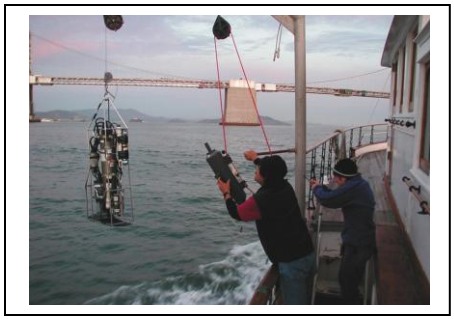
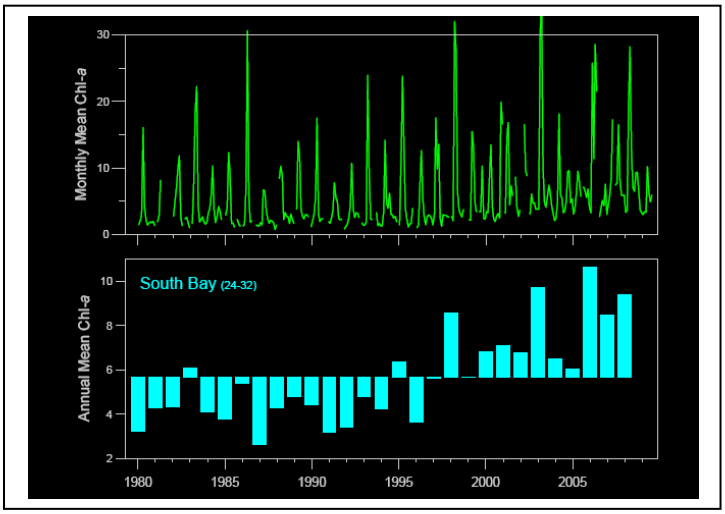
San Francisco Bay—Long-term, integrated, and multi-organizational studies conducted over 40 years in San Francisco Bay—known as the longest sustained program of research and observation in a U.S. coastal ecosystem—help resource managers and resource protection agencies understand the response of the Bay's aquatic community to the combined effects of climate variability, urbanization, changes in the hydrologic system, and the introduction of nutrients, organic contaminants, and trace elements.



Hydrologists collect water samples for analysis of long-term trends in nutrients, dissolved oxygen, chlorophyll a and other constituents in San

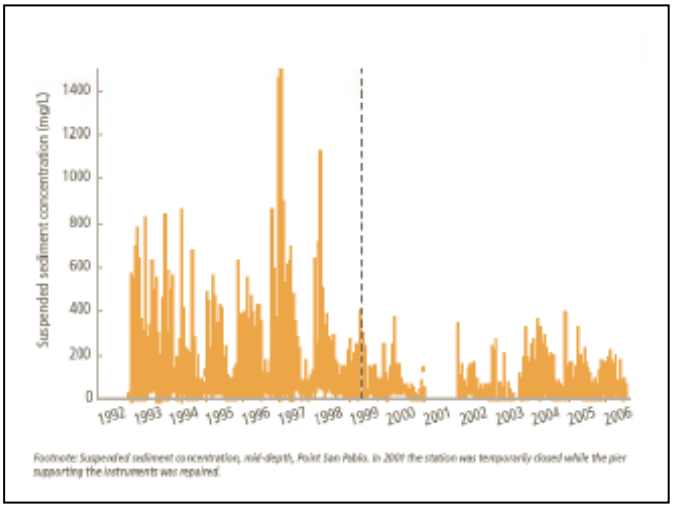
San Francisco Bay has historically been resilient to degradation from nutrient enrichment and not known for hypoxia or harmful algal species as found in other areas, such as Chesapeake Bay. This is despite the fact that San Francisco Bay, like Chesapeake Bay and other large estuaries, has elevated nutrient loadings. One manifestation of the resilience in San Francisco Bay has been relatively low concentrations of chlorophyll *a* (an indicator of phytoplankton biomass). Concentrations of chlorophyll *a*, however, have been increasing steadily since 1999.

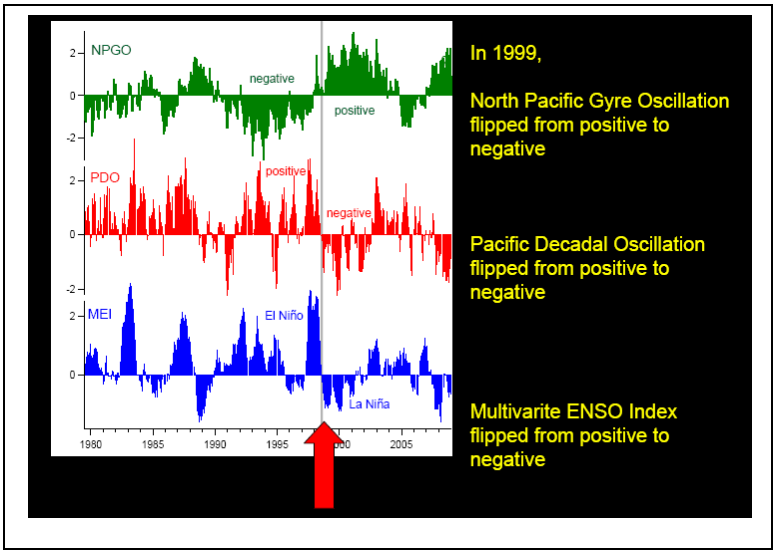


Chlorophyll a (an indicator of phytoplankton biomass) has been increasing since 1999. Conditions in San Francisco Bay may therefore reflect a reduced resilience to nutrient degradation, hypoxia, and harmful algal species.

Three possible reasons may explain the increases in chlorophyll *a* over the last 10 years. First, water clarity is increasing because turbidity is decreasing, which allows increased phytoplankton growth. Turbidity is decreasing in part because of human activities related to damming and flood control and continued depletion of the erodible pool of sediment dating back to the Gold Rush. Second, chlorophyll *a* is increasing in the Pacific Ocean so that the ocean is now a major source of photoplankton biomass to San Francisco Bay. Third, clams, which are a major consumer of phytoplankton, have decreased because of exceptionally large increases in clam predators beginning around 1999, including the English sole, Dungeness Crab, and Bay Shrimp (http://www.pnas.org/cgi/reprint/104/47/18561).

Decreases in suspended sediment since 1999 are evident in the time series of data from a station in Point San Pablo. Most sites monitored by USGS show similar decreases. Decreasing turbidity is leading to increasing phytoplankton biomass in San Francisco Bay.





The large physical and biological shifts described above occurred in San Francisco Bay after a dramatic shift in the ocean currents/atmospheric circulation system in 1999, signaled as sign reversals of the Pacific Decadal Oscillation and North Pacific Gyre Oscillation. These natural oscillations drive changes in climate, and along with human activities (such as related to damming of rivers) are leading to degradation of biological communities and water quality.

Lessons learned from the integrated assessments in San Francisco Bay: (1) Biological communities and water quality are influenced by both human activities (i.e. damming rivers that reduce sediment supply and turbidity) and natural climatic oscillations; (2) Estuaries are influenced by their connectivity to the oceans (not just watersheds and terrestrial connections); and, (3) Long-term climatic cycles (20 to 30 years) can have large impacts on estuaries, oceans, and coastal ecosystems.

The increase in water clarity and nutrient loadings in San Francisco Bay are likely to persist, leading to continued phytoplankton abundance. Management of nutrients and development of nutrient criteria are now critical for a Bay that historically was resilient. Continued monitoring and tracking of nutrients, sediment, and phytoplankton abundance is needed in this dynamically changing ecosystem to help forecast future effects of climatic change on water quality and biological communities in the coastal zone.

Network activities have been ongoing in San Francisco since 2007, funded by USGS in support of the Ocean Research Priorities Plan, as well as through partnerships with local, state, regional, and federal organizations. Highlights include (1) nutrient monitoring at selected sites to continue tracking nutrient loadings to the Bay; (2) monitoring and assessment of the composition of the phytoplankton community (including the presence and threat of harmful algal species); and, (3) real-time monitoring for suspended sediment and quantification of the suspended-sediment flux to the Bay. Data are managed and made available through a public, web accessible database containing more than 40 years of water-quality data. Statistical tools and guides are being developed to analyze time series of water quality, extract trends and significance levels, and assess seasonal and long-term patterns of variability, which will be useful to other water-quality monitoring programs across the Nation.

Major partners:

- San Francisco Estuary Institute
- Regional Monitoring Program for Water Quality in the San Francisco Estuary
- Point Reyes Bird Observatory;
- Sun Microsystems
- Central and Northern California Ocean Observing System (CENCOOS)
- California Coastal Conservancy
- South Bay Salt Pond Restoration Project
- California Department of Fish and Game
- California Coastal Conservancy
- University of Washington
- Georgia Tech
- University of California
- National Science Foundation National Center for Ecological Analysis and Synthesis
- U.S. Fish and Wildlife Service (FWS)
- U.S. Geological Survey (USGS)
- National Oceanography and Atmospheric Administration (NOAA)
- U.S. Bureau of Reclamation

Web access:

- http://sfbay.wr.usgs.gov/access/wqdata/index.html
- http://sfbay.wr.usgs.gov/sediment/cont_monitoring/

Contacts: Jim Cloern, jecloern@usgs.gov, (650) 329-4594 and David Schoellhamer, dschoell@usgs.gov, (916) 278-3126