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# **Report on the Environment**

## **Trend Summary Protocol**

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# ROE Trend Summary Protocol

## 1. Introduction

The Report on the Environment (ROE) team within the U.S. Environmental Protection Agency (EPA) Office of Research and Development (ORD) has enhanced the presentation of information on the ROE website by adding summaries of indicator trends, or changes in indicators over time. In 2020, ORD convened subject matter experts from EPA Program Offices for a series of workshops to brainstorm approaches. Following the workshops, an EPA ROE trends workgroup further developed the concept and plan for presenting a summary of indicator trends on the ROE website. A new, sortable summary table allows ROE users to see, at a glance, trend directions either for all indicators, or for user-selected subsets of indicators (e.g., within a given indicator theme area such as air or health). This trend summary table includes two elements:

- Symbols representing trend direction for each indicator.
- Key stories providing brief, high level descriptions of each indicator trend.

The purpose of this document is to lay out the ROE protocol for defining the trend direction for each indicator and developing the associated key stories. This protocol serves as a roadmap for establishing the trend direction symbols and key stories for existing ROE indicators and any new (or newly updated) indicators as they are added to the ROE.

## 2. Approach for Assigning Trend Direction Symbols

For most ROE indicators, a single symbol is used to represent the *environmental or human health favorability* of its temporal trend (or “change”, in the case of indicators with only two time points). For each indicator, a symbol is assigned from the following four possibilities:

Getting better



Neutral



Getting worse



Mixed picture



The four symbols are intended to clearly indicate the direction of the trend for each indicator. The current approach was selected as the most accessible and straightforward representation of a given trend, after considering several alternatives (e.g., arrows, red or green colors, a stoplight design). The “full circles” are symbolic of a favorable trend or getting better, while the “empty circles” denote an unfavorable trend or getting worse. The “half full circles” represent neutral trends, or not getting better or worse overall. The “alternating shaded quadrants circles” denote a mixed picture, or trends both getting better and getting worse over time across a particular indicator’s exhibits. The circles clearly and consistently communicate favorable and unfavorable trend directions. In contrast, arrows (or colors) can be misleading if only defining changes in directionality (i.e., increasing or decreasing) and not favorability (e.g., an increasing trend could be favorable for some indicators, yet unfavorable for others).

Text adjacent to each symbol indicates how the trend direction (or lack thereof) was determined: either by statistical testing or professional judgment (described below). Trend assessment includes all of an indicator's (or exhibit's) available data, and not simply its values at the starting and ending time points.

- **Statistical testing:** Where statistical testing on an indicator has been conducted by the EPA Program Office or other source that provided the data, the determination of whether an indicator is “getting better” (see Examples 1-2 in Section 3), “getting worse” (Examples 3-4), “mixed picture” (Examples 5, 6), or “neutral” (Examples 7, 8) is based upon the results of that testing. Statistical testing is used to understand the significance of an observed trend (i.e., whether it is likely or unlikely to be a product of chance). Statistical testing information is the same as that provided in the indicator exhibit footnotes and technical documentation. No *de novo* statistical analyses on indicator data are performed as part of assessing or defining trend direction.
- **Professional judgment:** Where statistical test results have not been provided by the EPA Program Office or other source that provided the data, trend direction determination is made by the ROE team, in consultation with data providers as needed, based upon their professional judgment. Methods of assessment in such cases may include visual inspection of time series and/or examination of raw data associated with exhibits.

The technical documentation for each indicator documents the methods used in the trend assessment. This information appears in Section 14, “Statistical/Trend Analysis,” in the standard form that all ROE indicators use. For statistical testing, this explanation already exists; it either describes statistical tests in detail or it points to another publication that already provides such detail. The following two examples demonstrate how the technical documentation covers statistical methods:

- “The indicator text refers to long-term rates of change, which were calculated using ordinary least-squares regression, a commonly used method of trend analysis. The long-term tide gauge reconstruction trend reflects an average increase of 0.06 inches per year. The 1993–2013 trend is 0.14 inches per year for the reconstruction, and the 1993–2021 trend for the NOAA altimeter-based time series is 0.12 inches per year. All of these trends are highly significant statistically ( $p < 0.001$ ). Exhibit 1 shows a 95 percent confidence interval around the long-term reconstruction, and Church and White (2011) provide more information about long-term rates of change and their confidence bounds.”
- “EPA conducted a statistical analysis to determine whether the differences between 2008-2009 and 2013-2014 categorical estimates were statistically significant. The difference between the two surveys was statistically significant when the resulting 95 percent error bars around the difference estimate did not cross zero. See U.S. EPA (2020b) for additional information about these statistical methods. Following this procedure, EPA found that the following changes over time were significant...”

The following three examples show how EPA has augmented the technical documentation to explain how professional judgment was applied:

- “Although this indicator does not present the results of statistical testing, visual inspection of Exhibit 1 shows that all forest components—and their sum—have increased steadily in biomass throughout the period of record. Every year shows an increase over the prior year. With nearly three decades of data, and very little year-to-year variability or “noise” evident, the climate scientists and forest experts who compiled this indicator have made the judgment that carbon storage is increasing over time. This conclusion is supported by EPA’s annual *Inventory of Greenhouse Gas Emissions and Sinks*, which reflects the state of the science and additional external expert review, as well as peer-reviewed literature that documents afforestation (net forest growth) in the United States.”
- “Although this indicator does not present the results of statistical testing, each of the source studies on which it was based contained their own statistical analyses of change in wetland acreage over specific time periods. These underlying analyses concluded with confidence that wetland acreage declined in each period except for one. Based on the totality of these analyses, the study authors—the U.S. Fish and Wildlife Service—have concluded that wetland acreage has decreased over the full period covered. EPA concurs with the Fish and Wildlife Service’s expert judgment on this point.”
- “Although this indicator does not present the results of statistical testing, it is apparent to the observer’s eye that some of the time series shown in the graph visually suggest an overall increase, some have a decrease, some are approximately flat, and some have notable ups and downs over time. This observation alone is sufficient to support the EPA team’s professional judgment that trends are too varied to assess them all as pointing in a single direction.”

Many ROE indicators include multiple exhibits that display different subsets (e.g., geographic, demographic) of the data. Because trend symbols provide a high-level overview of directionality, they are displayed at the level of the indicator rather than of the individual exhibit. Where indicators include exhibits that trend in different directions (i.e., some getting better and others getting worse), a determination of “mixed picture” is made, even if statistical testing has determined that the trends for individual exhibits are significant. The Cardiovascular Disease Prevalence and Mortality indicator is an example, wherein prevalence and mortality are two different variables (the latter displayed multiple ways across multiple exhibits) that do not necessarily trend in the same direction. For indicators such as this one, a determination of “mixed picture” is made.

The neutral symbol is applied to two other circumstances: 1) where the trend is indeterminate (e.g., no obvious trend is visible), and 2) where no statement can be made regarding the environmental favorability of an apparent trend. Examples of each of these cases are provided in the following section.

In addition to the above considerations, the following apply in determining trend symbols:

- If an indicator includes both national and regional components, the national component guides selection of the symbol.
- When data for an indicator are available for only a single point in time, the trend summary indicates “N/A” to convey that no trend can be determined.

- Although the term “trend” is sometimes restricted to data with three or more points in time, the above symbols are applied to instances of data for only two points in time. However, in such cases the word “change” is used rather than “trend” in the key stories.

### 3. Examples of Trend Symbols

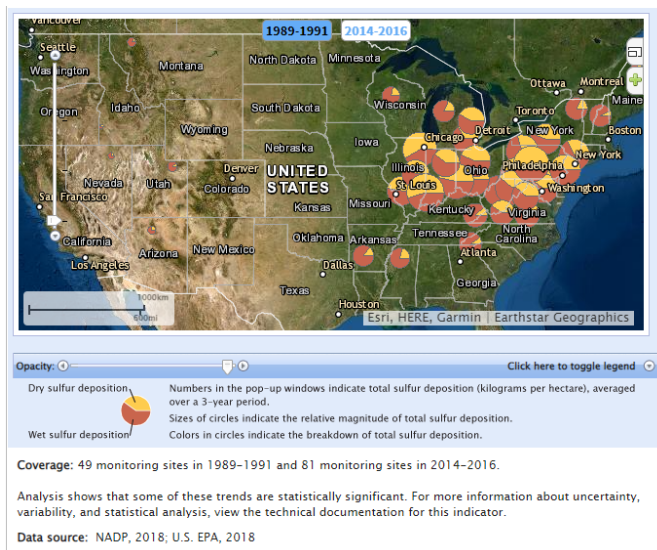
This section presents eight examples, each of which illustrates application of the above-described trend symbols to one current ROE indicator. Examples of “getting better” and “getting worse,” as determined based on both statistical testing and professional judgment, are shown, as are examples of “mixed picture” because of multiple metrics trending in different directions, based on both statistical testing and professional judgment. Examples of “neutral” are shown because of both indeterminate trend and ambiguous environmental favorability, based on professional judgment; no corresponding examples based on statistical testing are currently available among ROE indicators.

**Example 1. ROE Indicator:** [Acid Deposition](#) – Exhibit 3. Total sulfur deposition in the contiguous U.S., 1989-1991 (a) and 2014-2016 (b)

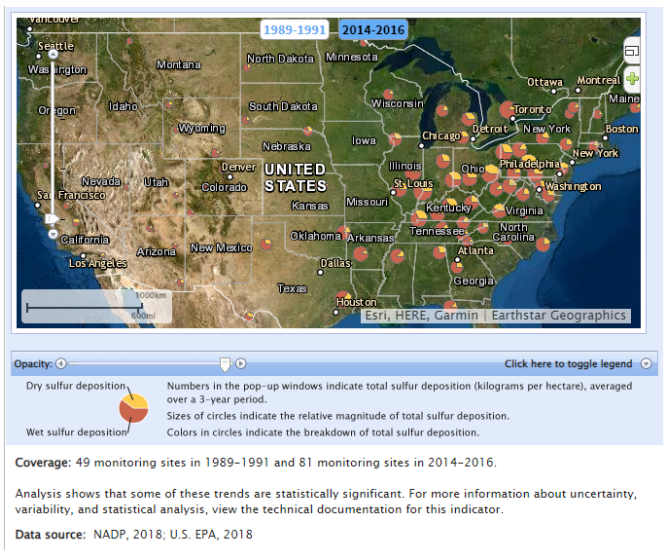
Trend direction: Getting better, based on statistical testing



a)



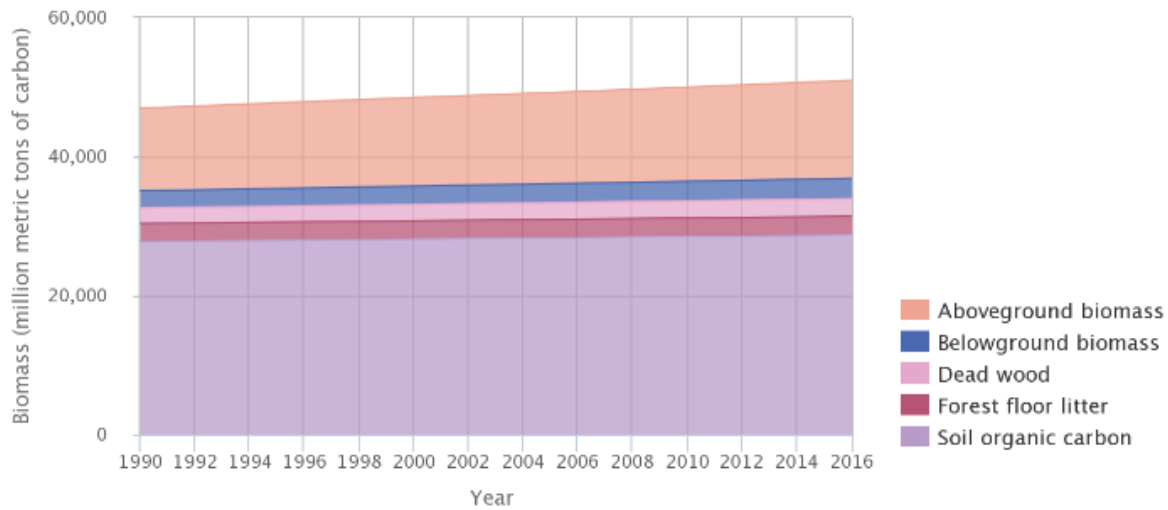
b)



**Example 2. ROE Indicator:** [Carbon Storage in Forests](#) – Exhibit 1. Total forest biomass in U.S., by forest component, 1990-2016

Trend direction: Getting better, based on professional judgment





**Coverage:** Contiguous 48 states and southern Alaska.

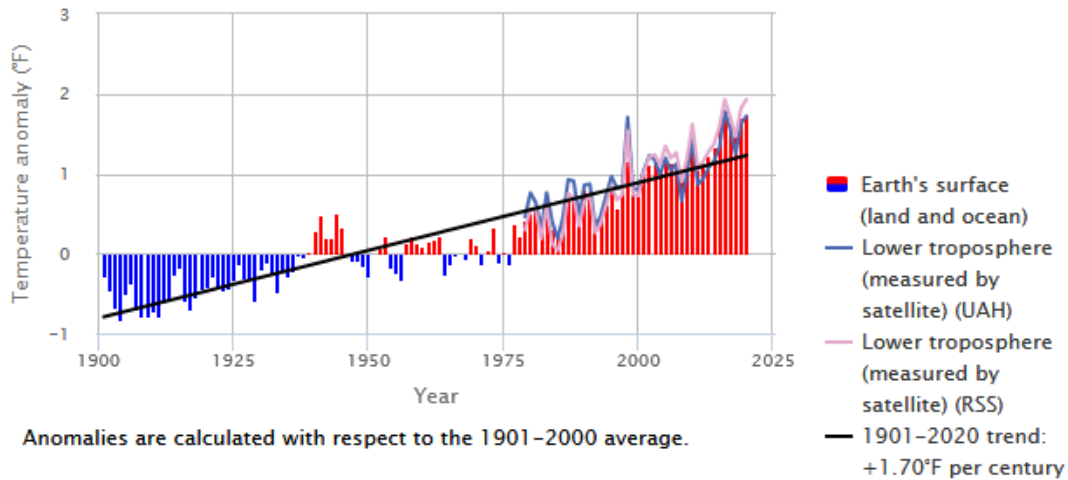
See text for definitions of categories.

Information on the statistical significance of the trends in this exhibit is not presented here. For more information about uncertainty, variability, and statistical analysis, view the technical documentation for this indicator.

**Data source:** U.S. EPA, 2018

**Example 3. ROE Indicator:** [Temperature and Precipitation](#) – Exhibit 2. Annual temperature anomalies worldwide, 1901-2020

Trend direction: Getting worse, based on statistical testing



Anomalies are calculated with respect to the 1901-2000 average.

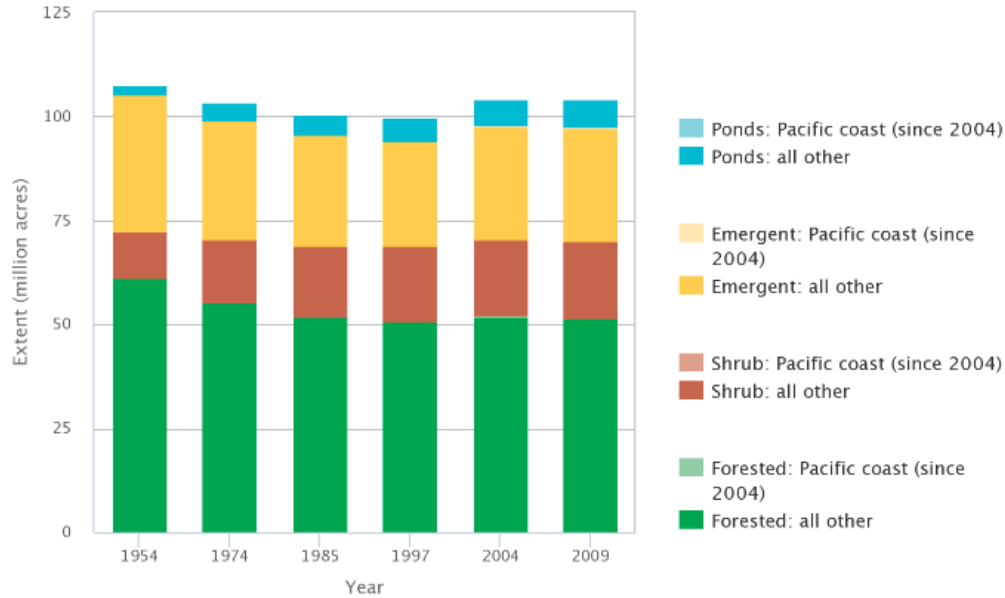
Surface data come from a combined set of land-based weather stations and sea surface temperature measurements. Satellite measurements cover the lower troposphere, which is the lowest level of the Earth's atmosphere. "UAH" and "RSS" represent two different methods of analyzing the original satellite measurements.

Analysis shows that this trend is statistically significant. For more information about uncertainty, variability, and statistical analysis, view the technical documentation for this indicator.

**Data source:** NOAA, 2021

**Example 4. ROE Indicator: [Wetlands](#)** – Exhibit 2. Extent of selected freshwater wetlands in the contiguous U.S., 1954-2009

Trend direction: Getting worse, based on professional judgment



No analysis was conducted during the 1960s.

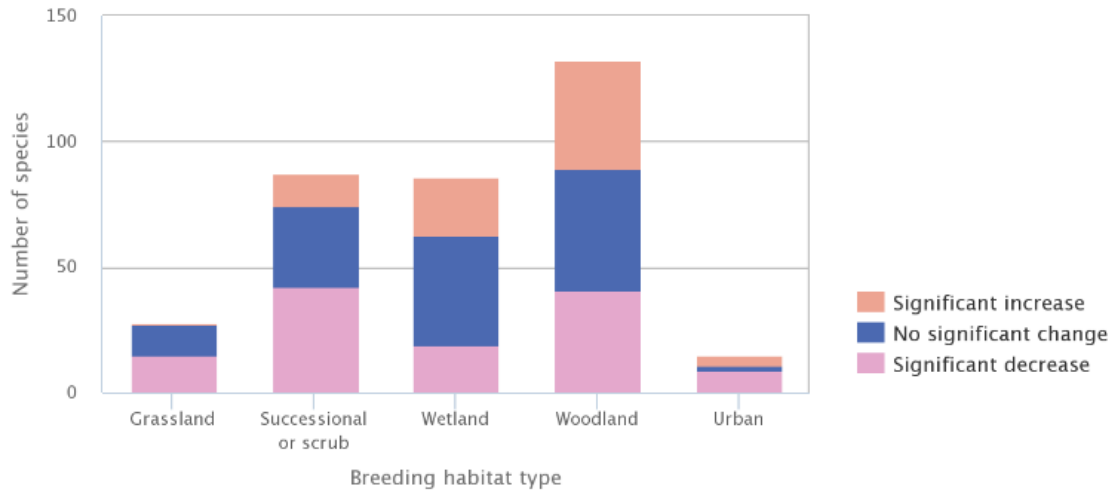
Prior to 2004, surveys did not include freshwater wetlands along the Pacific coast.

Information on the statistical significance of the trends in this exhibit is not currently available. For more information about uncertainty, variability, and statistical analysis, view the technical documentation for this indicator.

**Data source:** Dahl, 2011

**Example 5. ROE Indicator:** [Bird Populations](#) – Exhibit 1. Changes in bird populations in the U.S. by type of breeding habitat, 1966-2015

Trend direction: Mixed picture, based on statistical testing (multiple components trend in different directions)



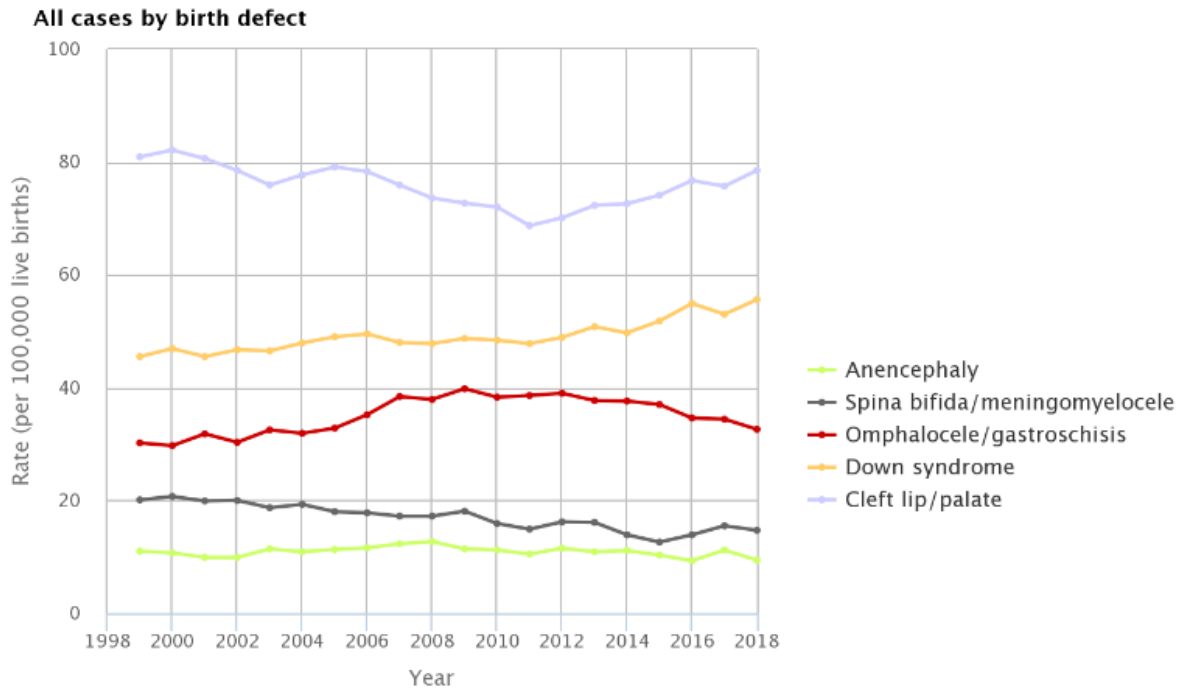
**Coverage:** 348 bird species observed as part of the annual North American Breeding Bird Survey in the contiguous U.S. and southeastern Alaska.

"Significant" indicates a population increase or decrease that is statistically significant with 95 percent confidence. For more information about uncertainty, variability, and statistical analysis, view the technical documentation for this indicator.

**Data source:** Sauer et al., 2017

**Example 6. ROE Indicator: [Birth Defects](#)** – Exhibit 1. Rate of live births in the U.S. with specific birth defects (congenital anomalies), as reported on the 1989 and 2003 Standard Certificates of Live Birth, 1999-2018

Trend direction: Mixed picture, based on professional judgment (multiple components trend in different directions)

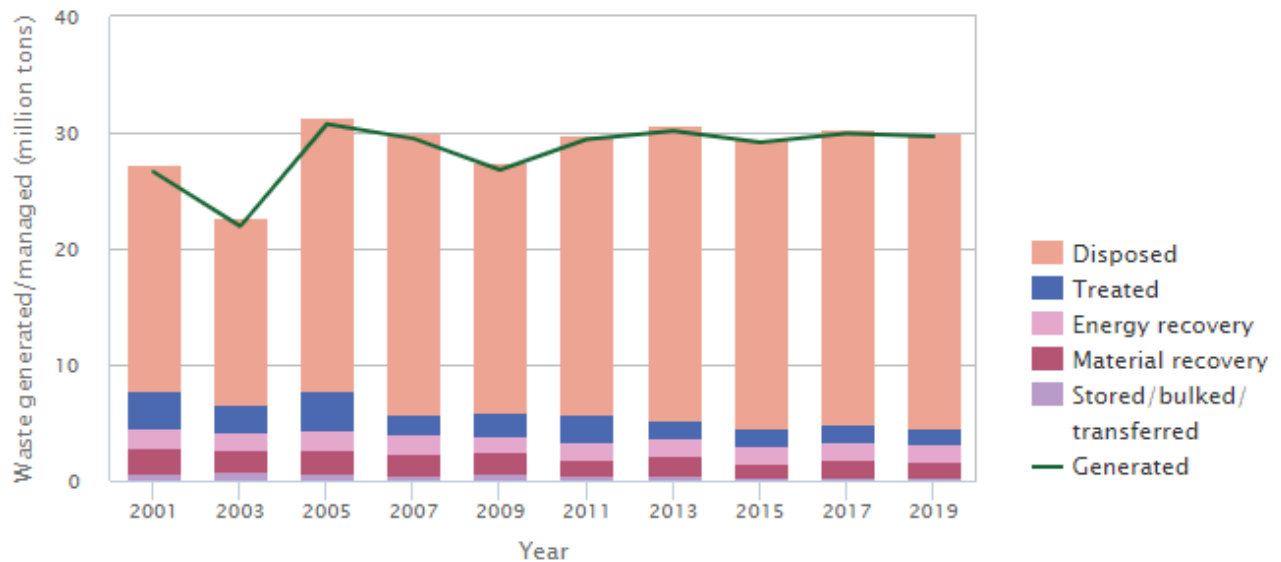


Information on the statistical significance of the trend in this exhibit is not currently available. For more information about uncertainty, variability, and statistical analysis, view the technical documentation for this indicator.

**Data source:** NCHS, 2001, 2002a,b, 2003, 2005, 2006, 2007, 2009, 2010a,b, 2011, 2012a, 2013, 2014a, 2015a,b, 2017, 2018a,b, 2019

**Example 7. ROE Indicator: [Hazardous Waste](#)** – Exhibit 1. RCRA hazardous waste generation and management in the U.S., 2001-2019

Trend direction: Neutral, based on professional judgment (trend is indeterminate)



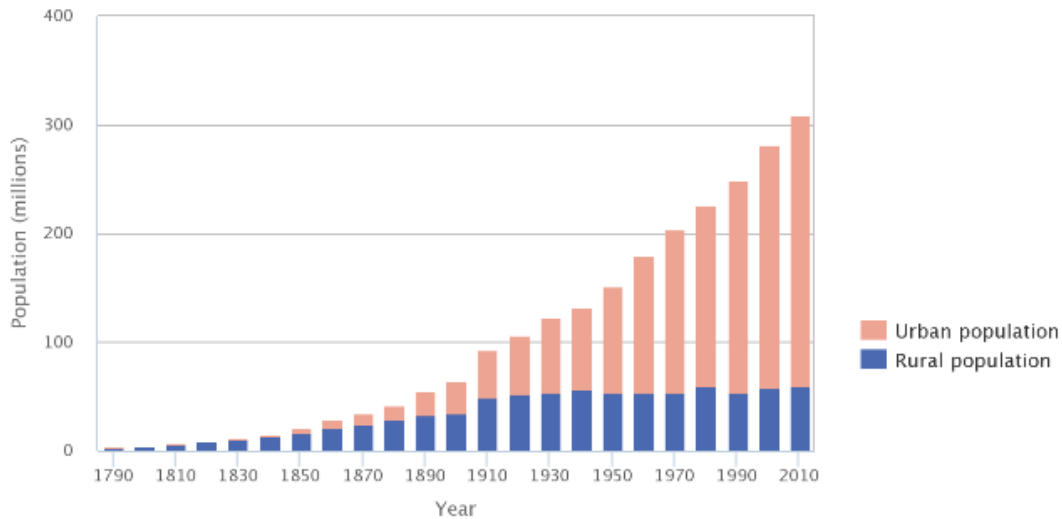
Individual management practice quantities do not add up to the total quantity generated. See text for details.

Information on the statistical significance of the trends in this exhibit is not presented here. For more information about uncertainty, variability, and statistical analysis, view the technical documentation for this indicator.

**Data source:** U.S. EPA, 2022

**Example 8. ROE Indicator:** [Urbanization and Population Change](#) – Exhibit 1. Population and urbanization in the U.S., 1790-2010

**Trend direction:** Neutral, based on professional judgment (no statement can be made regarding environmental favorability of apparent trend)



**Coverage:** 50 states and the District of Columbia.

Information on the statistical significance of the trends in this exhibit is not currently available. For more information about uncertainty, variability, and statistical analysis, view the technical documentation for this indicator.

**Data source:** U.S. Census Bureau, 1993, 2004, 2013

#### 4. Format for Key Stories




The key story summarizes the indicator trend and provides useful high-level contextual information. Key stories conform to the following format, for consistency across indicators:




- Each key story consists of one to three complete sentences in a single paragraph.
- For indicators that are national in scope and include separate exhibits for different regions, the first sentence makes a statement about the trend or absence thereof.
- In rare cases, the first sentence defines the indicator or explains how it is measured before addressing the trend in the second sentence. This approach is only used for an indicator that is not intuitive based on its title alone.
- Data are used where possible to support the trend statement, excerpting or paraphrasing from “What the Data Show” or from the explanatory notes that appear below exhibits. Key numbers are included when effective but are avoided if they clutter key stories or are overly precise (e.g., 37.42 percent).



- When the trend statement is based on statistical testing, statistical testing is acknowledged in the narrative.
- If there are regional variations, this is described in the second or third sentence.
- The final sentence notes any other EPA report or effort with which it is important to emphasize that the ROE indicator trend is consistent. Here are two examples from the 2019 ROE trends report:
  - “This indicator trend is consistent with trends identified in the most recent indicator report published by EPA’s Climate Change Division, in 2016.”
  - “This indicator trend matches trends identified in EPA’s National Coastal Condition Report (NCCR 4).”
- Key stories are meant to be able to stand alone, meaning the statement includes key years, geographic coverage, and other fundamentals so the reader does not have to look this information up elsewhere.

Table 1 below provides an example ROE trend summary table for eight ROE indicators, for illustration purposes. The table includes the indicator name, ROE theme area, years of data, trend symbol and description, and the key story.

**Table 1. Example ROE Trend Summary Table**

ROE Indicator	Theme	Years of data	Trend	Key Stories
<a href="#">Acid Deposition</a>	Air	1989 - 2016	<p><i>Statistically significant</i> Getting better</p> 	<p>Acid deposition happens when sulfur dioxide and nitrogen oxides in the atmosphere form acidic compounds that fall to the ground in rain and snow (wet deposition) or as dust (dry deposition). Acid deposition in the contiguous U.S. has decreased over the past few decades. Between 1989 and 2016, total sulfur deposition decreased by 85 percent, and total nitrogen by 43 percent.</p>
<a href="#">Carbon Storage in Forests</a>	Ecological Condition	1990 - 2016	<p><i>Professional judgment</i> Getting better</p> 	<p>The total amount of carbon stored in U.S. forests increased by 8.5 percent between 1990 and 2016. In 2016, carbon storage in forests offset approximately 9 percent of the nation's greenhouse gas emissions. Soil holds the largest amount of carbon, followed by aboveground biomass such as stems, branches, and leaves. This indicator is consistent with EPA's <a href="#">Inventory of U.S. Greenhouse Gas Emissions and Sinks</a>.</p>
<a href="#">Temperature and Precipitation</a>	Ecological Condition	1901 - 2020	<p><i>Statistically significant</i> Getting worse</p> 	<p>Since 1901, surface temperatures across the contiguous 48 states have risen at an average rate of 0.17°F per decade. Total precipitation has increased by 0.20 inches per decade during this time. Temperature has increased almost everywhere, while precipitation has increased in some regions but decreased in others. This indicator is consistent with the most recent indicator report published by EPA's Climate Change Division.</p>

ROE Indicator	Theme	Years of data	Trend	Key Stories
<a href="#">Wetlands</a>	Water	1954 - 2009	<i>Professional judgment</i> Getting worse 	Total wetland acreage has declined since the 1950s, but the rate of loss appears to have slowed over time. Some types of wetlands have declined more dramatically than others, and a few types have increased. Urban and rural development, forestry, and conversion to deep water have led to wetland loss. Agricultural and other lands have seen a growth in wetlands, in part through creation of ponds.
<a href="#">Bird Populations</a>	Ecological Condition	1966 - 2015	<i>Statistically significant</i> Mixed picture 	Bird populations have experienced both increases and decreases over time across various breeding habitats. There are 348 bird species included in this indicator. The populations of 84 species have increased significantly, and 126 have decreased significantly.
<a href="#">Birth Defects</a>	Health	1999 - 2018	<i>Professional judgment</i> Mixed picture 	Rates for the 10 types of birth defects tracked here have varied over time, with increases in some conditions and decreases in others. Four conditions are most common in the U.S.: hypospadias (males only), cleft lip/palate, cyanotic congenital heart disease, and Down syndrome. Some conditions are more common with younger mothers; others with older mothers.

ROE Indicator	Theme	Years of data	Trend	Key Stories
<a href="#">Hazardous Waste</a>	Land	2001-2019	<i>Professional judgment</i> Neutral 	<p>The U.S. generated 21.9 to 30.7 million tons of hazardous waste per year between 2001 and 2019. Most of this waste was disposed of through underground injection into deep wells. During this time period, hazardous waste generation per capita did not change much, while hazardous waste generation per dollar of GDP decreased.</p>
<a href="#">Urbanization and Population Change</a>	Land	1790 - 2017	<i>Professional judgment</i> Neutral 	<p>Since 1910, the urban population in the U.S. has grown by nearly 500 percent, while the rural population has grown by 19 percent. Eighty-one percent of the U.S. population was considered urban in 2010. There are variations in population and land development across regions. Between 1982 and 2012, the percent change in the amount of developed land in the U.S. was larger than the percent change in the U.S. population, which indicates “sprawl.”</p>

## 5. Summary

The ROE Trend Summary Protocol documents the approach used to determine ROE indicator trend direction, assign representative symbols, and develop key stories. The Trend Summary table allows ROE users to see at a glance, ROE indicator trend directions and associated key stories. This protocol serves as a roadmap for the ROE indicator trend summary information presented for existing indicators and new (or newly updated) indicators as they are added to the ROE.

## 6. Quality Assurance

This work was conducted under the U.S. EPA Quality Assurance (QA) program to ensure data are of known and acceptable quality to support their intended use. Surveillance of the work by the programmatic scientific leads ensured adherence to QA processes and criteria, as well as quick and effective resolution of any problems. The QA manager and programmatic scientific leads have determined under the QA program that this work meets all U.S. EPA quality requirements. This report was written with guidance from the QAPP titled Environmental Indicators and Report on the Environment (ROE), Scientific, Technical, and Administrative Support (L-HEEAD-0031299-QP-1-1). As part of the QA system, a quality product review is done prior to management clearance.