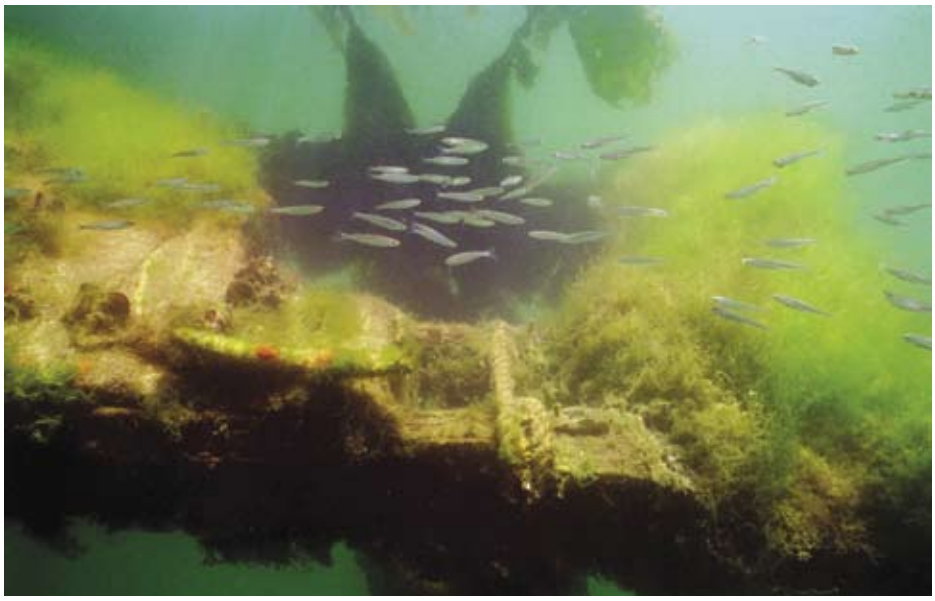
CHAPTER SIX

Artificial Structures

ARTIFICIAL STRUCTURES ARE FOUND throughout the estuary and therefore are exposed to the full range of estuarine conditions, in particular to all salinities. Artificial structures include a wide variety of human-built objects, mainly associated with development, and discarded objects (Figure 6-1). Artificial structures were built to protect shorelines and shoreline structures (seawalls, jetties, revetments), for transportation (bridge and pier pilings, wharfs, moorings, wrecks, derelict vessels, the reserve or "mothball" fleet in Suisun Bay) and recreation (fishing piers, boat ramps, marinas, duck blinds), to support industry (shore-side buildings, water intakes or outfalls, transmission towers, pipelines, cables), and more recently for restoration (oyster shell and artificial reef structures). Artificial structures (Figure 6-2) are similar to rocky habitats in that they alter local wave and current patterns and provide physical habitat for a variety of species. However, artificial structures differ from rocky habitats in their spatial distribution in the estuary, and contain structural features that do not occur on rock outcrops. Thus, the fish and invertebrate assemblages on natural rocks may differ from those on artificial substrates.



Sunken marine debris encrusted with algae and invertebrates provides artificial habitat for fish.

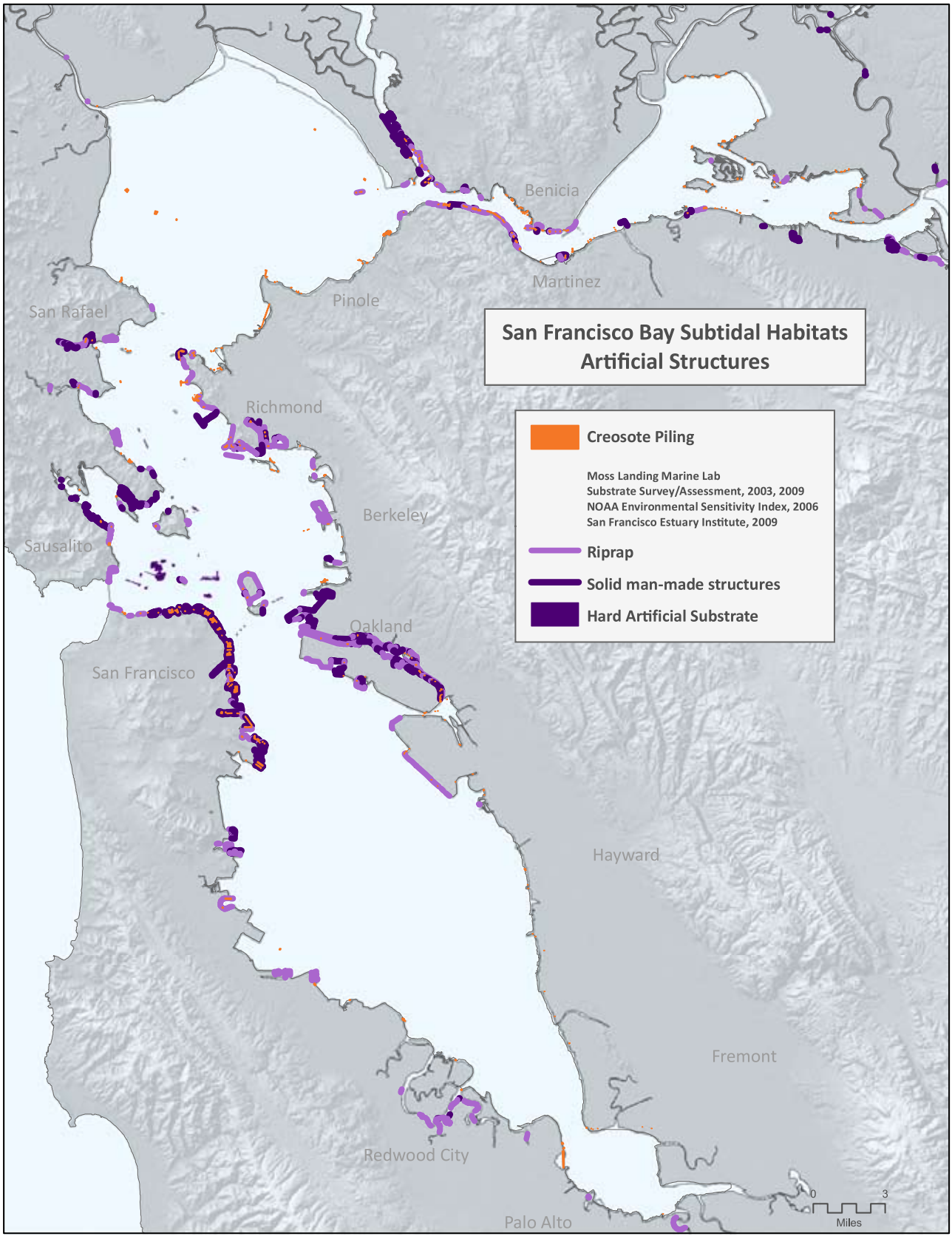


Figure 6-1: Distribution of Artificial Structures in San Francisco Bay.

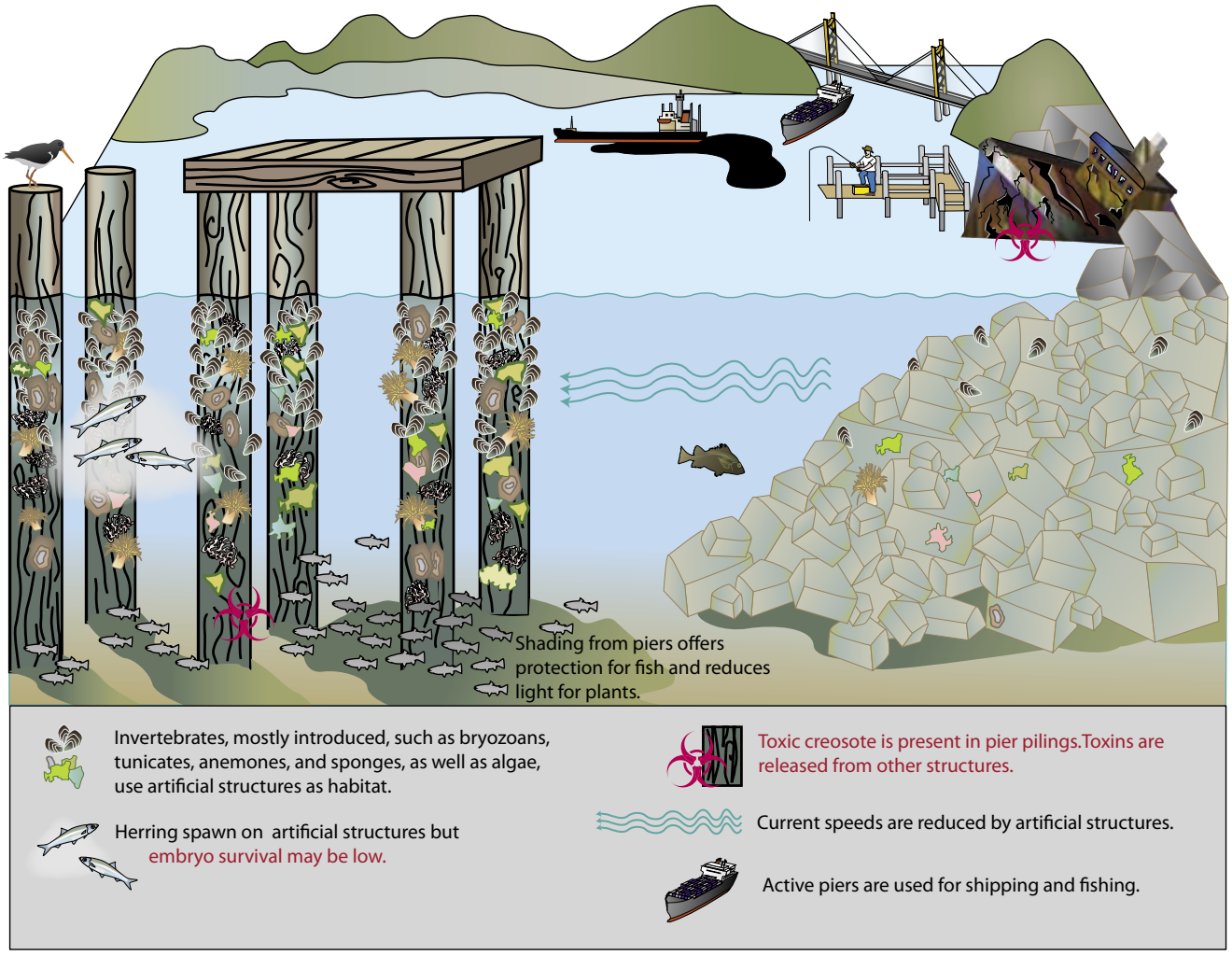


Figure 6-2: Conceptual diagram for artificial structures in the San Francisco Estuary. This diagram displays processes that occur in and on artificial substrates.

The potential removal of abandoned structures for aesthetic or practical reasons is of particular interest. Although artificial substrates function as habitat for many organisms such as herring, some substrates are potentially toxic. The removal of structures offers an opportunity for adaptive management, serving to answer questions about how structures in general affect the habitat and how this effect varies with structural material, size, shape, and location. On the other hand, the value of artificial structures as habitat may exceed the advantages of removing them, as discussed below.

Conceptual Model for Artificial Structures

Like rocky substrates, artificial structures alter wave patterns and flow fields, induce local scouring and deposition of sediment, and provide physical habitat (Appendix 2-2; Figures 6-2 and 6-3). Sessile organisms such as mussels and oysters use both habitats for attachment, and artificial structures provide refuge

and foraging areas for various organisms including fish, resting and nesting sites for birds, and haulouts for seals and sea lions.

However, these two habitat types differ in their distribution within the estuary. For example, some artificial structures such as rock jetties and revetments (riprap) may provide habitat resembling natural rock but were installed in locations that would not naturally have much rock. Since hard substrate is naturally in short supply in fresh to brackish regions of the estuary, it is likely that few native species in these regions are obligate users of hard substrate. Rather, most of the organisms found on artificial structures are not native to the estuary (Appendix 2-2). In addition, the placement of artificial substrates can differ from that of rock outcrops. Artificial structures may be isolated from the shore or the bottom or continuously exposed to surface conditions, and can shade the bottom (Appendix 2-2). These differences imply a different habitat value from that of natural rock outcroppings and boulders.

Structures can affect local wave and current patterns mainly by introducing additional friction. This reduces current speeds and breaks up waves, causing deposition of sediments in some areas and scour in others. When structures change the movement of sediment, coastal erosion may result in some places while other areas may need to be dredged. Walls and revetments in particular, designed to protect shorelines, can shift the focus of erosion to other nearby locations. Generally the effects of these structures on waves and currents are localized, so removing the structures may increase current speeds and wave energy in the immediate vicinity, potentially resulting in erosion. Larger-scale effects, for example from removal of large or numerous structures in narrow parts of the estuary, seem unlikely but should be investigated before any such removal is undertaken.

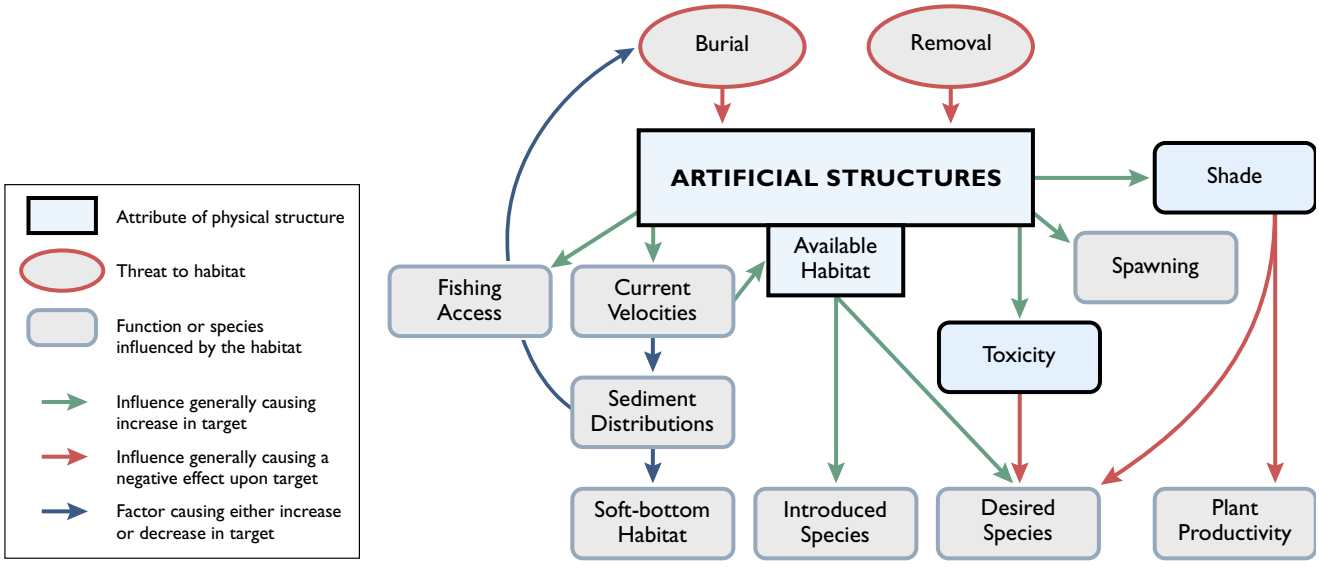


Figure 6-3: Influences on artificial structures, and functions and services provided by artificial structures. "Available habitat" refers to artificial structures that provide habitat for one or more species.

The "mothball fleet" of ships from World War II has released heavy metals into Carquinez Strait.

Many of the artificial structures in the bay have wooden pilings that were injected with creosote to minimize fouling (see Appendix 6-1). Creosote contains polycyclic aromatic hydrocarbons (PAHs) that are persistent in the environment and toxic to some organisms. Although the reproductive success of herring that spawn on creosote is unknown, experiments showed toxic effects on herring embryos from pieces of 40-year-old creosote-impregnated pilings (Vines et al. 2000). Strong circulation around pilings probably minimizes direct effects of creosote on motile organisms, but organisms that feed mainly on prey species inhabiting the pilings may be exposed to creosote through their food.

Piers and breakwaters, also often treated with creosote for its preservative qualities, are popular sites for recreational fishing because they provide easy access to the deeper waters of the bay and shoreline and because such structures attract fish.

Some other artificial structures may be local sources of toxic materials. For example, the reserve "mothball fleet" in Suisun Bay has released metals and paint debris into the estuary in the past; however, these ships are being removed, so such releases should not be a problem in the future.

This abandoned structure with creosote pilings presents both a human safety and environmental hazard.

Rock revetments (riprap) are one of the most abundant artificial substrates. Revetments lack the potential toxicity of pier pilings and may provide some of the same functions as natural rock substrate. However, before large-scale modification of the estuary, the areas now protected by rock would have consisted of mudflats and marshes, presumably more valuable habitat for supporting ecosystem services. Furthermore, the location and overall habitat value of constructed rock or concrete structures is unlikely to match that of natural rock, which often has a greater density and diversity of potential habitat for various organisms.

Rationale for Establishing Goals for Artificial Structures

Applying the approach outlined in Chapter 2 (Figure 2-1), it is clear that while artificial structures support some valued ecosystem services, they are not in short supply, and they can have some detrimental effects. If abandoned pier pilings interfere with the function of surrounding habitat, the decision tree would direct us to restore the surrounding habitat by removing the pier pilings. The advantages and disadvantages of doing this are being investigated and, if this activity is to be pursued, it should be done within an adaptive management framework (see Chapter 2) and based on recommended methods (see Appendix 6-1). Removing selected artificial substrates would be done in pilot projects to investigate and analyze the expected effects of eliminating this habitat and reversing its effects on local wave, current, and sedimentation patterns. One large-scale, long-term strategy for the Central Bay and the Richmond shoreline might be to restore eelgrass near sites where creosote pilings are being removed, to provide eelgrass as a natural substrate to attract spawning herring.

Advantages of removal may include:

- Reduced substrate for introduced species
- Reduced shading of the bottom and water column
- Reduced toxic effects of creosote and other contaminants
- Reduced restrictions to flow and sediment movement
- Restoration, re-creation, or realignment of intertidal mudflats, sand flats, rock, and shellfish, eelgrass, and macroalgal beds

Disadvantages may include:

- Disruption during removal (physical damage, turbidity, and toxicity)
- Reduced habitat for fish and invertebrates including native oysters
- Reduced resting or nesting sites for birds

Additional considerations for removal include:

- Reduced navigational hazards
- Aesthetics

- Reduced recreational fishing opportunities
- Loss of historical value and cultural connections

Goals for artificial structures focus on protecting the habitat value of existing and active structures, removing and preventing structures that are detrimental to the subtidal system, and improving our understanding of the role of artificial structures in the estuarine system.

The recommendations that follow focus on the potential for removing derelict creosote pilings at pilot locations, and enhancing the subtidal functions that artificial structures offer (see Chapter 10 for more detail).

Derelict creosote piling structures on the North Richmond shoreline.

TYPES OF ARTIFICIAL STRUCTURES IN SAN FRANCISCO BAY

Ships and Vessels
- Recreational boats
- Commercial vessels
- Abandoned vessels
- Exposed shipwrecks (Point Molate)
- Sunken shipwrecks
- National Defense Reserve Fleet (Suisun Bay)
- Houseboats (Richardson Bay)

Pilings
- Marina areas
- Ports
- Vehicle bridges
- Foot bridges
- Fishing piers

Wharves

Floating Docks
- Private docks
- Public docks

Abandoned, Derelict Piers
- Berkeley Pier
- Point Molate Pier

Jetties

Breakwaters
- Riprap breakwaters
- Concrete breakwaters

Other Riprap
- Hardened shoreline functioning as levee
- Concrete blocks and other debris

Seawalls and Bulkheads
- Wooden seawalls
- Concrete seawalls

Buoys

Pipeline

Cables

Transmission Towers/Power Lines

Power Plants
- Cooling-water Intakes

Outfall Structures
- Power plants
- Water treatment plants
- Other pipelines

Duck Blinds

Moorings

Anchors

Pacific Oyster Shell (Restoration Projects)

Large Debris
- Shopping carts
- Tires
- Abandoned equipment

The recommendations incorporate information from the San Francisco Estuary Institute's San Francisco Bay Creosote Piling and Artificial Structures Assessment (Appendix 6-1).

Science Goals for Artificial Structures

ARTIFICIAL STRUCTURES SCIENCE GOAL 1

Understand how artificial structures generally affect the estuarine ecosystem.

Question A. How do pier pilings and other unused artificial structures affect wave and current patterns?

This question is general, concerned with the overall evaluation of the ecosystem services provided by these structures and the potential harm of either leaving them in place or removing them.

Question B. What species use these structures for habitat, and is any of this use obligate?

Question C. How does habitat use change as areas of soft bottom and shoreline are converted to hard bottom, for example by construction of riprap?

Question D. How are rock-like artificial structures such as revetments and seawalls used by native oysters and other attached species, and how does that vary regionally?

These concrete "slagpools" provide limited habitat in comparison to a natural wetland or rocky intertidal edge, but can often show greater diversity of species and niche space than classic riprap. The pools host several species of seaweeds, mussels, oysters, barnacles, and a variety of other bay invertebrates.

Much of the bay shoreline has been riprapped.

The existing hard shoreline at Virginia Street on the Berkeley shoreline includes riprap, old concrete fill foundations from wharf and industrial facilities, and areas where concrete was simply poured onto the shoreline to act as a tidal barrier.

ARTIFICIAL STRUCTURES SCIENCE GOAL 2

Determine the roles of individual artificial structures proposed for removal.

Question A. What is the effect of removing a particular structure on local hydrodynamics and sediment transport?

This is related to Science Goal 1, Question A above, but concerns individual structures. The details of the structure, the physical configuration of the area, and the local current and wave environment all contribute to the alterations that a particular structure introduces. Removal may result in rapid erosion and resuspension of sediments when current speeds increase. Most of these structures fall below the spatial scale that today's hydrodynamic models can resolve, so investigation may require developing small-scale models together with field studies.

Question B. Which species use this particular structure for habitat, and how?

Removal should be contingent upon an investigation into the habitat value of the particular structure in the environment where it is found.

Question C. How important is this structure for recreational use?

This question is related to the previous one but also to issues of access and current use. Some piers are heavily used for fishing, and other structures may be used for fishing or birdwatching because they attract fish or birds.

Children fish at the Marin Rod and Gun Club historic pier.

CREOSOTE PILINGS IN SAN FRANCISCO BAY

Wooden pilings have been used in marine construction projects for thousands of years. Beginning with the Gold Rush, wooden wharves and piers proliferated on the San Francisco waterfront. Several creosote plants operated in Alameda and other areas. The remnants of old creosote-treated piers and dilapidated maritime facilities are common sights along the intertidal and subtidal shorelines of San Francisco Bay. Creosote was used from the mid-1800s into the 1950s as a method for preserving marine structures from decay. It is a complex mixture of chemicals, many of which are toxic to fish and other marine organisms. Because of concerns over toxicity, creosote was banned in 1993 by the California Department of Fish Game.

Removal of these structures has been proposed as a possible restoration focus for San Francisco Bay. Creosote-treated wood and debris removal operations are underway in other regions of the United States. There is particular concern that chemicals leaching from creosote-treated structures could harm Pacific herring, one of the last fisheries in the region, because herring spawn on hard surfaces, including old pier pilings. There is also concern that dilapidated creosote-treated pilings are hazards to navigation and that they will pose even greater hazards as sea level rises. Removal and encapsulation projects conducted at the Port of Oakland and the Port of San Francisco are discussed in Appendix 6-1.

Protection Goals for Artificial Structures

ARTIFICIAL STRUCTURES PROTECTION GOAL 1

Enhance and protect habitat functions and the historical value of artificial structures in San Francisco Bay.

- Artificial Structures Protection Objective 1-1: Improve water quality and hard substrate for habitat by encapsulating existing creosote pilings and piers, or by replacing them with inert materials, especially within current and historical herring spawning areas.
- Artificial Structures Protection Objective 1-2: When artificial structures (for example, shoreline stabilization structures) are installed, replaced, or maintained, use materials or methods that mimic natural habitat features, incorporate natural habitat (for example, emergent marsh, submerged aquatic vegetation, riparian vegetation, and oyster shell) into structure design, and use native seeding or other techniques to minimize establishment of invasive species. (See Chapter 10).

ARTIFICIAL STRUCTURES PROTECTION GOAL 2

Improve San Francisco Bay subtidal habitats by minimizing placement of artificial structures that are detrimental to subtidal habitat function.

Please see Appendix 2-2 for more information on the impacts of artificial structures.

Restoration Goals for Artificial Structures

ARTIFICIAL STRUCTURES RESTORATION GOAL 1

Where feasible, remove artificial structures from San Francisco Bay that have negative or minimal beneficial habitat functions.

- Artificial Structures Restoration Objective 1-1: Where appropriate, remove creosote pilings from intertidal and subtidal habitats of the bay, with a focus on those areas that have high concentrations of individual pilings or piling complexes and are within current and historic spawning grounds for herring.

  Artificial Structures Restoration Action 1-1-1: Initiate programmatic evaluation of pilings pursuant to the National Historic Register and associated guidelines.

There are more than 33,000 derelict creosote pilings in San Francisco Bay.

Artificial Structures Restoration Action 1-1-2: Remove 6,500 tons of creosote pilings from areas of high piling concentration (i.e., San Francisco Waterfront, Richmond Point, Napa River Mouth, and Carquinez Strait) within 5 years (see the following goal).

- Artificial Structures Restoration Objective 1-2: Where appropriate, remove shoreline stabilization structures and riprap from the bay that are no longer providing protection or may be contributing to coastal erosion.

ARTIFICIAL STRUCTURES RESTORATION GOAL 2

Promote pilot projects to remove artificial structures and creosote pilings at targeted sites in combination with a living shoreline restoration design that will use natural bioengineering techniques (such as native oyster reefs, stone sills, and eelgrass plantings) to replace lost habitat structure.

- Artificial Structures Restoration Objective 2-1: Fund three pilot restoration projects to test new material types and configurations for three types of artificial structures: riprap shoreline, breakwater, and dock. (See Chapter 10, Restoration Goals for Living Shorelines.)