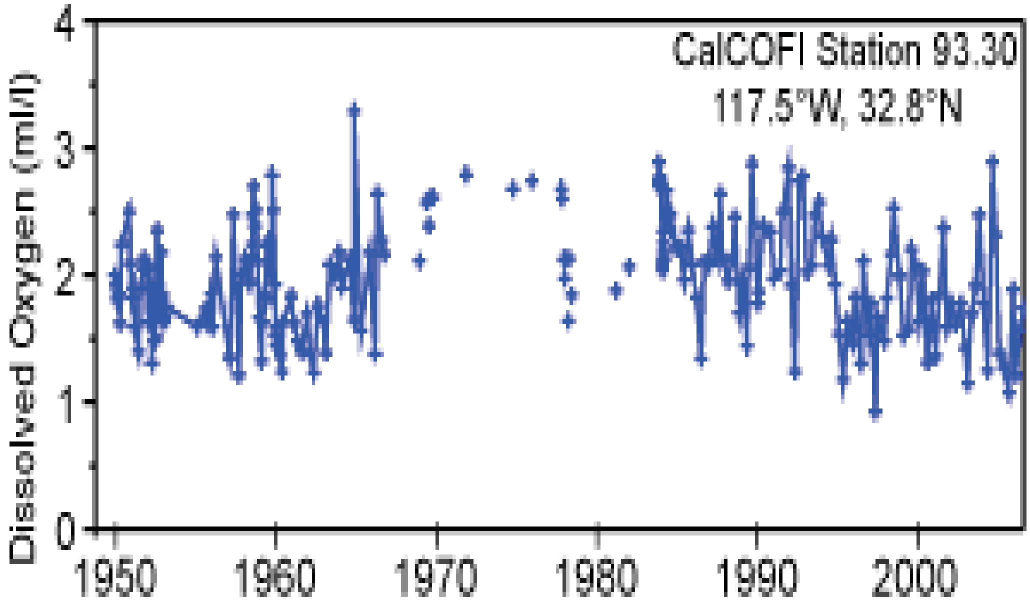
Impacts on physical systems

OXYGEN CONCENTRATIONS IN THE CALIFORNIA CURRENT

Dissolved oxygen levels in the southern California Current System are declining.

Dissolved oxygen levels off the coast of San Diego (at 200 m depth)

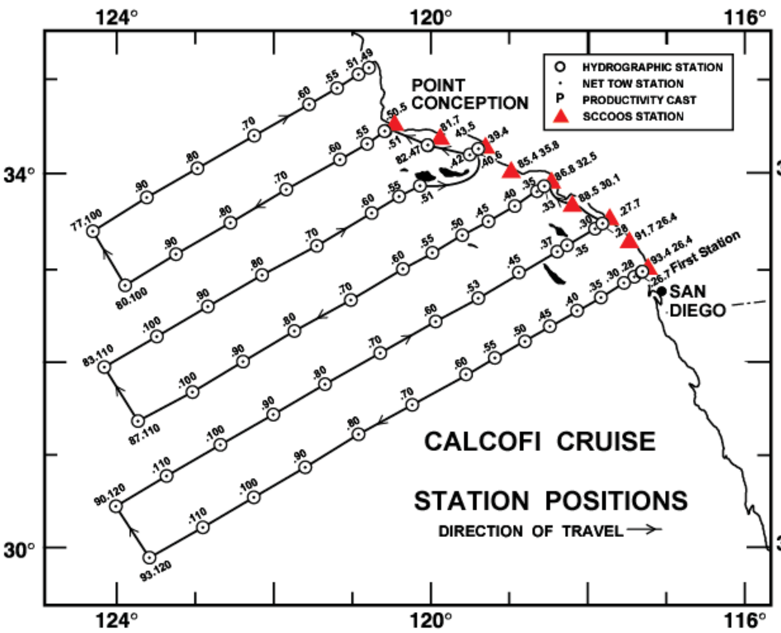


Source: Bograd et al., 2008

Note: The unconnected points denote a period of limited sampling during 1968 to 1983; the connected points denote regular scheduled surveys.

What is the indicator showing?

Measurements of dissolved oxygen concentrations in ocean waters off southern California have revealed a strong and persistent decline since the mid-1980s. As a result, the oxygen-deficient zone (waters having low dissolved oxygen concentrations at depths of about 100 – 1,000 meters) in this area has expanded closer to the surface. The graph above presents levels of dissolved oxygen at a location off the coast of San Diego, in the Southern California Bight (Station 93.30 on the map, next page). At this station, the depth of the oxygen-deficient zone is 90 meters shallower (i.e., moving into the oxygen-rich surface waters) in 2006 than in 1984. This station reveals the significant influence of the California Undercurrent, which transports waters of tropical origin into the Bight. (The Southern California Bight is the 400 miles of recessed coastline from Point Conception in Santa Barbara County, California, to Cabo Colnett, just south of Ensenada, Mexico (SCCWRP, 2008)).



Source: CalCOFI, 2008

Why is this indicator important?

Dissolved oxygen (DO) concentrations in the ocean provide an indication of physical and biological processes occurring in the marine environment, and their impacts on marine ecosystems. Climate change models predict a decline in mid-level concentrations of DO under global warming scenarios. Data from the southern California sampling program that provides the basis for the graph presented (see *Technical Considerations*, below) show large declines in DO between 1984 and 2006. The decrease in DO over the 23-year period was generally less than 10 percent at 50 to 100 meters deep, but ranged from 10 to 30 percent at 200 to 300 meters. These declines are consistent with observations from several regions of the western and eastern subarctic North Pacific. It should be noted that the DO concentrations in the Bight in recent years are similar to those seen in the late 1950s (McClatchie et al., In review).

Declining DO levels in ocean waters, and the associated changes in the depth and extent of oxygen-deficient zones, can lead to significant and complex ecological changes in marine ecosystems. In addition to the direct adverse effects of lower oxygen concentrations (hypoxia), shallower oxygen-deficient zones can also lead to a compression of favorable habitat for certain marine species and an expansion of favorable habitat for other species. During the last decade, the Humboldt squid (*Dosidicus gigas*) – which thrives in low-oxygen environments -- has expanded its range northward from Baja California to southeast Alaska, a shift that may have been affected by changes in the extent of oxygen-deficient zones (Gilly and Markaida, 2007).

What factors influence this indicator?
Oxygen enters the ocean through contact with the overlying atmosphere. It is produced in the oceanic surface layer by biological production, and is removed in sub-surface waters through the decomposition of sinking organic matter. Sub-surface oxygen concentrations are sensitive to the rate of surface-to-deep ocean circulation and mixing and biological production, as well as temperature and salinity (Joos et al., 2003). Hence, concentrations of DO are dependent on a number of physical and biological processes, including circulation, mixing, and biological production and respiration. Climate-driven changes in these processes are likely to be reflected in DO observations.

The declines in DO predicted by climate models are mostly attributed to enhanced thermal stratification near the surface due to warming, and a resultant reduction in the downward transport of oxygen from well-oxygenated surface waters into the ocean interior (Keeling and Garcia, 2002). Significant surface-intensified warming has been observed in the southern California Current System, with a subsequent increase in thermal stratification and large declines in DO levels. Although it has only been documented in the Bight, it is suspected that it has occurred throughout the California Current. These changes are consistent with a hypothesized reduction in vertical oxygen transport.

In addition, the Southern California Bight is impacted seasonally by the California Undercurrent, making it an important location to monitor changes in source waters (i.e., water masses carried into the area by ocean currents) to the southern California Current. The declining oxygen concentrations seen in this region imply a change in the properties of the source waters, although the precise mechanisms of the decline are not known. The declines observed off California are consistent with an observed expansion of the oxygen deficient zone in the tropical oceans (Stramma et al., 2008).

It should be noted that the observed DO levels could be influenced by both local thermodynamic or biological processes, as well as remote, large-scale, changes. The oxygen concentrations can vary with the depth, temperature and time of year of the water being measured. While both factors are important, quantification of their relative influences is not feasible at this time.

Technical Considerations:
Data Characteristics
The data presented are from sampling and monitoring conducted by the California Cooperative Oceanic Fisheries Investigations (CalCOFI) program. CalCOFI is a partnership of the California Department of Fish and Game, the National Oceanic and Atmospheric Administration (NOAA) Fisheries Service, and the Scripps Institution of Oceanography. Since 1949, CalCOFI has organized cruises to measure the physical and chemical properties of the California Current System and census populations of organisms from phytoplankton to bird fauna. This is the foremost observational oceanography program in the United States.

Currently, two to three week scientific cruises are conducted quarterly at a grid of ~66 stations off Southern California. At each station a suite of physical and chemical measurements are made to characterize the environment and map the distribution and abundance of phytoplankton, zooplankton and fish eggs and larvae (CalCOFI, 2008). The data reported here are DO concentrations in standard units of milliliters per liter, or mL/L. Details of the CalCOFI sampling protocol can be found at the CalCOFI website, www.calcofi.org.

Strengths and Limitations of the Data

The long historical time series of DO observations from the CalCOFI program provide a unique opportunity to investigate the relative role of physical and biological processes in controlling oxygen changes.

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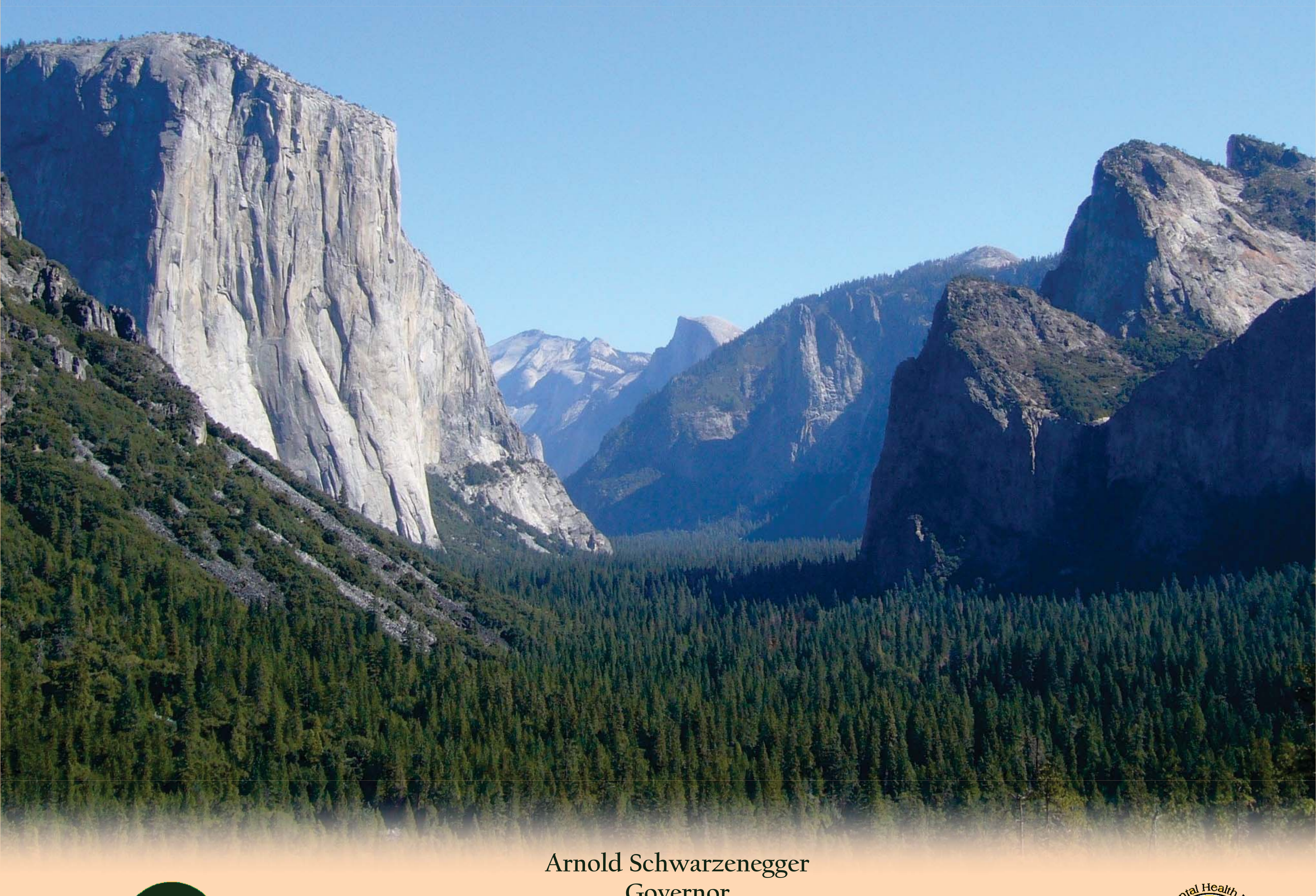
INDICATORS OF CLIMATE CHANGE IN CALIFORNIA

April 2009



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INDICATORS OF CLIMATE CHANGE IN CALIFORNIA

April 2009

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