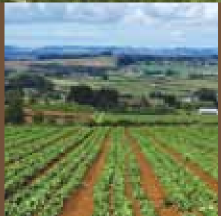
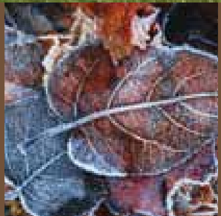
Society and

Heat-Related Deaths



Length of Growing Season



Plant Hardiness Zones

Ecosystems

The indicators in this report show that changes are occurring throughout the Earth's climate system, including increases in air and water temperatures, a rise in sea level, longer growing seasons, and longer ice-free periods on lakes and rivers. Changes such as these are expected to present a wide range of challenges to human society 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.

For society, increases in temperature are likely to increase heat-related illnesses and deaths, especially in urban areas. Changes in precipitation patterns will affect water supplies and quality, while more severe storms and floods will damage property and infrastructure (such as roads, bridges, and utilities) or cause loss of life. Rising sea levels will inundate low-lying lands, erode beaches, and cause flooding in coastal areas. Climate change also will affect agriculture, energy production and use, land use and development, and recreation.

Climate also plays an important role in natural ecosystems. An ecosystem is an interdependent system of plants, animals, and microorganisms interacting with one another and their environment. Ecosystems provide humans with food, clean water, and a variety of other services that could be affected by climate change. 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. Climate change could also increase the risk of extinction for some species.

The more the climate changes, the greater the risk of harm. The nature and extent of climate change effects, and whether these effects will be harmful or beneficial, will vary by time and place. 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.

Heat-Related Deaths

This indicator reviews trends in heat-related deaths in the United States.

Background

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

Heat waves have become more frequent in most of North America in recent decades (see the Heat Waves indicator on p. 24), and these events can be associated with increases in heat-related deaths.

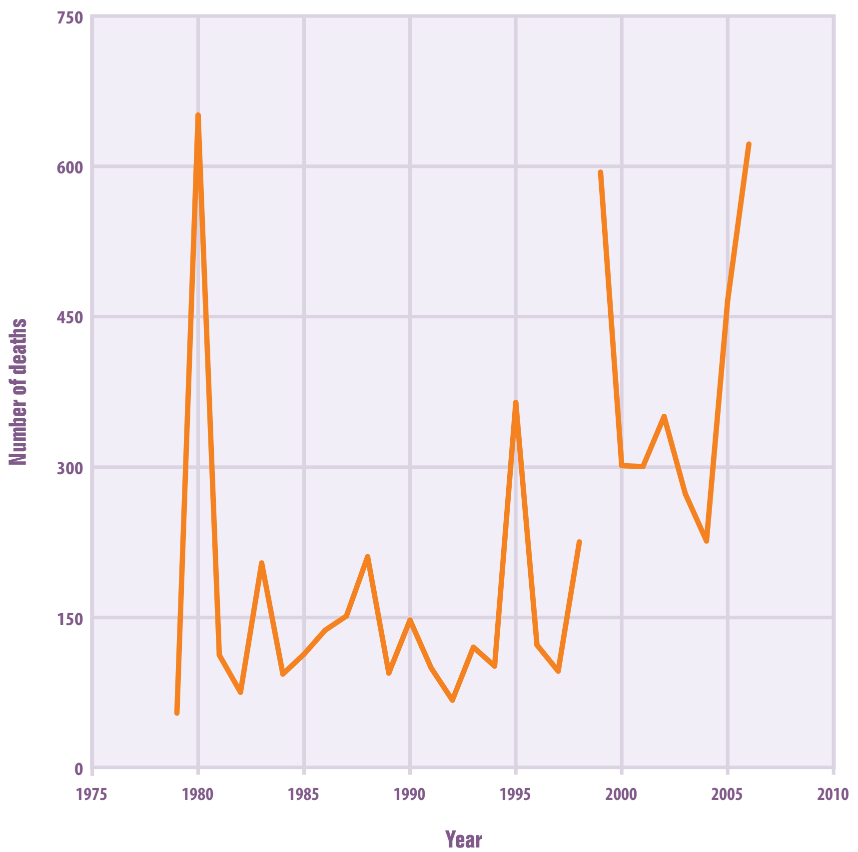
Older adults carry the highest risk of heat-related death. Across North America, the population over the age of 65 is expected to increase slowly until 2010, and then grow dramatically as the baby boom generation ages. People with certain diseases, such as cardiovascular and respiratory illnesses, are especially sensitive to heat.

About the Indicator

This indicator shows the number of heat-related deaths each year in the United States from 1979 to 2006, the years for which national data are available. The indicator is based on data from the U.S. Centers for Disease Control and Prevention, which maintains a database that tracks all deaths nationwide. Data in this indicator include only those deaths for which excessive natural heat was stated as the underlying cause of death on the death certificate. Other studies might consider a broader definition of "heat-related" by also including deaths for which heat has been listed as a contributing factor. For example, even in a case where cardiovascular disease is determined to be the underlying cause of death, heat could have contributed by making the individual more susceptible to the effects of the disease.

Figure 1. Heat-Related Deaths in the United States, 1979–2006

*This figure shows the annual number of heat-related deaths occurring in the 50 states and the District of Columbia from 1979 to 2006.**



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

Data source: CDC, 2009[1]

Key Points

- Overall, during the 28 years of data collection (1979–2006), 6,367 deaths were classified as heat-related (see Figure 1).
- Considerable year-to-year variability in the number of heat-related deaths makes it difficult to determine whether the United States has experienced a meaningful increase or decrease in heat-related deaths over time.
- Dramatic increases in cases of heat-related mortality are closely associated with the occurrence of heat waves, especially those of 1980 (St. Louis and Kansas City, Missouri), 1995 (Chicago, Illinois), and 1999 (Cincinnati, Ohio, and Chicago).

Indicator Limitations

Just because a death is classified as "heat-related" does not mean that high temperatures were the only factor that caused the death. Pre-existing medical conditions can significantly increase an individual's vulnerability to heat. This indicator does not include deaths for which heat was listed as a contributing cause but not the official underlying cause of death. Including deaths for which heat was a contributing cause would substantially increase the number of deaths shown in Figure 1. For example, the U.S. Centers for Disease Control and Prevention reported 54 percent more deaths resulting from exposure to extreme heat between 1999 and 2003 (totaling 3,442) when they included deaths for which heat was a contributing cause.[2]

Heat waves are not the only factor that can affect trends in "heat-related" deaths. Other factors include the vulnerability of the population, the extent to which people have adapted to higher temperatures, the local climate and topography, and the steps people have taken to manage heat emergencies effectively.

Heat response measures can make a big difference in death rates. These measures can include early warning and surveillance systems, air conditioning, health care, public education, infrastructure standards, and air quality management. 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, this plan cut heat-related deaths nearly in half compared with what was expected.[3]

Data Sources

Data for this indicator were provided by the U.S. Centers for Disease Control and Prevention (CDC) and are available in the CDC WONDER database in the Compressed Mortality File at: http://wonder.cdc.gov/mortSQL.html. In the CDC WONDER database for the period from 1979 to 1998, heat-related mortalities were classified as International Classification of Disease, Ninth Revision (ICD-9) codes E900 "excessive heat—hyperthermia" and E900.0 "due to weather conditions." For the period from 1999 to 2006, deaths were classified as ICD-10 code X30 "exposure to excessive natural heat—hyperthermia."

Length of Growing

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

Background

The length of the growing season in any given region represents 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.[4] 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 strain water supplies. 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.

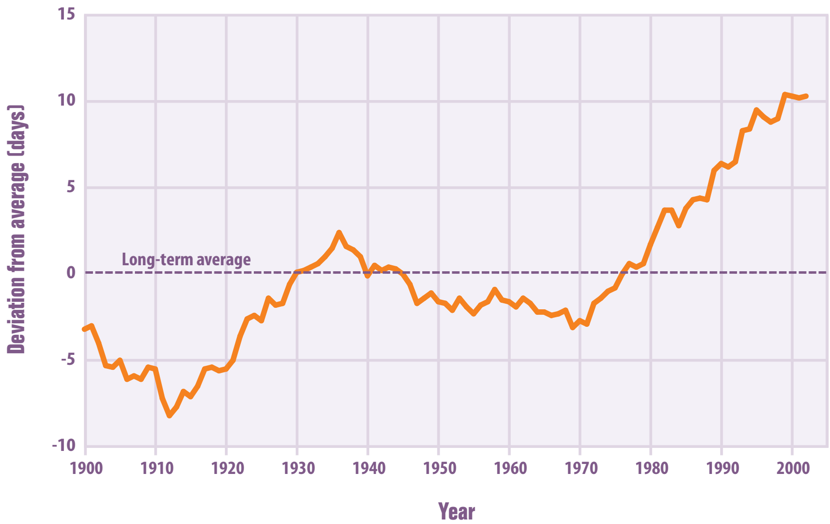
About the Indicator

This indicator looks at the length of the growing season in the lower 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 794 weather stations throughout the lower 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 spatially, then compared with a long-term average to determine the deviation from "normal" in any given year.

Figure 1. Length of Growing Season in the Lower 48 States, 1900–2002

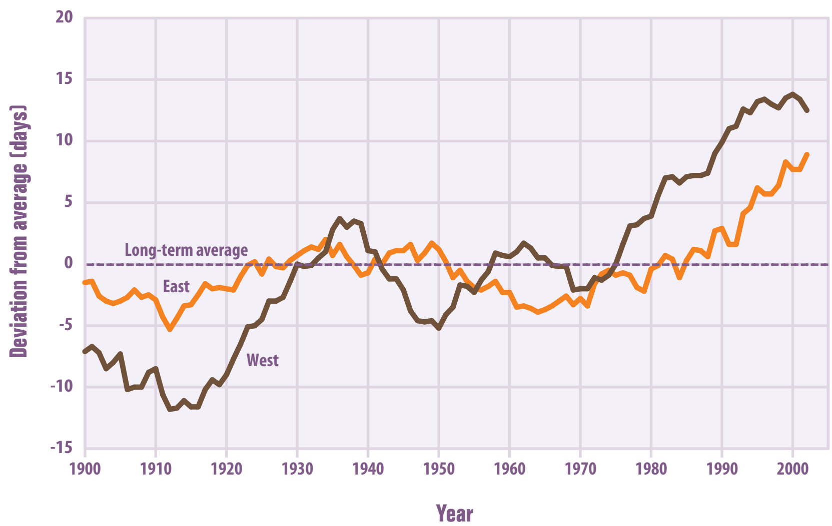
This figure shows the length of the growing season in the lower 48 states compared with a long-term average. For each year, the line represents the number of days shorter or longer than average. The trend line was smoothed using an 11-year moving average. Choosing a different long-term average for comparison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



Data source: Kunkel, 2009[5]

Figure 2. Length of Growing Season in the Lower 48 States, 1900–2002: 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. The trend line was smoothed using an 11-year moving average. Choosing a different long-term average for comparison would not change the shape of the trends.



Data source: Kunkel, 2009[6]

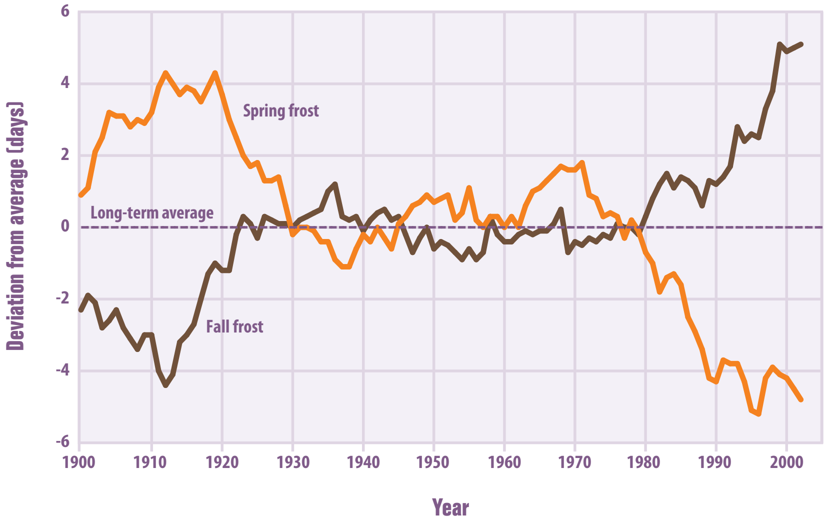
Season

Key Points

- The average length of the growing season in the lower 48 states has increased by about 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 20 days per century since 1900, compared with a rate of about six days per century in the East (see Figure 2).
- The final spring frost is now occurring earlier than at any point since 1900, and the first fall frosts are arriving later. Since 1985, the last spring frost has arrived an average of about four days earlier than the long-term average, and the first fall frost has arrived about three days later (see Figure 3).

Figure 3. Timing of Last Spring Frost and First Fall Frost in the Lower 48 States, 1900–2002

This figure shows the timing of the last spring frost and the first fall frost in the lower 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 trend lines were smoothed using an 11-year moving average. Choosing a different long-term average for comparison would not change the shape of the trends.



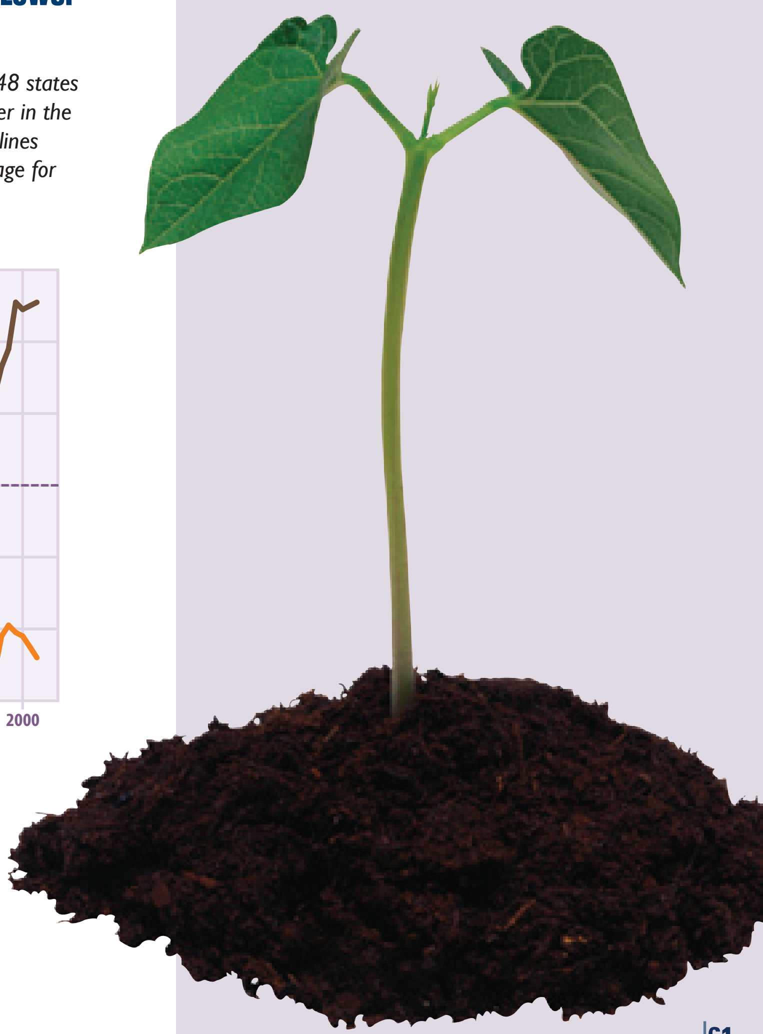
Data source: Kunkel, 2009[7]

Indicator Limitations

Changes in measurement techniques and instruments over time can affect trends. However, these data were carefully reviewed for quality, and values that appeared invalid were not included in the indicator. This indicator only includes weather stations that did not have many missing data points.

Data Sources

All three figures are based on 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. Trends were analyzed by Kunkel (2009).[8]



Plant Hardiness

This indicator examines shifts in plant hardiness zones in the lower 48 states.

Background

Plant hardiness zones are regional designations that help farmers and gardeners determine which plant species are expected to survive a typical winter. Locations are assigned a numbered plant hardiness zone based on an average of the lowest temperatures recorded each winter.

Average annual minimum temperature is used to determine hardiness zones because a single low temperature event such as a freeze is far more likely to harm plants than a single high-temperature event, such as an unusually warm day. Minimum temperature is considered a critical factor in a plant's ability to survive in a particular location.

As temperatures increase, plants are able to survive winters in areas that were previously too cold for them to thrive. These changes in growing patterns can influence agricultural production, and changes in wild plant distribution can have wide-ranging effects on ecosystems. For instance, the animal species present in a location could change as the animals move to seek out their preferred food source, or an invasive plant could harm native plant species.

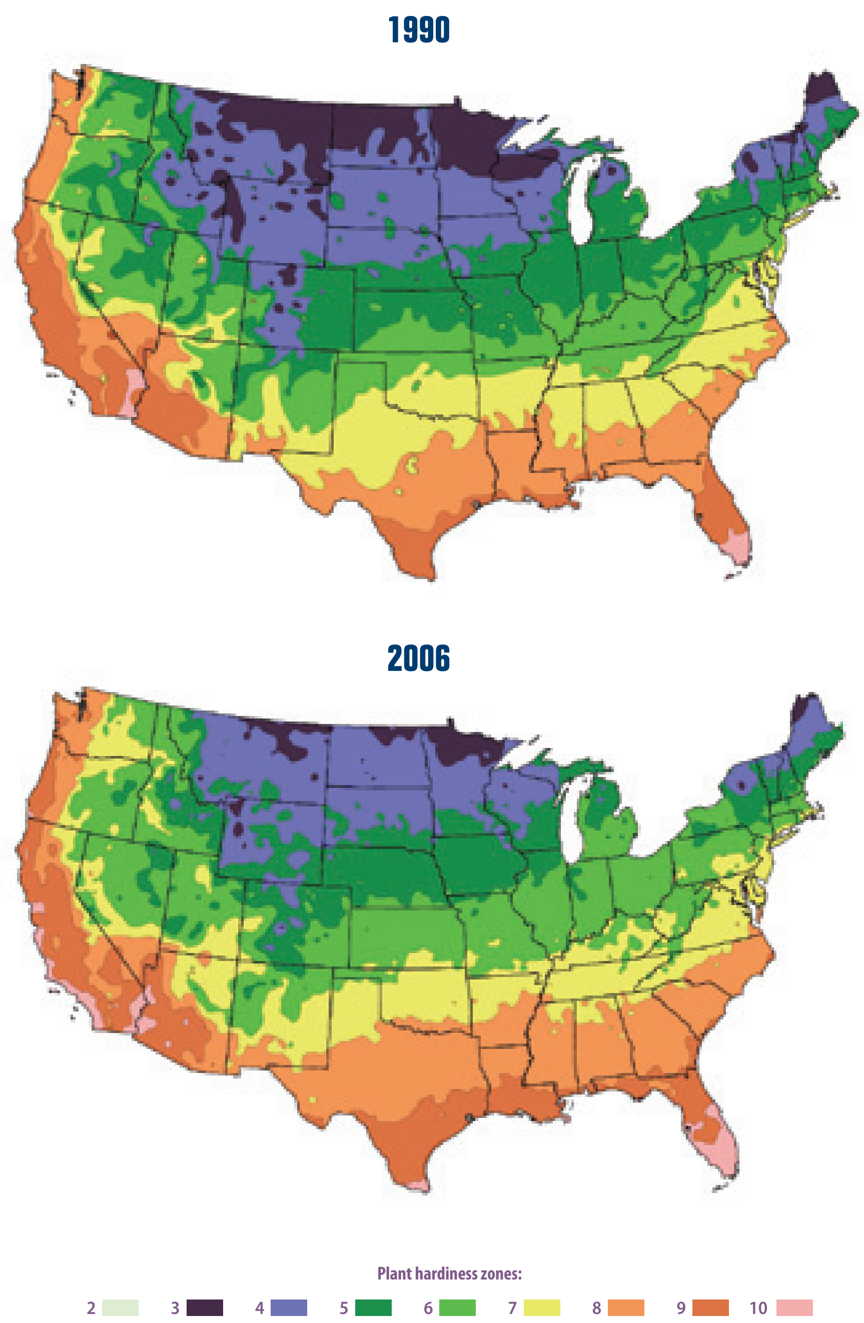
About the Indicator

The U.S. Department of Agriculture first published a plant hardiness zone map of the United States in 1960, and revised the map in 1990. This map is divided into numbered zones based on average annual low temperatures in 10-degree increments. For example, areas in Zone 7 have an average annual minimum temperature of 0 to 10°F, while areas in Zone 8 have an average annual minimum temperature of 10 to 20°F.

In 2006, the Arbor Day Foundation revised the map based on 15 years of temperature data collected by 5,000 National Oceanic and Atmospheric Administration weather stations across the United States. To determine how plant hardiness zones have shifted over time, this indicator compares the 1990 U.S. Department of Agriculture hardiness zone map with the 2006 Arbor Day Foundation hardiness zone map.

Figure 1. United States Plant Hardiness Zones, 1990 and 2006

This figure depicts plant hardiness zones in the lower 48 states in 1990 and 2006.



Data source: Arbor Day Foundation, 2006[9]

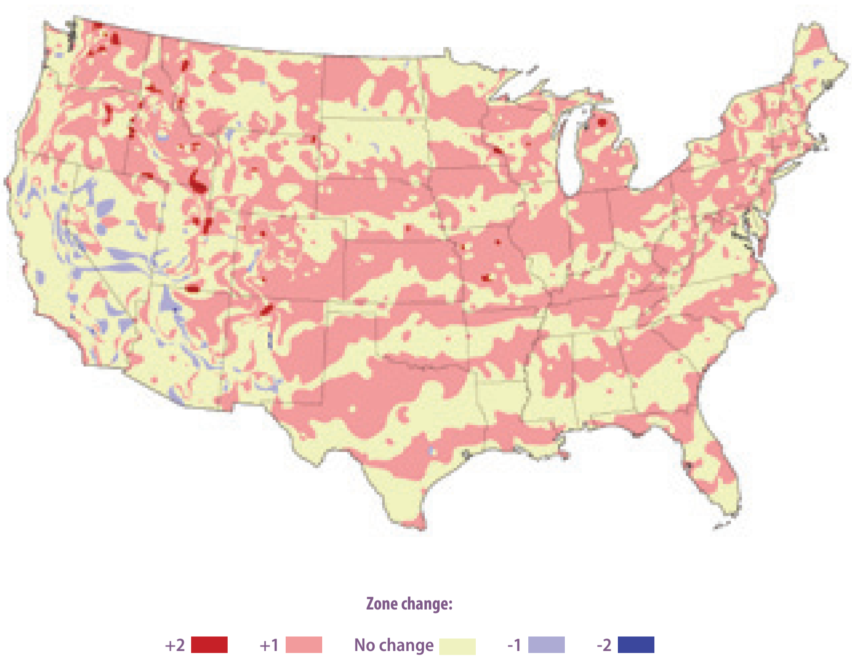
Zones

Key Points

- Between 1990 and 2006, hardiness zones have shifted noticeably northward, reflecting warmer winter temperatures (see Figures 1 and 2).
- Large portions of several states have warmed by at least one hardiness zone; for example, large parts of Illinois, Indiana, Ohio, and Missouri have shifted from Zone 5 to Zone 6, reflecting a sizable increase in average low temperatures (see Figures 1 and 2).
- A few scattered areas, mostly in the West, have cooled by one hardiness zone, while a few smaller areas have cooled by two hardiness zones (see Figure 2).

Figure 2. United States Plant Hardiness Zones, 1990 Versus 2006

This figure depicts changes in plant hardiness zones in the lower 48 states between 1990 and 2006.



Data source: Arbor Day Foundation, 2006[10]

Indicator Limitations

Changes in plant hardiness zones do not address maximum temperatures or the amount of precipitation present in a location, which can also affect plants' ability to thrive. Plant hardiness zones also do not take into account the regularity and amount of snow cover, elevation, soil drainage, and the regularity of freeze and thaw cycles. As a result, plant hardiness zone maps are less useful in the western United States, where elevation and precipitation vary widely. For example, both Tucson, Arizona, and Seattle, Washington, are in Zone 9 according to the 2006 map; however, the native vegetation in the two cities is very different.

Data Sources

The maps used in this indicator are available online at: www.arborday.org/media/map_change.cfm. The data used to create the map were provided by the National Oceanic and Atmospheric Administration's National Climatic Data Center, which provides temperature data and maps through its Web site at: www.ncdc.noaa.gov/oa/ncdc.html.

Leaf and Bloom

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.

Scientists have very high confidence that recent warming trends in global climate are linked to an earlier arrival of spring events.[11] 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. 60), 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 accurate indicators of 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 date and the first bloom date of lilacs and honeysuckles, which have an easily monitored flowering season, relatively high survival rate, and large geographic distribution (see map of lilac range at right). 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.[12]

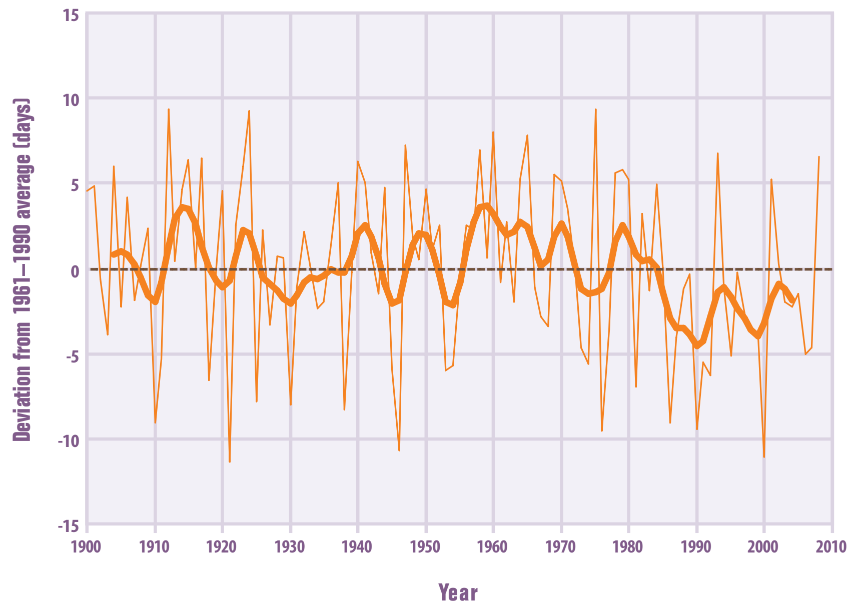
About the Indicator

This indicator shows trends in the timing of first leaf dates and first bloom dates in lilacs and honeysuckles across much of the lower 48 states (see map at right). Because many of the phenological observation records in the United States are less than 20 years long, models have been used to provide a more complete understanding of long-term trends.

(Continued on page 65)

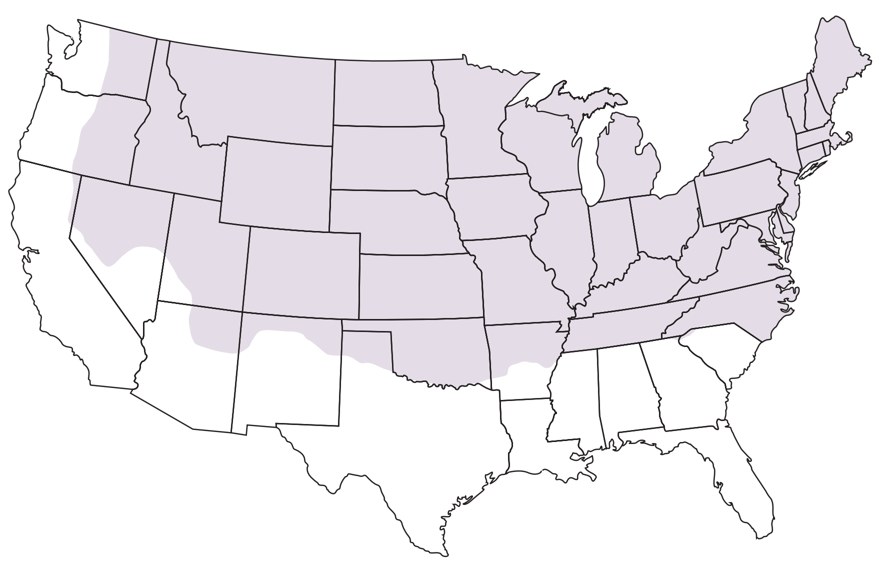
Figure 1. First Leaf Dates in the Lower 48 States, 1900–2008

This figure shows modeled trends in lilac and honeysuckle first leaf dates across the lower 48 states, using the 1961 to 1990 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 trend.



Data source: Schwartz, 2009[13]

Range of Lilacs Covered in This Indicator



Source: Schwartz, 2009[14]

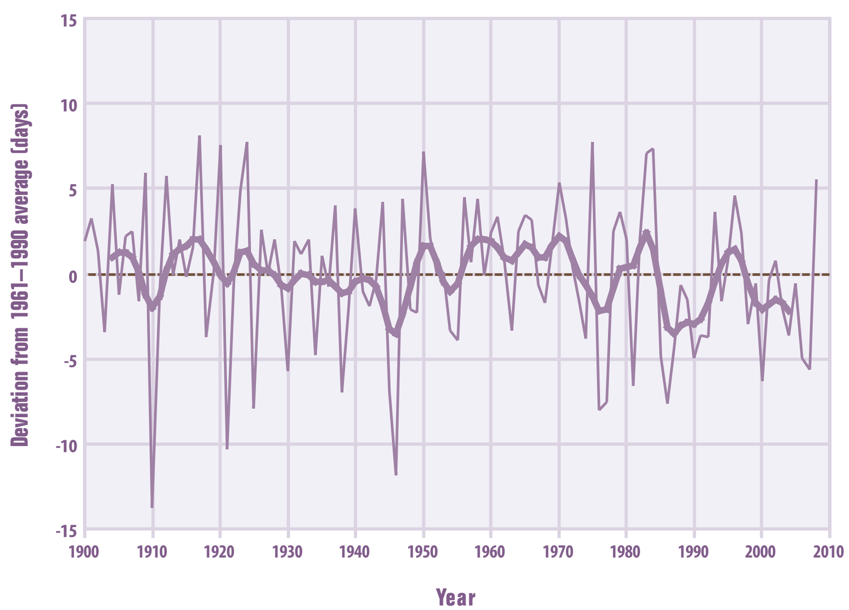
Dates

Key Points

- First leaf growth in lilacs and honeysuckles in the lower 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 seems to have begun around the 1980s (see Figure 1).
- Lilacs and honeysuckles are also blooming slightly earlier than in the past. However, the data show a high degree of year-to-year variability, which makes it difficult to determine whether this change is statistically meaningful (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 other studies have also found a trend toward earlier spring events, and many of these trends are more pronounced than the trends seen in just the lower 48 states.[15]

Figure 2. First Bloom Dates in the Lower 48 States, 1900–2008

This figure shows modeled trends in lilac and honeysuckle bloom dates across the lower 48 states, using the 1961 to 1990 average as a baseline. Positive values indicate that blooming occurred 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 trend.



Data source: Schwartz, 2009[16]

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 citizen scientists 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.

This indicator uses data from several hundred weather stations throughout the area where lilacs and honeysuckles grow. 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 1961 to 1990 average to determine the number of days' "deviation from normal." This indicator presents the average deviation across all stations.

Indicator Limitations

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 the use of 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 Schwartz et al. (2006).[17]

Bird Wintering

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 is seen 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. 22 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 might 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).

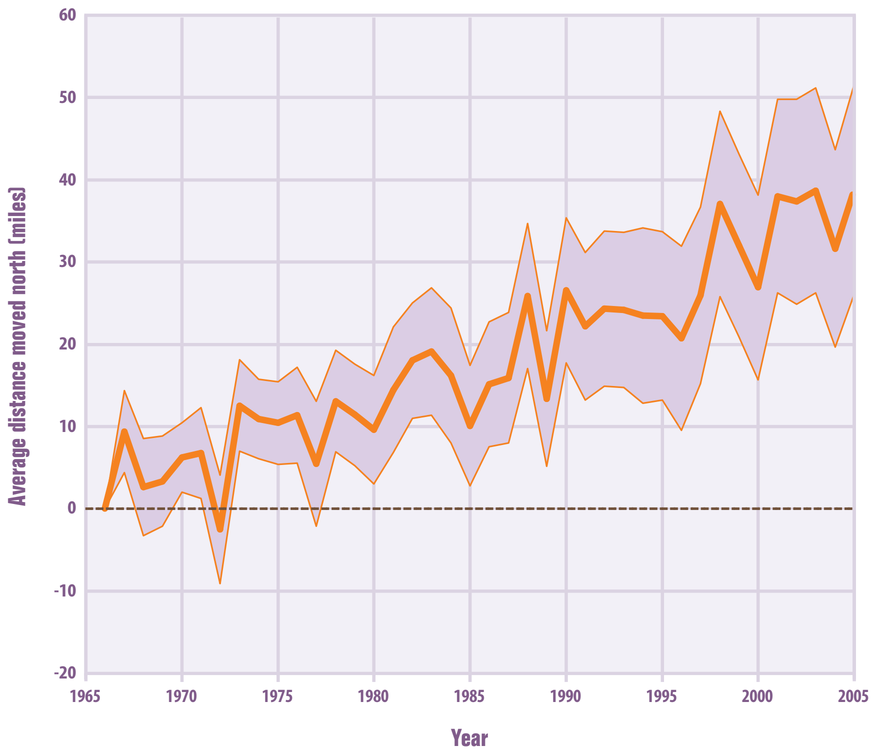
About the Indicator

This indicator looks at the "center of abundance" of 305 widespread North American bird species over a 40-year period. The center of

(Continued on page 67)

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[18]

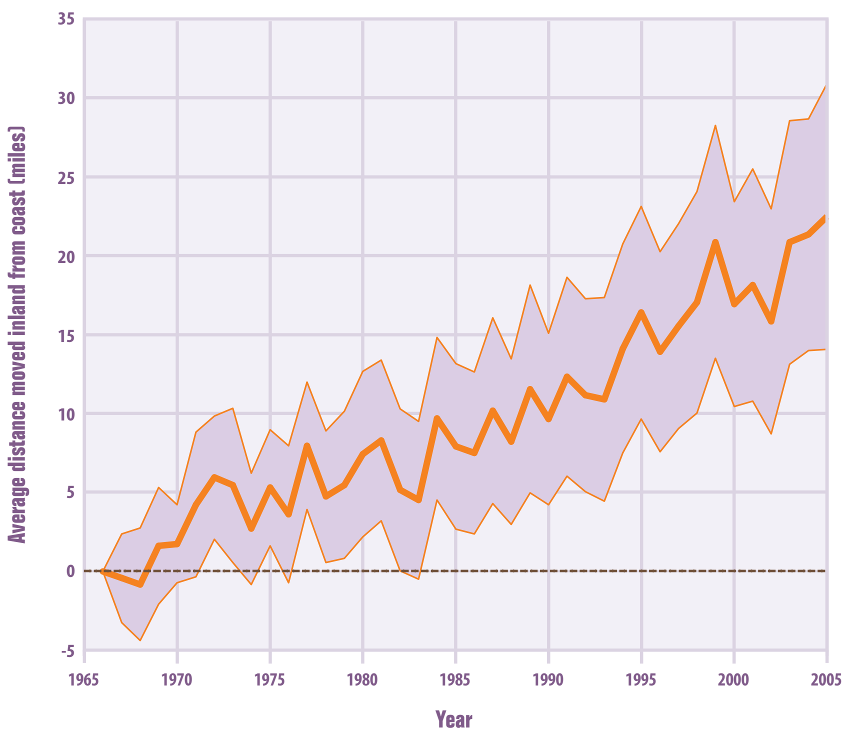
Ranges

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.[19]
- On average, bird species have also moved their wintering grounds farther from the coast since the 1960s (see Figure 2).
- Some species have moved farther than others. Of the 305 species studied, 177 (58 percent) have shifted their wintering grounds significantly to the north 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.[20]

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[21]

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 Limitations

Many factors can influence bird ranges, including food availability, habitat alteration, and interactions with other species. As a result, some of the birds covered in this indicator might have moved north for reasons other than changing temperatures. This indicator also 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 between coastal birds, grassland birds, and birds adapted to feeders, which all have varying abilities to adapt to temperature changes.[22]

Some data variations can be caused by differences between 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: www.audubon.org/Bird/cbc. Data for this indicator were analyzed by the National Audubon Society in 2009[23] and are available at: www.audubon.org/bird/bacc/index.html.