Introduction

(by Andrew Cohen, Korie Schaeffer, Katie McGourty, Natalie Cosentino-Manning, Susan Wainwright-De La Cruz, Meredith Elliot, and Sarah Allen)

PURPOSE AND NEED

This report describes the current status of knowledge of the primary subtidal habitat types in San Francisco Bay and their associated biota. For the most part, we did not attempt to describe trends over time, nor do we predict future conditions. Rather, information sources dating from the last 30 years are used to describe what we expect to find in San Francisco Bay in 2007. This report is meant to provide a common understanding of subtidal habitats in San Francisco Bay in support of the San Francisco Bay Subtidal Habitat Goals project. In compiling this report, we also provide a basis for future comparisons of habitat conditions and biotic assemblages.

The geographic scope of the report includes San Francisco Bay from Sherman Island at the base of the Sacramento-San Joaquin Delta (Delta) seaward to the outer Golden Gate Channel (i.e., Point Bonita and Point Lobos) and south to the southern extent of San Francisco Bay (Figure 1). The scope includes only tidally influenced areas within tributaries to San Francisco Bay, and does not include the Delta. Within this geographic area, we focus on subtidal habitats, which are below mean low water tidal height. We recognize, however, that subtidal habitats continue into intertidal areas, and that while there are certainly differences, the biota of subtidal and intertidal habitats overlap. Therefore, when appropriate and when information is available, we also discuss intertidal habitats.

Every effort was made to compile the best available information, including sources from peer-reviewed journals, agency reports, unpublished data, and expert knowledge of both scientists and resource managers working in San Francisco Bay.

PHYSICAL ENVIRONMENT

Topography and Substrates

San Francisco Bay contains four main basins (Figure 1). Suisun Bay and the diked wetlands of Suisun Marsh form the most upstream basin of the northern reach of the Bay. San Pablo Bay is the next downstream basin, and below that the Central Bay basin connects with the ocean through the Golden Gate. The large, shallow South Bay basin extends off the Central Bay. Various authorities have drawn the boundaries between basins in different places (Gunther 1987). Carquinez Strait has been included in either the Suisun or San Pablo Bay basins, or treated as a separate reach. The boundary between the San Pablo Bay and Central Bay basins has generally been set between San Pablo Strait (on a line connecting Point San Pedro to Point San Pablo) and the Richmond-San Rafael Bridge. Placement of the Central Bay-South Bay boundary has ranged from the Oakland Bay Bridge to the San Bruno shoal. The South Bay is sometimes divided into upper and lower basins, or subdivided into 2 or 3 sub-basins, with boundaries variously placed at San Bruno shoal, San Mateo Bridge or Dumbarton Bridge. Table 1 shows the basic measurements of these basins based on different segmentation schemes.

Figure 1. Area map of the San Francisco Bay showing landforms, major roads and bridges, and bay regions.

Table 1a. The area, depth and volume of San Francisco Bay after Conomos (1979).

Section	Area at MLLW (mi^2)	Area including mudflats (mi^2)	Average depth at MLLW (feet)	Average depth including mudflats[a] (feet)	Volume at MLLW (acre-feet)
Total	402	479	20	6.5	5,400,000

[a] Estimated graphically from hypsometric curve.

Table 1b. The area, depth and volume of San Francisco Bay after Jassby (1992).

Section	Area at MLLW (mi^2)	Area at MHHW (mi^2)	Mean Depth at MLLW (feet)	Volume at MLLW (acre-feet)
Suisun Bay / *Chipps Island to Benicia Bridge*	39	66	10	251,000
San Pablo Bay / *Benicia Bridge to San Pablo Strait*	100	170	11	697,000
Central Bay / *San Pablo Strait to Golden Gate and Oakland Bay bridges*	85	97	36	2,027,000
South Bay / *South of Oakland Bay Bridge*	181	236	13	1,540,000
Total	405	568	17	4,515,000

Table 1c. The area, depth and volume of San Francisco Bay after Monroe & Kelly (1992).

Section	Area at MLLW[a] (mi^2)	Mean Depth at MLLW (feet)	Volume at MLLW (acre-feet)
Suisun Bay / *Chipps Island to Benicia Bridge*	36	14	323,000
Carquinez Strait	12	29	223,000
San Pablo Bay / *Mouth of Carquinez Strait to Richmond-San Rafael Bridge*	105	9	605,000
Central Bay / *Between Richmond-San Rafael, Golden Gate and Oakland Bay bridges*	103	35	2,307,000
South Bay / *South of Oakland Bay Bridge*	214	11	1,507,000
Total	470	17	4,965,000

[a] Including saturated mudflats.

Table 1d. The area of San Francisco Bay after Goals Project (1999).

Section[a]	Subtidal Area[a] (mi^2)	Intertidal Area[b] (mi^2)	Total Area (mi^2)
Suisun Bay Subregion / *Antioch to Carquinez Bridge*	53	23	76
North Bay Subregion / *Carquinez Bridge to San Pablo Strait*	100	40	140
Central Bay Subregion / *San Pablo Strait to Golden Gate Bridge and Coyote Point-San Leandro Marina*	168	8	176
South Bay Subregion / *South of Coyote Point-San Leandro Marina*	76	38	114
Total	397	109	506

[a] Deep Bay/Channel plus Shallow Bay/Channel habitats.
[b] Tidal Flat plus Tidal Marsh habitats; boundary between Tidal Flat and Shallow Bay/Channel habitats appear to be between MLW and MLLW (Goals Project, Fig. 2.3).

Fifteen to eighteen thousand years ago during the last Ice Age, sea level was 120 meters (m) lower, the ocean shore lay west of the Farallon Islands, and the San Francisco Bay basins were a chain of broad river valleys with narrow canyons at Carquinez Strait, Racoon Strait (between Tiburon and Angel Island), and the Golden Gate. Around 10,000 years ago, rising sea level brought seawater in through the Golden Gate, and the Bay began to fill at a rate of nearly 2 centimeters (cm) per year (Atwater 1979) (Figure 2). By about 5,000 years ago, sea level was only about 8 m lower than today, the rate of rise slowed to 0.1 to 0.2 cm per year, sediments accreted, and mudflats and marshes formed around the San Francisco Bay (Atwater 1979).

In the past 160 years, human activities have dramatically reshaped the Bay by changing sediment supply, dredging channels and diking off large portions of the Bay (Herbold *et al.* 1992). Since 1990, mean sea level increased by 22 cm per century, and mean high water rose about 19 percent faster than mean sea level, resulting in an increase in tide range of about 60 millimeters (mm) per century (Flick *et al.* 2003). Global warming studies suggest that relative to 1990 global average sea level will rise by 8.9 to 87.9 cm by 2100 (IPCC 2001).

Today, the Bay at high tide covers approximately 500 mi^2 (Table 1), having been reduced by about 40 percent since 1850 (Conomos 1979, Monroe and Kelly 1992). A strong low tide exposes about one-sixth of this area (Conomos 1979), with the largest intertidal mudflats extending across the eastern and southern parts of the South Bay and the northern parts of San Pablo and Suisun Bays. Another third of the Bay is less than 2 m

South Bay and the northern parts of San Pablo and Suisun Bays. Another third of the Bay is less than 2 m
deep on a good low tide (Conomos 1979) (Figure 3). Narrow channels 10 to 20 m deep lead across the main basins into harbors and shipping terminals, maintained partly by dredging and partly by the scouring action of river and tidal currents. The deepest spot in San Francisco Bay, under the Golden Gate Bridge, is more than 110 m deep at low tide (Conomos 1979). Just outside the bay's mouth, a curving sandbar rises to within 9 m of the surface, built of sediments transported from the bay.

Most of the Bay's bottom is covered with sand, silt or clay, along with significant quantities of oyster shell fragments (of the native Olympia oyster *Ostrea conchaphila* and the exotic Virginia oyster *Crassostrea virginica* and Pacific oyster *C. gigas*). The channel floors in the northern reach are mostly sand, including much of the western portion of the Central Bay. Shell fragments occur over a good part of the southeastern and southwestern shallows in the South Bay. Otherwise, the Bay bottom is mostly mud, often quite soft, consisting of 80 percent or more of silt and clay (Figure 4). A few areas of bedrock rim the western part of the Central Bay and crop out at islands and a few shoreline locations. Artificial hard substrate is scattered across the Bay, including rip-rapped banks, jetties, breakwaters, seawalls, pilings, docks and piers, bridge and powerline supports, and debris.

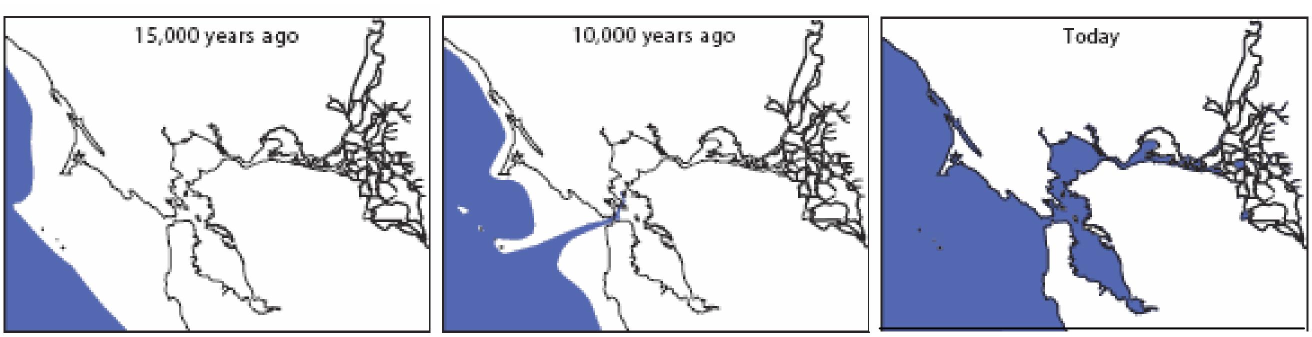

Figure 2. Sea level rise from 15,000 years ago to the present from Cohen (2000).

Figure 3. Bathymetry (shown in feet) of San Pablo, Central, and South Bays within San Francisco Bay.

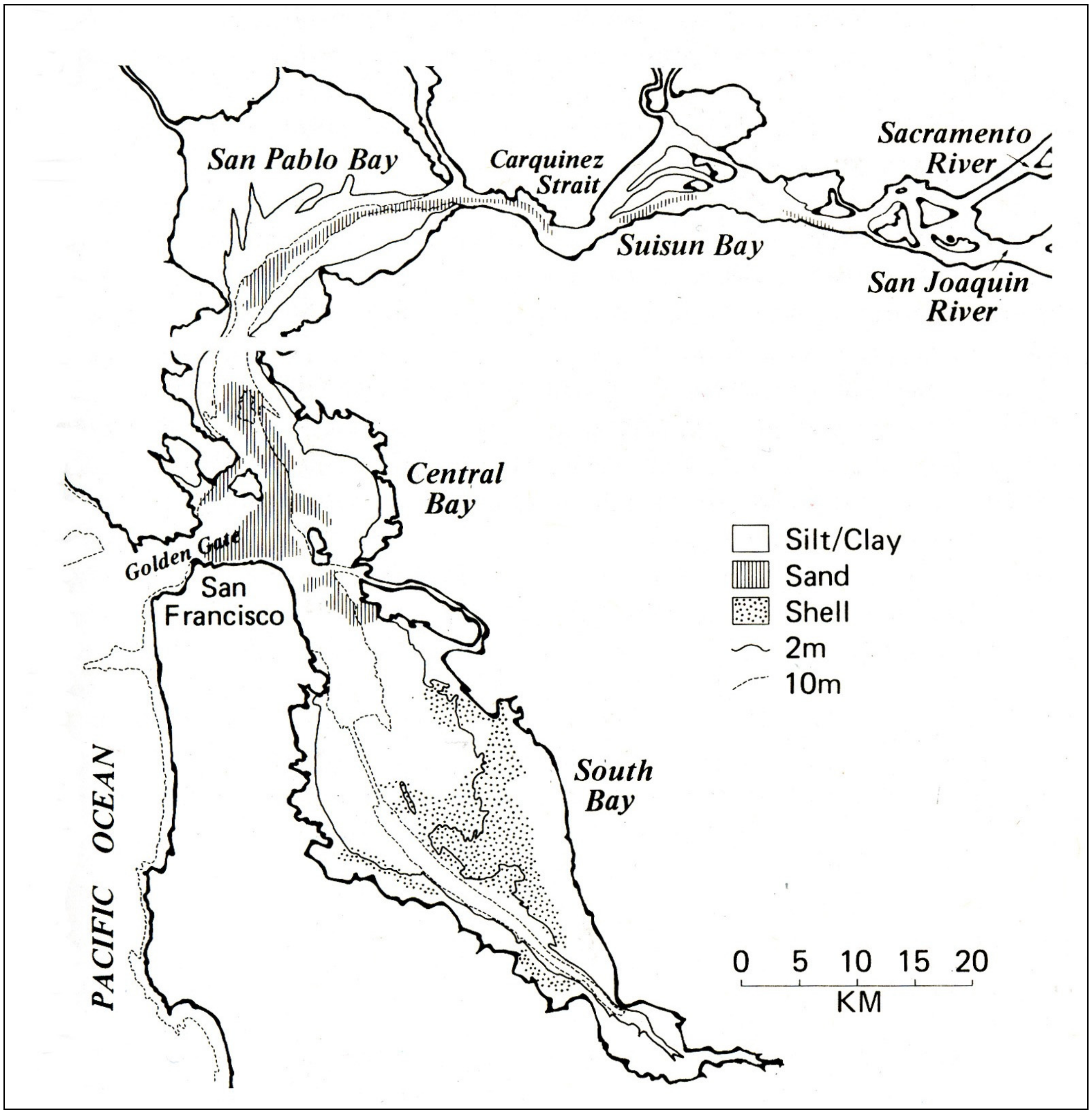

Figure 4. Map of generalized sediment types in San Francisco Bay from Monroe and Kelly (1992).

Tides and Tidal Currents

Tides are complex waves hundreds of miles long that are caused by the gravitational pull of the moon and the sun. The tidal range (the difference in height between high and low water) changes as the moon circles the earth every 28 days. The tides with the greatest range, called spring tides, occur during full and new moons, when the moon, sun, and earth are nearly aligned and the gravitational pulls of the moon and sun reinforce each other. Neap tides, with the least tidal range, occur during the moon's quarters, when the gravitational pulls from the moon and sun tend to cancel each other (Figure 5). Tidal ranges also vary over the year, with the highest highs and the lowest lows in the bay typically occurring around June and December (Cohen 2000).

Mixed, semi-diurnal tides, with two unequal high tides and two unequal low tides occurring about every 24 hours and 50 minutes, are typical of the west coast (Conomos 1979, Smith 1987). Twice each day, with each tidal cycle, a huge volume of salt water moves in and out of the Bay. This tidal prism, as it is called, averages about 1,300,000 acre-feet[1], or nearly a quarter of the Bay's total volume (Conomos 1979, Conomos *et al.* 1985, Largier 1996), though much of it consists of water that had flowed out of the Bay during recent tidal cycles (Monroe and Kelly 1992). In comparison, the average daily inflow of freshwater to the bay is only about 50,000 acre-feet.

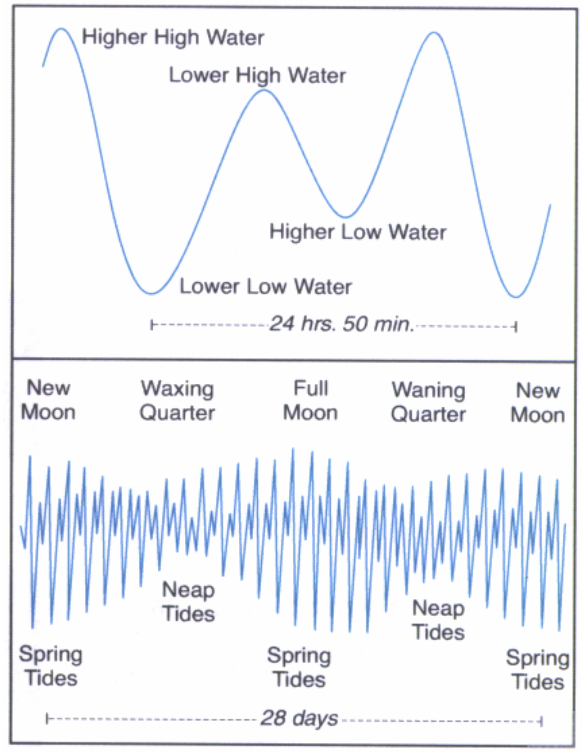

Figure 5. Schematic of tidal cycles near San Francisco Bay from Cohen (2000).

The rate at which tides move inward through the Bay is determined primarily by water depth and bottom friction. The tides progress quickly up channels (where tidal currents may be >1 m/second) and spread from the channels into the shallows (where tidal currents are <0.2 m/second). The northern reach's deep channel allows a greater volume of water to be moved by tidal action through San Pablo and Suisun Bays than through the South Bay (Herbold *et al.* 1992), and the tidal patterns in the two reaches are different. In the northern reach, the tidal range shrinks with distance from the ocean, from a mean range of about 1.7 m at the Golden Gate to about 1.2 m at Chipps Island, to 0.9 m in the Sacramento River at Sacramento. The high and low tides at Chipps Island occur about 3 to 3.5 hours later than the corresponding tides at the Golden Gate, and at Sacramento about 8 hours later than at the Golden Gate. In contrast, the tidal range increases as one proceeds south through the South Bay, due to reflection and reinforcement of the tide wave within the semi-enclosed basin. The tide range reaches 2.6 m at the southern end of the South Bay, where the tides lag the Golden Gate tides by 1 to 2 hours (Conomos 1979, Smith 1987, Monroe and Kelly 1992).

Tidal currents dominate the current patterns in the Bay. They are stronger in channels than in shallows, and usually parallel the depth contours. In the South Bay,

[1] *One acre-foot of water will cover an acre to a foot deep, and is equal to about 326,000 gallons.*

maximum currents occur at mid-tide and slack water occurs around high and low tide, but in the northern reach maximum currents occur later, just before high and low tide, with slack water at 1 to 2 hours after high and low tide. As a result, the South Bay begins to flood while San Pablo Bay is still ebbing, and some northern reach water thus enters the South Bay (Smith 1987).

Freshwater Inflows

The bay's watershed covers about 60,000 mi^2, or about 40 percent of California (Conomos 1979, Conomos *et al.* 1985). Roughly half of California's surface water supply falls as rain or snow within this region, and about half of that is diverted for human use. The remainder flows downstream into San Francisco Bay, with about 14 percent coming from local rivers (primarily Denverton Creek draining into Suisun Bay, Petaluma and Napa Rivers into San Pablo Bay, and Alameda and Coyote Creeks into South Bay (Herbold *et al.* 1992), and the rest entering through the Sacramento-San Joaquin Delta.

Located immediately upstream of the Bay's northern reach, the Delta is a thousand-square-mile triangle of diked and drained swampland. The remains of once-extensive tule marshes, fringe sloughs and channels that wind between "islands" of flat, levee-rimmed farmlands. The Delta is the central component of a vast plumbing system that extends through nearly the entire state. Water released from reservoirs in northern California flows down the Sacramento Valley and into the northern Delta, while large pumping stations pull water from the southern Delta and deliver it to southern cities and farms. Other systems divert water from tributaries in the Sierra Nevada; some is used locally, and some is piped to Bay Area cities. The long-term average outflow from the Delta into the bay is estimated at 17 million acre-feet per year, with another 2.7 million acre-feet entering from the local watersheds (Monroe and Kelly 1992).

Coastal Oceanographic Conditions

Conditions in the coastal ocean outside of the Golden Gate typically progress through three seasons over the course of the year. During the upwelling season, from March or April to July or August, strong and persistent winds from the northwest induce a southward-running surface current called the California Current. The Coriolis effect and Ekman transport produce a net offshore movement of water, which in turn, cause upwelling of bottom water along the coast. This cold, nutrient-rich water brought to the surface in the Gulf of the Farallones is then available for exchange with Bay water over the shallow bar outside the mouth of the Bay. During the relaxation, or oceanic, season from August to October or November, the winds and currents weaken, upwelling stops and surface waters warm, dissipating the coastal fog. In the winter, or Davidson Current season, winds are often from the south or southeast although winter storms bring intermittent strong winds from the west and southwest. The Davidson Current runs northward, producing a downwelling of surface water (Smith 1987, Herbold *et al.* 1992, Largier 1996).

This pattern is interrupted in El Niño years. In those years, warm tropical surface waters move northward, creating vertical density differences that can prevent upwelling (Herbold *et al.* 1992).

Salinity Stratification and Gravitational Circulation

An estuary is a partially enclosed body of water where fresh water meets and mixes with salt water from the ocean. The mixing zone in San Francisco Bay, where fresh and salt water meet, can move tens of miles upstream and downstream as river flows decrease and increase, and even further under extreme conditions. The 1862 flood pushed the mixing zone out beyond the Golden Gate for several weeks and freshened the ocean's surface as far as 40 miles from shore. At the opposite extreme, the 1931 drought pulled the mixing zone inland as far as Courtland on the Sacramento River and Stockton on the San Joaquin River (Smith 1987, Cohen 2000).

Because freshwater is lighter than water that contains a significant amount of dissolved salts, inflowing river water tends to float on top of, and only gradually mixes with, sea water in the bay. This stratification is usually stronger in winter and in wet years when river flows are greater (Conomos 1979), and occurs primarily in channels. Tidal currents during spring tides are typically 2 to 3 times stronger than during neap tides, and tend to increase vertical mixing and reduce stratification (Smith 1987). In the shallows, currents generated by wind and tides usually keep water mixed throughout the water column.

Freshwater inflows also create horizontal salinity gradients. Water from the Sacramento River and the eastside streams entering the Delta averages less than 0.1 part by weight of salt per thousand parts of water (parts per thousand or ppt), while San Joaquin River water entering the Delta has about 0.4 ppt of salt, primarily because of farm drainage (Monroe and Kelly 1992). Outflow from the Delta to the Bay is typically under 0.5 ppt, with the salinity increasing as one proceeds downstream to about 30 ppt near the mouth of the Bay, and about 33 ppt in the coastal ocean (Conomos 1979). At any location in the Bay, the salinity is generally lower when river flows are high.

Within San Francisco Bay, salinity also depends on water year type, and season (Cloern *et al.* 1999). In this report, we discuss salinity categories consistent with the Venice System (Anonymous 1959): limnetic (0 to 0.5 ppt), oligohaline (0.5 to 5.0 ppt), mesohaline (5.0 to 18.0 ppt), polyhaline (18.0 to 30.0 ppt), and euhaline (30.0 to 35.0 ppt). Based on recent work by Thompson *et al.* (2000) and Lee *et al.* (2003), Suisun Bay is typically oligohaline or mesohaline, San Pablo Bay and South Bay are typically polyhaline, and Central Bay is typically euhaline. Within each Bay region, salinities are typically lower in winter and spring than in summer and fall (Figure 6). As expected, salinities throughout San Francisco Bay tend to be lower in flood years and higher in drought years (Figure 7). Average winter salinity ranges from fresh to euhaline in flood years and from oligohaline to euhaline in drought years. Average summer salinity ranges from oligohaline to euhaline in flood years and mesohaline to euhaline in drought years.

The combination of horizontal and vertical salinity gradients can cause tidally-averaged currents of saltier water to flow landward along the bottom of the channels while fresher water flows seaward at the surface, a pattern known as gravitational (or estuarine) circulation (Figure 8). The place where the upstream and downstream currents meet and cancel out along the bottom is the null zone (Herbold *et al.* 1992, Cohen 2000). An entrapment zone can form downstream of a null zone, where suspended sediments carried by river flows clump up and start to settle on contact with saltier water, and suspended sediments, phytoplankton, zooplankton, and the drifting eggs and larvae of fish are concentrated by the downstream and upstream mix of currents (Arthur and Ball 1979, Herbold *et al.* 1992, Cohen 2000).

Bottom topography and other factors complicate this picture in the northern reach of San Francisco Bay. Research conducted during the 1990s has increased our understanding of gravitational circulation. In Suisun Bay, gravitational circulation increases with water depth, is suppressed by vertical mixing during spring tides, and is driven by the horizontal salinity gradient rather than absolute salinity (Schoellhamer and Burau 1998). Gravitational circulation is often well-developed in Carquinez Strait, with a null zone typically found near the upper end of the Strait (SFEP 1997). A zone of concentrated sediments, nutrients and small organisms often develops in Suisun Bay during spring and summer where the salinity is about 2 ppt, but not always close to a null zone (SFEP 1997).

Salinities are generally more uniform and higher in the South Bay than in the northern regions of San Francisco Bay (i.e., San Pablo and Suisun Bays), with high evaporation contributing to salinity (Conomos 1979). Freshwater discharge from the South Bay's tributaries is usually too little to stratify the water and cause gravitational circulation (Conomos 1979). Thus, residence time (the average length of time it takes for a water molecule or a dissolved contaminant to leave the system) is somewhat longer in the South Bay than in the northern reach (Conomos 1979, Smith 1987, Davis *et al.* 1991). In wet winters, however, flood flows from the northern reach enter the South Bay, causing two-layered gravitational flow with the fresher surface water flowing southward, and the saltier bottom water flowing northward towards the mouth of the Bay, the opposite pattern to that of gravitational circulation in the northern part of the Bay. This gravitational flow can substantially reduce residence times, and flush contaminants out of the South Bay (Cohen 2000). After the high discharges subside, the intrusion of ocean water raises the salinity in the Central Bay over that in the South Bay, and the direction of gravitational circulation reverses (Smith 1987). San Bruno Shoal may often restrict gravitational circulation to the northern part of the South Bay, though flows from Coyote Creek and Guadalupe River may also cause gravitational circulation at the southern end of the South Bay in extremely wet winters (Smith 1987).

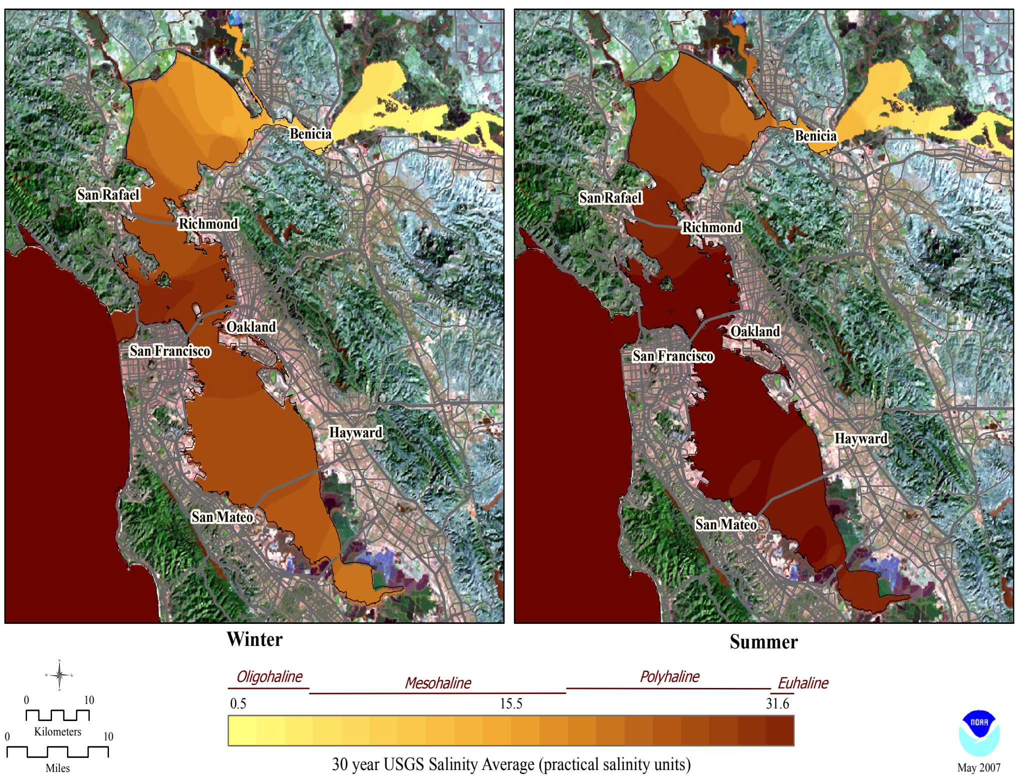

Figure 6. San Francisco Bay average salinity (winter and summer).

The salinity profiles for the months of February (winter) and September (summer) were derived from data found on USGS Water Quality of San Francisco Bay Website (http://sfbay.wr.usgs.gov/access/wqdata). Data for 39 monitoring stations were retrieved, plotted and averaged. Using GIS, an interpolated grid was produced of the salinity averages (Inverse Distance Weighting, fixed radius). Dates ranged from 1969 to 2006. Number of records per station ranged from 200-400.

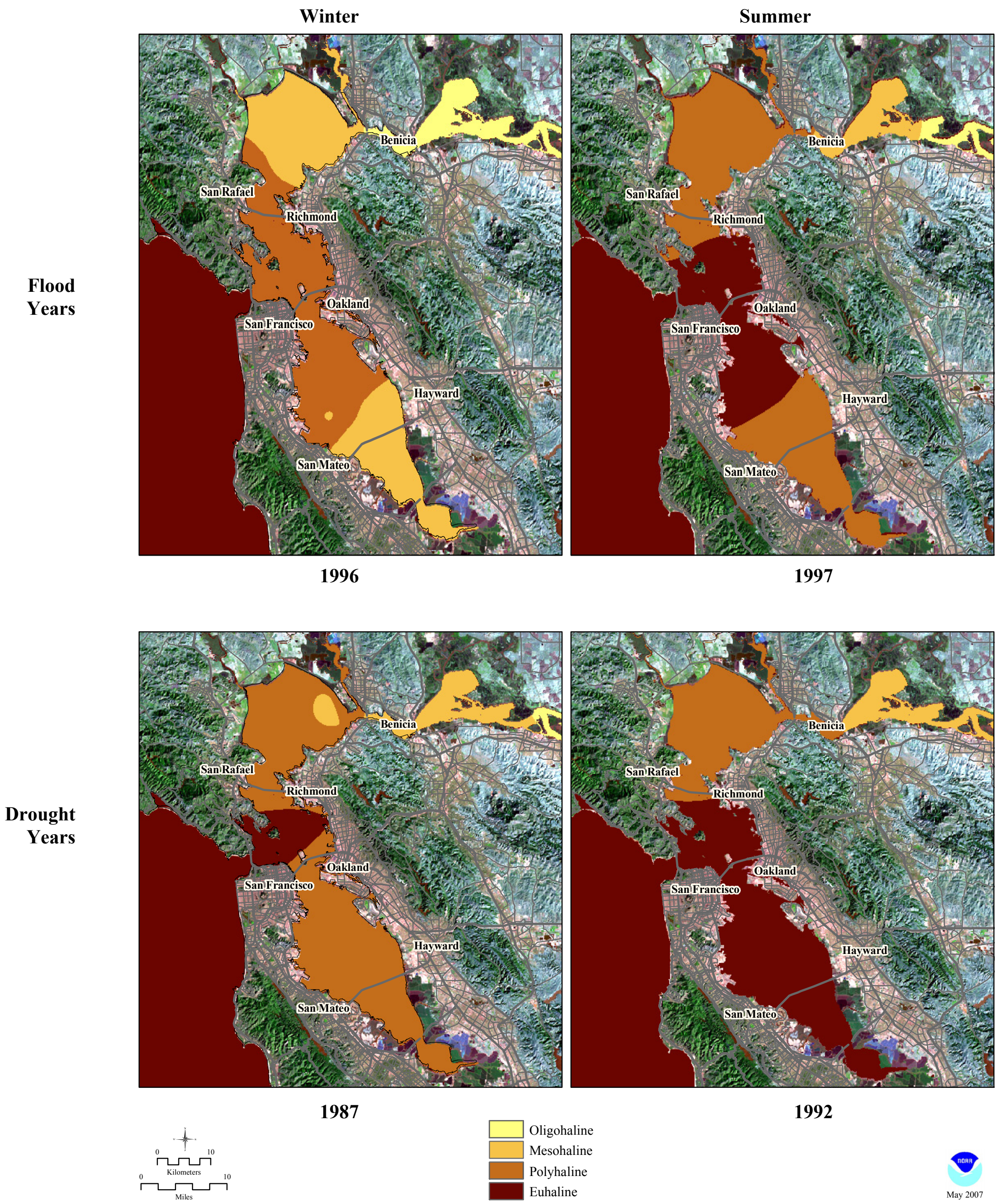

Figure 7. San Francisco Bay average salinity (winter and summer) for flood years 1996 and 1997 (top) and drought years 1987 to 1992 (bottom).

The salinity profiles for the months of February (winter) and September (summer) were derived from data found on USGS Water Quality of San Francisco Bay Website (http://sfbay.wr.usgs.gov/access/wqdata). Data for monitoring stations were retrieved, plotted and averaged. Using GIS, an interpolated grid was produced of the salinity averages (Inverse Distance Weighting, fixed radius). Number of records per station ranged from 0-70. Summer records omitted 6 stations located in southern San Francisco Bay.

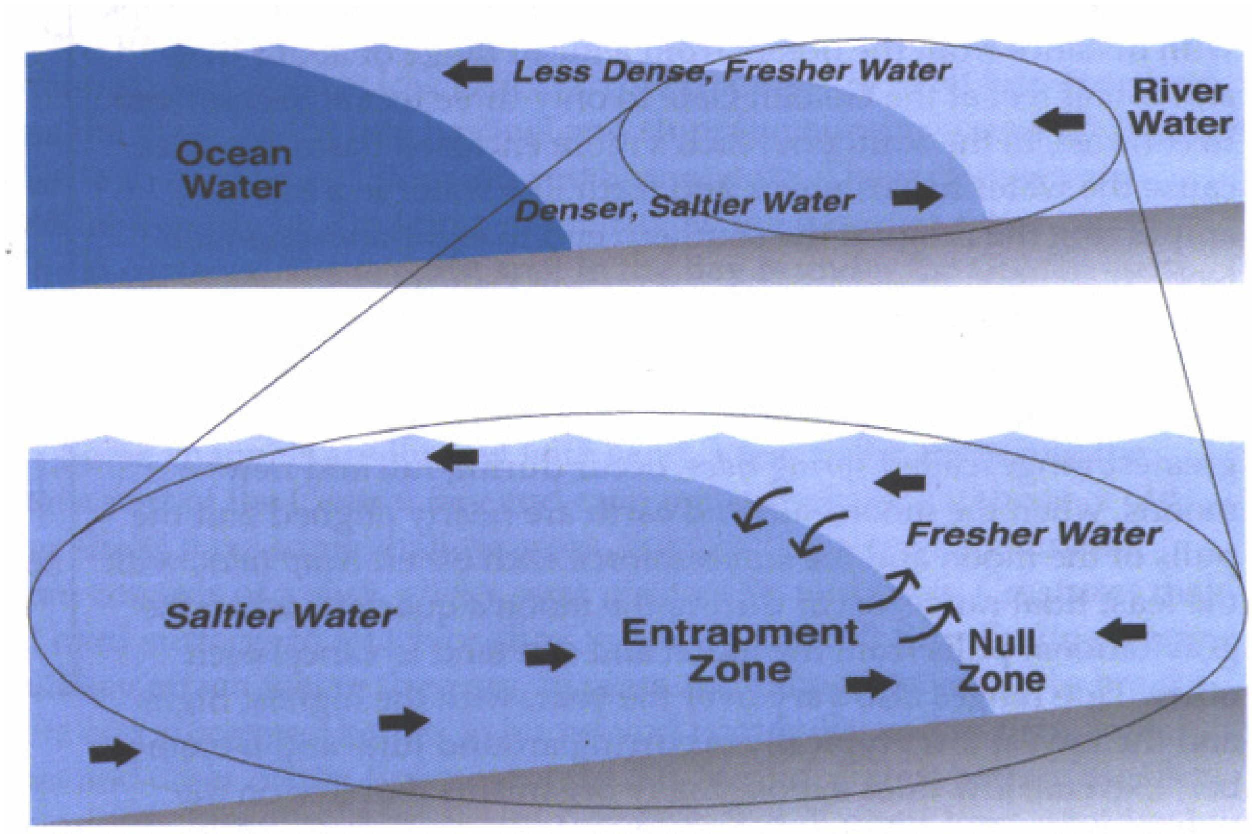

Figure 8. Schematic of estuarine circulation as occurs in San Francisco Bay from Cohen (2000).

Temperature

Water temperatures in San Francisco Bay range from about 10 to 20° C (Monroe and Kelly 1992), and are highest in shallow areas in the summer (Figure 9). Since the Bay is much shallower than the nearby coastal ocean, its seasonal temperature swings are greater, so that the Bay tends to be colder than the ocean during the winter, and warmer than the ocean the rest of the year (Largier 1996, Conomos 1979). Water in the Bay is warmer than inflow from tributaries, which also contributes to seasonal fluctuations in temperature. Baywide average winter temperatures are lower than summer temperatures. Average winter temperature in Suisun Bay, which receives flow directly from the Sacramento-San Joaquin Delta tends to be colder than the rest of San Francisco Bay. In summer when freshwater inflow is low, the more marine influenced Central Bay has the lowest average temperature, with average temperature increasing as you move northeast into San Pablo and Suisun Bays and as you move south through the South Bay.

Sediment Dynamics

The primary source of sediment in San Francisco Bay is erosion from the watershed and transport into the Bay with freshwater flow from tributaries. Large plumes of sediment are carried into the Bay during the first large storm of the year; less erodible sediments are then carried in during subsequent storms (Oltmann *et al.* 1999, Goodwin and Denton 1991, Ruhl *et al.* 2001). Most suspended sediment is from the Sacramento and San Joaquin Rivers, but sediment also comes from the Yolo Bypass, Mokelumne River, Calaveras River, Cosumnes River, and several other smaller streams (Oltmann 1996). From 1856 to 1887, more than 230 million cubic meters of sediment were deposited in San Pablo Bay (Jaffe *et al.* 1998), and approximately 115 million cubic meters of sediment were deposited in Suisun Bay (Cappiella *et al.* 1999). The majority of this sediment was debris from hydraulic gold mining in the Sierra Nevada (Cappiella *et al.* 1999, Jaffe *et al.* 1998). During this period, deposition occurred in nearly the entire Bay.

In contrast, from 1951 to 2001 the watershed sediment yield decreased by about one-half, and much of San Francisco Bay became erosional (Jaffe *et al.* 1998, Wright and Schoellhamer 2003). This decline is a result of the cessation of hydraulic mining, water distribution projects decreasing sediment supply by reducing frequency and duration of peak flow conditions, trapping of sediment in reservoirs, and riverbank protection (Wright and Schoellhamer 2003, Cappiella *et al.* 1999, Jaffe *et al.* 1998). The decrease in suspended sediment resulted in a decrease in the area of tidal flats, particularly in San Pablo Bay and Grizzly and Honker Bays within the Suisun Bay region (Cappiella *et al.* 1999, Jaffe *et al.* 1998).

As sediment is carried into San Francisco Bay with freshwater inflow, it deposits on the Bay bottom and begins a cycle of resuspension, transport, and deposition (Krone 1979). In San Francisco Bay, suspended sediment is driven by resuspension of sediments by currents and wind waves, and not from riverine input (Schoellhamer 2002). Physical processes that affect suspension and deposition, and thus, suspended sediment concentration, include diurnal, semidiurnal, monthly and semiannual tidal cycles, freshwater inflow, and wind-wave stress (Schoellhamer 2002, 2001). Suspended sediments accumulate in the water column as a spring tide approaches and slowly deposit as a neap tide approaches. This dynamic occurs because the duration of deposition and consolidation of newly deposited bed sediments is limited during a relatively short duration of slack water (Schoellhamer 1996). In San Francisco Bay, suspended sediment concentrations typically are greatest in spring when wind waves resuspend sediment recently delivered during high winter flows. Stronger winds during summer months cause wind shear that resuspends surface sediments in shallow water (Krone 1979, Schoellhamer 1996). Suspended sediment concentration decreases in late summer and autumn as supply of erodible sediment decreases (Schoellhamer 2002).

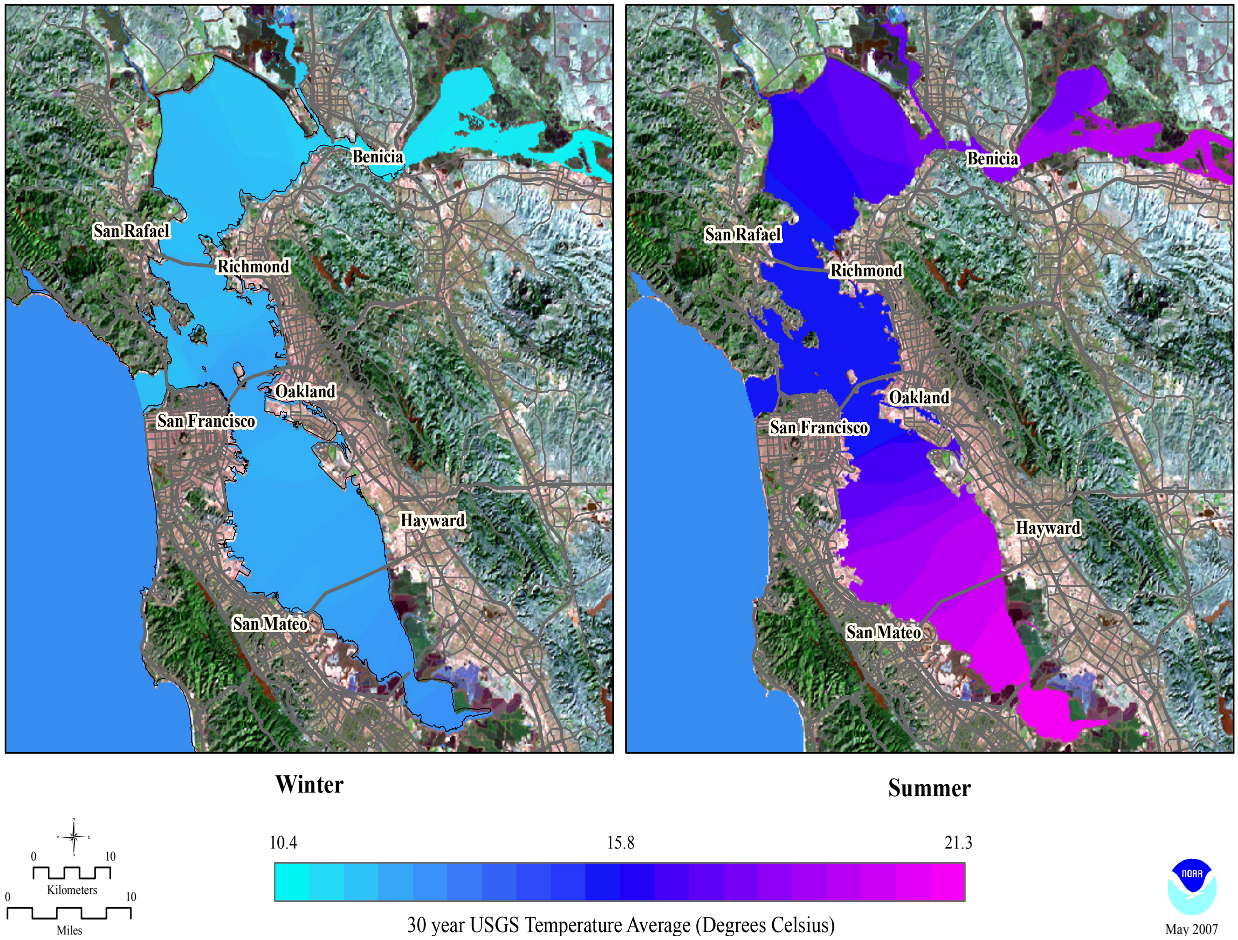

Figure 9. San Francisco Bay average temperature (winter and summer).

The temperature profiles for the months of February (winter) and September (summer) were derived from data found on USGS Water Quality of San Francisco Bay Website (http://sfbay.wr.usgs.gov/access/wqdata). Data for 39 monitoring stations were retrieved, plotted and averaged. Using GIS, an interpolated grid was produced of the temperature averages (Inverse Distance Weighting, fixed radius). Dates ranged from 1969 to 2006. Number of records per station ranged from 200 to 400.

Oxygen

Unlike many estuaries, mixing due to strong winds and shallow depths keeps San Francisco Bay waters well oxygenated, with oxygen saturation typically found all the way through the water column down to the sediment surface (Herbold *et al.* 1992). Prior to the 1960s, high concentrations of nutrients (nitrates and phosphates) in municipal wastewater discharges frequently caused rampant algal growth (known as eutrophication), whose subsequent decomposition depleted oxygen levels and sometimes produced noxious, rotten-egg odors along the shore (Monroe and Kelly 1992). However, the construction of primary and secondary treatment plants in the 1950s and 1960s (see below) largely eliminated these problems. On rare occasions, wastewater inputs, limited water circulation, and high summer temperatures at the southern end of the South Bay still combine to reduce oxygen levels (Monroe and Kelly 1992).

Contaminant Inflows and Legacy Pollutants

Serious contamination of San Francisco Bay waters started in the 1850s, with the mining and use of an estimated 3,500 tons of toxic mercury to separate gold from ore. By the late 1800s, oil spills and discharges and untreated domestic sewage were also taking a toll. During the first half of the 20th century, increasing amounts of industrial, agricultural, and automotive wastes entered the Bay (Monroe and Kelly 1992). Visual and nasal evidence of the fouling of the Bay eventually led to efforts to control this pollution. Municipal wastewater plants began the primary treatment of sewage (removal of solids and disinfection) in the 1950s, followed by secondary treatment (biological breakdown of organic material) in the 1960s, with tertiary treatment (targeting persistent pollutants or treating the effluent for reclamation) and pretreatment programs (reducing the industrial wastes discharged into municipal systems) starting at some plants in the 1970s. During the same period, outfalls were also moved to deeper water to dilute and disperse discharges with larger water volumes and stronger currents.

Currently, 47 municipal and 15 major industrial plants discharge trace metals and other contaminants into the Bay and Delta (SFWQCB 2007). Urban runoff carries metals, PAHs, PCBs and pesticides, along with floatable debris (predominantly plastic and polystyrene pellets) washed from streets, lawns, and industrial properties. Urban and agricultural runoff contains pesticides and herbicides, nitrates, phosphates applied as fertilizer, and selenium leached from the soil, which reaches the Bay in Delta outflow. Runoff from historic mining districts carries mercury and other toxic metals. Oil and petroleum products enter the Bay from accidental spills, leaks from boat and ship engines, and from storm drains when leaking or improperly disposed oil, grease, and antifreeze are washed off the streets. Chemical spills, leachate from landfills, herbicides used to control aquatic weeds, and contaminants that settle from the air can also end up in the Bay (Monroe and Kelly 1992, Cohen 2000).

Past discharges have also left significant quantities of mercury and other "legacy pollutants" buried in the Bay's sediments, which under some circumstances may become available for uptake by organisms. At some "hot spots" of former industrial activity or waste dumping, sediments show greatly elevated contaminant concentrations.

DELINEATION OF HABITATS

There are many ways to define and categorize habitat types. For the purpose of this report, habitat types were delineated by physical substrate and the presence of three-dimensional structure. The main habitat categories are: soft bottom (mud, sand, cobble/pebble/gravel, shell mix), natural and artificial hard bottom, shellfish beds (native oysters, clams, mussels), plant beds (marine algae beds and submerged aquatic vegetation beds), and the water column. It is important to note that within this list, two categories (plant beds and shellfish beds) are defined by the presence of biological organisms that are found on soft bottom or hard bottom substrates. These habitat categories only include those areas where individual organisms are at a high enough concentration to be considered a bed rather than any place an individual or a few individuals of that organism are found. We also have to recognize that presently the native Olympia oyster (*Ostrea conchaphila*) is not found in concentrations normally considered a "bed." In contrast to our method of habitat delineation, we include Olympia oyster bed as a habitat type in this report because of the historic presence of Olympia oyster beds in San Francisco Bay, and because scientists, restoration groups, and resource agencies have recently shown increasing interest in the status, function, and restoration of Olympia oysters in San Francisco Bay.

BIOTIC ASSEMBLAGES

For each habitat type, we describe existing taxa of plants, including both algae and angiosperms, invertebrates, fishes, birds, and marine mammals. In many cases, little information exists to describe these assemblages, and in those cases the lack of available information is noted. We do not attempt to describe organisms beyond these taxonomic groups (e.g., bacteria, protozoa). For many taxa, salinity is a driving factor in determining distribution and abundance by habitat type and location at a given point in time. Where appropriate and when information is available to do so, biotic assemblages are described by salinity ranges. If salinity association is not available, taxa are described by region of the Bay or location of biological sampling.

There are over 162 species of macroalgae (Josselyn and West 1985) and four species of submerged aquatic vegetation (SAV) in San Francisco Bay (Table 2). Both groups occur throughout the Bay, and provide habitat for a variety of fish, invertebrates, and birds. Some of the more common attached macroalgae include *Ulva (Enteromorpha) clathrata*[2], *U. (E.) intestinalis, U (E.) linza, U. californica (formally angusta) and U. lactuca , Bryopsis hypnoides, Cladophora sericea, Fucus gardneri, Polysiphonia denudata, Cryptopleura violacea, Gelidium coulteri, Gracilaria pacifica (formally verrucossa), Halkymenia schizymenioides, Polyneura latissima* (Kathy Ann Miller, University of California at Berkeley, pers. comm.), and *Chondracanthus (formally Gigtina) exaspertata*. Most of these species can be found attached to hard substrates, soft bottoms (mudflats) or epiphytic on SAV.

Data sources for invertebrate assemblages vary by habitat type and are location-based. For each species within an assemblage we indicate the general taxonomic group, the feeding mode, and the growth position or structure orientation (Table 3a-d). Feeding modes include: filter-feeders (filter out pelagic food particles), suspension feeders (trap particles from the water column), surface deposit feeders (feed on particles that have settled onto or grown on a substrate), sub-surface deposit feeders (depend on buried carbon sources), and carnivores (consume epifaunal and infaunal organisms). Growth position or structures built by an animal give them access to specialized food sources (e.g., surface tube dwelling, surface dwelling, deep tube dwelling, free living, etc).

[2] Hayden *et al.* 2003 merged species in the genus *Enteromorpha* into the genus *Ulva*, the current correct name.

Table 2. Common subtidal and intertidal plants within San Francisco Bay after Josselyn and West (1985).

Taxon	Division	Habitat	Native/non-native
Ulva (includes *Enteromorpha**)	Chlorophyta	Mud/rocks	Native
Bryopsis hypnoides	Chlorophyta	Rocks/sand	Native
Cladophora sericea	Chlorophyta	Rocks	Native
Codium fragile subspecies *tomentosoides*	Chlorophyta	Rocks/sand	Non-native
Fucus gardneri	Phaeophyta	Rocks	Native
Laminaria sinclairii	Phaeophyta	Rocks	Native
Egregia menziesii	Phaeophyta	Rocks	Native
Sargassum muticum	Phaeophyta	Rocks	Non-native
Polyneura latissima	Rhodophyta	Rocks	Native
Halkymenia schizymenioides	Rhodophyta	Rocks	Native
Polysiphonia denudata	Rhodophyta	Drift/epiphytic	Non-native
Cryptopleura violacea	Rhodophyta	Rocks	Native
Gelidium coulteri	Rhodophyta	Rocks	Native
Gracilaria verrucossa (formerly *pacifica*)	Rhodophyta	Sand/eelgrass/drift	Native
Chondracanthus (formerly *Gigartina*) *exaspertata*	Rhodophyta	Rocks/sand	Native
Ahnfeltiopsis (formerly *Gymnogongrus*) *leptophyllus*	Rhodophyta	Rocks/sand	Native
Phyllospadix scoleri/torreyi	Magnoliophyta	Rocks	Native
Zostera marina	Magnoliophyta	Mud/sand	Native
Ruppia maritima	Magnoliophyta	Mud/sand	Native
Potamogeton pectinatus	Magnoliophyta	Mud/sand	Native

* *Hayden et al. (2003) merged species in the genus Enteromorpha into the genus Ulva, the current correct name.*

Table 3a. Common invertebrate taxa on soft bottom substrates (sand/silt/clay) in San Francisco Bay by salinity category and topography.

Species		Feeding Mode	Growth Position	Relative Frequency	Seasonal Notes	Reference Locations
OLIGOHALINE						
Channel						
Americorophium spinicorne	amphipod	filter & deposit feeder	tube, free living	interannually/seasonally ephemeral		DWR-D4C
Americorophium stimpsoni	amphipod	filter & deposit feeder	tube, free living	interannually/seasonally ephemeral		
Gammarus daiberi	amphipod	deposit & scraper	free living/surface	interannually/seasonally ephemeral		
Corbicula fluminea	bivalve	filter & deposit feeder	surface-subsurface	common/persistent		
Corbula amurensis	bivalve	filter feeder	surface-subsurface	dry years or dry months only		
Limnodrilus hoffmeisteri	oligochaete	subsurface deposit	free living subsurface	common/persistent		
Varichaetadrilus angustipenis	oligochaete	subsurface deposit	free living subsurface	common/persistent		
Marenzellaria viridis	polychaete	surface deposit	tube to surface	common/persistent	spring & fall peak	
Channel Edge						
Corbicula fluminea	bivalve	filter & deposit feeder	surface-subsurface	common/persistent	spring peak common	DWR D4L & D4R
Varichaetadrilus angustipenis	oligochaete	subsurface deposit	free living subsurface	common/persistent		
Limnodrilus hoffmeisteri	oligochaete	subsurface deposit	free living subsurface	common/persistent		
Marenzellaria viridis	polychaete	surface deposit	tube to surface	common/persistent	spring & fall peak	
Laonome sp.	polychaete	surface deposit	tube to surface	low number/persistent		
Gammarus daiberi	amphipod	deposit & scraper	free living/surface	interannually/seasonally ephemeral	late spring/summer peak	
Americorophium spinicorne	amphipod	filter & deposit feeder	tube, free living	interannually/seasonally ephemeral	late spring/summer peak	
Americorophium stimpsoni	amphipod	filter & deposit feeder	tube, free living	interannually/seasonally ephemeral	late spring/summer peak	
Corbula amurensis	bivalve	filter feeder	surface-subsurface	dry years or dry months only	spring and/or fall peaks	
Rhithropanopeus harissii	decapod	detritus & omnivore	surface	low numbers/persistent		
Palaemon macrodactylus	decapod	detritus & omnivore	surface	common/persistent		
MESOHALINE						
Channel						
Corbula amurensis	bivalve	filter feeder	surface-subsurface	common/persistent	spring and/or fall peaks	EMAP 2001 11.1
Corbicula fluminea	bivalve	filter & deposit feeder	surface-subsurface	wet years		
Nippoleucon hinumensis	cumacean	surface deposit	free living/surface-subsurface	low number/persistent		
Heteromastus filiformis	polychaete	subsurface deposit	free living subsurface	low number/persistent		
Marenzellaria viridis	polychaete	surface deposit	tube to surface	low number/persistent		
Channel Edge						
Ampelisca abdita	amphipod	filter feeder	tube to surface	dry years - common		DWR D6, EMAP 2001 10.1, 8.1
Grandidierella japonica	amphipod	filter & deposit feeder	tube, free living	low number/persistent		
Corbula amurensis	bivalve	filter feeder	surface-subsurface	common/persistent	late fall/winter peak	
Nippoleucon hinumensis	cumacean	surface deposit	free living/surface-subsurface	common/persistent	spring/summer peak	
Synidotea laevidorsalis	isopod	carnivore	free living surface	dry years - common		
Marenzellaria viridis	polychaete	surface deposit	tube to surface	common/persistent		
Heteromastus filiformis	polychaete	subsurface deposit	free living subsurface	low number/persistent		

Table 3a. Common invertebrate taxa on soft bottom substrates (sand/silt/clay) in San Francisco Bay by salinity category and topography.

Species		Feeding Mode	Growth Position	Relative Frequency	Seasonal Notes	Reference Locations
MESOHALINE (continued)						
Slough Channels						
Ampelisca abdita	amphipod	filter feeder	tube to surface	common*	most common bayward	EMAP 2001 13-16 EMAP 2000 7.1, 7.4, 7.6, 6.4
Grandidierella japonica	amphipod	filter & deposit feeder	tube, free living	common*		
Monocorophium alienense	amphipod	filter & deposit feeder	tube, free living	common*		
Corbula amurensis	bivalve	filter feeder	surface-subsurface	common*		
Nippoleucon hinumensis	cumacean	surface deposit	free living/surface-subsurface	common*		
Tubificidae - unidentified	oligochaete	subsurface deposit	free living subsurface	common*		
Heteromastus filiformis	polychaete	subsurface deposit	free living subsurface	common*		
Marenzellaria viridis	polychaete	surface deposit	tube to surface	common*		
Shallow Subtidal						
Corbula amurensis	bivalve	filter feeder	surface-subsurface	dry years – common/persistent	summer and fall peak	DWR D7, EMAP 2001 5.1; 2000 4.2, 3.3
Marenzellaria viridis	polychaete	surface deposit	tube to surface	common/persistent	late spring/summer peak	
Nippoleucon hinumensis	cumacean	surface deposit	free living/surface-subsurface	common/persistent	dry years winter/spring peak; wet years spring peak	
Monocorophium alienense	amphipod	filter & deposit feeder	tube, free living	common/persistent	late fall/early winter peak	
Limnodrilus hoffmeisteri	oligochaete	subsurface deposit	free living subsurface	low number/persistent		
Americorophium stimpsoni	amphipod	filter & deposit feeder	tube, free living	wet years	summer peak	
Gammarus daiberi	amphipod	deposit & scraper	free living/surface	wet years	late fall/early winter peak	
POLYHALINE						
Channel						
Ampelisca abdita	amphipod	filter feeder	tube to surface	common/persistent		REM SPDeep, SBDeep, DWR D41, USGS SM31, SM49, D6, RMP BD41
Corophium acherusicum	amphipod	filter & deposit feeder	tube, free living	common/persistent		
Corophium heteroceratum	amphipod	filter & deposit feeder	tube, free living	common/persistent		
Molgula manhattensis	ascidian	filter feeder	surface	low numbers/persistent**		
Corbula amurensis	bivalve	filter feeder	surface-subsurface	common/persistent	spring and/or fall peaks	
Theora lubrica	bivalve	surface deposit	subsurface	common/persistent		
Macoma petalum	bivalve	filter & deposit feeder	subsurface	low numbers/persistent		
Musculista senhousia	bivalve	filter feeder	surface	low numbers/persistent**		
Mya arenaria	bivalve	filter feeder	subsurface	low numbers/persistent**		
Venerupis philippinarum	bivalve	filter feeder	subsurface	low numbers/persistent**		
Nippoleucon hinumensis	cumacean	surface deposit	free living/surface-subsurface	common/persistent		
Pyromaia tuberculata	decapod	detritus & omnivore	surface	common/persistent		
Tubificoides spp	oligochaete	subsurface deposit	free living subsurface	common/persistent		
Cirriformia spirabrancha	polychaete	surface deposit	surface-subsurface	common/persistent		
Exogone lourei	polychaete	carnivore		low numbers/persistent	more common in south bay	
Glycera armigera	polychaete	carnivore	subsurface	low numbers/persistent		
Heteromastus filiformis	polychaete	subsurface deposit	free living subsurface	low numbers/persistent		
Marenzellaria viridis	polychaete	surface deposit	tube to surface	low numbers/persistent		
Neanthes succinea	polychaete	surface deposit & scavenger	free living/surface-subsurface	low numbers/persistent		
Polydora cornuta	polychaete	filter & deposit feeder	tube to surface	low numbers/persistent		
Sabaco elongatus	polychaete	subsurface deposit	tubed, surface to .8m	low numbers/persistent	more common in south bay	
Streblospio benedicti	polychaete	surface deposit	tube to surface	low numbers/persistent		

Table 3a. Common invertebrate taxa on soft bottom substrates (sand/silt/clay) in San Francisco Bay by salinity category and topography.

Species		Feeding Mode	Growth Position	Relative Frequency	Seasonal Notes	Reference Locations
POLYHALINE (continued)						
Slough Channels						
Grandidierella japonica	amphipod	filter & deposit feeder	tube, free living	common in south bay		EMAP 2000 8.1, 9.2, 10.1, 10.3, 14.1, 10.2, 40.3, 44.2, 43.3, 44.1, EMAP 2001 18, 9, 17, 27, 95, 88, 86, 94, 84, 85, 92, 79, 93, 94; Takekawa *et al* 2005
Monocorophium alienense	amphipod	filter & deposit feeder	tube, free living	common in south bay		
Ampelisca abdita	amphipod	filter feeder	tube to surface	common*	most common bayward	
Monocorophium acherusicum	amphipod	filter & deposit feeder	tube, free living	common*		
Macoma petalum	bivalve	filter & deposit feeder	subsurface	common in south bay		
Mya arenaria	bivalve	filter feeder	subsurface	common in south bay		
Corbula amurensis	bivalve	filter feeder	surface-subsurface	common*		
Nippoleucon hinumensis	cumacean	surface deposit	free living/surface-subsurface	common in south bay		
Tubificidae - unidentified	oligochaete	subsurface deposit	free living subsurface	common*		
Neanthes succinea	polychaete	surface deposit & scavenger	free living/surface-subsurface	common in south bay		
Sabaco elongatus	polychaete	subsurface deposit	tubed, surface to .8m	common in south bay		
Heteromastus filiformis	polychaete	subsurface deposit	free living subsurface	common*	most common bayward	
Streblospio benedicti	polychaete	surface deposit	tube to surface	common*	most common bayward	
Shallow Subtidal						
Ampelisca abdita	amphipod	filter feeder	tube to surface	common/persistent	summer, early winter peak	DWR 41a, REM Coyote Pt., REM PA, USGS PA
Corophium heteroceratum	amphipod	filter & deposit feeder	tube, free living	common/persistent	spring and/or fall peak	
Monocorophium acherusicum	amphipod	filter & deposit feeder	tube, free living	sporadic	summer peak	
Corbula amurensis	bivalve	filter feeder	surface-subsurface	common/persistent	spring peak plus fall peak some years	
Gemma gemma	bivalve	filter & deposit feeder	subsurface	common/persistent	higher number in South Bay - peak in summer	
Macoma petalum	bivalve	filter & deposit feeder	subsurface	low numbers/persistent	higher number in South Bay - peak in summer	
Musculista senhousia	bivalve	filter feeder	surface	low numbers/persistent	higher number in South Bay - peak in summer	
Mya arenaria	bivalve	filter feeder	subsurface	low numbers/persistent	higher number in South Bay - peak in summer	
Venerupis philippinarum	bivalve	filter feeder	subsurface	low numbers/persistent	higher number in South Bay - peak in summer	
Anguinella palmata	bryozoa	filter feeder	surface	common/persistent		
Nippoleucon hinumensis	cumacean	surface deposit	free living/surface-subsurface	common/persistent	spring peak	
Pyromaia tuberculata	decapod	detritus & omnivore	surface	common/persistent		
Ilyanassa obsoleta	gastropod	algae-scraper	surface	common/persistent		
Sakuraeolis enosimensis	gastropod	carnivore-hydroids	surface	common/persistent	higher number in South Bay - may be spreading north	
Euchone limnicola	polychaete	filter feeder	tube to surface	low number/persistent South Bay		
Heteromastus filiformis	polychaete	subsurface deposit	free living subsurface	low numbers/persistent		
Sabaco elongatus	polychaete	subsurface deposit	tubed, surface to .8m	low numbers/persistent	more common in south bay	

Table 3a. Common invertebrate taxa on soft bottom substrates (sand/silt/clay) in San Francisco Bay by salinity category and topography.

Species		Feeding Mode	Growth Position	Relative Frequency	Seasonal Notes	Reference Locations
EUHALINE						
Channel (Deep Water)						
Ampelisca abdita	amphipod	filter feeder	tube to surface	common/persistent		
Monocorophium acherusicum	amphipod	filter & deposit feeder	tube, free living	common/persistent		
Molgula manhattensis	ascidian	filter feeder	surface	low numbers/persistent**	more common in South Bay	
Tellina nuculoides	bivalve	subsurface deposit	subsurface	common/persistent		
Mya arenaria	bivalve	filter feeder	subsurface	low numbers/persistent		
Stylatula elongata	octocoral	filter feeder	surface-subsurface	common/persistent	common in Central Bay	RMP, EMAP, USGS-EPA, REM SB Deep
Ameana spp.	polychaete	detritus & omnivore	tube to surface	common/persistent		
Euchone limnicola	polychaete	filter feeder	tube to surface	common/persistent		
Exogone lourei	polychaete	carnivore	subsurface	common/persistent		
Heteropodarke heteromorpha	polychaete	carnivore	free living subsurface	common/persistent		
Mediomastus spp	polychaete	subsurface deposit	free living subsurface	common/persistent		
Sabaco elongatus	polychaete	subsurface deposit	tubed, surface to .8m	low numbers/persistent	more common in South Bay	
Slough Channels						
Tharyx sp.		surface deposit	free living surface	common*		
Ampelisca abdita	amphipod	filter feeder	tube to surface	common*		
Grandidierella japonica	amphipod	filter & deposit feeder	tube, free living	common*		
Monocorophium acherusicum	amphipod	filter & deposit feeder	tube, free living	common*		
Macoma petalum	bivalve	filter & deposit feeder	subsurface	common*		
Mya arenaria	bivalve	filter feeder	subsurface	common*		
Tubificidae - unidentified	oligochaete	subsurface deposit	free living subsurface	common*		EMAP 2000 46.4; EMAP 2001 63-65,96
Cossura spp.	polychaete			common*		
Euchone limnicola	polychaete	filter feeder	tube to surface	common*		
Mediomastus californiensis	polychaete	subsurface deposit	free living subsurface	common*		
Polydora cornuta	polychaete	filter & deposit feeder	tube to surface	common*		
Psuedopolydora diopatra	polychaete	surface deposit	tube to surface	common*		
Streblospio benedicti	polychaete	surface deposit	tube to surface	common*		
Harbors						
Ampelisca abdita	amphipod	filter feeder	tube to surface	common*		
Grandidierella japonica	amphipod	filter & deposit feeder	tube, free living	common*		
Monocorophium acherusicum	amphipod	filter & deposit feeder	tube, free living	common*		
Monocorophium alienense	amphipod	filter & deposit feeder	tube, free living	common*		
Eudorella pacifica	cumacean	surface deposit	free living/surface-subsurface	common*		
Nippoleucon hinumensis	cumacean	surface deposit	free living/surface-subsurface	common*		
Tubificidae - unidentified	oligochaete	subsurface deposit	free living subsurface	common*		
Cossura spp.	polychaete			common*		EMAP 2000 19.2, 19.3, 47.3, 47.4, 32.2, 32.3, 32.6, 25.3, 26.1, 26.2; EMAP 2001 57-62, 66-67, 45-49, 39, 94, 35, 89, 90
Euchone limnicola	polychaete	filter feeder	tube to surface	common*		
Exogone lourei	polychaete	carnivore	free living	common*		
Glycinde armigera	polychaete	carnivore	subsurface	common*		
Heteromastus filiformis	polychaete	subsurface deposit	free living subsurface	common*		
Mediomastus spp.	polychaete	subsurface deposit	free living subsurface	common*		
Psuedopolydora diopatra	polychaete	surface deposit	tube to surface	common*		
Sabaco elongatus	polychaete	subsurface deposit	tubed, surface to .8m	common*		
Streblospio benedicti	polychaete	surface deposit	tube to surface	common*		
Harmothoe imbricata	scale worm	carnivore	free living	common*		

Table 3a. Common invertebrate taxa on soft bottom substrates (sand/silt/clay) in San Francisco Bay by salinity category and topography.

Species		Feeding Mode	Growth Position	Relative Frequency	Seasonal Notes	Reference Locations
EUHALINE (continued)						
Shallow Subtidal						
Ampelisca abdita	amphipod	filter feeder	surface tube	common/persistent		REM Berkeley, San Leandro, RMP
Corophium acherusicum	amphipod	filter & deposit feeder	tube, free living	common/persistent		
Corophium heteroceratum	amphipod	filter & deposit feeder	tube, free living	common/persistent		
Corophium insidiosum	amphipod	filter & deposit feeder	tube, free living	common/persistent		
Musculista senhousia	bivalve	filter feeder	surface	low numbers/persistent**		
Tubificidae - unidentified	oligochaete	subsurface deposit	free living subsurface	low numbers/persistent		
Phoronis spp.	phoronid	suspension feeder	tube to surface	common/persistent		
Euchone limnicola	polychaete	filter feeder	tube to surface	common/persistent		
Exogone lourei	polychaete	carnivore	subsurface	common/persistent		
Mediomastus spp	polychaete	subsurface deposit	free living subsurface	common/persistent		
Sphaerosyllis californiensis	polychaete	surface deposit	surface	common/persistent		
Glycinde polygnatha	polychaete	carnivore	subsurface	low numbers/persistent		
Leptochelia dubia	tanaid		surface	common/persistent		

Table 3b. Common invertebrate taxa on soft bottom substrate (shell mix) in San Francisco Bay.

Species		Feeding Mode	Growth Position	Relative Frequency	Seasonal Notes	Reference Locations
Diadumene lineata	anemone	suspension feeder	surface-attached	present		
Molgula manhattensis	ascidian	filter feeder	surface-attached	low numbers/persistent**		
Amphibalanus improvisus	barnacle	filter feeder	surface-attached	common/persistent		
Balanus crenatus	barnacle	filter feeder	surface-attached	common/persistent		
Corbula amurensis	bivalve	filter feeder	surface-subsurface	low numbers/persistent**		
Musculista senhousia	bivalve	filter feeder	surface-attached	low numbers/persistent**		
Venerupis philippinarum	bivalve	filter feeder	subsurface	low numbers/persistent**		
Amphipholis squamata	brittle star					
Watersipora subtorquata	bryozoan	surface deposit	surface-subsurface	present		
Eriocheir sinensis	crab	omnivores	surface-motile	present		
Hemigrapsus oregonensis	crab	omnivores	surface-motile	present		REM San Leandro (some samples) USGS SM35, SM42; Rapid Assessment intertidal benthos - epifauna at two or more sites
Crepidula convexa	gastropod	scraper, algae	surface-motile	common/persistent		
Crepidula plana	gastropod	scraper, algae	surface-motile	common/persistent		
Clytia aff. hemisphaerica	hydrozoan	suspension feeder	surface-attached	common/persistent		
Obelia longissima	hydrozoan	suspension feeder	surface-attached	present		
Gnorimosphaeroma oregonense	isopod	surface deposit	surface-motile	present		
Sphaeroma quoianum	isopod	algae	burrows, wood, mud	present		
Mytilus trossulus/galloprovincialis	mussel	filter feeder	surface-attached	present		
Haminoea japonica	opistobranch	carnivore	surface-motile	present		
Ammothea hilgendorfi	pycnogonid		surface-motile	present		
Assiminea californica	snail	surface deposit	surface-motile	low numbers/persistent**		
Urosalpinx cinerea	snail	carnivore	surface-motile	present		
Diadumene lineata	anemone	suspension feeder	surface-attached	present		

Table 3c. Common invertebrate taxa on hard bottom substrate (natural and artificial) in San Francisco Bay.

Species		Feeding Mode	Growth Position	Relative Frequency	Seasonal Notes	Reference Locations
MESOHALINE						
Ampithoe valida	amphipod	algae	surface tubes among algae	present		
Eogammarus confervicolus	amphipod	algae	surface-motile	present		
Monocorophium acherusicum	amphipod	filter & deposit feeder	tube, free living	present		
Diadumene sp.	anemone	suspension feeder	surface-attached	present		
Amphibalanus improvisus	barnacle	filter feeder	surface-attached	present		
Conopeum cf. tenuissimum	bryozoa	suspension feeder	surface-attached	present		
Garveia franciscana	hydrozoa	suspension feeder	surface-attached	present		
Gnorimosphaeroma oregonensis	isopod	surface deposit	surface-motile	present		Rapid Assessment Channel substrate and pilings habitat - seen at half or more of sites
Pseudosphaeroma campbellensis	isopod		surface-motile	present		
Sphaeroma quoianum	isopod	algae	surface-motile	present		
Synidotea laevidorsalis	isopod	surface deposit	surface-motile	present		
Mytilus trossulus/galloprovincialis	mussel	filter feeder	surface-attached	present		
Okenia plana	opistobranch	carnivore - bryozoans	surface-motile	present		
Ficopomatus enigmatica	polychaete	filter feeder	surface-attached	common/persistent		
Clathria prolifera	sponge	suspension feeder	surface-attached	common/persistent		
Halichondria bowerbanki	sponge	suspension feeder	surface-attached	common/persistent		
Haliclona sp.	sponge	suspension feeder	surface-attached	common/persistent		
POLYHALINE						
Caprella mutica	amphipod	filter feeder	surface-motile	common/persistent		
Incisocalliope derzhavini	amphipod		surface-motile	present		
Jassa marmorata	amphipod		surface-motile	present		
Monocorophium acherusicum	amphipod	filter & deposit feeder	tube, free living	present		
Stenothoe valida	amphipod		surface-motile	present		
Diadumene lineata	anemone	suspension feeder	surface-attached	present		
Diadumene sp.	anemone	suspension feeder	surface-attached	present		
Molgula manhattensis	ascidian	filter feeder	surface-attached	present		
Amphibalanus "amphitrite"	barnacle	filter feeder	surface-attached	present		
Amphibalanus improvisus	barnacle	filter feeder	surface-attached	present		
Balanus glandula	barnacle	filter feeder	surface-attached	present		
Musculista senhousia	bivalve	filter feeder	surface-attached	present		
Conopeum cf. tenuissimum	bryozoa	suspension feeder	surface-attached	present		
Schizoporella unicornis	bryozoa	suspension feeder	surface-attached	present		Rapid Assessment Channel substrate and pilings habitat - seen at half or more of sites
Polycera hedgepethi	gastropod	carnivore	surface-motile	common/persistent		
Ectopleura crocea	hydrozoa	suspension feeder	surface-attached	present		
Garveia franciscana	hydrozoa	suspension feeder	surface-attached	present		
Paranthura japonica	isopod		surface-motile	present		
Synidotea laevidorsalis	isopod	surface deposit	surface-motile	present		
Mytilus trossulus/galloprovincialis	mussel	filter feeder	surface-attached	present		
Ostrea conchaphila	oyster	filter feeder	surface-attached	present		
Neanthes succinea	polychaete	omnivore	surface	present		
Clathria prolifera	sponge	suspension feeder	surface-attached	common/persistent		
Haliclona sp.	sponge	suspension feeder	surface-attached	common/persistent		
Leucilla nuttingi	sponge	suspension feeder	surface-attached	common/persistent		
Halichondria bowerbanki	sponge	suspension feeder	surface-attached	present		
Mycale macginitiei	sponge	suspension feeder	surface-attached	present		
Sycon sp.	sponge	suspension feeder	surface-attached	present		

Table 3c. Common invertebrate taxa on hard bottom substrate (natural and artificial) in San Francisco Bay.

Species		Feeding Mode	Growth Position	Relative Frequency	Seasonal Notes	Reference Locations
POLYHALINE (continued)						
Ascidia zara	ascidian	filter feeder	surface-attached	common/persistent		
Botrylloides spp.	ascidian	filter feeder	surface-attached	common/persistent		
Botryllus spp.	ascidian	filter feeder	surface-attached	common/persistent		
Ciona intestinalis	ascidian	filter feeder	surface-attached	common/persistent		
Ciona savignyi	ascidian	filter feeder	surface-attached	common/persistent		Rapid Assessment Channel substrate and pilings habitat - seen at half or more of sites
Styela clava	ascidian	filter feeder	surface-attached	common/persistent		
Bugula neritina	bryozoa	filter feeder	surface-attached	common/persistent		
Bugula stolonifera	bryozoa	filter feeder	surface-attached	common/persistent		
Cryptosula pallasiana	bryozoa	filter feeder	surface-attached	common/persistent		
Schizoporella unicornis	bryozoa	filter feeder	surface-attached	common/persistent		
Watersipora subtorquota	bryozoa	filter feeder	surface-attached	common/persistent		
Slough Channels						
Amphibalanus improvisus	barnacle	filter feeder	surface-attached	present		Rapid Assessment Channel substrate and pilings habitat - seen at half or more of sites
Victorella pavida	bryozoa	suspension feeder	surface-attached	present		
EUHALINE						
Incisocalliope derzhavini	amphipod			present		
Jassa marmorata	amphipod		tube	present		
Monocorophium acherusicum	amphipod	filter & deposit feeder	tube, free living	present		
Podocerus braziliensis	amphipod		free, among hydroids	present		
Stenothoe valida	amphipod			present		
Metridium senile	anemone	suspension feeder	surface-attached	present		
Amphibalanus improvisus	barnacle	filter feeder	surface-attached	present		
Balanus crenatus	barnacle	filter feeder	surface-attached	present		
Balanus glandula	barnacle	filter feeder	surface-attached	present		
Hiatella artica	bivalve	filter feeder	surface-attached	present		
Modiolus rectus	bivalve	filter feeder	surface-attached	present		
Musculista senhousia	bivalve	filter feeder	surface-attached	present		
Alcyonidium parasiticum	bryozoa	suspension feeder	surface-attached	present		
Farella elongata	bryozoa	suspension feeder	surface-attached	present		
Hippothoa hyalina	bryozoa	suspension feeder	surface-attached	present		Rapid Assessment Channel substrate and pilings habitat - seen at half or more of sites
Caprella equilibra	caprellid	detritivores, carnivores, deposit feeders	surface-motile	present		
Caprella penantis	caprellid	detritivores, carnivores, deposit feeders	surface-motile	present		
Caprella verrucosa	caprellid	detritivores, carnivores, deposit feeders	surface-motile	present		
Ectopleura crocea	hydrozoa	suspension feeder	surface-attached	present		
Mytilus trossulus/galloprovincialis	mussel	filter feeder	surface-attached	present		
Nereis sp (not succinea)	polychaete	omnivore	surface-motile	present		
Phyllodocidae	polychaete	carnivore, scavengers	surface, free living	present		
Terebellidae	polychaete	surface deposit feeder		present		
Typosyllis nipponica	polychaete	carnivore	surface-motile	present		
Harmothoe imbricata	scale worm	carnivore	surface-motile	present		
Polynoidae	scale worm	carnivore	surface-motile	present		
Halichondria bowerbanki	sponge	suspension feeder	surface-attached	present		

Table 3d. Common invertebrate taxa on soft bottom substrate (shell mix) in San Francisco Bay.

Species		Feeding Mode	Growth Position	Relative Frequency	Seasonal Notes	Reference Locations
Ampithoe valida	amphipod	herbivore	on leaves			
Caprella mutica	amphipod	filter feeder	on leaves			
Corophium sp.	amphipod	filter feeder	on leaves			
Musculista senhousia	bivalve	filter feeder	among roots			
Conopeum tenuissimum	bryozoa	suspension feeder	encrusting on leaves			

We summarize the fishes found in San Francisco Bay based on review of ongoing surveys and existing reports by the California Department of Fish and Game (CDFG) (CDFG 2001; Table 4). CDFG began regular monitoring of fish and macroinvertebrate populations throughout the Bay in 1980, including the San Francisco Bay Study midwater and otter trawl surveys conducted from South San Francisco Bay to the Western Delta and beach seine data collected in South Bay from 1980 to 1987. CDFG currently samples at 52 sites throughout the Bay and Delta with nine sites within the South Bay (Orsi *et al.,* 1999). Results of this sampling is summarized for 1980 to 1995 by Orsi *et al.* (1999) and the San Francisco Bay Fish Index (The Bay Institute 2003).

Fish taxa by habitat are described by habitat category and salinity range, with a slight variation from the Venice Symposium categories. Table 4 includes species by salinity category within each habitat type. The table also includes information on whether a species is resident, using the San Francisco Bay during a part of its life history (e.g., juvenile nursery, adult), or whether the species are migratory, moving through San Francisco Bay between freshwater tributaries and the Pacific Ocean. Species that reproduce in freshwater and migrate to the ocean after birth are called anadromous. Species that reproduce in the ocean and migrate to freshwater after birth are called catadromous.

Table 4. Common fish and mobile invertebrate species of San Francisco Bay after K. Hieb (pers. comm.), Merkel & Associates (2005), and Entrix (1998).

				Subtidal Habitat Type									
				Soft Bottom Substrate			Hard Bottom Substrate	Shellfish Beds	Plant Beds				Water Column
Salinity	Scientific Name	Common Name	Status	Mud	Sand	Pebble / Cobble			Algae	Eelgrass	Surf Grass	Widgeon Grass	
Euhaline (25-35 ppt)	*Crangon nigromaculata*	blackspotted bay shrimp	N	J, A									R
	Lissocrangon stylirostris	smooth bay shrimp	N		J, A								
	Cancer gracilis	graceful rock crab	N	J, A	J, A								R
	Cancer antennarius	Pacific rock crab	N			J, A	J, A						R
	Cancer productus	red rock crab	N			J, A	J, A						R
	Mustelus henlei	brown smoothhound	N	J, A									
	Triakis semifasciata	leopard shark	N	J, A									
	Raja binoculata	big skate	N	J, A	J, A								
	Myliobatis californica	bat ray	N	J, A						J, A			
	Sardinops sagax	Pacific sardine	N										J, A
	Engraulis mordax	northern anchovy	N										R, J, A
	Porichthys notatus	plainfin midshipman	N	J, A		R							
	Leuresthes tenuis	California grunion	N			R				J, A			R, J, A
	Atherinopsis californiensis	jacksmelt	N							R, J, A			R, J, A
	Atherinops affinis	topsmelt	N							R, J, A			R, J, A
	Syngnathus leptorhynchus	bay pipefish	N							J, A			
	Sebastes auriculatus	brown rockfish	N			J, A	J, A						
	Ophiodon elongatus	lingcod	N			J							
	Genyonemus lineatus	white croaker	N	J, A									R
	Rhacochilus vacca	pile perch	N				J, A						
	Cymatogaster aggregata	shiner perch	N	J, A			J, A			J, A			
	Hyperprosopon argenteum	walleye surfperch	N				J, A			J, A			J, A
	Phanerodon furcatus	white seaperch	N				J, A						J, A
	Lepidogobius lepidus	bay goby	N	J, A									R
	Paralichthys californicus	California halibut	N	J, A	J, A								R
	Citharichthys stigmaeus	speckled sanddab	N	J	J								
Polyhaline (20-28 ppt)	*Crangon nigricauda*	blacktail bay shrimp	N	J, A									R
	Cancer magister	Dungeness crab	N	J			J						
	Clupea pallasii	Pacific herring	N				R		R	R			R, J, A
	Leptocottus armatus	Pacific staghorn sculpin	N	J, A									R
	Parophrys vetulus	English sole	N	J, A									

R Reproduction, includes eggs on substrate and pelagic eggs and larvae, but not pupping areas
J Juvenile nursery area
A Adult residence or forage area
N Native species
I Introduced species

Catadromous: rears in freshwater, reproduces in brackish salinities or higher
Anadromous: reproduces in freshwater, rears in brackish salinities or higher, or migrates through San Francisco Bay as juveniles

Table 4. Common fish and mobile invertebrate species of San Francisco Bay after K. Hieb (pers. comm.), Merkel & Associates (2005), and Entrix (1998).

				Subtidal Habitat Type									
				Soft Bottom Substrate			Hard Bottom Substrate	Shellfish Beds	Plant Beds				Water Column
Salinity	Scientific Name	Common Name	Status	Mud	Sand	Pebble / Cobble			Algae	Eelgrass	Surf Grass	Widgeon Grass	
Oligohaline / Mesohaline (0.5-20 ppt)	*Palaemon macrodactylus*	oriental shrimp	I	J, A			J, A						R
	Crangon franciscorum	California bay shrimp	N	J, A	J, A								R
	Acipenser medirostris	green sturgeon	N	J, A									
	Acipenser transmontanus	white sturgeon	N	J, A									
	Pogonichthys macrolepidotus	splittail	N	J, A									R, J, A
	Hypomesus transpacificus	delta smelt	N										R, J, A
	Spirinchus thaleichthys	longfin smelt	N	J, A									R, J, A
	Morone saxatilis	striped bass	I	J, A									R, J, A
	Acanthogobius flavimanus	yellowfin goby	I	J, A									R
	Platichthys stellatus	starry flounder	N	J, A	J, A								
Fresh (<0.5 ppt)	*Exopalaemon modestus*	Siberian prawn	I	J, A			J, A						R
	Eriocheir sinensis	Chinese mitten crab	I	J, A									R
	Lampetra tridentata	Pacific lamprey	N										J, A
	Lampetra ayresii	river lamprey	N										J, A
	Alosa sapidissima	American shad	I										R, J, A
	Dorosoma petenense	threadfin shad	I										R, J, A
	Ictalurus punctatus	channel catfish	I	J, A									
	Ameiurus catus	white catfish	I	J, A									
	Oncorhynchus tshawytscha	Chinook salmon	N										J, A
	Oncorhynchus mykiss	steelhead	N										J, A
	Cottus asper	prickly sculpin	N	J, A			J, A						R

R Reproduction, includes eggs on substrate and pelagic eggs and larvae, but not pupping areas
J Juvenile nursery area
A Adult residence or forage area
N Native species
I Introduced species

(grey) Catadromous: rears in freshwater, reproduces in brackish salinities or higher
(green) Anadromous: reproduces in freshwater, rears in brackish salinities or higher, or migrates through San Francisco Bay as juveniles

Bird and marine mammal taxa can not be characterized by salinity category, as individuals move throughout the Bay independent of salinity in search of prey items. Surveys of bird and marine mammal abundance and distribution in San Francisco Bay focus on seasonal counts or abundances at shore-based nests or haul-out sites. A general discussion of bird and marine mammal use of San Francisco Bay is included here because of the importance of subtidal habitats for their breeding and feeding. Information on specific habitat use is provided below in the habitat sections.

The bird species that utilize subtidal habitats in San Francisco Bay are listed in Table 5. The bird communities discussed in this chapter are divided into foraging guilds, including diving benthivores (feed in deeper water on benthic invertebrates), dabblers (feed in the upper water column of the shallow subtidal), piscivores (fish consumers), and opportunistic predators (Takekawa *et al.* 2001). San Francisco Bay is a critical Pacific Flyway wintering and stop-over site for migratory birds that depend on subtidal habitats. More than 300,000 wintering waterfowl use San Francisco Bay and associated ponds each year (Accurso 1992). Nearly 75 percent of these birds are bay and sea ducks that forage on benthic invertebrates in a variety of subtidal habitats.

During the spring and summer months, various seabird species use the Bay for breeding and foraging. Alameda Point hosts the largest least tern (*Sterna antillarum*) colony in the Bay, comprising an estimated 424 breeding pairs in 2005 (Hurt 2006). In 2005, approximately 450 nesting attempts for double-crested cormorant (*Phalacrocorax auritus*) were recorded on the San Francisco-Oakland Bay Bridge, and the Richmond-San Rafael Bridge had over 350 attempts (PRBO, unpub. data). Brandt's cormorants (*Phalacrocorax penicillatus*), pelagic cormorants (*P. pelagicus*), pigeon guillemots (*Cepphus columba*), western gulls (*Larus occidentalis*), and since 2004, California gulls (*L. californicus*), breed on Alcatraz Island in central San Francisco Bay. Recent Alcatraz population estimates are 1010 breeding attempts for Brandt's cormorants, 7 breeding attempts for pelagic cormorants, 30 to 40 breeding sites for pigeon guillemots, 1033 breeding pairs for western gulls, and 21 nests for California gulls (Acosta and Thayer 2006). While the Brandt's cormorant, western gull, and California gull colonies on Alcatraz have been expanding, pelagic cormorant and pigeon guillemot populations have been in decline (Acosta and Thayer 2006).

The most numerous diving duck species wintering on San Francisco Bay are greater scaup (*Aythya marila*), lesser scaup (*A. affinis*), canvasback (*A. valisineria*), and surf scoter (*Melanitta perspicillata*). Based on USFWS mid-winter waterfowl surveys, an average of 44 percent of greater and lesser scaup, 42 percent of scoters (three species combined), and 35 percent of canvasback in the lower Pacific Flyway winter in the San Francisco Bay estuary (Trost 2002). The greater scaup, lesser scaup, and surf scoter populations are all undergoing continental decline (USFWS 2006, Sea Duck Joint Venture Management Board 2001, Afton and Anderson 2001, Austin *et al.* 2000). Nationwide, total canvasback numbers are currently holding at their management goal of approximately 500,000 birds (USFWS 2006), but canvasback in San Francisco Bay are declining (Trost 2002). This species is closely monitored and hunting restrictions are frequently imposed (USFWS 2006). Causes of decline for these species are difficult to discern; however, San Francisco Bay remains a crucial over-wintering location for all four of them.

Two endangered bird species, the least tern and the brown pelican (*Pelecanus occidentalis*) are also migratory species that utilize San Francisco Bay. The largest least tern breeding colony in California north of San Luis Obispo County is located in San Francisco Bay. Due to their breeding habitat preferences of open gravel areas with sparse vegetation, human development has significantly decreased available breeding habitat in the San Francisco Bay area (Goals Report 2000). While the least tern population is increasing, breeding success has shown signs of decline since the mid-1990s (Elliott *et al.* 2006). Historic abundance of pelicans within San Francisco Bay is unknown. In 2006, over 2000 brown pelicans were observed on the Alameda breakwater island in July and August (Euing 2006).

Table 5. Common bird species that use subtidal habitats in San Francisco Bay.

Foraging Guild	Scientific Name	Common Name	Time of Year	Soft Bottom Substrate: Mud	Soft Bottom Substrate: Sand	Soft Bottom Substrate: Pebble / Cobble	Hard Bottom Substrate	Shellfish Beds	Plant Beds: Algal Beds	Plant Beds: Eelgrass	Plant Beds: Surf Grass	Plant Beds: Widgeon Grass	Water Column
Dabblers	*Anas clypeata*	northern shoveler	winter, more intertidal									F	R, F
	Anas strepera	gadwall	winter, year-round, more intertidal									F	R
	Anas acuta	northern pintail	winter, more intertidal									F	R, F
	Anas platyrhynchos	mallard	year-round, more intertidal									F	R, F
Diving Benthivores	*Podiceps nigricollis*	eared grebe*	winter										R, F
	Podiceps auritus	horned grebe*	winter, uncommon										R, F
	Aythya marila	greater scaup	winter	F	F	F		F	F	F		F	R
	Aythya affinis	lesser scaup	winter	F	F	F		F	F	F		F	R
	Aythya valisineria	canvasback	winter	F	F	F		F	F	F		F	R
	Aythya americana	redhead	winter, uncommon									F	R
	Oxyura jamaicensis	ruddy duck	winter	F	F	F		F	F	F		F	R
	Bucephala clangula	common goldeneye	winter	F	F	F		F	F	F			R
	Bucephala islandica	Barrow's goldeneye	winter	F	F	F		F	F	F			R
	Bucephala albeola	bufflehead	winter	F	F	F		F	F	F		F	R
	Melanitta fusca	white-winged scoter	winter, uncommon	F	F	F		F	F	F			R
	Melanitta perspicillata	surf scoter	winter	F	F	F	F	F	F	F			R
Piscivores	*Podilymbus podiceps*	pied-billed grebe**	year-round										R, F
	Podiceps grisegena	red-necked grebe**	winter, uncommon										R, F
	Gavia pacifica	Pacific loon	winter										R, F
	Aechmophorus occidentalis	Western grebe	winter										R, F
	Aechmophorus clarkii	Clark's grebe	winter										R, F
	Pelecanus erythrorhynchos	American white pelican	winter, post-breeding										R, F
	Pelecanus occidentalis	brown pelican	winter, post-breeding, juveniles year-round										R, F
	Phalacrocorax auritus	double-crested cormorant	year-round	F	F	F	F						R, F
	Phalacrocorax penicillatus	Brandt's cormorant	year-round	F	F	F	F						R, F
	Phalacrocorax pelagicus	pelagic cormorant	year-round	F	F	F	F						R, F
	Uria aalge	common murre	year-round, but concentrated more in late summer w/chicks										R, F
	Cepphus columba	pigeon guillemot	summer	F	F	F	F						R, F
	Mergus merganser	common merganser	year-round in upper estuary										R, F
	Mergus serrator	red-breasted merganser	winter										R, F
	Pandion haliaetus	osprey	year-round										F
	Sterna caspia	Caspian tern	summer							F			F
	Sterna forsteri	Forster's tern	year-round	F						F			F
	Sterna elegans	elegant tern	migration							F			F
	Sterna antillarum	least tern	summer	F	F	F				F			F
	Rynchops niger	black skimmer	summer										F

* Also feeds on invertebrates and fish on surface or in water column
** Also feeds on benthic invertebrates
*** Members of this guild may also feed in the intertidal or in terrestrial habitats, but are surface feeders on the open water

F Forage
R Roost or Raft

Table 5. Common bird species that use subtidal habitats in San Francisco Bay.

Foraging Guild	Scientific Name	Common Name	Time of Year	Subtidal Habitat Type: Soft Bottom Substrate			Hard Bottom Substrate	Shellfish Beds	Plant Beds				Water Column
				Mud	Sand	Pebble / Cobble			Algal Beds	Eelgrass	Surf Grass	Widgeon Grass	
Surface Feeders ***	*Larus occidentalis*	Western gull	year-round										R, F
	Larus californicus	California gull	year-round										R, F
	Larus delawarensis	ring-billed gull	winter	F	F								R, F
	Larus philadelphia	Bonaparte's gull	winter										R, F
	Larus argentatus	herring gull	winter	F	F		F	F					R, F
	Larus glaucescens	glaucous-winged gull	winter										R, F
	Larus canus	mew gull	winter	F	F		F						R, F
	Larus heermanni	Heermann's gull	winter, summer juveniles & post-breeding adults										R, F
	Phalaropus lobatus	red-necked phalarope	winter, uncommon										R, F
Other	*Branta canadensis*	Canada goose	year-round, more intertidal									F?	R
	Fulica americana	American coot	year-round, more intertidal										

* Also feeds on invertebrates and fish on surface or in water column
** Also feeds on benthic invertebrates
*** Members of this guild may also feed in the intertidal or in terrestrial habitats, but are surface feeders on the open water

F Forage
R Roost or Raft

Seven species of marine mammals occur in San Francisco Bay (Table 6). The harbor seal (*Phoca vitulina richardii*), California sea lion (*Zalophus californianus*), harbor porpoise (*Phocoena phocoena*), and the Eastern Pacific stock of the gray whale (*Eschrichtius robustus*) are the most common. In general, habitat association of marine mammals in San Francisco Bay is related to distribution of prey species. For example, gray whales might occur over mud habitat where they suck up invertebrates, and seals occur in habitats where fish prey concentrate, such as eelgrass beds. Additionally, harbor seals and sea lions use various intertidal substrates that are exposed at low to medium tide levels for resting and breeding.

Harbor seals are the only year-round resident of San Francisco Bay, using the area for breeding, pupping, foraging, and refugia. Harbor seals have been observed in waters as far inland as Sacramento, though use of habitat north of Suisun Bay is irregular (Goals Report 2000). Harbor seals haul out onshore at specific locations within San Francisco Bay, utilizing mostly rocks and mud flats exposed at low tides, sloughs, islands, and beaches, likely in proximity to food resources and distant from human activities (Allen 1991). Haul-out use varies by day, season, and year (Green *et al.* 2006). The primary colonies within San Francisco Bay are at Castro Rocks in the San Pablo Bay, Yerba Buena Island in Central Bay and Mowry Slough in the South Bay. Some colonies are only accessible at medium to high tides, such as the tidal mudflats and pickleweed marshes of Mowry and Newark Sloughs. Seals have abandoned several locations used in the past (e.g., Strawberry Spit) within San Francisco Bay due to human activities (Allen 1991).

Current population estimates are derived from aerial and land-based surveys conducted by the CDFG, the National Marine Fisheries Service, the U.S. Fish and Wildlife Service, San Francisco State University, the Marine Mammal Center of Sausalito, and the National Park Service (Lowry and Forney 2005, Vanderhoof and Allen 2005, Manna *et al.* 2006, Green *et al.* 2006). Surveys estimate the resident San Francisco Bay population to be between 500 and 700 individuals (Richmond-Bridge Harbor Seal Survey 2001, Grigg *et al.* 2004). Between 1965 and 2002, harbor seals are thought to have increased slightly in abundance at two sites in San Francisco Bay and to have abandoned one site completely (Allen 1991, Grigg *et al.* 2004). The average number of seals counted during the 2002 breeding/molt seasons was 117.5 at Castro Rocks, 96.6 at Yerba Buena Island and 147.6 at Mowry Slough. Because of their year-round residency within the Bay, harbor seals are exposed to elevated pollutant loads compared to outer coastal seals and have been a subject of research on marine mammal health (Risebrough *et al.* 1981, Kopec and Harvey 1995). There is a high incidence of red colored harbor seals in San Francisco Bay (~40 %), a condition related to iron oxide deposition on the seal fur, and the condition may be related to elevated pollutant levels (Allen *et al.* 1993, Kopec and Harvey 1995). Seals forage throughout the Bay and feed on what is seasonally abundant such as Pacific herring during the winter spawn. They eat small schooling fish such as smelt, anchovies and herring, rockfish, sculpin, perch, and midshipman, and invertebrates such as squid and mysid shrimp. Surprisingly, they also forage on non-native species such as yellowfin goby. During the breeding and molt seasons, harbor seals likely do not forage more than a couple of miles from their colonies because of thr requirement of attending pups, mating, or molting.

California sea lions use San Francisco Bay for refugia and foraging, but do not breed or pup within the Bay. California sea lions are most abundant within the Bay while migrating to and from their primary breeding areas on the Farallon and California Channel Islands, and when Pacific herring and salmon are spawning in the bay. Sea lions can travel far up into the Delta, but most concentrate feeding in Central Bay and where herring spawn. Similar to harbor seals, sea lions haul-out onshore, often utilizing anthropogenic structures such as boat docks and navigational buoys, although individuals may also haul out also on islands within San Francisco Bay, such as Alcatraz and Angel Islands. Historically, sea lions hauled out on Seal Rock near the Cliff House, but they abandoned the site in the 1980s. The largest California sea lion haul-out in San Francisco Bay is at the Port of San Francisco Pier 39, where up to 800 sea lions have been counted. Sea lions often float on the surface in large groups of 10 to 20 after feeding.

The harbor porpoise is a near-shore species, commonly observed near the Golden Gate Bridge and areas of Central Bay. A distinct genetic stock, the San Francisco-Russian River Stock, ranges from Point Arena to Monterey Bay. There are no good harbor porpoise population estimates. In the early 1980s, hundreds were killed incidentally in gill net fisheries, but since those fisheries were shifted offshore, few deaths have been reported. Harbor porpoise eat mostly small schooling fish and invertebrates, and along with seals and sea lions, will feed on herring and anchovies.

The Eastern Pacific gray whale migrates between calving grounds in Baja, Mexico to primary feeding grounds in Alaska and Canada on an annual basis. Gray whales are commonly sighted near the Golden Gate during peak migration periods (northward migration in spring and southward migration in winter), and annually a few individuals are observed within the Bay (Green *et al.* 2006). Occasionally, gray whales on their migration will forage in nearshore waters such as San Francisco Bay, Drakes Bay, Tomales Bay, and Monterey Bay. They prey mostly on invertebrates that live on or in soft sediments.

Table 6. Common marine mammal species of San Francisco Bay.

		Subtidal Habitat Type									
		Soft Bottom Substrate			Hard Bottom Substrate	Shellfish Beds	Plant Beds				Water Column
Scientific Name	Common Name	Mud	Sand	Pebble / Cobble			Algal Beds	Eelgrass	Surf Grass	Widgeon Grass	
Eumetopias jubatus	Steller sea lion	x	x	x	x		x	x	x	x	x
Zalophus californianus	California sea lion	x	x	x	x		x	x	x	x	x
Phoca vitulina	Harbor seal	x	x	x	x	x	x	x	x	x	x
Eschrichtius robustus	Gray whale	x	x					x	x	x	x
Megaptera novaengliae	Humpback whale							x			x
Phocoena phocoena	Harbor porpoise	x	x	x	x		x	x	x	x	x
Enhydra lutra	California sea otter	x	x	x	x	x	x	x	x	x	

Note: habitat association is based on location of prey items