Criteria for the Adoption and Support of
Subtidal Habitat Protection, Restoration and Enhancement

This document summarizes the basic criteria for Subtidal habitat projects to be eligible for adoption and support by the San Francisco Bay Joint Venture (SFBJV). Criteria and design recommendations will be based on habitat values and ecosystem services to benefit from subtidal habitat restoration. While some projects may serve multiple purposes, the primary purpose of the projects will be for the benefit and expansion of subtidal habitats.

Overview of the Benefits of Subtidal Habitats

San Francisco Bay is one of the largest estuaries on the West Coast and one of the most important both for the habitat it provides for fish and wildlife and for the many benefits and opportunities it offers people.

Subtidal habitat is a critical piece of this ecosystem. Subtidal habitat includes all of the submerged area beneath the bay's water surface: mud, shell, sand, rocks, artificial structure, shellfish beds, eelgrass beds, macroalgal beds, and the water column above the bay bottom. These unique habitats provide diverse three-dimensional structures, including sand waves more than three meters high. Eelgrass and shellfish beds act as ecosystem engineers and provide substrate for reproduction and food resources for species such as herring and salmon; rocky outcrops offer substrate for seaweeds and invertebrates; mixed sediments in shoals and channel banks are used by a variety of species. Many shellfish, macro- and micro-invertebrates, fish, marine mammals, diving ducks, and other wildlife feed, rest, hide, and reproduce in subtidal areas. Large populations of shorebirds feed on the estuary's subtidal and intertidal mudflats. Subtidal habitats also support a variety of ecosystem services, including nutrient cycling, climate regulation, flood protection, water quality maintenance, and sediment transport. Protection, restoration and enhancement of subtidal habitats will benefit these important ecosystem services.

A. **Essential Criteria for Adoption of Subtidal Habitat Projects**: To be considered for adoption by the San Francisco Bay Joint Venture (SFBJV), the project must satisfy the Essential Adoption Criteria outlined in Chapter 1, Section A. It must also satisfy the following four Essential Criteria for Adoption of Subtidal Habitat Projects:

   1. The primary purpose of the subtidal habitat project, and the SFBJV support, must be to provide beneficial ecosystem services. Target habitats should be identified (see Section B), and detailed success criteria must be specified according to the San Francisco Bay **Subtidal Habitat Goals** report (http://www.sfbaysubtidal.org/report.html).

   2. A site-specific restoration design or protection plan should be prepared for each project. Restoration design or protection plan should incorporate the requirements in the Subtidal Habitat Goals Project report, including the eelgrass bed report (http://www.sfbaysubtidal.org/PDFS/Ap8-1%20Eelgrass.pdf), the shellfish bed report (http://www.sfbaysubtidal.org/PDFS/Ap7-1%20Shellfish.pdf) or the creosote – artificial structure report (http://www.sfbaysubtidal.org/PDFS/Ap6-1%20Creosote-Artificial%20Structures.pdf).

   3. All permit requirements, including those that are in process of applications, should be specified, and the project proponent must agree to permit terms. If permits have not been secured but applications have been submitted, the SFBJV may still consider adoption and support for the project.

   4. The proposed project must meet all local, state and federal permit requirements including, but not limited to, local ordinances with grading permit requirements.

B. Target Subtidal Habitats

1. 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. Examples include clay, mud (silt + clay), gravel, and bivalve shell deposits. Most of the soft sediment in the estuary is fine material like silt and clay (Keller 2009), particularly on shoals. 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, a large area between the Golden Gate, Alcatraz and Angel Island and Middle Ground Shoal in Suisun, as well as in the deep water channels from Suisun through the Bay, silt to clay elsewhere, and a large shell deposit in the south bay as well as a few shell deposits near shore (Hymanson 1991). Soft-bottom and other mobile substrates are ecologically important and are a vital component of the San Francisco Estuary.

Microbial activity and deposition of organic matter in and on the surface of sediments support a rich food web. 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 bird. 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). 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.

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, which is important for water quality in the San Francisco Estuary.

Soft-bottom and other mobile substrate habitats are undergoing anthropogenic impacts. Contamination, dredging and sand mining are the main threats to benthic habitats.

The overarching goals that should be considered in restoration or protection activities are outlined below. See the Subtidal Habitat Goals report for more detailed restoration and protection measures (http://www.sfbaysubtidal.org/PDFS/04-Soft-Bottom.pdf).

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

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

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

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

e. 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.

2. **Rock Habitats**

There is relatively little naturally occurring hard substrate in the San Francisco Estuary (NMFS 2007). Rock substrates are important because they are habitat for many organisms and provide protection and food supply. Submerged rock can be colonized by a variety of organisms, such as attached algae, sponges, bryozoans, tunicates, hydrozoans, anemones, barnacles, mussels, and oysters. Numerous other invertebrate animals (for example, amphipods, isopods, crabs) and fishes (for example, prickly sculpin, rockfish) reside on, under, or near areas of hard substrate, using rocky habitats for protection or food supply (NMFS 2007). Some species, notably Pacific herring but also some invertebrates, use rock and other hard substrate as well as attached vegetation for spawning. Birds use exposed sections of hard substrate for resting and nesting, and seals and sea lions also rest on them at low tide.

Rock habitats undergo a plethora of human impacts. Blasting to remove or deepen outcrops for safety of navigation is a significant threat to rock habitats. Potential threats also exist from oil spills, trampling by humans, and colonization by invasive species.

The overarching goals that should be considered in restoration or protection activities are outlined below. See the Subtidal Habitat Goals report for more detailed restoration and protection measures of rock habitats (http://www.sfbaysubtidal.org/PDFS/05-Rock%20Habitats.pdf).

a. Promote no net loss of natural intertidal and subtidal rock habitats in San Francisco Bay.

b. Restore and maintain natural intertidal and subtidal rock habitats in San Francisco Bay.

3. **Shellfish Beds**

Shellfish beds are when shellfish congregate on hard substrate such as rock or shell aggregates, or mud/shell mix, together with the associated water column. There are five species of shellfish that occur in San Francisco – two native, one hybridized, and two invasive (NMFS 2007). Shellfish beds provide several ecosystem functions and support several ecosystem services. Shellfish beds are considered a "foundation species" or ecosystem engineer, altering their environment by increasing bottom roughness, reducing current speeds, and as a result, trapping sediments. Oysters also increase physical heterogeneity, which can increase diversity of other marine invertebrates and also result in higher fish diversity and abundances than in neighboring, less complex habitats. Increased abundance of native oysters can locally increase the number of other benthic invertebrates (Kimbro and Grosholz 2006). With their associated invertebrates, oysters provide food for fish, birds, and crabs.

Anthropogenic threats to shellfish habitats include water pollution, boating, shipping, and dredging. If these activities occur near oyster beds they can directly disrupt beds or resuspend sediments that inundate beds. Ocean acidification is considered a growing threat to calcareous organisms in the ocean, and may become important particularly in the Central Bay with its strong oceanic influence.

The overarching goals that should be considered in restoration or protection activities are outlined below. See the Subtidal Habitat Goals report for more detailed restoration and protection measures of shellfish habitats (http://www.sfbaysubtidal.org/shellfish.html).

a. Protect San Francisco Bay native shellfish habitats (particularly native oyster *Ostrea lurida*) through no net loss of existing habitat.

b. Protect areas in San Francisco Bay with potential for future shellfish expansion, restoration, or creation.

c. Increase native oyster populations in San Francisco Bay within 8,000 acres of potential suitable subtidal area over a 50-year time frame through a phased approach conducted within a framework of adaptive management.

4. Submerged Aquatic Vegetation

The term "submerged aquatic vegetation" (SAV) refers to all underwater flowering plants. In the San Francisco Estuary, SAV includes sago pondweed (*Stuckenia pectinata*), eelgrass (*Zostera marina*), and other species of seagrass, including widgeongrass (*Ruppia maritima*) (NMFS 2007). Seagrasses perform a wide variety of functions (Phillips 1984, Orth et al. 2006, Waycott et al. 2009). They alter local hydrodynamics, reducing the speed of currents. In doing so, they trap and stabilize fine sediment, reducing the average grain size in the bottom sediments and altering the local sediment chemistry. Globally they are much more productive per unit area than phytoplankton (Duarte and Chiscano 1999). Eelgrass transforms unstructured shallow-water areas into physically structured habitat that can support a wide variety of organisms. The complexity of this habitat can support residents that have a variety of life histories and feeding modes (Robertson 1980). Eelgrass beds have higher abundance, biomass, and productivity of consumer organisms than do unstructured habitats (Connolly 1997). Seagrass beds also provide a food source, either directly to grazers on the seagrass (amphipods, snails, ducks, geese) or indirectly, either to grazers on epiphytes, i.e., plants such as diatoms growing on grass blades, or predators consuming invertebrate grazers, or through detritus formed of dead plant material that supports the estuarine food web. Few fish species consume seagrasses directly, so the food supply from the seagrass beds to fish is indirect.

Eelgrass is the prominent SAV within the San Francisco Estuary. Eelgrass beds provide shelter and food to small fishes of a variety of species, such as pipefish, staghorn sculpin, and three-spined stickleback (Grant 2009). These include species that occupy eelgrass beds for their full life cycle (pipefish) and those that use eelgrass beds only as nurseries. The importance of this nursery habitat to the life histories of fish in San Francisco Bay is unknown. The extent to which eelgrass supports species of concern, like Pacific herring and salmon is not well known. A substantial increase in extent of eelgrass might provide resources for a wide variety of species. Eelgrass is used as a substrate for spawning by Pacific herring, which lay sticky eggs on the plant's blade. Finally, seagrass beds can serve as ecological sentinels, providing advance warning of deteriorating conditions such as increasing turbidity, wave action, temperature, or contaminants (Orth et al. 2006). Currently, about 1% of the San Francisco Estuary is eelgrass habitat and restoration attempts have had varying degrees of success.

Seagrasses in general are subject to many threats over short and long time scales, most due to human activities (Phillips 1984, Orth et al. 2006), and globally are in a state of decline (Waycott et al. 2009). The principal threat worldwide is probably eutrophication leading to excessive algal biomass and light limitation of seagrass growth (Orth et al. 2006). Other anthropogenic threats to SAV in San Francisco Bay include activities associated with shipping and boating, which can disrupt seagrass beds directly through destruction of plants by boat propellers, anchors and anchor chains, dredging, and construction of facilities (e.g., docks, harbors, breakwaters, ports). Indirect effects arise through increased suspended sediments due to dredging and boat wakes, or shading from structures such as docks. Hardening of the shoreline can reflect waves, increasing wave action and limiting or destroying beds. The overarching goals that should be considered in restoration or protection activities are outlined below. See the Subtidal Habitat Goals report for more detailed restoration and protection measures of submerged aquatic vegetation habitats (http://www.sfbaysubtidal.org/PDFS/08-Submerged.pdf).

a. Protect existing eelgrass habitat in San Francisco Bay through no net loss to existing beds.

b. Establish eelgrass reserves.

c. Identify and protect areas in San Francisco Bay for future eelgrass expansion, restoration, or creation.

d. Protect existing widgeon grass habitat in San Francisco Bay.

e. Protect existing sago pondweed habitat in San Francisco Bay.

f. Increase native eelgrass populations in San Francisco Bay within 8,000 acres of suitable subtidal/intertidal area over a 50-year time frame using a phased approach under a program of adaptive management.

5. Macroalgal Beds

Beds of macroalgae constitute the third biogenic habitat along with submerged aquatic vegetation and shellfish beds in San Francisco Bay and are by far the smallest in total extent. Four species of macroalgae were listed by NOAA (NMFS 2007) as sufficiently abundant to form beds: *Ulva spp*., *Gracilaria pacifica*, *Fucus gardneri*, and the introduced *Sargassum muticum*. The extent and characteristics of algal beds in San Francisco Estuary are poorly known. Like eelgrass beds, macroalgal beds provide both physical habitat and food for numerous organisms. Also like eelgrass beds, subtidal macroalgal beds can alter flow fields, providing small organisms with shelter from currents and predators, and can trap sediments, alter sediment chemistry, and provide a substrate for spawning. The red algae, *Gracilaria/Gracilariopsis spp*., are important substrate for herring roe in the bay. Intertidal macroalgae can retain water, providing a refuge for intertidal organisms like juvenile Dungeness crabs during low tides.

In contrast to eelgrass, many macroalgae provide a suitable food source to a variety of grazers, predominantly macroinvertebrates. At least one amphipod species, *Amphithoe valida*, readily consumes *Gracilaria sp*. Gulls and cormorants will pick macroalgae from the intertidal beach wrack to line their nests. The wrack produced by macroalgae is an important food source for invertebrates living interstitially on beaches, mudflats, and marshes. These invertebrates in turn provide a food source for shorebirds and many other species along the shore. In contrast to tropical regions where many herbivorous fish species feed on macroalgae, a relatively small number of fish species in temperate regions use macroalgae as a substantial part of the diet. The topsmelt, *Atherinops affinis*, common in San Francisco Bay, can feed on macroalgae (Logothetis et al. 2001). There is no published information on the importance of algal beds in support of populations of consumer organisms in the bay. Although algal beds constitute biogenic habitats, it is not clear whether they are always a desirable habitat.

Macroalgal beds are threatened by eutrophication. In addition to eutrophication, intertidal algal beds are vulnerable to other human disturbances such as trampling and recreational harvesting, as well as oil spills and the use of dispersants during cleanup (Foster et al. 1998).

The overarching goals that should be considered in restoration or protection activities are outlined below. See the Subtidal Habitat Goals report for more detailed restoration and protection measures of macroalgal beds (http://www.sfbaysubtidal.org/PDFS/09-Macroalgal.pdf)

a. Protect San Francisco Bay *Fucus* beds through no net loss to existing beds.

b. Protect San Francisco Bay *Gracilaria* beds through no net loss to existing beds.

6. 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 were built to protect shorelines and shoreline structures, for transportation and recreation, to support industry, and more recently for restoration (oyster shell and artificial reef structures). Artificial structures 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.

Like rocky substrates, artificial structures alter wave patterns and flow fields, induce local scouring and deposition of sediment, and provide physical habitat. 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. 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. 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.

Many of the artificial structures in the bay have wooden pilings that were injected with creosote to minimize fouling. Creosote contains polycyclic aromatic hydrocarbons (PAHs) that are persistent in the environment and toxic to some organisms. 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.

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.

The overarching goals that should be considered in restoration or protection activities are outlined below. See the Subtidal Habitat Goals report for more detailed restoration and protection measures of artificial structures (http://www.sfbaysubtidal.org/PDFS/06-Artificial%20Structures.pdf).

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

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

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

d. 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.

7. Habitat Integration/Living Shorelines

Using habitat integration in restoration provides the linking of restoration projects in subtidal habitats to those in adjacent marshes and uplands. Benefits of habitat integration arise from landscape-scale ecological processes, i.e., processes that extend over more than one habitat type. For example, restoration at a nearshore subtidal site may enhance sediment retention that would favor persistence of an adjacent marsh. Many ecosystem processes occur at a larger scale than individual habitats, and habitat integration as a restoration tool can expand the habitat functions gained by the restoration. Ecosystem processes and habitat functions that can benefit are biogeochemical processing, net organic production, movement of organisms, and reduction in the effects of habitat fragmentation. Using habitat integration to link nearby habitats can help reduce the sometime high cost of restoration.

It may also be possible to design restoration of subtidal habitats not only to protect and interact with marshes and uplands, but also as a substitute for or a complement to seawalls and breakwaters used to protect vulnerable shorelines. With rising sea level and ongoing loss of sediment, the value of shoreline protection and the consequences of erosion at unprotected shorelines become more apparent. The use of soft structures and incorporation of living materials into shoreline protection schemes, or living shorelines, can benefit habitats and ecosystem processes as well as protect shorelines from climate change impacts. Living shorelines can protect adjacent vulnerable shorelines, minimize externalities such as the transfer of erosion, and increase the extent of potentially valuable subtidal habitat.

The overarching goals that should be considered in restoration activities are outlined below. See the Subtidal Habitat Goals report for more detailed restoration measures for habitat integration and living shorelines (http://www.sfbaysubtidal.org/PDFS/10-Integrated.pdf).

a. Explore the integration of upland, intertidal, and subtidal habitats in San Francisco Bay.

b. Integrate habitat flexibility to increase resilience in the face of long-term change at habitat restoration sites around the bay.

c. Explore the use of living shoreline projects as a way to achieve multiple benefits in future shoreline restoration.

Appendix 2. References

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