California Marine Life Protection Act Initiative

Responses to San Francisco Bay Science Questions to Accompany the San Francisco Bay Options Report: Considering MPA Planning

June 2011

The San Francisco Bay Study Region (SFSR) is the fifth and final study region in which marine protected areas might be redesigned consistent with the California Marine Life Protection Act (MLPA); it has not yet been determined whether an MPA planning process will take place in the region, nor has a framework been identified for such a process.

A report prepared by the MLPA Initiative provides an initial look at the SFSR and identifies a limited, yet achievable, range of options for how, if at all, to approach MPA planning in the region. The report ("Options Report") provides background information on the unique setting of the SFSR, identifies existing bay projects, and considers lessons learned from previous MPA planning processes.

In developing the Options Report, a handful of science questions arose, responses to which could prove helpful in informing decisions about MPA planning in the SFSR. To help provide responses to those questions, the MLPA Initiative convened a work group composed of current MLPA Master Plan Science Advisory Team members and scientists with expertise in the San Francisco Bay (see Appendix A for the list of work group members). This document complements the Options Report and specifically addresses six questions:

1. From an ecological perspective, what are the general boundaries of San Francisco Bay and what criteria would be appropriate for specifically defining these boundaries?

2. What is the preliminary list of key and unique habitats to target for protection in San Francisco Bay? How are these habitats different from comparable habitats on the open coast? To the extent possible, provide general information about the abundance and spatial distribution of these habitats.

3. How can the goals of the MLPA be met for ecosystems within San Francisco Bay? What are the pertinent threats in the SFSR that may impair the efficacy of MPAs? What can an MLPA Initiative-type plannning process add to existing management efforts?

4. What are the consequences to California's statewide system of MPAs of not including San Francisco Bay in the network?

5. How might the existing MPA design guidelines in the master plan for MPAs be applicable to the MLPA San Francisco Bay Study Region? What types of modifications to the guidelines might be necessary to inform sound MPA design in the SFSR?

6. What are some examples of key species likely to benefit from MPAs in the SFSR?

San Francisco Bay Science Questions

1. ***From an ecological perspective, what are the boundaries of San Francisco Bay generally, and what criteria would be appropriate for defining these boundaries specifically?***

Response: The current boundaries of the SFSR are defined in *California Marine Life Protection Act Master Plan for Marine Protected Areas* as the areas of San Francisco Bay between the Carquinez Bridge to the east, and the Golden Gate Bridge to the west (including the south bay), that fall below mean high water (MHW) (DFG 2008). The existing boundaries were largely determined by management considerations, and thus may not reflect the ecologically relevant boundaries of the marine portions of the bay. Furthermore, the generalized description lacks the detail needed to delineate the location of the study region boundary on a site-specific basis, or provide a foundation for adapting the boundary in response to environmental changes, including sea level rise.

The estuarine system comprising San Francisco Bay is characterized by the confluence of fresh and salt water, and as such, bay habitats and the communities they support are heavily influenced by upstream conditions, including the volume and quality of freshwater flowing into the bay, as well as oceanic conditions (Kimmerer 2004). Although upstream and downstream linkages are important for understanding the bay ecosystem, defining clear boundaries for the SFSR will necessarily exclude some important and interconnected habitats both upstream and on the open coast.

In considering ecological criteria for defining the extent of the SFSR, the work group concluded that no single criterion would be sufficient to address the variety of boundary decisions that need to be made, but identified three main criteria that should be used to inform these decisions: tidal influence, salinity, and biological communities. In general, an area should meet all three of these criteria to be included within the SFSR.

Tidal influence is indicative of connectivity with the rest of the bay ecosystem through exchange of water masses, propagules, nutrients, and other materials, and thus is an important criterion for inclusion of an area within the SFSR. The zone of tidal influence includes areas at or below mean higher high water. The term “head of tide” is commonly used to define the upstream extent of an estuary; however, this definition alone may not be sufficient to define the SFSR because tidal influence often extends upriver to the City of Sacramento and beyond, including many tidally fresh habitats with no marine influence (Kimmerer 2004). Thus, while tidal influence is necessary, it is not a sufficient criterion for inclusion in the SFSR. Some confusion may arise in applying this criterion with respect to wetlands in the bay that occur behind dikes and tide gates, and thus are subject to muted or infrequent tidal influence. In these cases the degree of connectivity with the rest of the bay should be considered.

Salinity is a reasonable proxy for marine influence, but it can vary dramatically with river flow into the estuary, depth, and tidal cycle. One measure of salinity commonly used to describe the flow state of the estuary is “X2,” the distance from the Golden Gate up the axis of the estuary to where the tidally-averaged near-bottom salinity is 2 (as measured using the UNESCO Practical Salinity Scale of 1978, a unitless measurement of the concentration of dissolved salts in water in the form of a conductivity ratio).The threshold salinity of 2 is significant because it unambiguously indicates marine influence and defines the landward limit of salinity stratification (Kimmerer 2004). However, because the location of the low salinity transition zone marked by X2 varies markedly within and between years, this threshold may be most useful when averaged over time to define general estuarine boundaries, and may not be useful for determining specific boundary placement in smaller tributaries and tidal wetlands where extensive salinity records are not available.

Biological communities generally reflect environmental conditions, particularly salinity, integrated across timescales that are relevant to the life cycles of organisms. Because the presence of salt-tolerant plant communities, which can be partially assessed using remote sensing data, and sessile invertebrate communities can reflect both current and historical conditions, this criterion may be the most accurate of the three for defining specific boundary placement, provided that biological community information is available.

The work group recommends that the three criteria listed above be used to define the specific boundaries of the SFSR, and that decisions be based upon the best readily available information in any given location. In many cases, information may not be available to confirm that all three criteria are met; however, this should not prevent decision-making based upon the best available information and professional judgment.

Based on the criteria above, the work group agrees that Suisun Bay is an integral component of the San Francisco Bay ecosystem that is currently not included within the study region boundaries. Extensive salinity and flow records show that the low salinity transition zone marked by X2 is most often found within Suisun Bay, indicating that habitats and organisms within the bay are frequently exposed to marine influence. Furthermore, ecosystem management efforts regulate springtime flow so as to ensure that the location of X2 is west of the confluence of the San Joaquin and the Sacramento rivers; thus, marine influence east of this confluence should be minimal in the spring, and is typically most prominent during late summer and fall (Kimmerer 2004). With respect to the other two criteria, tidal influence and salt-tolerant biological communities are well documented throughout Suisun Bay (Mattern et al. 2002, Moyle et al. 2010, O'Rear and Moyle 2010, Peterson and Vayssieres 2010). Thus the work group recommends that the boundaries of the SFSR be expanded eastward to include Suisun Bay and that the upstream boundary of the study region be drawn near the confluence of the San Joaquin and Sacramento rivers, in the vicinity of Sherman Island.

2. ***What is the preliminary list of key and unique habitats to target for protection in San Francisco Bay? How are these habitats different from comparable habitats on the open coast? To the extent possible, provide general information about the abundance and spatial distribution of these habitats.***

Response: The SFSR is located entirely within the largest and most complex estuarine system in California, San Francisco Bay. As in previous MLPA study regions, the list of 'key' habitats should be refined to accurately reflect the variety of habitats that occur within the study region and the roles they play in supporting the marine populations, biodiversity, and functions of the bay ecosystem. Informed by the list of 'key' habitats used in previous study regions as well as the San Francisco Bay Subtidal Goals Project (Subtidal Goals 2010) and the Baylands Ecosystem Habitat Goals Project (Goals Project 1999), the work group identified eight potential 'key' habitats to target for inclusion in MPAs, listed below. Additionally, the work group identified three habitat categories that warrant further consideration; two of these are anthropogenic habitats that can provide ecological benefits but may not be universally appropriate to target for protection.

Potential 'Key' Habitats in the SFSR

Sandy beach habitat is relatively rare in the bay, occurring primarily in high-energy areas, including narrow straits and areas near the mouth of the bay (Subtidal Goals 2010). Sandy beaches within the bay likely support aquatic communities that differ from those on sandy beaches of the open coast and vary across salinity gradients.

Rocky shore habitat is also relatively rare in the bay, occurring primarily in high-energy areas, including islands, narrow straits, and areas near the mouth of the bay (Subtidal Goals 2010). Rocky shores within the bay likely support aquatic communities that differ from those on the open coast and vary across salinity gradients.

Soft bottom subtidal habitat is likely the most abundant habitat in the San Francisco Bay ecosystem, occurring throughout the bay and ranging from fine-grained mud or silt to coarse-grained pebbles and shell hash (Subtidal Goals 2010). Soft bottom habitats in the bay support aquatic communities that differ from those on the open coast and vary across salinity, energy, and depth gradients (Subtidal Goals 2010). These variations in soft bottom habitats and communities should be considered in designing MPAs. Further division of this habitat category based on depth, salinity, or grain size may be necessary to accurately reflect the diversity of soft bottom associated communities in the bay.

Rock subtidal habitat is relatively rare in the bay, occurring primarily in high-energy areas including narrow straits and areas near the mouth of the bay (Subtidal Goals 2010). Rocky subtidal habitats are likely to support marine communities that differ from those on the nearby open coast. It may be necessary to further divide this habitat into several depth or salinity categories to accurately reflect the diversity of rock associated communities in the bay.

Shellfish beds, especially native oyster (*Ostrea lurida*) and native mussel (*Mytilus trossulus*) beds play important roles in the San Francisco Bay ecosystem, filtering water and providing habitat structure for other species (Subtidal Goals 2010). Shellfish beds formed by these two species do not typically occur on the open coast, but occur in smaller estuaries elsewhere in the state. Although shellfish beds tend to occur in areas of rocky substrate, they should be considered a separate habitat category due to the unique communities they support. Shellfish beds composed primarily of non-native species also exist within the bay (Subtidal Goals 2010), but these may not be desirable targets for protection by MPAs.

Seagrass beds, especially eelgrass (*Zostera marina*), and widgeongrass (*Ruppia maritima*) play important roles in the bay ecosystem, providing food and habitat structure for a variety of other species (Subtidal Goals 2010). Other types of submerged aquatic vegetation that occur within the bay and may be appropriate target for protection include two surfgrass species (*Phyllospadix torreyi* and *P. scouleri*), and sago pondweed (S*tuckenia pectinatus*) (Subtidal Goals 2010). The two surfgrass species also occur along the open coast, but eelgrass is typically confined to estuarine environments, including smaller estuaries elsewhere in the state. Widgeongrass and sago pondweed occur in brackish to fresh water and thus are unlikely to occur on the open coast, but may occur in streams and estuaries elsewhere in the state.

Tidal marsh habitats are still relatively abundant in the bay although human activities have drastically reduced their extent as compared to historical levels. The category 'tidal marsh' encompasses a range of communities that vary across salinity and energy gradients (Goals Project 1999), from salt marsh communities dominated by pickleweed (*Sarcocornia pacifica*) and native cordgrass (*Spartina foliosa*), to low-salinity communities dominated by tule (*Schoenoplectus* spp.). Tidal marshes act as nurseries and foraging habitat for fish and other organisms, and typically occur in estuarine embayments including smaller estuaries elsewhere in the state, but are rare on the open coast. It may be necessary to further divide this habitat into several salinity categories to accurately reflect the diversity of tidal marsh communities in the bay.

Tidal flat habitats are relatively abundant in the more saline portions of the bay and often occur near tidal marshes. These areas of intertidal, fine-grained sediments without emergent vegetation support unique marine communities, including shorebirds and their invertebrate prey (Goals Project 1999). Tidal flats typically occur in estuarine embayments including smaller estuaries elsewhere in the state, but are rare on the open coast. Tidal flat communities may vary across salinity and other environmental gradients, thus it may be desirable to divide this habitat into several categories to accurately reflect the diversity of tidal flat communities in the bay.

Habitats that Warrant Further Consideration

Macroalgal beds, especially native *Fucus gardneri* beds, play an important role in the bay ecosystem, providing food and habitat structure for a variety of species (Subtidal Goals 2010). The distribution of macroalgal beds in the bay is not well known, but they primarily co-occur with rocky substrate, so the identification of a separate habitat category for MPA planning may be unnecessary. Two native macroalgal types, *Gracilaria pacifica* and *Ulva* spp., may also form beds on soft or cobble substrates, but these are likely to be more ephemeral due to the rapid growth rates of these species (Subtidal Goals 2010), and thus may not be appropriate targets for protection. The invasive species *Sargassum muticum* may also form macroalgal beds, but these would not be desirable to target for protection. Macroalgal beds in the bay provide biogenic habitat analogous to that provided by kelp forests on the open coast, but differ from kelp forests in algal composition and the aquatic communities they support.

Hypersaline ponds in San Francisco Bay are almost exclusively man-made structures built for the concentration and harvest of salt, although many are now managed to maximize their value to wildlife (Goals Project 1999). Salt ponds provide critical habitat and food resources for shorebirds and waterfowl, and may play a similar ecosystem function to, now rare, marsh pans (large and occasionally hypersaline ponds in well developed tidal marshes). Hypersaline ponds, especially those restored or otherwise managed to support native biodiversity, may be appropriate to target for protection in MPAs, but further consideration is needed to identify the specific characteristics of these ponds that are most likely to contribute to the goals of the MLPA. Small hypersaline pondsexist in estuaries elsewhere in the state, but the greatest concentration of such ponds occurs in San Francisco Bay.

Artificial structures are abundant in San Francisco Bay and come in a variety of forms, including pilings, rip-rap barriers, seawalls, docks, derelict vessels, pipelines, and mooring buoys (Subtidal Goals 2010). Artificial structures can provide habitat for native species, including herring and marine birds, but they can also have undesirable effects on the bay ecosystem by altering current and sedimentation patterns, reducing light availability, releasing toxic contaminants, and harboring invasive species. Creosote pilings are of special concern because they are numerous (Subtidal Goals 2010 estimates 33,000 derelict creosote pilings in the bay) and release hydrocarbon compounds that are toxic to a variety of marine life. Rock revetments (riprap) are also abundant in the bay and may provide some of the same functions as natural rock substrate, but their location in areas historically dominated by soft substrates may encourage growth of invasive species and alter current patterns, causing erosion in more natural habitats nearby (Subtidal Goals 2010). The sheer abundance of artificial structures in the bay, and their potentially complex role in the ecosystem, warrants consideration in MPA planning, although some types of artificial structures may not be appropriate targets for protection within MPAs. Artificial structures occur elsewhere along the California coast, but they are more abundant in the SFSR as compared to other study regions.

The habitats described here and the communities they support vary across salinity and other environmental gradients in the bay, thus the work group recommends that MPAs are placed so as to include ‘key’ habitats across a range of environmental conditions to encompass the full biodiversity associated with the San Francisco Bay ecosystem. In order to ensure that the diversity of habitats and aquatic communities in the bay is represented in an MPA network, it may be desirable to subdivide habitats based upon salinity or other environmental factors that have a substantial impact on the associated aquatic communities. In previous MLPA study regions, habitats were subdivided into depth categories based on a broad body of knowledge indicating that biological communities on the open coast vary with depth. Within many estuarine systems, community variation across salinity gradients is pronounced and well documented (Allen et al. 2006, Moyle and Cech 2000), thus the work group recommends division of habitats based upon salinity zones.

The most universally accepted system for classifying estuarine waters by salinity is the Venice System (Anonymous 1958), which roughly defines salinity zones that are likely to be ecologically relevant in a variety of marine and estuarine systems around the world. The Venice system, suggests division of San Francisco Bay into three salinity zones: oligohaline (low salinity, approximately 0.5-5[1]), mesohaline (intermediate salinity, approximately 5-18), and polyhaline (higher salinity, approximately 18-30). While the Venice system may provide convenient and widely accepted salinity categories, the biological relevance of these categories is supported by some studies (Ysebaert et al. 1998), questioned by others (Attrill and Rundle 2002, Bulgur et al. 1993), and has not been explicitly examined in San Francisco Bay. Furthermore, salinity is dynamic with marked diurnal, seasonal, and annual fluctuations within San Francisco Bay, which will complicate efforts to delineate static salinity zones for the purpose of habitat classification. Thus the work group recommends that the Venice system be used as a starting point, and that empirical ecological data collected from multiple habitats within the bay be used to refine or revise these salinity zones to ensure their biological relevance. Once salinity zones are defined and mapped, the work group recommends that habitat categories are subdivided by salinity (i.e. oligohaline, mesohaline, or polyhaline tidal marsh) and each resultant habitat type is represented in the MPA network. Alternatively habitat categories could be left broad and habitats could be replicated, to the extent possible, in each of the defined salinity zones.

In previous MLPA study regions, ‘bioregions’ were used to delineate regional variations in marine communities within the same habitat. These bioregions were derived from ecological community data and generally reflected environmental gradients, differences in geology or oceanography, or barriers to dispersal of marine organisms. The geographic extent of the SFSR is limited relative to previous MLPA study regions, and the various basins of the bay are interconnected by exchange of water masses, thus environmental gradients (other than salinity) and connectivity barriers are likely to be limited. Nonetheless, the work group recommends analysis of ecological data from the bay to determine whether differences in communities in like habitat (i.e. salt marshes in the same salinity zone support different communities) warrant the delineation of bioregions.

3. How can the goals of the MLPA be met for ecosystems within San Francisco Bay? What are the pertinent threats in SFB that may impair the efficacy of MPAs? What can an MLPA Initiative-type planning process add to existing management efforts?

Response: There are multiple factors in the urbanized San Francisco Bay area that are likely to affect the design and eventual efficacy of an MPA network, some of which may not be explicitly addressed by MPAs. MPAs may regulate any activity that results in take of or damage to living marine resources, including habitat modification activities, but relatively few MPAs designed in the MLPA Initiative planning process have explicitly addressed indirect take activities. Examples of threats that may not be explicitly addressed by MPAs include impaired water and sediment quality, the introduction and spread of invasive species, and dredging and other habitat modifications associated with shipping and industry. Although MPAs are clearly not a comprehensive solution to address all the ecological threats in the bay, they are an

[1] Salinity indicated in practical salinity units, which are unitless.

important tool that may supplement existing management efforts. Some ways that MPAs may add to existing management efforts in the bay include:

1. adding an umbrella of permanency and consistency to existing regulations and unifying management efforts pursued by numerous agencies and municipalities;
2. ameliorating cumulative impacts of multiple stressors, by restricting extractive activities in sensitive areas;
3. providing an effective framework for focusing on conservation of bay-wide biodiversity, the health of ecosystems, and the interactions within and between ecosystems through the protection of habitats and biological communities;
4. providing an important avenue for communication and outreach about ecosystem health and threats in the bay; and
5. providing incentives for preservation of ecosystem services, including the role of tidal marshes in buffering shorelines against sea level rise.

If carefully coordinated with numerous existing planning, management, and restoration efforts currently underway in the bay, the work group concluded that MPAs are likely to achieve the goals of the MLPA and contribute valuably to the statewide network. MPAs in the SFSR are likely to conserve biodiversity and ecosystem function by protecting ecosystems from extractive or damaging activities (goal 1), and thus protect marine life populations, in part, by conserving the habitats and ecosystem functions upon which they depend (goal 2). Furthermore, MPAs in the SFSR will contribute to the statewide network by protecting habitats and biological communities that are rare or do not occur elsewhere in the state (goal 4), and by providing connectivity between protected populations in the bay and on the open coast (goal 6). Due to the proximity of the SFSR to bay area cities, MPAs in the region are likely to provide valuable recreation, education, and research opportunities and enhance awareness of threats facing the bay ecosystem (goal 3).

In previous MLPA study regions, especially the urbanized south coast study region, threats to MPA effectiveness similar to those in San Francisco Bay were identified and stakeholders were advised to avoid locating MPAs in areas impacted by these external threats. Similarly, the work group recommends that external threats be identified and mapped to the extent possible and that this information be considered in choosing MPA locations in San Francisco Bay. A more detailed list of threats that should be considered in MPA planning includes water quality, shipping, petroleum industry, power plants, non-native species, habitat modification, and human disturbance.

Water quality: San Francisco Bay forms an estuary for the largest watershed in California, the Sacramento and San Joaquin River system of the Central Valley. These rivers drain immense agricultural landscapes, and also serve to carry wastes from municipal wastewater, landfills, and storm water runoff (CRWQCB 2010). There are 12 major industrial and 23 publicly-owned wastewater treatment facilities that discharge into the bay (including Suisun Bay), not counting other sources located upstream on major tributaries to the bay (CRWQCB 2010[2]). Landfills near the shores of the bay threaten to introduce leachate into the bay's waters (CRWQCB 2010), and urban areas in the bay's watershed are sources of diffuse pollution including seasonal storm water runoff and agricultural and other runoff during non-storm periods. Various parts of the bay are impaired for a variety of pollutants including pesticides, nutrients, polycyclic aromatic hydrocarbons (PAHs), metals, and pathogens (SWRCB 2010a). Pollutants are known to contaminate widespread areas of sediment in the bay; these pollutants include legacy pollutants such as mercury and polychlorinated biphenyls (PCBs) which are known to bioaccumulate in the food chain, as well as currently used pesticides and metals that may cause sediment toxicity. Sediments and benthic communities in many parts of the bay are known to be impacted by these constituents (CRWQCB 2010).

Shipping: Commercial shipping and recreational boating are important activities within the bay. Commercial and recreational vessels are known to have a variety of discharges including ballast water and hull fouling (which can contain non-native species), sewage, gray water, bilge water, and deck runoff, as well as posing an oil spill threat. This threat was realized recently when the Cosco Busan container ship struck the San Francisco–Oakland Bay Bridge in 2007, spilling roughly 50,000 gallons of bunker fuel into the bay's waters. Dredging to maintain shipping channels and harbors is extensive, and has impacts such as benthic community disturbance, suspension of contaminated sediment, and water column turbidity (Subtidal Goals 2010).There are also four approved dredge spoil disposal sites in the Bay (CRWQCB 2010).

Petroleum industry: There is an extensive infrastructure around the bay devoted to petroleum refining and transportation. Along with oil tankers and shipping traffic, these facilities pose an oil spill threat. Although potentially catastrophic when they occur, large oil spills are rare with less than 10% of oil spills involving more than 100 gallons of oil (Etkin 2001). Regardless of size, oil spills threaten marine and estuarine aquatic life, wildlife, and habitat including submerged and emergent vegetation (Subtidal Goals 2010).

Power plants: Three power plants that use once-through cooling are located in San Francisco Bay and the Sacramento-San Joaquin River Delta (SWRCB 2010b), although one of these plants (Potrero, in San Francisco) is currently shutdown. The remaining two plants are the Pittsburg and Contra Costa Generating Stations. Cooling water intakes harm estuarine life due to entrainment and impingement mortality as well as discharging thermal wastes (EPRI 2007).

Non-native species: San Francisco Bay is also home to over 200 non-native species, many of which may have been introduced from ballast water and shedding from vessel hulls (Cohen and Carlton 1998). Non-native species are considered biological pollutants and the bay is impaired due to their presence.

Habitat modification is extensive and ongoing in San Francisco Bay with permanent ecosystem-wide consequences. Common habitat modifications include shoreline armoring with riprap and seawalls, creating and maintaining bridges and marina facilities,

[2] The number of discharge points determined from a review of Figures 4-1 and 4-2 in the referenced Basin Plan.

diking and filling wetlands, and disrupting natural salinity conditions by the control and diversion of upstream flows from the Sacramento and San Joaquin rivers (Subtidal Goals 2010). As rising sea level increases flood risk to nearly $100 billion worth of infrastructure in California, roughly two-thirds of which is concentrated on San Francisco Bay (Pacific Institute 2009), pressure to armor shorelines is likely to increase. While MPAs may have little or no impact on habitats that have *already* been modified by human activities, they can restrict future habitat modification and provide incentives for the preservation of natural tidal marsh habitats to buffer against sea level rise.

Human disturbance incidental to extractive and non-extractive activities is extensive in the bay and includes trampling of aquatic life and disturbance of breeding and resting sites for birds and marine mammals (Goals Project 2000). Although most MPAs do not restrict access and thus are unlikely to prevent disturbance events, MPAs may reduce disturbances by restricting some extractive activities. In some areas, special closures that restrict access in order to protect especially vulnerable wildlife populations, may be appropriate. San Francisco Bay provides important habitat for waterbirds and shorebirds and is a key site along the Pacific flyway. With recent declines in marine diving ducks in the bay (Susan Wainwright DeLaCruz, USGS, personal communication), some important feeding and resting areas in the bay appear to be persistent over time and could potentially be served by MPAs or special closures. Other areas that provide shelter and/or resting spots to seabirds and marine mammals (e.g., small inlets in Marin County, Brooks Island, Alcatraz, Castro Rocks) may also benefit from protection in MPAs or special closures. No-boating areas could also be considered to protect sensitive habitats such as eelgrass.

4. ***What are the consequences to California's statewide system of MPAs of not including San Francisco Bay in the network?***

Response: As the largest and most complex estuarine system in California, San Francisco Bay supports a wide array of estuarine, marine, and anadromous species at various points in their life cycle. A variety of commercially and recreationally harvested species that are commonly associated with the open coast, use habitats within the bay as nursery or breeding habitats, including Pacific herring, California halibut, starry flounder and other flatfishes, salmon, Dungeness crab, and a number of sharks, skates, and rays (DFG 2001, DFG 2010, Goals Project 2000). Pacific herring, for example, are an important forage fish on the open coast, but breed primarily in estuaries; San Francisco Bay represents the only major herring spawning site south of Puget Sound.

The bay also supports a number of predominantly estuarine species including a variety of sharks, skates, and rays, sturgeon, flatfishes, native oysters, mussels, several native species of bay shrimp (genus *Crangon*) that have been commercially important in the past, numerous other invertebrates, and a wide variety of estuarine plants, seagrasses, and algae (DFG 2001, DFG 2010, Goals Project 2000). Habitats within the bay support seasonal and year-round populations of marine birds and mammals including shorebirds, waterfowl, diving birds, seabirds, harbor porpoises, harbor seals, and sea lions (Goals Project 2000). The bay and associated delta area also provides critical habitat for a number of rare, threatened, and endangered species of fish, birds, invertebrates, and plants, including: delta smelt (*Hypomesus transpacificus*), Sacramento splittail (*Pogonichthys macrolepidotus*), tidewater goby (*Eucyclogobius newberryi*), longfin smelt (*Spirinchus thaleichthys*), California clapper rail (*Rallus longirostris obsoletus*), California black rail (*Laterallus jamaicensis*), California least tern (*Sterna antillarum browni*), western snowy plover (*Charadrius alexandrinus nivosus*), Suisun thistle (*Cirsium hydrophilum hydrophilum*), and soft bird's-beak (*Cordylanthus mollis mollis*) (SFBJV 2000). By excluding San Francisco Bay from California's statewide MPA planning effort, the state would lose a valuable opportunity to target certain estuarine species for protection by MPAs, and to enhance the important ecological linkages between estuarine and open coast habitats.

The sheer size, complexity, and variability of the San Francisco Bay ecosystem is unique in California and thus harbors biological communities not found in many of California's smaller estuaries. Indeed, the San Francisco Bay estuary harbors roughly 15 endemic or near-endemic species, including fish, small mammals, birds, and marsh plants (Goals Project 2000), in contrast to low rates of endemism in California's smaller estuaries. Although the 'key' habitats identified in this document (see question 2, above) exist in many smaller estuaries, their configuration, both in terms of patch size and proximity to one another, is unique in San Francisco Bay with consequences for estuarine communities (Goals Project 1999, Subtidal Goals 2010). In order to represent the unique estuarine communities of San Francisco Bay within the statewide system of MPAs, the network should be extended into San Francisco Bay.

5. ***How might the existing MPA design guidelines in the master plan for MPAs be applicable to the MLPA San Francisco Bay Study Region? What types of modifications to the guidelines might be necessary to inform sound MPA design in the SFSR?***

Response: Four types of MPA design guidelines were used throughout the MLPA Initiative MPA planning process in the previous open coast study regions: 1) habitat representation, 2) habitat replication, 3) MPA size, and 4) MPA (habitat) spacing (DFG 2008). Each of these guidelines and its application to MPA design is described in further detail below along with information about how the guideline could be applied or modified to reflect the unique aspects of the SFSR.

The **habitat representation guideline** specifies that every 'key' marine habitat should be represented in the MPA network in order to protect the diversity of species that live in different habitats and those that move among habitats over their lifetime. The habitat representation guideline, in combination with a list of 'key' habitats identified for each study region and associated habitat maps, has served to identify the habitats to target for protection in MPAs. The scientific principles underlying this guideline remain constant, thus there is no need to tailor this guideline to the SFSR, other than identifying the habitats within the bay that should be targeted for protection in order to achieve the goals of the MLPA. A preliminary list of 'key' habitats is identified in the answer to question 2, above. Because San Francisco Bay contains habitats and communities not found in other California estuaries, or along the open coast, representation of 'key' habitats within the bay will play an important role in ensuring that the statewide system of MPAs represents the diversity of species and communities in California waters.

The **habitat replication guideline** specifies that 'key' habitats should be replicated across geographic and environmental gradients to protect the diversity of species and communities that occur across such gradients. In previous MLPA study regions, 'bioregions' have been used to delineate the environmental gradients that are most relevant to habitat replication. In the SFSR salinity defines the environmental gradient that is likely most relevant to habitat replication (see response to question 2). The practical application of the habitat replication guideline in previous MLPA study regions has encouraged the inclusion of each 'key' habitat in multiple MPAs distributed across the study region, with at least one 'replicate' of each habitat included in each 'bioregion'. In the SFSR, this guideline should encourage replication of 'key' habitats across biologically-relevant salinity zones. If a future decision is made to sub-divide habitat categories in the SFSR by salinity zone, as suggested in the response to question 2, replication of habitats across salinity gradients will be achieved as long as every 'key' habitat is replicated (to the extent possible) in the MPA network. If a decision is made to leave habitat categories broad, every 'key' habitat should be replicated (to the extent possible) in each of the biologically-relevant salinity zones.

In previous MLPA study regions, habitat replicates have been defined as sufficient habitat extent to encompass 90% of the biodiversity associated with the specific habitat. Assessments of the extent of habitat needed to encompass 90% of biodiversity have been calculated separately for each key habitat based upon empirical data collected from the study region, wherever possible. In the SFSR, similar ecological information should be used to define the extent of each habitat needed to constitute a 'replicate'. The scientific principles underlying the habitat replication guideline remain constant, thus the application of this guideline to the SFSR requires definition of key habitats, relevant environmental gradients (i.e. salinity), and assessment of the extent of each key habitat needed to encompass 90% of associated biodiversity.

The **MPA size guidelines** were developed to provide for the persistence of bottom-dwelling fish and invertebrates within MPAs. There are two components to the size guidelines, both based upon the movement patterns of a wide range of marine species. The alongshore size guideline specifies that MPAs should have an alongshore extent of 3-6 miles, or preferably 6-12 miles to encompass the within-habitat movements of adult organisms. The offshore size guideline specifies that MPAs should extend from the shoreline to deep waters offshore to encompass the between-habitat movements of organisms throughout their life cycle, and to protect species that inhabit different depth zones. In the open coast environment, the maximum offshore extent of an MPA is dictated by the boundary of state waters, 3 nautical miles from shore. Thus the two guidelines have been combined, simplified, and made operational as an areal measurement with the minimum size range of 9-18 square miles and a preferred size range of 18-36 square miles.

In San Francisco Bay, although the conceptual basis of the size guidelines applies, some of the assumptions made in both the articulation and simplification of the guidelines may not be relevant. The guidelines generally assume a linear distribution of habitats along the coast, increasing depth with distance from shore, and a tendency for adult movements to be constrained by both habitat and depth. For example, the guidelines reasonably assume that an organism that inhabits the kelp forest is more likely to travel alongshore, within the band of favorable kelp forest habitat, than it is to move offshore into deeper waters that do not support kelp, or into soft-bottom habitats. In the enclosed environment of San Francisco Bay, where depth does not necessarily increase with distance from shore and depths are similar across broad areas, the assumption of linear habitat distribution and alongshore home ranges, may not apply. Furthermore, the entire bay is within state waters, thus the state water boundary, 3 nautical miles offshore, is irrelevant to MPA planning. However, within the broad expanses of shallow open water and mud flat in the bay, fish and invertebrate home ranges are likely to be more-or-less equivalent in on-offshore and alongshore dimensions, suggesting that square, rather than elongate, MPAs might be most effective. To ensure that the home ranges of a variety of marine species are included within the MPAs, the original alongshore size guidelines can be used to determine the minimum dimensions of these MPAs (i.e. 3 miles on each side), yielding a minimum size of 9 square miles. If MPA planning is undertaken in San Francisco Bay, the work group recommends that a science team carefully consider the application of MPA size guidelines to the bay and make recommendations based upon the movement patterns of organisms and the structural distribution of habitats within the bay.

The MPA (**habitat**) **spacing guideline**, which specifies that MPAs should be located within 31-62 miles of one another, is based upon scales of larval dispersal and intended to ensure connectivity between marine populations in adjacent MPAs. Because many species are habitat-specific, the spacing guideline has been applied as a guideline for spacing between MPAs that contain like habitats. In the practical application to each study region, spacing has been measured as the straight-line distance between adjacent MPAs that are of at least minimum size and where both MPAs include sufficient extent of a particular habitat to constitute a ‘replicate’. Along the mainland coast, straight-line distance between MPAs is likely to be inversely correlated with larval connectivity. But, in areas where currents are known to be complex, such as San Francisco Bay, straight-line distance will provide a poor proxy for larval connectivity, and models of oceanographic currents will be more relevant. Existing information suggests a relatively high degree of connectivity of larvae and water masses across the bay, although connectivity between northern and southern portions of the bay may be reduced in years with low freshwater influx (Walters et al. 1985). Due to the likely high degree connectivity across the bay, spacing guidelines may be of secondary importance relative to the other guidelines. With respect to statewide network connectivity, the San Francisco Bay estuary provides nursery and breeding habitat for a variety of open coast species and contains habitats and communities not found elsewhere in the state (Goals Project 1999, Goals Project 2000, DFG 2001). The importance of protecting habitats within the bay should not be underestimated, but the across-habitat connectivity between the bay and open coast may be difficult to assess. Thus, the work group recommends that known patterns of water circulation and larval connectivity, both within the bay and between the bay and open coast habitats, be considered when applying spacing guidelines to the bay.

6. What are some examples of key species likely to benefit from MPAs in the SFSR?

Response: Species may benefit from MPAs in the bay in several different ways, based on their life history characteristics and movement patterns. Estuarine species that live in the bay throughout their life cycle and are fished commercially or recreationally or subject to other human disturbance may benefit directly from fishing restrictions imposed by MPAs as well as by restricting other activities (such as trampling, dredging, or construction). But, many other organisms use the bay during only a portion of their life cycle. If these species are not vulnerable to fishing or other extractive activities during the life stage they spend within the bay, as is the case with juvenile Dungeness crabs, MPAs may offer only indirect benefits. These indirect benefits result from ecosystem-based protection that preserves ecological linkages and may enhance habitat or food availability, reproductive success, or reduce predation. Most species are likely to receive a combination of direct and indirect benefits from MPAs. In the case of rare or endangered species, the indirect benefits provided by MPAs may ameliorate the impacts of cumulative stressors, and thus play an important role in enhancing local populations.

In order for a species to benefit directly from an MPA, it must be directly or indirectly impacted by some human activity that could be restricted by that MPA. Therefore human impacts, either through extraction or disturbance, are one of the filtering criteria used for generating a list of species likely to benefit from MPAs. The second filtering criterion relates to a species' movement patterns. Because MPAs provide spatial protection, organisms must have movement patterns that are amenable to protection with MPAs of the sizes considered in the MLPA Initiative planning process. Practically speaking, this means that adults must have relatively small home ranges or predictable feature associations, such as breeding aggregations, that are vulnerable to fishing or other human activities that may be restricted by MPAs.

The list of fish, invertebrate, bird, and mammal species in Table 1 does not represent a comprehensive list of species likely to benefit from MPAs in San Francisco Bay, but illustrates some of the more conspicuous species and describes how they meet the filtering criteria listed above.

Table 1. Partial list of species likely to benefit from MPAs in San Francisco Bay[3]

Common Name (*Scientific name*)	Human Impacts	Movement Patterns or Feature Association	Other Relevant Information
Invertebrates			
bay shrimp (*Crangon franciscorum,* and *C. nigricauda*)	Historically an important fishery, now commercially harvested in the bay for bait only. Several non-native species of bay shrimp also inhabit the bay.	Migration from low-salinity juvenile habitat to higher salinity adult habitat both within the bay and on the open coast.	Larvae are planktonic

[3] Information from DFG 2001, DFG 2010. Goals Project 2000, and SFBJV 2000.

Common Name (*Scientific name*)	Human Impacts	Movement Patterns or Feature Association	Other Relevant Information
Dungeness crab (*Cancer magister*)	No commercial or recreational fishing for Dungeness currently allowed in the bay, but intensive fishing on the open coast.	Juveniles use the bay as nursery habitat.	Larvae are planktonic
rock crabs (*Cancer antennarius,* and *C. productus*)	Recreational fishery in the bay.	Likely limited adult movement.	Larvae are planktonic
shore crabs (*Hemigrapsus oregonensis, H. nudus,* and *Pachygrapsus crassipes*)	Can be harvested for bait, populations reduced by introduced species	Likely limited adult movement.	Larvae are planktonic
Olympia oyster (*Ostrea lurida*)	Historically important fishery, now rare due to exploitation, habitat loss, and invasive species.	Very limited adult movement	Larvae are planktonic
California mud snail (*Cerithidea californica*)	Historically abundant, now rare and declining due to competition from an introduced species.	Low adult movement	Non-planktonic larvae.
limpets (*Collisella* spp. and *Tectura* spp.)	Recently abundant but now rare, likely as a result of subsistence harvest.	Low adult movement	Larvae are planktonic
turban snails (*Chlorostoma funebralis*)	Commonly harvested for food/ subsistence	Low adult movement	Long lived, large individuals may be 20 or 30 years old. Larvae are planktonic with short larval duration.
mussels (*Mytilus* spp.)	Commonly harvested for food/ subsistence	Very limited adult movement	Larvae are planktonic
Fishes			
bat ray (*Mylobatis californica*)	Recreational fishery in the bay	Bays serve as nursery habitat. Adult movement studies suggest they return to the same areas of bays year after year.	Live-bearing with low reproductive rate.
brown rockfish (*Sebastes auriculatus*)	Common in the commercial and recreational catch along the open coast, but less commonly caught in the bay.	Juveniles use the bay as nursery habitat. Adults have small home ranges (<2 kilometers) but generally live on the open coast.	Larvae are planktonic
California halibut (*Paralichthys californicus*)	Recreational fishery both in the bay and on the open coast	Seasonal adult movement and use of bay, juveniles use the bay as nursery habitat.	Larvae are planktonic

Common Name (*Scientific name*)	Human Impacts	Movement Patterns or Feature Association	Other Relevant Information
delta smelt (*Hypomesus transpacificus*)	Currently threatened, mainly affected by major habitat alteration and water diversions.	Adults live exclusively in brackish and fresh water areas of the bay, including Suisun Bay.	Currently listed as threatened under federal and endangered under state Endangered Species Acts. Larvae are planktonic.
jacksmelt (*Atherinopsis californiensis*)	Recreational fishery in the bay, (the most commonly caught species in the bay)	Spawn and rear in the bay. Adults are mobile schooling fish, spending time on the open coast.	Larvae are planktonic
leopard shark (*Triakis semifasciata*)	Recreational fishery in the bay	Bays serve as nursery habitat. Adult movement studies suggest they return to the same areas of bays year after year.	Live-bearing with low reproductive rate.
longfin smelt (*Spirinchus thaleichthys*)	Historical commercial fishery, now primarily caught as bycatch of the shrimp fishery.	Adult spawn in fresh and low salinity water, juveniles rear in brackish areas, and move to higher salinity as adults, with limited movements along the open coast.	Currently listed as threatened under the state Endangered Species Act. Larvae are planktonic
Pacific herring (*Clupea pallasii*)	The herring roe fishery is one of the few remaining commercial fisheries in the bay.	Adults are highly mobile, but aggregate in the bay to spawn. The bay is the only major spawning ground south of Puget sound.	Larvae are planktonic
Pacific sanddab (*Citharichthys sordidus*)	Recreational fishery in the bay (among top 10 species caught)	Moderately mobile, not estuarine dependent.	Larvae are planktonic
Pacific staghorn sculpin (*Leptocottus armatus armatus)*	Common in the recreational catch in the bay, but not often targeted	Both adults and juveniles inhabit the bay and have limited home ranges	Larvae are planktonic
Sacramento splittail (*Pogonichthys macrolepidotus*)	Historical recreational fishery.	Although primarily a fresh water species, adults use the brackish waters of Suisun Bay	Federally listed as a threatened species from 1999-2003. Larvae are planktonic.
salmonids (*Oncorhynchus tshawytscha, O. kisutch, and O. mykiss*)	Recreational fishery for Chinook (king) salmon in the bay, but coho salmon and steelhead trout are protected from take.	Adults migrate through the bay en route to freshwater spawning habitats. Juveniles rear in the bay during their transition from riverine to open coast habitats.	Coho salmon and winter run Chinook are currently listed as endangered under the federal Endangered Species Act.
starry flounder (*Platichthys stellatus*)	Recreational fishery in the bay and both recreational and commercial fisheries on the open coast.	Little is known about adult movements, but adults spawn near estuarine mouths and juveniles use low salinity estuarine habitats as nurseries	Larvae are planktonic.

Common Name (*Scientific name*)	**Human Impacts**	**Movement Patterns or Feature Association**	**Other Relevant Information**
white croaker (*Genyonemus lineatus*)	Recreational fishery in the bay and on the open coast	Juveniles use the bay as nursery habitat, adults exhibit movements outside the bay.	Larvae are planktonic.
white sturgeon (*Acipenser transmontanus*)	Recreational fishery in the bay	Juveniles and adults live in the estuary, but breed in the rivers.	Larvae are planktonic.
Birds			
California clapper rail (*Rallus longirostris obsoletus*)	Vulnerable to human disturbance, human-associated predators, and habitat modification.	Small adult home ranges, inhabit tidal salt and brackish marshes with the entire state's population occurring within the bay.	Federally listed endangered species.
California Black Rail (*Laterallus jamaicensis*)	Vulnerable to human disturbance, human-associated predators, and habitat modification	Small adult home ranges, inhabit tidal salt and brackish marshes with the majority of the state's population occurring within the bay.	State listed threatened species
California least tern (*Sterna antillarum browni*)	Vulnerable to human disturbance, introduced terrestrial predators, and reduction in forage base.	Small breeding populations in the bay and important rearing sites where juveniles learn to forage.	Federally listed endangered species. Occurs in the bay April-August.
canvasback (*Aythya valisineria*)	Vulnerable to habitat modification and loss of forage base due to habitat degradation and invasive species.	Migratory species that uses shallow open water areas, salt ponds, and mudflats in the bay during the winter months. No local breeding population.	The bay is among the top 10 wintering sites for canvasbacks in North America.
double-crested cormorant (*Phalacrocorax auritus*)	Vulnerable to human disturbance and loss of prey base.	Several breeding colonies within the bay. Forage primarily on schooling and benthic fishes within the bay and more estuarine than other cormorant species.	Year-round resident in the bay, breeding March-August.
northern pintail (*Anas acuta*)	Vulnerable to habitat modification, recent decline in numbers in the bay area.	Migratory species that uses mudflat, marsh, and salt pond habitats in the bay during the winter months. Small numbers breed in the bay area.	California is the most important overwintering area in North America.
red knot (Calidris canutus)	Vulnerable to human disturbance and habitat modification.	Migratory species uses mudflats within the bay during winter months, but does not breed in the bay area.	San Francisco bay is one of just 3 major overwintering areas on the Pacific coast.
ruddy duck (*Oxyura jamaicensis*)	Vulnerable to habitat modification and loss of forage base.	Migratory species that uses shallow open water areas and salt ponds in the bay during winter months. No local breeding population.	The bay is a critical wintering habitat the roughly 40% of the North American population that winters in California.

Common Name (*Scientific name*)	Human Impacts	Movement Patterns or Feature Association	Other Relevant Information
tule greater white-fronted goose (*Anser albifrons gambelli*)	Vulnerable to habitat modification and loss of forage which is primarily made up of aquatic plants.	Migratory species uses brackish tule marshes in Suisun Bay.	Federally listed threatened species.
western snowy plover (*Charadrius alexandrinus nivosus*)	Vulnerable to human disturbance, predation, and habitat modification.	Both migratory and resident populations use salt ponds and tidal flats as overwintering grounds. Eggs are laid on the ground usually in dry salt ponds.	Federally listed threatened species.
Mammals			
harbor porpoise (*Phocoena phocena*)	Vulnerable to human disturbance and bycatch in the gillnet fishery (currently closed in central California).	Mobile species, recently returned to the bay after more than 60 years of absence.	Low reproductive rate.
harbor seal (*Phoca vitulina*)	Vulnerable to human disturbance, especially during breeding season and at haulout sites.	Mobile species, but the bay supports a local population of 400-500 individuals.	Low reproductive rate.

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