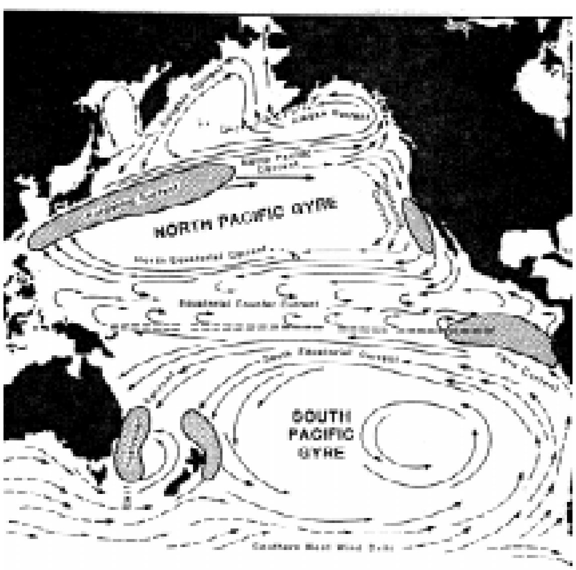
THE PACIFIC OCEAN

PACIFIC OCEAN CURRENTS



The Pacific Ocean is the largest body of water in the world. It occupies one third of the earth's surface -- covering nearly 70 million square miles.

At its widest point, the Pacific stretches about 12,300 miles, from Indonesia to the coast of Columbia in South America.

A major difference between the Pacific and Atlantic Oceans is the width of the equatorial region. The Pacific is more than twice as wide. Perhaps this difference explains why the Pacific sustains periodic El Niño and La Niña cycles and the Atlantic apparently does not.

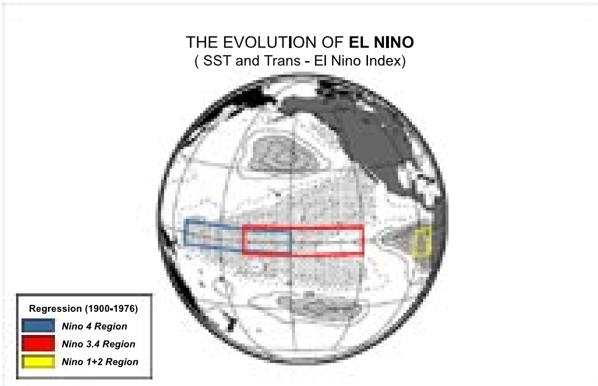
Currents are caused by the sun heating the equatorial ocean more strongly than the rest of the earth. Air rises from the surface and is replaced by inflow from the subtropics.

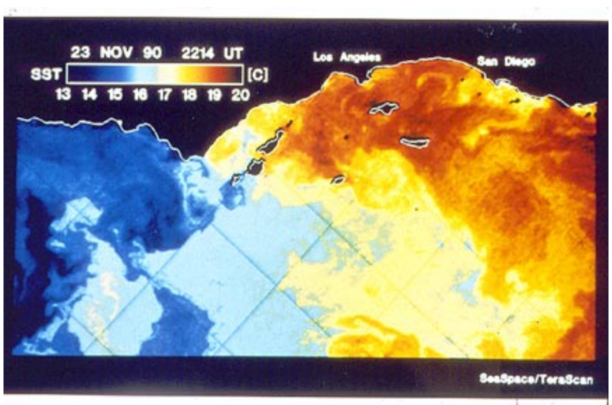
The Coriolis effect turns these inflows to the right in the northern hemisphere and to the left in the southern hemisphere, resulting in great trade-wind belts.

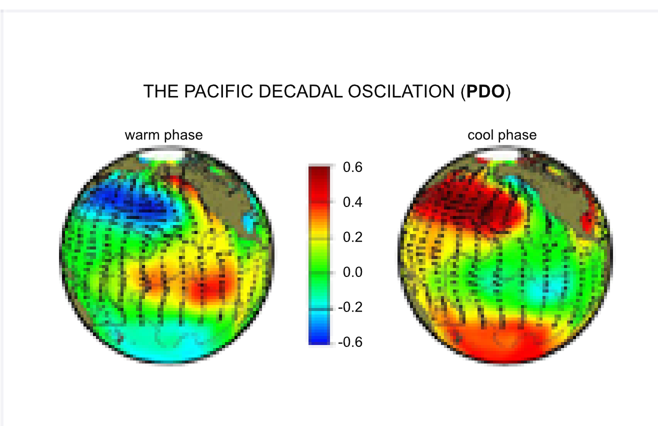
The dynamic action of wind on water sets up an ocean-atmosphere interaction in the tropical Pacific where the winds determine the water temperature -- cool water in the east and warm in the west -- but the water temperature also determines the winds. There is no doubt that the ocean-atmosphere system is interconnected.

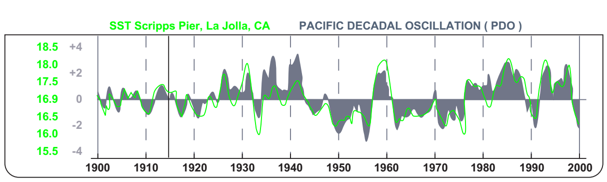
The winds blow toward warm water. The westward winds along the equator push warm water heated by the sun to the west, exposing the cooler water underneath in the east. This upwelling cools the eastern surface water. Because of the force of the trade winds, sea level at Indonesia is about one-half meter higher than at Peru.

The thermocline lies like a blanket between the cold, deep water and the warmer upper layer. In the western Pacific, trade winds pile up a thick layer of warm water, pushing down the thermocline in the west, while it rises in the east. Deep water is rich in nutrients; wherever there is upwelling there is life.









During El Niño events this system relaxes. Trade winds weaken and the warm water piled up in the western Pacific sloshes eastward. Warm water blankets the nutrient-rich cold water in the eastern Pacific, and upwelling weakens or subsides.

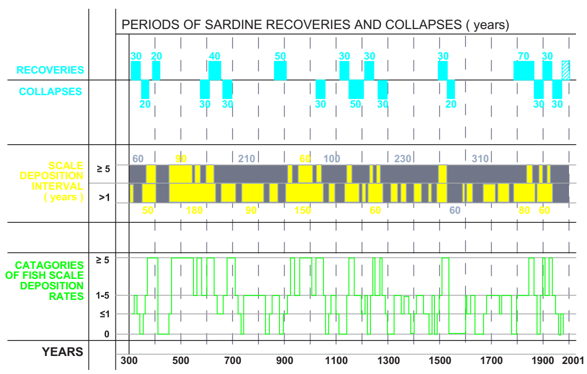
Because the warm pool of the western Pacific pumps great amounts of heat and moisture into the atmosphere, this system is one of the major driving forces of world climate.

The name El Niño refers to the warm phase of a large oscillation in which the surface temperature of the central and eastern tropical Pacific varies by up to 4 degrees Celsius, with associated changes in winds and rainfall patterns. The complete phenomenon is known as the El Niño / Southern Oscillation, or ENSO. The warm El Niño phase typically lasts about 8 to 10 months. The entire ENSO cycle can last 3 to 7 years and often includes a cold phase known as La Niña.

Recent studies also show that the ocean climate undergoes even broader warm-water and cold-water cycles, called “regime shifts”.

Scientists coined the term “Pacific Decadal Oscillation” (PDO) to describe a long-lived ENSO-like pattern of Pacific climate variability.
The climatic fingerprint of PDO events is most visible in the North Pacific and North America, while ENSO events are most visible in the tropics. But strong ENSO events can ripple up the North American coastline and override the cold-water California Current flowing south.

Several studies find evidence for just two full PDO cycles in the past century:
“cool” PDO regimes prevailed from 1890 to 1924 and again from 1947 to 1976, while “warm” PDO regimes dominated from1925 to 1946 and from 1977 through at least the mid-1990s.
PDO events have persisted for 20 to 30 years, or even longer.



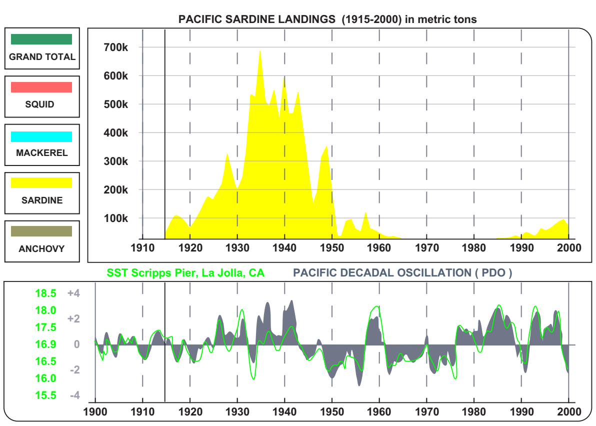
Causes for ENSO and PDO cycles are not known at present. However, scientists have measured major changes in northeast Pacific marine ecosystems and fish stocks, correlated with phase changes in the PDO.

Oceanic cycles greatly affect marine life.
The Pacific sardine is a good example of how the ocean climate affects cycles of abundance.

Biologists analyzed fish scale deposits in anaerobic sediments of the Santa Barbara Basin off southern California. They found that sardines and anchovies both tend to vary in abundance over a period of about 60 years -- cold-water cycles favor anchovies and warm-water cycles favor sardines.

The scale deposition record shows nine major recoveries and subsequent collapses of the sardine population over 1700 years. The graph shows collapses and recoveries of the sardine biomass from 270 AD through 1970. The average time for a recovery of the sardine population is 30 years.

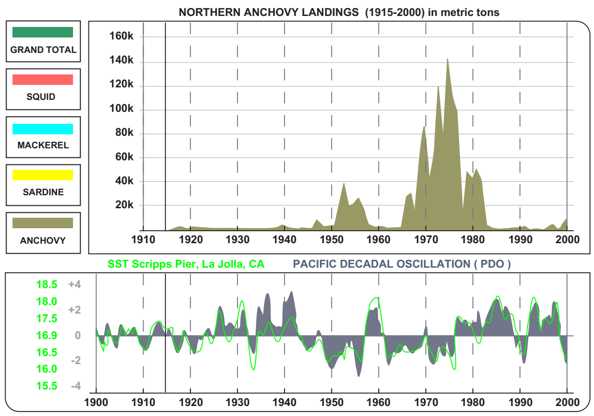
What this graph doesn't show is the most recent recovery of California sardines, which began in the late 1970s. In 1998 scientists declared the Pacific sardine to be officially "recovered." They estimated spawning biomass at more than one million metric tons. Further, they found the current recovery not unlike those of the past in its rate or magnitude.



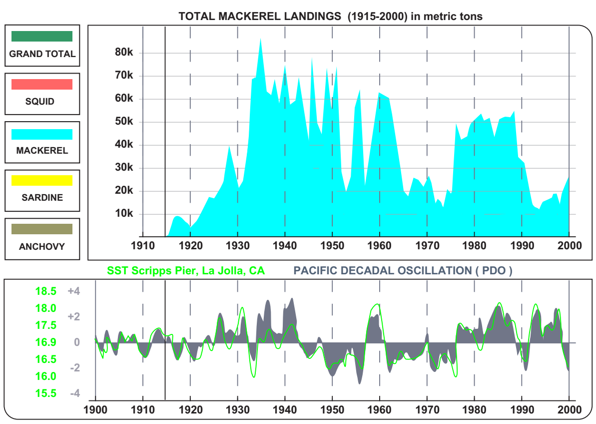
Charting the harvest of sardines since the early 1900s, compared to oceanic PDO cycles, illustrates the ocean's influence on sardine abundance. Adding the average annual sea surface temperature at Scripps Pier, in southern California, further emphasizes the key role that water temperature plays in the cycle. As scale deposits have shown, sardines disappeared periodically even without fishing pressure.

After the sardine resource collapsed, California closed the sardine fishery in the early 1970s. Sardines began returning to abundance beginning around 1978. Today's sardine harvest is strictly regulated. The harvest guideline is set on a sliding scale of 5 to 15 percent of the estimated spawning biomass. The harvest percentage is determined in part by the three-year average sea surface temperature.

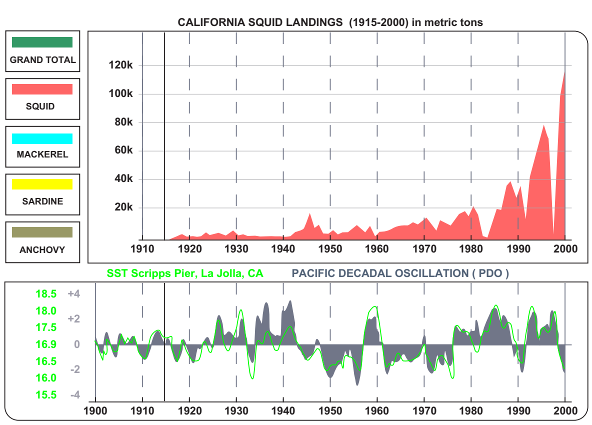
Cycles of abundance of all California's coastal pelagic "wetfish" species are strongly influenced by natural oceanic cycles.



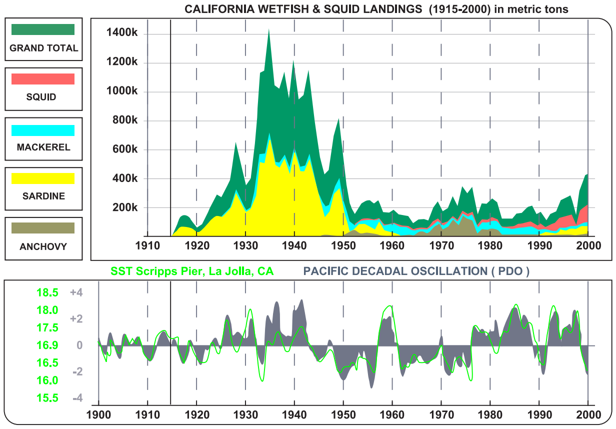
Anchovy landings from 1916 through 2000 illustrate their abundance during cold-water cycles. As with sardines, regulations as well as markets also play a major role in the harvest. A decline in reduction plants paralleled the decline in the anchovy harvest. The advent of soy protein as an inexpensive substitute for fish meal also helped to shrink demand for anchovy. Still, a portion of the harvest is processed for human consumption -- some at upscale restaurants.



Pacific mackerel, often called blue mackerel, is another wetfish species influenced by oceanic cycles. These mackerel are most abundant in southern California, moving northward during summer, and south during winter, especially during El Niño cycles.
In 1928, the first large-scale canning of mackerel catapulted the Pacific mackerel fishery to prominence. Almost overnight the mackerel catch rose from 10th to the second largest in California behind sardines. Landings peaked in 1935.
The mackerel resource then experienced a long decline. A moratorium curtailed the harvest in 1970. In the late 1970s, with the return of a warm-water cycle, Pacific mackerel stocks rebounded. The fishery resumed with a strict quota. Pacific mackerel ranked first in volume of finfish landings in California from 1984 through 1991.



Today, market squid is among California's most valuable fisheries. Squid abundance is highly variable, in part due to the species' very short life span, and in large part due to oceanic water temperature cycles. Squid virtually disappear from California in El Niño cycles, and landings plummet. Studies suggest a correlation between water temperature and the squid catch 18 months later in Monterey Bay. Warmer than usual water temperatures usually precede good landings. Since the 1982-83 El Niño, the bulk of the squid harvest has come from southern California.



The ocean's cycles have a profound effect on the cycles of abundance of coastal pelagic species. Today, however, California's marine fisheries are strictly regulated to prevent potential overharvesting.

Flexibility in fishery management is essential to afford fishermen and processors the ability to maximize the harvest of these cyclical stocks.