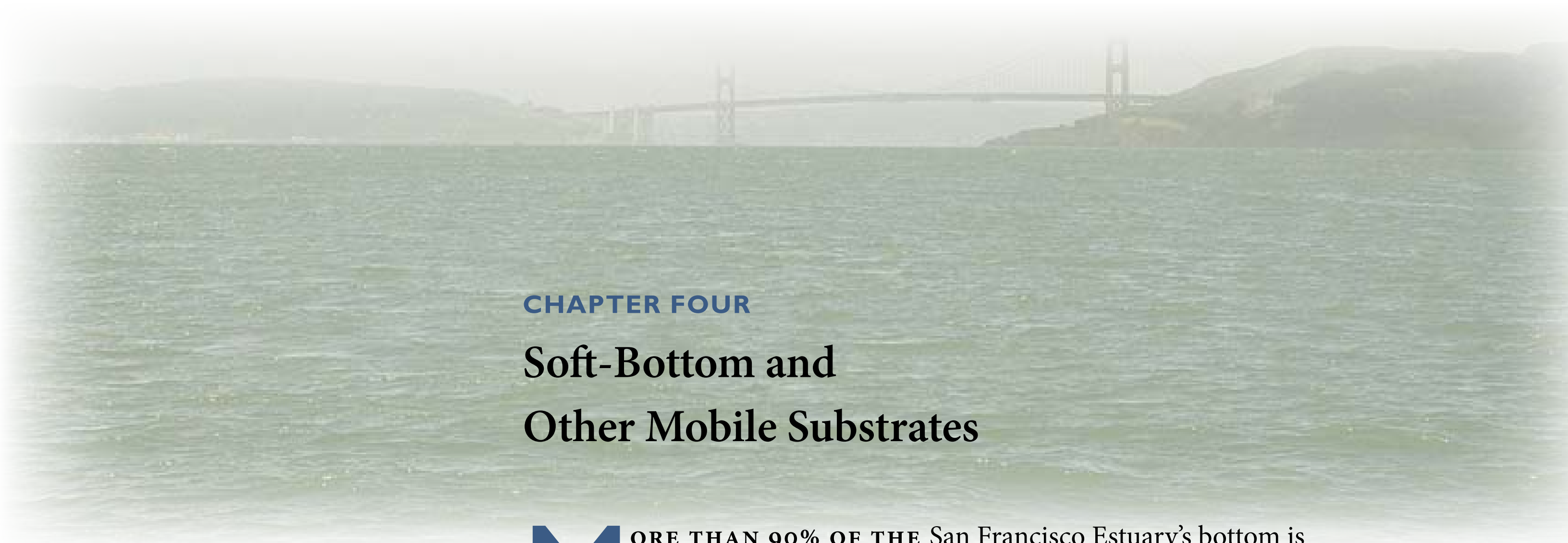


CHAPTER FOUR

Soft-Bottom and Other Mobile Substrates

More than 90% of the San Francisco Estuary's bottom is composed of particles that are small enough to be moved by tidal currents. Soft-bottom habitats include the substrate, organisms living on or within the substrate, and the overlying water column. See Figure 4-1.

Soft-bottom habitat includes sediments that range in size from clay (0.001–0.0039 mm) to silt (0.0039–0.0625 mm), and sand (0.0625–2 mm). "Mud" refers to clay and silt together. All of these particles can readily be moved by tidal currents. Larger particles such as gravel (2–64 mm) and cobble (64–256 mm), are somewhat mobile and are also included in this category. Deposits of bivalve shells can be mobile and are also considered in this section.

Pebbles and cobbles on the bottom of San Francisco Bay near Angel Island.

Most of the soft sediment in the estuary is fine material (Keller 2009), particularly on shoals. Sand deposits are found throughout deeper parts of the Central Bay, the main channel through San Pablo Bay into Carquinez Strait, and parts of the Suisun Bay channel (Figure 4-3 in Hanson et al. 2004). Most of this material, out to the sill seaward of the Golden Gate, originated within the bay and its watershed (P. Barnard, USGS, 2010, pers. comm.). Parts of the Central Bay that have been mapped in detail reveal large areas of sand waves (Greene et al. 2007), and some deposits of gravel and cobble occur east of the Golden Gate (Keller 2009). Apparently all but the larger boulders are moved by very strong

An endangered California clapper rail takes refuge in cordgrass on intertidal mudflats.

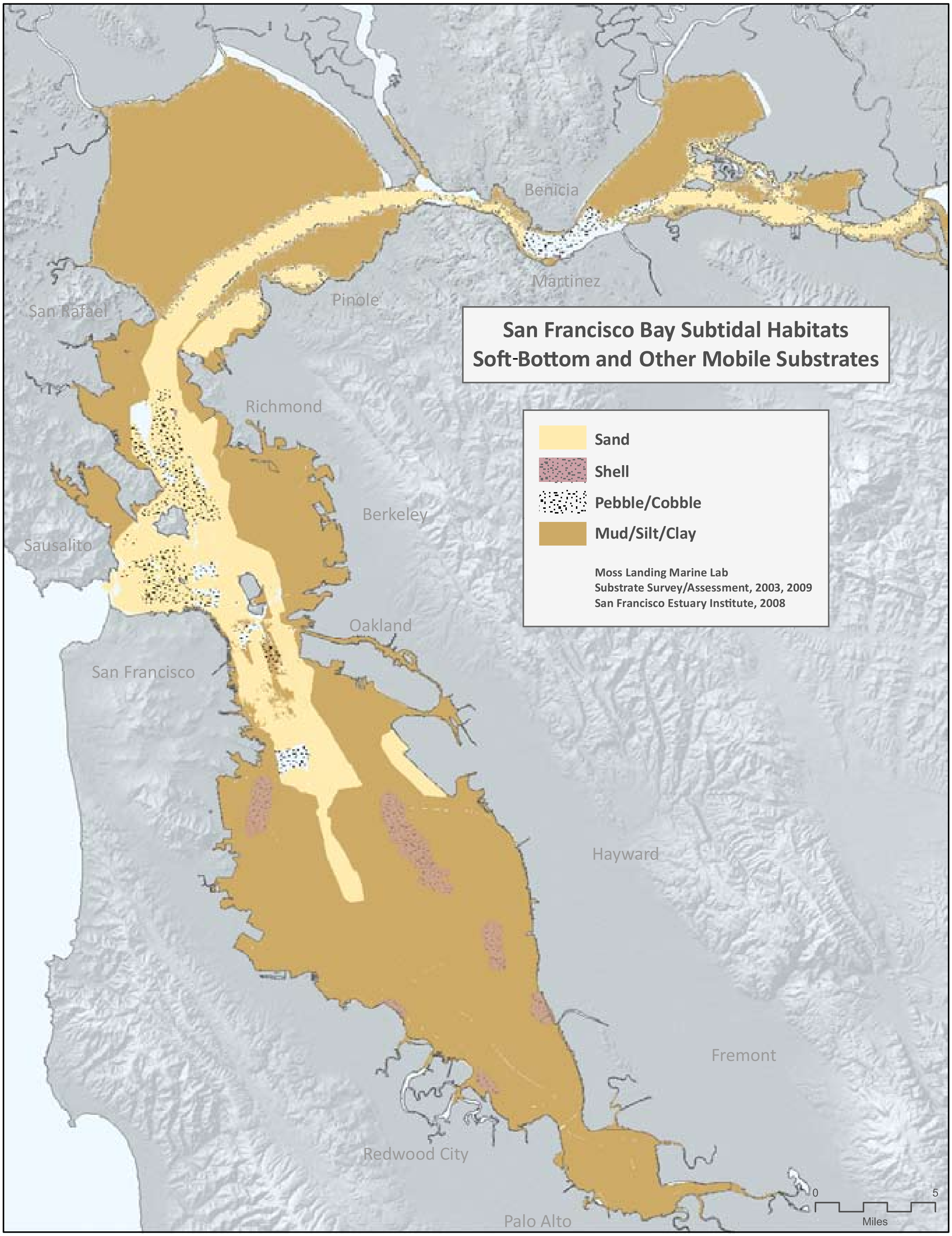


Figure 4-1: Distribution of Soft-Bottom Habitats in San Francisco Bay.

tidal currents in that region, and flood dominance of bottom currents in parts of the cross-section results in sorting of sediments with grain size decreasing eastward from the Golden Gate (Keller 2009).

Sandy beaches occur mainly in the Central Bay, but there are far fewer than were present historically, and all of the remaining beaches are constrained by shoreline development. Benthic surveys in the northern estuary have shown sand deposits in the channels, silt to clay elsewhere, and a few shell deposits near shore (Hymanson 1991). However, these surveys lack the spatial resolution of the Central Bay mapping. Shell hash from native oysters is found in extensive but localized deposits in the South Bay, where it is presumably trapped by current patterns. Gravel and cobble are uncommon except in certain areas of the Central Bay.

Conceptual Model for Soft Substrates

Sediment grain size is the key to movement and sorting of sediments and to the biological and chemical conditions in the sediments (Figure 4-2 and Figure 4-3). Grain size is largely a function of proximity to sediment sources such as rivers and the ocean, and of water movement, which includes waves, tides, and tidally-averaged currents. Fine-grained, soft substrate is the most common substrate in most estuaries. Paradoxically, fine-grained sediments are

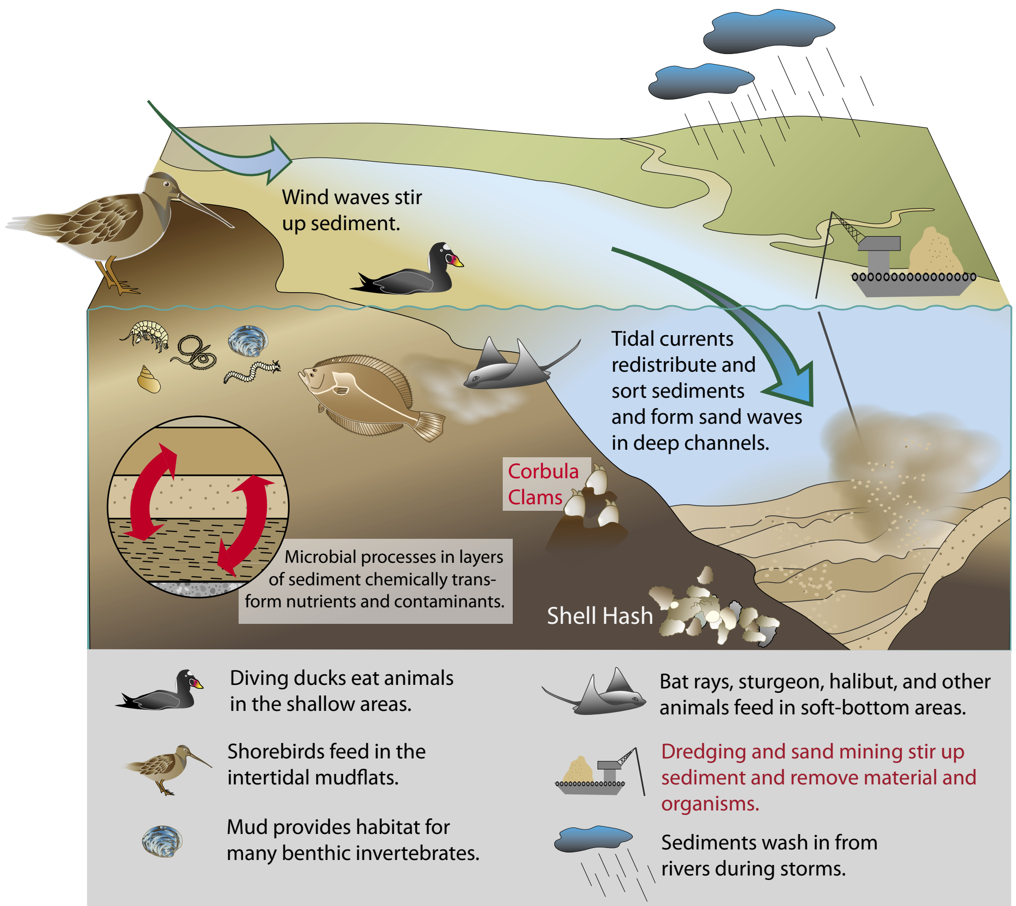


Figure 4-2: Conceptual diagram for soft-bottom substrates in the San Francisco Estuary. This diagram displays key processes that occur in and on soft substrates, some of the ecosystem services these substrates provide, and threats to soft substrates.

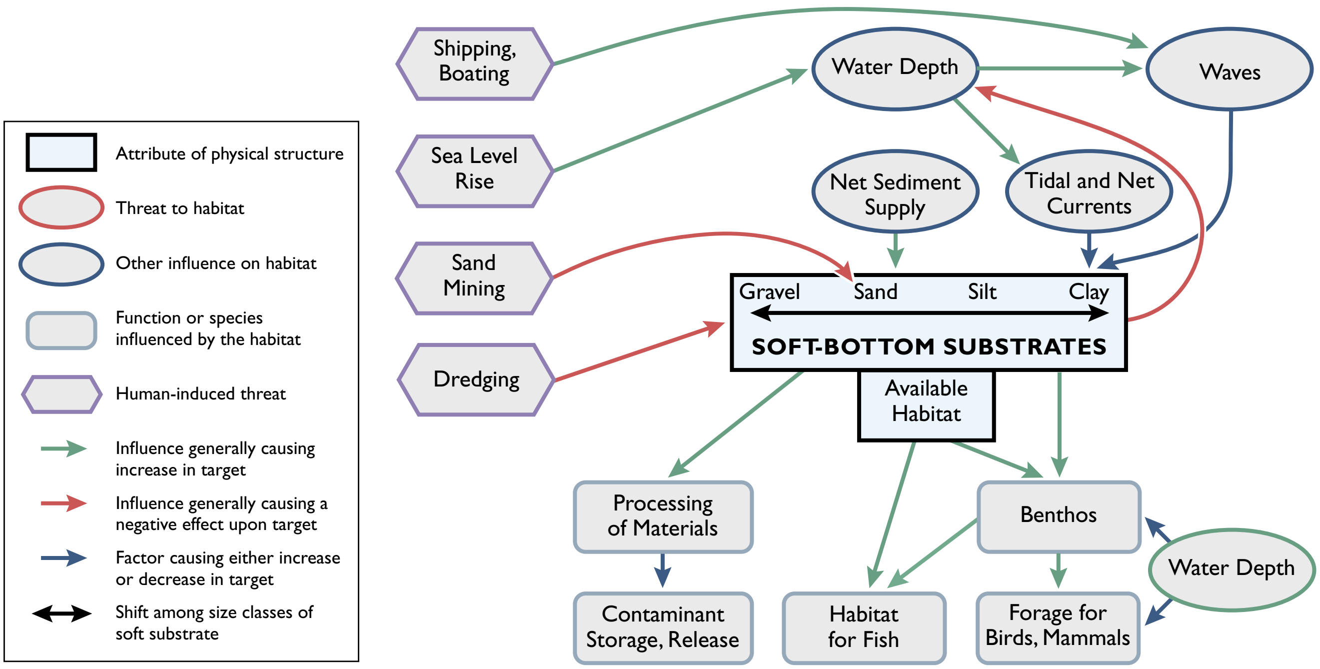


Figure 4-3: Influences on soft substrate, and functions and services provided by soft substrate. "Available habitat" refers to soft substrate that provides habitat for one or more species.

readily kept in suspension by tidal currents and wind-driven waves, but once deposited they can become consolidated, sometimes with the aid of organisms such as mats of microalgae and biofilm, making them more resistant to erosion than sand. This combination results in the establishment and maintenance of shoals and mudflats composed of fine sediments, and the bimodal depth distribution of much of the estuary, with its extensive shoals cut by narrow, deep channels. The shoals act as a sediment reservoir, storing fine sediments from winter floods, which are then resuspended by strong tidal currents and wind waves and gradually winnowed out through the dry, windy summer and fall (Schoellhamer et al. 2007). The strong current regime makes the San Francisco Bay floor a dynamic environment with major bedforms such as sand waves that shift in position and shape. Over time, significant alteration of the bay floor takes place, and substrate types may move or disappear entirely (Greene et al. 2007).

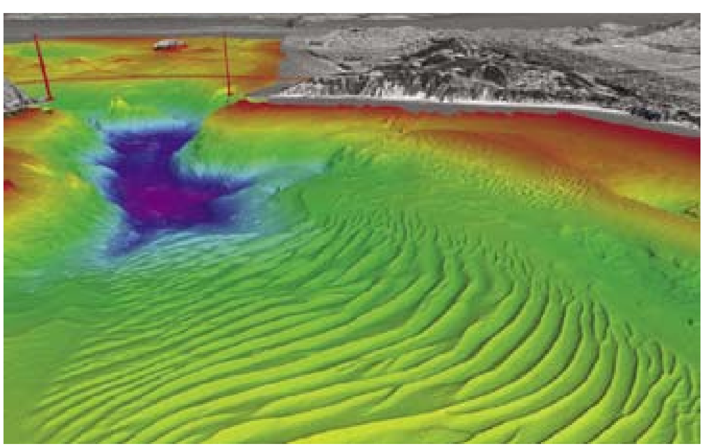
Coarser sediments are confined to high-energy environments where waves (beaches and sand bars), river flows (sand deltas), or tidal currents (bay-mouth bars, sand waves, channel bottoms) inhibit deposition of finer sediment. Sand deposits may also be found where past storms and floods have increased currents temporarily. Sand moves primarily as bedload but can also be transported in suspension by strong tidal currents or river flood flows.

Grain size is critical for the establishment of flora and fauna. Larger sediment particles such as cobble, gravel, or shell, if they remain in place long enough, may provide substrate for settlement of organisms otherwise found on hard substrates, such as oysters and barnacles, and clams may occupy spaces between cobbles. Fine-grained sediment is generally stable and compact enough to allow many kinds of organisms to reside in or on the sediment. Because of its mobility, sand is not a favorable substrate for many benthic organisms, and only those well adapted to a transitory environment are found there. Mixed sand and mud deposits can be stable enough to support diverse benthos (J. Thompson, USGS, 2009, pers. comm.). Some species of fish, notably California halibut, occur over sandy bottom, but the exact nature of that relationship is unknown. Juvenile Dungeness crab may use sand waves and formations as transit routes to migrate out to the ocean.

For some species, the paucity of benthic food resources limits the value of sandy habitat. Fine-grained sediment is a key component in estuaries for chemical transformations mediated by microbes, such as nitrogen fixation, denitrification, and oxidation and reduction of metals. Substances in sediments diffuse much more slowly than in the turbulent water column. Microbes oxidize organic matter within sediments, and the limited diffusion of oxygen and other substances sets up a sharp vertical gradient in oxidation state of the sediments. This allows for a variety of microbially mediated oxidation-reduction reactions to occur in thin but distinct layers. For example, a vertical profile of activities in the sediment proceeds from photosynthesis at the surface to aerobic respiration in the upper, well-oxygenated layer, and then to various kinds of anaerobic respiration resulting in denitrification, metal reduction, sulfide and methane production, and other processes that create black, sulfurous sediments below the sediment surface.

Despite extensive studies, particularly in the last decade, very little is known about these microbial activities in the sediments of the San Francisco Estuary. In particular, production by benthic microalgae has been estimated only for limited areas of mudflat (Guarini et al. 2002). Benthic chemical processes and exchange with the overlying water column have been measured in only a few studies, most of them limited to South San Francisco Bay (e.g., Grenz et al. 2000).

A multibeam sonar image of sand wave formations on the bottom of the bay.



Microbial activity and deposition of organic matter in and on the surface of fine-grained sediments support a rich food web of infauna (organisms living in the sediment), epifauna (those living on the surface of the sediment), and demersal species (motile fish or macroinvertebrates associated with the sediment surface). The near-surface sediments, their microbial flora, and settled organic matter from the overlying water column support deposit feeders such as polychaete worms and some clams. Filter feeders use the sediment more for support than for food, obtaining particles or even dissolved organic matter from the overlying water column. Many of the macro-organisms produce burrows that irrigate deeper sediments,

Bat ray on sand.

altering the positions of the oxidation-reduction zones. Most benthic organisms have planktonic larval stages that drift in the water for days to weeks before settling to the bottom. Benthic production supports a variety of predators in the overlying water column. Predation can disrupt sediments and re-oxygenate near-surface sediments; in shallow waters, bat rays and some sharks and other fish disturb the bottom searching for food, leaving depressions in the sediment.

Invertebrates living in intertidal to subtidal mudflats support large numbers of shorebirds and diving ducks that feed during low tide. The shoals of San Francisco Bay are designated by the National Audubon Society as an Important Bird Area, a site that provides essential habitat for one or more species of birds; these shoals are particularly important to diving ducks.

To summarize, interactions between the water column and the sediment are strong. They occur through physical (settlement and resuspension), chemical (transport and transformation of byproducts of microbial activity), and biological processes (feeding and burrowing by benthic and water-column or demersal organisms, production and settlement of larvae).

Species Composition

As in most estuaries, the soft bottom harbors most of the San Francisco Estuary's benthic organisms (Schaeffer et al. 2007) but probably not most of its species.

Green sturgeon.

Benthic species composition is highly variable and depends on water depth, sediment grain size, and position along the estuarine salinity gradient. Most of the species of the soft-bottom benthos are introduced, and species composition is highly variable in time and space (Nichols and Thompson 1985). Species composition at any one location is largely determined by the overlapping distributions of the species in salinity space (Schaeffer et al. 2007, Figure 35 in Kimmerer 2004). Distributions of benthic organisms shift as the salt field moves in response to changing freshwater flow. For example, when the salt field moves landward during a dry period, a region that was once fresh becomes brackish. Freshwater organisms die or fail to settle in this region, and more salt-tolerant species, previously excluded by low salinity, begin to settle there. The reverse happens with an increase in freshwater flow. In both cases it can take months after the die-off of the initial group of organisms for the new group to settle and grow. During these periods, regions of the estuary are left depauperate (Nichols 1985).

The introduced overbite clam *Corbula amurensis* seems to be an exception to the above pattern, as it is found in all salinities from oceanic almost to freshwater, where its distribution overlaps with that of the introduced freshwater clam *Corbicula fluminea*. Filtration by these clams has an overwhelming influence on the plankton of the overlying water (Alpine and Cloern 1992, Thompson 2005, Lopez et al. 2006).

Harbor seal.

Benthic organisms support many demersal fish, including recreationally important species (e.g., California halibut, striped bass) and threatened species such as green sturgeon. Some demersal fish such as bat rays forage on mudflats at high tide. Numerous bird species forage in shallow soft substrate, including diving ducks (canvasback, greater and lesser scaup, surf scoter). The San Francisco Estuary is a key stop on the Pacific Flyway for ducks and shorebirds, which forage in salt ponds and intertidal mudflats (Warnock et al. 2002). Marine mammals forage on the bottom (gray whales) or consume demersal and pelagic fish (seals, sea lions).

Sediment Budgets

Gray whale.

Several attempts have been made to estimate sediment budgets for the estuary, summarized by Cohen (Appendix 2-1) and McKee et al. (2006). About 57% of the sediment load to San Francisco Bay comes from the Central Valley (McKee et al. 2006), the rest entering the bay from local watersheds and the ocean. Most of the sediment budgets have not distinguished among particle sizes, so determining budgets for subsets of the sediment pool (e.g., sand, or individual basins) will be difficult. In particular, sediment supply from the rivers is probably important to the sand budget only during high-flow years, and then only if bedload transport is included in the estimate. Schoellhamer et al. (2005) constructed a sediment budget and estimated the import of sand from the coastal ocean at about 5.5 million cubic meters per year, but more recent work shows that the sand sill outside the Golden Gate is probably of estuarine and watershed origin (P. Barnard, USGS, 2010, pers. comm.). Sediment deposits in the bay are replenished largely by the major rivers, with some sediment coming

A subtidal slough meanders through a mudflat.

A sand barge near the Port of San Francisco.

from the coastal ocean as well as local tributaries and erosion. The entire sedimentary system of the estuary and its watershed underwent a substantial alteration due to a large increase in sediment from hydraulic mining in the watershed in the late 1800s. The sediment budget for the estuary may still be out of equilibrium because of this historical modification (Jaffe et al. 2007, Hanes and Barnard 2007). The influx of sediment during hydraulic mining caused shoaling in much of the estuary, but much of the excess material has since eroded away.

The present sediment budget is uncertain, but erosion of mudflats and shoals is likely to continue because of reduced sediment supply due to water control structures, damming of rivers (Appendix 2-1, Wright and Schoellhamer 2004, McKee et al. 2006), and the loss of the large pool of sediment from hydraulic mining (Jaffe et al. 2007, Schoellhamer 2009). One result of decreased sediment supply is likely to be loss of mudflats, possibly accelerated by the capture of intertidal areas by the invasive hybrid cordgrass (Neira et al. 2006). In addition, the supply of sand from the rivers has been greatly reduced, and aggregate mining likely exceeds the supply rate, resulting in an ongoing loss of sand from the estuary.

Threats to Soft Substrates

Threats to the soft-bottom communities are numerous; although many are localized, their overall impacts may be large (see Figure 4-4). Dredging and dredge material disposal associated with shipping and boating disturb the bottom periodically in relatively small areas of the estuary. Wakes from ships and ferries can accelerate erosion of shoals. Construction in or adjacent to the estuary, for example, for bridges, piers, and harbors, causes short-term disruption. Permanently installed structures displace the benthic habitat and cause long-term alteration of patterns of sediment movement and deposition. All of these activities can disrupt the functions of the soft bottom by killing or removing organisms, mixing the sediments, and disrupting the layers of different oxidation conditions. More broadly, activities that alter sediment transport and deposition, current patterns, or salinity distributions can disrupt soft-bottom communities. Globally, the most pervasive harm to these communities arises from hypoxia due largely to eutrophication, which has not been an issue in this estuary for several decades (see Chapter 3, Water Column).

The Port of Oakland's Inner Harbor 50' deepening project.

Contaminants

Contamination by chemical substances is widespread in sediments in the estuary (e.g., Oros et al. 2007) with some areas identified as contaminant “hot spots.” Contaminants are a particular issue for soft substrates for several reasons. First, many organic compounds and metals bind to fine-grained sediments and are available for transfer up the benthic food web. Second, contaminants (e.g., mercury, silver, DDT) can be stored in sediments long after their

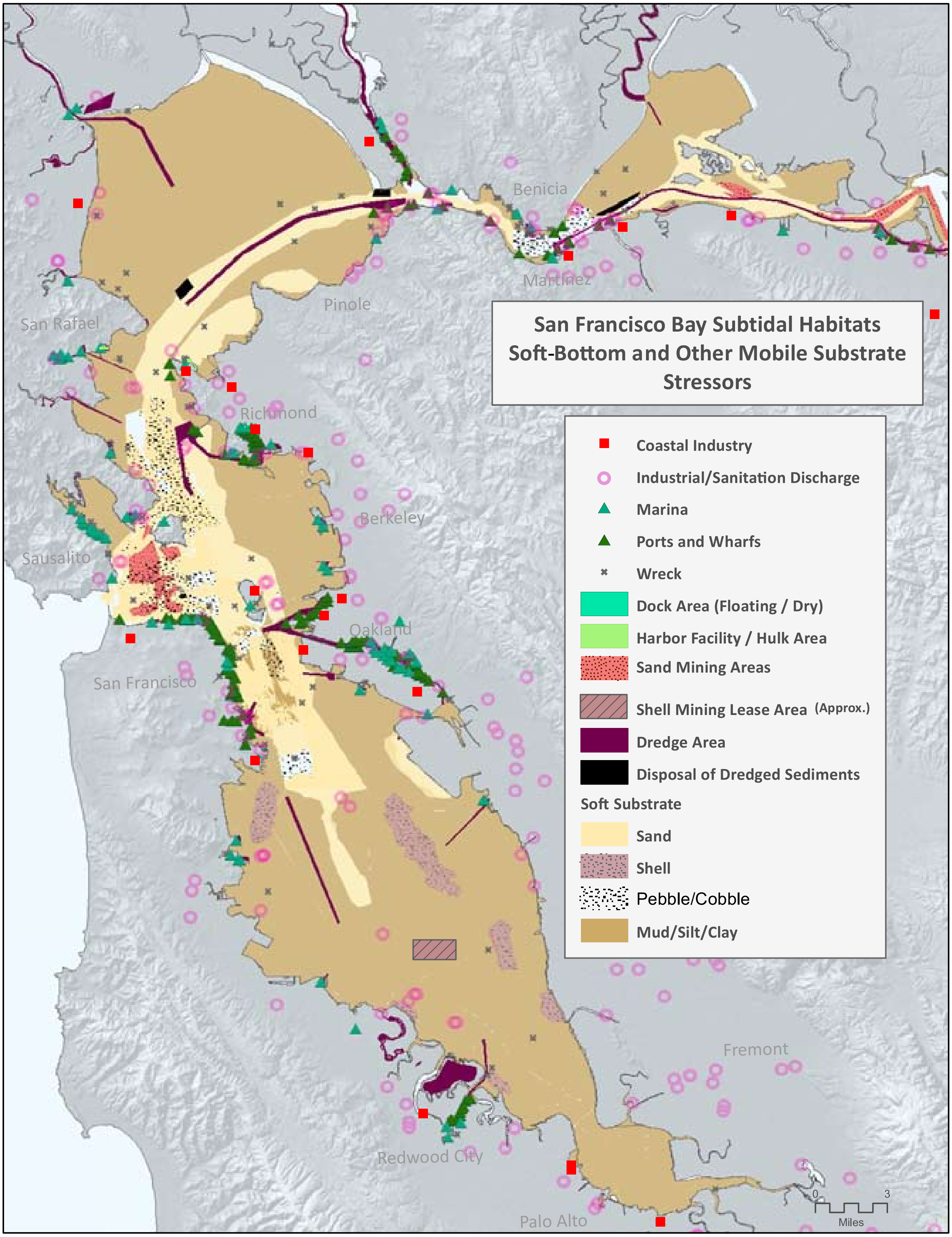


Figure 4-4: Locations of Soft-Bottom Habitat Stressors in San Francisco Bay.

inputs to the estuary have been stopped. Third, metals in the sediments can be reduced to soluble forms by microbial activity, increasing their bioavailability. Finally, the erosion in some areas due to sediment imbalance may be resuspending deeper sediments with their contaminant loads into the water column, making the contaminants available to the food web. Chemical contamination can significantly disrupt survival, fitness, or reproductive success of various organisms including fish (Ostrach et al. 2008) and birds (Takekawa et al. 2002, Ackerman et al. 2008). In addition, sediment-bound contaminants such as mercury, PCBs, and organic compounds can be concentrated in the food web, resulting in concentrations in fish that prompt warnings to limit consumption by humans. Contamination identified in testing can limit the utility of dredged material for wetland restoration and other purposes. Emerging contaminants such as endocrine disruptors may have ecological effects although the importance of sediments as reservoirs for these contaminants is less clear than for the other substances mentioned above.

Benthic Disruption/Removal

Mining for sand occurs under several leases in the Central Bay, and Suisun Bay (Hanson et al. 2004). During March 2002–February 2003 about 1.3 million cubic meters was mined, mostly from the Central Bay (Hanson et al. 2004). The relationship of this volume of sand to either the extant quantity of sand or the sand supply rate is being investigated (P. Barnard, USGS, 2009, pers. comm.). There is evidence of net loss of 14 million cubic yards of sand between 1997 and 2008 in lease areas in Central Bay (P. Barnard, USGS, 2009, pers. comm.). Potential environmental effects of sand mining were reviewed by Hanson et al. (2004). These include entrainment of water column and benthic organisms in the dredge suction, impacts associated with the sediment plumes, and removal of benthic habitat. Entrainment of water column organisms probably has a

Maintenance dredging at the Port of Richmond.

Intertidal and subtidal mudflats support many resident and migrant shorebirds.

Invasive cordgrass threatens mudflats.

minor impact because of its small scale. The volume of water ingested by the sand dredges is around three to four times the volume of the sand mined (Hanson et al. 2004), which amounts to about 0.1% annually of the volumes of the estuarine basins where sand mining occurs. Sediment plumes are unlikely to have lasting effects given the high background turbidity; dredging plumes were found to have only a localized effect (Schoellhamer 2002). The scale of the loss of benthic organisms is unknown mainly because their abundance in sandy areas is unknown. Since the lease areas are well-delineated, a comparative study between lease and non-lease areas could be conducted to help resolve whether substantial resources are being lost through sand mining.

Areas of shell hash, particularly in the South Bay, have also been mined for industrial uses of the shell, leaving large depressions that are clearly visible on sonar records. The impact of current and historical mining on the amount of shell deposits and on benthic biota is unknown; however, historic mining has resulted in changes to bathymetry (Jan Thompson, USGS, 2009, pers. comm.).

Rationale for Establishing Goals for Soft Substrates

The approach outlined in Chapter 2 leads to the conclusion that soft-bottom habitats are perhaps threatened by decreasing sediment supply, locally by the effects of dredging and sand mining, and by various contaminants. However, since there is no real opportunity for increasing the quantity of these habitats, the best we can do is to improve their quality and manage them properly.

The soft-bottom habitats that are of principal concern, in terms of persistence and maintenance, are intertidal and subtidal mudflats, which are threatened by erosion and encroachment of cordgrass. The term "mudflat" is used below to include both subtidal and intertidal areas. Loss of mudflats will likely be accelerated by sea level rise if the rate of rise exceeds the rate of sediment accumulation or wave action increases because of hardened shorelines. Increases in ferry travel on the bay would increase erosion along soft shorelines due to wakes. There is no obvious mechanism for protecting mudflats, so some consideration might be given either to establishing buffer zones or other methods to minimize the impact of wakes in important mudflats, or to manipulating sediments to encourage growth and maintenance of mudflats.

The ecological benefits of mudflats in the estuary have not been quantified, although large numbers of birds are observed to forage there. The relationship between quantity of mudflat and the numbers or distribution of various bird species, and use of the mudflats by other groups of organisms, would need to be determined to support informed choices about protection of these areas. A better understanding of both the function of sand habitats and the effect of sand mining on subtidal or intertidal habitats is needed to better manage sand habitat in the bay.

Goals for soft sediment habitats focus on protection, including reducing effects of contaminants and bottom disturbance, preventing loss of mudflats and beaches, and improving our understanding of ecosystem services and threats to this habitat as well as our ability to protect it. Other goals and objectives are intended to reduce impacts from existing known contaminants, so that they are not contributing to bioaccumulation in fish, birds, or mammals. Intertidal mudflats and sand beaches are of particular concern because of their habitat value for various fish and birds, and because of long-term threats to their existence. Protection goals should not limit creation of other desirable habitats (e.g., eelgrass beds, native oyster beds) within existing soft sediment habitats. As soft bottom sediments are by far the most abundant subtidal habitat type in San Francisco Bay, conversion to eelgrass or shellfish beds at appropriate sites is encouraged.

Science Goals for Soft Substrates

SOFT SUBSTRATE SCIENCE GOAL 1

Understand the extent of ecosystem services provided by soft-bottom habitats.

Question A. How important are mudflats in the life cycles of birds and other organisms that use them?

What would be the impact on the bird or fish populations of a substantial loss of mudflats? At present, bird populations may be limited by conditions in remote locations, but if the local habitat shrinks and alternatives are not available, mudflat area could become the chief limiting factor to bird populations. Alternatively, birds and fish may simply forage elsewhere.

Question B. What is the distribution of various sediments by size and depth throughout the estuary?

A better set of sediment maps for the parts of the estuary not already thoroughly surveyed would help to assess conditions and define actions. These maps would have to be updated periodically to account for erosion and deposition.

Question C. What is the overall sediment budget for the estuary and its major basins, and the relationship of sand removal to sand supplies?

A better grasp of the estuarine sediment budget would be useful both for projecting long-term changes in sediment distributions and for placing sand mining in context. An understanding of the sand budget for mining lease areas is essential for effectively managing the mining activities.

Question D. What is the spatial extent of shell deposits and what services do they provide?

There is no information on the importance of shell deposits as habitat, and little information on their spatial extent.

Shorebirds feed on intertidal and subtidal mudflats.

Question E. What is the ecological value of intertidal and subtidal sand deposits?

These deposits are important in beach formation, but their ecological value is poorly known.

Question F. What are the species composition of the benthos, key functions occurring in the soft sediment, and ecosystem services supported by soft sediment?

This applies to all depths and grain sizes. Although much of the emphasis for management is on sand mining areas and mudflats, the deep soft-bottom habitat comprises much of the estuary's area and is therefore likely to be far more important in supporting ecosystem services than other habitat types that occupy small areas.

SOFT SUBSTRATE SCIENCE GOAL 2

Understand the threats to mudflats and other soft-bottom habitats.

Question A. How are individual mudflats changing over time, and what is causing them to change?

To predict the fate of individual mudflats requires knowledge of sediment budgets at basin and sub-basin scales, and also the short-term, local processes of deposition and wind- and current-driven resuspension. Encroachment of cordgrass and restoration of salt ponds are both localized and quantifiable, and determining their influence on mudflats should therefore be tractable. Furthermore, local vertical movement due to seismic activity may alter sea level relative to the elevation of mudflats. A long-term monitoring program of rates of change in area and elevation of mudflats would be valuable.

Question B. How and why do mudflats differ regionally in their support of species such as shorebirds and bottom-feeding fish?

A decline in extent of mudflats in one region may result in a behavioral shift of these species to other regions, but only if other conditions are suitable.

Therefore, knowing the use of different regions and the underlying motivations behind those specific uses would help in understanding the likely responses to changes in mudflat extent.

Question C. Is it feasible to construct simulation models of the formation and erosion of mudflats?

Improved hydrodynamic models of the estuary provide useful predictions of conditions under alternative scenarios of inflow, bathymetry, and sea level. However, modeling sediments is considerably more difficult than modeling the movement of water. Modeling scenarios may be feasible, but predictive modeling seems beyond our current reach because of the difficulties in estimating coefficients for deposition and erosion.

Question D. What are the broad-scale impacts of sand and shell mining and dredging on sediments and on estuarine biota?

Management of these habitats requires knowledge of local and estuary-wide impacts to gauge the cumulative impacts of sand and shell mining, including the effects of persistent borrow pits left after removal of material, and the contributions of individual mining leases to these impacts.

Question E. What is the recovery time of the benthos from disturbance?

This information is essential for answering the previous question. Most impact assessments focus only on the immediate impact, but disturbances could persist.

Sand beaches and offshore sand shoals provide roosting habitat for birds.

SOFT SUBSTRATE SCIENCE GOAL 3

Determine suitable methods for protecting mudflats and beaches.

Question A. What methods are available for protecting mudflats and beaches, and how effective are they?

An initial review of the available information on engineering long-term solutions to mudflat and sand beach loss should be the first step in answering this question. Depending on the results of such a review, experimental manipulations might be considered to test alternative approaches using adaptive management over the long term.

Question B. How do mudflats in different parts of the estuary differ in their sensitivity to change, and in their support of the ecosystem services that are at risk?

If ways to protect mudflats are available, it is essential to determine which mudflats provide the most support for desired ecosystem services, which are at high risk of loss or degradation because of changing sea level, erosion, or other threats, and which can be protected most effectively.

SOFT SUBSTRATE SCIENCE GOAL 4

Understand the magnitude of the ecological risks posed by contaminants bound to the sediments.

Question A. What are the distributions and concentration of various contaminants in estuarine sediments?

Contaminant concentrations are an important consideration for management of sediments in the estuary. Decisions about dredging, dredge disposal, and removal of artificial habitat, which may disturb sediment-bound contaminants, must be made with knowledge about the contaminants likely to be released. However, developing maps of the distributions of contaminants may not be cost-effective beyond what is already being done by the Regional Monitoring Program. Individual contaminant measurements are expensive, and distributions can be very heterogeneous spatially, and temporally variable as sediments move around. Therefore, site-specific investigations may be more cost-effective than attempting to develop general maps of contaminant distributions.

Question B. What ecological risks (distinct from risks to human health) do these contaminants pose?

Mercury and selenium from the environment have been shown to impair the health of organisms in higher trophic levels such as birds and some fish. However, knowledge of the risks of some other contaminants, and particularly multiple contaminants, is not well developed. As with questions about distribution, answers to this question may be more specific to certain locations and contaminants, rather than broad and general.

Protection Goals for Soft Substrates

SOFT SUBSTRATE PROTECTION GOAL 1

Consider the potential ecological effects of contaminated sediments when developing, planning, designing, and constructing restoration projects or other projects that disturb sediments.

- Soft Substrate Protection Objective 1-1: Identify and prioritize ecological risks associated with contaminated sediments in the estuary.

  Soft Substrate Protection Action 1-1-1: Work with the appropriate agencies to identify and prioritize ecological risks associated with contaminated sediments and locations where priority risks occur within the estuary.

  Soft Substrate Protection Action 1-1-2: Work with the appropriate agencies to develop a sampling protocol to assist interested parties in delineating the extent of contaminated sediments that may pose an ecological risk at non-dredging sites.

- Soft Substrate Protection Objective 1-2: Develop an effective solution to address contaminated sediments that are determined to pose an ecological risk.

  Soft Substrate Protection Action 1-2-1: Collaborate with the appropriate agencies to develop a simplified regulatory process for voluntary cleanups.

  Soft Substrate Protection Action 1-2-2: Develop funding sources to support delineation of contamination, planning, and contaminant removal.

  Soft Substrate Protection Action 1-2-3: Provide funding for and development of regional multi-user rehandling and disposal facilities for contaminated bay sediments.

- Soft Substrate Protection Objective 1-3: Work collaboratively on monitoring and prioritizing emerging contaminants of concern and relevant protocols and policies that may impact bay sediments, and restoration or other projects.

  Soft Substrate Protection Action 1-3-1: Promote discussion of emergent contaminants affecting soft substrates and research needs at existing annual or semiannual forums including the State of the Estuary conference, Dredge Material Management Office's annual meeting, and Regional Monitoring Program annual meeting.

  Soft Substrate Protection Action 1-3-2: Develop stable funding sources to continue the joint NOAA/State Water Resources Control Board mussel watch data collection and early detection of emerging pollutants pilot project.

SOFT SUBSTRATE PROTECTION GOAL 2

Promote no net increase in disturbance to San Francisco Bay soft bottom habitat.

- Soft Substrate Protection Objective 2-1: Minimize bottom disturbance in the bay.

  Soft Substrate Protection Action 2-1-1: For new construction projects, encourage placement in appropriate areas, such as areas of low sedimentation.

  Soft Substrate Protection Action 2-1-2: For projects involving reconfigurations of existing structures, encourage placement of project components in a way that avoids or minimizes the need for dredging.

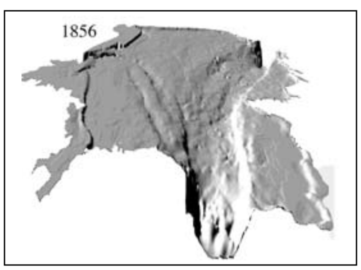
- Soft Substrate Protection Objective 2-2: Minimize placement of structures in subtidal and intertidal soft bottom habitats of the bay. (See Artificial Structures, Chapter 6, and discussion of how to minimize impacts from restoration and living shoreline projects in Chapters 3, 7, and 8).

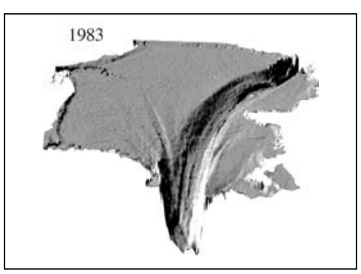
SOFT SUBSTRATE PROTECTION GOAL 3

Promote no net loss of San Francisco Bay subtidal and intertidal sand habitats.

- Soft Substrate Protection Objective 3-1: Continue the efforts of the interagency sand mining working group to encourage harvests of sand at levels replenished through natural processes.

SOFT SUBSTRATE PROTECTION GOAL 4





Three-dimensional images show long-term changes in the soft bottom of San Pablo Bay.

Develop a coordinated, collaborative approach for regional sediment management for San Francisco Bay.

- Soft Substrate Protection Objective 4-1: Promote riparian restoration techniques that provide for sediment storage capacity in stream and wetland systems while allowing for excess sediment to be transported to the bay through natural hydrogeomorphic processes.

- Soft Substrate Protection Objective 4-2: Develop and promote flood control methods, including floodplain restoration, that nourish marshes from the watershed.

- Soft Substrate Protection Objective 4-3: Promote beneficial reuse of suitable dredged sediment in habitat restoration/beach nourishment projects.

  Soft Substrate Protection Action 4-3-1: Determine storage and stockpile locations for dredged sand for later beneficial reuse. Develop restoration projects that are in close proximity to dredging projects.

Soft Substrate Protection Action 4-3-2: Identify funding sources and facilitate transport of mud and sandy material from maintenance dredging projects to areas needing sediment, including in areas using the Reef Ball© technique associated with native oyster and living shoreline restoration (see Chapters 7, 10).

Restoration Goals for Soft Substrates

In developing restoration goals for sand beaches, existing efforts to increase sand beach protection and restoration, including those described in "Prospects for San Francisco Bay Beach Expansion" (Baye 2007, unpublished) were considered.

SOFT SUBSTRATE RESTORATION GOAL 1

Encourage the application of sustainable techniques in sand habitat replenishment or restoration projects.

- Soft Substrate Restoration Objective 1-1: Promote sand beach creation, restoration, and replenishment projects that use clean, maintenance-dredged sand where possible and in areas where sand is deposited, such as at the river delta interface. See Figure 4-5.
- Soft Substrate Restoration Objective 1-2: Consider incorporating living shoreline techniques to retain sand, either from natural deposition or from sand replenishment.

Sand Replenishment Project Examples	Project Contact
Crown Beach in Alameda	**East Bay Regional Park District**
Vincent Park in Richmond	**Bob Battalio, PWA**
Pier 94 Sand Nourishment Project	**Roger Leventhal, FarWest Restoration Engineering**

POTENTIAL SAND BEACH CREATION, RESTORATION, AND REPLENISHMENT SITES

- Eastshore State Park, including Albany Beach
- Pt. Isabelle Regional Shoreline, Albany and Richmond
- Pt. Pinole Regional Shoreline, Pinole
- San Rafael shoreline
- San Leandro Regional Shoreline
- Hayward Regional Shoreline
- San Francisco southeastern shoreline
- Coyote Point

SOFT SUBSTRATE RESTORATION GOAL 2

Encourage removal of artificial structures that have negative impacts on soft bottom habitat function. (See Artificial Structures, Chapter 6).

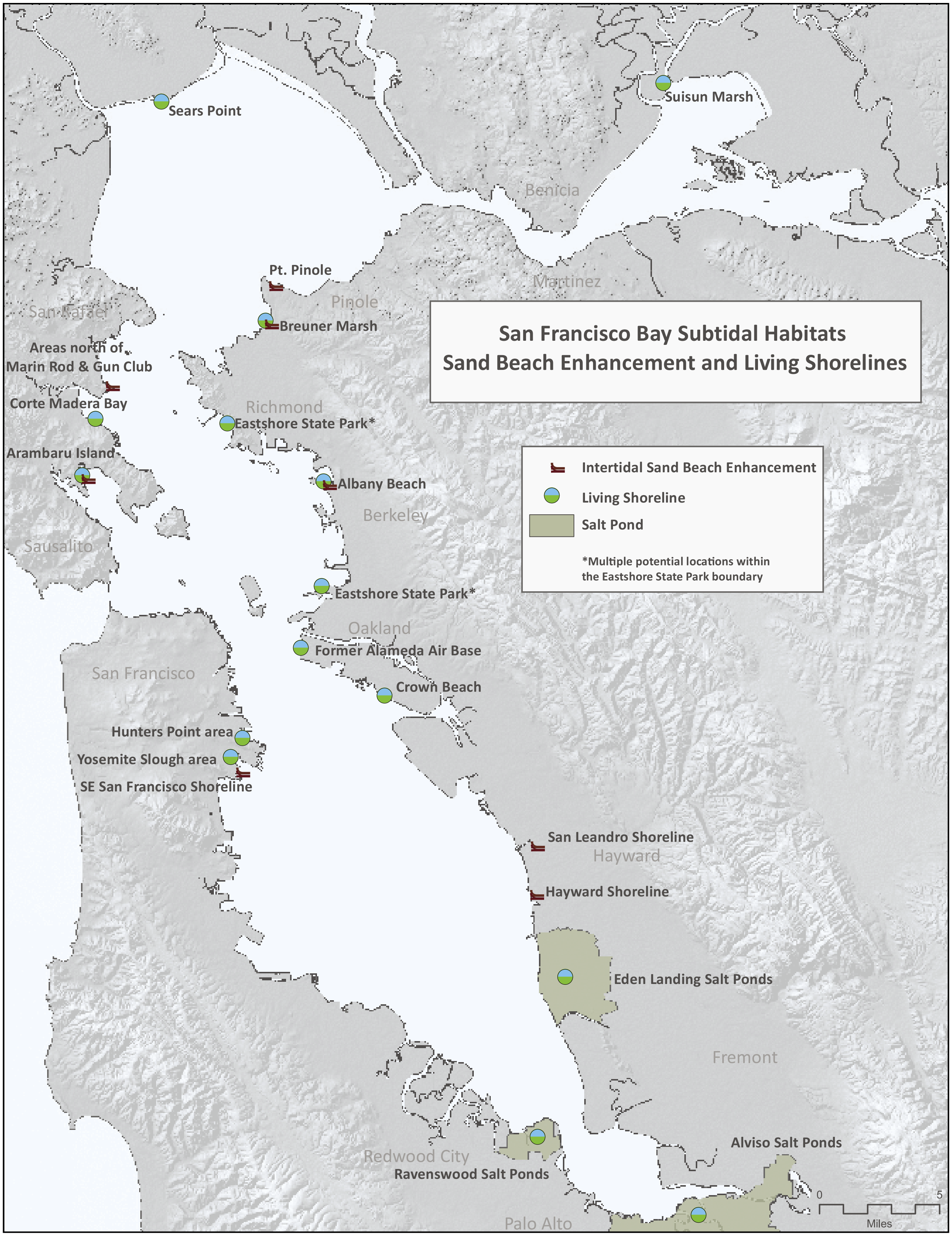


Figure 4-5: Suggested locations for pilot intertidal sand beach enhancement and living shorelines.