

2 San Francisco Bay

Overview

San Francisco Bay is a large coastal embayment located on the Pacific Coast of the State of California. It consists of 5 major water bodies—Suisun Bay, Carquinez Strait, San Pablo Bay, Central Bay, and South Bay—and connects to the open sea only through the 2~3 km wide Golden Gate Strait. The Sacramento-San Joaquin Delta lies in the east of Suisun Bay, where two major inflowing rivers, the Sacramento and San Joaquin Rivers, meet. Freshwater from these rivers merges with the incoming ocean water from the Golden Gate Strait to form an estuary mainly at the northern area of the Bay.

Location

Basic information¹⁵

Surface area: 1,040 km²

Volume: 7 km³

Average depth: 6 m

Maximum depth: 110 m

Nature

< Background >

San Francisco Bay has a catchment area of approximately 156,000 km², covering about 40% of California State. The catchment area provides drinking water to over 23 million Californians (approximately two-thirds of the state's population) and irrigation water to 18,000 km² of farmland.¹

Before human-induced modifications, extensive wetlands surrounded the Bay, but now much of the shoreline has been turned into residential, industrial, agricultural, and commercial areas. As a consequence of this, the Bay is facing various environmental problems. However, the Bay still supports vast ranges of plant and animal species, and also continues to play a vital role for the people of California.



Climate

The Bay catchment area has a Mediterranean climate, characterized by cool, wet winters and warm, dry summers. In the inland area, the average temperature is about 6 °C in winter and 26 °C in summer. Temperatures in the coastal area show less variation, with mean monthly temperatures ranging from 10 to 16 °C.²

Precipitation varies greatly within the catchment area. In the wettest area, annual precipitation is around 1,500 mm.²

Topography

A relatively deep channel runs throughout the Bay, but the Bay is mostly shallow, with an average depth of only 6 m. Most of the coastline has a shallow slope, except along Carquinez Strait and part of Central Bay where the coastline is steep. At the Golden Gate, the entrance to the Bay, the water is at its maximum water depth of approximately 110 m.^{3,15}

Hydrology

The Bay receives the majority of its freshwater from the Sacramento and San Joaquin Rivers. Freshwater from these two rivers influences the salinity and water circulation patterns of the Bay, especially in the northern region. Salinity in the north of the Bay varies considerably and increases along a gradient from the Sacramento-San Joaquin Delta to Central Bay. The mean annual salinity at the mouth of the Sacramento River is slightly less than 2 ppt; in Suisun Bay it is about 7 ppt; and in Central Bay it increases to about 30 ppt. However, large inflows from the above rivers dramatically drop the average salinity of the Bay. For example, the average salinity of the Bay dropped from 26.1 ppt to 9.0 ppt during the 1997 floods, reducing the salinity of the Bay from 79% seawater to only 27% seawater.^{2,4}

The southern region receives only minor amounts of freshwater from the surrounding watershed. Thus circulation patterns and salinity are regulated by a combination of oceanic and northern-region waters that enter from Central Bay. Since there is no significant freshwater input, the salinity levels are usually higher and more uniform in the southern region. However, as in the above example, salinity in the southern region can be altered by large floods in the northern region.²

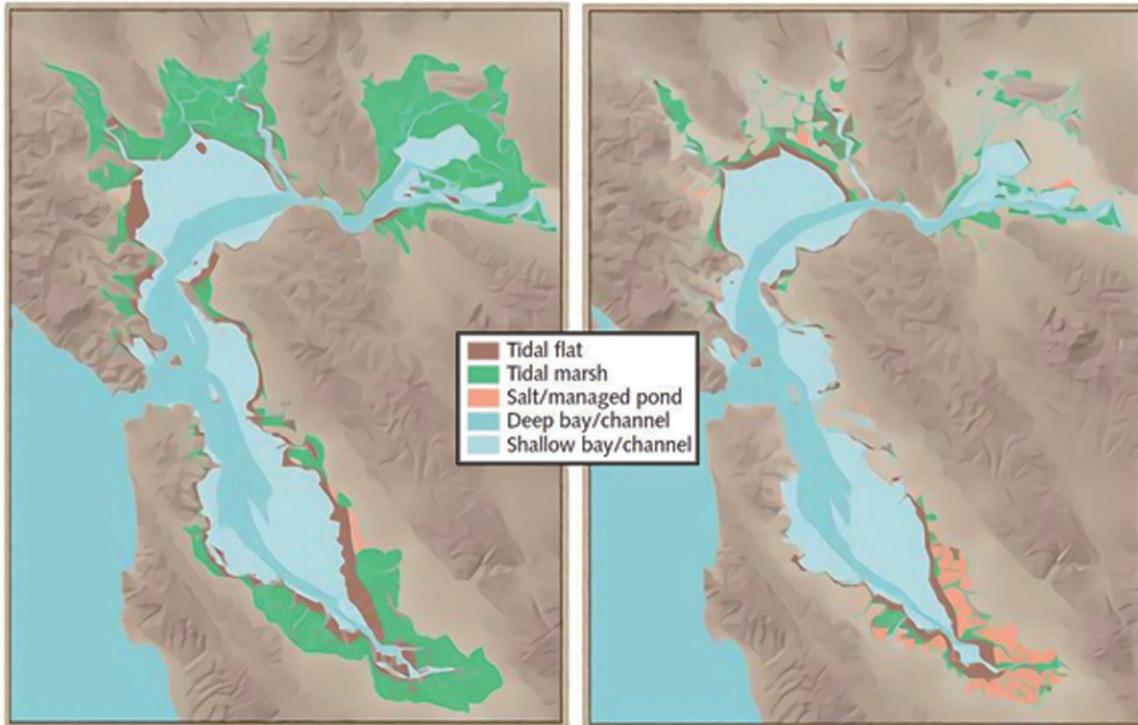
The water temperature of the Bay varies geographically and seasonally, ranging from 10 to 20 °C. During the summer, water in the northern region is usually warmer than the ocean, due to atmospheric heating and river input, whereas in winter

the Bay is usually cooler than the ocean. The water temperature of the southern region is intermediate between the ocean and river temperatures.²

< Surrounding environment >

Habitat

The majority of the water area of the Bay has a sandy mud bottom, but diverse habitats for life exist along the coastal zone, such as sand beach, reef, seagrass bed, mudflats, and wetlands. However, the distribution area of these habitats has significantly shrunk compared to before, due to development started in the 1800s. In particular, mudflats and wetlands were artificially filled, diked, drained, and converted into agricultural, industrial, and urban lands, and they have decreased prominently. For instance, approximately 800 km² of wetlands existed before, but there is currently approximately 200 km² of wetlands, including those artificially made, which is approximately one fourth of the previous wetland area.⁵



Distribution change of mudflats and wetlands in San Francisco Bay (Comparison between 1800 and 2009)⁵

Currently, wetlands are distributed in parts of South Bay, San Pablo Bay, and Suisun Bay. Despite their significant decrease and separation, they still support a wide range of animal life, including precious species, and provide valuable open space and recreational opportunities.

Biota

A wide variety of freshwater, brackish, marine and anadromous fish species are found in the Bay, which is consistent with a brackish environment, totaling more than 130 species. Freshwater species include Threadfin shad, bluegill and carp. Brackish species include delta smelt, starry flounder and yellowfin goby. Marine species include Pacific herring, English sole and white croaker. Anadromous species include Chinook salmon, white sturgeon and striped bass. Many of the fish species in the Bay are endemic.²

Marine mammals, such as the California sea lion and harbor seals, are also found in the Bay. Harbor seals settle in the Bay and come ashore to rest and give birth and are seen in Central Bay and the southern region of South Bay. The population of harbor seals is estimated to be around 500.⁶

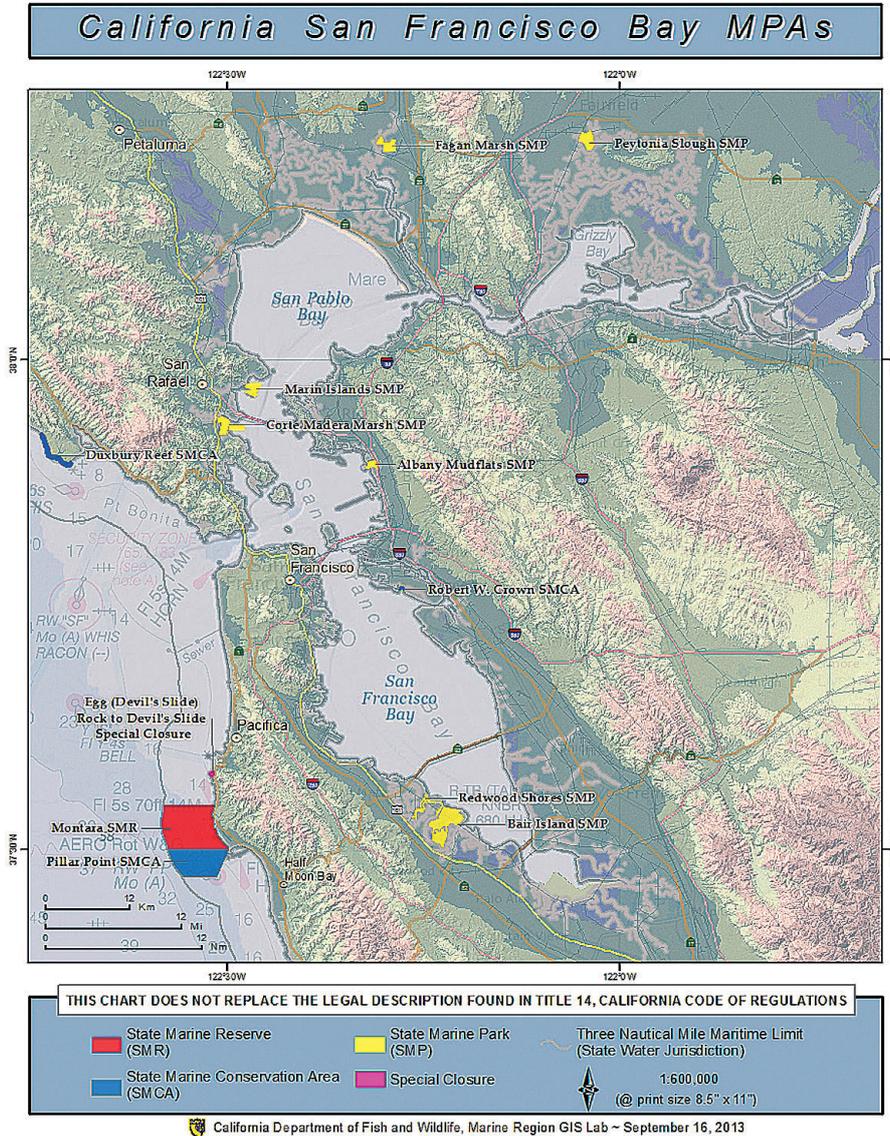
The wetlands surrounding the Bay support a vast range of bird species. Over half of the birds that migrate along the Pacific Flyway are known to stop-over to rest and feed.



Parent and child of harbor seals in San Francisco Bay⁶

Protected Area

Various types of protected areas designated and managed by the nation and/or the state are dotted around the Bay and contribute to conserving wildlife and their habitats. Major protected areas include the National Wildlife Refuge and the state-managed Ecological Reserve, Wildlife Area, and State Marine Parks which are intended to conserve mudflats, wetlands, and islands as important habitats for birds, fish, and mammals.⁷



Location map of State Marine Parks¹⁴

History and Culture

< History >

San Francisco Bay was land covered by glaciers until 20,000 years ago. It was formed at the end of the last ice age when melting continental ice sheets caused the sea level to rise, and the seawater penetrated the Coast Range through the Golden Gate Strait and began to fill the Bay. Over the last 6,000 years, the sedimentation has formed mudflats and wetlands, creating an amazing and intricate ecosystem. However, starting with the mid-1800s Gold Rush, human use and development in and around the estuary has led to its degradation and the decline of many important native species.⁸

Social Environment

< Population >

The population of the San Francisco Bay area has increased rapidly, from about 3 million in 1950 to about 7 million at present. The catchment area has approximately 10 million people, one-third of California's population. The population density is high in the counties surrounding South Bay, such as San Francisco, San Mateo and Santa Clara.²

< Land use >

The 12 counties (Alameda, Contra Costa, Marin, Napa, Sacramento, San Francisco, San Joaquin, San Mateo, Santa Clara, Solano, Sonoma and Yolo) in the Bay catchment area contain almost 3,600 km² of urban land. Of this total, residential development occupies almost 2,400 km², commercial properties and light industry about 600 km², and heavy industry over 640 km². In addition, the region encompasses over 7,200 km² of intensive agricultural land and over 15,200 km² of other agricultural and rural lands. Until recently, almost all of the people, jobs and housing were located on the flatlands immediately surrounding San Francisco and San Pablo Bays, and in a few major centers along the principal rivers in the Delta. However, during the last two decades, population growth has begun to shift away from these urban centers, following the development of state and interstate highways further inland. Urbanization of these once rural lands threatens the balance of the estuarine ecosystem by eliminating or modifying sensitive wetlands, altering stream courses and watershed lands, and polluting the waters that flow into the estuary.⁶

< Industry >

Major industries related to the Bay area include shipping, tourism, commercial fishing, agriculture and manufacturing. Many of these industries are heavily dependent on the Bay environment.²

Shipping

The Bay area is a major west coast shipping center, with millions of tons of cargo passing through the Golden Gate Strait each year. There are 6 public ports in the Bay, and the annual tonnage handled at these ports has increased at a dramatic rate over the past decades. In contrast, the number of ships arriving has decreased because of the trend towards large ships. This, in turn, has increased the need for more frequent dredging.²

Fisheries

The Bay supports commercial bait shrimp, herring, and dungeness crab fisheries and is the only commercial fishery of urban area in the nation. The herring fishery is, by far, the largest commercial fishery in the Bay and their high priced eggs (herring roe) are exported to the Japanese market.²

Tourism

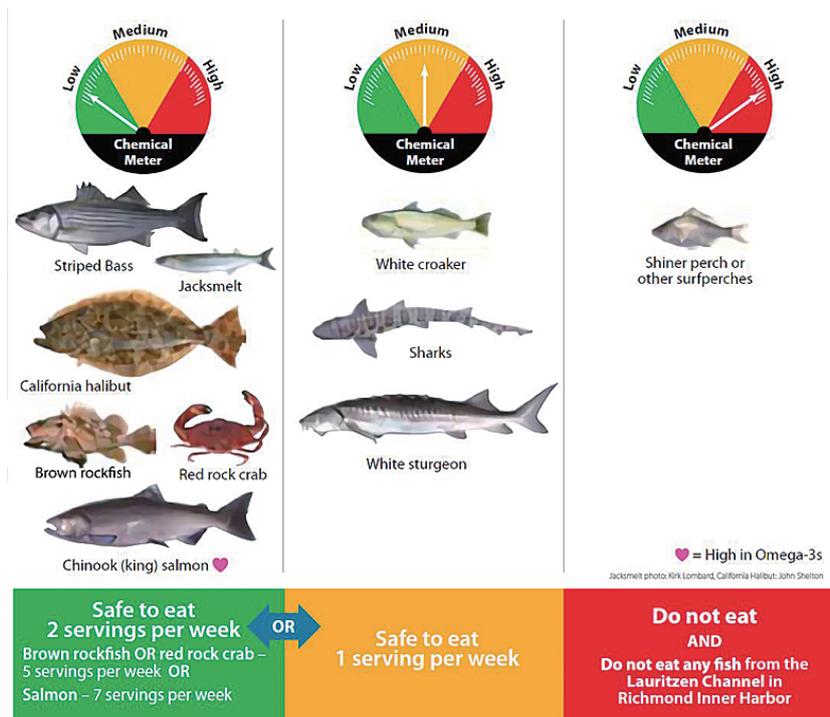
The Bay area is famous for its scenic beauty and attracts millions of tourists every year. The popular tourist attractions are closely tied to the Bay's scenic values and productivity such as the Golden Gate Bridge and Fisherman's Wharf.²

Environmental Problems

The Bay has faced various environmental problems, such as disappearance of wetlands, water pollution, and decreasing biological resources, with the mid-1800s Gold Rush as a turning point. In order to address these environmental problems, the US Environmental Protection Agency and the state government established the San Francisco Estuary Project (SFEP) in 1987, based on the Clean Water Act, and formulated the Comprehensive Conservation and Management Plan (CCMP) aimed at the Bay, and delta environmental conservation and maintenance through the project. The CCMP was formulated through discussion among relevant ministries and agencies, the private sector, and residents over 5 years, and it shows action plans for 9 fields (aquatic resources, wildlife, wetland management, water use, pollution prevention and reduction, dredging and waterway modification, land-use management, community participation and education, research and monitoring). This plan was updated in 2007 according to a recent change in the situation.⁹ Major environmental problems the Bay is facing and efforts to deal with them are explained hereinafter.

< Water and Sediment Pollution >

An environmental monitoring survey (Regional Monitoring Program: RMP) has been conducted on a regular basis for water quality, bottom sediment, and organisms, mainly by the San Francisco Estuary Institute (SFEI) since 1993. Based on such results, the water quality of the Bay has improved significantly in recent years because of the development and enhancement of regulations, and improved wastewater treatment technology. However, relatively high concentrations of pollutants such as PCBs, methyl mercury, and dioxin are still detected in fish, and the state government advises people to lower their intake of some fish. Furthermore, high concentrations of PCBs are particularly detected in surfperch (Embiotocidae), perhaps due to their habitat along the coastal area, where pollutants have accumulated to high concentrations, and it is recommended that the intake of surfperch be reduced. With respect to bottom sediment, according to toxicity testing using aquatic organisms, the results showed approximately 70% of samples were toxic in the 2009 survey. This water pollution and sediment contamination is known to be caused by the ongoing negative legacy of mining development and discharge of untreated wastewater, and it is believed that it will take several decades for concentrations to fall to safe levels.⁵



Type of fish whose intake is recommended to be reduced⁶

< Other Environmental Problems >

Decrease and Regeneration of Habitats

Habitats (wetlands, mudflats) for characteristic organisms in the Bay have significantly decreased due to development, but various attempts to preserve these habitats, including restoration projects, have been made. For example, more wetlands were created or restored in Suisun Bay, San Pablo Bay, South Bay, etc. by effective use of dredged sand and introducing seawater through the restoration project. Recently, an old saltpan in South Bay was restored as over approximately 60 km² of wetland (South Bay Salt Pond Restoration Project). In addition, if filling wetland due to development cannot be avoided, it is required to offset the disappearance of wetland by creating the same-quality wetland. Other attempts include preparation of wetland restoration guidelines (Baylands Ecosystem Habitat Goals Report), establishment of a protected area for research purposes (San Francisco National Estuarine Research Reserve), development of an evaluation method for habitats (California Rapid Assessment Methodology), and elimination of an introduced plant species *Spartina alterniflora*.⁹



Wetland Restoration through South Bay Salt Pond Restoration Project (Left: before restoration, Right: after restoration)¹⁰

Decline of Biological Resources

Fishing resources on the whole are declining in the Bay. Specifically, the population of migrating fish in the Bay has declined roughly in the 50–90% range compared to levels in the 1980s, except in Central Bay. Moreover, the existing 6 species of fish (such as winter-run/spring-run Chinook salmon, Delta smelt, Green sturgeon) are designated as endangered species by the nation or the State. The primary factors that have driven these species towards extinction are habitat loss through development, introduction of invasive species, river water diversions, agriculture activities and water pollution. For example, dam construction has drastically reduced spawning populations of Chinook salmon by



Delta Smelt¹¹

blocking their upstream migration route. Its spawning population in the Bay's tributaries has declined by nearly 70%, compared to levels in the early 1900s.^{2,5} The population of Delta smelt is estimated to have declined slightly by 2.4% in 2005, compared to the level in 1993 when it was designated as an endangered species.¹¹

On the other hand, large-scale herring spawning was observed in the Bay in 2011, and the Harbor porpoise has returned after just over six decades. Resource recovery signs have been seen to a certain extent.^{5,13}

Introduced species

Many of the benthic species in the Bay are either accidentally or intentionally introduced. During the past 140 years, more than 100 introduced species have become established. Most of the large invertebrates in the Bay's shallows are now dominated by introduced species. Species of great concern are the green crab, Chinese mitten crab and Asian clam. Green crabs have reduced the abundance of 20 invertebrate species, including native species. Chinese mitten crabs have clogged power-plant cooling systems and are thought to weaken levees and banks through burrowing. The Asian clam is now the dominant benthic organism in many parts of the Bay and is suspected of being the main cause for the reduction of zooplankton abundance.^{2,12}

Related organizations and NGOs

- San Francisco Bay Conservation and Development Commission <<http://www.bcdc.ca.gov/>>
- San Francisco Estuary Partnership <<http://www.sfestuary.org/>>
- Friends of the San Francisco Estuary <<http://friendsofsfestuary.weebly.com/>>
- San Francisco Estuary Institute <<http://www2.sfei.org/>>
- Save the Bay <<http://www.savesfbay.org/>>

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