neighborhood" extends about ¼ mile in all directions, and its "larger neighborhood" extends to about 2½ miles. This analysis relies upon computer analyses of satellite data on millions of individual pixels.

The Data Gap
The satellite data used for this indicator in the 2002 *State of the Nation's Ecosystems* report identifies features that are at least 100 feet on a side (10,000 square feet), but does not distinguish smaller or narrower features such as roads, power lines, and residential development in otherwise-wooded areas. Future analyses would include these smaller features by using satellite data that can discern smaller nonforest areas, or using ancillary information, such as mapped databases showing the location of these smaller features.

This analysis also treats all nonforest land uses similarly, whether they are clumped together, spread evenly across a landscape, or strung together in a line (e.g., a road or power line). Different types of breaks in forest cover may affect forests in different ways—concentrations of nonforest cover may have major impacts on local habitat suitability, while linear features such as roads can act as barriers to species movement. Future analyses might weigh some nonforest areas or patterns more than others, although the specific methods for doing this have not been developed.

Feasibility Rating

Filling this data gap is rated as "highly and immediately feasible." The primary data for this indicator are likely to be readily available (i.e., the National Land Cover Dataset), and ancillary information (such as roads data) is also reasonably available.

Options for Filling This Gap
This indicator is currently under review by a group of experts, with the goal of improving the full suite of landscape pattern indicators presented in the 2002 *The State of the Nation's Ecosystems* report. Early indications are that this Task Group will recommend significant changes to this indicator, probably changing the data requirements. However, before the Task Group was convened, several experts indicated that filling the data gap as it is described above would require less than $100,000, with ongoing costs of $100,000 per reporting cycle.

System: Grasslands and Shrublands
Indicator: Area and size of grassland and shrubland patches
Data Gap: Data processing

Estimated Cost To Fill Data Gap:

Initial costs:	Less than $100,000
Ongoing costs:	Less than $100,000 per reporting cycle

This indicator is expected to change substantially for the 2007 *State of the Nation's Ecosystems* report; any data gaps associated with this new indicator will have to be evaluated at a later date.

Indicator
This measure would report the percentage of grasslands and shrublands in patches of different sizes. Patch sizes and percentages would be reported separately for grasslands and shrublands. The total area occupied by patches of a certain size will be reported as a percentage of the total area of either grasslands or shrublands. The patch sizes for this indicator are as follows: less than 10 acres, 10–99 acres, 100–999 acres, 1000–9999 acres, and 10,000 acres or greater.

The Data Gap
Calculating this index requires digital data and specialized software designed to analyze landscape spatial patterns. The most commonly used software for analyzing landscape spatial patterns (Fragstats) is not capable of processing the very large file sizes that would be required to calculate this index for the entire nation. It may be possible to carry out this analysis using a statistical sampling technique, analytical approaches relying on GIS software, or other analytical approaches; however, the details of this were not resolved in time for the 2002 *State of the Nation's Ecosystems* report.

Feasibility Rating
Filling this data gap is rated as "highly and immediately feasible" because the data for this indicator are likely to be available from a single, central location (i.e. the National Land Cover Dataset) and relatively small amounts of resources are required to undertake the require analyses.

Options for Filling This Data Gap
That this indicator is currently under review by a group of experts convened by The Heinz Center to improve the full suite of landscape pattern indicators across all of the ecosystems presented in the 2002 *State of the Nation's Ecosystems* report. Early indications are that this Task Group will recommend significant changes to this indicator. Such a change would produce a new set of data requirements that might require other or additional data.

That said, before convening the Task Group, The Heinz Center convened a small group of experts to discuss the possible costs involved with filling the data gap as it is described above. The group's opinion was that less than $100,000 would be required to do so, with ongoing costs of $100,000 per reporting cycle.

System: Urban/Suburban
Indicator: Suburban/rural land use change
Data Gap: Analysis of existing data (indicator definition required)

Estimated Cost To Fill Data Gap:

Initial costs:	Less than $100,000
Ongoing costs:	Less than $100,000 per reporting cycle

This indicator was undefined in the 2002 report, and work is under way to provide a definition and data source evaluation. It is likely that costs will be consistent with the above estimate.

Indicator
Undefined in 2002. Will be defined by ongoing effort.

The Data Gap
The satellite land cover data that will almost certainly form the basis for this indicator are available, but they have not yet been analyzed.

Feasibility Rating
Filling this data gap is rated as "highly and immediately feasible" because the data for this indicator are likely to be available from a single, central location (i.e., the National Land Cover Dataset) and relatively small amounts of resources are required to undertake the require analyses.

Options for Filling This Data Gap
This indicator is currently under review by a group of experts convened by The Heinz Center to improve the full suite of landscape pattern indicators across all the ecosystems presented in the 2002 *State of the Nation's Ecosystems* report. Early indications are that this Task Group will

recommend significant changes to this indicator. Such a change would present a new set of data requirements that may require other or additional data.

That said, before convening the Task Group, the Heinz Center convened a small group of experts to discuss the possible costsof filling the data gap as it is described above. The group's opinion was that less than $100,000 would be required to do so, with ongoing costs of $100,000 per reporting cycle.

System: Fresh Waters, Urban/Suburban
Indicator: Riparian vegetation (streams/rivers and lakes)
Data Gap: Riparian vegetation (streams/rivers and lakes)

Estimated Cost To Fill Data Gap

Coarse resolution national reporting	
Improvements to National Hydrography Dataset	$0.75 to $1.0 million (one time)
Periodic comparison with land cover	$30,000 to $50,000
Urban / suburban reporting	Cost Estimates Not Available

Indicator
This gap is related to two indicators. One would describe the percentage of both stream/river miles and shoreline miles in naturally occurring lakes and ponds that are lined with trees, shrubs, and other plants. The other would report on stream/river miles in urban/suburban areas only.

Data Gap
There are two components to this data gap.

1. It is not currently possible to identify naturally occurring lake and pond shorelines. No national database distinguishes impounded water bodies from natural ones, or identifies which natural lakes are dammed at their outlets. Thus, while it is possible to identify which water bodies have significantly altered land cover along their shores, it is not possible to distinguish those where alteration would be an expected consequence of construction or management (e.g., reservoirs) and those where natural/semi-natural land cover would normally occur. Addressing this gap would require improvements to the linkage between the National Hydrography Dataset and the U.S. Army Corps of Engineers' dam dataset.

2. Coarse-resolution (30-meter pixel) land cover data are available and were reported in the 2002 *State of the Nation's Ecosystems* report. These are, however, only marginally satisfactory for this purpose on a nationwide scale and are not satisfactory at all for effective reporting at the scale of a few feet to tens of feet that is required for urban/suburban reporting. Locally generated data (e.g., municipal surveys) are not believed to be available over a sufficiently large area to support adequate reporting, would likely be inconsistent from

area to area, and are expensive to obtain. Higher resolution land cover data are available but are more costly than the 30-meter data in wide scale use.

Feasibility Rating

Providing coarse-resolution national-scale assessment of the extent of vegetated shorelines of streams/rivers and naturally occurring lakes is rated as "highly and immediately feasible" because the data for this indicator are likely to be available from a single, central location (e.g., the National Land Cover Dataset and the National Hydrography Dataset), the work required to enhance the NHD is relatively straightforward (and is, in fact, being undertaken by USGS, albeit without sufficient funding to complete the work in a timely fashion), and, once these enhancements are completed, relatively small amounts of resources would be required to undertake the required analyses.

Providing a finer-grained urban/suburban reporting capability is rated as "highly and immediately feasible" because the primary apparent obstacle is the cost of finer-resolution land cover data.

Options for Filling This Gap

1. *Identifying natural lakes and ponds.* This would require remedying limitations in the existing NHD to enable distinctions to be made between natural water bodies and those that are created or dammed.

Upgrading the National Hydrography Dataset would require cross-referencing the NHD, which identifies water bodies, with the U.S. Army Corps of Engineers' national database of dam locations. A simple, although less accurate approach would entail cross-referencing of the NHD with the Corps dataset; USGS estimates this one-time cost as between $200,000 and $1.0 million. However, the NHD contains errors of both commission and omission in the identification of water bodies (some NHD water bodies do not exist in nature, and some actual water bodies are not shown). EPA estimates that remedying these errors (through the use of archival imagery), cross-referencing the Corps dataset, and procuring limited amounts of new imagery or photographs to resolve any remaining areas of uncertainty would cost between $750,000 and $1.0 million.

Reconciliation of the NHD and dam datasets is also required to address the gap relating to reporting on the amount of stream/river miles impounded behind dams. See "Extent of Key Habitat Elements, page 35.

2. *Coarse-scale nationwide assessment.* This would require integration of the NHD with remote sensing imagery, such as the National Land Cover Dataset. Periodic comparisons of the NHD and land cover from remote sensing would be relatively inexpensive (perhaps $30,000–$50,000 per time). However, EPA has conducted similar analyses without charge for the State of the Nation's Ecosystems project.

This approach, used in the 2002 *State of the Nation's Ecosystems* report, would continue to provide marginally acceptable nationwide estimates, but these would not be useful for urban/suburban areas (see below).

3. Urban / Suburban Assessment. We were not able to obtain cost estimates for providing finer-resolution land cover data. (These data are available at resolutions down to 1 meter, and perhaps even finer.)

System: Urban and Suburban Areas
Indicator: Total impervious area
Data Gap: Geographic extent, data collection and integration

Estimated Cost To Fill Data Gap

To complete mapping for current period (2001 data):	$525,000 to $650,000
Future mapping costs:	$0 to $1.65 million per reporting cycle

The Indicator
The extent of impervious surface is a direct measure of the degree of urbanization, and it strongly affects both water quality in urban and suburban areas and replenishment of groundwater. This indicator classifies urban and suburban areas according to the percentage of impervious surface—roads, parking lots, driveways, sidewalks, rooftops, and the like—they contain. The indicator uses several thresholds: less than 10% impervious surface in the region, at least 10%, at least 20%, and at least 30%.

The Data Gap
At the time the 2002 *State of the Nation's Ecosystems* was being completed, geographic coverage was incomplete for data collected on total impervious area, and existing data had not been compiled regionally or nationally. Further, no standard methods for estimating the amount of impervious surface had been established, and the methods available were not adequate to distinguish small features such as driveways and sidewalks. (This is in large part because existing broadly available satellite data are too coarse to resolve these objects.)

Feasibility Rating
Filling this gap is rated as "highly and immediately feasible" because the technology for doing so has been developed and is being implemented (albeit not for the entire United States) by the U.S. Geological Survey. Funding is neither complete nor certain, however.

Options for Filling This Data Gap
The U.S. Geological Survey has provided an estimate of the cost of assessing impervious surface area, based on a relatively new data analysis protocol. Estimates of impervious surface will be based on a combination of existing 30-meter remote sensing land cover data and high-resolution

digital orthophotos and will cover all urban and suburban areas in the lower 48 states and Hawaii.

The Multi-Resolution Land Characteristics (MRLC) Consortium (of which USGS is a member) is developing the 2001 National Landcover Dataset (NLCD 2001). As a part of NLCD 2001, "imperviousness" is being determined for 66 mapping zones across the conterminous United States. For NLCD 2001, imperviousness was chosen in an effort to improve the precision of the urban intensity classification used in the original NLCD 1992. As of April 2004, 40–45 of the 66 zones in the conterminous U.S. plus Hawaii are either funded or pledged to be funded by USGS, USDA Forest Service, EPA, or NOAA.[1] The USGS estimates that it costs approximately $25,000 per mapping zone, suggesting that it will cost approximately $525,000 to $650,000 (21 to 26 mapping zones) to complete this project.

Development of both NLCD 1992 and NLCD 2001 and related products such as the impervious surface work described here can be characterized as *ad hoc* in terms of funding. Multiple agencies contribute funds, in a more or less "pass the hat" approach. This is illustrated by the status of the urban impervious area mapping—several agencies have funded work in portions of the country of specific interest to them, leaving a gap that precludes national characterization. Thus, the estimated unmet need for conducting this work in the future is between zero (all 66 analysis units are paid for by partner agencies) and $1.65 million (all 66 analysis units require funding). It is important to note that these estimates assume that the basic data layer for future NLCD efforts is funded as well.

[1] See http://www.mrlc.gov/mrlc2k_imperviousness_status.asp for a map of the mapping zones.

Gap or Cluster Definition

This gap consists of a number of individual gaps, each of which requires the extent or area of specific habitat elements. With one exception, all are aquatic habitat components (and the exception, total impervious area, is of concern largely because of its effect on aquatic systems). They include the following:

- Coastal wetlands (West Coast only)
- Coral reef extent
- Seagrass extent
- Impounded stream area
- Altered wetlands area
- Channelized or leveed streams (miles)
- Stream bank vegetation (width and length) (in both urban/suburban areas and nationwide)
- Total impervious area (in both urban/suburban areas and nationwide)

Costs to Fill This Gap

This cluster contains a number of disparate elements, cost estimates for many of which are not available. Individual costs range from nominal or zero to about $2 million per year. See table on following page.

Feasibility Rating

Most of these gaps are "highly and immediately feasible" or "moderately feasible." Only one, identification of the area of channelized or leveed streams, is considered "challenging."

Gap Description	Feasibility	Initial Cost	Annual Costs	Comments
Coastal elements				
Coastal wetlands (west coast only)	Highly and immediately		$0 (NOAA Coastal Change Analysis Program)	Data would be inconsistent with freshwater wetlands data and would not distinguish coastal from other wetlands
		$250,000 (FWS)	$10,000–100,000/year (USFWS National Wetlands Inventory)	Lower costs are for sampling; higher costs are for full mapping
Coral reef extent	Highly and immediately		$1.0 million per year	Currently funded until 2007
Seagrass extent	Moderately	Existing sources $250,000 (assessment of sources)	Costs not available until assessment complete	
		New federal program $3.0 million (pilot study)	$18 million per 10-year cycle, or $1.8 million per year	
Freshwater Elements				
Impounded stream area	Highly and immediately	$750,000 to $1 million minimum	Not available	
Altered wetlands area	Moderately	Not available	Not available	
Channelized or leveed streams (miles)	Challenging	Not available	Not available	
Stream bank vegetation (width and length) (in both urban/suburban areas and nationwide)	Moderately	Not available	Not available	
Other				
Total impervious area (in both urban/suburban areas and nationwide)	Highly and immediately	$525,000 to $650,000 (current cycle)	$0 to $1.65 million per reporting cycle (future cycles)	Uncertainties result from lack of ability to predict agency contributions to project.

Coasts and Oceans	**Coastal wetlands (West Coast)**
Coasts and Oceans	**Coral reef extent**
Coasts and Oceans	**Seagrass extent**
Fresh Waters	**Impounded stream area**
Fresh Waters	**Altered wetlands**
Fresh Waters	**Channelized or leveed streams**
Urban/Suburban	**Total impervious area (urban/suburban) (also included in Landscape Pattern cluster, p. 20)**
Urban/Suburban	**Riparian / stream bank vegetation**

System: Coasts and Oceans
Indicator: Coastal living habitats (coral reefs, wetlands, seagrasses, and shellfish beds)
Data Gap: Data for wetlands on the West Coast

Estimated Cost To Fill Data Gap – Options

National Wetlands Inventory: full mapping (West Coast)	$1.0 million every analysis period (e.g., 10 years)
National Wetlands Inventory: status and trends estimate	$250,000 to establish baseline $75,000 every analysis period (e.g., 10 years)
NOAA C-CAP	No additional cost

Indicator
The overall indicator reports the acreage over time of coastal habitats whose defining feature is that they are composed of living organisms (seagrasses, mangrove forests, and coastal wetlands) or are built by them (coral reefs, shellfish beds).

The Data Gap
Data for coastal wetlands from the U.S. Fish and Wildlife Service's National Wetlands Inventory (FWS, NWI) excluded the Pacific coast, where coastal wetlands are "patchily distributed." The NWI methodology (see below) could not capture statistically valid information on this wetland type in areas with such patchy distribution.

Feasibility Rating
Filling this gap is rated as "highly and immediately feasible" because there are two existing programs with the capability of providing large-scale (i.e., regional, national) data on wetlands extent. These are the NOAA Coastal Change Analysis Program (C-CAP) and the U.S. Fish and Wildlife Service's National Wetlands Inventory. There would be developmental issues in designing a program to report on this gap, but these are judged to be well within the capabilities of these agencies.

Options for Filling This Data Gap

There are four potential methods for filling this data gap. The first involves a NOAA program (Coastal Change Analysis Program) that identifies land cover (including wetlands) in the coastal zone. The second and third are based on existing or improved methods used by the U.S. Fish and Wildlife Service's National Wetlands Inventory. The fourth involves amalgamation and perhaps enhancement of available state data on coastal wetlands.

Coastal Change Analysis Program

NOAA is conducting a land cover and land cover change inventory of the whole U.S. coastal zone through the Coastal Change Analysis Program. The inventory is based on analysis of remotely sensed data in conjunction with other spatial data such as elevation, hydrology, infrastructure, and National Wetland Inventory (where available). C-CAP products report the presence, location, and acreage of land cover categories, including freshwater and estuarine wetlands. The relative scale of C-CAP data makes it most suitable to broad-area or regional analyses.

The NOAA Coastal Change Analysis Program can provide data on wetland occurrence within certain distances of the coast (these data do not distinguish between coastal and other wetland types, although these distinctions can sometimes be inferred from location). The inland extent of C-CAP coverage includes the U.S. coastal zone, as well as significant estuarine drainage areas. Acreage calculations can be made from various distances away from the shoreline, but any such limitation is arbitrary, and will likely include some freshwater wetlands in some areas and miss some coastal wetlands in others. The U.S. Fish and Wildlife Service's National Wetlands Inventory is charged with providing comprehensive data on national status and trends, including coastal wetlands, on a 10-year cycle. At present, combining FWS-NWI and C-CAP data is challenging, because of significant differences in methodologies, and there have been few comparisons of the results of the two methods (or those used by state or federal regulatory agencies).

Wetlands estimates for the U.S. coastal zone could be provided by C-CAP with no additional funding.

U.S. Fish and Wildlife Service National Wetlands Inventory

The National Wetlands Inventory has two primary products—maps identifying the location and type of wetlands in the United States and "status and trend" reports prepared every 10 years in response to congressional mandate. So far, NWI has mapped 90% of the lower 48 states, and 34% of Alaska. About 44% of the lower 48 states and 13% of Alaska is digitized.

NWI is currently bringing together all digitally mapped wetlands data for the United States and would be able to produce reports summarizing the type and extent of wetlands based on existing map data.[2] However, the information in the digital maps is dated—much of it was created with aerial photography from the 1980s. Thus, this approach would be useful only if resources were available to update the maps.

[2] This may require digitizing some additional maps, but this is believed to be minimal.

NWI estimates that periodic updates of the wetlands maps for the West Coast would cost approximately $1 million per update (these would be undertaken perhaps once a decade). It is important to note that this approach would produce very high-quality results—since they are based on a census, not statistical sampling. However, since the estimates of wetlands trends for the East and Gulf coasts are from statistical sampling programs (see below), the results would not be strictly comparable.

NWI "status and trends" methodology relies on permanent, randomly selected 4-square-mile plots that serve as the basis for periodic estimates of wetland area and change.[3] This methodology is not sufficient to derive statistically sound estimates for certain wetlands types in certain ecological settings, including coastal wetlands on the West Coast.

NWI estimates that a new and independent sampling design could be implemented, at a cost of approximately $250,000 for an initial baseline survey and an additional $75,000 per assessment cycle (currently every ten years) in order to determine trends. These data would be directly comparable with the data for the Atlantic and Gulf Coasts, as reported in the 2002 *State of the Nation's Ecosystems* report.

State Wetland Data

States have active wetland conservation, management, and regulatory programs, and many states have gathered data on wetlands extent and change. We contacted the four West Coast states (California, Washington, Oregon, and Alaska) and received a response from Oregon, indicating that the state has conducted a statewide coastal wetlands survey, including change estimates. However, this survey used the "full census" approach noted in the NWI discussion above and was in fact conducted by NWI staff. In addition, the study (using 2002 data and comparing to mid-1980s reference photos) is a one-time-only study; costs for updating are not currently programmed by the state. Thus, this method does not appear to provide an alternative approach for filling this gap.

[3] The NWI methodology uses a permanent study design, based initially on stratification of the 48 conterminous states by state boundaries and 35 physiographic subdivisions. Within these subdivisions are 4375 randomly selected, 4-square-mile (2560 acres) sample plots. These plots were examined with the use of aerial imagery, ranging in scale and type; most were 1:40,000 scale, color infrared, from the National Aerial Photography Program.

System: Coasts and Oceans
Indicator: Coastal living habitats (coral reefs, wetlands, seagrasses, and shellfish beds)
Data Gap: Lack of data on the extent of coral reefs

Estimated Cost To Fill Data Gap

Baseline mapping:	Funded if current allocations continue to 2007
Updates:	Up to $1.0 million per year

Indicator
The overall indicator reports the acreage over time of coastal habitats whose defining feature is that they are composed of living organisms (such as seagrasses, mangrove forests, and coastal wetlands) or are built by them (such as coral reefs or shellfish beds).

The Data Gap
Most coral reefs in U.S. waters, especially those in the Pacific Ocean, have not been accurately mapped with modern techniques and at a scale relevant to emerging conservation issues. However, in March 2000 the federal interagency Coral Reef Task Force (CRTF) released a plan of action (http://coralreef.gov/CRTFAxnPlan9.PDF) committing the agencies to produce comprehensive digital maps of all coral reefs in the United States and trust territories. This interagency effort will produce maps at both low and high resolutions that address locally identified conservation and management needs. NOAA estimates that, with continuation of existing funding (approximately $1.5 million per year), all shallow coral reefs (those in water less than about 100 feet, or 30 meters, deep) will be mapped by 2007. However, there are no funds currently programmed for updates of this mapping.

Feasibility Rating
Filling this gap is rated as "highly and immediately feasible" because a program has been put in place to accomplish the baseline mapping for this task, and a formal structure created for continuing coordination of monitoring activities. The CRTF is conducting baseline mapping, and Executive Order 13089 provides for interagency and intergovernmental coordination of monitoring. The methods for collecting these data are reasonably well developed, with the exception of deep-water reefs.

Options for Filling This Data Gap
NOAA estimates that approximately $1 million annually would be required to fund satellite-based monitoring to detect changes in the extent of coral reefs on a semi-annual basis with a 4-m resolution. Costs would presumably be lower if data were collected less frequently.

Indicator: Coastal living habitats (coral reefs, wetlands, seagrasses, and shellfish beds)
Data Gap: Seagrasses: adequate geographic coverage and aggregation of existing data
Estimated Cost To Fill Data Gap

Assessment of potential of existing data sources	$250,000
Pilot study for new program	$3.0 million
New inventory program	$18 million/10 years, or $1.8 M/ yr
Filling gaps in existing sources	Estimate requires assessment of existing sources

Indicator
The overall indicator reports the acreage over time of coastal habitats whose defining feature is that they are composed of living organisms (seagrasses, mangrove forests, and coastal wetlands) or are built by them (coral reefs, shellfish beds).

The Data Gap
Data for seagrasses and other submerged aquatic vegetation are available for many, but not all, areas. Available data have not been aggregated to determine their feasibility for synthesis to produce national estimates.

Feasibility Rating
Filling this gap is rated as "moderately feasible." There are some uncertainties about the extent, quality, and timeliness of existing data, and there is no well-developed mechanism for assessing these data and institutional linkages for obtaining these data on a consistent basis. In addition, the methods for assessing seagrass extent are not well established, and a moderately scaled pilot study would be required to address technology, basic survey design, and other issues. However, these factors were judged to be manageable, with adequate funding.

Options for Filling This Data Gap
There are two basic approaches to filling this data gap. The first is to develop a new inventory program focused on statistically valid estimates of seagrass and other submerged aquatic vegetation. The second is to utilize existing data collection efforts undertaken by federal agencies, states, local governments, academic institutions, and the like to develop such estimates. If the second option is chosen, it may be necessary to augment existing efforts, resulting in a hybrid of existing and new efforts.

New Inventory Program
It would be possible to develop a periodic national survey of seagrasses and submerged aquatic vegetation. Such a program might rely on aerial photogrammetry and acoustic surveys and could have a minimum mapping unit of roughly 0.25 acres. Each iteration of such a survey would require several years to complete, so it might be appropriate to report every five or ten years.[4]

[4] However, many large-scale surveys are moving to a continuous inventory approach, where sampling is conducted at a lower level of effort continuously, rather than during a concentrated inventory period. The USDA Forest

An initial estimate is that such a program would cost about $18 million per 10-year inventory cycle, or about $1.8 million per year.

There are a host of design considerations, and NOAA recommends that a pilot study, costing approximately $3 million, be undertaken to enable more informed decision making.

Issues to be addressed in such a pilot study include

- The definition of vegetation to be covered. Submerged aquatic vegetation includes some species of seagrasses and kelp that exist in relatively clear water, and can thus be surveyed by relatively low-cost optical methods. Other types of submerged habitats, including both deep-water areas and turbid brackish waters, may require more costly (and less accurate) acoustic remote sensing methods.

- Advances in technology that might improve results or lower costs. Current remote sensing practices point towards photogrammetry as the principal means of data collection. However, the capabilities of digital photography and multispectral imaging are improving greatly, and they will likely become methods of choice within the next 5 to 10 years. Another focus of the pilot study would be a rigorous examination of the accuracy of acoustic devices, such as side-scan sonar, for delineating seagrass and other submerged vegetation.

- Basic design issues such as whether a statistical sampling program could be employed or whether comprehensive coverage is required. This aspect of the study could build on existing partner networks; most notably Chesapeake Bay (Virginia and Maryland), Great Bay (New Hampshire), and Tampa Bay (Florida).

- Data demand and delivery issues. The data from such a program would have many collateral uses and would be in high demand by resource agencies, academia, and private sector. The best ways to meet the demands for this imagery would have to be explored to ensure maximum value is obtained from the overall effort.

Use of Existing/Expanded Data Sources

The ecological importance of submerged aquatic vegetation has been increasingly recognized in recent years, with a concomitant growth in efforts to understand how extensive these resources are, what factors affect their persistence or decline, how they can be restored, and so on. These studies have been undertaken by a wide range of federal, state, local, academic, and other institutions.

An assessment of the feasibility of relying upon these existing distributed efforts would require investigation of their scope and methods. The goal would be to determine whether the geographic coverage and sampling strategies are appropriate for use in developing statistically valid estimates and whether the data from different programs are sufficiently similar that they can be combined. If coverage or comparability issues are identified, the assessment would have

Service's Forest Inventory and Analysis Program and the NRCS National Resources Inventory are both moving in this direction.

to explore the feasibility and costs of expanding or re-structuring these efforts to address these concerns. Finally, the assessment would have to address institutional issues to ascertain the likely prospect of such a program providing consistent data over the foreseeable future. We estimate the cost of such an investigation at approximately $250,000. A pilot survey to determine the availability and utility of existing data would provide an estimate of the degree to which these sources could be used as a basis for reporting on this indicator.

System: Fresh Waters
Indicator: Altered freshwater ecosystems (Freshwater)
Data Gap: Stream / river miles impounded behind dams

Estimated Cost To Fill Data Gap

Improvements to National Hydrography Dataset (also required for the pond/lake shoreline element)	$750,000 to $1.0 million (one time)
Linkage to digital elevation data	Not available at this time
Assessment of upstream extent of inundation	Not available at this time

Indicator
This gap is one element of a larger indicator that reports on several freshwater ecosystem components, including

- *Impounded streams:* the percentage of stream and river miles that have been impounded behind a dam
- *Altered wetlands:* wetland acres that have been excavated, impounded, diked, partially drained, or farmed
- *Leveed or channelized streams:* the percentage of stream and river miles that have been leveed or channelized
- *Riparian vegetation:* streams/rivers and naturally occurring pond and lake shoreline-miles that have agricultural or urban/suburban land cover within about 100 feet of the water's edge (reservoirs and constructed lakes are excluded)

This note concerns impounded streams. (Descriptions of the altered wetlands and leveed/channelized streams components follow immediately below, while the riparian vegetation component is described in the Landscape Pattern cluster, p. 18.)

The Data Gap
The U.S. Army Corps of Engineers maintains a database of the locations of dams (and thus the downstream end of impoundments). However, this database has not been cross-linked with

databases providing stream locations and channels and digital elevation, both of which would be required to identify the upstream extent and length of impounded areas.

Feasibility Rating
Filling this gap is rated as "highly and immediately feasible" because there are several agencies (USGS, EPA) with both broad familiarity with the required data sets and the capabilities to manipulate and combine these data sets.

Options for Filling This Gap
Filling this data gap would require two steps. The first would be to link the Corps of Engineers database with the existing National Hydrography Dataset (NHD) and with related digital elevation data. The second would entail an analysis of the upstream extent of inundation (based on dam height and upstream elevation).

Upgrading the National Hydrography Dataset by cross-linking with the Corps of Engineers' national data base of dam locations could be done simply (and less accurately) a one-time cost of between $200,000 and $1.0 million, according to USGS. However, the NHD contains errors of both commission and omission in the identification of water bodies (some NHD water bodies do not exist in nature, and some actual water bodies are not shown). EPA estimates that remedying these errors (through the use of archival imagery), cross-referencing the Corps data set, and procuring limited amounts of new imagery or photographs to resolve any remaining areas of uncertainty would cost about between $750,000 and $1.0 million. (Note that these costs are also required to address two elements of this indicator's data gap—the assessment of the degree of shoreline alteration in ponds and lakes, as measured by reporting on riparian vegetation.)

Costs for linking this database with appropriate digital elevation data and for the analysis of upstream extent of inundation are not available at this time.

System: Fresh Waters
Indicator: Altered freshwater ecosystems
Data Gap: Altered wetlands

Estimated Cost To Fill Data Gap

Complete baseline inventory of altered wetlands	$5-7 million over 3 years
Periodic resurvey to determine trends	Up to $15 million per year (10-year cycle)

Indicator
This gap is one element of a larger indicator that reports on several freshwater ecosystem components, including

- *Impounded streams:* the percentage of stream and river miles that have been impounded behind a dam
- *Altered wetlands:* wetland acres that have been excavated, impounded, diked, partially drained, or farmed
- *Leveed or channelized streams:* the percentage of stream and river miles that have been leveed or channelized
- *Riparian vegetation:* streams/rivers and naturally occurring pond and lake shoreline-miles that have agricultural or urban/suburban land cover within about 100 feet of the water's edge (reservoirs and constructed lakes are excluded)

This note concerns altered wetlands. (The impounded streams component is described above, and leveed/channelized streams immediately below. The riparian vegetation component is described in the Landscape Pattern cluster, p. 18.)

The Data Gap
The U.S. Fish and Wildlife Service's National Wetlands Inventory includes identification of "altered wetlands"—those that are excavated, impounded, diked, partially drained, or farmed. However, only a portion of the NWI data are available in a digital database format that would support national reporting (the rest are essentially in paper form).

In addition, the NWI data are moderately to highly dated (some are from the 1980s) and there is no program in place or in design that would resurvey the nation's wetlands to provide more recent data and to support continuing reporting in the future.

Feasibility Rating
Filling this gap is rated as "moderately feasible" because while the US Fish and Wildlife Service has the capability to undertake the required data collection and reporting, fully implementing this indicator would require conversion of the program to one capable of updating the information (either in whole or by statistical sampling) periodically, which has never been done. FWS did not provide estimates of the cost of this program evolution, but consultations with experts familiar with the program believe a cost of $150 million for a ten year cycle ($15 million per year) is a reasonable initial estimate, which should be refined.

Options for Filling This Gap
This gap might be filled in two ways. The first would involve completion of the digitizing of the National Wetlands Inventory (about half the area of the lower 48 states is as yet undone). This would cost between $5 and $7 million and require about 3 years. (Estimates for mapping the remaining 5% of wetlands in the lower 48 and all wetlands in Alaska and Hawaii are not available.)

This step would provide only a one-time snapshot of wetland condition (and one with data that are significantly out of date in some cases). Periodic remapping of the entire United States on a periodic basis would be a fairly large undertaking, and would provide benefits far beyond this indicator. USFWS did not provide estimates for the cost of this step, but we estimate that this might require $150 million per mapping period (approximately 10 years), or about $15 million per year.

The second approach would be to combine data collection on wetland condition with the periodic (every 10 years) wetland change surveys conducted under the Emergency Wetlands Resources Act. No estimates of the cost of this approach are available.

System: Fresh Waters
Indicator: Altered freshwater ecosystems
Data Gap: Channelized or leveed rivers and streams

Estimated Cost To Fill Data Gap

Estimates not available; methods for data collection are not defined.

Indicator
This gap is one element of a larger indicator that reports on several freshwater ecosystem components, including

- *Impounded streams:* the percentage of stream and river miles that have been impounded behind a dam
- *Altered wetlands:* wetland acres that have been excavated, impounded, diked, partially drained, or farmed
- *Leveed or channelized streams:* the percentage of stream and river miles that have been leveed or channelized
- *Riparian vegetation:* streams/rivers and naturally occurring pond and lake shoreline-miles that have agricultural or urban/suburban land cover within about 100 feet of the water's edge (reservoirs and constructed lakes are excluded)

This note concerns leveed/channelized streams. (The impounded streams and altered wetlands components are described above. The riparian vegetation component is described in Landscape Pattern, p. 18.)

The Data Gap
No known data source exists that would support either a baseline assessment of the number of channelized or leveed river/stream miles or periodic assessment of increases or decreases in river alteration.

Feasibility Rating
Filling this data gap is rated as "challenging" because we are aware of no entity that collects this kind of data on anything but a small-area or project-by-project basis. Protocols for either centralized or decentralized data collection would need to be developed, as would field capabilities, reporting methods, and so on.

Options for Filling This Gap
No cost estimates are available for this gap.

System: Fresh Waters, Urban / Suburban
Indicator: Riparian vegetation (streams/rivers and lakes)
Data Gap: Riparian vegetation (streams/rivers and lakes)

See p. 18 (Landscape Pattern cluster) for a full description of this gap.

Estimated Cost To Fill Data Gap

Coarse resolution national reporting	
Improvements to National Hydrography Dataset	$0.75 to $1.0 million (one time)
Periodic comparison with land cover	$30,000 to $50,000
Urban / suburban reporting	Cost Estimates Not Available

System: Urban and Suburban Areas
Indicator: Total impervious area
Data Gap: Geographic extent, data collection and integration

See p. 20 (Landscape Pattern cluster) for a full description of this gap.

Estimated Cost To Fill Data Gap

To complete mapping for current period (2001 data):	$525,000 to $650,000
Future mapping costs:	$0 to $1.65 million per cycle

Gap or Cluster Definition

This cluster of four gaps relates to reporting on contaminant exposure associated with human health. It includes data on concentration of contaminants in the edible portion of freshwater and saltwater fish, as well as information on specific high-concern contaminants (DDT, PCBs, mercury) in fish and shellfish sold for human consumption. Finally, it addresses a gap in data on contaminants in soils in urban/suburban areas.

Costs To Fill This Gap

EPA and USGS estimated the cost of reporting on contaminants in the edible portion of fish; for freshwater, costs depend upon the reporting level – it is much less costly to provide information at the national level than to provide state-by-state estimates.

Gap Description	Initial Costs	Ongoing Costs
Freshwater fish: national estimates (USGS)	NA	$600,000 to $1.0 million/year
Freshwater fish: state + national estimates (EPA)	Not Available (NA)	$5 million/year
Saltwater fish (EPA)	NA	$2.7 million/year
DDT, PCBs, mercury in marketed fish	NA	NA
Contaminants in urban/suburban soil	NA	NA

FDA was asked to provide estimates on the targeted "sold for consumption" gap but did not reply, and no agency commented on the costs for reporting on urban/suburban soils.

Feasibility Issues

Filling the freshwater and saltwater fish tissue gaps is considered to be "highly and immediately feasible," because the agencies involved (USGS, EPA) currently manage programs of similar scope and focus. Reporting on contaminant levels in marketed fish is rated as "moderately feasible." The Food and Drug Administration has programs that are similar in nature, but filling this gap would require development of new protocols, sampling design, coordination with state health and environmental authorities, and so on. The urban/suburban soils gap is rated as "challenging" to fill, because there is no clear agency lead and we are unaware of similar large-scale programs to use as a basis for design of the new effort.

ABOUT THE GAPS

Core National	**Chemical contaminants (freshwater fish, edible)**
Core National	**Chemical contaminants (saltwater fish, edible)**
Coasts & Oceans	**Selected contaminants in fish and shellfish (for human consumption)**
Urban/Suburban	**Contaminated soils**

Indicator: Chemical contamination
Data Gap: Freshwater fish tissue (edible portion)

Estimated Cost To Fill Data Gap

USGS (NAWQA)	-	$0.6 million to $1.0 million per year
	-	5- year reporting cycle
	-	national-level estimates only
EPA (EMAP)	-	$5 million per year
	-	5-year reporting cycle
	-	national and state-level estimates

Indicator
The overall indicator reports on contaminants[5] found in streams, groundwater, sediment, and fish tissue. Two types of reporting are done for this indicator: the frequency of detection (i.e., percentage of sampled sites in which contaminants are detected) of contaminants[6] and the frequency with which these occurrences exceed established human health standards and guidelines and aquatic life guidelines.

The Data Gap
Data are not available to compare contamination of the edible portion of freshwater fish tissue to human health standards and guidelines because the entire fish, rather than the edible portion, has been analyzed by the USGS National Water-Quality Assessment (NAWQA) program, which provided contaminant data for other components of the core national indicator.

There are additional needs to fully assess chemical contamination in fish tissue, although these additional needs are somewhat beyond the scope of "filling data gaps." For many contaminants, there are no standards or guidelines defining safe exposure levels for humans or aquatic organisms. For example, drinking water standards and guidelines do not exist for 33 of 76 pesticides analyzed in fresh waters, and there are no aquatic life guidelines for 48 of these 76 pesticides.[7] Current standards and guidelines do not account for mixtures of chemicals or for seasonal occurrences of very high concentrations. In addition, potential effects on reproductive, nervous, and immune systems, as well as on particularly sensitive people, are not well understood.

Feasibility Rating
Filling this gap is rated as "highly and immediately feasible" because there are two existing programs with a history of conducting large-scale (i.e., national-scale) monitoring and reporting of data on ecosystem parameters that include freshwater tissue contamination levels, and there is an existing infrastructure for survey design, collection, and analysis. These programs are the

[5] Pesticides, selected degradation products, polychlorinated biphenyls (PCBs), polyaromatic hydrocarbons (PAHs), volatile organic compounds, other industrial contaminants, trace elements, nitrate, and ammonium.
[6] Nitrate, ammonium, and trace elements such as cadmium and chromium occur naturally and thus are not included in the occurrence graphs.
[7] Data were provided by USGS and were current as of the 2002 report.

EPA Environmental Monitoring and Assessment Program (EMAP) and the USGS National Water-Quality Assessment program (NAWQA). To a large degree, EMAP is a research and development program, not an operational monitoring program, while NAWQA has more of an operational character, although it too retains some aspects of a research program. The techniques and methods for collecting and analyzing these data are well known.

Options for Filling This Data Gap

Two agencies provided estimates of the cost of filling this data gap, using different assumptions about the number of sites needed to provide adequate data for national estimation as well as different per-site costs.

NAWQA

The U.S. Geological Survey's National Water-Quality Assessment estimated that approximately 200 sites would be required to provide sufficient data for a national estimate of edible-portion fish contamination. Providing comparable data over time requires a high degree of regional/national consistency in terms of target fish species and age class and sex of target organisms. The higher the need for consistency of approach, the more personnel time is needed in the field to obtain sufficient numbers of the target individuals for analysis. Given this requirement, and assuming analysis of fish fillets for a broad suite of organochlorine pesticides, PCBs, dioxin, mercury, and other trace elements, per-site costs might range from $15,000 to $25,000. Thus, an overall estimate would be from $3.0 million to $5.0 million. These costs would be incurred over a multiyear reporting cycle—if estimates were desired every 5 years, then annual costs would be $0.6 million to $1.0 million. (Note that the USGS estimates did not specifically contemplate a 5-year period, but rather estimated costs for the overall activity, which potentially could be completed in 1–2 years. These costs were spread over 5 years by The Heinz Center, for comparative purposes, and because it is unlikely that reporting would be conducted every year or two years. Additional discussion of program design and timing is needed.)

The USGS program would provide national-level estimates only (as contrasted with EPA's state-level and national-level estimates) and that the USGS estimates would not be probability based.

EMAP

EPA's Environmental Monitoring and Assessment Program is a research and development program that is being considered for expansion and transition to an operational monitoring program. EMAP's estimates for filling this data gap call for a larger number of sites overall, so as to be able to provide probability-based, statistically significant estimates at both the national and state levels. Thus EPA recommends approximately 50 sites per state, or 2500 sites in total. EMAP per-site costs are $10,000, for a total of $25 million per reporting cycle, or about $5 million per year for a five year cycle.

However, the per-site costs noted here would support sampling for a broader range of parameters, and thus the EPA program would provide data other than fish tissue contamination.

Our current understanding of the data gap for contaminants in fish tissue in the Great Lakes is incomplete and will require further investigation. As part of its estimate for filling the data gap for contaminants in saltwater fish (whole fish and the edible portion, see immediately below), EPA estimated that it would cost approximately $4 million per assessment cycle to do a similar

analysis for the Great Lakes. This was based on approximately 50 sampling sites for each of the eight Great Lakes states.

System: Core National Indicators
Indicator: Chemical contamination
Data Gap: Saltwater fish (whole and edible portion)

Estimated Cost To Fill Data Gap:

Continuing costs (per 5-year assessment cycle)	$13.5 million ($2.7 M / year)

This estimate covers all costs necessary to implement the program, which includes data collection on a range of indicators in addition to this one. Startup cost estimates not provided.

Indicator
The overall indicator reports on contaminants[8] found in streams, groundwater, sediment, and fish tissue. Two types of reporting are done for this indicator: the frequency of detection (i.e., percentage of sampled sites in which contaminants are detected) of contaminants[9] and the frequency with which these occurrences exceed established human health standards and guidelines and aquatic life guidelines.

(Note: NOAA operates a "Mussel Watch" program as part of its National Status and Trends Program. Mussel Watch provides annual data from approximately 250 sites nationwide. However, in order to provide consistency between fresh and saltwater portions of this indicator, a decision was made to recommend fish-based reporting. This issue may be revisited during development of the 2007 report.)

The Data Gap
Data were not available to report on saltwater fish tissue, either for frequency of detection or for comparison with human health standards (edible portion) or wildlife consumption / aquatic life guidelines (whole fish).

There are additional needs to fully assess chemical contamination in fish tissue, although these additional needs are somewhat beyond the scope of "filling data gaps." For many contaminants, there are no standards or guidelines defining safe exposure levels for humans or aquatic organisms. For example, as of 2002, drinking water standards and guidelines do not exist for 33 of 76 pesticides analyzed in fresh waters, and there are no aquatic life guidelines for 48 of these 76 pesticides.[10] Current standards and guidelines do not account for mixtures of chemicals and seasonal occurrences of very high concentrations. In addition, potential effects on reproductive,

[8] Pesticides, selected degradation products, polychlorinated biphenyls (PCBs), polyaromatic hydrocarbons (PAHs), volatile organic compounds, other industrial contaminants, trace elements, nitrate, and ammonium.
[9] Nitrate, ammonium, and trace elements such as cadmium and chromium occur naturally and thus are not included in the assessments of frequency of detection.
[10] Data were provided by USGS and were current as of the 2002 report. We are not aware of comparable data for saltwater fish.

nervous, and immune systems and on particularly sensitive people are not well understood.

Feasibility Rating
Filling this gap is rated as "highly and immediately feasible" because EPA has a significant history of development of the tools and field procedures for this type of sampling: EPA's Environmental Monitoring and Assessment Program (EMAP), or a successor program, the National Coastal Assessment (NCA), which has focused on fish tissue. In addition, NOAA's National Status and Trends program (NS&T), which has focused on mussel tissue contamination, has a similar base of experience in large-scale toxicity sampling and reporting. The techniques and methods for collecting and analyzing these data are well known.

Options for Filling This Data Gap
EPA's Environmental Monitoring and Assessment Program is a research and development effort that pioneered the collection of broad-scale probability-based ecological monitoring data. A follow-on operational program for coastal areas—the National Coastal Assessment program—would collect data for this indicator, as well as many others. NCA is not currently funded.

EPA has developed estimates for the implementation of the National Coastal Assessment. The relevant part of this program involves the collection of data for a suite of indicators/parameters, using a sampling design that provides estimates at a state and regional level. In addition to data on contamination in both edible portion and whole fish for all U.S. waters (both estuarine and coastal ocean) except Alaska, these parameters include contamination in estuary sediments and benthic community condition

EPA's estimates do not distinguish between costs that are attributable to specific indicators, so the estimates provided below are for the entire program, not just the benthic community condition elements. EPA estimates that it will cost approximately $13.5 million per cycle[11] for all U.S. waters except those off Alaska.

The EPA estimates are based on the following factors:

- There are 23 coastal states and 5 island territories
- Each state and island territory would require approximately 50 sampling sites to provide adequate coverage. (Note that sampling in Pennsylvania, Delaware and New Jersey would overlap in the Delaware River estuary, presenting an opportunity for cost savings. Therefore, the total number of states for calculation purposes was reduced to 22.)
- Each sampling site would cost approximately $10,000 per reporting cycle.

System: Coasts and Oceans
Indicator: Selected contaminants in fish and shellfish
Data Gap: No national reporting program on contaminant concentrations

[11] We have assumed a 5-year reporting cycle for the EPA approach.

Estimated Cost To Fill Data Gap
No estimates are available at this time.

Indicator
This indicator measures the concentration of PCBs, mercury, and DDT in the edible tissue of seafood from U.S. coastal waters. For comparison, the graphs would also include information on the levels at which the Environmental Protection Agency and the Food and Drug Administration recommend that action (such as consumption advisories) be taken.

The Data Gap
The FDA, EPA, and state governments have a variety of monitoring and reporting programs in place, but these programs do not provide the basis for national reporting on contaminant concentrations. Several factors contribute to the inability to aggregate existing databases. States collect data for different purposes, not all sampling strategies are based on a random sample, different techniques are used to sample fish and do not adhere to the same standards for assimilating composite samples, and different analytical methods are used to measure the total concentration of contaminants in fish, potentially resulting in different outcomes.

Feasibility Rating
Filling this gap is rated as "moderately feasible." Two factors were considered. The first is that many agencies (the Food and Drug Administration, Environmental Protection Agency, U.S. Geological Survey) have experience with sampling and/or analysis of fish (including edible portions) for contaminants. Thus, collectively, there is experience with both market-based assessments and analytical techniques. That said, however, there is no such program in existence, and any new program of this type would be subject to high levels of public scrutiny by consumer organizations, environmental interests, fishers, and others engaged in marketing and selling fish.

Options for Filling This Data Gap
No estimates are available at this time.

System: Urban and Suburban Areas
Indicator: Chemical contamination
Data Gap: Soils

Estimated Cost To Fill Data Gap
No estimates are available at this time.

Indicator
This indicator reports on contaminants found in urban and suburban streams and soils.

The Data Gap
Data are not currently available to report in a consistent manner on chemical contamination in urban and suburban soils. The 2002 *State of the Nation's Ecosystems* report included data on contaminant levels in urban and suburban streams.

Feasibility Rating
Filling this gap is rated as "challenging" because doing so would require additional consultation to develop a detailed indicator design, there are only a few cities/metro areas with the infrastructure in place to collect this information, and e there is no federal agency that has a complementary mandate or a history of collecting these types of data to undertake or coordinate the required activities.

Options for Filling This Data Gap
Neither USGS nor EPA provided estimates of the cost of collecting data on urban soil contamination or on the extent of and potential for reliance upon existing data collection by states, local governments, and others for reporting on this indicator.

Gap or Cluster Definition
This gap relates to the need to provide nitrogen loading and yield data in areas for which data are not currently available.

Costs To Fill This Gap
One option for filling this gap would be to reestablish the 130 long-term monitoring sites eliminated from the USGS National Stream Quality Accounting Network, at a cost of approximately $6.5 million per year. USGS provided no estimates for startup costs for these activities.

It may be possible to use data from a variety of other sources to fill in at least some of the gap identified in the 2002 report. This might involve using data from the USGS National Water Quality Assessment (many study sites are located in areas where 2002 data were not available) and from states and other monitoring sources. No cost estimates are available for this approach.

Gap Description	Initial Costs	Ongoing Costs
Re-establish stream monitoring sites	Not Available	$6.5 million/year
Using alternative data sources	Not Available	Not Available

Feasibility Issues
Filling this gap by reestablishing the 130 National Stream Quality Accounting Network sites is considered to be "highly and immediately feasible," because USGS operates many such sites and has the capability and procedures for maintaining them. The feasibility of filling this gap with data from alternative sources depends upon the option. If NAWQA sites are used, there should be relatively little integration involved, and thus is likely to be "highly and immediately feasible." Use of disparate federal, state, and other data sources would require development of new data-sharing networks, assessment of consistency of data, and the like, and is considered to be "challenging."

ABOUT THE GAP

Core National **Movement of nitrogen**

System: Core National Indicators
Indicator: The Movement of Nitrogen
Data Gap: Geographic coverage

Estimated Cost To Fill Data Gap

Reestablish National Stream Quality Accounting $6.5 million/year

Network sites

Indicator
This indicator reports the yield of nitrogen from major watersheds: pounds of nitrogen per square mile of watershed area that drains into rivers and streams through discharges, runoff, and other sources. It also reports the load of nitrate, a common form of nitrogen, from major rivers: tons of nitrate carried to the ocean each year by the four largest U.S. rivers.

The Data Gap
There is incomplete geographic coverage for this indicator because of insufficient USGS data to calculate the loads for substantial portions of the nation (see map on p. 46 of the 2002 report).

Feasibility Ranking
Filling this gap is rated as "highly and immediately feasible" because USGS maintains the capability for collecting water quality data through its existing network of stations (National Stream Quality Accounting Network) and filling this gap would simply require reestablishment of sites eliminated during the 1990s because of budget constraints. The techniques and methods for collecting and analyzing these data are well known.

Options For Filling This Data Gap
USGS believes that data collection could be undertaken by reestablishing the 130 long-term monitoring sites that were eliminated from the National Stream Quality Accounting Network program in 1995. Sampling these sites 18 times per year (monthly and during periods of high flow) would cost approximately $50,000 per site per year, for a total of roughly $6.5 million dollars per year.

State-based entities could undertake this work, providing there is a mechanism (including training) for ensuring consistency, standardization, and quality in field and laboratory protocols and that funding was sufficient. A state-based effort would likely require significant start-up funds.

Gap or Cluster Definition

This cluster consists of gaps for reporting carbon stored in both forest and grassland/shrubland ecosystems, and for reporting farmland soil organic matter, which can also be reported as amounts of carbon stored. The forest gap is for below-ground storage; above-ground carbon is already adequately reported by the Forest Service. The grassland/shrubland gap covers both above- and below-ground carbon.

Costs To Fill This Gap

We have been informed that one important element of this gap – storage of carbon below ground in forests—will be addressed in the next several years using existing programmatic resources in the Forest Service. Additional costs are estimated for urban forests (about 10% of the nation's forests may be considered "urban") and for the fate of carbon incorporated into products. Taken together, the forest, grassland/shrubland, and farmland estimates are approximately $10 million per year.

Gap Description	Initial Costs	Ongoing Costs
Farmlands soil organic matter		$1.0 million / year
Forest carbon storage – forests		Covered in agency budgets
Forest carbon storage – urban forests		$3.2 million / year
Forest carbon storage – products		$2 million / year
Grass/shrub carbon storage	$1.5 million (over 3 years)	$4.25 million /year
Total	**$1.5 million (over 3 years)**	**$10.45 million / year**

An alternative approach to obtaining cropland organic matter estimates may be to make use of existing data collected by public and private soil analysis laboratories. Issues of data coverage and consistency and access to data on private lands would need to be addressed in a feasibility study before this option could be fully evaluated.

Feasibility Issues

Filling the forest and farmland gaps is considered to be "highly and immediately feasible," because the relevant agencies (Forest Service and Natural Resources Conservation Service, NRCS) already have programs in place to collect these or similar data. Filling the grassland/shruland gap is considered to be "moderately feasible" because doing so would require development of survey mechanisms on federal rangelands (the estimates here are based on expansion of the NRCS National Resources Inventory onto these lands.)

ABOUT THE GAPS

Farmlands	**Soil organic matter**
Forests	**Forest carbon storage**
Grasslands/Shrublands	**Grassland/shrubland carbon storage**

System: Farmlands
Indicator: Soil organic matter)
Data Gap: National-level monitoring of soil organic matter

Estimated Cost To Fill Data Gap

Existing data (augmented as needed)	
Initial assessment of existing data sources	$500,000 to $1.0 million
Additional monitoring, data aggregation, etc	Estimated during initial assessment
Natural Resources Inventory	$1,006,500 per year

Indicator
This indicator reports how much organic matter there is in the top 4–6 inches of cropland soil. This will be reported nationally over time, and by region for the most recent year of data.

The Data Gap
While there are baseline estimates of the amount of organic matter in soils across the United States, there is no mechanism for systematic monitoring of changes in these amounts.

Efforts are under way, however, to develop techniques to use satellite data to estimate organic matter in surface soils.

Feasibility Rating
Filling this gap is rated as "highly and immediately feasible" because there is an existing program (USDA National Resources Inventory) that maintains a sampling frame and statistical reporting infrastructure. Additional field resources are the primary constraint on adding this indicator.

Reliance upon existing data (augmented as needed) would be considered a "moderately feasible" option because the coverage, quality, and timing of existing data are not known at this time, and thus the processes for aggregating them cannot be developed and the nature of the program needed to augment them cannot be determined.

Options for Filling This Data Gap
There are two options for filling this gap.

Existing Data (Augmented As Needed): Soil organic matter measurements are often included in routine soil tests, but there is no unified effort in place to collect and analyze the results over appropriate regions. Thus, one option would be to identify the potential sources of aggregate soil testing information (e.g., major soil testing labs, state departments of agriculture, and the like) and to assess the ability to use existing data for national and regional reporting. This assessment

would include the ability and practicality of accessing the data (it is assumed that permission would have to be obtained from individual landowners), the spatial coverage of existing data, methodological consistency, and the like. This assessment would identify whether additional sampling was needed or whether any changes were needed to ensure comparability of data from different labs or regions. Additional considerations would potentially involve defraying additional costs to labs for reporting, and the costs and methods for organizing a national data aggregation effort.

This would be a significant feasibility study, costs for which are estimated at $500,000 to $1.0 million.

National Resources Inventory: The second option would rely upon the USDA Natural Resources Conservation Service's National Resources Inventory, a national program that reports on a variety of characteristics and trends for the nation's nonfederal lands (primarily rural lands).

NRCS has estimated the cost for providing a nationally consistent, statistically valid estimate of soil organic matter, through on-site measurements at sites used for the NRI program. This would provide annual estimates (after a three-year startup phase) for cultivated and noncultivated cropland, Conservation Program (CRP) land, and both irrigated and nonirrigated pasturelands. The program would be based on sampling at about 3500 locations (7000 sample points altogether) per year.

Cost estimates have been provided by NRCS:

Laboratory costs:	$574,000	
Statistical support and services	$100,000	
Field staff	$262,500	
Equipment	$70,000	
Total	$1,006,500	per year

NRCS believes these are "high end" estimates and that costs could probably be reduced. For example, salary costs might be lowered by using trained technicians or properly trained students.

Other Important Considerations

Other Desirable Data: Soil organic matter is heavily influenced by land use and management practices. Data describing dominant soils, cropping patterns, and, particularly, water management practices such as irrigation and drainage would enhance the utility of the basic monitoring data described here.

These ancillary data are not currently collected by the NRI but are being collected by a newly established NRI initiative, the Conservation Effects Assessment Project (CEAP), which was established to quantify the environmental benefits of conservation programs. There is a potential to link the monitoring of organic matter to the same sub-sample of NRI points being used for the CEAP effort, enabling linkage of use and management data to observed onsite soil properties. While not necessary for reporting on soil organic matter conditions and trends, such a linkage would enable research to help explain observed conditions in terms of soil properties and land use/management decisions.

Links to Other Indicators: Obtaining access permissions and getting to actual locations are significant cost drivers for any field monitoring program. Data for other indicators from the *State of the Nation's Ecosystems* report, such as soil salinity and soil biological condition, as well as other relevant data, could be collected once a sampling strategy and scientifically defensible procedures and protocols have been developed. Using site visits for multiple purposes could reduce costs and improve data quality.

System: Forests
Indicator: Carbon storage
Data Gap: Carbon in soils, forest floors, wood products, and on non-timberlands

Estimated Cost to Fill Data Gap

Carbon storage in nonurban forests	No additional funding required
Carbon storage in urban forests	$3.2 million per year
Carbon storage in wood products, landfills	$2.0 million per year
Total	$5.2 million per year

(The Forest Service did not provide "initial" or "startup" cost estimates.)

Indicator
The overall indicator reports how much carbon is stored in forests, including trees, soil, and plant litter on the forest floor, and in wood products (e.g., wood used in housing, newspapers).

The Data Gap
Data are available only for wood (standing trees) on timberlands,[12] but do not include estimates for wood on nontimberlands. Data are not currently available for forest soils, forest floors (including leaf litter) and down woody debris, or wood products (including wood in use, wood in landfills, wood burned for energy, and wood burned or wood that decomposes without being used for energy).

Feasibility Rating
Filling this data gap is rated as "highly and immediately feasible." The USDA Forest Service has plans in place to collect the required data for nonurban soil carbon, forest floor litter, and down woody debris). In addition, initial estimates and plans have been developed for urban forest monitoring, but no such plans are in place for carbon stored in products and landfills.

Options for Filling This Gap

[12] "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 to be sufficient to support commercial harvest under current economic conditions. Lands on which harvest is prohibited by statute are not included as timberlands.

The required data for reporting on change in carbon in nonurban forest soils, forest floors and down woody debris, and in nontimberland forests will be available at no additional cost in about 10 years (reporting on baseline amounts of carbon in any one of these pools may begin before that time, but it will take 10 years to have adequate data to report changes). This is based on the assumption that current funding levels will be sufficient, and that no new funds are required.

Gradual improvements in methods for estimating carbon in wood products should sufficiently improve the quality of these data, and it is expected that no new funds will be necessary.

Urban forests represent 5–10% of the nation's forests, but the program noted above will not address carbon storage in these areas, nor will it provide consistent tracking of wood incorporated into products, like paper and, dimensional lumber. Different products "store" their carbon for different periods (e.g., paper may be used once, then disposed of in a landfill, where it may contribute to methane generation.) USDA estimates the cost of addressing these two areas at $3.2 million and $2.0 million per year, respectively.

System: Grasslands and Shrublands
Indicator: Carbon storage
Data Gap: Nationwide monitoring of carbon in soil and vegetation

Estimated Cost To Fill Data Gap:

First three years:	$4.75 million
Each succeeding year:	$4.25 million

Indicator
This indicator will report the total amount of carbon stored in soil and plants in grasslands and shrublands.

The Data Gap
Data are not currently available to provide systematic monitoring and reporting of soil and vegetation carbon. The minimum data that are required for this indicator are percentage soil organic matter (SOM) in surface soil layers and carbon stored in plant material, estimated on an area basis. Intensive, long-term data are available from the Long Term Ecological Research (LTER) sites, including those in Alaska, Michigan, Minnesota, Kansas, Colorado, and New Mexico (there are two sites in New Mexico). Such sites could provide substantial validation for more widely dispersed measurements.

Options for Filling This Data Gap

The USDA Natural Resources Conservation Service provided estimates of the likely costs of utilizing the National Resources Inventory (NRI) program to obtain national consistent, statistically valid estimates of carbon storage in grasslands and shrublands. This approach would provide annual estimates, after a three-year startup phase. The program would be based on sampling at about 7000 locations per year. These estimates assume that NRI sampling, currently limited to private rangelands, is expanded to included rangelands in federal and other

ownerships, which would constitute a significant expansion of the operational scope of the NRI program). Cost estimates provided by NRCS are shown below:

Startup costs		$1,500,000 (one time; spread over 3 years)
Ongoing costs		
Laboratory costs		$1,148,000
Statistical support and services		$200,000 per year
Field staff		$2,625,500 per year
Equipment		$280,000 per year
Total	First 3 years	$4,753,500 per year
	Succeeding years	$4,253,500 per year

Gap or Cluster Definition
This cluster consists of gaps related rare or declining ("at risk") species or communities.

- Three gaps involve the need to report on *plants that are strongly associated with particular ecosystems* (freshwater, grasslands / shrublands, and forests). The 2002 report included information on animals that are strongly associated with these systems, but additional funding was required to process the data on the larger number of plant species.
- Two gaps involve reporting on *coastal at risk species, including both plants (macroalgae) and animals*. These species are not well represented in Heritage data.
- Three gaps reflect the need to *incorporate trend data* into the reporting on at risk species. This would enable reporting on population trends, enable users to distinguish between species that are naturally rare and those that are in decline, and distinguish actual trends and projected threats.
- Two gaps would address *at-risk communities.* One would support reporting on the area of forest community types that have been significantly reduced in overall area (more than 70% reduction from presettlement area), and the other would support reporting on at-risk riparian and wetland plant communities

Costs To Address This Gap
Based on estimates provided by NatureServe, it appears that approximately $1.5 million in initial costs and about $100,000 per year in ongoing costs would address this gap.

Gap Description	Initial Costs	Ongoing Costs (per 5-year cycle)
Reporting on plants by ecosystem	$277,000	$1200
Reporting on coastal species	$300,000	$111,500
Improved trends reporting	$661,000	$349,000
Community types		
Forest	$55,000	$25,000
Wetlands / Riparian	$165,000	$50,000
Total	**$1.46 million**	**$536,700**

These estimates cover the analysis and reporting of data collected by Natural Heritage programs and integrated by NatureServe. Thus, they represent additional, marginal costs to report on these indicators, not the full costs that would be required to duplicate this service in another institution.

Feasibility Issues
NatureServe and the state-based Natural Heritage network are a longstanding operational monitoring and reporting program. The data required for most of these analyses (except coastal) are generally available or are being collected by the network, and NatureServe has the capacity to undertake these analyses. The gaps related to at-risk *species* are considered "highly and immediately feasible," although the coastal gap is considered "moderately feasible." The riparian and forest communities gaps are considered "moderately feasible": in the former case, there is no existing national classification system for riparian areas (and one is needed to enable

this gap to be filled), while the latter involves reconciliation of data from at least two sources.

ABOUT THE GAPS

Core National	**At-risk species (overarching data gaps: trend data, actual trends versus threats, naturally rare versus declining)**
Forest	**At-risk forest plants**
Forest	**Forest communities—significantly reduced area**
Fresh Waters	**At-risk freshwater and wetland plants**
Fresh Waters	**At-risk riparian communities**
Grasslands/Shrublands	**At-risk grassland/shrubland plants**
Coasts and Oceans	**At-risk plants and animals**

System: Core National Indicators
Indicator: At-Risk Native Species
Data Gaps: (Data Gaps Common to Multiple At-Risk Species Indicators)
Distinguishing between naturally rare and declining species
Distinguishing between actual recent trends and presumed threats
Establishing trends in the number of species of a given status rank

These three data gaps are relevant to both the Core National Indicator of At-Risk Native Species and the four ecosystem-specific at-risk species indicators (At-Risk Native Marine Species, Forest Species, Freshwater Species, and Grassland and Shrubland Species). The improvements described here are applicable across the Natural Heritage/NatureServe[13] data system and are not broken out by ecosystem type and thus are not provided as part of the estimates for the ecosystem-specific at-risk species indicators.

Estimated Cost To Fill Data Gap

Initial Costs	$661,150
Ongoing Costs	$348,500 maximum per assessment cycle[14] (Some costs may be covered; see note at end)

The Indicator
The at-risk native species indicators in the 2002 *State of the Nation's Ecosystems* report describe the relative risk of extinction of native plant and animal species. Species are ranked according to their risk of extinction, and the percentage of species in each risk class is reported. Degrees of risk range from very high ("critically imperiled" species are often found in five or fewer places

[13] The Natural Heritage Network is a group of more than 50 programs, primarily housed in and funded by state governments, that collects data on a variety of species and ecological community attributes. The network is coordinated by NatureServe, a nonprofit organization.
[14] We assume this work would be undertaken to accommodate a roughly 5-year assessment cycle.

or have experienced very steep declines) to moderate ("vulnerable" species are often found in fewer than 80 places or have recently experienced widespread declines). Species ranked "secure" or "apparently secure" are not reported.

The Data Gaps

Distinguishing between species that are naturally rare and those that are rare as a result of population decline. The Natural Heritage Network and NatureServe use an 11-factor scheme for assessing risk[15]. Elevated risk levels for a particular species may be due to historical or recent population declines, or they may reflect natural rarity; biologists often consider very rare species to be at risk even in the absence of recent declines or current threats. Even though population declines may be considered in the ranking process, these data are not consistently gathered, and the NatureServe/Heritage data management system does not provide sufficient information on which factors are used for individual species, thus making it impossible to distinguish between species for whom population decline is a significant factor in their overall ranking and those that are naturally rare.

Distinguishing between recent trends and presumed threats. In some cases changes in NatureServe's species rankings can be attributed to actual changes in population, while other changes in rank were made because of the existence of presumed threats to individual species and the presumed implication for future short-term population trends. As with the previous gap, there are both limitations on the availability of recent trend data for many species and limitations on the ability of the NatureServe/Heritage data system to support distinctions between species ranks in which presumed threatS play a major role and those for which actual recent population trends are predominant.

Trends in the number of species of a given status rank. The system of gathering and managing data on species status used by the Natural Heritage Network and NatureServe does not have a standardized, periodic process for review of the status ranks of species. Therefore, it is not appropriate to compare the number of species in any given status rank with the number in that status rank in any other time period.

Feasibility Rating

Filling this gap is rated as "highly and immediately feasible" because there is in place a state-based network of programs to collect the relevant data (state-based Heritage programs) and a centralized organization with the mission of providing consistency of methods and integration of data across individual programs (NatureServe). Designing a program to report on this gap would require some new development, but doing so is likely to be within the network's capabilities.

Options for Filling This Data Gap

The primary need for these gaps is to gather and incorporate adequate information into the ranking system on short- and long-term population trends for at-risk species (i.e., those ranked as having an increased risk of extinction). NatureServe has developed estimates of the costs to undertake these activities, which are outlined in the table below. Up-front costs to fill all of the identified data gaps would be about $661,150, and costs incurred at every major update (e.g., every 5 years) would be about $348,500 (see notes below).

[15] See http://www.natureserve.org/explorer/ranking.htm for a description of the ranking system.

Initial Costs		
Applicable Data Gap	**Description**	**Cost**
Rare / decline distinction; Trends in species rank	Establish short- and long-term trend data for	
	Vertebrates (650 species)	$66,000
	Selected invertebrates (300 species)	$14,850
	Vascular plants (4700 species)	$569,300
Recent / presume threat distinction	Ability to distinguish between actual recent trends and projected short-term trends, which are based on presumed threats.	$11,000
	Total Initial Costs	**$661,150**

Ongoing Costs (per 5-year cycle)		
Applicable Data Gap	**Description**	**Cost**
Trends in species rank	Periodically update status data	
	Vertebrates (2537 species)	$62,700
	Selected invertebrates (3464 species)	$85,800
	Vascular plants (16,000 species)	$200,000
	Total Ongoing Costs	**$348,500**

Note on "Initial Costs": This write-up provides cost estimates for establishing short- and long-term trend data only for species that are at "elevated risk" of extinction (those ranked G1 through G3 in the Heritage system). This means that trend data will not be established for other species, including those not at "elevated risk" but which may be declining and, therefore, approaching an at-risk classification. NatureServe estimates additional costs of $191,400 for vertebrates, and $30,250 for selected invertebrates in order to be able to provide trend data on species not currently at risk; a similar estimate for vascular plants was not provided.

Note on "Ongoing Costs": NatureServe anticipates that some, but not all, of the $348,500 needed to update data on the at-risk status of species (and thus provide sound trends in the number of species of different ranks) will be secured from current funding partners. Thus, the figure cited here should be considered a maximum.

Data Gap: Forest plants

This write-up describes activities and costs needed to allow assessment of the status of forest plant species. However, these costs should be considered in conjunction with the costs and activities described above, in "At-Risk Species: Overarching Data Gaps," which addresses activities needed to improve the quality of the information provided about individual species and to update these data on a regular basis.

Estimated Cost To Fill Data Gap

Initial costs:	$89,895	
Ongoing costs:	$400	(every 5 years)

Indicator
This indicator reports on the relative risk of extinction of native forest species. The risk categories are based on such factors as the number and condition of individuals and populations, the area occupied by the species, population trends, and known threats. Degrees of risk reported here range from very high ("critically imperiled" species are often found in five or fewer places or have experienced very steep declines) to moderate ("vulnerable" species are often found in fewer than 80 places or have recently experienced widespread declines). In all cases, a wide variety of factors contribute to the overall ratings.

The Data Gap
The 2002 *State of the Nation's Ecosystems* included data on the overall status of vascular plants, but cost and time constraints made it impossible to report on the status of plants that occur primarily in forest settings, freshwater settings, or grasslands and shrublands. In order to do so, it is necessary to identify those species that are found primarily in one habitat type, and are not broad generalists. These data could be derived from expert reviews of data in the NatureServe/Natural Heritage program database.

Feasibility Rating
Filling this data gap is rated as "highly and immediately feasible" because the basic data needed are already available and NatureServe has the capability to undertake the required analyses.

Options for Filling This Data Gap
The costs provided here are from NatureServe and presume that the work described here would be done through the Heritage network.
NatureServe, the nongovernmental organization that manages the Natural Heritage network in collaboration with state-based Heritage programs, estimates that providing the data for this data gap would cost approximately $90,000 in up-front costs and a minor amount for recurrent costs necessary to update taxonomies. Estimated costs are detailed in the table below Note that NatureServe provided a single, combined estimate for forests, grasslands/shrublands, and fresh waters (total of $276,560 initially, and $1200 ongoing); one-third of these costs has been attributed to this indicator.

One-Time Costs

Ecosystem group taxonomy[16]	6,875
Attribute plants to major ecosystem groups[17]	83,020
Total one-time costs	**$89,895**
Ongoing Costs (per 5-yer cycle)	
Attribute plants to major ecosystem groups[18]	400
Total ongoing costs	**$400**

System: Forests
Indicator: Forest community types with significantly reduced area
Data Gap: Historic and current area of forest types

Estimated Cost to Fill Data Gap:

Initial costs: $55,000
Ongoing costs: $25,000 (every 5 years)

Indicator

This indicator would report whether those forest community types that cover significantly fewer acres than they did in presettlement times are increasing or decreasing in area, and by how much. It would also report the total area occupied by these much-reduced forest community types—those that have been reduced by 70% or more in area.

In this context, the term "community types" is intended to represent a classification level that is finer in resolution than would be the case with "SAF forest types" or "FIA types." These classifications (developed or used by the Society of American Foresters and Forest Inventory and Analysis) are fairly coarse scale, with approximately 18 groupings in the FIA system for the entire United States, including Alaska); it is these "forest types" that are used in the 2002 Report's "forest area" indicator. At the other end of the spectrum, the Natural Heritage programs

[16] This cost represents a portion of the cost of development of a system of "major ecosystem groups"—a set of approximately 50 broad habitat types—midrange between "forests" or "coastal waters" and the very specific plant community associations (of which there are several thousand) currently used by NatureServe. This important intermediate step is required to allow aggregation of association-level data to the four major "natural or semi-natural" ecosystem types used in the 2002 *State of the Nation's Ecosystems* report (forests, grasslands/shrublands, fresh waters, and coasts and oceans). We have included one-fourth of this cost (overall cost = $27,500) because there are four major systems that would be covered by such a system.

[17] This cost represents a portion of the total to attribute plants to the major ecosystem groups, the total of which should be partitioned between the major ecosystem types (forests, fresh waters, and grasslands-shrublands)—we have simply divided the total into thirds; because of the minimal number of higher plant taxa in marine systems, it does not seem fair to partition any of this cost to the data gap for marine species. The same logic applies to Ongoing Costs.

[18] This cost represents updating of taxonomy and similar reviews on an ongoing basis. Initial updating of taxonomy is a significant component ($18,333 for each of the three ecosystem types, or $55,000 for all three) is included within the "one-time costs.

employ a very fine-scale classification—"associations." The objective of the "forest community types with significantly reduced area" indicator is to rely upon a system that is midway between these two extremes. This probably will be something like NatureServe's set of "ecological systems." See http://www.natureserve.org/publications/usEcologicalsystems.jsp.

The Data Gap
Data on historic and current area of many forest community types are not available. NatureServe and the USDA Forest Service Forest Inventory and Analysis (FIA) program are collaborating on development of methods to estimate the area of forest type from existing FIA data. It is also possible to estimate historic area, but this has not been done on a comprehensive basis.

Feasibility Rating
Filling this gap is rated as "moderately feasible" because it would involve development of new methods and the cross-linking of data sets from a variety of sources.

Options for Filling This Data Gap
NatureServe, the nongovernmental organization that manages the Natural Heritage network in collaboration with state-based Heritage programs, estimates that providing the data for their share of the collaborative project with the Forest Service to fill this data gap will cost approximately $55,000 in up-front costs and $25,000 every 5 years to provide updated data. They propose a two-stage collaborative process. First, Kuchler potential vegetation maps would be used to approximate forest/savanna community type and area circa 1600. Error bounds would be calculated using presettlement vegetation maps from several states/local jurisdictions. Kuchler types (~70) will then be cross-walked to the Forest Service's FIA types circa 1963. This would provide a 1600-to-1963 trend dataset and would enable identification of FIA types with >70% loss. Second, FIA would then be linked to NatureServe Ecological Systems classifications and the National Land Cover Dataset (NLCD) cover types. FIA data would carry forward, providing acreage trends for forest/savanna ecological systems (>70% reduced area for about 60 types) through 1990. Both FIA and NLCD acreages would provide estimates circa 1990.

System: Fresh Waters
Indicator: At-risk native freshwater species
Data Gap: Freshwater and wetland plants

This write-up describes activities and costs that would allow assessment of the status of freshwater plant species. However, these costs should be considered in conjunction with the costs and activities described above, in "At-Risk Species: Overarching Data Gaps," which addresses activities needed to improve the quality of the information provided about individual species and to update these data on a regular basis.

Estimated Cost To Fill Data Gap:

Initial costs:	$89,895	
Ongoing costs:	$400	(every 5 years)

Indicator
This indicator reports on the relative risk of extinction of native freshwater species. The risk categories are based on such factors as the number and condition of individuals and populations, the area occupied by the species, population trends, and known threats. Degrees of risk reported here range from very high ("critically imperiled" species often are found in five or fewer places or have experienced very steep declines) to moderate ("vulnerable" species often are found in fewer than 80 places or have recently experienced widespread declines). In all cases, a wide variety of factors contribute to the overall ratings.

The Data Gap
The 2002 *State of the Nation's Ecosystems* report included data on the overall status of vascular plants, but cost and time constraints made it impossible to report on the status of plants that occur primarily in forest settings, freshwater settings, or grasslands and shrublands. In order to do so, it is necessary to identify those species that are found primarily in one habitat type, and are not broad generalists. These data could be derived from expert reviews of data in the NatureServe/Natural Heritage program database.

Feasibility Rating
Filling this data gap is rated as "highly and immediately feasible" because the basic data needed are already available and NatureServe has the capability to undertake the required analyses.

Options for Filling This Data Gap
NatureServe, the nongovernmental organization that manages the Natural Heritage network in collaboration with state-based Heritage programs, estimates that providing the data for this data gap would cost approximately $100,000 in up-front costs and a minor amount for recurrent costs necessary to update taxonomies. Estimated costs are detailed in the table below. Note that NatureServe provided a single, combined estimate for forests, grasslands/shrublands, and fresh waters (total of $276,560 initially, and $1200 ongoing); one-third of these costs have been attributed to this indicator.

One-Time Costs	
Ecosystem group taxonomy[19]	6,875
Attribute plants to major ecosystem groups[20]	83,020
Total one-time costs	**$89,895**
Ongoing Costs (per 5-year cycle)	
Attribute plants to major ecosystem groups[21]	400
Total ongoing costs	**$400**

System: Fresh Waters

Indicator: At-risk freshwater plant communities
Data Gap: Riparian communities

[19] See notes 16 and 17 above.
[20] See notes 16 and 17.
[21] See note 18 above.

Estimated Cost To Fill Data Gap

Initial costs:	$165,000	
Ongoing costs:	$50,000	(every 5 years)

Indicator
This indicator reports on the percentage of wetland and riparian plant communities that are at different degrees of risk of extinction. These status ranks are based on such factors as the remaining number and condition of occurrences of the community, the remaining acreage, and the severity of threats to the community type. Degrees of risk reported here range from very high ("critically imperiled" communities often are found in five or fewer places or have experienced very steep declines) to moderate ("vulnerable" communities often are found in 80 or fewer places or have experienced widespread declines). Communities ranked as "secure" or "apparently secure" are not listed. In all cases, a wide variety of factors contribute to overall ratings.

The Data Gap
No classification system exists for riparian systems in the U.S. National Vegetation Classification System (NVCS)—the federal standard for vegetation information, which is used by NatureServe. Therefore, NatureServe does not yet assess riparian systems.

Feasibility Rating
Filling this data gap is rated as "moderately feasible" because it appears that the required analyses are relatively straightforward, and because NatureServe has the capability to undertake these analyses and an existing network to report the data regularly.

Options For Filling This Data Gap
NatureServe, the nongovernmental organization that manages the Natural Heritage network in collaboration with state-based Heritage programs, estimates that approximately $165,000 would be necessary in order to complete the classification for all U.S. riparian and wetland plant communities, including those found in Alaska, which account for nearly 50% of the wetland communities. This estimate includes $55,000 needed to distinguish between naturally rare community types and those that are experiencing recent declines. Ongoing costs, which would be incurred at the time of each major update of the data (e.g., every 5 years), would be about $50,000.

System: Grasslands and Shrublands
Indicator: At-risk native grassland and shrubland species
Data Gap: Grassland and shrubland plants

This write-up describes activities and costs needed to allow assessment of the status of grassland and shrubland plant species. However, these costs should be considered in conjunction with the

costs and activities described above, in "At-Risk Species: Overarching Data Gaps," which addresses activities needed to improve the quality of the information provided and to update these data on a regular basis.

Estimated Cost to Fill Data Gap

Initial costs:	$89,895	
Ongoing costs:	$400	(every 5 years)

Indicator

This indicator reports on the status of native grassland and shrubland species with respect to their *relative risk of extinction*. These status ranks are based on multiple factors: the number and condition of individuals and populations, the area occupied by the species, population trends, and known threats. Degrees of risk reported here range from very high ("critically imperiled" species often are found in five or fewer places or have experienced very steep declines) to moderate ("vulnerable" species often are found in fewer than 80 places or have recently experienced widespread declines). In all cases, a wide variety of factors contribute to overall ratings.

The Data Gap

The 2002 *State of the Nation's Ecosystems* report included data on the overall status of vascular plants, but cost and time constraints made it impossible to report on the status of plants that occur primarily in forest settings, freshwater settings, or grasslands and shrublands. In order to do so, it is necessary to identify those species that are found primarily in one habitat type and are not broad generalists. These data could be derived from expert reviews of data in the NatureServe/Natural Heritage program database.

Feasibility Rating

Filling this data gap is rated as "highly and immediately feasible" because the basic data are available and NatureServe has the capability to undertake the required analyses.

Options For Filling This Data Gap

The costs provided here are from NatureServe and assume that the work described here would be done through the Heritage network.

NatureServe, the nongovernmental organization that manages the Natural Heritage network in collaboration with state-based Heritage programs, estimates that providing the data for this data gap would cost approximately $90,000 in up-front costs and a minor amount for recurrent costs necessary to update taxonomies. Estimated costs are detailed in the table below. Note that NatureServe provided a single, combined estimate for forests, grasslands/shrublands, and fresh waters (total of $276,560 initially, and $1200 ongoing); one-third of these costs have been attributed to this indicator.

One-Time Costs	
Ecosystem group taxonomy[22]	6,875

[22] This cost represents a portion of the cost of development of a system of "major ecosystem groups"—a set of approximately 50 broad habitat types—midrange between "forests" or "coastal waters" and the very specific plant community associations (of which there are several thousand) currently used by NatureServe. This important

Attribute plants to major ecosystem groups[23]	83,020
Total one-time costs	**$89,895**
Ongoing Costs (per 5-yer cycle)	
Attribute plants to major ecosystem groups[24]	400
Total ongoing costs	**$400**

System: Coasts and Oceans
Indicator: At-risk native marine species[25]
Data Gap: Marine animals (mollusks, corals, fishes) and plants (seagrasses, macroalgae)

This write-up describes activities and costs needed to allow assessment of the status of coastal plant and animal species. However, these costs should be considered in conjunction with the costs and activities described above, in "At-Risk Species: Overarching Data Gaps," which addresses activities needed to improve the quality of the information provided and to update these data on a regular basis.

Estimated Cost to Fill Data Gap:

Initial costs:	$300,000
Ongoing costs:	$111,500 (every 5 years)

Indicator
This indicator will report on the relative risk of extinction of native marine species, both plants and animals. The risk categories are based on such factors as the number and condition of individuals and populations, the area occupied by the species, population trends, and known threats. Degrees of risk to be reported here range from very high ("critically imperiled" species are often found in five or fewer places or have experienced very steep declines) to moderate ("vulnerable" species are often found in fewer than 80 places or have recently experienced widespread declines). Species ranked as "secure" or "apparently secure" would not be reported.

intermediate step is required to allow aggregation of association-level data to the four major "natural or semi-natural" ecosystem types used in the State of the Nation's Ecosystems report (forests, grasslands/shrublands, fresh waters, and coasts and oceans). We have included one-fourth of this cost (overall cost = $27,500) because there are four major systems that would be covered.

[23] This cost represents a portion of the total to attribute plants to the major ecosystem groups, the total of which should be partitioned between the major ecosystem types (forests, fresh waters, and grasslands-shrublands)—we have simply divided the total into thirds; because of the minimal number of higher plant taxa in marine systems, it does not seem fair to partition any of this cost to the data gap for marine species. The same logic applies to Ongoing Costs.

[24] This cost is relatively low because $18,333 ($55,000 across all ecosystem types) was added to the estimate for "attributing plants to major ecosystem groups"; it is for updating the taxonomy initially rather than on an ongoing basis.

[25] This gap is relevant for both the coasts and oceans section of the report (for which references are provided above) and the core national indicator, At-Risk Native Species (p. 52).

The data would also be presented on a regional basis for estuaries and coastal waters out to 200 miles.

Note: this indicator is designed to be consistent with the risk rankings used in the state-based Natural Heritage network, which generally has relatively sparse information on marine species at present, but whose coverage is expanding in this area. Other "at-risk species" indicators in the 2002 *State of the Nation's Ecosystems* report utilize the Heritage data and methods.

The Data Gap
No aggregated source of data exists on the risk of extinction for a broad spectrum of marine species. The primary exceptions are species that are commercially harvested or listed for protection under the Endangered Species Act and Marine Mammal Protection Act.

Feasibility Rating
Filling this gap is rated as "moderately feasible" because, although there is in place a state-based network of programs to collect the relevant data (Heritage programs) and a centralized organization with the mission of providing consistency of methods and integration of data across individual programs (NatureServe), extending this network's coverage to include a significant new arena (marine species) would require considerable program development.

Options for Filling This Data Gap
NatureServe, the nongovernmental organization that manages the Natural Heritage network in collaboration with state-based Heritage programs, estimates that providing the data for this indicator would cost approximately $300,000 in up-front costs and about $112,000 to update the listings every 5 years.

This work would involve initial and ongoing assessment of the status of approximately 6500 mollusk species, 400 coral species, 2500 marine fish species, 20 vascular plant species, and over 100 species of kelp and other macroalgae. Most of the work would be conducted by biologists employed in state Heritage programs.

One-Time Costs	
Animals (corals, mollusks & fish)	273,500
Plants (vascular plants, kelp & other macroalgae)	22,660
Ecosystem group taxonomy[26]	6,875
Total one-time costs	**303,035**
Ongoing Costs (per 5-year cycle)	
Animals	105,000
Plants	6,500
Total ongoing costs	**111,500**

[26] This cost represents a portion of the cost of development of a system of "major ecosystem groups" – a set of approximately 50 broad habitat types—midrange between "forests" or "coastal waters" and the very specific plant community associations (of which there are several thousand) currently used by NatureServe. This important intermediate step is required to allow aggregation of association-level data to the four major "natural or semi-natural" ecosystem types used in the State of the Nation's Ecosystems report (forests, grasslands/shrublands, freshwater, and coasts and oceans). We have included one-fourth of this cost (overall cost = $27,500) because there are four major systems that would be covered.

Gap or Cluster Definition

Gaps in this cluster relate to reporting on non-native plant cover in forest, grass/shrub, and farmland systems, and to the occurrence of non-native species in freshwater and coastal systems.

A review, now under way, of all non-native species indicators is likely to result in significant changes to the 2002 indicator definitions. The work described here is nevertheless viewed as an important priority.

Costs To Fill This Gap

There are substantial uncertainties regarding the costs to fill this gap:

- Methods for collecting data on non-native plant cover in forests are being developed by the Forest Service, but funding is uncertain. We have been provided with an estimate, but have not been able to ascertain whether this represents funds already available or whether all or part of it is a currently unfunded shortfall.
- USDA (NRCS) estimated the cost of a national program to collect data on non-native plant cover on the nation's grasslands and shrublands at approximately $2.5 million per year. Alternatively, it might be possible to rely upon efforts of federal, state, nonprofit, academic, and other institutions, but determining whether this is possible requires study of data coverage and consistency issues and development of a mechanism for ensuring consistent collection and regular reporting. Finally, improved remote sensing methods may become available, but it is not possible to estimate their cost at present.
- Based on the USDA estimates for grasslands and shrublands, we believe a federal program to collect data on non-native plants on farmlands would cost about $1.2 million per year. However, farmland data collection poses the same set of choices (evaluate existing data, remote sensing, national program) as with grasslands and shrublands.
- Freshwater non-native species are currently reported based on a program that relies upon museum and published reports, not field surveys. Expanding this coverage would require about $250,000 per year and about $700,000 in startup costs; developing a field-based program would cost $2.5 million and implementing it as much as $10-12 million per year.
- Costs for the coastal portion of this gap are not available at this time.

Gap Description	Initial Costs	Ongoing Costs
Forest plant cover	Not Available[27]	
Grassland and shrubland plant cover • Existing data sources – feasibility study • New federal / national program • Remote sensing-based approach	 $500,000 Not provided Unknown	 Unknown $2.5 million /year Unknown
Farmland plant cover • Existing data sources – feasibility study • New federal / national program • Remote sensing-based approach	 $500,000 Not provided Unknown	 Unknown $1.25 million /year Unknown
Freshwater • museum/publications • field data collection	 $680,000 $2.5 million	 $240,000 $10-12 million /year
Coasts and Oceans	Not Available	Not Available
Total	Depends upon options chosen	

Feasibility Issues
Filling the forest data gap is considered "highly and immediately feasible," because the Forest Service is already testing the field protocols, and has experience and infrastructure that can support this work. The freshwater museum/published reports option is considered to be "moderately feasible," because it would involve expansion of an existing network of collaborators to cover a significantly larger set of species. All other gaps are considered to be "challenging" because they would involve establishment of new field programs, testing and development of new protocols, development of data management capacity and the like.

ABOUT THE GAPS

- **Forest** — **Forest non-native plant cover**
- **Grasslands/Shrublands** — **Grass/shrub non-native plant cover**
- **Farmland** — **Native Vegetation in Farmland Areas**
- **Fresh Waters** — **Non-native freshwater species**
- **Coasts & Oceans** — **Non-native species**

A review of all non-native species indicators, now under way, is likely to result in significant changes to the 2002 indicator definitions.

System: Forests
Indicator: Area covered by non-native plants

[27] The Forest Service has indicated that as much as $20 million might be needed to accomplish this work, but we have not been able to determine whether these are one-time or annual costs or a combination of the two.

Data Gap: Coverage in overstory and understory

Estimated Cost To Fill Data Gap

Initial Costs:	
Ongoing Costs:	Unknown – up to $20 million. See note

Note: As much as $20 million will be necessary for the Forest Service to perform the necessary data collection for this data gap, but we are uncertain as to whether

- This is represents funds currently programmed for this activity, or whether all or part represents a currently unfunded shortfall
- These are one-time or ongoing costs, or what the split might be between these two categories.

Indicator
This indicator describes the degree to which non-native plants are found in U.S. forests. It will report the percentage of the total area that is made up of non-native plants. This will be broken down by the percentages that are covered by non-natives in the overstory (large trees that form the canopy) and understory (shrubs, ground plants, and smaller trees).

The Data Gap
A standardized approach for reporting on the area of non-native plants at the national level is not available. However, development and testing of protocols for reporting non-native plant cover is currently under way by the USDA Forest Service's Forest Inventory and Analysis (FIA) program.

This indicator is currently being revised by a Heinz Center task group charged with evaluating the full suite of non-native species indicators in the 2002 *State of the Nation's Ecosystems* report. Thus, it is very likely that a new indicator will be proposed that may have somewhat different implications in terms of data needs.

Feasibility Rating
Filling this data gap is rated as "highly and immediately feasible" because the USDA Forest Service already has developed the plans to collect the required data, and maintains an infrastructure for plot identification, field data collection, and so on.

Options for Filling this Data Gap
The Forest Service has developed the technical methods for implementing a monitoring program that identifies all species of vegetation—both native and non-native—on a subset of all FIA plots. This effort would support the indicator described here, but there is conflicting information about whether the resources (as much as $20 million per year) are available to support the effort.

System: Grasslands and Shrublands

Indicator: Non-native plant cover
Data Gap: Geographic coverage and aggregation of existing data

Estimated Cost To Fill Data Gap

Option 1:	Utilize data from existing programs	
	Feasibility study:	Preliminary assessment under way. Additional funding ($500,000) will be required
	Ongoing costs:	Unknown
Option 2:	New national program	$2.48 million per year
	Ongoing costs:	No startup cost estimates provided
Option 3:	Remote sensing	Speculative

Indicator
This indicator will report the percentage of plant cover in grasslands and shrublands that is made up of non-native species and will include data for both invasive non-native species and all non-native species.

The Data Gap
Existing data on non-native plants from many state and federal agencies, nongovernmental organizations, and universities have not been integrated to provide consistent information over large areas. Further, there is no single program that has the authority or mission to collect these data from field sampling.

Options for Filling This Data Gap
There are three options for filling this data gap. The first is to rely upon existing programs in federal, state, and local agencies that that collect these data, and to develop mechanisms to ensure consistency in data collection and reporting and a central mechanism to aggregate the data. The second option would be to develop a standardized survey and sampling approach that would provide national and regional-level data, and the third would rely on not-yet-developed (or not widely available) remote sensing methodologies.

There are a number of existing programs that collect data on non-native species in grasslands, with different programs collecting different data on different scales and with different methods. Data from these various sources must be evaluated to determine its suitability for aggregation to provide regional and national estimates of the area occupied by non-native plant species. The Heinz Center is currently undertaking a preliminary feasibility study to identify data sources that might be used to report on this indicator. Because this survey is collecting general data about a wide range of data sources and topics, some additional funding might be needed to explore in more detail the candidate data sources that might be useful for this indicator.

This preliminary study will help determine the extent and coverage of the data collected by existing programs and determine its suitability for reporting on plant cover. Additional work will be needed to quantify the need for additional collection, and assess the feasibility of ensuring consistency in data collection and reporting methods. Such a study would also have to determine the nature and scale of a central reporting effort (i.e., to collect the data from multiple sources, address methodological differences, prepare reports, and the like). We estimate this cost at approximately $500,000.

The second option would be to implement a nationally consistent effort to collect these data. USDA's Natural Resources Conservation Service, which operates the National Resources Inventory (NRI), provided the estimates shown here.

These estimates assume that monitoring will take place within the National Resources Inventory framework and would include both private and federal rangelands. NRI sampling and statistical criteria, protocols, and methodologies would be adopted. To cover both public and private lands adequately would require sampling 14,000 primary sampling units (PSUs) each year. (This approach would produce a statistically valid national estimate after the third year, and then every year thereafter.) The revisit cycle for any specific point would likely be every 5 years. According to NRCS, high-quality NRI imagery and photo interpretation are also necessary for locating each PSU.

Costs of a new national program (startup costs not provided)	
Personnel	$1,050,000
Imagery and maps	$ 770,000
Photography interpretation	$ 262,500
Statistical support	$ 400,000
Total	$2,482,500 per year

NRCS also recommends that ancillary data on land use and management should be gathered in order to link sampled properties to trends observed in the data. Further, since sampling costs include obtaining permissions and travel to sites, data collection opportunities should be optimized by sampling for multiple purposes, as is allowed within the NRI framework.

The above cost estimates are somewhat conservative, and sample size may need to be increased to provide adequate coverage (e.g., NRI grazed forest lands and pasturelands are not included in the above). However, personnel costs could potentially be decreased if trained technicians or students conduct the sampling.

The third option involves remote sensing methodologies that are likely to be developed in the near term and that will be able to identify many common/widespread non-native species. It is not now possible to predict the cost of these approaches.

Feasibility Rating

Filling this gap is rated as "challenging." There are two options for filling this gap, both of which require development of new institutional arrangements (and in one case, a field data collection program). Reliance upon the Natural Resource Conservation Service's National Resources

Inventory would require expansion of the NRI program onto federal lands, which has not been done before, and development of field protocols and practices, training of staff, etc. Reliance upon existing data would require completion of a feasibility study to decide whether these data are in fact sufficient; to identify an institution to gather, analyze, and synthesize the data from a potentially very large number of sources on a regular basis; and to outline any additional data collection needs.

Other Notes
This indicator is currently under review by a group of experts, with the goal of improving the full suite of non-native species indicators presented in 2002 *The State of the Nation's Ecosystems* report. Early indications are that this Task Group will continue to recommend areal coverage by non-native species as an important indicator.

System: Farmlands
Indicator: Non-native vegetation
Data Gap: Non-native Vegetation in Farmland Areas

Estimated Cost to Fill Data Gap

The following are based on the options outlined in the previous description (non-native plant cover – grasslands and shrublands), adjusted for the smaller amount of land to be covered.

Option 1:	Utilize data from existing programs	
	Feasibility study:	Preliminary assessment under way. Additional funding ($500,000) will be required. (This is the same study as described in the grasslands/ shrubland estimate above and should not be double counted.)
	Ongoing costs:	Unknown
Option 2:	New national program	$1.24 million per year
	Ongoing costs:	No startup cost estimates provided
Option 3:	Remote sensing	Speculative

System: Fresh Waters
Indicator: Non-native species
Data Gap: Aquatic animals and plants

Estimated Cost To Fill Data Gap

Option 1: Literature/Museum-Based Surveys	$680,000 startup $240,000 per year
Option 2: Field Surveys	
Fish and invertebrates, 1–2-year cycle	$2.5 million (startup) $10-12 million per year
Plants or nonfish vertebrates (e.g., amphibians, mammals)	Not Available

Indicator
This indicator reports the percentage of all hydrologic units having one of several ranges of established non-native species. Introduced species are those that are not native to the watershed in which they are found. These species may be from outside North America, or they may be from another part of this continent. Established species are those that have established persistent breeding colonies.

The Data Gap
USGS maintains the Nonindigenous Aquatic Species (NAS) database. NAS data for fish were used in the 2002 *State of the Nation's Ecosystems* report, but the database managers did not believe that data on other aquatic vertebrates, invertebrates, or plants were of sufficient quality for national reporting purposes.

Feasibility Rating
Filling this gap is rated as "moderately feasible" because it would require expansion and enhancement of the existing mechanisms for reporting on non-native species. These currently involve reports from an extended but informal network of observers in federal, state, local, and nongovernmental entities, supplemented by literature reviews, and organized by USGS. Thus, this gap would require a planning effort to develop the field protocols and possibly the federal–state institutional arrangements to undertake the work on a nationally consistent basis.

Options for Filling This Data Gap
There are two options for filling this data gap. The first is to report on the distribution of non-native aquatic plants and animals (except fish, for which data are available at present) by using information from existing literature and museum collections. The second option would be to augment these data with field survey work.

The costs shown for literature and museum-based option would make the information on taxonomic groups other than fish comparable to that which currently exists for non-native fishes (and thus suitable for national reporting). The higher costs for the plant field surveys reflect the lack of sufficient existing expertise and manpower within USGS.

According to USGS, augmenting literature and museum-based information with field data could be accomplished through an effort involving both existing programs, such as the USGS

Biomonitoring Environmental Status and Trends (BEST), combined with a reporting network involving states and other parties. USGS believes this effort should, if established, include fish, in addition to other taxonomic groups, despite the fact that some data are already available on non-native fish distributions. (Expanding to field surveys would greatly improve the quality and timeliness of fish data, when compared to the existing literature-based data.)

USGS believes that a program that provides data on a 1–2-year cycle (important because of the rapid expansion of many non-native species), and that includes invertebrates and fish (but not other vertebrates or plants) would cost approximately $2.5 million to start and about $10-12 million per year to operate.

Finally, it should be noted that any estimates for field surveys are dependent upon the spatial extent of the sampling, the resolution, and the level of confidence desired.

Options	Initial/Startup Costs	Ongoing (Annual) Costs
Literature / museum	180,000 (animals) $500,000 (plants) $680,000 total	$90,000 (animals) $150,000 (plants) $240,000 total
Field surveys		
Fish, invertebrates	$2.5 million	$10–12 million
Plants, nonfish vertebrates	Not Available	Not Available

This indicator is currently under review by a group of experts, with the goal of improving the full suite of non-native species indicators presented in 2002 *The State of the Nation's Ecosystems* report. It is likely that this Task Group will recommend changes in the basic indicator described here, which may increase the cost of reporting.

System: Coasts and Oceans
Indicator: Non-native species
Data Gap: Indicator definition required

Estimated Cost To Fill Data Gap

Not available. This indicator was undefined in the 2002 *State of the Nation's Ecosystems* report. A multi-ecosystem task group is now working to define and recommend an indicator and to assess data needs.

BIOLOGICAL COMMUNITY CONDITION MEASUREMENTS

Gap or Cluster Definition
This gap includes expansion and increased consistency among measures of the condition of biological communities in fresh waters, and data collection for the as-yet undefined core national

indicator of the "condition of plant and animal communities" (which may include the fresh water indicator).

Costs To Fill This Gap

Information provided here is for the freshwater portion of this gap only. No cost estimates are possible without further definition of the core national indicator.

Filling this gap could be accomplished through ensuring consistent implementation of data collection programs at the state level, or through a national (federal) program.

Most states are developing or have implemented programs to measure biological integrity, but an assessment would be required to determine the comparability of these state programs and either develop means to use information from different programs or estimate the costs and feasibility of having states move toward a common, comparable standard.

EPA estimated that a nationally consistent program would cost $50 million per year ($25 million for streams/wadeable rivers and $25 million for lakes). This program would provide data on a number of parameters in addition to biological integrity, including water chemistry, clarity, fish tissue contaminants, riparian/shoreline characteristics, and watershed characteristics. EPA was not able to provide information on whether this program could be implemented on a longer time scale (e.g., providing estimates every 5 years instead of annually), but we have assumed that this would be possible and that reporting would occur every 5 years, thus reducing the annual costs.

Options For Filling Gap	Initial Costs	Ongoing Costs
State-based program	Study required	Not Available
Federal program	Not Available	$10 million / year

Feasibility Issues

Filling this gap through a state based program is considered to be "challenging," because ensuring consistency among a large number of programs, some of which have been in place for some time, is always difficult. Filling the gap through a federal program is considered "moderately feasible," because EPA has developed the general framework for implementing such programs. Implementation as an operational program would require additional planning, but this is achievable. However, measuring biological condition in lakes is not as well developed as for flowing waters, and this portion would require more time and research to implement fully.

ABOUT THE GAPS

Core National **Condition of Plant and Animal Communities**
Fresh Waters **Status of freshwater animal communities**

System: Core National Indicators
Indicator: Condition of Plant and Animal Communities (undefined indicator)
Data Gap: Undefined indicator

Estimated Cost To Fill Data Gap

Estimates not available

Indicator
This indicator, as it was described in the 2002 report, would report on the percentage of land area and stream and coastline length according to the level of disturbance, management, or physical alteration. The indicator was listed as "undefined" because there were substantial uncertainties about several aspects.

The Data Gap
Work is currently under way to define this indicator for the 2007 report, but it is not yet possible to provide either a description of the indicator or an assessment or potential data sources.

Feasibility Rating
See above

Options for Filling This Gap
See above.

System: Fresh Waters
Indicator: Status of freshwater animal communities: fish and bottom-dwelling animals
Data Gap: Consistent nationwide criteria and implementation

Estimated Cost To Fill Data Gap

Existing Data Sources:	Costs unavailable at this time	
National Program:	Streams / wadeable rivers:	$25 million per year
	Lakes / reservoirs:	$25 million per year
	Larger rivers	Costs unavailable at this time

Indicator
This indicator reports on "biological integrity"—the degree to which the suite of fish and bottom-dwelling animals in a lake or stream resembles what one might find in a relatively undisturbed lake or stream in the same region. Tests assess the number of different species, the number and condition of individuals, and food chain interactions for fish and bottom-dwelling

(or benthic) animals, which include insects, worms, mollusks, and crustaceans. High scores indicate close resemblance to "natural" conditions, and low scores indicate significant deviation from them.

The Data Gap
While biological integrity is measured in many places, there are important gaps in geographic coverage, and there are important impediments to use of data that are collected. These impediments include, first, the fact that current techniques are generally applicable to streams and wadeable rivers; those for larger rivers and lakes are not well developed. Secondly, different states and agencies (including EPA) use different methods. Differences include whether comparisons are made to "average" sites or to "minimally impaired" sites and on how quantitative rankings are used (e.g., EPA uses an index of biological integrity (IBI) scaled to 100, while some state programs use a scale of 1 to 60).

There are currently no national criteria for assessing biological integrity, but EPA has published guidelines for the development of such criteria, and methods and criteria for several regions and states are under development.

In order to develop a nationally consistent set of observations, there must be consistency in key aspects of the monitoring in different states. Without a common reference condition, IBI rankings will not be comparable from state to state. In addition, comparing testing results from different places requires some consistency in scoring methods. Finally, it is important that sampling be sufficiently intensive to obtain sound estimates of the "true" condition of a water body or a region.

Feasibility Rating
Filling this gap is rated "challenging" because, while there are a large number of states that have begun to employ the required "indices of biological integrity," these developments have occurred without any overall consistency. Implementing this indicator on a more consistent basis would therefore probably require some states to modify their existing practice. Alternatively, if a nationally consistent, centrally implemented program were chosen for implementation, both USGS and EPA have experience in conducting large-scale water-related monitoring and this experience could be used in developing a new program.

Options for Filling This Data Gap
There are two options for filling this gap. The first would involve reliance upon the extensive efforts of states and other entities already collecting biological integrity data; the second would involve establishment of a nationally consistent program to provide state and national-level estimates of biological integrity.

Existing Data Sources

Reliance upon existing data collection sources would require

- Establishment of nationally consistent methods for collecting and interpreting data. This step would require completion of the methods development currently under way (for

lakes and larger rivers) and negotiation of a consensus among all states on the use of consistent methods or development of cross-walking approaches that enable data from different states to be aggregated in a statistically responsible fashion. These methods should include consistent approaches for streams/wadeable rivers, larger rivers, and lakes, and should provide guidance on the statistical selection of sampling sites.

- Assessment of the current geographic coverage of monitoring.

- Augmentation of monitoring where needed to ensure the statistical soundness of any estimates or to address other gaps.

Development of nationally consistent monitoring approaches among the 50 states, particularly when many states are implementing methods that might need to be changed, is a non-trivial challenge. EPA has developed technical guidance for assessing biological integrity, but a significant effort would be required to ensure consistent state implementation. State resources for both methods development and monitoring are limited, and states often develop methods that are tailored for their specific needs. Achieving consistent state implementation will require attention to the incentives for states to modify their approaches (and spend money) and to the appropriate allocation of financial responsibility for water quality monitoring.

Implementing this approach would probably require a significant initiative on the part of the Environmental Protection Agency to complete the technical methods development and enter into negotiations with states to implement statistically sound, methodologically consistent assessment approaches. Identification of unmet monitoring needs and resource requirements would have to be undertaken as part of this activity.

Nationally Consistent, Centrally Implemented Program

EPA's Environmental Monitoring and Assessment Program has developed estimates of the cost of implementing a statistically based random sampling approach to assessing multiple water quality parameters on a nationwide basis. This approach would cover streams / wadeable rivers and lakes (larger rivers would not be covered by the estimates described here), and would provide estimates of condition that are valid at both the state and national level.

EPA estimates that this monitoring program would cost $25 million a year for the streams/wadeable rivers portion, and $25 million a year for the lakes / reservoirs portion. This program would monitor multiple parameters in addition to biological integrity.

Several aspects of this estimate have not been clarified by EPA. Importantly, they involve whether this monitoring must be done annually or whether it could be spread over a 5-year reporting period (thus substantially reducing costs); the number of lakes to be sampled is also unclear, which has large cost implications. Thus, these estimates may be higher than warranted.

Gap or Cluster Definition

This cluster includes two overlapping gaps–stream habitat quality generally (freshwater indicator) and stream habitat quality in farmlands areas (farmlands indicator). The third, closely related, indicator is riparian area condition in grasslands and shrublands. All three indicators were described as "needing development" in the 2002 report; that is, no specific metrics were identified. Stream habitat condition is described largely, although not exclusively, in terms of in-stream characteristics (ripples/pools, sediment, large woody debris, bank stability). Riparian condition includes such factors as water flows, streambed physical condition, riparian vegetation composition, structure, and use by different species.

Costs To Fill This Gap

Without clear definitions of the specific metrics that might be used, and in particular the degree to which they might be measurable using remote sensing, identifying costs is quite difficult. A very rough estimate is that a effort of as much as $10 million, over several years, would be required to develop and test the indicator parameters. Actual reporting, based on 1- or 5-meter remote sensing imagery across the entire country, could cost as much as $10 million per 5- or 10-year reporting cycle.

Gap Description	Initial Costs	Ongoing Costs
Indicator design	$10 million	
Indicator monitoring and reporting		$1–2 million/year

Feasibility Issues

Filling this gap is considered to be "challenging." The specific metrics have not been identified (including whether a remote sensing–based indicator is feasible), and no agency or network of agencies currently manages data collection that is focused on the same or similar characteristics and habitat factors on an operational basis. It would clearly be several years before this indicator could be made operational.

Farmlands	**Stream habitat quality**
Fresh Waters	**Stream habitat quality**
Grasslands/Shrublands	**Riparian condition**

System: Fresh Waters, Farmlands, Grasslands and Shrublands
Indicator: Stream habitat quality, riparian area condition
Data Gap: Undefined indicators

Estimated Cost To Fill Data Gap

Initial Cost:	$10 million
Ongoing Costs:	$1–2 million

These are very rough estimates, based on the assumption that it is possible to obtain sufficient data to report on these indicators using high resolution remote sensing imagery.

Indicator: Stream Habitat Quality
This indicator, as described in the 2002 *State of the Nation's Ecosystems* report, would describe stream habitat quality by comparing the habitat in any given stream segment against the habitat that would be found in a relatively undisturbed stream in the same region. The index used for comparison would incorporate the presence of riffles and pools, the size of streambed sediments and the degree to which larger gravel and cobbles are buried in silt, the presence of branches, tree trunks, and other large woody pieces, and the stability of the bank.

Indicator: Riparian Condition
This indicator would describe the condition of riparian (streamside) areas. The condition of these areas will be rated using an index that combines key factors such as water flows, streambed physical condition, riparian vegetation composition and structure, and use by various species.

Data Gap
Both of these indicators were listed as "needing development" in the 2002 report because there are multiple methods, each apparently with its own strengths and weaknesses, for assessing stream habitat quality and riparian condition. In the absence oft some approach to reconciling these methods or choosing one as a primary method, the project team decided not to select one specific method. In addition, methods for using high resolution (i.e., 1- or 5-meter) are still under development.

Feasibility Rating
Filling this gap is rated as "challenging," for several reasons. The first is that there needs to be a "shaking out"—based on testing multiple methods across a range of ecosystem conditions—to determine the "best" method, or to develop approaches to combining data from different methods. Second, this method (or these methods) needs to be applied in a manner that will support valid statements about the overall condition of the nation's stream habitat. One method

for doing so would be to collect a fairly large number of field samples, distributed throughout the United States to support regional and land cover (e.g., farmland) estimates. A second method, currently being researched, would use high-resolution remote sensing imagery, combined with ground truthing.

Options for Filling This Gap

There are several major options for filling this gap. For field programs, it would be possible to develop a unified, probably federal, program to collect these data on a sufficiently broad scale to support the needed reporting. Alternatively, it would be possible to employ a distributed data collection approach in which states, federal agencies, and perhaps others collect the data where it was needed, and using consistent protocols. Presumably, standards and incentives could be employed to encourage participation.

Reporting on this indicator using remote sensing would require one or multiple entities to acquire the required data and conduct appropriate analyses and reporting.

Gap or Cluster Definition
This gap relates to the availability of information on the fraction of the nation's major regional aquifers in which water levels are declining, increasing, or stable.

Costs To Fill This Gap
Filling this gap would require an assessment of the coverage and comparability of existing data and development of methods for comparing results from different aquifers. Because USGS believes that existing data collection is not adequate, we have assumed that costs would be incurred to implement monitoring in perhaps 30 regional systems for which data are not currently adequate. Finally, data collection from multiple federal, state, and local sources would require funding, but estimates are not available for this element.

Gap Description	Initial Costs	Ongoing Costs
Assessment of existing data	$0.5 to $2 million	
First-time data collection (filling gaps)	$4–6 million (over 5 years)	
Ongoing data collection		$0.4–$0.8 million per year
Data aggregation and reporting		Not Available
Total	**$4.5–$8 million**	$0.4–$0.8 million per year

Feasibility Issues
Filling this gap is considered "moderately feasible." Many of the elements are in place— many aquifers are monitored, and USGS has field and analytical capabilities that are clearly adequate for this task. Complicating factors include the need to develop the procedures to aggregate data from many different sources (including reconciliation of dissimilar data) and to develop the mechanisms to gather data from many sources and provide integrated reporting.

ABOUT THE GAP

System: Fresh Waters
Indicator: Groundwater levels
Data Gap: Geographic coverage and data aggregation

Estimated Cost To Fill Data Gap

Feasibility study (years 1–3)	$500,000 to $1.0 million (total)
New data collection for 30 major aquifer systems	
First time (5 years)	$4 to $6 million total ($0.8 to $1.2 million per year)
Continuing	$0.4 to 0.8 million per year
Data aggregation and reporting	Estimate not available at this time

Indicator
This indicator would describe changes in water levels in major regional aquifers by reporting the fraction of the total area of regional aquifers that declined, increased, or remained stable in comparison to a previous period, and would be reported every 5 years.

The Data Gap
Despite the availability of groundwater level data in many states and for portions of many major aquifer systems, there are significant gaps in monitoring of water levels, and the data that are available have not been aggregated to provide national, regional, or often even aquiferwide assessments. USGS recently outlined the steps necessary to develop such an indicator program, in response to a request from Congress. This outline indicated that a year or more would be required to conduct a survey to identify existing data relevant to groundwater indicators and to determine appropriate ways to synthesize these data. Specific indicators and data reporting processes (i.e., national, regional, and sectoral) could then be developed.

To ensure national coverage, the following points must be addressed:

- Data must be collected from areas that represent the full range of topographic, hydrogeologic, climatic, and land use environments within the major aquifers.

- Data must be collected using standardized methods from monitoring wells or other wells not affected by local pumping. There must also be consistency regarding the timing of measurements so that the status of major aquifers in a region or in the entire country can be presented as a snapshot in time. Finally, there must be agreement on methods for comparing results from different aquifers—consistent definitions for aggregate categories such as "significant increase," "significant decrease," and "no significant change" are required.

- Plans must be in place to ensure long-term viability of observation-well networks and data collection programs, including plans for a combination of data collection at long-term monitoring wells and periodic synoptic measurements.

- There must be agreement among the agencies or other sources of data on electronic data storage, access, and dissemination. The agencies that will be responsible for leadership in compiling and publishing the data must be identified.

Feasibility Rating
Filling this gap is rated as "moderately feasible" because the U.S. Geological Survey has the expertise to undertake the required assessments or to provide consistency to assessments undertaken by other federal, state, or local entities. However, there are no established mechanisms for conducting these assessments on a regular basis, and it may be that additional data will need to be collected or research conducted to enable reporting on specific aquifers.

Options for Filling This Gap
Filling this data gap will require three separate steps.

The first is an assessment of the availability, quality, coverage, and consistency/comparability of existing water-level data. This information will form the basis for detailed planning to fill key

gaps, for the identification of the need for and feasibility of changes in existing practice needed to provide consistent data and of the cost of those changes, and for the design of a system for data aggregation and reporting.

We estimate the cost of this feasibility study at between $500,000 and $1.0 million; it will require approximately 2-3 years.

The second step would involve the implementation of monitoring in major areas for which data are not presently collected. USGS believes it is reasonable (as an initial estimate) to plan on such monitoring in approximately 30 major aquifer systems, at a first-time cost of $4 million to $6 million and a continuing cost of $2 million to $4 million. These costs would begin after the assessment of data availability and would be spread so as to provide national estimates every five years. Thus, costs would be as follows:

Years 1-3	$500,000 to $1.0 million in total – data availability assessment
Years 4-8	$0.8 M to $1.2 M per year – initial data collection for new areas
Years 9 onward	$0.4 to $0.8 M per year – ongoing data collection

The third step would involve the aggregation and reporting of data from both new and existing data sources on a continuing basis. No estimate of additional costs (above those for the 30 major systems, outlined above) is available.

Appendix C

Other Data Gaps Identified in 2002 *State of the Nation's Ecosystems* Report

CORE NATIONAL INDICATORS

System: Core National Indicators
Indicator: Ecosystem Extent
Data Gap: Extent of brackish waters

The Indicator

The indicator uses the extent of brackish waters as an ecologically based definition of the scope of the nation's "coastal waters." The overall indicator presents the area of the four major land-based ecosystem types covered in this report (forests, farmlands, grasslands and shrublands, and urban and suburban areas) as a percentage of the total U.S. land area. It also reports on a key component of freshwater ecosystems (freshwater wetlands).

The Data Gap

Some data on salinity are collected on a local or regional basis; however, these data are not compiled into a single, easily accessible source.

System: Core National Indicators
Indicator: Chemical Contamination
Data Gap: Saltwater fish (whole)

Indicator

The overall indicator reports on contaminants found in streams, groundwater, sediment, and fish tissue. Two types of reporting are done for this indicator: the frequency of detection (i.e., percentage of sampled sites in which contaminants are detected) of contaminants and the frequency with which these occurrences exceed established human health standards and guidelines and aquatic life guidelines.

The Data Gap

Data were not available to report on saltwater fish tissue, either for frequency of detection or for comparison with human health standards (edible portion) or wildlife consumption/aquatic life guidelines (whole fish). The human health standards gap, which generally requires analysis of the edible portion of fish, is rated as high priority (see p. 40)

System: Core National Indicators
Indicator: Outdoor Recreation
Data Gap: Data on running and jogging; distinction between freshwater and saltwater activities

Indicator

The core national indicator reports the number of times Americans over the age of 15 took part in a variety of outdoor recreational activities. (Each time someone took part in an activity is counted: if the activity took place over multiple days, each day counts as a separate event, and if

a person took part in several activities on a single day, each activity is counted as a separate event.)

The Data Gap
The USDA Forest Service's National Survey on Recreation and the Environment (NSRE), which collects data on the public's participation in outdoor activities, does not provide data on running and jogging. In addition, it does not distinguish between salt water and fresh water for the majority of water-related activities (i.e., all those other than fishing), thus also making it impossible to report on freshwater-related activities.

System: Core National Indicators, Freshwater
Indicator: Outdoor Recreation (Core National Indicator)
Data Gap: Participation in Freshwater Recreational Activities (Freshwater)

Indicator
The core national indicator reports the number of times Americans over the age of 15 took part in a variety of outdoor recreational activities. (Each time someone took part in an activity is counted: if the activity took place over multiple days, each day counts as a separate event, and if a person took part in several activities on a single day, each activity is counted as a separate event.)

The freshwater indicator reports on the number of times Americans took part in a variety of water-related activities (e.g., swimming, boating, hunting, fishing).

The Data Gap
The USDA Forest Service's National Survey on Recreation and the Environment (NSRE), which collects data on the public's participation in outdoor activities, does not provide data on running and jogging. In addition, they do not distinguish between saltwater or freshwater for the majority of water-related activities (i.e., all those other than fishing), thus also making it impossible to report on freshwater related activities.

System: Core National Indicators
Indicator: Natural Ecosystem Services
Data Gap: Indicator Requires Further Development

The Indicator
This indicator would report on the levels of key services provided by "natural" ecosystems—forests, grasslands and shrublands, fresh waters, and coasts and oceans. The goods, or products, these ecosystems provide—such as fish, wood products, and food—can be counted, and a monetary value often placed upon them. Some services, such as recreation, are also fairly easily quantified. But many of the services provided by natural ecosystems are less tangible and more difficult to quantify, including such vital processes as purification of air and water, detoxification and recycling of wastes, regulation of climate through storage of carbon dioxide, regeneration of

soil fertility, and maintenance of the earth's startling variety of plants and animals, which we use to sustain ourselves, but which we also enjoy for their own sake. Natural ecosystem processes reduce the severity of floods, promote pollination of crops and natural vegetation, ensure dispersal of seeds, control agricultural pests, and protect coasts and hillsides from erosion.

However, this indicator is not sufficiently defined to permit identification of specific data gaps.

COASTS AND OCEANS

System: Coasts and Oceans
Indicator: Coastal living habitats (coral reefs, wetlands, seagrasses, and shellfish beds)
Data Gap: Lack of data on extent of shellfish beds

Indicator

The overall indicator reports the acreage over time of coastal habitats whose defining feature is that they are composed of living organisms (such as seagrasses, mangrove forests, and coastal wetlands) or are built by them (such as coral reefs or shellfish beds).

The Data Gap

Data are not available to describe and track the extent of shellfish beds. The only potentially related national information is from the NOAA-produced National Shellfish Register of Classified Growing Waters. The Register has been produced every 5 years since 1966; the most recent is the 1995 Register, released in 1997 (http://spo.nos.noaa.gov/projects/95register/). The Register summarizes the number and area of shellfish beds in estuarine and nonestuarine commercial shellfish-growing waters, which are classified as such according to sanitary guidelines administered by the Interstate Shellfish Sanitation Conference (ISSC). States have been encouraged to monitor as broad a range of shellfish growing areas within their waters as possible, in order to protect public health. However, this source does not provide data on non-commercial shellfish beds and relict beds, which can still provide habitat for other species. Furthermore, the area of beds reported can change because of a change in the area being monitored, rather than an actual change in area of shellfish beds.

System: Coasts and Oceans
Indicator: Shoreline Types
Data Gap: Lack of data for certain regions; lack of regularly repeated monitoring

Indicator

The overall indicator reports the miles of coastline in several categories, including beach; mud or sand flats; steep sand, rock, or clay cliffs; wetlands; and coastline "armored" with bulkhead or riprap. The coastline includes oceanfront areas and the shoreline of estuaries and bays.

The Data Gap

Data are not currently available for six of nine coastal regions (North Atlantic, Mid-Atlantic, Gulf of Mexico, Gulf of Alaska, Bering Sea, and Hawaii).

System: Coasts and Oceans
Indicator: Areas with Depleted Oxygen
Data Gap: Adequate monitoring coverage, consistent data collection, aggregation of data

Indicator

This indicator will report, for estuaries and coastal waters 25 miles out to sea, the percentage of area where the lowest oxygen levels fall within specified concentration ranges for at least 1 month: anoxic (no oxygen present), hypoxic (up to 2 parts per million, or ppm), low (between 2 and 4 ppm), and adequate (more than 4 ppm).

The Data Gap
There are a large number of measurements of dissolved oxygen taken in estuaries and open waters of the ocean by state, federal, academic, and other programs. However, two problems remain. The first is that there is no mechanism in place to assess the spatial and temporal coverage and precision of these efforts to determine where sampling is adequate for reporting on this indicator and to assemble and report those data. The second is that there are believed to be significant areas in which existing sampling is inadequate because it is too infrequent, too widely scattered, insufficiently precise, and so on.

System: Coasts and Oceans
Indicator: Contamination in Bottom Sediments
Data Gap: Lack of data for certain estuary areas; lack of data for nonestuary areas within 25 miles of shore (Note: depending upon funding, this gap may extend to ALL estuary data. See text below.)

Indicator
This indicator reports the percentage of sediments that exceed federal guidelines for concentrations of four major classes of contaminants—pesticides, polychlorinated biphenyls (PCBs), polycyclic aromatic hydrocarbons (PAHs), and heavy metals. The indicator reports on estuaries and ocean waters within 25 miles of the coast that have bottom sediments with varying degrees of contamination, the lowest indicating *possible* effects on fish and other aquatic organisms from 1 to 4 contaminants and the highest indicating *probable* effects from at least one contaminant.

The 2002 report provided data for estuaries in the Mid-Atlantic, South Atlantic, and Gulf Coast regions, while the 2003 Web update provided data for estuaries in the North Atlantic, Southern California, and Pacific Northwest.

The Data Gap
No program exists to provide nationally consistent data on sediment contamination in ocean waters (i.e., outside of estuaries) along the coast. In addition, even though the 2002 report and 2003 Web update included data for estuarine areas for this indicator, there is considerable uncertainty about EPA's ability to provide these data in the future. These data were provided by EPA's Environmental Monitoring and Assessment Program (EMAP), but it is highly likely that EMAP will not continue to provide these data in the future. EMAP is a research and development program, and according to EPA, production of these data on an ongoing operational basis is dependent upon implementation of a "national coastal assessment," a program for which the future funding picture is unclear. Thus, while data are available now for the nation's continental coastline, for the future this entire indicator may be considered a "data gap."

System: Coasts and Oceans
Indicator: Coastal Erosion
Data Gap: Lack of consistent data collection and lack of aggregation of existing data

The Indicator
This indicator will report how much of the U.S. coast is managed in an attempt to control erosion and how much remains in a "natural" state, with no erosion control. For "managed" areas, the indicator reports what fraction is armored or nourished. For unmanaged areas, the indicator reports what fraction is eroding, accreting (gaining land area), or stable.

The Data Gap
Shoreline stability assessments are now conducted as short-term or single-purpose projects, primarily at the local level. Data collection methods and analysis protocols of local assessments often differ, making comparison of site-specific reports and data compilation for regional or national reporting difficult. Such comparisons are also hindered by the lack of standard methods (e.g., what level of vertical change qualifies an area as "eroding," and for how long after a sand engineering project is completed should an area be considered "nourished"?)

System: Coasts and Oceans
Indicator: Unusual Marine Mortalities
Data Gap: Sea turtles; seabirds, fish, and shellfish

The Indicator
This indicator reports the occurrence of "unusual" mortalities of marine animals. Unusual mortality events (UME) are characterized by an abnormal number of dead animals or by the appearance of dead animals in locations or at times of the year that are not typical for that species. For larger animals like whales, dolphins, porpoises, seals, sea lions, sea otters, manatees, and sea turtles, where a small number of deaths is significant, the indicator will report the actual number of dead individuals. For smaller, more abundant, animals (seabirds, fish, and shellfish), the indicator will report the number of mortality events, rather than number of individual deaths.

The Data Gap
There is no program for seabirds, fish, and shellfish similar to that in place for marine mammals. Sea turtle strandings are monitored through NOAA, the Fish and Wildlife Service, and local partners, but significant improvements are needed to enhance reporting capabilities. Also needed are guidelines for what constitutes a UME for seabirds, fish, and shellfish, which typically perish in much larger numbers than mammals, and for sea turtles.

System: Coasts and Oceans
Indicator: Harmful Algal Blooms

Data Gap: Lack of data in certain geographic areas and lack of aggregation of existing data

Indicator
This indicator will report the number of harmful algal blooms (HABs) of low, medium, and high intensity for estuaries and ocean waters within 200 miles of shore. Harmful algal blooms are defined as an increased abundance of algae species that cause illness in people or marine animals or the actual occurrence of algae-caused illnesses.

The Data Gap
There are no nationwide monitoring or reporting programs for harmful algal blooms. In addition, a broadly applicable indictor system would require some scale on which to compare and aggregate blooms of different species, sizes, and durations. There are no currently accepted standards for defining blooms in this way.

System: Coasts and Oceans
Indicator: Benthic Conditions In Open Waters / Condition of Bottom-Dwelling Animals
Data Gap: Lack of continuing data production for estuaries and near-coastal waters (within 25 miles of shore)

Indicator
This indicator describes the condition of worms, clams, snails, and shrimplike animals in bottom sediments ("benthic communities") by reporting the percentage of area in which these communities are in "undegraded," "moderate," and "degraded" condition. The indicator is calculated by comparing the number and kinds of animals found in a sampling site with those that would be expected in an undisturbed area of similar character (a reference site).

The Data Gap
Few data are available on benthic community condition in coastal ocean waters (out to 25 miles).Data on benthic community condition and the methods necessary to interpret these data and combine them into community condition indices are available from most estuarine areas of the country with the exception of Alaska and Hawaii. These data were included in the 2002 *State of the Nation's Ecosystems* report (several regions) and updated (with additional regions—all except Alaska and Hawaii) in the report's 2003 Web update. However, even though data were reported for this indicator in both the 2002 report and the 2003 Web update, there is considerable uncertainty about EPA's ability to provide these data in the future. Data for the 2002 report were provided by EPA's Environmental Monitoring and Assessment Program (EMAP), but it is highly likely that EMAP will not continue to provide these data in the future. EMAP is a research and development program, and according to EPA, production of these data on an ongoing operational basis is dependent upon implementation of a "national coastal assessment," a program for which the future funding picture is unclear. Thus, while data are available now for the nation's continental coastline, for the future this entire indicator might be considered a "data gap."

System: Coasts and Oceans
Indicator: Chlorophyll concentrations
Data Gap: Lack of chlorophyll concentration data for estuaries

Indicator
The overall indicator reports the chlorophyll concentration in estuaries and ocean waters within 25 miles of shore. For estuaries, the indicator is intended to report the percentage of estuary area in three ranges: below 5 parts per billion (ppb), between 5 and 20 ppb, and above 20 ppb, using data for the season with the highest average concentration.

The Data Gap
Most estuaries are not sampled frequently enough or thoroughly enough to produce comparable data. Monitoring data do exist for some estuaries, but need to be assembled into a uniform, national database, and new programs would be required for the remaining estuaries. A combination of aircraft and satellite remote sensing and *in situ* measurements will be required to report on the estuarine component of this indicator.

System: Coasts and Oceans
Indicator: Status of commercially important fish stocks
Data Gap: Current data do not cover all stocks

Indicator
This indicator tracks the percentage of commercially important fish species, or "stocks," that are increasing or decreasing in size. Only stocks whose population increased or decreased by at least 25% are reported. Trends are based on the estimated weight, or "biomass," of the entire stock.

The Data Gap
There are 203 "stock groups" under federal fisheries jurisdiction, representing over 950 individual stocks. Of these 203, only 45 stock groups had sufficient information to support calculation of this indicator for the 2002 report. These stocks represent approximately 75% of the weight of fish caught in U.S. waters.

System: Coasts and Oceans
Indicator: Recreational Water Quality
Data Gap: Lack of consistent data on water quality at beaches used for contact recreation

Indicator
This indicator will report the percentage of "beach-mile-days" affected by various levels of *Enterococcus*, a bacterium that indicates contamination with human or animal waste. A "beach-mile-day" is one mile of beach affected for one day—100 miles of beach affected for one day would count the same as 1 mile affected for 100 days. These data would be presented in several categories (<35, 35–104, and >104 organisms per milliliter) and as a percentage of total beach-

mile-days (e.g., one week at 40 organisms/ml for 10 miles of beach would be 70 beach-mile-days in the 35–104 concentration range).

The Data Gap

While a great deal of information is collected on coastal recreational water quality (typically by city or country health departments), the data are scattered, incomplete, and inconsistent.

FARMLANDS

System: Farmlands
Indicator: Shape of "Natural" Patches in the Farmland Landscape
Data Gap: Analysis of existing data

Indicator

This indicator describes the shape of patches of "natural" lands in the farmland landscape by reporting on the percentage of the total patch area that is found in "compact" patches (e.g., like a circle), "elongated" patches (e.g., like a long narrow rectangle), and an intermediate class of patch shape. These classes are defined based on the ratio of the perimeter, or edge, of each patch to its area; these perimeter-to-area ratios will be divided by patch area for the sake of comparison. "Natural" areas include forest, grasslands and shrublands, wetlands, and lands enrolled in the Conservation Reserve Program. These data would be presented nationally and by region for the most current year.

The Data Gap

The land cover data necessary to report this indicator are available but have not been analyzed. Calculating this indicator using existing data will require specialized software designed to analyze landscape spatial patterns. The most commonly used software (Fragstats) for analyzing landscape spatial patterns is not capable of processing the very large file sizes that would be required to calculate this index for the nation. There may be simpler approaches with fewer computing demands, but these have not been fully explored. It might be possible to make use of existing remote-sensing data through a procedure involving random sampling.

System: Farmlands
Indicator: Soil salinity
Data Gap: Broad, consistent monitoring of salinity

Indicator

This indicator would report the percentage of cropland with different levels of salt content, measured in decisiemens per meter (dS/m). A map showing the percentage of land in major cropland regions with elevated salt levels would accompany the nationwide data.

The Data Gap

No unified program of data collection and analysis of soil salinity exists at the national level, and there is no monitoring program to detect changes over time.

System: Farmlands
Indicator: Soil Biological Condition
Data Gap: National-level monitoring program of nematodes

Indicator

This indicator would report the percentage of croplands in three different ranges on the Nematode Maturity Index (NMI), an index that measures the types of roundworms, or nematodes, in the soil. A map showing the percentage of cropland in each major cropland region with low index values (indicating disturbed soils) would accompany the nationwide data.

The Data Gap
The NMI has gained broad scientific acceptance and is a promising indicator, but no nationwide monitoring program has yet adopted it.

System: Farmlands
Indicator: Status of Animal Species In Farmland Areas
Data Gap: Indicator Requires Further Definition

The Indicator
This indicator would report on the status of wildlife in farmland areas. Farmlands—including both croplands and the patches of natural lands that are intermingled with them—are home to many kinds of wildlife. Some species would be found in the forests, grasslands, or shrublands from which the farmlands were created. Such species may find fewer habitat opportunities in farmland areas, but may take advantage of remaining patches of habitat and remain in the area, but at low population levels. However, there are many species that favor the kinds of conditions found in areas with extensive farmlands, and these species are often more common than they were before conversion to agriculture.

However, this indicator is not sufficiently defined to permit identification of specific data gaps.

System: Farmlands
Indicator: Recreation on Farmlands
Data Gap: Type and amount of recreation on farmlands

Indicator
This indicator would report the number of days spent fishing, hunting, viewing wildlife, or engaged in other recreational activities on the nation's farmlands.

The Data Gap
There are no national datasets that document the type and level of recreation on farmlands. Adequate reporting would require modification of existing surveys to elicit information either on the location of recreational activities or on the amount of recreation on farms.

FORESTS

System: Forests
Indicator: Forest Age
Data Gap: Nontimberland forests

Indicator

This indicator reports the percentage of forestlands in the West and the East with stands in several age classes (1–19 years, 20–59 years, etc).

The Data Gap

USDA Forest Service data are currently available only for timberlands. Data on the age class of forest trees are not available for national parks and wilderness areas and other forest land not classified as timberlands. Data on slow-growing forests and those in parks and wilderness areas are being collected, but they are not yet available.

System: Forests
Indicator: Fire frequency
Data Gap: Historic fire frequency

Indicator

This indicator describes the frequency with which grasslands and shrublands are burned by wildfire. It would report the fraction of these lands that experience wildfire much more or less frequently, moderately more or less frequently, or with about the same frequency as in presettlement times. This indicator requires information on both historic and current fire frequency.

The Data Gap

Current fire frequency data are generally available, but historic fire frequency data have been measured (from tree ring scars and similar evidence) at a relatively small number of sites across the United States.

System: Forests
Indicator: Recreation in forests
Data Gap: Type and amount of recreation in forests

Indicator

This indicator would report the number of days per year that people engage in a variety of recreational activities in forests. Activities such as walking, hiking and backpacking, fishing and hunting, wildlife viewing, cross-country and downhill skiing, and snowmobiling would be included.

The Data Gap

As of 2002, there were no national datasets that documented the type and amount of recreation in forests. Adequate reporting would e require modification of existing surveys to elicit information either on the location of recreational activities or on the amount of recreation in forested areas.

FRESH WATERS

System: Fresh Waters
Indicator: Extent of freshwater ecosystems
Data Gap: Length of streams and rivers by size or flow class

Indicator

This indicator reports the area of wetlands and lakes, reservoirs, and ponds and the length of small, medium, and large streams and rivers.

The Data Gap

No standardized method has been adopted and applied that classifies streams and rivers by relevant characteristics such as size or flow rates.

System: Fresh Waters
Indicator: Phosphorus in lakes, reservoirs, and large rivers
Data Gap: Phosphorus in lakes and reservoirs

Indicator

This indicator reports the average concentration of phosphorus in lakes, reservoirs, and large rivers. Total phosphorus concentrations are reported in four ranges: below 20 parts per billion (ppb), from 20 to 50 ppb, from 50 to 100 ppb, and 100 ppb or more.

The Data Gap

There are no datasets that are known to provide representative phosphorus values for the nation's lakes and reservoirs. Adequate reporting on lake phosphorus requires multiple samples (4–6) over the course of a year, and USGS estimates that at least 2000 lakes would need to be sampled to provide national (and probably regional or state-level) estimates.

System: Fresh Waters
Indicator: Water Clarity in Lakes
Data Gap: Geographic coverage

Indicator

This indicator would report the percentage of lake and reservoir area with low-, medium-, and high-clarity water (ponds are not included because of their shallow depth). A map would show regional patterns of change.

The Data Gap

Available data do not provide representative coverage at the national level because some areas are heavily sampled, while in other areas few or no lakes are tested.

System: Fresh Waters
Indicator: Animal Deaths and Deformities
Data Gap: Nonwaterfowl mortalities, amphibian deformities

Indicator
This indicator reports on the number of animals that died during unusual mortality events during five-year periods for waterfowl, fish, amphibians, and mammals, and on deformity events for amphibians.

The Data Gap
Mortality data for mammals and amphibians are currently collected by the U.S. Geological Survey (USGS), but these data are incomplete and therefore not suitable for national reporting. USGS also collects data on amphibian deformities, but no widespread monitoring program or systematic surveying is conducted. There is also no reporting mechanism for fish die-offs.

System: Fresh Waters (see also Core National Indicator)
Indicator: Participation in Freshwater Recreational Activities
Data Gap: Data on participation in freshwater recreational activities

Indicator
The indicator reports on the number of times Americans took part in a variety of water-related activities (e.g., swimming, boating, hunting, fishing).

The Data Gap
The USDA Forest Service's National Survey on Recreation and the Environment (NSRE), which collects data on the public's participation in outdoor activities, does not distinguish between saltwater or freshwater for the majority of water-related activities (i.e., all those other than fishing), thus making it impossible to report on freshwater related activities.

GRASSLANDS AND SHRUBLANDS

System: Grasslands and Shrublands
Indicator: Land Use
Data Gap: Data on the extent of livestock raising, oil/gas/mining, rural residences, "protected areas," and high-intensity recreation

Indicator

This indicator will describe how many acres of grasslands and shrublands are devoted to six major land uses: livestock raising, rural residences, oil and gas development and mining, Conservation Reserve Program (CRP) lands, "protected areas," and high intensity recreation.

The Data Gap

With the exception of CRP lands, there is no consistent reporting of the acreage in the six major land use categories listed above. A standardized set of definitions and criteria for classifying land uses is needed, along with the development of mechanisms to account for the acreage and changes in each category over time.

System: Grasslands and Shrublands
Indicator: Nitrate in grassland and shrubland groundwater
Data Gap: Data aggregation

Indicator

This indicator reports on the concentration of nitrate in groundwater in grassland and shrubland areas. Specifically, the indicator reports the percentage of groundwater sites with average nitrate concentrations in one of four ranges (less than 0.1 ppm, 0.1 to 0.5 ppm, 0.5 to 1 ppm, and greater than 1 ppm), in areas that are primarily grassland or shrubland.

The Data Gap

Data on nitrate concentrations in groundwater have not been aggregated to enable national reporting. Such data currently available in fragmentary form and are collected by many different agencies and institutions; the coverage, quality and comparability of these measurements is unknown.

System: Grasslands and Shrublands
Indicator: Depth to Shallow Groundwater
Data Gap: Data availability/integration

Indicator

This indicator will describe the depth to shallow groundwater in grassland and shrubland areas. Specifically, it will report the percentage of grassland and shrubland areas where the depth to groundwater falls within several ranges (less than 5 feet, 5 to 10 feet, 10 to 20 feet, and more than 20 feet).

The Data Gap
Limited data are available on shallow aquifers. Shallow aquifer levels have been mapped in some states, but the data have not been integrated. Because shallow groundwater depth is particularly important for the maintenance of riparian and wetland communities, measuring shallow groundwater depth along rivers and streams should be a higher priority than measuring it in other areas.

System: Grasslands and Shrublands
Indicator: Fire Frequency
Data Gap: Historic fire frequency

Indicator
This indicator describes the frequency with which grasslands and shrublands are burned by wildfire. It would report the fraction of these lands that experience wildfire much more or less frequently, moderately more or less frequently, or with about the same frequency as in presettlement times. This indicator requires information on both the historic and current fire frequency.

The Data Gap
Current fire frequency data are generally available, but historic fire frequency data have been measured (from tree ring scars and similar evidence) at a relatively small number of sites across the United States.

System: Grasslands and Shrublands
Indicator: Recreation on grasslands and shrublands
Data Gap: Type and amount of recreation in grasslands and shrublands

Indicator
This indicator will report the number of days per year that people engage in a variety of recreational activities on the nation's grasslands and shrublands. Activities will include hunting and fishing; off-road vehicle (ORV) driving, motorsports, mountain biking, and snowmobiling; bird watching and nature study; and hiking and camping. (Other categories necessary to describe grassland/shrubland recreation more fully may be added when data become available.)

The Data Gap
There are no national datasets that document the type and amount of recreation on grasslands and shrublands. Adequate reporting would require modification of existing surveys to elicit information either on the location of recreational activities or on the amount of recreation in grassland/shrubland areas.

URBAN AND SUBURBAN AREAS

System: Urban and Suburban Areas
Indicators: Urban Heat Island
Data Gap:

This indicator would describe the difference between urban and rural air temperatures for major U.S. metropolitan areas. Temperatures within urban areas would be compared to those in less-developed surrounding areas.

Extremely hot weather is responsible for greater loss of human life in the United States than hurricanes, lightning, tornadoes, floods, and earthquakes combined. Building density and type, amount of road surface, and energy use, as well as local topography and regional weather patterns, all work together to modify a city's climate. The urban heat island effect is often noticed most at night when buildings and other constructed surfaces radiate the heat they have accumulated during the day. Beyond posing a threat to human health (through heat stroke, for example) and raising air conditioning costs, the heat island effect can cause physiological stress in other animals, change the mix of plants and animals that live in the area, and even lead to changes in the distribution of pathogens. Elevated temperatures also accelerate the formation of ground-level ozone and other air pollutants that adversely affect human health.

However, this indicator is not sufficiently defined to permit identification of specific data gaps.

System: Urban and Suburban Areas
Indicators: Species status
Data Gap: Presettlement species lists and current status

Indicator
This indicator reports the percentage of "original" vertebrate animals and vascular plants that are at risk of displacement or have been displaced from metropolitan areas (i.e., major cities and their suburbs found within the urban/suburban areas defined by this report. This definition does not include smaller towns or broadly dispersed suburbanizing areas.) "Original species" are defined as those existing before European settlement in what is now a metropolitan area.

The Data Gap
The historical data necessary to establish lists of original species are incomplete, and current information on their status, especially within cities and their suburbs, is not systematically collected and reported. When available, the amount, quality, and format of such data are extremely variable.

System: Urban and Suburban Areas
Indicator: Disruptive species
Data Gap: Regional species lists; presence/absence by metropolitan area

Indicator

This indicator would report 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. Specifically, the indicator will report the number of larger metropolitan areas with 5 or fewer, from 6 to 10, from 11 to 20, and more than 20 disruptive plant and animal species. It would also report the number of disruptive native and non-native plant and animal species on a regional basis, for the most current year. (This indicator is being reviewed by a group of experts working to increase the consistency of indicators of non-native species for the 2007 *State of the Nation's Ecosystems* report. While this indicator addresses both non-native and native disruptive species, the review may result in changes to the indicator.)

The Data Gap
Regional lists of disruptive species do not exist. Creating them requires definition of thresholds that distinguish truly disruptive species from those that cause fewer problems, as well as consistent policies for including species based on their potential to cause damage, as shown by experiences in other locations. Monitoring and reporting programs also need to be put in place to track the occurrence of disruptive species. Many knowledgeable individuals and institutions could participate, but no entity currently has the mandate to coordinate such an activity.

System: Urban and Suburban Areas
Indicator: Status of Animal Communities in Urban and Suburban Streams
Data Gap: Urban / suburban coverage

Indicator
This indicator reports on "biological integrity" in streams in urban and suburban areas. Biological integrity is a measure of the degree to which the suite of fish and bottom-dwelling (or benthic) animals (including insects, worms, mollusks, and crustaceans) resembles what one might find in a relatively undisturbed stream in the same region. Tests assess the number of different species, number and condition of individuals, and food chain interactions. High scores indicate close resemblance to "reference" or undisturbed condition.

The Data Gap
Testing for biological integrity in streams is becoming more common, but these programs are generally implemented by states and appear not to provide adequate coverage, or, in the case of bi- or tri-state metropolitan areas, coordination and consistency between states, to enable statements to be made about metropolitan areas (as contrasted with an entire state or regions within it).

System: Urban and Suburban Areas
Indicator: Publicly Accessible Open Space per Resident
Data Gap: Identification of publicly accessible open space

Indicator

This indicator would report the amount of open space—land that is dominated by "natural" surfaces, like grass or woods, along with lakes, rivers, beaches, and wetlands—that is accessible to the general public in large metropolitan areas. Specifically, the indicator would report the percentage of metropolitan areas with different amounts of open space per resident.

The Data Gap
There are no consistent or comprehensive surveys of the amount of publicly accessible open space in cities and suburban areas. A combination of satellite remote sensing and local tax and land records would likely be required to report this indicator fully.

System: Urban and Suburban Areas
Indicator: Natural Ecosystem Services
Data Gap: Indicator Requires Further Development

The Indicator
This indicator is intended to report on the myriad services provided by natural ecosystems in urban and suburban areas. For example, forested areas reduce stormwater runoff, when compared to paved areas, and trees cool streets and buildings, reducing energy consumption; trees also reduce urban noise levels. Natural areas, including forests, grasslands and shrublands, beaches, lakes, streams, and wetlands, also provide recreational opportunities, increase property values and community amenities, and are aesthetically pleasing. A parallel core national indicator would provide these data for the nation as a whole.

However, this indicator is not sufficiently defined to permit identification of specific data gaps.