# INDICATORS OF CLIMATE CHANGE IN CALIFORNIA

## REPORT SUMMARY

*Understanding climate change and its impacts through indicators*

*-2009-*

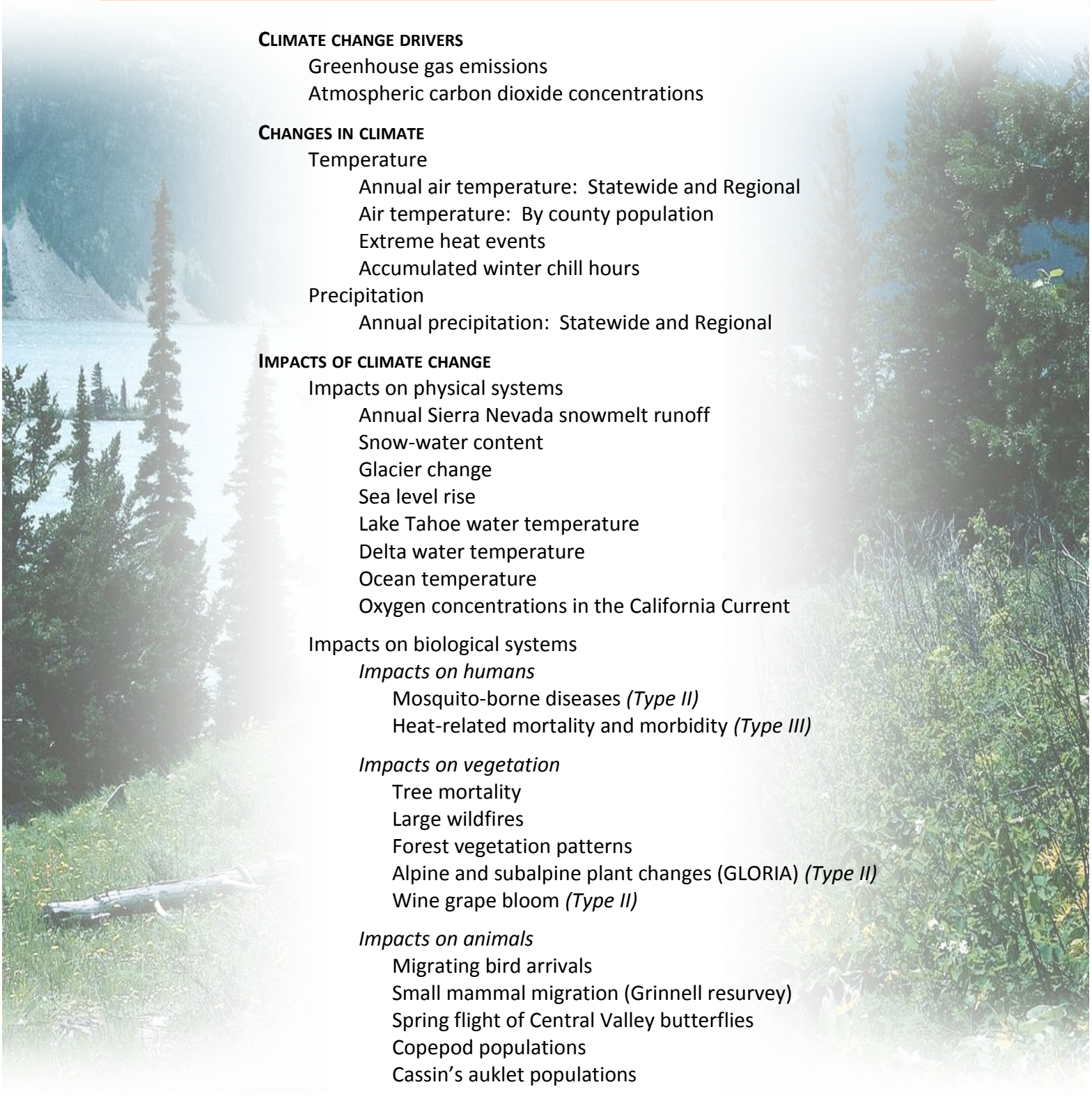
California Environmental Protection Agency - Office of Environmental Health Hazard Assessment

Arnold Schwarzenegger
Governor

Linda Adams
Secretary for
Environmental Protection

Joan E. Denton, Ph.D.
Director, Office of Environmental
Health Hazard Assessment

# INDICATORS OF CLIMATE CHANGE*



**CLIMATE CHANGE DRIVERS**

- Greenhouse gas emissions
- Atmospheric carbon dioxide concentrations

**CHANGES IN CLIMATE**

- Temperature
  - Annual air temperature: Statewide and Regional
  - Air temperature: By county population
  - Extreme heat events
  - Accumulated winter chill hours
- Precipitation
  - Annual precipitation: Statewide and Regional

**IMPACTS OF CLIMATE CHANGE**

- Impacts on physical systems
  - Annual Sierra Nevada snowmelt runoff
  - Snow-water content
  - Glacier change
  - Sea level rise
  - Lake Tahoe water temperature
  - Delta water temperature
  - Ocean temperature
  - Oxygen concentrations in the California Current
- Impacts on biological systems
  - *Impacts on humans*
    - Mosquito-borne diseases *(Type II)*
    - Heat-related mortality and morbidity *(Type III)*
  - *Impacts on vegetation*
    - Tree mortality
    - Large wildfires
    - Forest vegetation patterns
    - Alpine and subalpine plant changes (GLORIA) *(Type II)*
    - Wine grape bloom *(Type II)*
  - *Impacts on animals*
    - Migrating bird arrivals
    - Small mammal migration (Grinnell resurvey)
    - Spring flight of Central Valley butterflies
    - Copepod populations
    - Cassin's auklet populations

* Indicators are classified based on availability of data as follows:

| | |
|---|---|
| Type I: | adequate data are available for presenting a status or trend; unless otherwise noted, environmental indicators listed are classified as Type I |
| Type II: | further data collection/analysis/management is needed before a status or trend can be presented |
| Type III: | conceptual indicators for which systematic data collection is not in place |

# Introduction

Climate change is one of today's most formidable environmental challenges. It is also one of the most difficult to tell stories of our time. Policy-makers, news media and the public want to see evidence of climate change for themselves, right here and right now. Yet, for many, climate change remains clouded in abstraction. Most climate change stories focus on global evidence, scenarios, and projections. Broad trends spanning decades and hemispheres simply don't hit home.

California began one of the earliest efforts to track and reduce greenhouse gas emissions and to support research to better understand climate change and its impacts. Palpable signs or "indicators" of climate change in California can be found in this wealth of scientific research and environmental monitoring. These indicators help tell the story of how California's climate is changing and how these changes are influencing many of our natural systems.

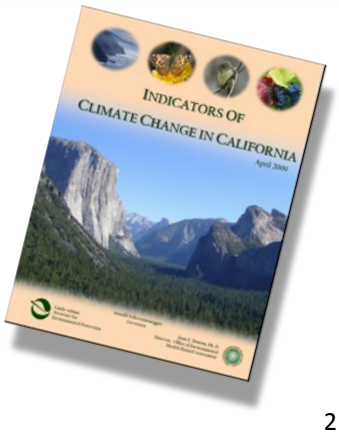
# Tracking Climate Change and Its Impacts

Environmental monitoring, research projects and other scientific studies generate data for tracking trends. Environmental indicators summarize data from these sources to facilitate communication to a broad audience. They are valuable tools for tracking and reporting on changes in the environment.

The report, *Indicators of Climate Change in California,* draws upon data collection, monitoring and studies by state and federal agencies, universities and research institutions. It presents a compilation of environmental indicators that collectively describes:

- changes to the state's climate
- drivers of these change
- impacts of climate change

This summary highlights environmental indicators selected from the report.

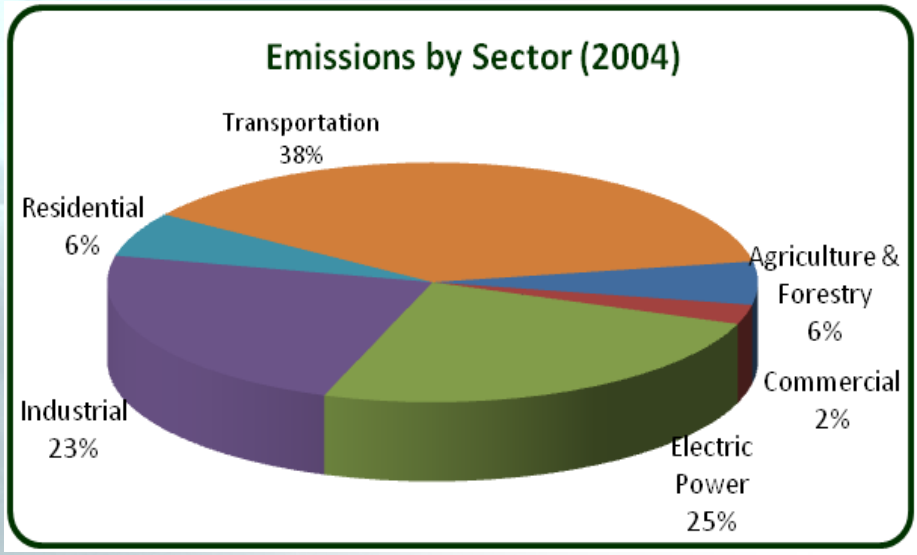



The full report can be downloaded from:
http://www.oehha.ca.gov/multimedia/epic/climateindicators.html.

# CLIMATE CHANGE DRIVERS

Changes in the composition of the atmosphere can alter the Earth's energy balance. Climate scientists attribute most of the warming since the 1950's to increasing levels of greenhouse gases (GHGs) in the atmosphere. These gases warm the Earth's surface by trapping heat. Water vapor, methane, nitrous oxide, halocarbons, ozone, and carbon dioxide ($CO_2$) are examples of GHGs.

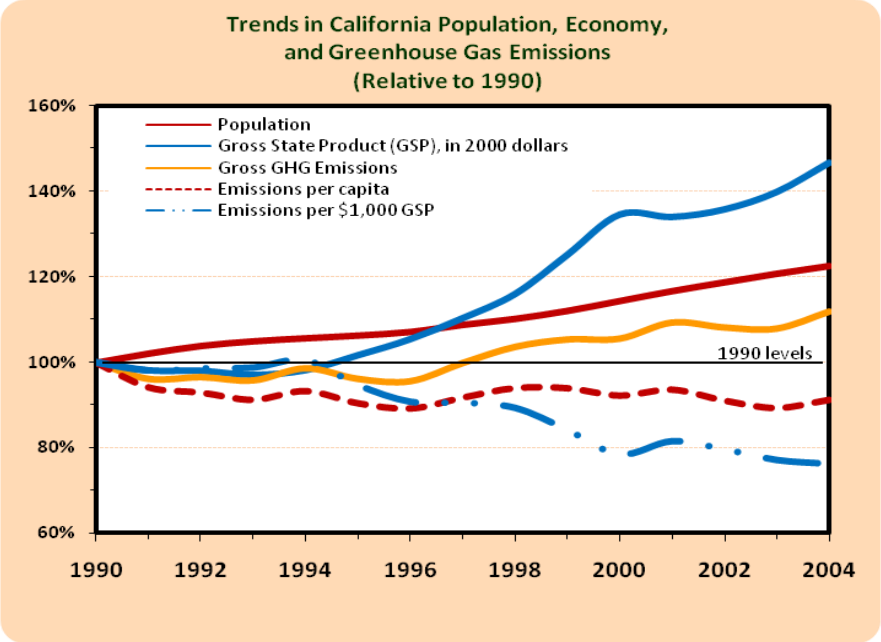
$CO_2$ from the combustion of fossil fuels makes up the largest proportion of global GHG emissions. In California, emissions from transportation, electrical power generation and the industrial sector account for over 80 percent of the GHG emissions (see pie chart). The transportation sector alone is responsible for more than one-third of all GHG emissions in California.




Source: ARB, 2008

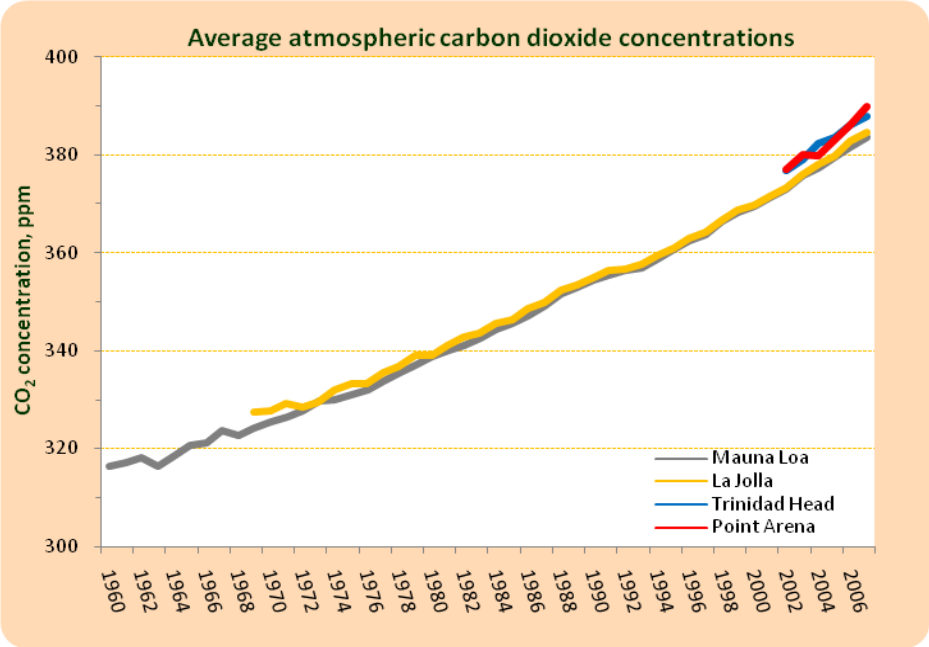
California emissions of GHGs have increased by about 10 percent between 1990 and 2004. The state's population increased by 27 percent over the same period. Gross state product (GSP)—a measure of economic output—increased by 47 percent. Despite these increases, GHG emissions per person and per $1,000 GSP have both declined.

California emits much less $CO_2$ per person than the rest of the United States. When compared to other countries, California is second only to France in having the lowest $CO_2$ emissions per $1,000 of economic output.



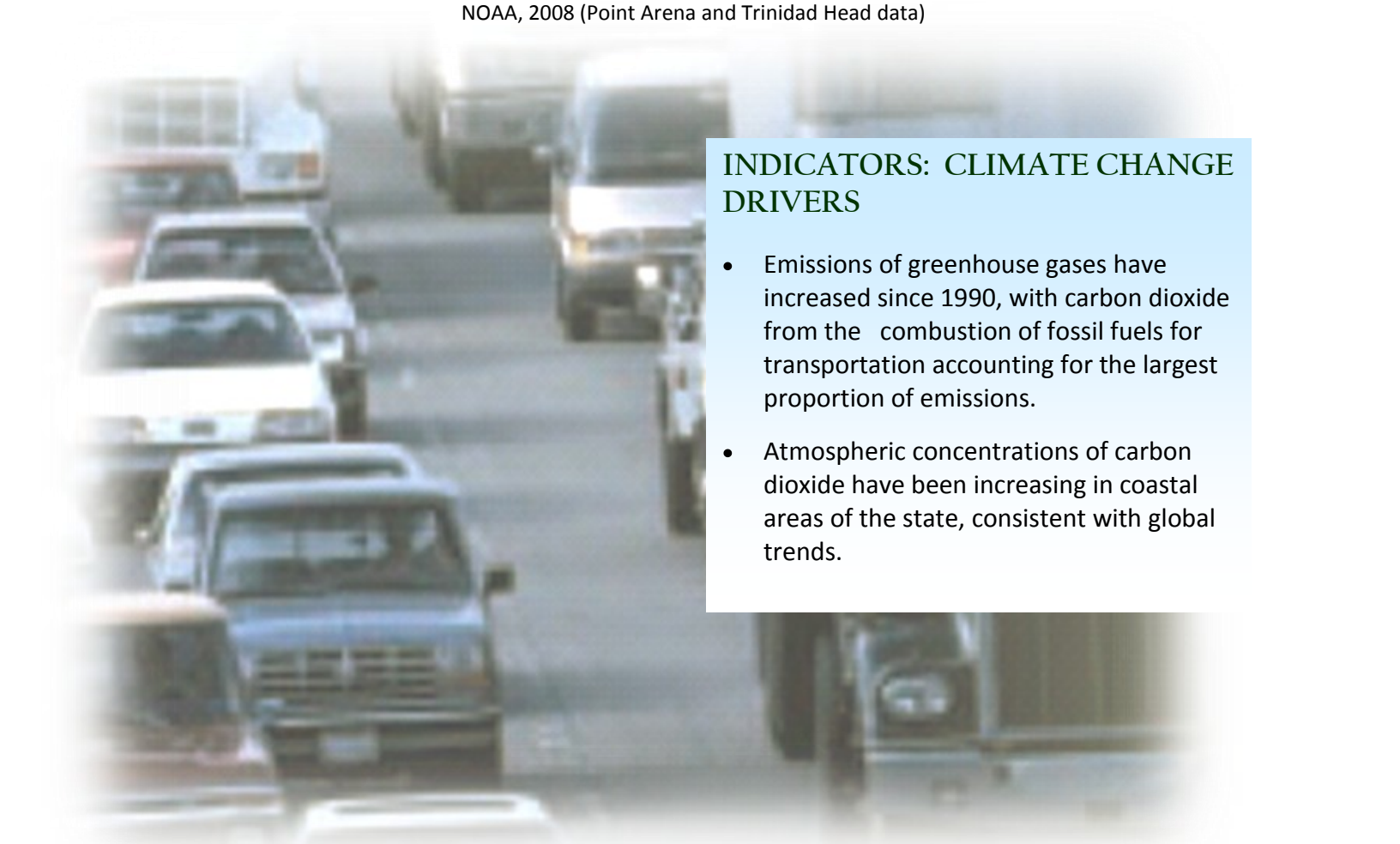

Source: ARB, 2008

The most important GHG associated with human activities is $CO_2$. Rising atmospheric $CO_2$ levels were first documented by Charles D. Keeling in 1958 at Mauna Loa, Hawaii.




The trend at Mauna Loa is similar to those observed at coastal sites in California: measurements at La Jolla which began in the late 1960's, as well as measurements at Trinidad Head and Point Arena which began in the early 2000's all show rising levels (see graph).

Sources: Keeling, et al. 2008 (La Jolla and Mauna Loa data): NOAA, 2008 (Point Arena and Trinidad Head data)



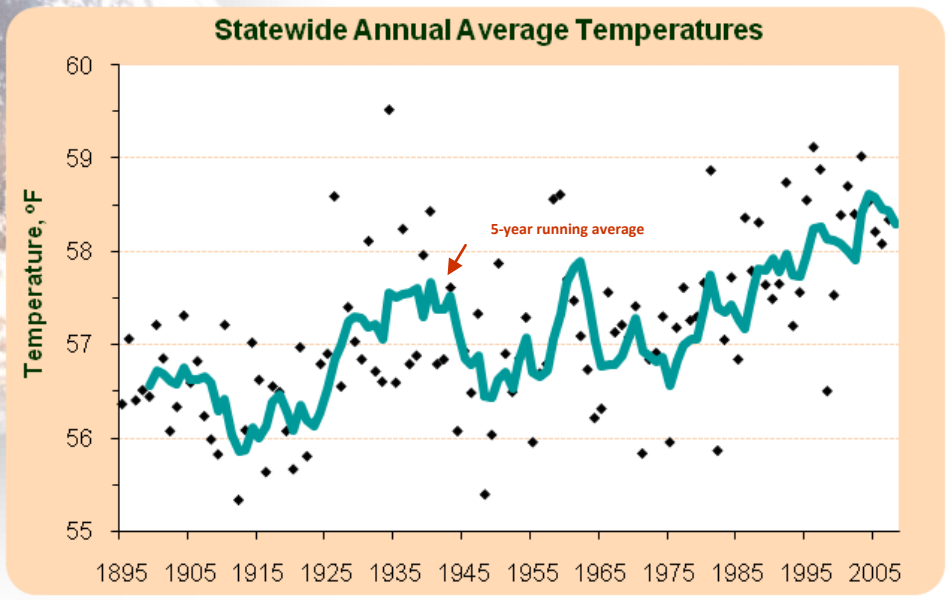
## INDICATORS: CLIMATE CHANGE DRIVERS

- Emissions of greenhouse gases have increased since 1990, with carbon dioxide from the combustion of fossil fuels for transportation accounting for the largest proportion of emissions.
- Atmospheric concentrations of carbon dioxide have been increasing in coastal areas of the state, consistent with global trends.

# CHANGES IN CLIMATE

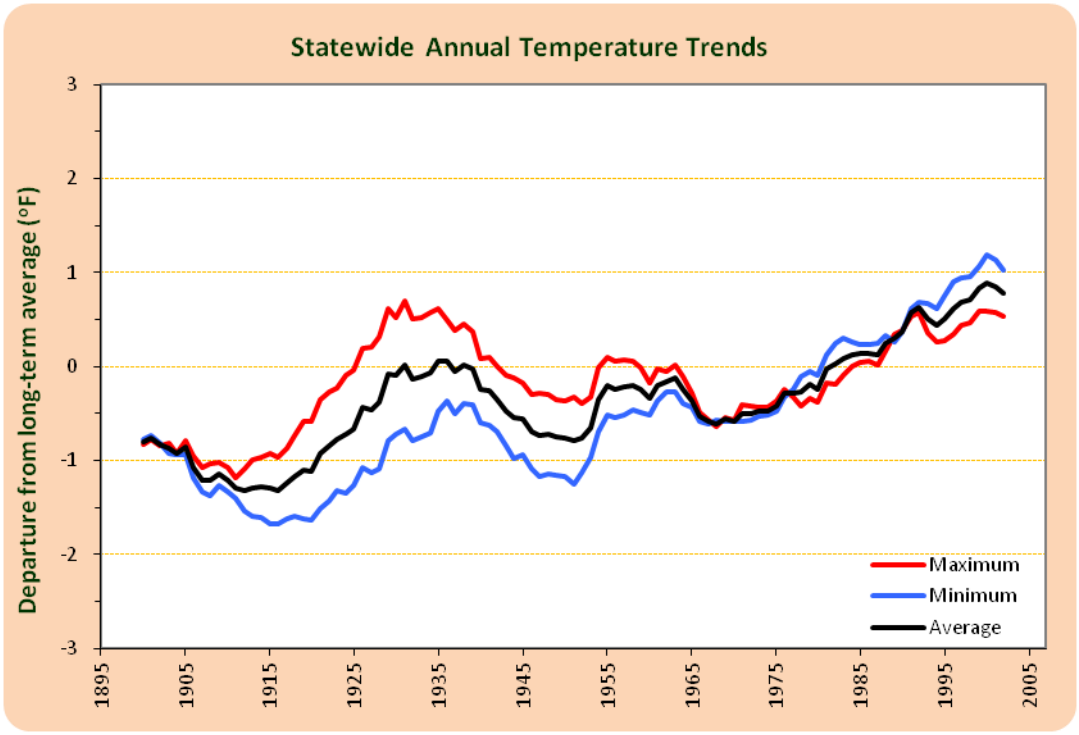
Temperature is a direct indication of climate change. It is an important physical environmental factor that plays a role in agriculture, forestry, water supply and human and ecosystem health.

California's temperatures have been rising over the past century. This warming trend is consistent with changes occurring globally.



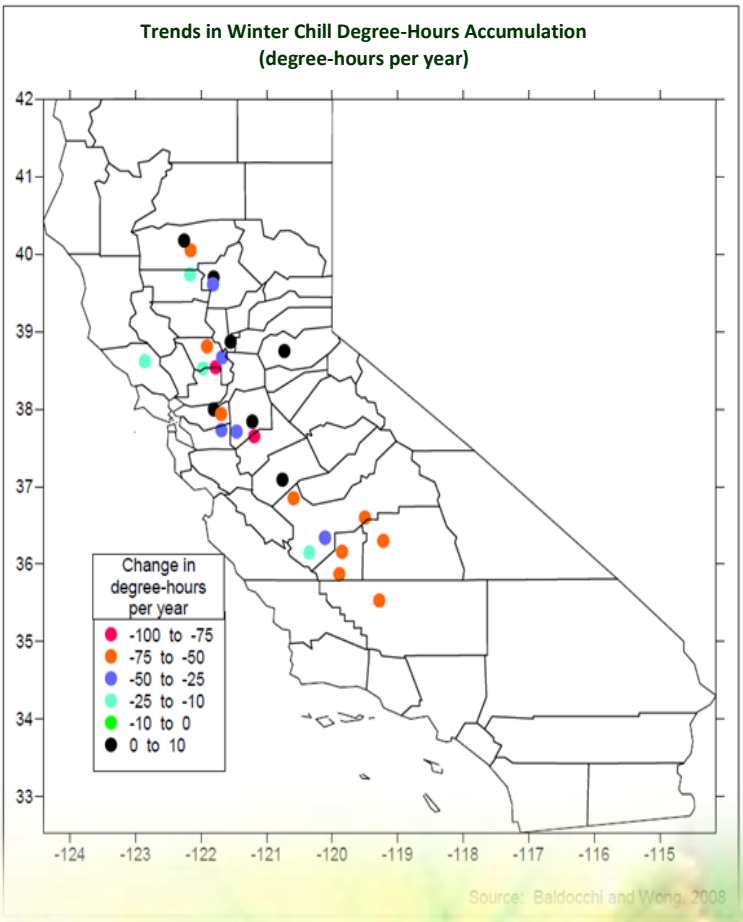

Source: DRI, 2008

The graph below shows trends in minimum, average, and maximum statewide temperatures relative to long-term temperatures (In other words, how these "departed" from the long-term average). Minimum temperatures—which correspond to nighttime temperatures—have been increasing at a faster rate than maximum temperatures since the mid-1970s.




Source: DRI, 2008

Agricultural regions of California are warming. Warmer temperatures extend the length of the growing season. This can increase the yield of perennial vegetation; it can also reduce the length of the dormant period. Fruit trees require an extended period of cold temperatures to become dormant and to bear fruit.



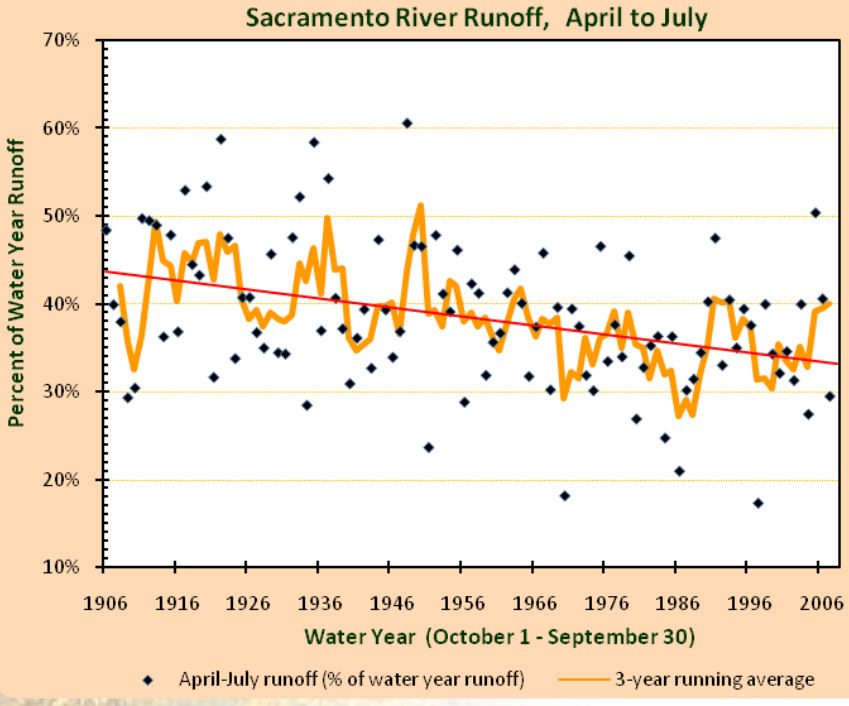

Winter chill degree-hours (the amount of time (temperatures below 45°F or 7.2°C, a threshold temperature for dormancy) has been decreasing significantly across the fruit-growing valleys of the state.

## INDICATORS: CHANGES IN CLIMATE

- Counties with populations over 1 million are warmer than those with populations under 100,000.
- Summertime extreme heat—especially at night—is rising. Extreme heat events can result in heat-related deaths and illnesses, decreased agricultural production, increased irrigation requirements, and greater electricity demands.
- During winter, the warming trend is reflected in decreasing "chill hours" in fruit-growing regions of the state. Many fruit trees require a critical period below a temperature threshold to produce flowers and fruit.
- Precipitation trends show little change over the past century.

# Impacts of Climate Change on Physical Systems

From October to March, snow accumulates in the Sierra Nevadas. This snowpack preserves much of the year's water supply in cold storage. Spring warming releases the water as snowmelt runoff. Over the past century, spring runoff to the Sacramento River has decreased by 10 percent. Lower runoff volumes from April to July may indicate: (1) warmer winters, during which precipitation falls as rain instead of snow; and (2) earlier springtime warming.




Source: DWR, 2008

Glaciers are important indicators of climate change. They respond to the combination of winter snow and spring and summer temperatures. Over the past century, temperatures in the Sierra Nevadas have been warming, especially in the spring. Likewise, the surface areas of seven Sierra Nevada glaciers studied have decreased by about 20 to 70 percent relative to 1900.

**Darwin Glacier**

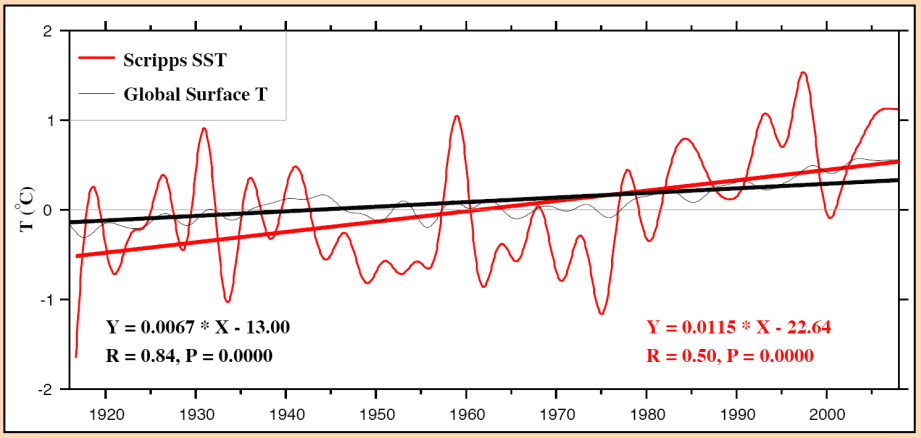
**1908**

G. K. Gilbert

**2004**

H. Basagic

**Sea Surface Temperature Anomalies**
**La Jolla, California**




Source: Schwing, 2008

Ocean temperature readings off La Jolla provide the longest continuous record of its kind on the West Coast of the United States and the Pacific Rim. At this location, sea surface temperatures have risen by about 1.8°F or 1° C since 1916.

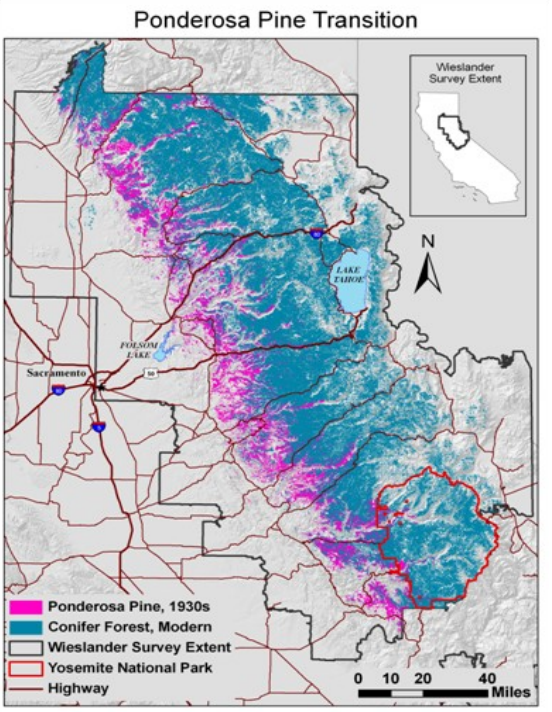
## INDICATORS: IMPACTS ON PHYSICAL SYSTEMS

- Spring snowmelt from the Sierra Nevada to the Sacramento River has declined over the past century.
- The average amount of water stored in the state's snowpacks is largely unchanged, although snow-water content has declined in the northern Sierra Nevada but increased in the southern Sierra Nevada.
- Glaciers in the Sierra Nevada have decreased in area over the past century.
- Sea levels measured at stations in San Francisco and La Jolla have been rising.
- Water temperatures in Lake Tahoe over the past 30 years, and ocean water temperatures at La Jolla over the past century, are rising. However, water temperatures in the southern Sacramento-San Joaquin River Delta over the past decade have stayed roughly the same.
- Oxygen concentrations are decreasing in California ocean waters.

# IMPACTS OF CLIMATE CHANGE ON BIOLOGICAL SYSTEMS

Plants and animals reproduce, grow and survive within specific habitat ranges defined by climatic and environmental conditions. Species may respond to changes in these conditions by a shift in range boundaries.

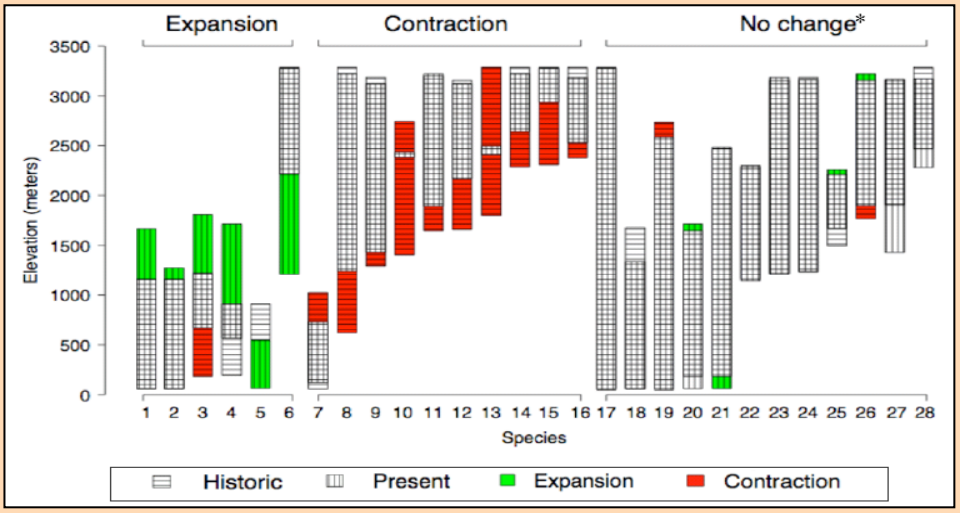
The lower edge of the Sierra Nevada Mountains' conifer-dominated forests has been retreating upslope over the past 60 years. The map on the right shows the present-day Ponderosa Pine (conifer) forest as blue areas. In the 1930s, the range of the Ponderosa Pine extended into the area in pink. This pink area corresponds to elevations experiencing warmer winter nights.




Source: Thorne, 2006.

Changes in elevational range have also been observed among small mammals in Yosemite National Park (see figure below). About half of the species of small mammals surveyed in the Park are found at different elevations today compared to early in the last century. Most of the species have moved to higher elevations by an average of approximately 500 meters. A reduction or narrowing in elevational range ("range contraction") was more common than an expansion in range. Range contractions mostly involved an upward shift of the lower elevational limit. This upward shift is of concern because habitat area decreases at higher elevations.

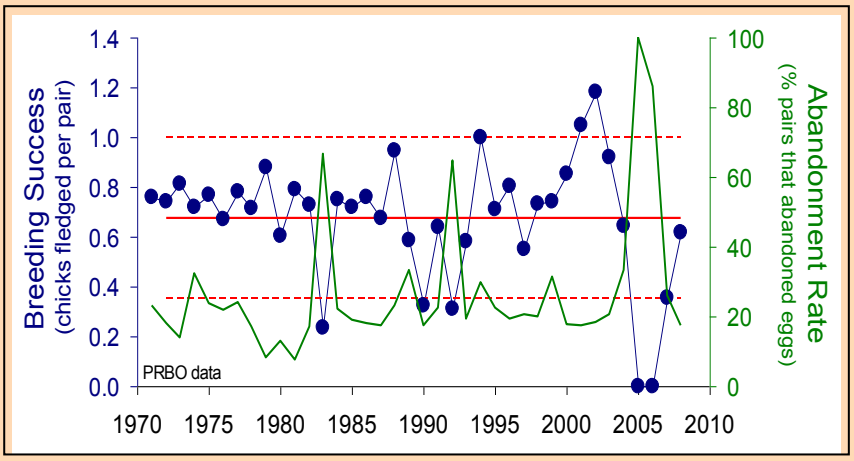
**Shifts in elevational range of small mammals Yosemite National Park**
**Historic (1911-1920) vs. Present (2003-2006)**




Source: Moritz et al., 2008

Ocean warming is a factor affecting the coastal food web, from plankton to seabird populations. The Cassin's Auklet is a small, diving seabird that feeds on zooplankton. In California, the largest auklet colony is on Southeast Farallon Island (located 26 miles off San Francisco). The breeding success of this colony—measured as the number of offspring produced by each breeding pair at monitored nest boxes—has become more variable over time, with unprecedented reproductive failures in 2005 and 2006. Auklet breeding success and abandonment rates signal changes in prey availability when the birds are reproductively active (March through August).

**BREEDING SUCCESS OF AUKLETS ON THE FARALLON ISLANDS, CA***




* The solid red line shows the long-term mean breeding success (0.68 chicks per pair). Dashed red lines show ±80 percent confidence intervals.

## INDICATORS: IMPACTS ON BIOLOGICAL SYSTEMS

- Tree deaths in the Sierra Nevada have increased with rising temperatures.
- The frequency of large wildfires has increased.
- The lower edge of the conifer-dominated forests in the Sierra Nevada has been retreating upslope over the past 60 years.
- Small mammals in Yosemite National Park are found today at different elevational ranges compared to earlier in the century.
- The spring and fall arrivals of some migratory birds are changing.
- Butterflies in the Central Valley have been arriving earlier in the spring over the past four decades.
- Auklet breeding success on the Southeast Farallon Islands off the California coast has been more variable, with unprecedented reproductive failures in 2005 and 2006.

# References


ARB, 2008. California Air Resources Board, Planning and Technical Support Division, Emission Inventory Analysis Section. Sacramento, California.

Baldocchi, D. and Wong, S., 2008. Accumulated winter chill is decreasing in the fruit growing regions of California. Climatic Change 87(Supplement 1): S153-S166.

Basagic, H.J., 2008. Quantifying Twentieth Century Glacier Change in the Sierra Nevada, California. Master of Science Thesis. Portland, Oregon: Portland State University.

DRI, 2008. Desert Research Institute, Division of Atmospheric Science, Reno, Nevada.

DWR, 2008. California Department of Water Resources, Division of Flood Management. California Cooperative Snow Surveys, 1929-present. http://cdec.water.ca.gov/snow/

Gilbert, G.K., 1904. Variations of Sierra Glaciers. Sierra Club Bulletin V(1): 20-25.

Keeling, R.F., S.C. Piper, A.F. Bollenbacher and S. J. Walker. Scripps CO2 Program, http://scrippsco2.ucsd.edu. Scripps Institution of Oceanography, University of California, La Jolla, California.

Moritz, C., J.L. Patton, C.J. Conroy, J.L. Parra, G.C. White, S.R. Beissinger, 2008. Impact of a Century of Climate Change on Small Mammal Communities in Yosemite National Park, USA. Science 322:261-264. 10 October 2008.

NOAA, 2008. National Oceanic and Atmospheric Administration. NOAA ESRL GMD Tall Tower Network. Retrieved May 21, 2008 from http://www.esrl.noaa.gov/gmd/ccgg/towers/index.html.

PRBO, 2008. PRBO Conservation Science, Petaluma, California. http://www.prbo.org/cms/index.php

Schwing, F 2008. Pacific Grove, California: Pacific Fisheries Environmental Service, NOAA Fisheries ervice.

Thorne J., Kelsey T., Honig, J. and Morgan B., 2006. The development of 70-year old Wieslander Vegetation Type Maps and an assessment of landscape change in the central Sierra Nevada. California Energy Commission; Public Interest Energy Research Program. Sacramento, California.

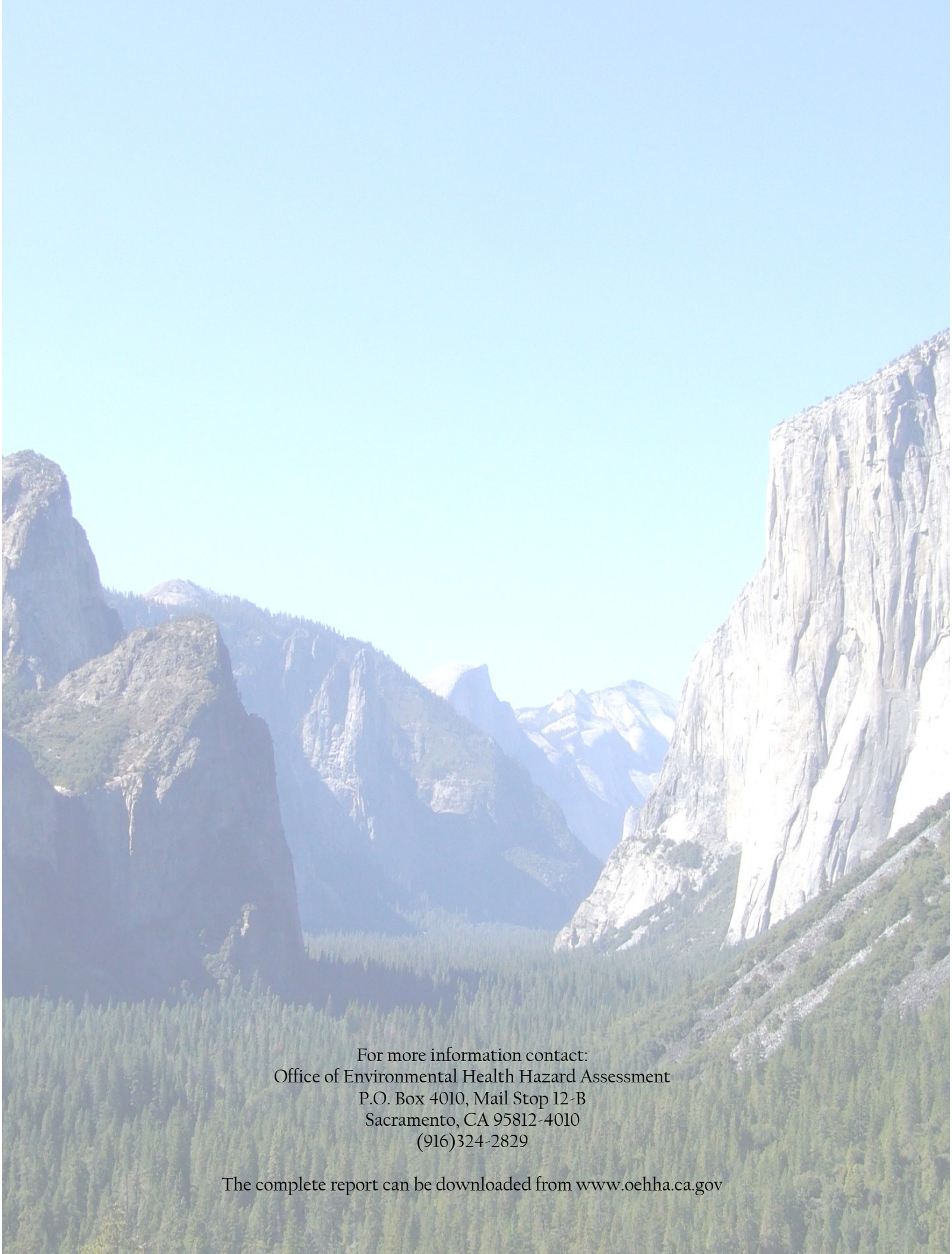
# ACKNOWLEDGEMENTS

The Office of Environmental Health Hazard Assessment is grateful
to the technical staff and researchers
who contributed their ideas, data, findings, and other information for inclusion in
*Indicators of Climate Change in California.*

OEHHA especially acknowledges the support of
Guido Franco of the California Energy Commission's
Public Interest Energy Research Program, and
Andrew Altevogt and Eileen Tutt of the Cal/EPA Office of the Secretary.

Document Design: Angela De Palma-Dow, OEHHA
Photo credits:
Yosemite Valley, California– Linda Mazur, OEHHA
Painted lady butterfly– Jim Ellis, California Academy of the Sciences
Ruby-crowned kinglet– Rick Lewis, PRBO Conservation Services
Grapes– Johan van der Hoven, Prospective Innovations

Printed on recycled paper



For more information contact:
Office of Environmental Health Hazard Assessment
P.O. Box 4010, Mail Stop 12-B
Sacramento, CA 95812-4010
(916)324-2829

The complete report can be downloaded from www.oehha.ca.gov