
California is experiencing a climate crisis that is increasingly taking a toll on the health and well-being of its people and on its unique and diverse ecosystems. Every Californian has suffered from the effects of record high temperatures, dry winters, prolonged drought, and proliferating wildfires in recent years. California's biodiversity is threatened as alterations to habitat conditions brought about by a changing climate are occurring at a pace that could overwhelm the ability of plant and animal species to adapt.

This fourth edition of the *Indicators of Climate Change in California* report continues to track changes in the state's climate and its impacts in the state. Indicators are scientific measurements that track trends and conditions relating to climate change. Collectively, the indicators portray a statewide picture of how climate change has been impacting the environment and people of California. Through these indicators, the report tells the state's climate change story, starting with the human influences on climate, or "drivers," followed by the changes in climate Californians have been experiencing, and then their consequences on the physical environment, on plant and animal species, and on human health.

This report contains a new section highlighting how California Tribes* have witnessed climate change. Eight Tribes provide accounts of their unique experiences in this section. OEHHA also conducted a series of Tribal listening sessions with over 40 Tribes. These reflect a diversity of perspectives, cultures, beliefs, landscapes, and climate change experiences, and are represented in various sections throughout the report. The information shared in these sessions illustrates the value of Tribal knowledge, acquired from long histories of interaction with the Earth that predate instrumental records. These long-term perspectives advance the understanding of climate change, and can inform policy and action.

## REPORTS ON THE IMPACTS ON CALIFORNIA TRIBES

Amah Mutsun Tribal Band
Big Pine Paiute Tribe of the Owens Valley
Big Valley Band of Pomo Indians of California
Bishop Paiute Tribe
Karuk Tribe
North Fork Rancheria of Mono Indians of California
Pala Band of Mission Indians
Santa Ynez Band of Chumash Indians

*In this report, the term "California Tribes" refers to all Tribal Nations in the state, including those that are non-federally recognized and currently landless.

This summary presents highlights following the organization of the report: (1) climate change drivers; (2) changes in climate; (3) impacts on physical systems; (4) impacts on vegetation and wildlife; (5) impacts on human health; and (6) impacts on Tribes. While many indicators clearly show a trend in the direction expected with climate change, they also reflect the variability that is inherent in the Earth's atmosphere, oceans and other complex systems across seasons, between years, or even between decades.

# INDICATORS OF CLIMATE CHANGE IN CALIFORNIA

## CLIMATE CHANGE DRIVERS

Greenhouse gas emissions
Atmospheric greenhouse gas concentrations
Atmospheric black carbon concentrations
Acidification of coastal waters

## CHANGES IN CLIMATE

Air temperature
Extreme heat events
Winter chill
Cooling and heating degree-days
Precipitation
Drought

## IMPACTS ON PHYSICAL SYSTEMS

Snow-water content
Snowmelt runoff
Glacier change
Lake water temperature
Salmon River water temperature
Coastal ocean temperature
Sea level rise
Dissolved oxygen in coastal waters

## IMPACTS ON VEGETATION AND WILDLIFE

### *On vegetation*

Marine harmful algal blooms
Forest tree mortality
Wildfires
Ponderosa pine forest retreat
Vegetation distribution shifts
Changes in forests and woodlands
Subalpine forest density
Fruit and nut maturation time
Navel orange worm

### *On wildlife*

Spring flight of Central Valley butterflies
Migratory bird arrivals
Bird wintering ranges
Small mammal and avian range shifts
Copepod populations
Nudibranch range shifts
Chinook salmon abundance
Cassin's auklet breeding success
California sea lion pup demography

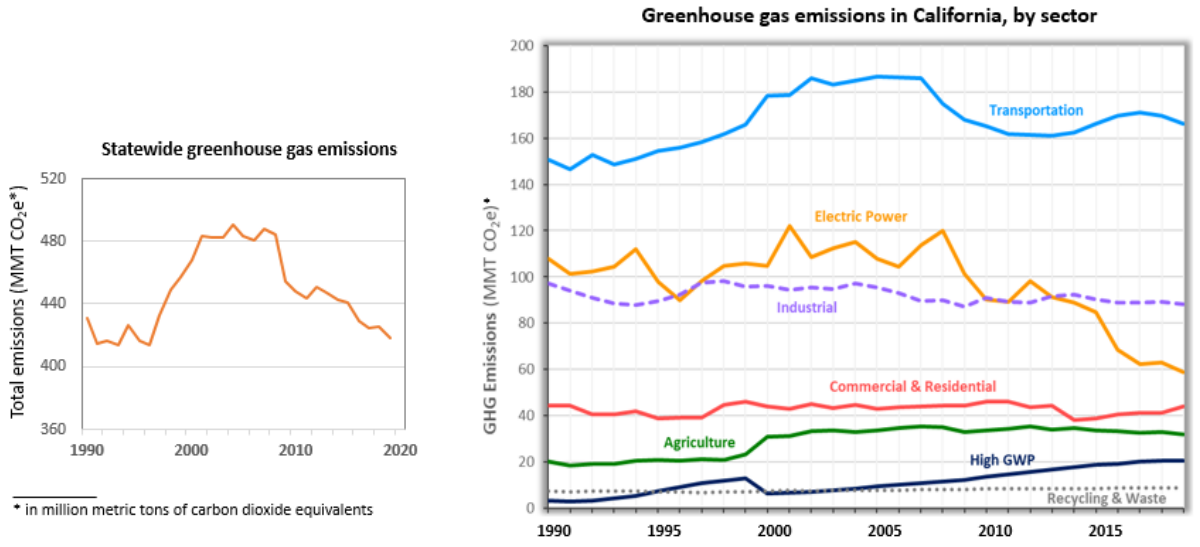
## IMPACTS ON HUMAN HEALTH

Heat-related deaths and illnesses
Occupational heat-related illness
Valley fever
Vector-borne diseases
Wildfire smoke

## Climate Change Drivers

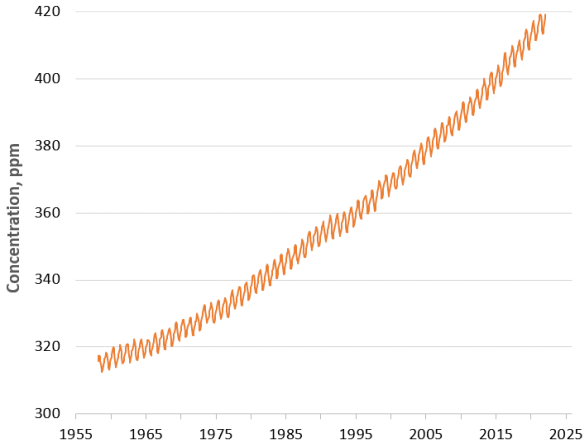
Since the Industrial Revolution, the burning of coal, gasoline and other fossil fuels, along with changes in land use, have increased global greenhouse gas concentrations in the atmosphere by more than 50 percent. Much of the warming is due to carbon dioxide, the most abundant greenhouse gas, which persists for centuries in the atmosphere. Methane, fluorinated gases, and black carbon (a particulate produced by burning) are more powerful heat trapping gases that have also significantly increased, along with atmospheric concentrations, although these chemicals are less persistent in the atmosphere. The evidence is unequivocal that the buildup of greenhouse gases in the atmosphere from human activities is driving changes in climate, leading to cascading impacts.

In California, **greenhouse gas emissions** peaked in 2004 and have since been trending downward – evidence of the success of the state's pioneering efforts in reducing emissions. Notably, the 2020 emissions reduction goal (of 1990 levels) was reached in 2016, four years ahead of schedule. Carbon dioxide comprised about 80 percent of the total greenhouse gas emissions in 2019. The transportation sector is the largest source, accounting for 40 percent of all such emissions.

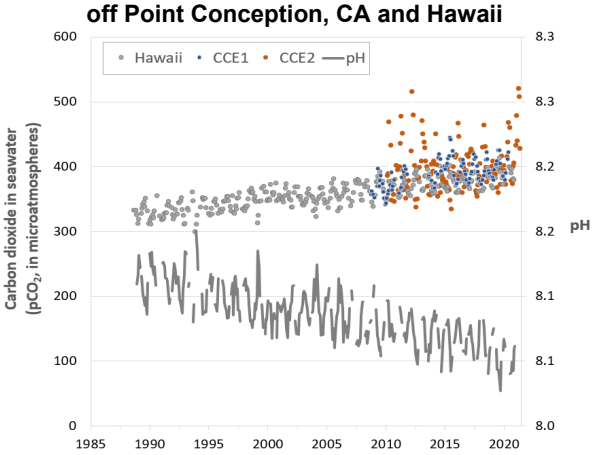



*Left: After peaking in 2004, statewide greenhouse gas emissions have declined, falling below 1990 levels (431 million metric tons of carbon dioxide equivalents) in 2016. Right: The transportation and electric power sectors drive most of the year-to-year changes in emissions. Use of renewable energy has led to large decreases in emissions in the electric power sector.*

Reductions in emissions will not be immediately reflected as corresponding declines in their **atmospheric concentrations**. Global carbon dioxide concentrations have increased by about 30 percent over the past six decades. Similarly, atmospheric levels of other greenhouse gases (methane, nitrous oxide and certain fluorinated gases) continue to increase.




*Carbon dioxide concentrations have increased from 315 ppm in 1958 to about 416 ppm in 2021 at Mauna Loa, Hawaii, where the longest continuous global measurements have been taken. Measurements at California coastal sites also show increasing trends (not shown).*



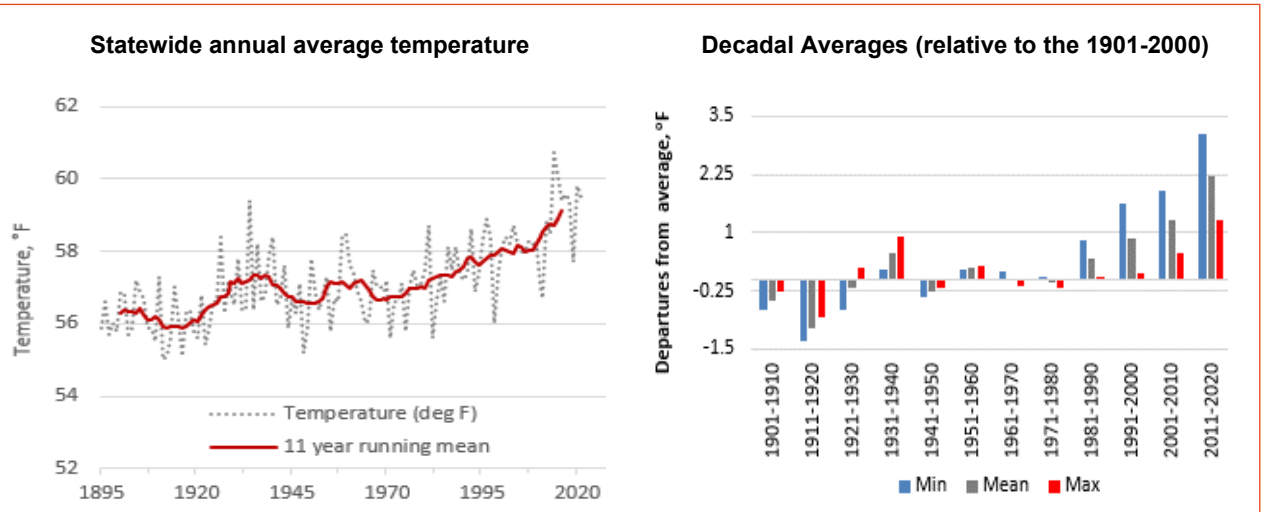

*Levels of carbon dioxide in seawater off Hawaii have increased (by about 1.8 microatmospheres per year) over the past three decades, accompanied by increasing acidity (decreasing pH). While not long enough to show a trend, levels off Central California over the same period are similar (CCE1), but are more variable closer to the coast (CCE2).*

The ocean absorbs 20 to 30 percent of carbon dioxide emissions, reducing this greenhouse gas buildup in the atmosphere. However, this drawdown of atmospheric carbon dioxide comes at a cost. It changes the chemistry of seawater, leading to **ocean acidification**. Measurements off Hawaii since 1988 show carbon dioxide levels in seawater steadily increasing along with acidity. Signs of ocean acidification are becoming evident in California, where levels similar to Hawaii's have been measured off the Central coast since 2010. Ocean acidification makes it harder for the shells of ecologically and economically important species including krill, oysters, mussels, and crabs to form, and can even cause them to dissolve. Coupled with warming ocean waters and reduced dissolved oxygen levels ocean acidification poses a serious threat to global marine ecosystems.

# Changes in Climate

Climate is generally defined as “average weather,” or the long-term weather pattern in an area. Human influence has warmed the atmosphere, ocean, and land, leading to measurable, widespread, and rapid changes in our climate. These changes impact California in multiple ways, and are magnified when multiple climate-related phenomena occur at the same time. For example, warm rain events and melting snowpack increase flood risk; unusually high temperatures accompanied by a lack of rainfall exacerbate drought; and hot, dry, windy conditions increase wildfire risk.

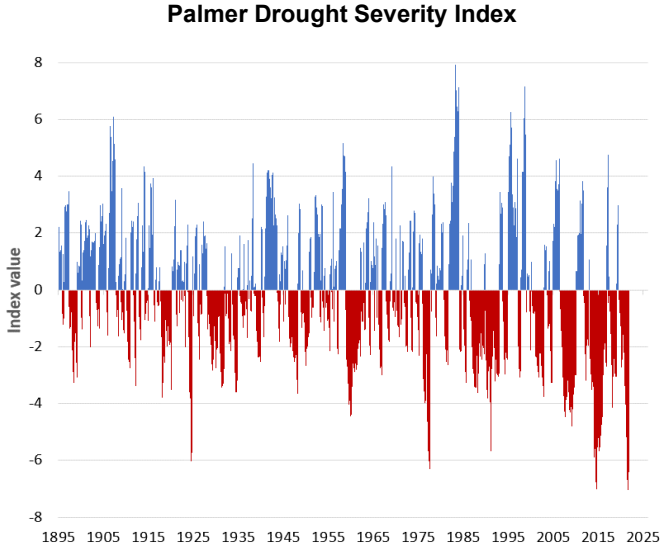
Since 1895, annual average **air temperatures** in California have increased by about 2.5 degrees Fahrenheit (°F). Warming occurred at a faster rate beginning in the 1980s. Recent years have been especially warm: Eight of the ten warmest years on record occurred between 2012 and 2022; 2014 was the warmest year on record. Temperatures at night, which are reflected as minimum temperatures, have increased by almost three times more than daytime temperatures. Nighttime warming has been more pronounced in the summer and the fall, increasing by about 3.5°F over the last century, and Southern California has warmed faster than Northern California.




*Annual average statewide temperatures have increased, warming at a faster rate beginning in the 1980s. Decadal averages show marked warming during the last four decades—with each decade successively warmer than the preceding. Compared to yearly averages between 1901 and 2000, average minimum and maximum temperatures were higher by 3.1°F and 1.3°F, respectively, in 2011 to 2020.*

As air temperatures have warmed, more **precipitation** has been falling as rain instead of snow at high elevations. The amount of annual precipitation has also become more variable in the past four decades. Winter storms transporting large volumes of water vapor —called “atmospheric rivers” — play a role in this variability. The duration, intensity, and frequency of these storms are affected by warmer air and changing ocean conditions.

Although a naturally occurring feature of California's climate, **drought** conditions have become more frequent and more intense. A combination of hotter temperatures and low precipitation years – especially when snowpack and snowmelt runoff are low--mean drier conditions. California has been getting drier since 1895. By the end of the 2021 water year (which begins in October and ends in September the next year), drought conditions were comparable to those during 2012 to 2016, the most severe drought period on record. In California and across the southwestern United States, 2000 to 2021 has been the driest 22-year period over the past 1,000 years, part of what scientists call an emerging "megadrought" era.




*The Palmer Drought Severity Index measures the relative dryness of a region by incorporating readily available temperature, precipitation, and soil moisture data. Between 2010 and 2021, there were 48 months when Index values were at or below -3 (representing severe drought), including eight months with values below -6 (representing very extreme drought).*

Indicators of **changes in climate** also show that:

- **Extreme heat events** in California have become more frequent since 1950, especially in the last decade. These are events when temperatures are at or above the highest 5 percent of historical values. Over the past 70 years, extreme heat events increased by 1 to 3 per decade at 10 of 14 locations studied. Heat waves, defined as two or more consecutive heat events, have also become more frequent in the past decade. Averaging 1 to 3 per year in earlier decades, daytime heat waves more than doubled to 5 to 6 per year in five locations studied; nighttime heat waves similarly increased to 5 to 7 per year at 10 locations, and up to as high as 10 per year at one (Blue Canyon).

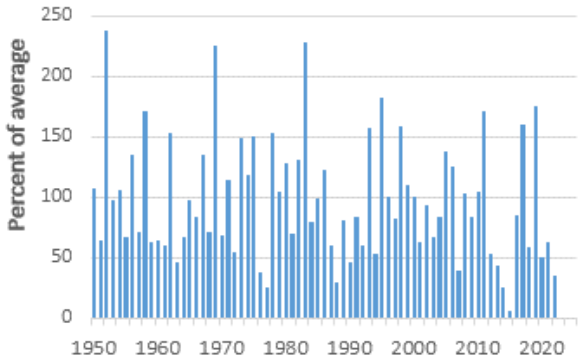
- Across California's Central Valley, **winter chill**, a period of cold temperatures required for dormancy by fruit and nut trees to flower and fruit, has been declining.

- The energy needed to cool buildings during warm weather — measured by "**cooling degree days**" — has increased in California, while the energy needed to heat buildings during cold weather — measured by "**heating degree days**" — has decreased.

# Impacts on Physical Systems

Warming temperatures and changing precipitation patterns have altered California's "physical systems" — the ocean, lakes, rivers, glaciers, and snowpack – upon which the state depends. Winter snowpack and spring snowmelt runoff from the Sierra Nevada and southern Cascade Mountains historically provided approximately one-third of the state's annual water supply. The amount of water stored in the snowpack, referred to as **snow-water content**, varies widely from year to year, and is lower in years with warm winters. Measured on April 1st, when the snowpack has historically been deepest, snow-water content has ranged from a high of about 240 percent of average in 1952 to a record low of 5 percent of average in 2015. In 2022, it was 35 percent of average.

**Snow-water content, as a percentage of average**

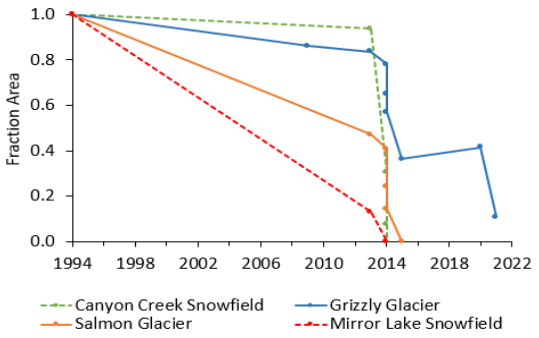



Credit: DWR

*Snow-water content measured on April 1st (when the snowpack has historically been deepest) has ranged from a high of about 240 percent of average in 1952 to a record low of 5 percent of average in 2015. In 2022, snow-water content was 35 percent of average. Average snow-water content is about 28 inches.*

Reduced snowpack and earlier spring warming have led to an eight percent drop in the fraction of spring **snowmelt runoff** into the Sacramento River and the San Joaquin River over the past century. Reduced spring runoff means less water for domestic and agricultural uses, for hydroelectric generation, and for cold-water habitats and forest ecosystems.

**Change in area: Trinity Alps glaciers and snow fields**




*By 1994, Grizzly and Salmon Glaciers had lost about 80 percent of their 1885 area (not shown). By 2015, Salmon Glacier and the two snowfields had disappeared. By 2021, what remains of Grizzly Glacier is about 10 percent of its 1994 area.*

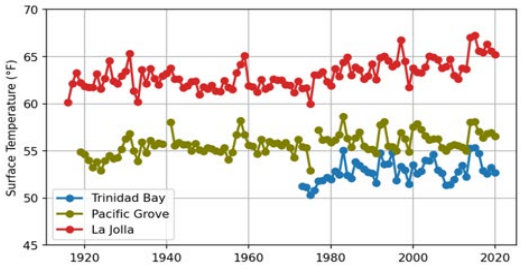
Snow and cold temperatures also sustain glaciers and year-round snowfields. Today, glaciers are among the most visible casualties of climate change. Winter temperatures determine glacier mass gain and summer temperatures determine glacier loss. Mountain **glaciers** have melted dramatically over the past century. Since 1903, seven of the largest glaciers in the Sierra Nevada have lost 65 to 90 percent of their area.

In the Trinity Alps, two snowfields and one of two glaciers had disappeared entirely by 2015. What remains of the second glacier in 2021 is arguably too small to be considered a glacier any longer. While glaciers may feel remote and inaccessible, glacial runoff

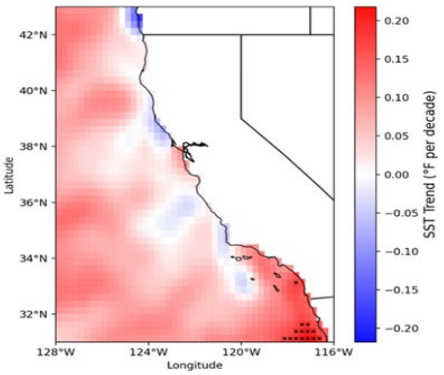
provides critical cold freshwater habitat for many aquatic species, including California salmon populations.

The ocean absorbs about 90 percent of the excess heat from rising global temperatures. California **coastal ocean temperatures** have warmed, particularly off Southern California. A century of measurements at La Jolla show sea surface temperatures warming by 0.3°F per decade—a trend corroborated by four decades of satellite-based data. The dire ecological consequences of warming waters were evident during a period of unusually high ocean temperatures (a "marine heat wave") off the California coast from 2014 to 2016: mass strandings of marine mammals and sea birds, initiation of a toxic algal bloom that led to the closure of crab fisheries, and loss of kelp forests. Changes in the abundance and distribution of prey forced humpback whales to move closer to shore, leading to a record number of whale entanglements in fishing gear.

**Annual average sea surface temperatures at selected shore stations (1916-2020)**




**Satellite-based sea surface temperature trends along the California Coast (1982-2021)**




*Left: Nearshore coastal waters have warmed 0.2°F per decade at Pacific Grove, and 0.3°F per decade at La Jolla and Trinidad Bay. Right: Satellite-based records show that waters off the California coast are largely warming. A distinct warming trend is evident off Southern California, especially near shore.*

Indicators of the impacts of climate change on **physical systems** also show that:

- **Sea level rise** is occurring along the California coast, at 1 to 2 millimeters (0.04 to 0.08 inch) per year. (The exception is Crescent City, where movement of the Earth's plates have caused an uplift of the land surface.) Sea level rise can lead to flooding, beach erosion, bluff retreat, and other impacts on low-lying areas of the coast.
- Increased air temperatures and reduced snowmelt have led to warming temperatures in freshwater bodies. **Lake water temperatures** at Lake Tahoe, when averaged across all depths, have increased by about 1°F over the past half century. Surface water temperatures have warmed by almost twice as much in the same period; six of the last ten years ranked among the warmest. Warming waters affect the lake's key physical and biological processes. In the Northern California Klamath Mountain region, **Salmon River water temperatures** have increased by as much as 2°F per decade since the mid-1990s, threatening spring-run Chinook salmon in the watershed.
- **Oxygen concentrations** in ocean waters off Southern California have declined since the mid-1990s. Declining dissolved oxygen concentrations, in concert with ocean acidification and warming ocean temperatures, threaten species diversity and abundance, and marine food webs.

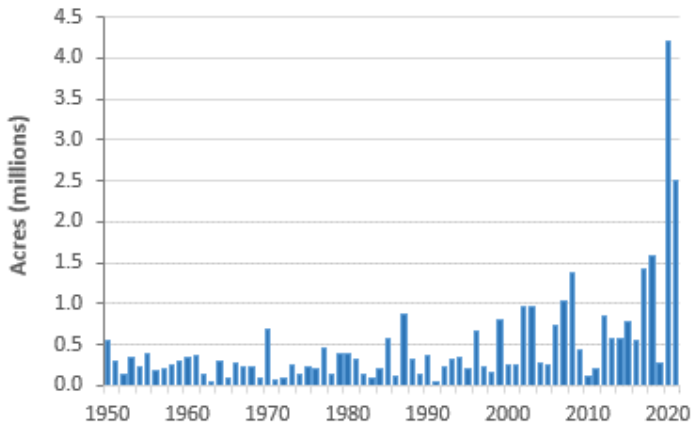
## Impacts on vegetation and wildlife

Climate change has altered habitats and impacted ecosystems across the planet, threatening biodiversity. In California, plant and animal species have responded to a changing climate. Some species have moved northward or to higher elevations. Others have experienced shifted timing of key life cycle events, altered community composition, or population decline. These responses have been shown to track climate patterns, including natural variability, as well as the influence of land use, land management, environmental pollution, and other human activities.

Vegetation

When plant water demand exceeds the amount available in the soil, vegetation becomes stressed, and more easily succumbs to attacks by pests and pathogens. Hot and dry conditions increase the water deficit and make dead vegetation easier to burn, heightening wildfire risk. The unprecedented scale of **tree deaths** in California forests has increased fuel loads, increasing the risk of large, severe wildfires. An estimated 170 million trees died between 2010 and 2021, peaking in 2016, the fourth year of the extreme drought.

Over the last 20 years, the area burned by **wildfires** across California has increased dramatically. In 2020 alone, 4.2 million acres burned, more than double the area burned in any other year on record. Ten of the 20 largest wildfires since 1950 burned in 2020 and 2021. The 2020 August Complex burned more than one million acres in seven counties, making it the state's first "gigafire." The recent wildfires have caused deaths and injuries, widespread exposures to harmful levels of wildfire smoke, displacement and disruption of communities, damage to structures and property, and tragic losses among some of the state's most iconic species: coast redwoods, giant sequoias, and Joshua trees.




*The area burned by wildfires has increased in the last two decades. The average area burned each year in the 2000s and 2010s was twice the 1990s average, and in 2020-2021 was ten times higher.*

Crops are also affected by climate change. In parts of the Central Valley, certain **fruits and nuts** are maturing more quickly with warming temperatures, leading to earlier harvests. The report presents data on prunes and one walnut variety. Shorter maturation times generally lead to smaller fruits and nuts, potentially causing a significant loss of

revenue for growers and suppliers. Processing tomatoes have also been maturing faster over the past four decades in Yolo County and four other top tomato-producing counties.

Indicators of the **impacts of climate change on vegetation** also show that:

- The state's **forests and woodlands** have changed: today there are 80 percent more small trees and 70 percent fewer large trees in parts of Southern California forests compared to the 1930s; similar patterns are seen statewide. Pines occupy up to 55 percent less area, and in certain parts of the state, oaks cover up to 40 percent more area. Reduced moisture and warmer conditions favor oaks over pines; wildfires remove conifers and facilitate the establishment of broadleaf forests. These changes are influenced by climate factors as well as forest management. These changes are influenced by climate factors as well as forest management and fire suppression practices.

- Changes in the distribution or density of vegetation have also been observed. On the western side of the northern Sierra Nevada Mountains the lower edge of the **Ponderosa pine forest** has moved upslope. Across the north slope of Deep Canyon in the Santa Rosa Mountains in Southern California the dominant plant species have moved upslope. In the **subalpine forests** of the Sierra Nevada (elevations 7,500 to 11,000 feet), small tree densities have increased, while large tree densities have decreased.

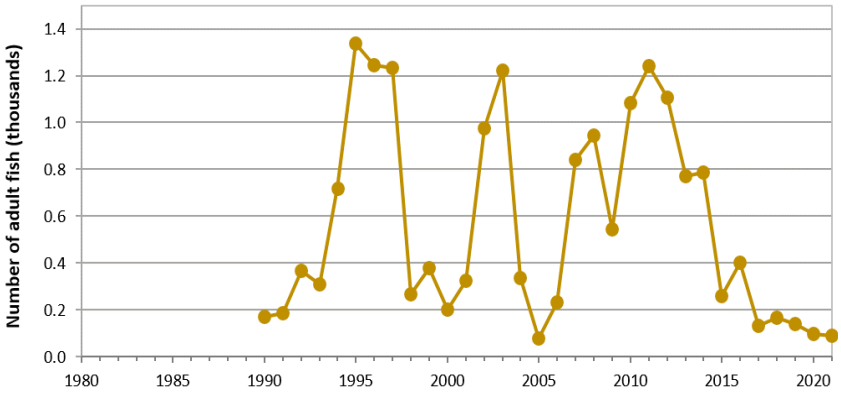
- The risk of crop damage has increased as certain insects multiply faster with warmer temperatures. The **navel orangeworm,** for example, is an insect pest that causes severe damage to Central Valley walnuts, almonds, and pistachios. Over the past four decades, the time required for this pest to complete its life cycle has decreased and the number of generations per season has increased. Each new generation during a season poses an increased threat to California's nut crops.

- Patterns of **marine harmful algae blooms** in California coastal waters have been changing, influenced in part by warming ocean temperatures. The presence of the algae and the toxins they produce is highly variable, and monitoring data are not long enough to discern trends. However, since 2018 blooms of red tide-forming algae have become more frequent and more abundant at Santa Cruz Wharf. Toxins produced by these algae can move up the food chain, and when consumed, can cause illness in people, or death in fish, marine mammals, and seabirds.

Wildlife

A landmark study conducted over a century ago (known as the Grinnell Survey) serves as a historical baseline of the habitat conditions and the distribution and abundance of birds and mammals at study sites in selected regions of California. These sites were resurveyed to document habitat and species changes over the past century. Today, certain birds and mammals are found at different elevations in the Sierra Nevada (Lassen, Yosemite and Sequoia and King's Canyon) compared to a century earlier. **Range shifts** were observed in almost 75 percent of the small mammal species and over 80 percent of the bird species surveyed. In the Mojave Desert, which has become warmer and drier over the past century, widespread collapse of bird communities has occurred. Populations of prairie falcons, turkey vultures, chipping sparrows, mourning doves and other birds have declined. By contrast, small mammal populations have remained stable. As desert conditions became hotter and drier, dehydration was a major factor in the decline of bird populations.

Climate-influenced changes in freshwater and ocean conditions are threatening the survival of Chinook salmon in Northern California rivers. Chinook salmon are legendary for migrating from the streams where they were hatched to the ocean, travelling as far as a thousand miles, only to return to the same streams to spawn. **Chinook salmon abundance** across the state has historically declined due to dams and other human influences that restrict fish passage.




*In the Salmon River, spring-run numbers have generally plummeted over the last decade. The counts in each of the last five years have ranged from about 90 (in 2021) to 170 (in 2018), far below the long-term average (570 fish).*

The timing of the adult migration from the ocean to the stream where they were born defines salmon "runs." Most of California's Chinook salmon runs are in the Central Valley in the Sacramento and San Joaquin River basins, and in the Klamath Basin in the Klamath and Trinity Rivers and tributaries, including the Salmon River. Salmon River spring-run populations have suffered huge declines, with extremely low counts in the last five years. They have hence been designated as a threatened species. These counts reflect a clear signal of the impacts of climate change on salmon, given the minimal human influences on the Salmon River watershed.

The Sacramento River is home to four salmon runs: the winter, spring, fall, and late-fall runs. When environmental conditions threaten salmon survival, hatcheries and cold water dam releases help sustain and rebuild fish populations. These practices became especially

important during the 2012-2016 drought, which caused reduced flows in the watershed, elevated water temperatures, and decreased prey availability. The winter-run, the least abundant of the runs, has seen periods of alarmingly low numbers, and is listed as a threatened species. This run spawns in the summer months when water temperatures are their warmest and has persisted largely due to cold water releases and addition of hatchery fish.

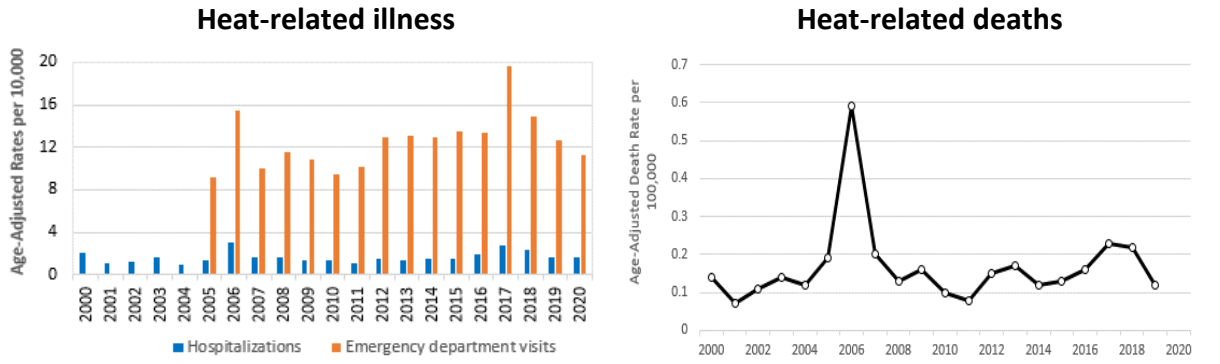
Indicators of the **impacts of climate change on wildlife** also show that:

- **Copepod populations** in the California Current fluctuate, mirroring the variability in ocean conditions that reflect changes in temperature and ocean currents. Cold waters from the north transport copepod species with higher nutritional value than those carried by warm waters from the tropics. During the period of unusually warm ocean conditions in 2015 to 2016, the copepod community was dominated by warm-water species. Copepods are at the base of the food chain, and when cold-water copepods are abundant, so are other species, notably salmon and the small fish that they prey on.
- Species responses to changing ocean conditions have included:
  - Fewer **California sea lion pup** births, higher pup mortality, and poor pup conditions at San Miguel Island off Santa Barbara during years when sea surface temperatures are unusually warm in their breeding area. In these years, the fish they feed on are less abundant and the nursing mothers must either travel farther to obtain food, or eat less nutritious prey.
  - A northward expansion of the range of a **nudibranch** sea slug, *Phidiana hiltoni*, from the Monterey Peninsula to Bodega Bay since the mid-1970s, a distance of almost two hundred miles.
  - Variability in the breeding success of **Cassin's auklets**, a seabird species on Southeast Farallon Island near San Francisco, associated with fluctuating availability of krill and other prey in nearby ocean waters.
- Over the past 50 years, several **Central Valley butterfly species** have been appearing earlier in the spring, a shift correlated with hotter and drier conditions in the region. Changes in seasonal timing among interacting species—for example, butterflies and their plant food sources—could disrupt population dynamics across animal and plant species.
- Observed responses among migrating birds include changing patterns of spring and fall **migratory bird arrivals** at Point Reyes National Seashore in northern California, and range shifts northward and closer to the coast among **wintering bird species** statewide.

## Impacts on human health

Climate change directly impacts human health through exposures to heat, floods, and other weather events. In addition, it indirectly affects health by exacerbating health threats through higher levels of air pollutants, degraded water quality, and increased populations of disease vectors.

Heat causes more reported deaths per year on average in the United States than any other weather hazard, yet heat-related illnesses and deaths are generally preventable. Heat rash, heat cramps, heat exhaustion, and heat stroke fit the classical case definition of heat-related illness. However, heat exposure can produce other health effects, and aggravate a broad range of health conditions. As temperatures warm, emergency department visits due to heat-related illnesses are on the rise in California. Hospitalizations and deaths spike in years with especially high summertime temperatures. This is notable given that **heat-related illnesses and deaths** are often unrecognized and underreported, and therefore the actual number of victims is likely considerably higher.



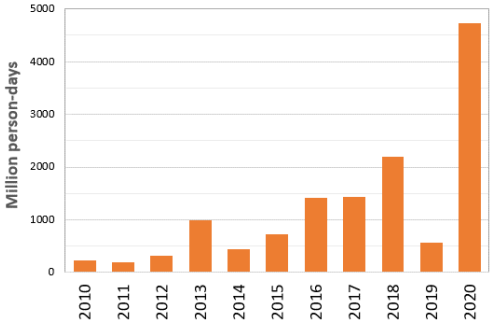

*Left: California heat-related hospitalizations and emergency room visits for which heat stress was explicitly listed as the diagnosis are shown. Emergency room visits and hospitalizations were highest in 2017, when summertime temperatures were unusually high, and in 2006, the year of a prolonged heat wave. (Data for emergency department visits were not available until 2005.)*

*Right: Deaths for which the main or contributing cause is coded as heat-related were highest in 2006. Period covered is from May to September of each year.*

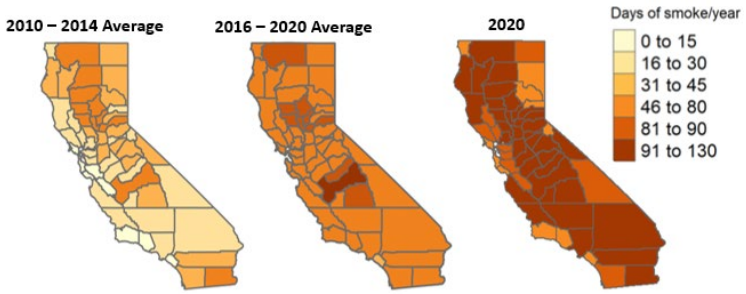
As climate change increases the frequency, size, and duration of wildfires in the state, the health of Californians is increasingly threatened by exposures to **wildfire smoke**. Wildfire smoke consists of fine particulate matter (PM2.5) and other hazardous compounds that can irritate the eyes, nose and lungs, and worsen chronic heart and respiratory diseases. Wildfire smoke can also impact mental health. Based on satellite imagery, an estimate of potential exposure of people in areas where wildfire smoke plumes were present ("person-days") has been increasing since 2010. There were fewer days each year, on average, when smoke plumes were present in 2010 to 2014 compared to 2016 to 2020. The last five-year period includes 2020, the worst year on record for wildfires. That year, the fire season was marked by several large wildfires burning at the same time; smoke plumes

were present in every county for at least 46 days. For weeks, daily maximum PM2.5 levels remained hazardous, according to the Air Quality Index, in several areas of the state.

**Potential population exposures to wildfire smoke**




**Number of wildfire smoke days by county**




*Left: Potential exposures to wildfire smoke – based on the number of days when plumes were present and the number of people living in those areas (measured as "person-days") – have significantly increased over the past decade. Right: In 2010-2014, smoke plumes were present in 11 counties at least 46 days per year on average, compared to 56 counties in 2015-2020. In 2020, when a record-high 4.2 million acres burned across the state, smoke plumes were present in every county for 46 days or more; 36 counties had 91 or more smoke plume days.*

Indicators of the **impacts of climate change on human health** also show that:

- **Occupational heat-related illnesses** reported by California workers increased between 2000 and 2017 from a rate of about 3.5 to 10 per 100,000. Employees in protective services (firefighters and police) and farmworkers had the highest rates of illness.

- With warming temperatures and changes in precipitation, the number of mosquitos (known as "vectors") carrying West Nile Virus increase. This is just one example of **vector-borne disease** patterns in California affected by climate change. West Nile Virus currently poses the greatest mosquito-borne disease threat in the state. Higher temperatures shorten the time it takes both for the mosquito to complete its life cycle (from egg to adult) and for the virus to multiply in the mosquito. As a result, there are a greater number of infected mosquitoes to potentially infect humans.

- The incidence of **Valley fever** has increased over the past 20 years in California. Valley fever is caused by inhaling spores of the *Coccidioides* fungus that is endemic in the soil in the Central Valley and Central Coast regions of the state. Although the reasons for increased cases are likely multifactorial, drought, dry soil conditions, and other climate-related changes play a major role in fungal proliferation and spore dissemination, and eventual human and animal infection with Valley fever.

# Impacts on California Tribes

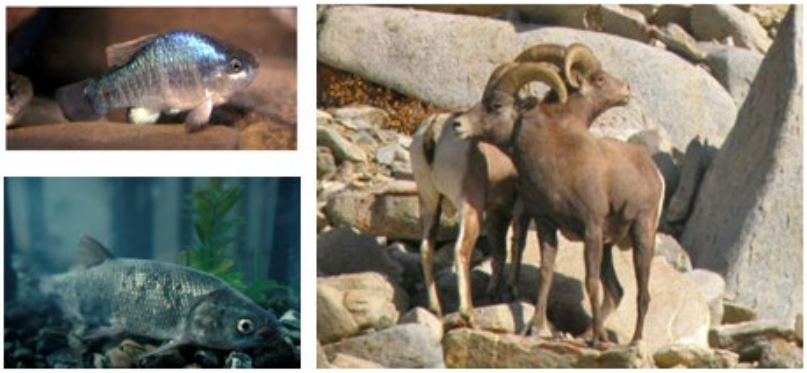
Climate change poses a threat to California's Tribes through impacts on the ecosystems in which they live and are connected, as the health of a Tribe is tied to the health of the environment. California Tribes are the original biologists, historians, climatologists, and scientists of this land. Tribal knowledge, acquired from long histories of their interaction with the earth, is a key component in advancing the full understanding of climate change and addressing its impacts.

Credit: L'eaux Stewart

*The Eastern Sierras route to the Palisades, part of the traditional territory of the Big Pine Paiute Tribe of the Owens Valley*

When Tribes speak of nature, they include themselves. The earth provides food, medicines, fibers and ceremonial materials that are embedded within cultural, social, spiritual, economic, political systems, and daily Tribal life. Knowledge of the unique interactions between species and their habitat provides the foundation for Tribal actions to manage the landscape.

Climate change is impacting Tribes throughout California. Warming temperatures, changing precipitation patterns, and intensifying droughts have increased reliance on groundwater, degraded aquatic habitat, stressed vegetation, and diminished previously abundant wildlife. As the environment is impacted by climate change, Tribal health suffers.



Credit: Joe Ferreira (UCD), Richard Macedo (CDFG); CDFW, 2021

*Culturally important species include (clockwise from left): Owens Valley pupfish, Clear Lake hitch, and big horn sheep.*

From the Tribal lands in the Owens Valley, where emissions from the now dry Owens Lake make it the largest single source of particulate matter (PM10) in the United States, to the soaring temperatures in Southern California, Tribes are experiencing a wide range of impacts. They have seen a reduction of native foods and culturally important plants and

animals. In addition to PM10 exposures, elevated ozone concentrations on warmer days, and more frequent days with wildfire smoke pose risks to the health of the Tribes. Toxins produced by harmful algal blooms threaten their food and water and impair their ability to use lakes and rivers. The physical, cultural, and spiritual health of Tribes are suffering as climate change intensifies.


Credit: Karuk Tribe

*One of 22 Karuk Tribal cultural indicators, the Púfpuuf, or Pacific Giant Salamander, camouflaging with its environment*

Coastal Tribes have witnessed rising sea levels, along with the loss of kelp forests, making parts of the coast more vulnerable to erosion and exposing cultural artifacts. Kelp forests, which used to provide a protective buffer to the coast, are collapsing along parts of the coast due in part to the cascading impacts of warming ocean waters. Coastal Tribes note that access to traditional sites along the shoreline is more difficult with these impacts and this hampers the Tribe's ability to pass knowledge down to younger generations.

California Tribes are acting to protect their communities from the adverse effects of climate change. Habitable climate is critical to protecting tribal sovereignty, culture, and community cohesion. The Tribes are actively working to manage and protect their lands and limit the impact climate change is having on their right to hunt, fish, gather, and continue their cultural practices – activities that are integral to their health, well-being, and livelihood.

Credit: Middleton Rancheria of Pomo Indians of California

*Sunrise at Mount Konocti, Lake County*

## Emerging climate change issues

Changes and impacts in California's environment that are plausibly influenced by climate change, though not yet established, are referred to in the report as emerging issues. Scientifically defensible hypotheses, models, and/or limited data support the assertion that certain observed or anticipated changes are in part due to climate change.

Among the emerging issues described in this report are:

- Reductions in the duration and extent of Central Valley and coastal fog, which play a vital role in their respective ecosystems.
- Increased lightning activity with warming air temperatures.
- Apparent increased frequency and extent of harmful algal blooms in freshwater bodies, and how much is attributable to climate change versus nutrient discharges and other anthropogenic factors.
- Transmission of bluetongue, a viral disease of sheep, goats, and cattle transmitted by biting midges.
- Changing climate conditions that allow invasive agricultural pest species like the Oriental fruit fly to thrive in places where they previously could not survive.
- Influence of shifts in temperature and rainfall on reported declines in bumble bee populations globally and in California, in light of other factors including insecticides, pathogens infections and habitat loss.
- Increasing levels of aeroallergens plants and mold, which trigger asthma and hay fever.
- Increasing risks of food- and waterborne infections due to changes in climate.
- Increasing transmission of zoonotic diseases, that is, infectious diseases shared between humans and animals.