Society and

INDICATORS IN THIS CHAPTER

Streamflow

Ragweed Pollen Season

Length of Growing Season

Ecosystems

The indicators in this report show that changes are occurring throughout the Earth's climate system, including increases in air and ocean temperatures, more extreme weather events, a rise in sea level, widespread melting of glaciers, and longer ice-free periods on lakes and rivers. Changes such as these can present a wide range of challenges to human well-being, the economy, and natural ecosystems.

While species have adapted to environmental change for millions of years, climate change could require adaptation on larger and faster scales than current species have successfully achieved in the past.

What is happening?

For society, human health effects from increases in temperature are likely to include increases in heat-related illnesses and deaths, especially in urban areas. Changes in precipitation patterns and timing affect streamflow and water availability, while more severe storms and floods damage property and infrastructure (such as roads, bridges, and utilities) and cause loss of life. Warming temperatures are also affecting the length of the growing season in the United States as the timing between the last (spring) and first (fall) frost has expanded by nearly two weeks over the last 100 years.

Changes in climate can affect ecosystems by influencing animal behavior, such as nesting and migration patterns, as well as the timing and extent of natural processes such as flower blooms and the length of pollen seasons in many areas.

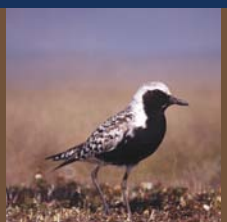
Why does it matter?

Ecosystems provide humans with food, clean water, and a variety of other services that can be affected by climate change. While species have adapted to environmental change for millions of years, the climate changes being experienced now could require adaptation on larger and faster scales than current species have successfully achieved in the past, thus increasing the risk of extinction for some species.

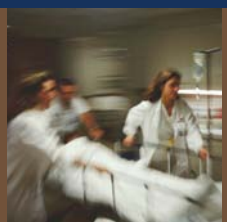
The more the climate changes, the greater the potential effects on society and ecosystems. The nature and extent of climate change effects, and whether these effects will be harmful or beneficial, will vary regionally and over time. The extent to which climate change will affect different ecosystems, regions, and sectors of society will depend not only on the sensitivity of those systems to climate change, but also on their ability to adapt to or cope with climate change.

For detailed information about data used in these indicators, see the online technical documentation at: www.epa.gov/climatechange/indicators.

Leaf and Bloom Dates



Bird Wintering Ranges



Heat-Related Deaths

Streamflow

This indicator describes trends in the volume of water carried by streams across the United States, as well as the timing of peak flow.

Background

Streamflow is a measure of the amount of water carried by rivers and streams, and it represents a critical resource for people and the environment. Changes in streamflow can directly influence the supply of drinking water and the amount of water available for irrigating crops, generating electricity, and other needs. In addition, many plants and animals depend on streamflow for habitat and survival.

Streamflow naturally varies over the course of a year. For example, rivers and streams in many parts of the country have their highest sustained flow when snow melts in the spring. The amount of streamflow is important because very high flows can cause erosion and damaging floods, while very low flows can diminish water quality, harm fish, and reduce the amount of water available for people to use. The timing of peak flow is important because it affects the ability of reservoir managers to store water to meet people's needs later in the year. In addition, some plants and animals (such as fish that migrate) depend on a particular pattern of streamflow as part of their life cycles.

Climate change can affect streamflow in several ways. Changes in the amount of snowpack and earlier spring melting (see the Snowpack indicator on p. 58) can alter the size and timing of peak streamflows. More precipitation is expected to cause higher average streamflow in some places, while heavier storms (see the Heavy Precipitation indicator on p. 30) could lead to larger peak flows. More frequent or severe droughts will reduce streamflow in certain areas.

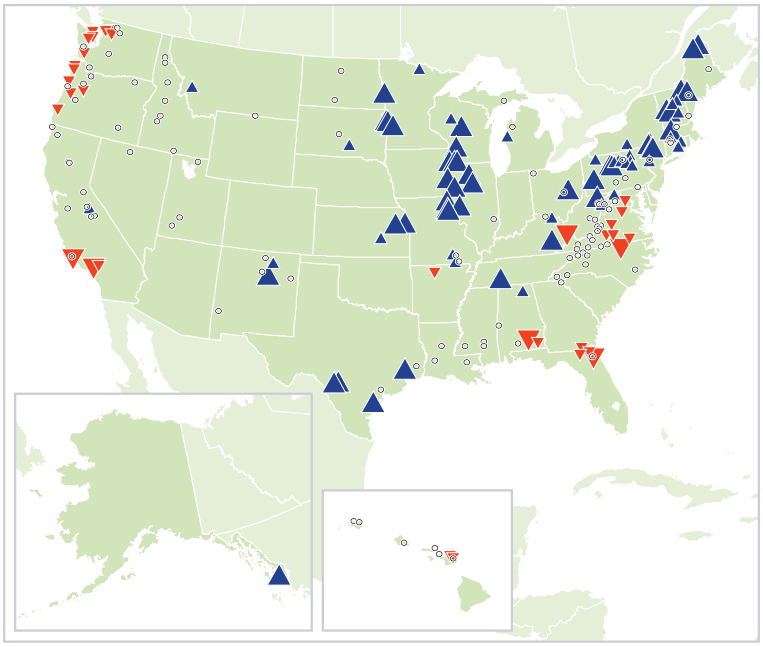
About the Indicator

The U.S. Geological Survey measures streamflow in rivers and streams across the United States using continuous monitoring devices called stream gauges. This indicator is based on 211 stream gauges located in areas where trends will not be artificially influenced by dams, reservoir management, wastewater treatment facilities, or other activities.

(Continued on page 63)

Figure 1. Volume of Seven-Day Low Streamflows in the United States, 1940–2009

This map shows percentage changes in the minimum amount of water carried by rivers and streams across the country, based on the long-term rate of change from 1940 to 2009. Minimum streamflow is based on the seven-day period with the lowest average flow during a given year.

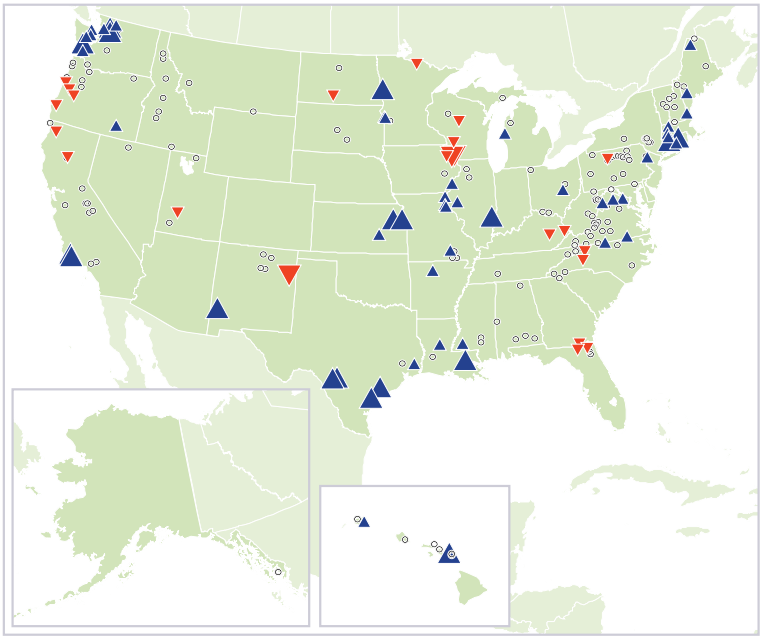


Data source: USGS, 2012[1]

More than 50% decrease | 20% to 50% decrease | 20% decrease to 20% increase | 20% to 50% increase | More than 50% increase

Figure 2. Volume of Three-Day High Streamflows in the United States, 1940–2009

This map shows percentage changes in the maximum amount of water carried by rivers and streams across the country, based on the long-term rate of change from 1940 to 2009. Maximum streamflow is based on the three-day period with the highest average flow during a given year.



Data source: USGS, 2012[2]

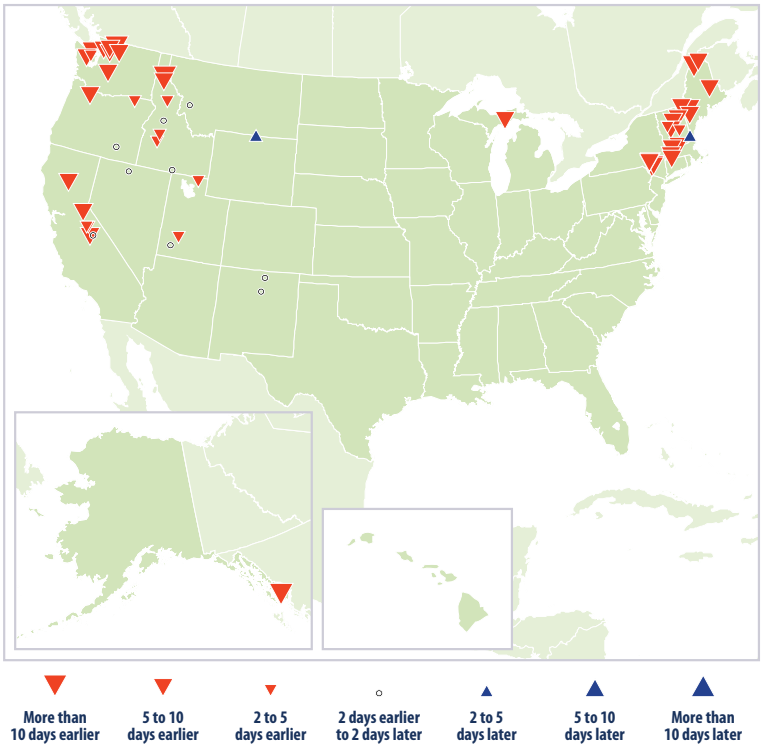
More than 50% decrease | 20% to 50% decrease | 20% decrease to 20% increase | 20% to 50% increase | More than 50% increase

Key Points

- Over the past 70 years, seven-day low flows have generally increased in the Northeast and Midwest (in other words, on the driest days, streams are carrying more water than before). Low flows have generally decreased (that is, streams are carrying less water than before) in parts of the Southeast and the Pacific Northwest. Overall, more sites have seen increases than decreases (see Figure 1).
- Three-day high-flow trends vary from region to region across the country. For example, streams in the Northeast have generally seen an increase or little change in high flows since 1940, while some West Coast streams have seen a decrease and others have seen an increase (see Figure 2). Overall, more sites have seen increases than decreases.
- Sixty percent of the streams measured show winter-spring runoff happening more than five days earlier than it did in the past. The most dramatic change has occurred in the Northeast (see Figure 3).

Figure 3. Timing of Winter-Spring Runoff in the United States, 1940–2009

This map shows changes in the timing of peak spring flow carried by rivers and streams, based on the long-term rate of change from 1940 to 2009. This analysis focuses on parts of the country where streamflow is strongly influenced by snowmelt. It is based on the winter-spring center of volume, which is the date when half of the streamflow between January 1 and May 31 of each year has passed.



Data source: USGS, 2012[3]

This indicator examines three important measures of streamflow conditions that occur over the course of a year. Figure 1 looks at the driest conditions each year, which are commonly calculated by averaging the lowest seven consecutive days of streamflow over the year. This method captures the year's most severe, sustained dry spell. Figure 2 examines high flow conditions, which are commonly calculated as the highest average flow over three consecutive days. Based on typical weather patterns, three days is an optimal length of time to capture runoff associated with large storms and peak snowmelt.

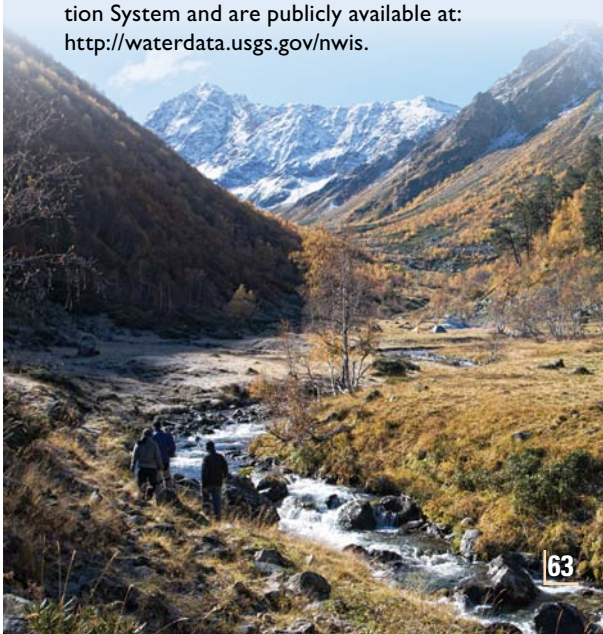
Figure 3 shows changes in the timing of spring runoff over time. This measure is limited to 55 stream gauges in areas where at least 30 percent of annual precipitation falls as snow. Scientists look at the total volume of water that passes by a gauge between January 1 and May 31 and then determine the date when exactly half of the water has gone by. This date is called the winter-spring center of volume. A long-term trend toward an earlier date suggests that spring snowmelt is happening earlier.

Indicator Notes

Measurements were taken in areas where streamflow is not highly affected by human influences, including changes in land cover. However, changes in land cover and land use over time could still influence streamflow trends at some streams. The gauges used for this indicator are not evenly distributed across the country.

Data Sources

Streamflow data were collected by the U.S. Geological Survey. These data came from a set of watersheds with minimal human impacts, which have been classified as reference gauges.[4] Daily average streamflow data are stored in the National Water Information System and are publicly available at: http://waterdata.usgs.gov/nwis.



Ragweed Pollen Season

This indicator depicts changes in the length of ragweed pollen season in the United States and Canada.

Background

More than half of Americans have at least one allergy.[5] Allergies are a major public health concern, with hay fever (congestion, runny nose, itchy eyes) accounting for more than 13 million visits to physicians' offices and other medical facilities every year.[6] One of the most common environmental allergens is ragweed, which can cause hay fever and trigger asthma attacks, especially in children and the elderly. An estimated 26 percent of all Americans are sensitive to ragweed.[7]

Ragweed plants mature in mid-summer and produce small flowers that generate pollen. Ragweed pollen season usually peaks in late summer and early fall, but these plants often continue to produce pollen until the first frost. A single ragweed plant can produce up to a billion pollen grains in one season, and these grains can be carried long distances by the wind.[8]

Climate change can affect pollen allergies in several ways. Warmer spring temperatures cause some plants to start producing pollen earlier (see the Leaf and Bloom Dates indicator on p. 68), while warmer fall temperatures extend the growing season for other plants such as ragweed (see the Length of Growing Season indicator on p. 66). Warmer temperatures and increased carbon dioxide concentrations also enable ragweed and other plants to produce more pollen.[9] This means that many locations could experience longer allergy seasons and higher pollen counts as a result of climate change.

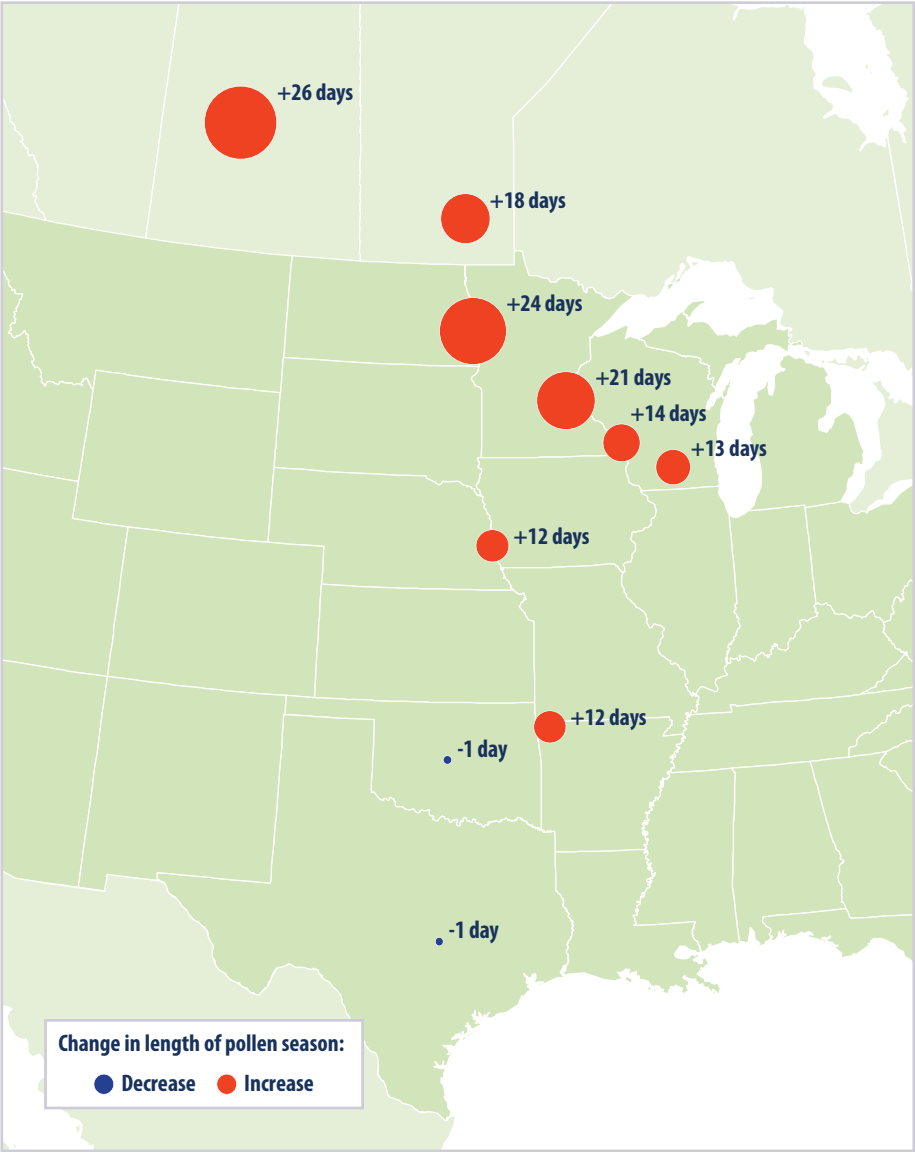
About the Indicator

This indicator shows changes in the length of the ragweed pollen season in 10 cities in the central United States and Canada. These locations were selected as part of a study that looked at trends in pollen season at sites similar in elevation but across a range of latitudes from south to north. At each location, air

(Continued on page 65)

Figure 1. Change in Ragweed Pollen Season, 1995–2011

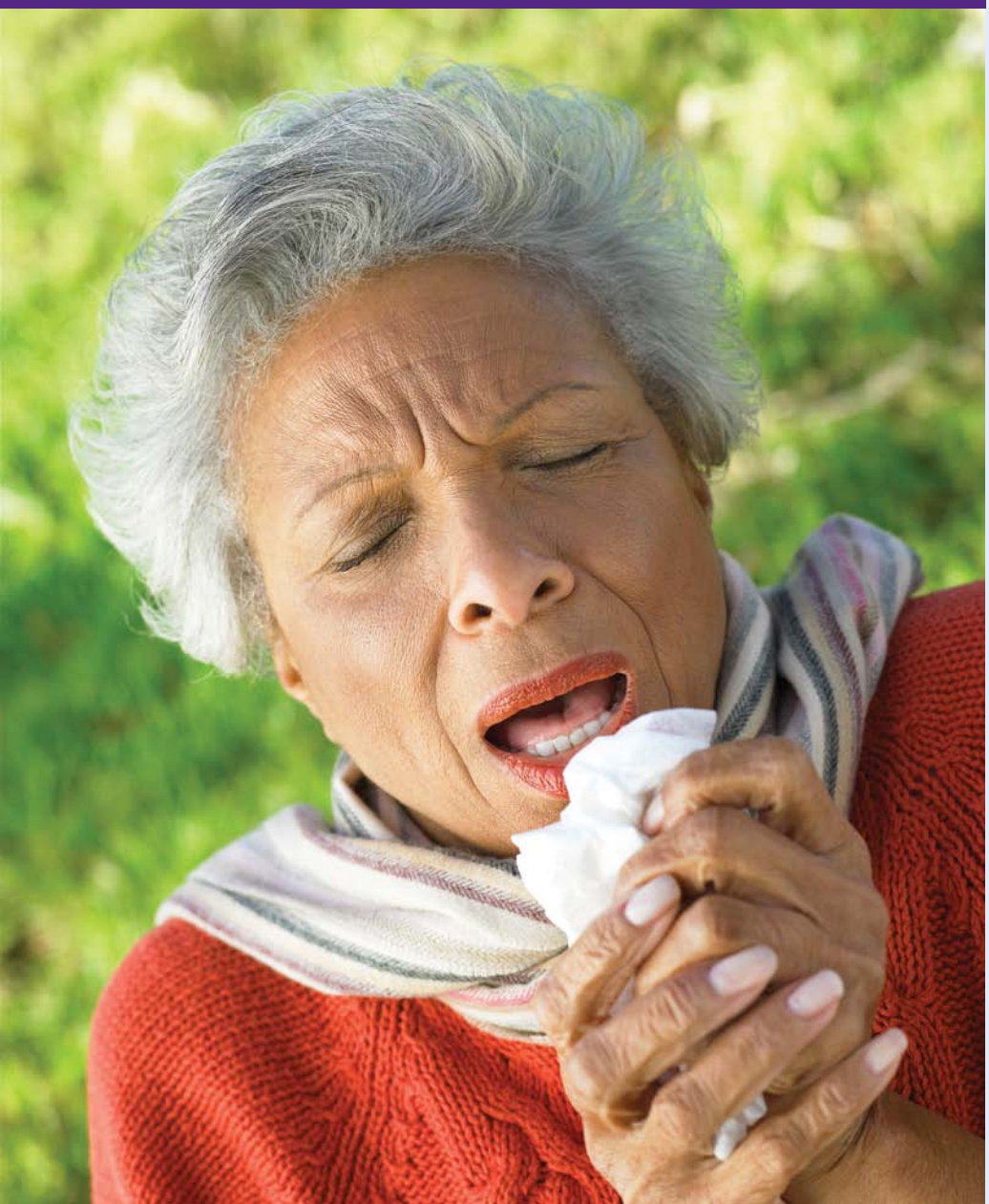
This figure shows how the length of ragweed pollen season changed at 10 locations in the central United States and Canada between 1995 and 2011. Red circles represent a longer pollen season; blue circles represent a shorter season. Larger circles indicate larger changes.



Data source: Ziska et al., 2012[10]

Key Points

- Since 1995, ragweed pollen season has grown longer at eight of the 10 locations studied (see Figure 1).
- The increase in ragweed season length becomes more pronounced from south to north. Ragweed season increased by 24 days in Fargo, North Dakota, and 26 days in Saskatoon, Saskatchewan (see Figure 1). This trend is consistent with many other observations showing that climate is changing more rapidly at higher latitudes.[11]
- The trends in Figure 1 are strongly related to changes in the length of the frost-free season and the timing of the first fall frost. Northern areas have seen fall frosts happening later than they used to, with the delay in first frost closely matching the increase in pollen season. Meanwhile, some southern stations have experienced only a modest change in frost-free season length since 1995.[12]



samples have been collected and examined for at least 16 years as part of a national allergy monitoring network. Pollen spores are counted and identified using microscopes.

Pollen counts from each station have been analyzed to determine the start and end dates of each year's ragweed pollen season. Because the length of ragweed season naturally varies from year to year, statistical techniques have been used to determine the average rate of change over time. This indicator shows the total change in season length from 1995 to 2011, which was determined by multiplying the average annual rate of change by the number of years in the period.

Indicator Notes

This indicator is based on data from a limited number of cities in the central states and provinces. These cities cover a broad range from north to south, however, which allows researchers to establish a clear connection between pollen season changes and latitude.

Many factors can influence year-to-year changes in pollen season, including typical variations in temperature and precipitation, extreme events such as floods and droughts, and changes in plant diversity. Adding more years of data would provide a better picture of long-term trends, but widespread data were not available prior to 1995.

This indicator does not show how the intensity of ragweed pollen season (pollen counts) might also be changing.

Data Sources

Data for this indicator come from the National Allergy Bureau, which is part of the American Academy of Allergy, Asthma, and Immunology's Aeroallergen Network. Data were compiled and analyzed by a team of researchers who published a more detailed version of this analysis in a scientific journal with data through 2009.[13]

Length of Growing Season

This indicator measures the length of the growing season in the contiguous 48 states.

Background

The length of the growing season in any given region refers to the number of days when plant growth takes place. The growing season often determines which crops can be grown in an area, as some crops require long growing seasons, while others mature rapidly. Growing season length is limited by many different factors. Depending on the region and the climate, the growing season is influenced by air temperatures, frost days, rainfall, or daylight hours.

Changes in the length of the growing season can have both positive and negative effects. Moderate warming can benefit crop and pasture yields in mid- to high-latitude regions, yet even slight warming decreases yields in seasonally dry and low-latitude regions.[14] A longer growing season could allow farmers to diversify crops or have multiple harvests from the same plot. However, it could also limit the types of crops grown, encourage invasive species or weed growth, or increase demand for irrigation. A longer growing season could also disrupt the function and structure of a region's ecosystems and could, for example, alter the range and types of animal species in the area.

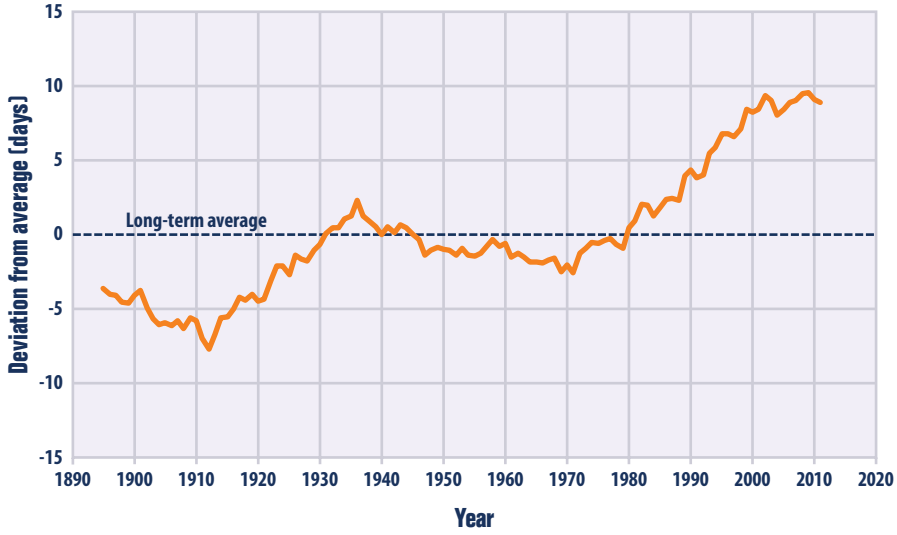
About the Indicator

This indicator looks at the impact of temperature on the length of the growing season in the contiguous 48 states, as well as trends in the timing of spring and fall frosts. For this indicator, the length of the growing season is defined as the period of time between the last frost of spring and the first frost of fall, when the air temperature drops below the freezing point of 32°F.

Trends in the growing season were calculated using temperature data from 750 weather stations throughout the contiguous 48 states. These data were obtained from the National Oceanic and Atmospheric Administration's National Climatic Data Center. Growing season length and the timing of spring and fall frosts were averaged across the nation, then compared with long-term average numbers (1895–2011) to determine how each year differed from the long-term average.

Figure 1. Length of Growing Season in the Contiguous 48 States, 1895–2011

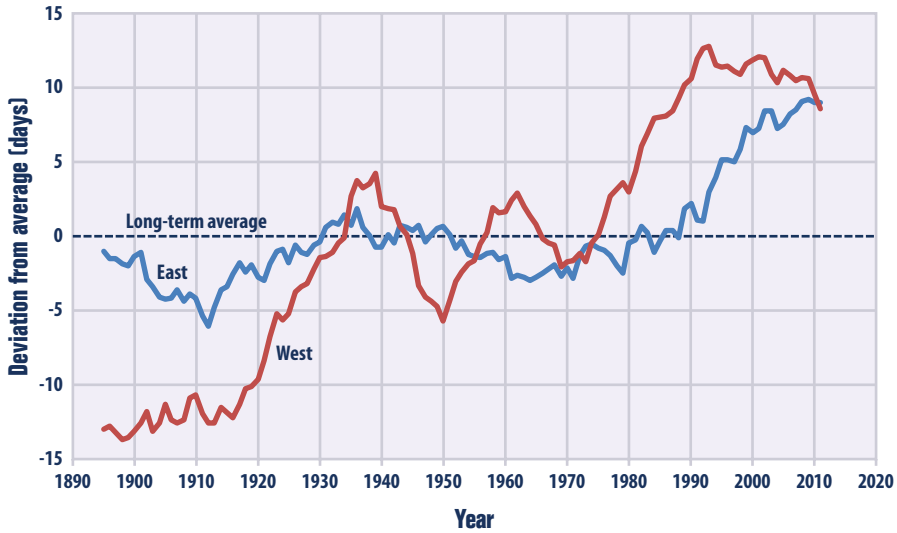
This figure shows the length of the growing season in the contiguous 48 states compared with a long-term average. For each year, the line represents the number of days shorter or longer than average. The line was smoothed using an 11-year moving average. Choosing a different long-term average for comparison would not change the shape of the data over time.



Data source: Kunkel, 2012[15]

Figure 2. Length of Growing Season in the Contiguous 48 States, 1895–2011: West Versus East

This figure shows the length of the growing season in the western and eastern United States compared with a long-term average. For each year, the line represents the number of days shorter or longer than average. The lines were smoothed using an 11-year moving average. Choosing a different long-term average for comparison would not change the shape of the data over time.



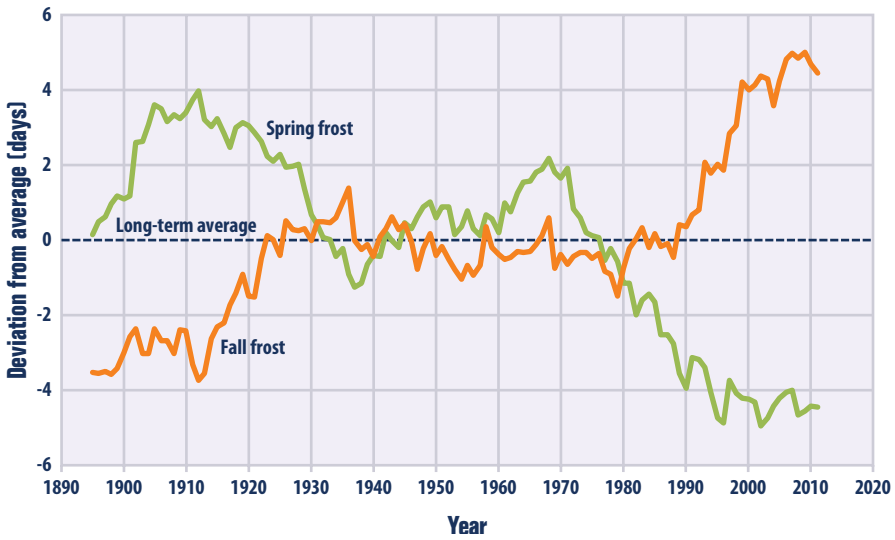
Data source: Kunkel, 2012[16]

Key Points

- The average length of the growing season in the contiguous 48 states has increased by nearly two weeks since the beginning of the 20th century. A particularly large and steady increase occurred over the last 30 years (see Figure 1).
- The length of the growing season has increased more rapidly in the West than in the East. In the West, the length of the growing season has increased at an average rate of about 22 days per century since 1895, compared with a rate of about eight days per century in the East (see Figure 2).
- The final spring frost is now occurring earlier than at any point since 1895, and the first fall frosts are arriving later. Since 1980, the last spring frost has occurred an average of about three days earlier than the long-term average, and the first fall frost has occurred about two days later (see Figure 3).

Figure 3. Timing of Last Spring Frost and First Fall Frost in the Contiguous 48 States, 1895–2011

This figure shows the timing of the last spring frost and the first fall frost in the contiguous 48 states compared with a long-term average. Positive values indicate that the frost occurred later in the year, and negative values indicate that the frost occurred earlier in the year. The lines were smoothed using an 11-year moving average. Choosing a different long-term average for comparison would not change the shape of the data over time.



Data source: Kunkel, 2012[17]

Indicator Notes

Changes in measurement techniques and instruments over time can affect trends. This indicator only includes data from weather stations with a consistent record of data points for the time period.

Data Sources

All three figures are based on temperature data compiled by the National Oceanic and Atmospheric Administration's National Climatic Data Center, and these data are available online at: www.ncdc.noaa.gov/oa/ncdc.html. Frost timing and growing season length were analyzed by Kunkel (2012).[18]

Leaf and Bloom Dates

This indicator examines the timing of leaf growth and flower blooms for selected plants in the United States.

Background

The timing of natural events, such as flower blooms and animal migration, is influenced by changes in climate. Phenology is the study of such important seasonal events. Phenological events are influenced by a combination of climate factors, including light, temperature, rainfall, and humidity. Different plant and animal species respond to different cues.

Scientists have very high confidence that the earlier arrival of spring events is linked to recent warming trends in global climate.[19] Disruptions in the timing of these events can have a variety of impacts on ecosystems and human society. For example, an earlier spring might lead to longer growing seasons (see the Length of Growing Season indicator on p. 66), more abundant invasive species and pests, and earlier and longer allergy seasons.

Because of their close connection with climate, the timing of phenological events can be used as an indicator of the sensitivity of ecological processes to climate change. Some phenological indicators cover broad trends, such as overall "leaf-on" dates (when trees grow new leaves in the spring), using a combination of satellite data and ground observations. Others rely on ground observations that look at specific types or species of plants or animals. Two particularly useful indicators of the timing of spring events are the first leaf dates and the first bloom dates of lilacs and honeysuckles, which have an easily monitored flowering season, relatively high survival rate, and large geographic distribution. The first leaf date in these plants relates to the timing of "early spring," while the first bloom date is consistent with the timing of later spring events, such as the start of growth in forest vegetation.[20]

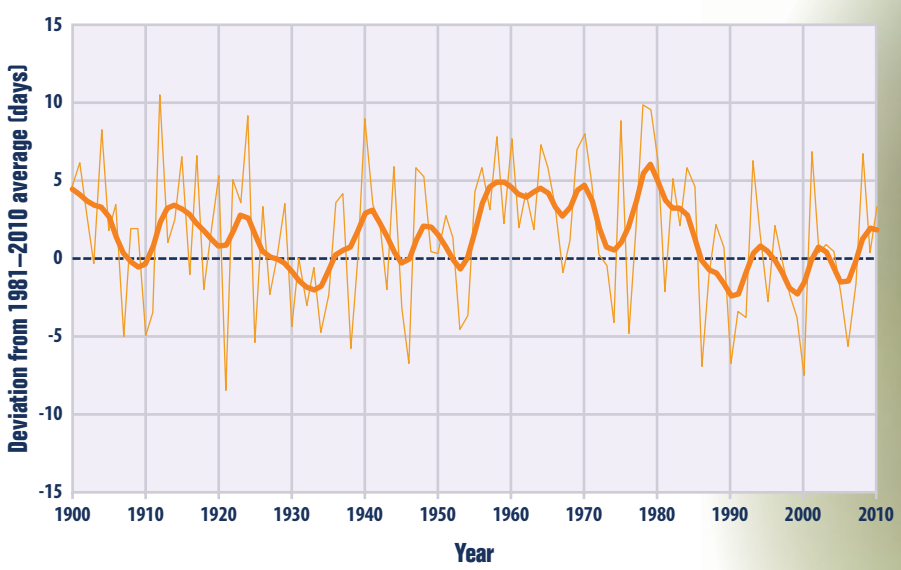
About the Indicator

This indicator shows trends in the timing of first leaf dates and first bloom dates in lilacs and honeysuckles across the contiguous 48 states. Because many of the phenological observation records in the United States are less than 40 years long, and because these records may have

(Continued on page 69)

Figure 1. First Leaf Dates in the Contiguous 48 States, 1900–2010

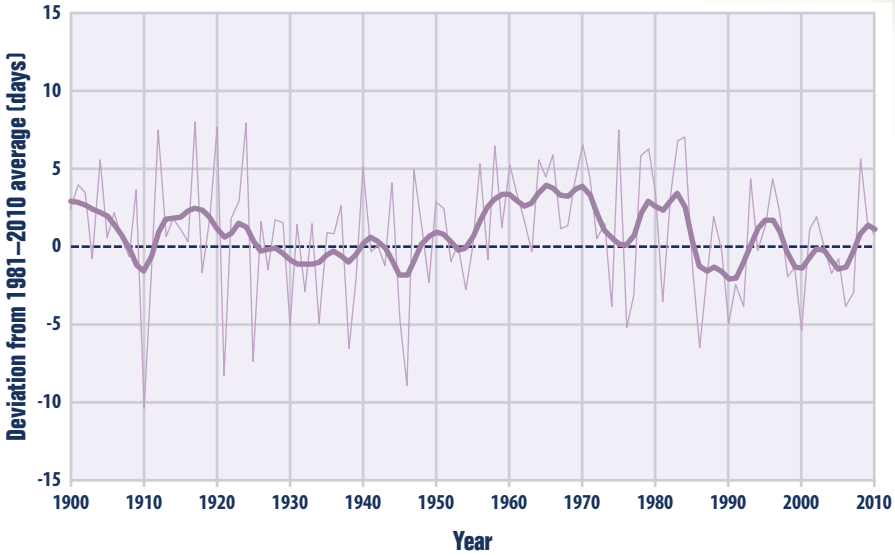
This figure shows modeled trends in lilac and honeysuckle first leaf dates across the contiguous 48 states, using the 1981 to 2010 average as a baseline. Positive values indicate that leaf growth began later in the year, and negative values indicate that leafing occurred earlier. The thicker line was smoothed using a nine-year weighted average. Choosing a different long-term average for comparison would not change the shape of the data over time.



Data source: Schwartz, 2011[21]

Figure 2. First Bloom Dates in the Contiguous 48 States, 1900–2010

This figure shows modeled trends in lilac and honeysuckle first bloom dates across the contiguous 48 states, using the 1981 to 2010 average as a baseline. Positive values indicate that blooming began later in the year, and negative values indicate that blooming occurred earlier. The thicker line was smoothed using a nine-year weighted average. Choosing a different long-term average for comparison would not change the shape of the data over time.



Data source: Schwartz, 2011[22]

Key Points

- First leaf growth in lilacs and honeysuckles in the contiguous 48 states is now occurring a few days earlier than it did in the early 1900s. Although the data show a great deal of year-to-year variability, a noticeable change toward earlier dates seems to have begun around the 1980s (see Figure 1).
- Lilac and honeysuckle bloom dates show a high degree of year-to-year variability, which makes it difficult to determine whether a statistically meaningful change has taken place (see Figure 2).
- Other studies have looked at trends in leaf and bloom dates across all of North America and the entire Northern Hemisphere. These studies have also found a trend toward earlier spring events—some more pronounced than the trends seen in just the contiguous 48 states.[23]

gaps in time or space, computer models have been used to provide a more complete understanding of long-term trends nationwide.

The models for this indicator were developed using data from the USA National Phenology Network, which collects ground observations from a network of federal agencies, field stations, educational institutions, and citizens who have been trained to log observations of leaf and bloom dates. For consistency, observations were limited to a few specific types of lilacs and honeysuckles. Next, models were created to relate actual leaf and bloom observations with records from nearby weather stations. Once scientists were able to determine the relationship between leaf and bloom dates and climate factors (particularly temperatures), they used this knowledge to estimate leaf and bloom dates for earlier years based on historical weather records. They also used the models to estimate how leaf and bloom dates would have changed in a few areas (mostly in the far South) where lilacs and honeysuckles are not widespread.

This indicator uses data from several hundred weather stations throughout the contiguous 48 states. The exact number of stations varies from year to year. For each year, the timing of first leaf and first bloom at each station was compared with the 1981 to 2010 average to determine the number of days' "deviation from normal." This indicator presents the average deviation across all stations.

Indicator Notes

Plant phenological events are studied using several data collection methods, including satellite images, models, and direct observations. The use of varying data collection methods in addition to different phenological indicators (such as leaf or bloom dates for different types of plants) can lead to a range of estimates of the arrival of spring.

Climate is not the only factor that can affect phenology. Observed variations can also reflect plant genetics, changes in the surrounding ecosystem, and other factors. This indicator minimizes genetic influences by relying on cloned plant species (that is, plants with no genetic differences).

Data Sources

Leaf and bloom observations were compiled by the USA National Phenology Network and are available at: www.usanpn.org. This indicator is also based on climate data that were provided by the U.S. Historical Climatology Network and are available at: www.ncdc.noaa.gov/oa/climate/research/ushcn. Data for this indicator were analyzed using methods described by McCabe et al. (2011).[24]

Bird Wintering Ranges

This indicator examines changes in the winter ranges of North American birds.

Background

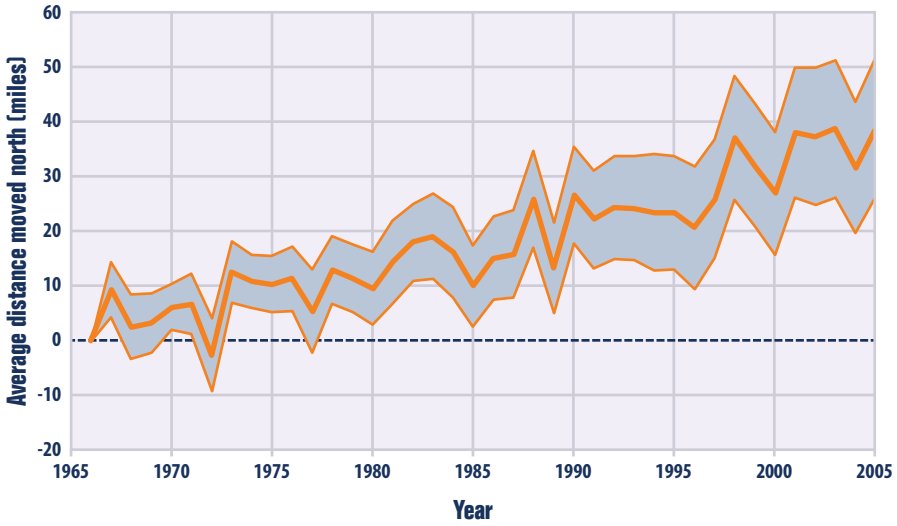
Changes in climate can affect ecosystems by influencing animal behavior and distribution. Birds are a particularly good indicator of environmental change for several reasons:

- Each species of bird has adapted to certain habitat types, food sources, and temperature ranges. In addition, the timing of certain events in their life cycles—such as migration and reproduction—is driven by cues from the environment. For example, many North American birds follow a regular seasonal migration pattern, moving north to feed and breed in the summer, then moving south to spend the winter in warmer areas. Changing conditions can influence the distribution of both migratory and nonmigratory birds as well as the timing of important life cycle events.
- Birds are easy to identify and count, and thus there is a wealth of scientific knowledge about their distribution and abundance. People have kept detailed records of bird observations for more than a century.
- There are many different species of birds living in a variety of habitats, including water birds, coastal birds, and land birds. If a change in habitats or habits occurs across a range of bird types, it suggests that a common force might be contributing to that change.

Temperature and precipitation patterns are changing across the United States (see the U.S. and Global Temperature indicator on p. 24 and the U.S. and Global Precipitation indicator on p. 28). Some bird species can adapt to generally warmer temperatures by changing where they live—for example, by migrating further north in the summer but not as far south in the winter, or by shifting inland as winter temperature extremes grow less severe. Nonmigratory species might shift as well, expanding into newly suitable habitats while moving out of areas that become less suitable. Other types of birds might not adapt to changing conditions and could experience a population decline as a result. Climate change can also alter the timing of events that are based on temperature cues, such as migration and breeding (especially egg-laying).

Figure 1. Change in Latitude of Bird Center of Abundance, 1966–2005

This figure shows annual change in latitude of bird center of abundance for 305 widespread bird species in North America from 1966 to 2005. Each winter is represented by the year in which it began (for example, winter 2005–2006 is shown as 2005). The shaded band shows the likely range of values, based on the number of measurements collected and the precision of the methods used.



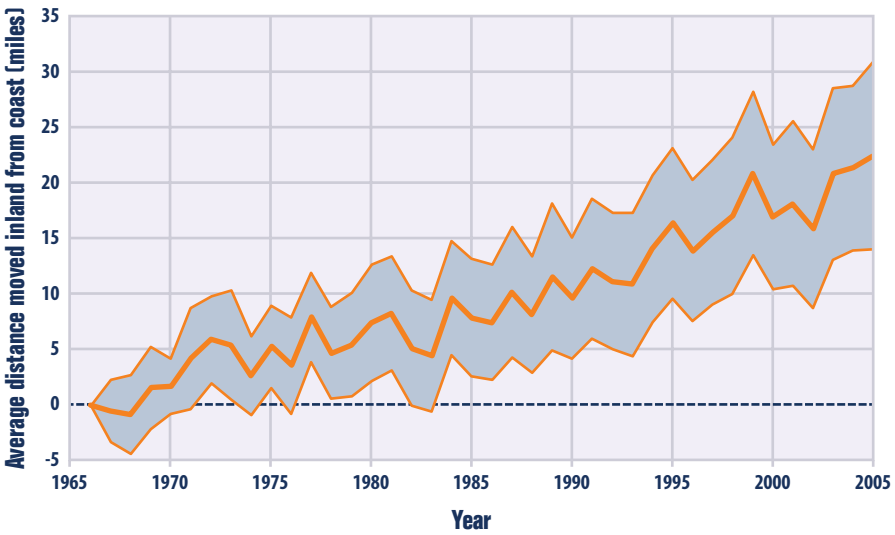
Data source: National Audubon Society, 2009[25]

Key Points

- Among 305 widespread North American bird species, the average mid-December to early January center of abundance moved northward between 1966 and 2005. The average species shifted northward by 35 miles during this period (see Figure 1). Trends in center of abundance are closely related to winter temperatures.[26]
- On average, bird species have also moved their wintering grounds farther from the coast since the 1960s (see Figure 2). This shift also relates to changes in winter temperatures.[27]
- Some species have moved farther than others. Of the 305 species studied, 177 (58 percent) have shifted their wintering grounds significantly northward since the 1960s, but some others have not moved at all. A few species have moved northward by as much as 200 to 400 miles.[28]

Figure 2. Change in Distance to Coast of Bird Center of Abundance, 1966–2005

This figure shows annual change in distance to the coast of bird center of abundance for 305 widespread bird species in North America from 1966 to 2005. Each winter is represented by the year in which it began (for example, winter 2005–2006 is shown as 2005). The shaded band shows the likely range of values, based on the number of measurements collected and the precision of the methods used.



Data source: National Audubon Society, 2009[29]

About the Indicator

This indicator looks at the "center of abundance" of 305 widespread North American bird species over a 40-year period. The center of abundance is a point on the map that represents the middle of each species' distribution. If a whole population of birds were to shift generally northward, one would see the center of abundance shift northward as well.

For year-to-year consistency, this indicator uses observations from the National Audubon Society's Christmas Bird Count, which takes place every year in early winter. The Christmas Bird Count is a long-running citizen science program in which individuals are organized by the National Audubon Society, Bird Studies Canada, local Audubon chapters, and other bird clubs to identify and count bird species. The data presented in this indicator were collected from more than 2,000 locations throughout the United States and parts of Canada. At each location, skilled observers follow a standard counting procedure to estimate the number of birds within a 15-mile diameter "count circle" over a 24-hour period. Study methods remain generally consistent from year to year. Data produced by the Christmas Bird Count go through several levels of review before Audubon scientists analyze the final data, which have been used to support a wide variety of peer-reviewed studies.

Indicator Notes

Many factors can influence bird ranges, including food availability, habitat alteration, and interactions with other species. As a result, some of the birds included in this indicator might have moved north for reasons other than changing temperatures. This indicator does not show how responses to climate change vary among different types of birds. For example, a more detailed National Audubon Society analysis found large differences among coastal birds, grassland birds, and birds adapted to feeders, which all have varying abilities to adapt to temperature changes.[30]

Some data variations can be caused by differences among count circles, such as inconsistent level of effort by volunteer observers, but these differences are carefully corrected in Audubon's statistical analysis.

Data Sources

Bird center of abundance data were collected by the annual Christmas Bird Count organized by the National Audubon Society and Bird Studies Canada. Recent and historical Christmas Bird Count data are available at: http://birds.audubon.org/christmas-bird-count. Data for this indicator were analyzed by the National Audubon Society in 2009[31] and are available at: www.audubon.org/bird/bacc/index.html.

Heat-Related Deaths

This indicator presents data on deaths classified as "heat-related" in the United States.

Background

When people are exposed to extreme heat, they can suffer from potentially deadly heat-related illnesses such as heat exhaustion and heat stroke. Heat is the leading weather-related killer in the United States, even though most heat-related deaths are preventable through outreach and intervention (see EPA's Excessive Heat Events Guidebook at: www.epa.gov/heatisland/about/pdf/EHEguide_final.pdf)

Unusually hot summer temperatures have become more frequent across the contiguous 48 states in recent decades[32] (see the High and Low Temperatures indicator on p. 26), and extreme heat events (heat waves) are expected to become longer, more frequent, and more intense in the future.[33] As a result, the risk of heat-related deaths and illness is also expected to increase.[34]

Increases in summertime temperature variability may increase the risk of heat-related death for the elderly and other vulnerable populations.[35] Older adults carry the highest risk of heat-related death, although young children are also sensitive to the effects of heat. Across North America, the population over the age of 65 is growing dramatically as the baby boomer generation ages. People with certain diseases, such as cardiovascular and respiratory illnesses, are especially vulnerable to excessive heat exposure, as are the economically disadvantaged.

Some studies suggest that the number of deaths caused by extremely cold temperatures might drop in certain areas as the climate gets warmer, while others do not expect the number to change at all.[36,37] Any decrease in cold-related deaths, however, will not be enough to outweigh the increase in heat-related deaths.[38,39]

About the Indicator

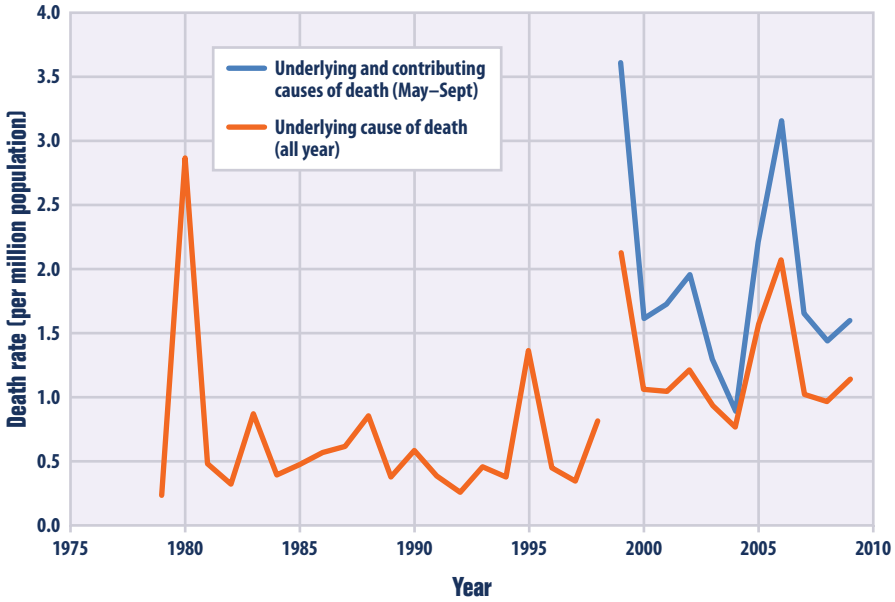
This indicator shows the annual rate for deaths classified by medical professionals as "heat-related" each year in the United States, based on death certificate records. Every death is recorded on a death certificate, where a medical professional identifies the main cause of death (also known as the underlying cause), along with other conditions that contributed to the death. These causes are classified using a set of standard codes. Multiplying the annual number of deaths per U.S. population that year by one million will result in the death rate shown in Figure 1.

This indicator shows heat-related deaths using two methodologies. One method shows deaths for which excessive natural heat was stated as the underlying cause of death from 1979 to 2009. The other data series shows deaths for which heat was listed as either the underlying cause or a contributing cause, based on a broader set of data that at present can only be evaluated

(Continued on page 73)

Figure 1. Deaths Classified as "Heat-Related" in the United States, 1979–2009

This figure shows the annual rates for deaths classified as "heat-related" by medical professionals in the 50 states and the District of Columbia. The orange line shows deaths for which heat was listed as the main (underlying) cause. The blue line shows deaths for which heat was listed as either the underlying or contributing cause of death during the months from May to September, based on a broader set of data that became available in 1999.*



* Between 1998 and 1999, the World Health Organization revised the international codes used to classify causes of death. As a result, data from earlier than 1999 cannot easily be compared with data from 1999 and later.

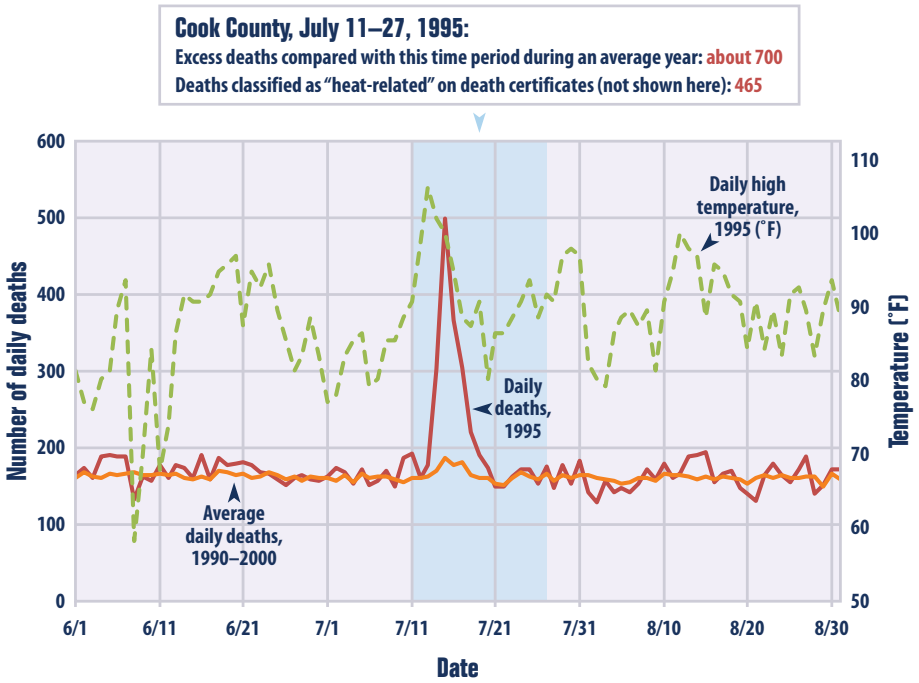
Data source: CDC, 2012[40,41]

Key Points

- During the 31 years of data collection (1979–2009), the death rate as a direct result of exposure to heat (underlying cause of death) generally hovered around 0.5 deaths per million population, with spikes in certain years (see Figure 1). Overall, a total of over 7,000 Americans suffered heat-related deaths since 1979.
- For years where the two records overlap (1999–2009), accounting for those additional deaths in which heat was listed as a contributing factor results in a higher death rate—nearly double for some years—compared with the estimate that only includes deaths where heat was listed as the underlying cause. However, even this expanded metric does not necessarily capture the full extent of heat-related deaths.
- The indicator shows a peak in heat-related deaths in 2006, a year that was associated with widespread heat waves and was the second-hottest year on record in the contiguous 48 states (see the U.S. and Global Temperature indicator on p. 24).
- Considerable year-to-year variability in the data and certain limitations of this indicator make it difficult to determine whether the United States has experienced a meaningful increase or decrease in deaths classified as "heat-related" over time. Dramatic increases in heat-related deaths are closely associated with both the occurrence of hot temperatures and heat waves, though these deaths may not be reported as "heat-related" on death certificates. For example, studies of the 1995 heat wave event in Chicago (see example on p. 73) suggest that there were hundreds more deaths than were actually reported as "heat-related" on death certificates.

Example: Examining Heat-Related Deaths During the 1995 Chicago Heat Wave*

Many factors can influence the nature, extent, and timing of health consequences associated with extreme heat events.[42] Studies of heat waves are one way to better understand health impacts, but different methods can lead to very different estimates of heat-related deaths. For example, during a severe heat wave that hit Chicago between July 11 and July 27, 1995, 465 heat-related deaths were recorded on death certificates in Cook County.[43] However, studies that compared the total number of deaths during this heat wave (regardless of the recorded cause of death) with the long-term average of daily deaths found that the heat wave led to about 700 more deaths than would otherwise have been expected.[44] Differences in estimated heat-related deaths that result from different methods may be even larger when considering the entire nation and longer time periods.



*This graph shows data for the Chicago Standard Metropolitan Statistical Area.

Data sources: CDC, 2012;[45] NOAA, 2012[46]

back to 1999. For example, in a case where cardiovascular disease was determined to be the underlying cause of death, heat could be listed as a contributing factor because it can make the individual more susceptible to the effects of this disease. Because excessive heat events are associated with summer months, the 1999–2009 analysis was limited to May through September.

Indicator Notes

Several factors influence the sensitivity of this indicator and its ability to estimate the true number of deaths associated with extreme heat events. It has been well-documented that many deaths associated with extreme heat are not identified as such by the medical examiner and might not be correctly coded on the death certificate. In many cases, the medical examiner might classify the cause of death as a cardiovascular or respiratory disease, not knowing for certain whether heat was a contributing factor, particularly if the death did not occur during a well-publicized heat wave. By studying how daily death rates vary with temperature in selected cities, scientists have found that extreme heat contributes to far more deaths than the official death certificates might suggest.[47] This is because the stress of a hot day can increase the chance of dying from a heart attack, other heart conditions, or respiratory diseases such as pneumonia.[48] These causes of death are much more common than heat-related illnesses such as heat stroke. Thus, this indicator very likely underestimates the number of deaths caused by exposure to heat.

Just because a death is classified as "heat-related" does not mean that high temperatures were the only factor that caused or contributed to the death. Pre-existing medical conditions can significantly increase an individual's vulnerability to heat. Other important factors, such as the overall vulnerability of the population, the extent to which people have adapted to higher temperatures, and the local climate and topography, can affect trends in "heat-related" deaths. Heat response measures such as early warning and surveillance systems, air conditioning, health care, public education, cooling centers during heat waves, infrastructure standards, and air quality management can also make a big difference in death rates. For example, after a 1995 heat wave, the city of Milwaukee developed a plan for responding to extreme heat conditions in the future; during the 1999 heat wave, heat-related deaths were roughly half of what would have been expected.[49]

Future development related to this indicator should focus on capturing *all* heat-related deaths, not just those with a reported link to heat stress, as well as examining heat-related illnesses more systematically.

Data Sources

Data for this indicator were provided by the U.S. Centers for Disease Control and Prevention (CDC). The 1979–2009 underlying cause data are publicly available through the CDC WONDER database at: http://wonder.cdc.gov/mortSQL.html. The 1999–2009 analysis was developed by CDC's Environmental Public Health Tracking Program, which provides a summary at: www.cdc.gov/nceh/tracking.