CHAPTER TWO

Planning Decisions and Considerations

THE SUBTIDAL GOALS PROJECT FOCUSES on habitats rather than individual species (except for those habitats that are created by a single species, e.g., eelgrass or oyster beds), an approach that avoids prioritizing some species over others. The key decisions and planning considerations described here were developed by the administrative core group representing the lead agencies, with extensive input from all of the active committees and consultants (see Appendix 1-1 for more information about committee roles and processes). The following key decisions were made in identifying goals for subtidal habitat:

The administrative core group held multiple meetings with committee members and stakeholders to discuss Subtidal Goals development.

- The geographic scope of the Subtidal Goals Project is San Francisco Bay from Sherman Island west to the southern extent of the bay and seaward to the Golden Gate (Point Bonita to Point Lobos). Although the delta is not included in the project scope, conditions in the delta and their relationship to subtidal habitat in the bay are addressed in the sections on freshwater input and climate change (see Chapter 3).
- For the purposes of this project, *"subtidal habitat"* includes all submerged areas of the bay. The project also includes certain *intertidal habitats* that were not specifically addressed in the 1999 Baylands Ecosystem Goals Report: intertidal mudflats, eelgrass, sand beaches, rocky intertidal and subtidal areas, and artificial substrate.
- The report uses a precautionary approach, erring on the side of conserving and protecting resources.
- Available information about existing conditions serves as a baseline.
- The goals build upon opportunities and information developed by existing subtidal pilot projects, including in-the-water monitoring, restoration, mitigation, and research projects in San Francisco Bay.
- This document avoids setting priorities among habitats; however, restoration of some may result in conversion of others. For example, some soft substrate may be lost or enhanced through restoration of eelgrass or shellfish beds.
- Because there is a great deal of uncertainty about the functions and value of subtidal habitats and the utility and likely success of restoration,

Eelgrass thrives in Raccoon Strait between Angel Island and the Tiburon Peninsula.

this report recommends using an adaptive management approach in implementing the goals. See discussion of adaptive management later in this chapter.

- As part of adaptive management, progress on achieving the goals—as measured by improved scientific understanding and practical experience in subtidal habitat restoration and protection—should be reviewed and evaluated in a report by 2020. The goals can then be modified as needed. Interim updates on particular topics can potentially be provided within 10 years, and discussed at regional forums and conferences.

Rationale for Setting Goals

Goals for each of the subtidal habitats are based on the Vision Statement described in Chapter 1 and the Foundational Science Goals described in Chapter 3, taking into account the extent of scientific understanding of each habitat. These specific habitat goals lead to actions in one of four broad directions:

- Enhancing, creating, or restoring particular habitats
- Protecting habitats
- Observing habitats, taking no action
- Eliminating artificial habitats

This section describes the process that was used in choosing a course of action for investigating, protecting, and restoring each habitat. The process began with a determination that a given habitat is likely to provide some valued ecosystem services, and then proceeded through a decision tree to determine the most suitable course of action (Figure 2-1).

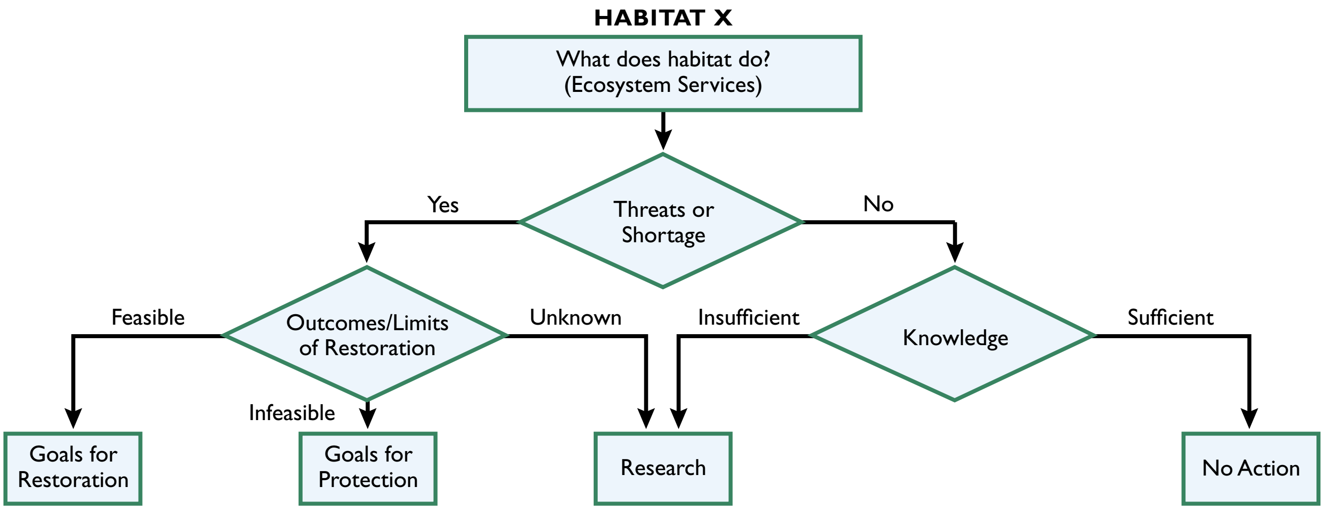

Figure 2-1: Decision tree for the Subtidal Habitat Goals Project, illustrating the pathway considered in the goal development process.

The decision tree helped decide which of these ecosystem services to emphasize, and how far to go in taking protection or restoration actions for a particular habitat. This process is not meant to be static. Improved knowledge, including experience gained through progress toward achieving the goals, and changes in the system will require revisiting these decisions periodically. This can be done through a formal program of adaptive (i.e., experimental) management, discussed later in this chapter.

West Coast Native Oyster meetings bring together researchers and restoration practitioners working on native oyster projects in California, Oregon, and Washington.

Vetting each habitat through Figure 2-1 led to the following conclusions (more specific details are presented in Chapters 4–9):

- Subtidal shoals to intertidal mudflats support valued services and are under various threats from human activities and climate change. Opportunities for restoration are based on uncertain techniques, so this report emphasizes protecting habitat and applying restoration methods experimentally.
- Muddy soft-bottom habitat is essential for some species and probably supports the most ecosystem services of any habitat. Although soft-bottom habitat is plentiful in the bay, it is threatened by various activities. Few opportunities exist to restore it, so protection goals are emphasized instead.
- Sand bottom is mined for sand, but little is known about its role in non-extractive ecosystem services. This lack of knowledge leads to a recommendation to protect existing sand resources while learning more about the impacts of sand mining and the value of this habitat type to species and the ecosystem services it provides.
- Rock outcrops support ecosystem services and are under threat, but restoration would be logistically difficult and therefore unlikely, calling for protection actions and research-based pilot restoration only.

- Artificial structures support valued ecosystem services but also can impair others. Since they are artificial, most of them cannot be considered to be in short supply, nor are they under threat. Conversely, there is interest in removing some of them, leading to an expansion of other more favorable habitats.
- Several habitats (e.g., eelgrass, oyster beds) have clear benefits in supporting valued ecosystem services, although the degree of support is uncertain. They are likely in short supply and under various threats, and restoration has been successful at small scales. Therefore restoration goals are the principal focus for these habitats, although protection goals are also necessary.
- Macroalgal beds support ecosystem services (although at a small scale), but they can also be nuisances under some conditions. Because it is unknown whether and which species of macroalgal beds are under threat or in short supply, the decision tree process led to identifying research goals only.
- The water column forms the background for all of the other habitats. It supports all ecosystem services. Its existence is not threatened, but water quality could become degraded. However, as discussed in Chapter 3, water quality is the province of various agencies and is not addressed in this project.

Graduate students monitor eelgrass beds.

Considerations for Research

Three key principles govern the establishment of science goals for subtidal habitats:

1. Acknowledge key gaps in the knowledge needed for effective protection and restoration;
2. Take a broad, long-term perspective;
3. Acknowledge and allow for limitations on gathering knowledge.

Key knowledge gaps: These gaps include such fundamental information as the spatial extent of some of the habitats and their functions in the ecosystem. Filling these gaps will take time, but that should not delay actions to protect habitats. Rather, restoration and protection should be designed and practiced to allow for these gaps and to reduce either their size or their effect on desired outcomes. In addition, research plans should address the most time-critical knowledge gaps first, specifically in terms of how they will affect meeting project goals through protection and restoration activities. These key knowledge gaps are set forth below as questions.

Which ecosystem services do the target habitats support, and how?

This is a relatively straightforward question that can be answered by considering the conceptual models of the habitats within the context of the overall model. The answer may be "we don't know," although we have listed ecosystem services likely to be provided by one or more habitats (Chapter 1). For example, intertidal mudflats are well known to support various species of birds that are either species of concern, have intrinsic value, or provide recreational opportunities for birdwatchers. This may be reason enough to protect such habitat. By contrast, sandy bottom provides a resource for sand mining, but its support of other ecosystem services is poorly understood. This points to a key role for research.

What is the relationship between quantity of the habitat and the amount or value of those ecosystem services?

This is a much harder question to answer than the previous one, but it should form the basis for all decisions about restoration and protection of habitats. If the potential area suitable for restoration of a habitat can be estimated, what would be the ecosystem-scale response if all of that habitat were to be restored? How would that change if only 10% or 50% were restored?

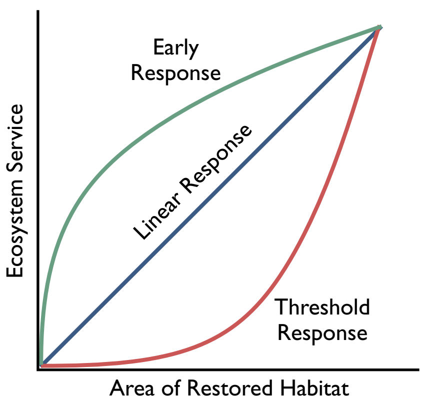

Figure 2-2: Schematic diagram of potential alternative responses of the extent or amount of an ecosystem service to restoration or loss of habitat area. The benefit of small-scale restoration depends heavily on the actual form of this curve.

The default assumption is that habitat value increases linearly with habitat area, but other responses are possible (Kondolf et al. 2008). For example, the number of birds that feed on mudflats in winter could be limited initially by feeding conditions in the local habitat and then by conditions in their remote summering habitat. In that case, restoration may have little effect on birds once the quantity of local habitat exceeded some threshold (upper curve, Figure 2-2). Conversely, there may be a threshold of habitat area above which some part of the ecosystem shifts into a different, preferable state, in which case the cumulative restoration must exceed the threshold before this benefit is achieved (lower curve, Figure 2-2).

What interactions (conflicts or synergies) are likely among those services or the ecosystem processes that produce them?

This is one of the more difficult topics, and answers may be limited to speculation. In particular, restoration of one habitat implies reduction in quantity of another.

What are the threats to various habitats or the species using them?

Threats are those stressors (Appendix 2-1) that are likely to reduce the quantity or impair the quality of a habitat. These include such influences as physical damage (e.g., from dredging, sand mining, shipping, trawling, boat wakes), contaminants, climate change and sea level rise, and over-harvest. Identifying direct threats is fairly straightforward, but indirect threats are harder to establish. For example, how would overfishing affect eelgrass beds?

What actions would enhance or diminish the amount or value of ecosystem services?

This question is intended to encompass deliberate actions taken either to restore a habitat, or to accomplish some other goal (e.g., building a ferry terminal) that might affect a habitat.

Broad perspective: The goals should account for both long-term change in the estuary and spatial patterns at all scales. Research that informs managers about future conditions and applies broadly across the estuary should take the highest priority.

The estuarine ecosystem has changed substantially and will continue to change (see Table 3-1 and Appendix 2-2). The local influences of climate change that have been forecast and observed include rising sea level and a shift to an earlier snowmelt peak in the Sierra, resulting in a larger seasonal cycle in freshwater flow and salinity. Increasing temperature is likely to have a predominantly indirect effect through the northward shift in distributions of organisms, with the likely result of species extirpations and species introductions to the estuary. Other effects, such as increased wind speed and increased frequency or severity of storms, are forecast with less certainty or without consensus among climate models. Human responses to climate change, such as building hard structures to protect against rising sea level, could have profound effects on subtidal habitats.

Significant impacts from climate change will occur over time scales of decades to a century and longer. Over that time frame, many other changes will likely occur in the estuary, including population growth, which will result in increased demand for water supply, waste discharge, infrastructure, recreation, and development near the bay. Changes in transportation such as a substantial increase in ferry traffic would have significant impacts on subtidal habits throughout the estuary. Changes in management and plumbing of the delta will influence annual and interannual patterns of salinity in the bay.

Random or unpredictable events, notably earthquakes but also levee failures in the delta, are reasonably sure to happen sometime during the next century. Multiple levee failures in the delta will have a tremendous effect on the entire estuary because salinity will penetrate farther into the estuary and (in some scenarios) the tidal prism will increase. As with sea level rise, human responses to these events will affect long-term outcomes; for example, whether flooded islands will be diked and drained, and how water managers will respond.

Limits to knowledge: The research goals should be achievable in a reasonable time and be realistic as to the likely outcomes. Conducting research in natural ecosystems is difficult, particularly so in estuaries. These systems are extraordinarily variable in space and time and have myriad interacting components, only a handful of which can be observed in a research program. Monitoring is essential but generally limited to counts of organisms (e.g., fish), collected during the day in deep water. Most ecosystem processes are unmonitored. Human impacts are frequent and sometimes subtle, such as impacts from contaminants, including oil, and alteration of the sediment budget. Finally, the estuary's water is turbid, and even intertidal habitats can be seen only when exposed at low tide. All this is not to say that gaining knowledge is impossible, but that these limitations should be acknowledged in determining research priorities and sequencing, and in setting expectations for the information needed for restoration and protection.

The waters of San Francisco Bay inside the Golden Gate.

Adaptive Management

Adaptive management (Holling 1978, Walters 1986) is specifically designed as a way of managing in the face of uncertainty. This approach treats protection actions as experiments, acknowledging the value of learning as well as that of taking action. This approach is entirely consistent with the current state of knowledge regarding subtidal habitats; in most cases, not enough is known to support well-informed decisions even about whether to restore or protect habitats. In such a preliminary state of knowledge, taking action without an experimental, analytical component would be unwise.

Adaptive management (AM) has had a mixed record, mainly because of institutional resistance to implementation and because many people use the term without fully understanding the meaning. One of the key impediments to AM arises in attempts to apply it to large, complex, unreplicated systems. When the system can be subdivided to allow for replication and controls, the experimental aspects of AM become much more powerful and informative. The Subtidal Goals Project is therefore ideally suited to an adaptive approach at the project level, because habitats can be subdivided for different treatments.

Numerous documents outline the approaches to be used in AM (for example, Thom 2005). Most center on a diagram of the AM process emphasizing that the process is cyclic and has multiple decision points. Figure 2-3 presents such a diagram customized for the Subtidal Goals Project. It expands on the decision tree in Figure 2-1 to include the key elements of adaptive management. The key points to take from this diagram are that AM requires both (1) an explicit statement of expectations in the form of models and metrics to evaluate progress; and (2) explicit loops from the synthesis of data and re-examination of outcomes back to all of the decision points. This process forces managers to think about how to measure and display performance and how to determine

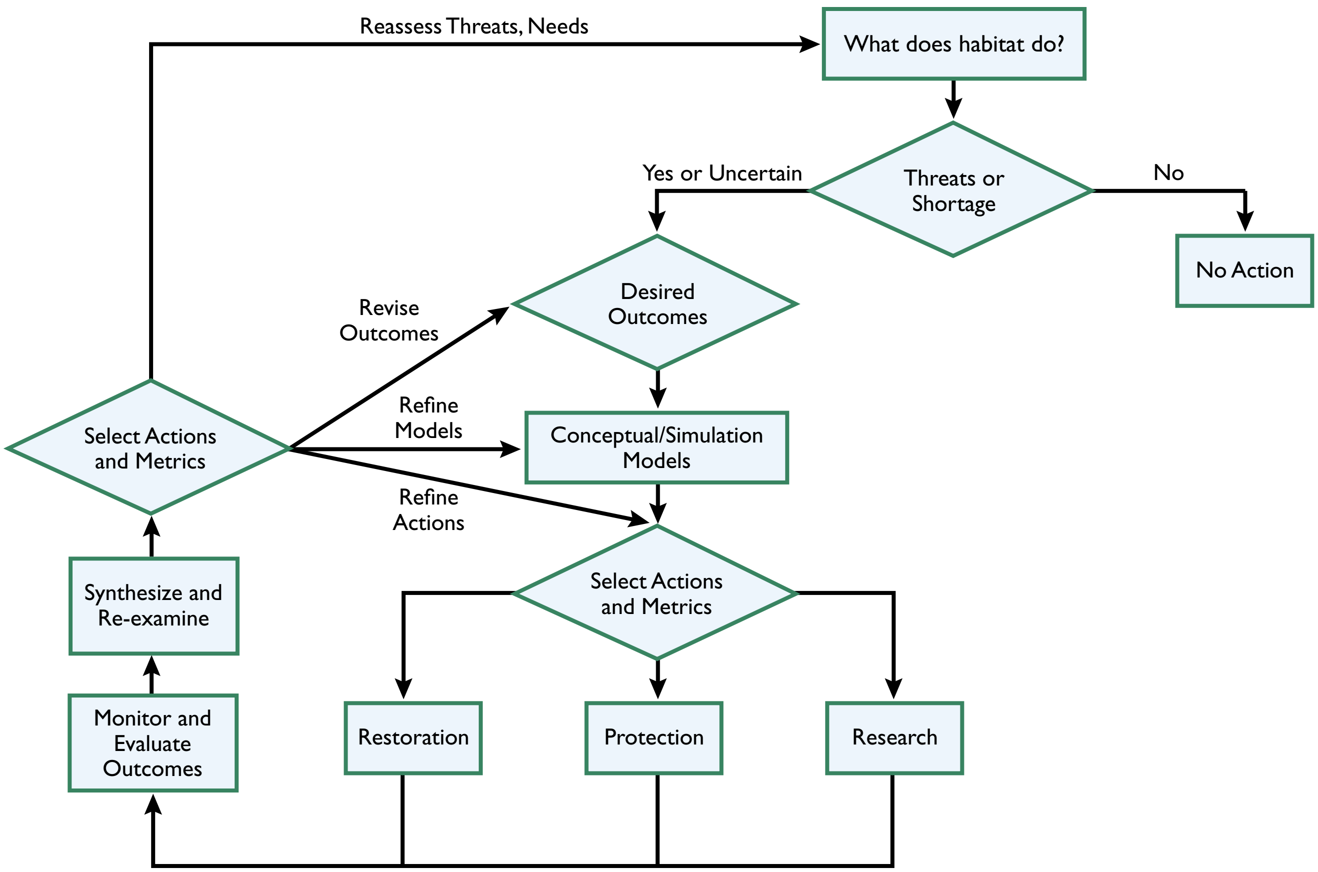

Figure 2-3: Flow diagram of the sequence of activities in adaptive management in the Subtidal Habitat Goals Project. Starting from the top, the ecosystem services provided by the habitat are identified; then threats to the habitat or shortage of the quantity of that habitat are evaluated. This may lead to a decision to take no action (see Figure 2-1); otherwise, a series of steps are taken including making decisions about desired outcomes, development of models, and choice of scale of the action. The action may emphasize restoration, maintenance of the habitat (e.g., through regulatory protection), or research. Every one of these actions, however, requires a set of metrics to evaluate progress, and a process of monitoring and evaluation that leads to periodic synthesis and re-examination of the action. This results in a feedback loop in which any of the decision points or preparatory activities can be revised and the whole process refined. The feedback loops would likely come at progressively longer time scales going up the diagram, since they would require progressively more complex decisions.

Below: Biologists study invertebrate use of restored oyster reefs in San Rafael.

whether an action is working as expected. Thus, the key elements of AM that distinguish it from most other kinds of management include:

- Explicit statements of problems and goals.
- Clear conceptual models of processes to be affected.
- Predictions of outcomes of the action and potential alternatives, and performance measures; predictions may be based on simulation modeling.
- Designed monitoring programs with embedded analysis for evaluating progress toward goals and consistency with the vision.
- A team charged with evaluating results and making recommendations for revising goals, desired outcomes, models, or actions.
- An entity with the authority and will to maintain the process and make changes recommended by the evaluation team.

Please see Chapter 11 for additional ideas on how adaptive management can be applied to achieve the subtidal goals.

Considerations for Protection

This report is a planning document and not meant to be policy or regulation (see discussion in Chapter 1). Agencies and organizations may use this report as a guidance document when implementing their authorities and mandates, or developing or updating policies. Protection goals included in the following chapters were developed with the intent of protecting subtidal habitats in San Francisco Bay, and were not weighed against other agency mandates or socioeconomic concerns, such as public access or economic development. Any policy modification or policy development will entail a separate process in which an individual agency will need to analyze the recommendations within the context of its existing authorities and mandates.

This report takes a precautionary approach. When the decision process (described above) directed focus on research goals for a particular habitat, protection goals were also included in order to maintain existing habitat while research is conducted and evaluated for future protection or restoration needs.

Below: Biologists access subtidal habitats in deep bay muds. Right: A plankton tow in San Francisco Bay.

Creosote pilings provide roosting areas for birds.

For all habitat types, protection goals focus on preservation. When information existed about specific threats, more detailed protection objectives and actions were included.

The resource management committee identified policy-level stressors that can degrade or otherwise influence subtidal habitats:

1. Freshwater inflow
2. Invasive species
3. Climate change

From this list, freshwater inflow and climate change were looked at in a broad sense (see Chapter 3), and specific goals were developed for invasive species (see Chapter 3). Funding allowed five additional stressors to be evaluated, so the resource management committee prioritized five stressors that can degrade or otherwise influence subtidal habitats:

1. Contaminants
2. Bottom Disturbance
3. Suspended Sediments
4. Placement of Artificial Structures
5. Nutrients

Consultant Dr. Andrew Cohen developed narrative descriptions for each stressor (see Appendix 2-1). Working with the resource management committee, the administrative core group conducted an exercise to compare severity, scope, and irreversibility of these stressors against each subtidal habitat type (see Appendix 1-1). This exercise resulted in the following key conclusions:

1. Bottom disturbance is a stressor of concern across several habitats.
2. Placement of artificial structures is a potential stressor of concern for the shellfish and submerged aquatic vegetation "living" habitats.

A derelict creosote piling structure slowly falls into the bay.

3. Eelgrass habitat has multiple stressors of concern.
4. Contaminants are a stressor of concern for soft substrate, especially mud habitat.

This was the starting framework for developing protection goals. This information was then further developed by science advisor Dr. Wim Kimmerer and incorporated into conceptual models for each habitat, which more fully describe the functions of and threats to the habitats and form the resulting basis for all of the goals (see Chapters 4–9).

Considerations for Restoration

In this report, the term restoration includes creating, enhancing, remediating, and rehabilitating habitat (see definition in Chapter 1). The restoration goals are not meant to return subtidal habitats in San Francisco Bay to conditions that existed in the past. Rather, they are meant to improve upon conditions that exist today, with restoration targets based on what is known about limiting factors and the potential for habitats to be created or enhanced within the bay.

Restoring a habitat should be undertaken with a clear view of the long-term prospects for success whenever possible, using an adaptive management approach. This will require answers to the research questions in the following sections. Although there are gaps in knowledge, restoration should still be pursued at an experimental level based on potential habitat distributions. An assessment could begin by determining the maximum possible extent of valued habitats for which restoration or protection is an identified priority, such as eelgrass and oyster beds and mudflats. How much of that habitat is actually likely to exist over the next 50 years, at what level of effort and cost, and what will be the result in terms of ecosystem services? (See Foundational Science Goal 1 for each habitat type in Chapter 3.) Answers to these questions, however approximate, will help to scale expectations and plans for restoration, and these answers will be refined as knowledge improves.

Restoration should also be designed for the long term, and planning must therefore account for expected long-term changes (see Foundational Science

Goal 2 for each habitat type in Chapter 3). Restoration should be targeted to locations and situations where long-term success is most likely. This requires a better understanding of the likely success of restoration in particular areas, the local processes and conditions as they may affect the habitat, and the present and future threats.

Mapping of Subtidal Habitat

An important first step in developing the subtidal goals was collecting and mapping baseline subtidal habitat geospatial data for the entirety of San Francisco Bay. The Subtidal Goals Project has assembled existing subtidal habitat data layers and created the first set of comprehensive GIS maps[1] illustrating the locations and extent of the bay's core subtidal habitats.[2] See also Figure 2-4. Habitat data, from side-scan sonar and multibeam data and sediment samples, were compiled from a 2003 report (Greene et al 2003), as well as anecdotally from experts involved in the Subtidal Goals Project. The 2003 report distinguished 91 different bottom types in the Central and South Bays at the time of data collection although these likely change as strong tidal currents transport sediments around. For the purposes of this project, these 91 habitat types were consolidated, on the basis of their predominant sediment, into 6: soft substrates (including mud, sand, gravel, cobble, and shell mix); rock; artificial structures; shellfish beds; submerged aquatic vegetation beds; and macroalgal beds. This approach, while necessary for the purposes of the project, undoubtedly simplifies habitat types throughout the bay, when in reality most subtidal areas are a vast combination of varying and ever-changing substrates.

In addition, existing data layers of activities (and artificial structures) that can impact the bay's subtidal habitats were collected and mapped to spatially illustrate the relationship between habitats and stressors. Finally, for some habitat types in the bay, proposed restoration sites are shown, based upon areas that had successful existing pilot projects or were identified as suitable habitat (see Chapters 7 and 8). Three types of maps were created and included in this report:

1. Habitat distribution maps
2. Stressor maps. There are four main stressor categories, and each has multiple activities that have been mapped:

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1. The information for the GIS maps for the San Francisco Bay Subtidal Habitat Goals Project came from a variety of sources, including NOAA's 2003 Electronic Navigation Charts and 2006 Environmental Sensitivity Index; 2002 CDFG Bathymetry maps; Gary Greene et al. October 2003 Report: Benthic Habitat Maps of San Francisco Bay Interpreted from Multibeam Bathymetric Images and Side-Scan Sonar Mosaics; Merkel & Associates, Inc. 2010. San Francisco Bay Eelgrass Inventory October–November 2009. Submitted to: California Department of Transportation and National Marine Fisheries Service.; Native oyster survey data Grosholz et al. 2007; the Water and Emergency Transit Agency (WETA); the San Francisco Harbor Commission; the U.S. Coast Guard; and others. Subtidal Habitat Goals Project committee members also provided anecdotal information based upon their knowledge of habitat distributions, which was incorporated into the maps.

2. For a description of additional mapping and surveying needs, see Chapter 11.

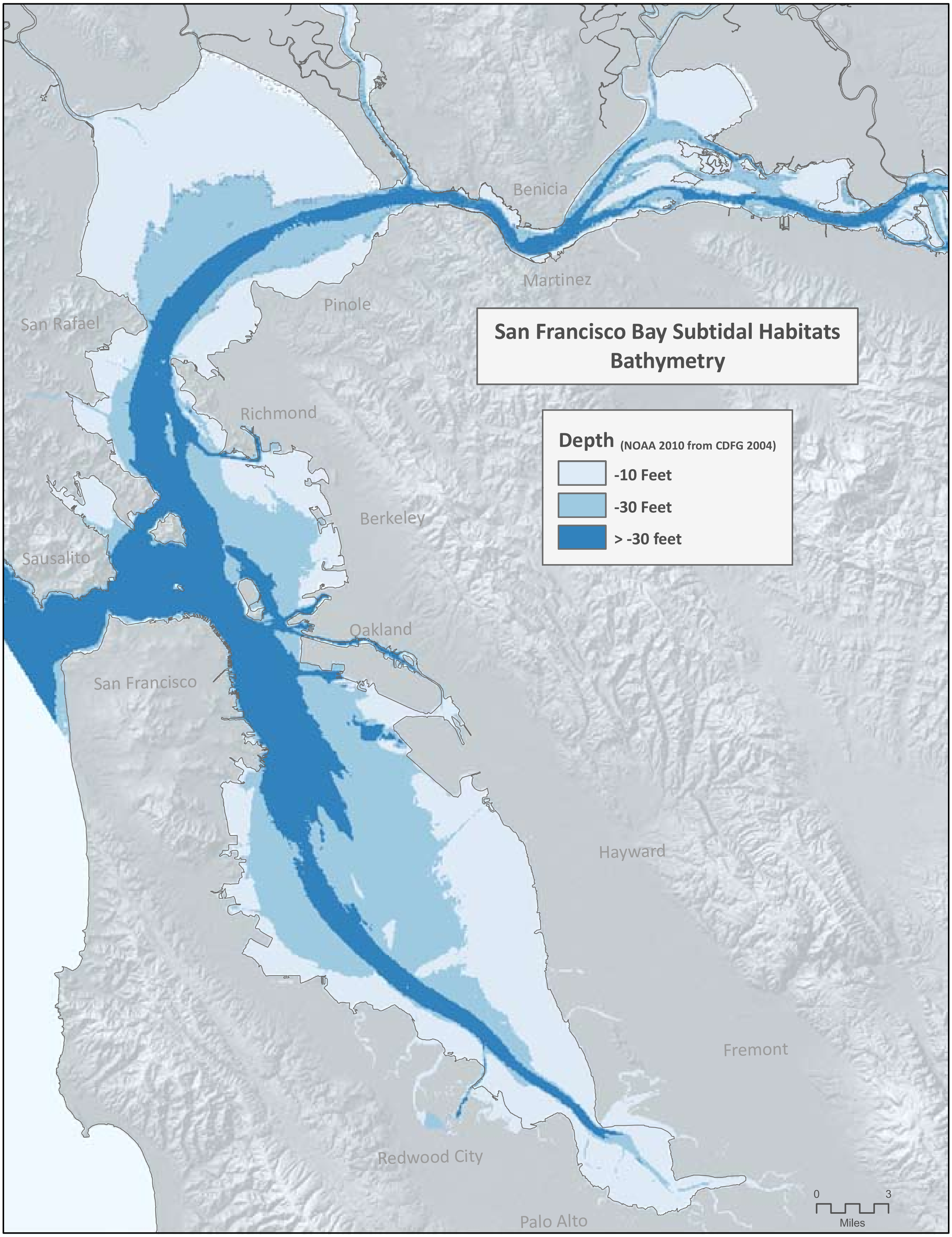


Figure 2-4: San Francisco Bay Bathymetry Map (NOAA 2010 from CDFG 2004), broken down into three depth categories: less than 10', less than 30', and greater than 30'.

Surf scoters on open water.

- Activities that increase or redistribute contaminants: wastewater discharge, coastal industry (power generation, oil refining, and chemical processing), dredging and disposal, sand mining, shell mining, commercial fishing, research and education, natural resource management and restoration, and urban development.
- Activities that increase bottom disturbance: shipping, construction of marinas, ports and wharfs, dredging and disposal, sand mining, shell mining, commercial fishing, research and education, natural resource management and restoration.
- Activities that increase suspended sediments: commercial fishing, dredging and disposal, sand mining, shell mining, research and education, natural resource management and restoration, and urban development.
- Placement of artificial structures: ports and wharfs, pilings, buoys, berthing areas, beacons, duck blinds, among others; and activities associated with coastal industry, bridges, wastewater discharge, commercial shipping and recreational boating, and urban development.

3. Proposed restoration site locations: native oysters, native eelgrass, and suggested pilot locations for intertidal sand beaches and living shorelines.
4. Ownership of the subtidal lands: public and private parcel ownership data. (See Figure 2-5.)

Although there are some data gaps that need to be filled and more maps that need to be made (see next section), the maps in this report should allow individuals, agencies, non-profits, governments, and others to see the submerged areas of the bay in an entirely new light. With these maps,

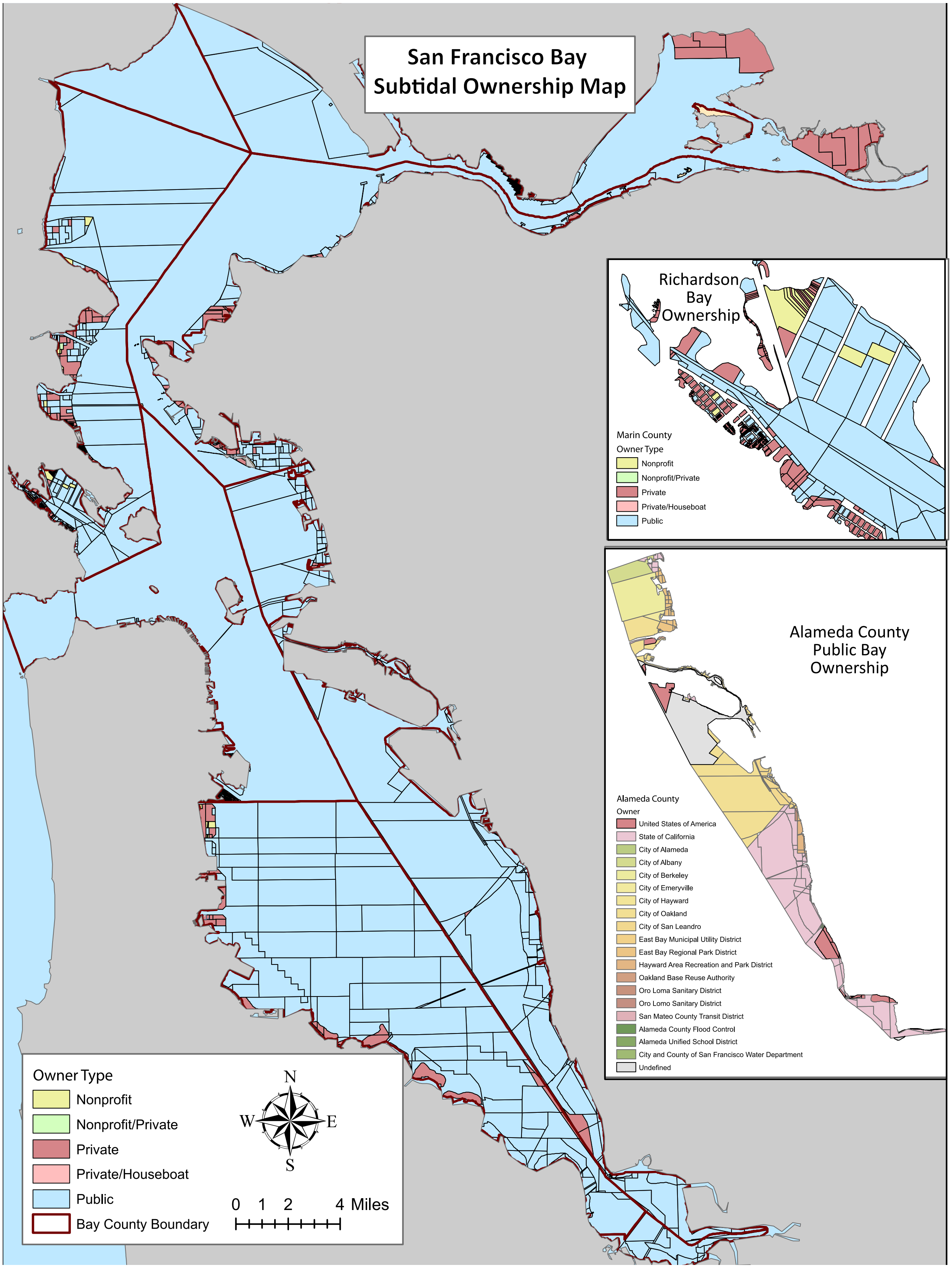
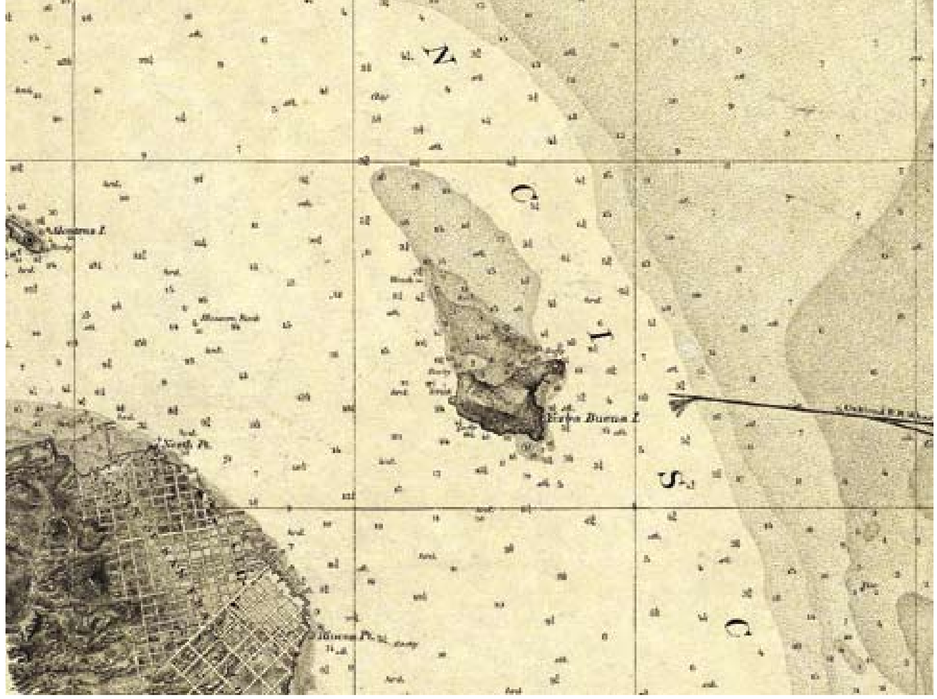


Figure 2-5: San Francisco Bay Subtidal Lands Parcel Ownership. Parcel ownership data compiled by Dan Robinson, NOAA fellow at BCDC, 2008.



Central Bay segment of historic hydrographic sheets developed by the former US Coast Survey.

interested parties will be able to access a wealth of data and new information for use in their own projects. These maps will

- improve existing resource management
- provide better data for use in research projects
- allow a finer assessment of stressor impacts on particular habitats at given site locations
- highlight appropriate restoration project sites
- facilitate improved cumulative impact assessments
- illustrate and help resolve overlapping human use conflicts
- allow consideration of lands for acquisition and restoration

The information in the maps can also be used in potential future Marine Protected Area or Marine Spatial Planning projects in San Francisco Bay.

Additional Mapping and Data Needed to Implement the Goals

1. Nearshore bathymetry: Updated bathymetry data for the entirety of the bay, and specifically for the bay's shallow areas from the shoreline to 3m below mean sea level. Existing bathymetric data sets do not show this area accurately enough to properly manage impacts and implement protection strategies.
2. Physical setting: Stratigraphy needs to be determined bay-wide to better understand the structure of habitats. More than 90% of the bay's bottom is made up of soft, unconsolidated sediments. Research goals in Chapters 4–9 provide the basis for the need to better define areas of mud, sand, and shell hash, so managers can better assess potential impacts and protection strategies. Because they have been mapped as navigation hazards, large

rocky outcrops are probably the best mapped habitats, but small rock and cobble could be better delineated in the bay.

3. Living bottom types: Excellent mapping data are available for native oysters in intertidal and shoreline areas. But there is only anecdotal information supporting the existence of subtidal populations of native oysters, and these areas have never been mapped. Eelgrass beds were mapped in 2003 and again in October 2009 by Merkel & Associates, Inc., but ongoing monitoring is needed to understand interannual variability in distribution and density of all subtidal habitats, particularly for macroalgal beds and submerged aquatic vegetation other than eelgrass since no spatial data exists for these habitats.

4. Tracking soft-bottom habitat types: High-resolution sub-bottom seismic reflection profiling systems can be used to determine the thickness of sedimentary units, which, along with repeated bathymetric surveys, can then be used to track the dynamic and ever-shifting nature of the bay's subtidal habitats. Using this data, a mapping effort could be undertaken to distinguish persistent and temporal habitats and address the dynamic influences that re-work the bay-floor.

5. Hardened shorelines: There is a need to better understand fill type, especially in regard to assessing the impact of wave velocities and rising sea levels in order to better predict their impacts on foreshore slopes. Understanding various fill types and the nature of hardened shorelines better informs the planning of subtidal restoration sites and techniques, as well as helps plan for sea level rise and other climate change impacts throughout San Francisco Bay.

Researchers at the San Rafael oyster and eelgrass restoration site.

6. Submerged creosote pilings: The San Francisco Estuary Institute (SFEI) and NOAA conducted a detailed survey and mapped most of the creosote piling complexes that could be seen at low tide above the surface via boat (see Appendix 6-1). This survey documented over 33,000 derelict pilings in the bay, and estimated at least that many more pilings (and stubs of pilings) occur below the surface of the water at low tide. Beyond locating and mapping these submerged pilings to improve navigational safety, this mapping effort provides information for any potential future removal projects.

7. ESI data: NOAA's Environmental Sensitivity Index maps were released in 2006. Since then, innumerable changes have occurred to the bay shoreline. The Environmental Sensitivity Index (ESI) Maps for California are being updated, pending funding. An update to the San Francisco Bay ESI maps is needed to include the most recent information on the location and extent of subtidal habitats along the shoreline, any changes to management boundary areas, and subtidal restoration projects.

Raccoon Strait is one of the naturally deepest areas of the bay.

8. NOAA's hydrographic sheets: Based on data collected in the bay since the 1850s by the former Coast Survey, NOAA's "H" sheets are similar to the Terrestrial "T" sheets, which have been valuable in developing maps to illustrate the comparison between past and present wetland habitats in the bay (see SFEI's Ecoatlas). "H" sheets include depths based on boat soundings and information about bottom types based on bottom grab samples. Nearly all of the depths on the H sheets have been digitized (Dr. Bruce Jaffe, USGS, 2010, pers.comm.), but additional work needs to be done to analyze the bottom type against current conditions.

9. Human uses: Although the Subtidal Goals Project has gathered extensive data on human activities that may impact subtidal habitats, additional mapping of the bay's current and predicted future human uses is needed to assess stressors and restoration site considerations.

10. Oil spill response: The Office of Oil Spill Prevention and Response GIS maps should be regularly updated to include high priority subtidal protection areas and locations of available equipment, and used during future oil spills in San Francisco Bay.

11. Database and mapping tool for active subtidal restoration and monitoring projects: Such a database could be accessed and used by multiple partners (academic, non-profit, consultant, and agency). The subtidal database could be linked to existing databases such as the San Francisco Bay Joint Venture restoration database and the Wetland Tracker.