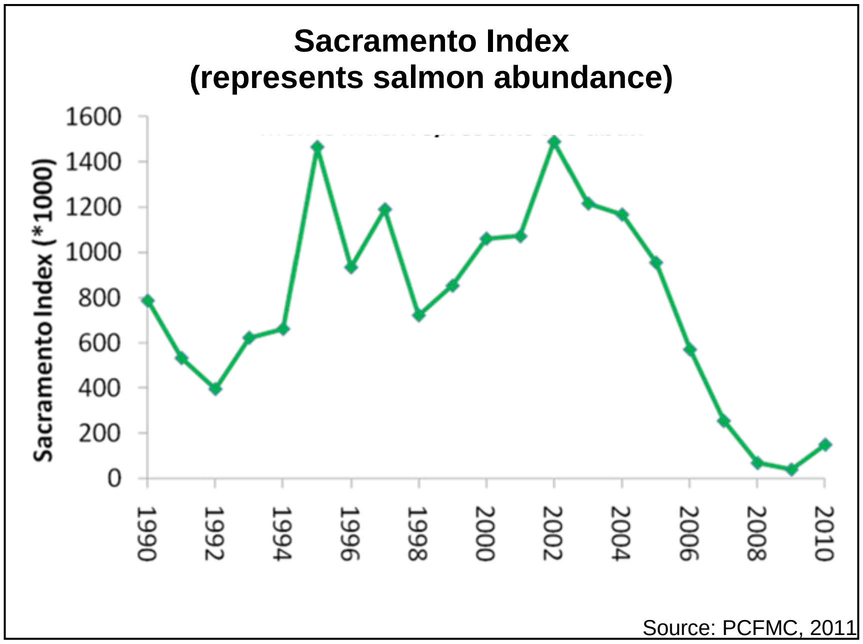
SACRAMENTO FALL RUN CHINOOK SALMON ABUNDANCE (NEW)

Salmon juvenile survival, and resultant adult abundance, has become more variable through time with extreme juvenile mortality events in 2005 and 2006.

Photo: Allen Harthorn

Central Valley chinook salmon (*Oncorhynchus tshawytscha*) rear in the fresh water of the Central Valley, migrate to feeding grounds in the Pacific Ocean, and return to fresh water to spawn. Survival during the initial months of ocean life is dependent on available prey (largely krill, forage fish and crab larvae).



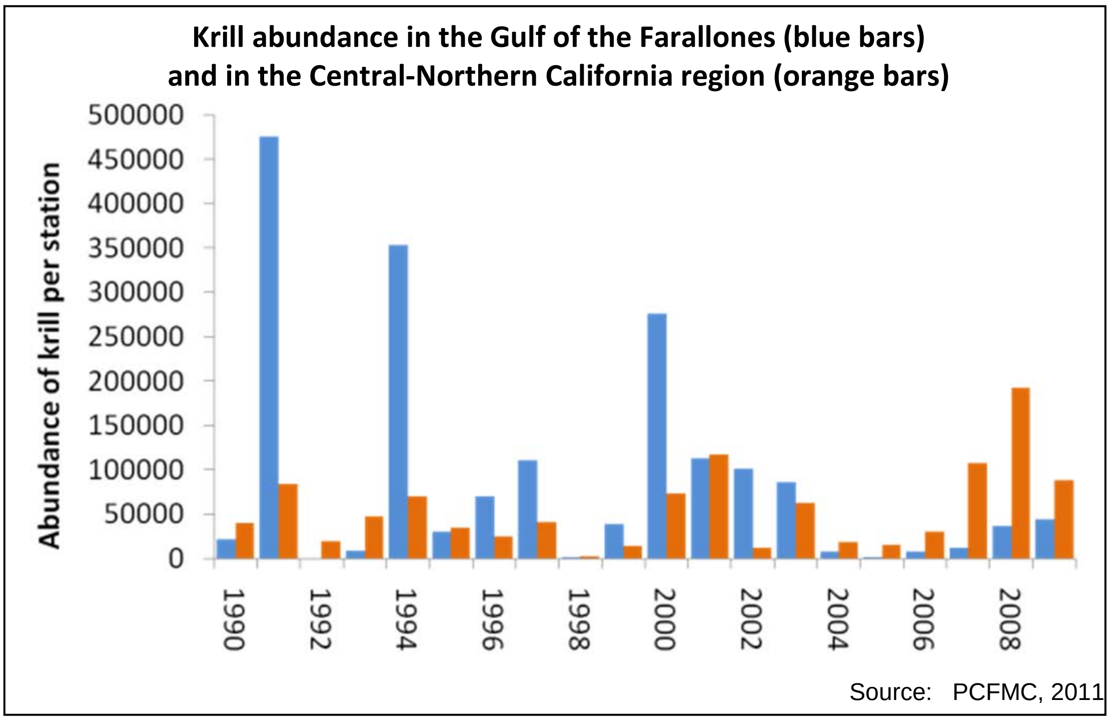
What is the indicator showing?

Scientists have found strong evidence that growth and survival of chinook salmon during the first period at sea largely determines later adult abundance. Chinook salmon abundance fluctuates year to year but since 2004 has declined dramatically in the Central California region. The graph shows the abundance of adult fall run chinook salmon originating from the region between 1990 and 2010 (PCFMC, 2011). Abundance is represented by the *Sacramento Index* which is the sum total of adult salmon in the harvest and the spawning grounds (O'Farrell et al., 2008). This index describes the cumulative result of overall conditions in the region that support chinook salmon over the previous two years.

Why is the indicator important?

The chinook salmon is the largest of the Pacific Ocean species and has great cultural, economic and ecological value. These fish are legendary for their migrations from the streams where they are hatched, across vast stretches of the Pacific Ocean, and back to spawn in their streams of origin. Sacramento River fall chinook salmon have been the largest contributor to ocean salmon harvest off California and Oregon for decades (O'Farrell et al., 2008). As a top predator, salmon can inform us of ocean ecosystem health. In combination with an understanding of the processes underlying salmon abundance, scientists can use the conditions of the ocean ecosystem two years prior to allow for rough estimates of the future abundance of adult chinook salmon. Climate change-related influences on the ocean (e.g., increased sea surface temperature and upwelling changes) may enter into predictions of future salmon abundance.

What factors influence this indicator?
The distribution of krill and other prey in the Gulf of the Farallones is related to the abundance of adult salmon two years later. If prey is not in the proximity of the juvenile salmon feeding grounds, adult salmon survival will be lower. Production of krill and other prey in the Gulf is dependent on an appropriate timing and strength of upwelling winds (see Appendix A). Weak or late-onset upwelling, such as during El Niño-like conditions, lead to a warmer layer at the surface of the water column due to limited deep mixing. When this occurs, krill abundance is shifted southward away from where juvenile salmon reside and out of their feeding area.



The graph above shows krill abundance in the Gulf of the Farallones (blue bars), where juvenile salmon feed as they enter the ocean, between 1990 and 2010 (O'Farrell et al., 2008). Typically the amount of krill in the Gulf is greater than in the other surface waters in the central-northern California region (orange bars). However, in recent years there has been a shift to higher krill abundance in the greater region and less in the Gulf.

The rapid decline in krill in the juvenile salmon feeding area beginning in 2001 and up through 2007 parallels the sharp decline in salmon abundance beginning in 2004. The upwelling began exceptionally late in 2005 and 2006, creating a mismatch between juvenile salmon entering the ocean and available food (Lindley et al., 2009). Because krill became more abundant in the Gulf area in 2009, salmon abundance was predicted to and has rebounded in 2011 from the recent collapse.

Although the salmon-prey relationship and its dependence on ocean dynamics appear to be well-established, it is not yet clear whether increasingly variable ocean processes reflect climate change. The success of salmon populations also depends on conditions in streams and in the Sacramento-San Joaquin Delta, important habitat for early life stages. For example, water flow and temperature conditions necessary for salmon growth and survival are impacted by dams, diversions, land use and bedded sediments. Furthermore, overfishing of salmon both inland and at sea can influence measures of salmon abundance.

Technical Considerations

Data Characteristics

The Sacramento Index is derived from the sum of Sacramento River Fall Chinook (SRFC) ocean fishery harvest south of Cape Falcon between September 1 and August 31; the recreational harvest of SRFC in the Sacramento River Basin; and adult escapement (counts of fish returning to spawn) (O'Farrell et al., 2008). The data were obtained from the Pacific Fisheries Management Council (http://www.pcouncil.org/salmon/stock-assessment-and-fishery-evaluation-safe-documents/preseason-reports/2011-preseason-report-i/).

Strengths and Limitations of the Data

The Sacramento Index has been calculated for a period of three decades. The techniques for estimating the index have been well vetted. However, the index does not account for the different age classes of salmon. Environmental conditions are known to alter the age structure of the population. For example, ocean upwelling and prey availability can enhance or retard salmon maturation, affect their return to spawn, and thus alter the population's age structure. Changes in age structure introduce uncertainty into the relationships between krill availability and fall-run salmon abundance. Wells et al. (2007) demonstrated that poor ocean conditions can lead to a later age at maturation and consequently the age structure of the population could be greater than average during those years. A more rigorous index of abundance would identify age class of the individuals and thereby capture the environmental effects on the population from a specific year.

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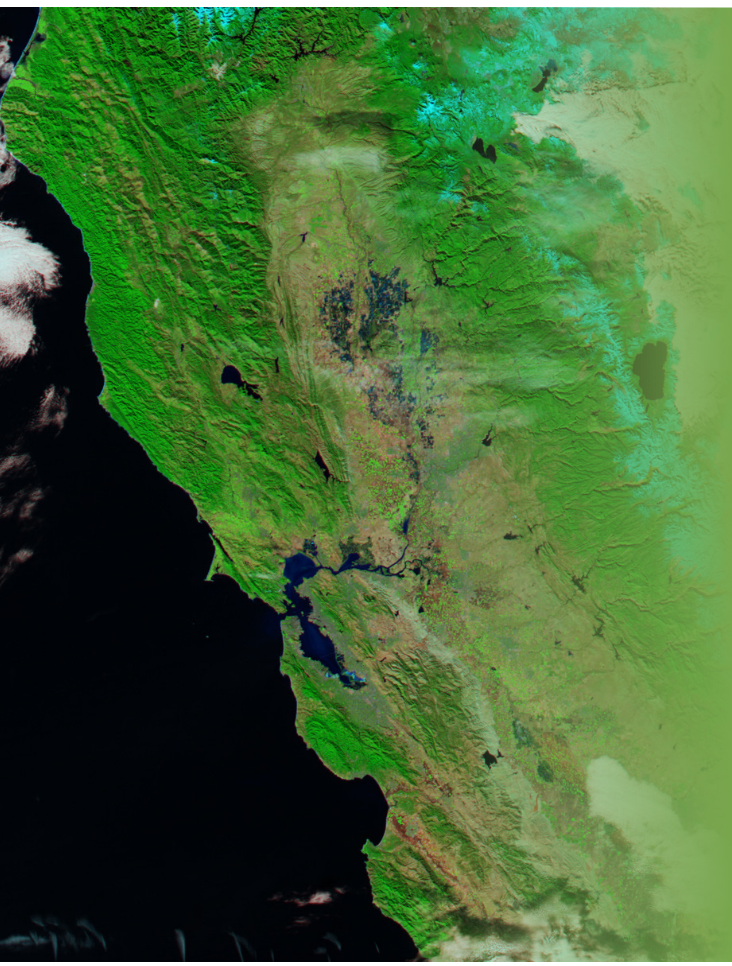

Indicators of Climate Change in California

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INDICATORS OF CLIMATE CHANGE IN CALIFORNIA

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