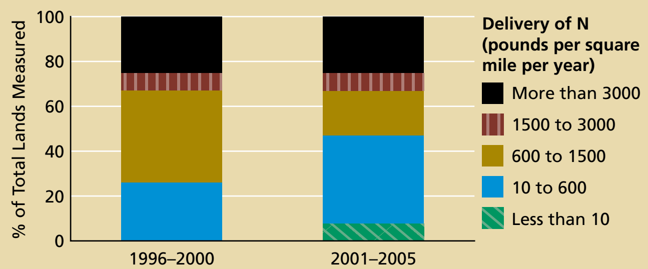
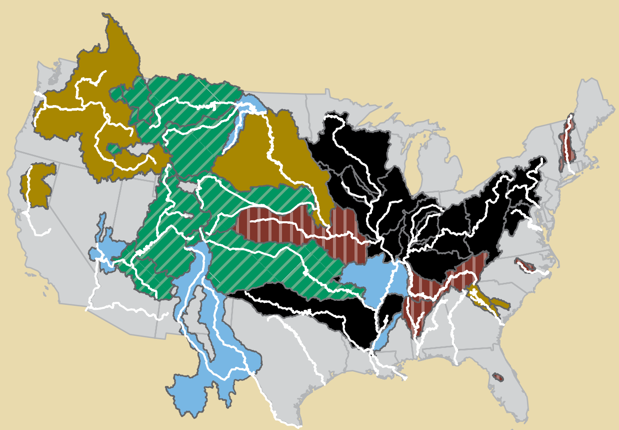
The Movement of Nitrogen

Delivery of Total Nitrogen to Streams and Rivers from Major Watersheds



Delivery of Total Nitrogen to Streams and Rivers from Major Watersheds (2001–2005)



Total Nitrogen (pounds of nitrogen per square mile per year)

Data not available | 10 to 599 | 1,500 to 2,999
Less than 10 | 600 to 1,499 | 3,000 and above

Data source: U.S. Geological Survey's National Stream Quality Network (NASQAN), National Water Quality Assessment (NAWQA), and Federal–State Cooperative Program. Coverage: areas of the lower 48 states with major river basins and available data. Technical details: The delivery of nitrogen to streams and rivers is averaged across the area of the watershed and reported as pounds of nitrogen per square mile.

Why Is the Movement of Nitrogen to Coastal Waters Important? Nitrogen is an important plant nutrient and is essential to all life. Nitrogen is an abundant component of the earth's atmosphere, but it is unavailable to most life in gaseous form. In order to be used by plants and other organisms, nitrogen gas must be "fixed," or converted to a "reactive" form, that plants can use, such as nitrate. Nitrogen is fixed and accumulates in ecosystems through natural processes, such as the growth of nitrogen-fixing plants like clover and soybeans. However, human activity has greatly increased the amount of reactive nitrogen added to ecosystems. The largest human-caused input of nitrogen to ecosystems comes from the conversion of atmospheric nitrogen gas into fertilizers. Additional reactive nitrogen gas is produced by the combustion of fossil fuels. Reactive nitrogen from all these sources can ultimately enter streams and rivers. Excess nitrogen transported to coastal waters by rivers can lead to low oxygen conditions, threaten fish and animal life, and degrade coastal water quality.

What Does This Indicator Report?

- For major watersheds, the amount of nitrogen that enters rivers and streams through discharges, runoff, and other sources
- For several major rivers, the input of nitrate to coastal waters (nitrate is often the most abundant form of nitrogen that is readily usable by aquatic plants and algae)
- When data become available, atmospheric deposition of nitrogen on coastal waters

What Do The Data Show?

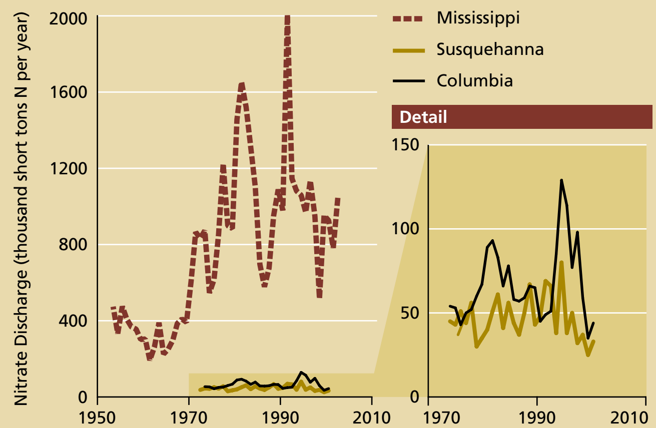
- Most of the watersheds with the most nitrogen delivered to streams and rivers are within the Mississippi River basin, which covers more than 40% of the land area of the lower 48 states.
- For 21% of the land area measured, the amount of nitrogen moving from the land to streams dropped from more than 600 pounds per square mile per year in 1996–2000 to less than 600 pounds per square mile per year in 2001–2005. More years of data will be needed in order to establish whether this is a downward trend or simply variability between years.
- The Mississippi, Susquehanna, and Columbia combined discharged approximately 1 million tons of nitrogen in the form of nitrate to coastal waters in 2002; the Mississippi alone accounted for more than 90% of the total.

The Movement of Nitrogen *(continued)*

- Between 1955 and 2004 the discharge of nitrate from the Mississippi doubled; since 1983, there has not been a significant trend in discharge, although additional years of data may reveal a statistically significant downward trend in discharge.
- There has been no clear upward or downward trend in nitrate input to the coast from the Susquehanna and Columbia rivers since records were first taken in the mid-1970s.

Why Can't This Entire Indicator Be Reported at This Time? A complete picture of nitrogen loading to coastal waters would account for all sources, including nitrogen deposited from the atmosphere to land and water surfaces. The data presented here include atmospheric nitrogen that enters coastal waters after being deposited on terrestrial and freshwater systems, but atmospheric nitrogen that is deposited directly onto coastal water surfaces is not included. Direct atmospheric deposition may represent an important source of nitrogen in coastal systems, but data are not available for reporting on the nation's coastal waters.

Nitrate Input to Coastal Waters by Major U.S. Rivers



Data Source: U.S. Geological Survey's National Stream Quality Network (NASQAN), National Water Quality Assessment (NAWQA), and Federal–State Cooperative Program. Coverage: major rivers with available data. Note that the 2002 Report included data for the St. Lawrence River, but monitoring of the St. Lawrence has since been discontinued.

Movement of Nitrogen

Data Gap

Data are not adequate for national reporting on atmospheric deposition of nitrogen on coastal waters.

Understanding the Data Nitrogen transported from the land to waterways, and ultimately to the ocean, can stimulate plant growth in coastal waters. Excessive growth of algae can lead to hypoxic areas in coastal waters (hypoxia is a term for very low oxygen conditions in which most fish and other marine animals cannot survive). For more information on hypoxia in coastal waters, see Areas with Depleted Oxygen, p. 75.

A variety of human activities increase the availability of nitrogen on land and the subsequent movement of nitrogen from streams and rivers into coastal waters. Humans "fix" nonreactive nitrogen gas in the production of fertilizer. Direct discharge into streams and rivers occurs from sewage systems (due to both normal treatment plant discharges and "overflows" that occur during storms in those systems that are combined with storm drains) and industrial discharges, such as those that contain nitrogen-rich corrosion inhibitors. Indirect, or nonpoint, sources of nitrogen include runoff from fertilized cropland and lawns, failing septic systems, and malfunctioning facilities for storing animal manure. Years with higher than usual rainfall in a river basin will likely lead to higher than usual amounts of nitrogen being delivered to streams and rivers and ultimately coastal waters.

Atmospheric deposition is also a significant source of nitrogen in some ecosystems. Exhaust from engines and other combustion sources adds reactive forms of nitrogen to the air, where they contribute to the formation of smog and increased ground-level ozone. Nitrogen is also lost to the air as ammonia and nitrogen oxides from agricultural fields. Nitrogen in the air is transported and redeposited as ammonia gas, or combined with snow, rain, or dust and deposited either on land or directly in coastal waters.

Other indicators report on the amount of nitrate in streams or groundwater in farmlands (p. 107), forests (p. 140), grasslands and shrublands (p. 205), and urban and suburban areas (p. 238).

The technical note for this indicator is on page 277.

collected in different years. Every effort has been made here to identify consistent land cover categories and time periods.

Data Availability: Please see references to other technical notes or source links above.

The Data Gap

For additional detail on data for coral reefs and seagrasses and other "submerged aquatic vegetation" as well as vegetated wetlands in other areas please see the technical note for Coastal Living Habitats (p. 287). Further discussion on the absence of national data on lake area is found in the technical note for Extent of Freshwater Ecosystems (p. 314).

The land-cover maps derived from the NLCD could not be compared when data analyses were being completed for this report edition. This was due to intercomparability issues between the two available time points (1992 and 2001). Efforts are underway to make these two time points comparable, which should permit an analysis for small areas how the land cover changed between the two time points.

Data necessary to report on the area of rare community types are likely to become available for a current time point (see discussion in technical note for Forest Community Types with Significantly Reduced Area, p. 311). Such data will need to be periodically updated to permit estimates of changing area of these rare types.

Pattern of "Natural" Landscapes

The Indicator

This indicator describes general patterns of land cover across landscapes that are characterized predominantly by the presence of "natural" land cover (i.e., forest, grassland, shrubland, wetlands, and other water). This is done using two related approaches. The first reports the composition of the surroundings of "natural" pixels on land cover maps using a square observation window that was 1-km on a side or approximately 240 acres in size. Data are reported for several key categories of land-cover composition—ranging from those pixels surrounded by 100% other "natural" pixels (i.e., "core natural") to those pixels having a mix of cropland and development above particular thresholds in the surrounding 240 acres. The second component of the indicator focuses on the resulting "core natural" pixels. "Core natural" pixels that touched were joined together to form polygons across the landscape and the size of these polygons, or patches, is reported.

Substantial Changes to the Indicator Design: This indicator was defined for the 2008 edition of this report by the Landscape Pattern Task Group (see http://www.heinzctr.org/ecosystems for a forthcoming task group report).

The Data

The data for this indicator are derived from two sources. The primary source is the National Land Cover Dataset (NLCD), which is a product of the Multi-Resolution Land Characterization (MRLC) Consortium (see program description on p. 274). In addition, this land-cover map was augmented with data from ESRI on paved roads, which are considered a type of development.

Data Description: The following NLCD categories were treated as "natural" for this indicator: (11) water; (12) perennial ice/snow; (31) barren land (rock/sand/clay); (41) deciduous forest; (42) evergreen forest; (43) mixed forest; (52) shrub/scrub; (71) Grassland/herbaceous; (90) Woody wetlands; and (95) Emergent herbaceous wetlands.

Data Manipulation: Analysts with U.S. Forest Service and the U.S. Environmental Protection Agency performed all steps of this analysis. They started by merging the ESRI street map with the 2001 edition of the NLCD, converting pixels in the NLCD to a new classification of "developed" in cases where a paved road was found to overlap the road. A square analysis tool (window) was centered on every pixel within the map and then the composition of pixels within the window was recorded. A 1-km analysis window was used. Data were reported in the various compositional categories shown. For those pixels that had 100% "natural" surroundings, patches were formed, but only for pixels that shared a common edge (i.e., it was not sufficient if the edge of pixels touched). The area of these patches was reported, by state, and then these data were summarized by region. This procedure caused some patches to be split by state boundaries, meaning that some patches were cut into one or more smaller patches.

Data Quality/Caveats: The barren land category includes features that are decidedly "non-natural" (e.g., it includes strip mines)—it was decided that this category should be included given that "natural" features, such as beaches and bedrock, are also included within the category.

Data Availability: NLCD data are available at http://www.mrlc.gov. The ESRI data come bundled with geographic information system (GIS) software (see http://esri.com); see also ESRI (2005).

Movement of Nitrogen

The Indicator

This indicator reports both how much nitrogen enters major rivers from their watersheds, and how much nitrogen (in the form of nitrate) is delivered by several major rivers to the U.S. coastal ocean. The amount of nitrogen entering rivers from major watersheds is defined as the pounds of nitrogen per square mile of watershed area. The amount of nitrate delivered to the nation's coastal waters is defined as the tons of nitrate carried to the ocean each year and is shown for three of the largest U.S. rivers. When data become available, the indicator will also include atmospheric inputs of nitrogen to coastal areas, in the form of wet and dry deposition.

The Data

Total nitrogen is the preferred form for reporting on the amount of nitrogen delivered from the U.S. landscape to coastal waters, but because the historical record for it for the Mississippi River is short, we chose instead to present nitrate data. Further, nitrate is the largest component of total nitrogen and serves as a strong proxy of total nitrogen. The three major rivers included represent approximately 48% of the freshwater inputs to coastal waters. Note that, because of the upstream location of some of the gauge stations used, key discharges—such as the cities of New Orleans and Baton Rouge—are not captured by these data; we hope that future estimates can resolve this shortcoming. For consistency with other studies (Goolsby et al. 1999), the Mississippi River discharge includes only the portion of the Atchafalaya River that comes through the Old River Diversion.

Data Description: Riverine loads of total nitrogen were estimated using streamflow and water-quality data collected by the U.S. Geological Survey (USGS) as part of the National Stream Quality Accounting Network (NASQAN), the National Water-Quality Assessment (NAWQA) Program, and the Federal–State Cooperative Program. A few of the stream gauges, most notably those at the mouth of the Mississippi River and on the Rio Grande River, are operated by the U.S. Army Corps of Engineers or the International Boundary and Water Commission rather than the USGS.

Data Manipulation: Stream discharge (streamflow) is estimated by frequent measurement of water depth (stage), which is converted to discharge by use of a rating curve. Data are reported as daily averages. Typically water-quality samples are representative of the entire river cross-section (depth- and width-integrated) at the time of collection.

At the sites for which data are included in this report, samples were collected between 1996 and 2005. A minimum of 20 samples collected in at least 3 of the 5 years and in all seasons for both the 1996–2000 and 2001–2005 time periods were required to estimate loads at a site. Data was available for each of the years at most stations. The median number of observations per station for each period was 51 and ranged from 20 to 319.

A regression model relating total nitrogen load to discharge, day-of-year (to capture seasonal effects), and time (to capture any trend over the period) was developed for each station using statistical techniques suitable for data with censored observations (loads derived from concentrations less than the analytical detection limit). These models were then used to make daily estimates of total nitrogen load. Separate models were developed to estimate total nitrogen loads for the 1996–2000 and 2001–2005 time periods.

For the maps, these daily loads were summed for each 5-year period to estimate the load for the entire period and divided by 5 to obtain the average-annual load for each watershed. The standard error of the average-annual load is generally less than 10% of the mean but can be as high as 18%. The incremental load was then calculated as the difference between the output load that flowed from the watershed and the input(s) to the watershed. Outputs include the load at the downstream stations. In the arid western areas, it was assumed that solutes accompanied any water that was lost to irrigation or transfers to other watersheds (i.e., piping water across watershed boundaries). The incremental yield (shown in the maps) is defined as the incremental load divided by the watershed area. The white areas of the map are areas for which insufficient USGS data exist to calculate loads.

For the time-series plots, the daily loads were summed to determine the annual loads shown in the figure. Note that most of the year-to-year variation in the loads is due to differences in runoff, with wet years having higher loads and dry years having lower loads.

Data Availability: Data used in this indicator are summarized by Wilson et al., (2008), available at http://pubs.usgs.gov/of/2008/1110/. All USGS data are available at http://waterdata.usgs.gov/nwis. Further information on NASQAN and the NAWQA program can be found at http://water.usgs.gov/nasqan/ and http://water.usgs.gov/nawqa. The NASQAN Web site contains stream discharge data collected by the U.S. Army Corps of Engineers.

2008 Report Data Update: The new and revised annual nitrogen load data provided by USGS for Update 2005 were revised to account for the increased drainage area in the Columbia and Susquehanna rivers. The USGS Open File report 2006 (http://pubs.usgs.gov/of/2006/1087/) documents the changes made to the nitrogen load data for Update 2005 and in the 2008 report.

The Data Gap

This indicator is intended to include reporting on the percent of U.S. area for which ranges of wet inorganic nitrogen deposition (annual average kg per hectare) have been measured; however, data are inadequate for national level reporting at this time. Further work is needed to assess the relative magnitude of direct atmospheric nitrogen deposition (AD-N) to coastal waters. In the absence of measured or modeled data, direct deposition of atmospheric nitrogen to coastal areas cannot be reported.

Data from the National Atmospheric Deposition Program (NADP) and CASTNet were used by NOAA staff to evaluate the order of magnitude of direct AD-N to estuaries relative to other N sources. While spatial coverage of the NADP (wet deposition) and CASTNet (dry deposition) networks is currently not adequate to produce robust estimates for direct AD-N to coastal areas, rough preliminary calculations for selected estuaries suggested that direct AD-N ranges from negligible to ~17% of total N loading.

The Community Multiscale Air Quality (CMAQ) model is a potential future source of estimates for direct AD-N to coastal areas. The model runs 4-dimensional data assimilation for meteorology and emissions data and produces estimates for wet and dry AD-N; however, it currently does not adequately account for sea salt error or surf zone effects. In addition, current resolution is too coarse (36 km^2) for estimating for estuarine surfaces as model grids are likely to overlap both land and sea—better resolution (12 km^2) is planned.

Carbon Storage

The Indicator

This indicator reports on changes in carbon density (carbon stored per unit area) and changes in total carbon stored in major ecosystem types, as well as how much recent global carbon dioxide and methane concentrations (chosen for their relevance to ecosystem functions such as photosynthesis and decomposition) deviate from long-term average concentrations. The goal is to provide an overall view of changing carbon levels in U.S. ecosystems and to distinguish the effects of land cover conversion (changes in the extent of ecosystem types)