California Marine Life Protection Act Initiative

Draft Methods Used to Evaluate Marine Protected Area Proposals in the MLPA North Coast Study Region

November 17, 2010

NOTE: This draft is for the purpose of presenting new portions to the MLPA Master Plan Science Advisory Team (SAT) at its meeting of November 17-18m 2010. This document does not include Appendix C, Levels of Protection and Associated Catch Information. The appendix will be added when the revised version becomes available, after the above-named SAT meeting. .

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Executive Summary

This document provides the guidelines for design and methods used to evaluate alternative marine protected area (MPA) proposals for the California Marine Life Protection Act (MLPA) North Coast Study Region (NCSR). The MPA proposals are being developed through California's MLPA Initiative, a public/private partnership designed to assist the State of California in implementing the MLPA [California Fish and Game Code, Section 2853]. Developing and evaluating alternative MPA proposals is one component of an iterative process designed to "reexamine and redesign California's MPA system to increase its coherence and its effectiveness at protecting the state's marine life habitat and ecosystems," as mandated by the MLPA.

The MLPA North Coast Regional Stakeholder Group (NCRSG) creates alternative MPA designs that integrate a variety of scientific and personal knowledge. Evaluations of these alternative MPA proposals are conducted relative to the MLPA goals (Table 1-1 in Chapter 1), scientific guidelines described in the *California Marine Life Protection Act Master Plan for Marine Protected Areas* (hereafter called the *Master Plan*) and developed by the MLPA Master Plan Science Advisory Team (SAT), California Department of Fish and Game (DFG) feasibility criteria and California Department of Parks and Recreation guidelines. Potential impacts to commercial and recreational consumptive users also are evaluated. Evaluations are conducted by the SAT, MLPA Initiative staff, and contractors to the MLPA Initiative.

In addition to the guidelines for MPA design and associated evaluation methods, a discussion of the analysis and identification of bioregions in the NCSR is also included in this document. Bioregions are areas of the ocean with reduced population connectivity or distinct biological communities due to specific conditions such as ocean circulation and habitat. The consideration of bioregions in the design and evaluation of a network of MPAs is critical in ensuring that the diversity of marine communities is adequately represented in MPAs.

Evaluations conducted by the SAT to address the scientific guidelines in the *Master Plan* include levels of protection, habitat representation and replication, and MPA size and spacing. Additional analyses conducted by the SAT include birds and mammals, bio-economic modeling, and water quality. MLPA staff evaluate recreational, education and study opportunities while an MLPA contractor, Ecotrust, conducts an analysis of potential commercial and recreational fishery impacts.

The California Department of Fish and Game (DFG) conducts a feasibility analysis where alternative MPA proposals are evaluated against a set of feasibility criteria developed by DFG. The California Department of Parks and Recreation (State Parks) conducts an analysis where alternative MPA proposals are evaluated against a set of guidelines for MPA proposals developed by State Parks.

Bioregions

To help ensure that MPAs established under the MLPA include adequate representation of the marine communities and species diversity representative of California, MPAs must be distributed across biogeographically distinct areas. Both the MLPA and the *Master Plan* identify two biogeographic regions: 1) Point Conception north to the California-Oregon border and 2) Point Conception south to the U.S.-Mexico border. These biogeographic regions are delineated by their broad differences in species assemblages, and are widely recognized by marine scientists.

In each study region, the SAT has conducted analyses to determine if the study region should be divided distinct "bioregions." Bioregions are regions of distinct biological assemblages distinguished by different community compositions, the presence or absence of certain key species, or disruptions to population connectivity among habitats. The establishment of bioregions recognizes that although

species assemblages within a study region might be broadly similar, there are subtle differences among communities that should be captured in an MPA array.

Due to a variety of data on population connectivity, oceanography, geology, and hydrology, the SAT identified two bioregions that characterize the MLPA North Coast Study Region. The North bioregion extends from the mouth of the Mattole River to the Oregon border, while the South bioregion extends from the mouth of the Mattole River to Alder Creek in Mendocino County. It should be noted that although the bioregions stop at the study region boundaries for planning purposes, their biological relevance likely extends beyond those boundaries.

The SAT recommends including representation of all key habitats in each bioregion (see habitat representation). Representation of key habitats in each of the bioregions in the NCSR will be considered as part of the habitat representation evaluation for alternative MPA proposals. Replication of habitats will also be evaluated for each bioregion and the entire NCSR.

Levels of Protection

Types of activities that may be allowed within the three types of marine protected areas (state marine conservation area, state marine park, and state marine reserve) differ in the level of protection they provide to marine ecosystems. To facilitate comparisons among alternative MPA proposals, the SAT assigns a “level of protection” to each MPA based on the uses allowed within its boundaries.

Levels of protection are based upon the ~~likely~~ potential impacts of proposed activities to the ecosystems within an MPA. Conceptually, the SAT seeks to answer the following question in assigning levels of protection: “How much ~~will~~ might an ecosystem differ from an unfished or unharvested ecosystem if one or more proposed activities are allowed?”

State marine reserves (SMRs) are, by definition, unharvested ecosystems, therefore they receive the highest protection level, “very high”. MPAs that allow extractive activities receive levels of protection ranging from “high” for low-impact activities, to “low” for activities that alter habitat and thus ~~are likely to~~ have a potentially large impact on the ecosystem. Both direct impacts (those resulting directly from the gear used or the removal of target or non-target species) and indirect impacts (ecosystem-level effects of species removal) are considered in the levels of protection analysis. Table ES-1 summarizes levels of protection assigned to various targeted species and gear types. As the need arises, the SAT will evaluate additional targeted species and gear types.

Table ES-1. Levels of protection and associated activities

Color Code	Level of Protection	MPA Types	Activities Associated with this Protection Level
	Very high	SMR	No take
	High	SMCA SMP	Salmon and other pelagic finfish[a] (H&L or troll in waters >50m depth); pelagic finfish[a] except salmon (spearfishing) coastal pelagic finfish[b] (H&L, round-haul net, dip net, cast net, hand); Pacific lamprey (H&L, hand harvest, spear, bow and arrow, dip net); eulachon (dip net); non-living shells (hand)
	Mod-high	SMCA SMP	Dungeness crab (trap, hoop-net, diving, hand); salmon and other pelagic finfish[a] (troll in water <50m depth); surf and night smelts (dip net, a-frame net, cast net); sharks, skates, and rays (spear, harpoon, bow and arrow in non-estuarine waters); trout except steelhead rainbow trout (H&L); California halibut, flounders, soles, turbots, and sanddabs (spearfishing); market squid (H&L, round-haul net, dip net cast net, hand);
	Moderate	SMCA SMP	Redtail surfperch (H&L from shore); surfperch (H&L from shore); California halibut, flounders, soles, turbots, and sanddabs (H&L); coonstripe shrimp and spot prawn (trap); clams (intertidal hand); nori/laver and sea lettuce[c] (intertidal hand); salmon and other pelagic finfish[a] (H&L in waters <50m depth); white sturgeon (H&L); sharks, skates, and rays (H&L);
	Mod-low	SMCA SMP	Pacific halibut (H&L); rockfishes, cabezon and other sculpins, lingcod and other greenlings, California moray eel, wolf eel, and monkeyface and rock prickleback (H&L, spearfishing, trap, hand, bow and arrow); red abalone (free-diving); urchin (diving), surfperch (H&L); shiner surfperch (H&L, dip net, cast net); unspecified finfish (H&L, spearfishing); sharks, skates, and rays (H&L, spear, harpoon, bow and arrow in estuarine waters); limpets and turban snails (hand); octopus (H&L, hand); crabs (trap, hoop net, hand); Turkish towel and Mendocino grapestone[d] (intertidal hand);
	Low	SMCA SMP	Rock scallop (diving); mussels (hand); bull kelp (hand); ghost shrimp (hand); sea palm (intertidal hand); canopy-forming algae[e] (intertidal hand); native oysters (hand); unspecified shrimps (hand); unspecified marine invertebrates (hand); unspecified marine algae (hand)

Notes: SMR = state marine reserve SMCA = state marine conservation area SMP = state marine park
H&L = hook and line m=meters

The SAT is currently reviewing the level of protection for numerous activities; this table will be updated as activities are reviewed and approved by the SAT. It should be noted that staff is working with the SAT to coordinate terminology for particular gear types that is consistent with both the activities being proposed by the NCRSG and as defined in regulations under California Fish and Game Code. Thus the descriptions here may change in a future version of this document.

[a] *The grouping "pelagic finfish" includes: northern anchovy (Engraulis mordax), barracudas (Sphyraena spp.), billfishes* (family Istiophoridae), dolphinfish (Coryphaena hippurus), Pacific herring (Clupea pallasi), jack mackerel (Trachurus symmetricus), Pacific mackerel (Scomber japonicus), salmon (Oncorhynchus spp.), Pacific sardine (Sardinops sagax), blue shark (Prionace glauca), salmon shark (Lamna ditropis), shortfin mako shark (Isurus oxyrinchus), thresher sharks (Alopias spp.), swordfish (Xiphias gladius), tunas (family Scombridae), and yellowtail (Seriola lalandi). *Marlin is not allowed for commercial take.*

[b] *The grouping "coastal pelagic finfish" includes: Northern anchovy (Engraulis mordax), Pacific herring (Clupea pallasi), jack mackerel (Trachurus symmetricus), Pacific mackerel (Scomber japonicus), and Pacific sardine (Sardinops sagax).*

[c] *Porphyra spp. (Nori, Laver), Ulva spp. (Sea Lettuce),*

[d] *Chondrocanthus/Gigartina exasperata (Turkish Towel), and Mastocarpus spp. (Mendocino Grapestone).*

[e] *The grouping "canopy-forming algae" includes the following harvested groups: Alaria spp. (Wakame), Lessonioposis littoralis (Ocean Ribbons), Laminaria spp. (Kombu), Saccharina/Hedophyllum sessile ('Sweet' Kombu), Egregia menzeisii (Feather Boa), and Fucus spp. (Bladder wrack or Rockweed).*

The level of protection assigned to an MPA that allows multiple uses is the lowest level of protection designated for any of the uses. The SAT acknowledges that multiple uses within an MPA may have cumulative impacts on the ecosystem that exceed those of the individual activities, but such cumulative impacts are difficult to predict and the SAT has not addressed this concern in assigning levels of protection. The levels of protection assigned by the SAT are used in all subsequent SAT analyses. Only MPAs at the three highest levels of protection, “moderate-high,” “high,” and “very high,” contribute toward replication and are considered as part of the size and spacing analysis.

Habitat Representation

The SAT recommended that “for an objective of protecting the diversity of species that live in different habitats and those that move among different habitats over their lifetime, every ‘key’ marine habitat should be represented in the MPA network[1].” California’s key marine habitats are described in the MLPA and have been further subdivided by the SAT to reflect important ecological differences at different depths. This habitat classification yields a total of 22 key habitats for which habitat representation is assessed contingent upon habitat map quality: rocky shore, sandy beach, surfgrass, coastal marsh, tidal flats, estuarine waters, eelgrass, kelp, hard and soft substrates in four depth zones (0-30 meters, 30-100 meters, 100-200 meters, and greater than 200 meters), submarine canyons, pinnacles, upwelling centers, retention zones, river plumes, and oceanographic fronts.

In evaluating habitat representation the SAT considers:

- The availability of habitats across the entire NCSR
- The availability of habitats within the two bioregions of the NCSR
- The percentage of available habitat protected in MPAs across six levels of protection
- The distribution of habitat protection across the two bioregions

Habitat Replication

Habitat replication within broad biogeographic regions is required by the *Master Plan*. The *Master Plan* identifies just two biogeographic regions in California: 1) Point Conception north to the California-Oregon border and 2) Point Conception south to the U.S.-Mexico border. The *Master Plan* recommends three to five replicates of each key habitat type within marine reserves in each biogeographic region. The northern biogeographic region encompasses three open coast study regions, including the NCSR. The guideline of three to five replicates will be applied at this scale and account for replication in all study regions north of Point Conception. Considering the physical and biological gradients across the NCSR, the SAT has additionally recommended at least one replicate of each key habitat be included in each of the two bioregions of the NCSR.

To count as a replicate of any given habitat, a MPA must contain enough habitat to encompass 90% of the biodiversity associated with that habitat. The minimum area to encompass 90% of the associated biodiversity varies by habitat and is determined from biological surveys. A summary of the minimum areas for replicates of key habitats in the NCSR is in Chapter 5 (and in Table ES-2.).

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[1] *California Marine Life Protection Act Master Plan for Marine Protected Areas*

Table ES-2. Amount of habitat in an MPA necessary to encompass 90% of local biodiversity

Habitat	Amount of habitat needed to encompass 90% of biodiversity	Data Source
Rocky shores and offshore rocks	0.55 linear miles	PISCO Biodiversity
Nearshore rocky reefs and kelp forest (0-30 m)	1.1 linear miles *including the full 0-30m depth zone*	PISCO Subtidal
Rocky reef 30-100 m	0.13 square miles	Starr Surveys
Rocky reef 100-3000 m	0.13 square miles	Starr Surveys
Beaches	1.1 linear miles	*See below*
Soft bottom 0-3000 m [a] *(includes replicates of 0-30m, 30-100m and >100m soft bottom)*	10 square miles total mapped soft bottom Distributed across depth zones including at least: 1.1 mi 0-30m 5 sq mi 30-100m 1 sq mi >100m	NMFS trawl surveys, 1977-2007
Soft bottom 0-100 m [a] *(includes replicates of 0-30m and 30-100m soft bottom)*	7 square miles total mapped soft bottom Distributed across depth zones including at least: 1.1 mi 0-30m 5 sq mi 30-100m	NMFS trawl surveys 1997-2007
Soft bottom 0-30 m *when not combined with other depth zones*	1.1 linear miles *including the full 0-30m depth zone*	*See below*
Soft bottom 30-100 m *when not combined with other depth zones*	7 square miles	NMFS trawl surveys 1997-2007
Soft bottom >100 m *when not combined with other depth zones*	17 square miles	NMFS trawl surveys 1997-2007
Estuarine Habitats [b]	0.12 square miles (77 acres) total estuarine area Distributed across estuarine habitats including at least: 0.04 sq mi coastal marsh (25 acres) 0.04 sq mi eelgrass (25 acres)	SONGs sampling

[a] *Trawl survey data indicate that large amounts of soft bottom habitat are required to encompass 90% of biodiversity if each depth zone is replicated independently. Since soft bottom associated species tend to utilize multiple depth zones, the SAT recommends that soft bottom habitats across multiple depth zones are included in the same MPA or MPA cluster.*

[b] *Estuarine habitat replication thresholds are based upon data from small coastal estuaries in the south and central coast regions and may not be applicable to the large estuarine areas in Humboldt Bay.*

In evaluating replication of key habitats, the SAT:

- combines contiguous MPAs at or above the three highest levels of protection into “MPA clusters.” Replication analyses are conducted at three different levels of protection: “moderate-high,” “high,” and “very high” and include all MPAs at or above the stated level of protection.
- considers whether there is a minimum amount of each key habitat present within an MPA cluster, and whether the MPA cluster meets the minimum size threshold, as described below.

- tabulates the number of replicate MPA clusters for each habitat within the biogeographic region (Point Conception to the California-Oregon border) relative to the guideline of three to five replicates per biogeographic region
- tabulates the number of replicate MPA clusters for each habitat within both of the NCSR bioregions relative to SAT guidance to include at least one replicate of each habitat per bioregion.

MPA Size

The *Master Plan* recommends that "for an objective of protecting adult populations, based on adult neighborhood sizes and movement patterns, MPAs should have an alongshore span of five to ten kilometers (3-6 [statute] miles) of coastline, and preferably 10-20 km (6-12.5 [statute] miles). Larger MPAs would be required to fully protect marine birds, mammals, and migratory fish[2]."

The SAT recommended that MPAs extend from intertidal to offshore areas for an objective of protecting the diversity of species that live at different depths and to accommodate the movement of individuals to and from shallow nursery or spawning grounds to adult habitats offshore. The recommended offshore span is from the mean high tide line to the offshore state waters boundary, generally a distance of 3.45 statute miles (3 nautical miles), except in some areas (e.g., offshore rocks) where state boundaries may extend farther.

Taking into account these two guidelines, the SAT recommended a minimum area of 9 to 18 square statute miles for each MPA, and preferably 18 to 36 square statute miles. The recommendation of a minimum area of 9 square statute miles is a simplified combination of the along-shore and offshore size guidelines and allows for the possibility that the alongshore span may be less (or greater) than three statute miles or the offshore span may be less than 3.45 statute miles. The guidelines for minimum and preferred areas of proposed MPAs will receive priority above the individual guidelines for alongshore and offshore spans. Additionally, the SAT recommends consideration of the configuration of proposed MPAs. Configurations with maximum area-to-perimeter ratios (e.g., 3 x 3 statute miles) are more likely to achieve greater protection for a variety of adjacent habitats and associated species than narrow and long MPAs (e.g.,1 x 9 statute miles).

In evaluating the size of MPAs, the SAT:

- combines contiguous MPAs at or above the three highest levels of protection into "MPA clusters." Size analyses are conducted at three different levels of protection: "moderate-high," "high," and "very high" and include all MPAs at or above the stated level of protection.
- tabulates the number of MPA clusters in each size range (below minimum, minimum size range, preferred size range).

MPAs containing estuarine habitat are not evaluated against the general rule that replication of habitat needs to be within an MPA cluster that is at least nine square miles.

MPA Spacing

The *Master Plan* recommends that "for an objective of facilitating dispersal of important bottom-dwelling fish and invertebrate groups among MPAs, based on currently known scales of larval

[2] California Marine Life Protection Act Master Plan for Marine Protected Areas

dispersal, MPAs should be placed within 50-100 km (31-62 [statute] miles) of each other" along the coast. Neighboring MPAs placed closer than 50 km (31 statute miles) apart also meet the guideline for spacing for the goal of designing a network of MPAs.

In evaluating the spacing of MPAs along the coast, the SAT:

- combines contiguous MPAs at or above the three highest levels of protection ("moderate-high," "high," and "very high") into "MPA clusters" that include all MPAs at or above the stated level of protection.
- considers MPA clusters of sufficient size (minimum MPA cluster size of nine square miles), with sufficient amounts of key habitats included to constitute a habitat replicate.
- determines the distance between replicates of key habitats within MPAs relative to the minimum spacing guideline of 31-62 statute miles.
- estimates the distance between MPAs that protected patches of the same key habitat.
- analyzes distances between neighboring MPAs separately for each key habitat.

Modeling

Two spatially-explicit bioeconomic models were developed, vetted, and utilized to evaluate alternative MPA proposals in the north central coast study region (NCCSR) and south coast study region (SCSR) planning processes of the MLPA Initiative; both models were extended for use in the NCSR. The models are the University of California, Davis "Spatial Sustainability and Yield" model (UCD model) and the University of California, Santa Barbara "Flow, Fish, and Fishing" model (UCSB model). Two models were developed to confirm that model outputs were reasonable and consistent. Since both models report consistent results, the SAT modeling work group determined that a single model (UCSB model and hereafter referred to as "the model") could be used to evaluate MPA proposals, with two sets of assumptions that reflect the key differences between the UCSB and UCD models.

The model uses spatial data on habitat, fishery effort, and proposed MPA locations and regulations to simulate the population dynamics of fished species. It then generates predicted spatial distributions of species abundances, yields, and profits for 7 representative species for each alternative MPA proposal. Importantly, the model incorporates the population dynamic consequences of spatially explicit fishing regulations.

The two original models (UCD and UCSB) differed in details regarding, for example, how specifically population dynamics are modeled, how the steady-state impacts of fisheries outside of protected areas are parameterized, and what units are used to express conservation and economic values. Despite these differences, the two models gave closely agreeing results in the SCSR and the first round of evaluations for the NCSR. A key structural difference in the models leading to slightly different results is the method for simulating the movement of adult fishes and invertebrates. Therefore, the UCSB model is currently run in a second mode that emulates the UCD approach to simulating home range movement (the UCD home range formulation); these model runs are identical to the original UCSB model in every other respect.

The model includes the following structural elements: (a) larval connectivity across patches driven by ocean currents, pelagic larval duration, and spawning season, (b) larval settlement regulated by species density in available habitat, (c) growth and survival dynamics of the resident (adult) population, (d) reproductive output increasing with adult size, (e) adult movement (e.g., home ranges), and (f) harvest in areas outside of MPAs.

Model outputs from the evaluation of alternative MPA proposals must be compared to each other to understand the potential impacts of changes to the design because outputs are not expressed in terms of minimum or maximum threshold values. For the modeling evaluation of alternative MPA proposals, the SAT provides:

- maps of biomass (conservation value) for each of 7 representative species and an average of all modeled species, region-wide and for individual MPAs
- maps of fishery yield (economic return) for each of 7 representative species and an average of all modeled species, region-wide and for individual MPAs
- maps of spatial fishing intensity for each of 7 representative species and for an average of all model species
- plots showing the trade-offs between biomass (conservation value) and fishery yield (economic return) for each alternative MPA proposal
- diagrams that illustrate the level of connectivity between different places in the NCSR for the suite of 7 representative species
- tables showing biomass and self-recruitment for individual MPAs in each alternative MPA proposal

Birds and Mammals

MPAs may benefit marine birds and mammals by potentially reducing human disturbance at breeding colonies or rookeries and at roosting and haul-out sites. Species foraging nearshore may also benefit from increased prey availability. To evaluate the protection afforded by alternative MPA proposals to birds and mammals, the SAT:

- identifies proposed MPAs or special closures that contribute to protection of birds and mammals.
- identifies focal species likely to benefit from MPAs and for which data are available.
- identifies important breeding and foraging hot spots for marine birds and mammals.
- estimates the proportion (of total numbers of individuals) of breeding birds at colonies and the number of rookeries potentially benefiting by proposed MPAs.
- Estimates the number and size of marine bird roosts sites and proportion (of total numbers of individuals) of mammals at haulouts potentially benefiting by proposed MPAs.
- estimates the proportion of available near-colony foraging areas protected by proposed MPAs, defined by evaluating protection of buffered areas around colonies.
- estimates the number of available neritic foraging ‘hot spots’ protected by proposed MPAs, defined by at-sea densities of marine birds and mammals.
- estimates the proportion of estuarine and coastal beach habitats protected and density and diversity of shorebirds and waterfowl protected by proposed MPAs.

Water Quality

While water quality is not subject to management under the MLPA, it may be important in designing alternative MPA proposals. Where water quality is significantly compromised, marine life may be affected. Impaired water quality may lead to changes to population rates (growth, reproduction, and

mortality), population abundance, and ecological community composition through a variety of interactions (e.g., decreased diversity, loss of sensitive species and abundance of tolerant species).

For MPA network design, the SAT recommends including areas already designated as areas of special biological significance (ASBSs) because these areas benefit from protection beyond that offered by standard waste discharge restrictions. The SAT recommends avoiding locations of poor or threatened water quality, including:

- areas that are significantly impacted by a variety of pollutants from storm drain and agricultural runoff as well as areas impacted by dredge disposal activities
- municipal sewage or industrial outfalls

The SAT determined that MPAs may be placed in or near areas of impaired water quality if there are other reasons to place MPAs in such areas.

Since water quality evaluations are not mandated by the MLPA, these guidelines based on consideration of water quality are secondary to other MPA network design guidelines. Other guidelines (including bioregions, habitat representation and replication, and MPA size and spacing) should be used to drive design of alternative MPA proposals. Water quality considerations may be incorporated if other guidelines have been met.

Recreational and Commercial Fishery Impacts

While fishery impacts are not the focus of the MLPA, they may be considered in designing alternative MPA proposals. The evaluation of maximum potential recreational and commercial fishery impacts utilizes region-specific data collected by MLPA contractor Ecotrust on areas of importance.

To evaluate the potential recreational and commercial fishery impacts, MLPA Initiative staff and contractors:

- conduct local knowledge interviews with recreational and commercial fishermen, using an interactive, custom computer interface, to collect geo-referenced information about the extent and relative importance of study region commercial and recreational fisheries.
- organize impact analyses by port, fishery, and/or user group.
- evaluate and summarize the maximum potential impacts on commercial, commercial passenger fishing vessel (CPFV), and recreational fishing grounds both in terms of total area and value affected, with results summarized for both study region fishing grounds and total fishing grounds[3].
- conduct an impact analysis for commercial and CPFV fisheries.
- consider or identify “outliers” (i.e., fisheries and individual fishermen likely to experience disproportional impacts).
- assess the effect of existing fishery management area closures and other constraints on fishing grounds.

[3] Impact analyses represent a “worst case scenario” in which fisherman cannot fish in a different location.

1. Overview

The California Marine Life Protection Act (MLPA) found that California's marine protected areas (MPAs) were established on a piecemeal basis and lacked sound scientific guidelines (California Fish and Game Code, Section 2851). The development and evaluation of draft MPA proposals is one component of an iterative process designed to "reexamine and redesign California's MPA system to increase its coherence and its effectiveness at protecting the state's marine life habitat and ecosystems," as mandated by the MLPA.

A wide range of external array proponents submitted proposed MPA arrays on February 1, 2010 as part of the MLPA process. The MLPA North Coast Regional Stakeholder Group (NCRSG) will also create alternative MPA proposals that integrate a variety of scientific and personal knowledge.

Evaluations of alternative MPA proposals are conducted relative to MLPA goals (Table 1-1), scientific guidelines provided in the *Master Plan* and developed by the SAT, feasibility criteria developed by the California Department of Fish and Game (DFG), and guidelines developed by the California Department of Parks and Recreation (State Parks). Potential impacts to commercial and recreational consumptive users also are evaluated. Evaluations are conducted by the SAT, MLPA Initiative staff, DFG, State Parks and contractors to the MLPA Initiative.

Table 1-1. MLPA goals and evaluation elements relating to each goal

MLPA Goal	Evaluation Elements
1. To protect the natural diversity and abundance of marine life, and the structure, function, and integrity of marine ecosystems.	• levels of protection • habitat representation • modeling • birds and mammals
2. To help sustain, conserve, and protect marine life populations, including those of economic value, and rebuild those that are depleted.	• levels of protection • MPA size and spacing • modeling • birds and mammals
3. To improve recreational, educational, and study opportunities provided by marine ecosystems that are subjected to minimal human disturbance, and to manage these uses in a manner consistent with protecting biodiversity.	• habitat replication • (MPA and habitat size) • recreational, educational & study opportunities
4. To protect marine natural heritage, including protection of representative and unique marine life habitats in California waters for their intrinsic value.	• levels of protection • habitat representation and replication
5. To ensure that California's MPAs have clearly defined objectives, effective management measures, and adequate enforcement, and are based on sound scientific guidelines.	• California Department of Fish and Game Feasibility Analysis • California Department of Fish and Game Goals and Objectives Analysis • California Department of Parks and Recreation
6. To ensure that the state's MPAs are designed and managed, to the extent possible, as a network.	• size and spacing • (MPA and habitat size) • modeling

2. Bioregions

The *California Marine Life Protection Act Master Plan for Marine Protected Areas* divides the California coast into five study regions. The MLPA North Coast Study Region (NCSR), from the California/Oregon border in Del Norte County to Alder Creek near Point Arena in Mendocino County, is the fourth region to be studied. The MLPA Master Plan Science Advisory Team (SAT) may further divide the study regions into multiple bioregions. Bioregions are regions of distinct biological assemblages distinguished by different community compositions, the presence or absence of certain key species, or disruptions to population connectivity among habitats.

Bioregions should not be confused with biogeographic regions. Bioregions are determined by the SAT to help meet the goals of the MLPA by ensuring the full diversity of communities is represented in California's system of marine protected areas (MPAs). Biogeographic regions are large-scale regions of similar species assemblages. California contains parts of two biogeographic regions: the San Diegan region extends from Point Conception southward, while the Oregonian region extends from Point Conception northward. Biogeographic regions are delineated using broad changes in the presence/absence of species, while bioregions recognize more subtle differences in species assemblages and community structure.

Bioregions play a key role in the MPA design process. The SAT strongly encourages replication of MPAs in each bioregion to ensure the full diversity of a given habitat is represented. For example, in the MLPA South Coast Study Region, an MPA placed at a kelp forest near Santa Barbara would not protect the same suite of species as an MPA placed at a kelp forest near Catalina Island, even though they are both considered kelp forests during SAT evaluations. Due to differences in community composition, the Santa Barbara coastline and Catalina Island are part of different bioregions, thus encouraging the placement of MPAs at kelp forests in both bioregions and representing the full diversity of the habitat type. Additionally, SAT evaluations are conducted for each bioregion, which provides more detail about how alternative MPA proposals differ.

In previous study regions, the SAT has delineated bioregions based primarily on intertidal community data from rocky shores. In the NCSR, these data do not indicate a strong break in bioregions (Blanchette et al. 2008). However, other sources of data suggest there is a break in population connectivity at Cape Mendocino due to the oceanographic and geomorphologic conditions of the area (e.g. Dawson et al. 2001, Cope 2004, Sotka et al. 2004, Field and Ralston 2005, Broitman et al. 2008, Francis et al. 2009, Hyde and Vetter 2009). The oceanography of the area is fairly well studied, and features such as a large eddy off Cape Mendocino and a strong upwelling in the area lend support for a potential barrier to connectivity in the area (e.g. Magnell et al. 1990, Kosro et al. 1991, Largier et al. 1993, Pullen and Allen 2001).

Additionally, nearshore habitats north of the Cape Mendocino area are heavily influenced by terrestrial sediments through runoff from major rivers such as the Eel and Klamath (Nittrouer 1999, Sommerfield and Nittrouer 1999). Habitats south of the Cape Mendocino area, however, experience much lower sedimentation due to less freshwater inflow in that area. This difference in geomorphology and hydrography could lead to differences in community structure.

An important concern in establishing a bioregion break in the Cape Mendocino area is determining the location of the bioregion boundary. There are several prominent features, including False Cape, Cape Mendocino, the mouth of the Mattole River, and Punta Gorda, each of which could serve as a geographic boundary between bioregions. Studies in the region have not collected data at a small enough spatial scale to resolve the location of a bioregion boundary, so the SAT considered a number of factors to determine where the boundary should be located.

The SAT determined the mouth of the Mattole River as an appropriate boundary between northern and southern bioregions (Figure 2-1). A major consideration for selecting the boundary is the desire to keep major habitats such as contiguous rocky reefs in single bioregions. The mouth of the Mattole River neatly divides two major rocky reef systems and the branching arms of the submarine Mattole Canyon, making it an ideal candidate for the bioregion boundary. Additionally, a bioregion boundary at the mouth of the Mattole River offers one of few locations in the Cape Mendocino area that is accessible by road (a consideration for monitoring purposes) and there is strong public support for the bioregion boundary at this location.

Though the evidence for bioregions in the NCSR is not as striking as that in other study regions, there is sufficient evidence to suggest that the NCSR should be divided into two bioregions with a boundary at the mouth of the Mattole River. Furthermore, establishing two bioregions will provide more detail during the SAT evaluations of alternative MPA proposals.

Figure 2-1. Bioregions in the MLPA North Coast Study Region

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3. Protection Levels (Goals 1, 2, 4 and 6)

Status of this chapter: The SAT approved the text of this chapter on July 28, 2010, and a number of additional LOP assignments on October 14, 2010. Changes to text from the July 28, 2010 version are in underline and strikeout. Changes to LOP assignments from the October 14, 2010 version are in underline and strikeout.

Summary of the MLPA Guidelines Regarding Level of Protection

The Marine Life Protection Act (MLPA) calls for an improved network of marine protected areas (MPAs) that includes a "marine life reserve component," and may include "areas with various levels of protection." To facilitate comparison between MPA proposals allowing various uses, the MLPA Master Plan Science Advisory Team (SAT) has developed a framework for assessing the level of protection provided by a proposed MPA.

The level of protection (LOP) concept is simple: the more permissive an MPA, the lower its LOP. Permissiveness, as used here, means the degree to which the MPA's fishing regulations permit impacts to habitat or community structure. If a proposed MPA permits activities ~~having~~ with the potential for high impact on habitat or community structure, then that MPA is said to have a low LOP. An MPA which permitted no human fishing activity at all would on the other hand be said to have a high LOP.

Why Categorize MPAs by Protection Levels?

The SAT needs a method by which to evaluate the overall conservation value of entire proposed arrays of MPAs. Each MPA in a proposal will be designated as one of three types of marine protected areas: state marine reserve (SMR), state marine conservation area (SMCA), or state marine park (SMP). While the SMR, where no appreciable take of any species is allowed, is clearly the most protective of the MPA types, the relationship between the SMCA and the SMP is less clear. There is great variation in the type and magnitude of activities that may be permitted within these MPAs. It is expected that proposals will, in addition to naming each of its MPAs with one of these types, also specify what activities are to be permitted in each MPA. This gives designers of MPA proposals flexibility in crafting MPAs that either individually or collectively fulfill the various goals and objectives specified in the MLPA. However, this flexibility may mean that to evaluate an array of MPAs only by their type of designations may lead to deceptive results. For this reason, the SAT looks beyond the MPA type (SMR, SMP or SMCA) to the proposed permitted activities to determine the LOP an MPA will afford.

Marine Protected Area (MPA) Types

SMRs provide the greatest level of protection to species and to ecosystems by prohibiting take (with the exception of permitted scientific take for research, restoration or monitoring). The high level of protection attributed to an SMR is based on the assumption that no other appreciable level of take or alteration of the ecosystem will be allowed. Thus, of the three types of MPAs, SMRs provide the greatest likelihood of achieving MLPA goals 1, 2, and 4.

SMPs are designed to provide recreational opportunities and therefore can allow some or all types of recreational take of a wide variety of fish and invertebrate species by various means (e.g. hook and line, spear fishing). Because of the variety of species that potentially can be taken and the potential magnitude of recreational fishing pressure, SMPs that allow recreational fishing provide

lower protection and conservation value relative to other, more restrictive MPAs (e.g. SMRs). Although SMPs may have lower value for achieving MLPA goals 1 and 2, they may assist in achieving other MLPA goals.

SMCAs potentially have the most variable levels of protection and conservation of the three MPA types because they may allow any combination of commercial and recreational fishing.

Conceptual Framework for Assigning Levels of Protection

Levels of protection are based upon the ~~likely~~ potential impacts of proposed activities to the ecosystems within the MPA. Conceptually, the SAT seeks to answer the following question in assigning levels of protection: "How much ~~will~~ might an ecosystem differ from an unharvested ecosystem (i.e. no take area) if one or more proposed activities are allowed?" To arrive at an answer, the SAT will evaluate the potential ecosystem impacts of each activity that is proposed to be permitted in an MPA. Where multiple permitted activities are proposed, the one with the greatest potential impact will be used to determine the LOP for that MPA.

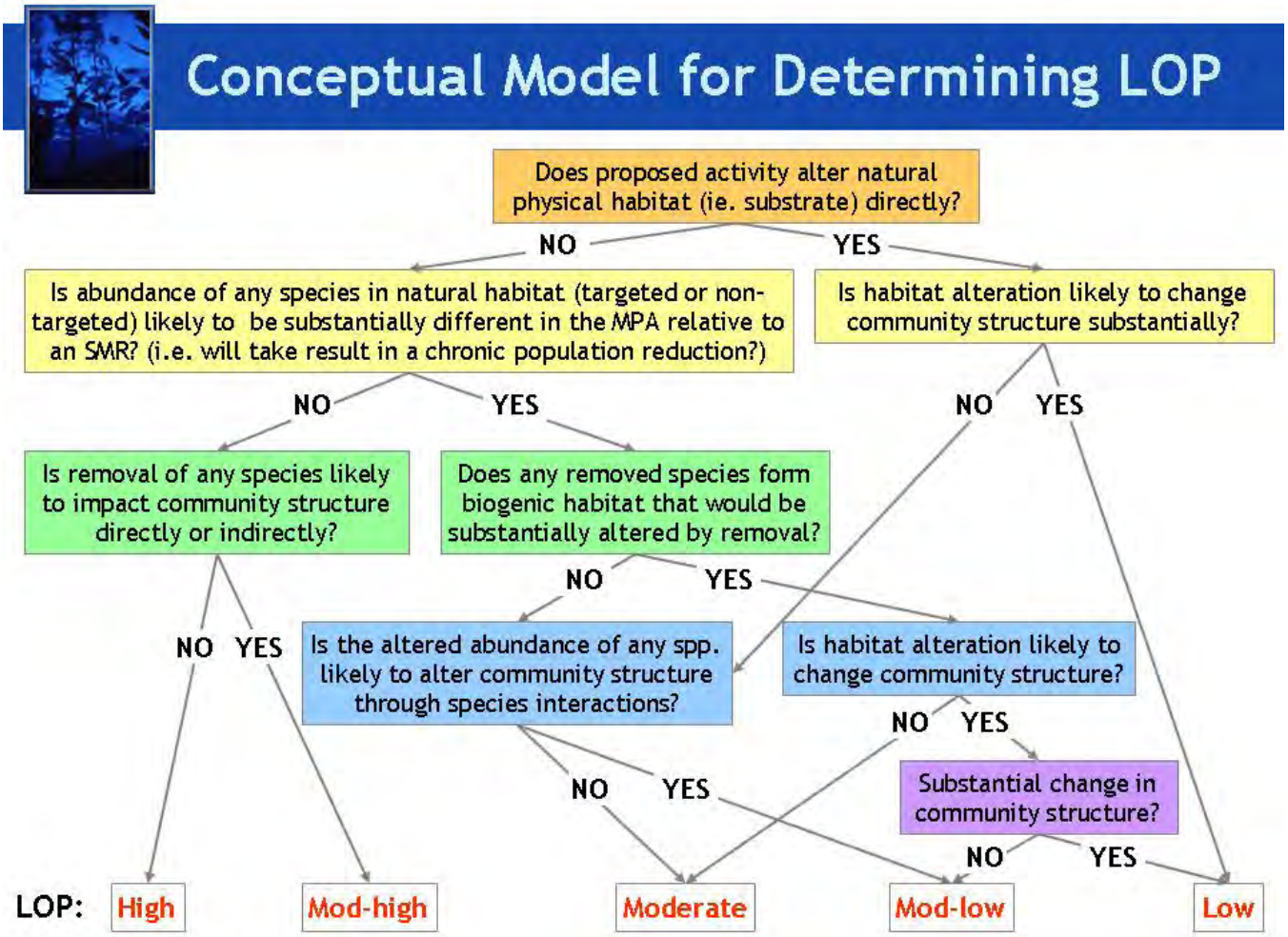
It is important to note that LOPs are based on the *potential* impacts of a proposed activity, and do not predict the status of any fishery or the abundance of any organism. With wise management or minimal harvest levels, the realized impacts of harvest activities on the marine ecosystem may be substantially lower than those assessed by the LOP. Because the magnitude and spatial distribution of harvest within MPAs is not regulated and unpredictable in the future, LOPs are not based on existing patterns or magnitude of take. Instead, LOPs assess the certainty that an MPA will achieve the goals of the MLPA *regardless* of the spatial distribution and magnitude of take. An MPA that has been assigned a high LOP is likely to contain marine communities that resemble those in an unharvested ecosystem (i.e. no take area), even if allowed activities are intense within the MPA. MPAs with lower LOPs (especially those below moderate-high) are less likely to contain marine communities that resemble those in an unharvested ecosystem, especially if harvest activities are intense within the MPA. The lower the LOP, the greater the risk that activities allowed within the MPA could compromise the MPA's ability to achieve the goals of the MLPA.

SMRs are, by definition, unharvested ecosystems, therefore we ascribe to them the highest protection level, "very high." MPAs that allow extractive activities are assigned levels of protection ranging from "high" for low-impact activities, to "low" for activities that alter habitat and thus are likely to have a large impact on the ecosystem. Both direct impacts (those resulting directly from the gear used or removal of target or non-target species) and indirect impacts (ecosystem-level effects of species removal) are considered in the levels of protection analysis. Figure 3-1 presents the decision flow for determining the level of protection of a proposed MPA based on one permitted activity. It asks questions about the activity so as to result in an LOP designation for the MPA where that activity will be allowed. This same decision flow will be used for every activity that is proposed to be permitted, so that the one resulting in the lowest LOP designation for a particular MPA is the one that will determine the LOP designation actually assigned.

As the term is used here, "activity" refers to:

- take of a particular species,
- by a particular method,
- at a particular range of depths.

Figure 3-1. Conceptual Model for Determining the Level of Protection in an MPA Based on an Extractive Activity Permitted There



In applying the conceptual model presented in Figure 3-1, the SAT makes three important assumptions:

- Any extractive activity can occur locally to the maximum extent allowable under current state and federal regulations.
- For the purpose of comparison, an unharvested system is a marine reserve that is successful in eliminating fishing and other extractive uses within the MPA.
- The proposed activity is occurring in isolation from other activities (i.e. without cumulative effects of multiple allowed activities). This assumption is based upon limitations in the SAT's ability to assess the cumulative impacts of multiple activities, not a belief that cumulative impacts do not occur.

The SAT identifies the potential impacts of a proposed activity by considering two main categories of impacts: (1) direct impacts of the activity, and (2) indirect impacts of the activity on community structure and ecosystem dynamics. In the case of fishing, direct impacts may include habitat disturbance and removal of target and non-target species caused by the fishing gear or method. Indirect impacts may include any change in the ecosystem caused by removal of target and non-target species. In general, removal of resident species that are likely to benefit from MPAs are

considered to have potential impacts on species interactions, especially if those species play an integral role in the food web or perform a key ecosystem function (e.g. biogenic structure).

Levels of Protection for the North Coast Study Region

The levels of protection as they apply to the north coast study region are presented below. For an MPA that allows multiple activities, the lowest LOP designation resulting from any allowed activity is the one assigned to that MPA. The SAT acknowledges that multiple uses within an MPA may have cumulative impacts on the ecosystem that exceed those of the individual activities; such cumulative impacts are difficult to predict and the SAT has not addressed this concern in assigning levels of protection.

For the purpose of assigning levels of protection, a “substantial” change in the abundance of a species is defined as a change in abundance that is likely to be persistent and detectable through comparison with a no-take area.

Very High – no take of any kind allowed. This designation applies only to SMRs.

High – Proposed activities were assigned this level of protection if the SAT concluded that the activity: 1) does not directly alter habitat, 2) is unlikely to substantially alter the abundance of any species relative to an SMR, and 3) is unlikely to have an impact on community structure relative to an SMR. The mobility of removed species (both target and associated catch) was an important factor in determining the activity’s impact on abundance and community structure. Individuals of highly mobile species are expected to move frequently between MPAs and unprotected waters, so local abundance of these species is unlikely to be different in a fished area relative to an SMR. Altered abundance of a species, and the associated changes in ecological interactions (e.g. predator/prey, competitive, or mutualistic relationships) are what drives changes in community structure. If the proposed activity is unlikely to alter the abundance of *any* species relative to an SMR, community structure is likewise anticipated to be unaltered and the activity is expected to have little impact on the ecosystem.

Moderate-high – Activities were assigned this level of protection if the SAT concluded that the activity: 1) does not directly alter habitat, 2) may alter the abundance of a targeted or non-targeted species relative to an SMR, but this change in abundance is not likely to be substantial relative to natural variations in population and 3) has some potential to alter community structure relative to an SMR. Changes in community structure could be caused by a change in the size structure of the targeted population or a temporary reduction in the local abundance of a species thereby altering the functional role of a species in a community but having little long-term impact on the local population. Activities assigned this level of protection are generally characterized by uncertainty regarding ecosystem impacts. This uncertainty arises in one of three ways: 1) the movement range of the target species is either uncertain or short enough that reserve effects are possible, yielding uncertainty as to whether the abundance of this species will be altered relative to an SMR, 2) the level or composition of incidental catch is uncertain making it unclear whether the abundance of any non-target species will be altered relative to an SMR, or 3) the ecological role of any removed species is unclear, leading to uncertainty about how removal may alter community structure relative to an SMR.

Moderate – Activities were assigned to this level of protection if the SAT concluded that the activity was likely to alter habitat or substantially alter species abundance in the area relative to an SMR, but that these changes were unlikely to impact community structure substantially. Activities that are likely to cause minor habitat perturbations or alter the abundance of species that play a minor ecological role (e.g. one of many prey items) received this level of protection.

Moderate-low – Activities were assigned to this level of protection if the SAT concluded that the activity was likely to alter habitat (either through direct habitat damage or removal of species that form biogenic habitat) or substantially alter species abundance in the area relative to an SMR, but changes to community structure are likely to occur primarily through species interactions, not habitat effects.

Low – Only activities that impact habitat in a way that is likely to significantly alter community structure were assigned to this level of protection. Activities with the potential to alter habitat substantially either through damage to substrate or removal of habitat-forming organisms received this low level of protection.

Coastal MPAs are most effective at protecting species with limited range of movement, most of which are closely associated with seafloor habitats. Less protection is afforded to more wide-ranging, transient species like salmon and other pelagics (e.g. albacore and pelagic sharks). This has led to proposals of SMCAs that prohibit take of bottom-dwelling species, while allowing the take of transient pelagic species. However, fishing for some pelagic species, near the sea floor or over rocky substrate in relatively shallow water, may increase the likelihood of inadvertently catching resident species that are likely to otherwise receive protection within the MPA. Although depth- and habitat-related bycatch information for specific fisheries are not readily available, it is likely that bycatch is highest in shallow water where bottom fish move close to the surface and become susceptible to the fishing gear.

Participants at a national conference on benthic-pelagic coupling considered the nature and magnitude of interactions among benthic (bottom-dwelling) and pelagic species, and the implications of these interactions for the design of marine protected areas. At this meeting, scientists, managers, and recreational fishing representatives concluded that bycatch is higher in depths where seafloor is less than 50 meters depth (27 fathoms,164 ft) and is lower in depths where seafloor is greater than 50 meters depth (Grober-Dunsmore 2008). This information, along with associated-catch information provided by DFG, contributed to SAT's categorization of MPAs into levels of protection.

In assigning depth-dependent levels of protection the SAT recognizes that other MPA design considerations may necessitate capturing multiple depth zones within an MPA. For example, an MPA designed to allow take of pelagic finfish in deep (>50m depth) waters may include a small area of shallower (<50m depth) habitat because of the necessity for straight-line MPA boundaries. To accommodate these real-world design constraints in assigning depth-dependent levels of protection the SAT considers an MPA to include a given depth-zone only if it contains more than 0.2 square miles of that depth zone.

Table 3-1. Levels of protection and associated activities

Color Code	Level of Protection	MPA Types	Activities Associated with this Protection Level
	Very high	SMR	No take
	High	SMCA SMP	Salmon and other pelagic finfish[a] (H&L or troll in waters >50m depth); pelagic finfish[a] except salmon (spearfishing) coastal pelagic finfish[b] (H&L, round-haul net, dip net, cast net, hand); Pacific lamprey (H&L, hand harvest, spear, bow and arrow, dip net); eulachon (dip net); non-living shells (hand)
	Mod-high	SMCA SMP	Dungeness crab (trap, hoop-net, diving, hand); salmon and other pelagic finfish[a] (troll in water <50m depth); surf and night smelts (dip net, a-frame net, cast net); sharks, skates, and rays (spear, harpoon, bow and arrow in non-estuarine waters); trout except steelhead rainbow trout (H&L); California halibut, flounders, soles, turbots, and sanddabs (spearfishing); market squid (H&L, round-haul net, dip net cast net, hand);
	Moderate	SMCA SMP	Redtail surfperch (H&L from shore); surfperch (H&L from shore); California halibut, flounders, soles, turbots, and sanddabs (H&L); coonstripe shrimp and spot prawn (trap); clams (intertidal hand); nori/laver and sea lettuce[c] (intertidal hand); salmon and other pelagic finfish[a] (H&L in waters <50m depth); white sturgeon (H&L); sharks, skates, and rays (H&L);
	Mod-low	SMCA SMP	Pacific halibut (H&L); rockfishes, cabezon and other sculpins, lingcod and other greenlings, California moray eel, wolf eel, and monkeyface and rock prickleback (H&L, spearfishing, trap, hand, bow and arrow); red abalone (free-diving); urchin (diving), surfperch (H&L); shiner surfperch (H&L, dip net, cast net); unspecified finfish (H&L, spearfishing); sharks, skates, and rays (H&L, spear, harpoon, bow and arrow in estuarine waters); limpets and turban snails (hand); octopus (H&L, hand); crabs (trap, hoop net, hand); Turkish towel and Mendocino grapestone[d] (intertidal hand);
	Low	SMCA SMP	Rock scallop (diving); mussels (hand); bull kelp (hand); ghost shrimp (hand); sea palm (intertidal hand); canopy-forming algae[e] (intertidal hand); native oysters (hand); unspecified shrimps (hand); unspecified marine invertebrates (hand); unspecified marine algae (hand)

Notes: SMR = state marine reserve SMCA = state marine conservation area SMP = state marine park
H&L = hook and line m=meters

The SAT is currently reviewing the level of protection for numerous activities; this table will be updated as activities are reviewed and approved by the SAT. It should be noted that staff is working with the SAT to coordinate terminology for particular gear types that is consistent with both the activities being proposed by the NCRSG and as defined in regulations under California Fish and Game Code. Thus the descriptions here may change in a future version of this document.

[a] *The grouping "pelagic finfish" includes: northern anchovy (Engraulis mordax), barracudas (Sphyraena spp.), billfishes* (family Istiophoridae), dolphinfish (Coryphaena hippurus), Pacific herring (Clupea pallasi), jack mackerel (Trachurus symmetricus), Pacific mackerel (Scomber japonicus), salmon (Oncorhynchus spp.), Pacific sardine (Sardinops sagax), blue shark (Prionace glauca), salmon shark (Lamna ditropis), shortfin mako shark (Isurus oxyrinchus), thresher sharks (Alopias spp.), swordfish (Xiphias gladius), tunas (family Scombridae), and yellowtail (Seriola lalandi). *Marlin is not allowed for commercial take.*

[b] *The grouping "coastal pelagic finfish" includes: Northern anchovy (Engraulis mordax), Pacific herring (Clupea pallasi), jack mackerel (Trachurus symmetricus), Pacific mackerel (Scomber japonicus), and Pacific sardine (Sardinops sagax).*

[c] *Porphyra spp. (Nori, Laver), Ulva spp. (Sea Lettuce),*

[d] *Chondrocanthus/Gigartina exasperata (Turkish Towel), and Mastocarpus spp. (Mendocino Grapestone).*

[e] *The grouping "canopy-forming algae" includes the following harvested groups: Alaria spp. (Wakame), Lessonioposis littoralis (Ocean Ribbons), Laminaria spp. (Kombu), Saccharina/Hedophyllum sessile ('Sweet' Kombu), Egregia menzeisii (Feather Boa), and Fucus spp. (Bladder wrack or Rockweed).*

The SAT's LOP Designations for Potential Allowed Uses

The SAT considers each potential allowed use individually to arrive at the decisions summarized in Table 3-1. A complete decision matrix of all uses for which an LOP designation has been approved by the SAT is in Appendix C1 of this document. This subsection presents an in-depth description of the rationale for each decision made by the SAT.

In cases where the allowed uses for a group of organisms have unspecified gear types or species (e.g. "marine invertebrates"), the SAT gives an LOP equivalent to the lowest LOP assigned to any species that would fall within the grouping. For example, since mussels have been assigned a Low LOP and are marine invertebrates, the grouping "marine invertebrates" receives a Low LOP, even though some group members (e.g. Dungeness crabs) would receive a higher LOP if they were singled out. Unspecified groupings of "shrimps" and "marine algae" also receive Low LOPs, while "finfish" receives a Moderate-Low LOP.

LOP Designations for Fishes

California halibut, flounders, soles, turbots, and sanddabs (hook and line, spear):

Direct impacts: Take of California halibut (*Paralichthys californicus*), flounders, soles, turbots, and sanddabs (many species in families Paralichthyidae and Pleuronectidae) by hook and line or spear is unlikely to alter habitat. These flatfishes~~California halibut~~ are moderately mobile species that inhabit a wide range of habitats in California. Although the movement patterns of California halibut are not fully understood, several studies indicate that young (mostly sub-legal sized) ~~California halibut~~ individuals stay within 2-5 km of their tagging release site for months or years, while some move hundreds of km within that same time period (Domeier and Chun 1995, Posner and Lavenberg 1999). Additionally, California halibut are rare in the north coast study region, occurring in the region almost exclusively in Humboldt Bay. Due to their limited distribution in the region and their potential to move only short distances, the abundance of California halibut may be altered ~~substantially~~ by take relative to an SMR. Likewise, flounders, soles, turbots, and sanddabs potentially have small home ranges; one study on lefteye flounder (*Engyprosopon grandisquama*) found home ranges from 31-92m^2 that were occupied for up to 21 months (Manabe et al. 2000). Thus these species may also be altered by take relative to an SMR, though movement patterns are poorly studied.

Associated catch on hook and line trips targeting California halibut in the north coast is primarily composed of bait fish and estuarine and soft bottom associated species, but does include a number of rocky reef species, (totaling ~5% of total catch see Appendix C2). In addition to altering the abundance of halibut, fishing for this species using hook and line may alter the abundance of associated catch species including demersal sharks, skates and rays and a variety of reef fish including rockfish, lingcod, and greenlings. However, since spear fishers target specific, individual fish, there is basically no associated catch using this technique. Therefore, two LOPs have been assigned to this group of flatfishes based on fishing gear types. It is important to note that the LOP for each of these species or species groups was determined individually. Since they all received the same LOP for the same reasons, they are being presented here together as a group.

Indirect impacts: California halibut are important predators in the benthic ecosystem, feeding on a variety of schooling fish and benthic organisms (Cailliet et al. 2000). However, there are a variety of other important benthic predators present in estuarine habitats in the north coast study region, so the removal of California halibut is unlikely to substantially alter community structure. Similarly, flounders, soles, turbots, and sanddabs can serve an important function as predators in the coastal benthic ecosystem, though many predators exist in these habitats.

Level of protection: **Moderate-High** for spearfishing
Moderate for hook and line ~~Level of protection: **Moderate**~~

Coastal pelagic finfish (hook and line, round haul net, dip-net, cast net, hand):

Direct impacts: The term "coastal pelagic finfish" includes northern anchovy (*Engraulis mordax*), Pacific herring (*Clupea pallasi*), jack mackerel (*Trachurus symmetricus*), Pacific mackerel (*Scomber japonicus*), and Pacific sardine (*Sardinops sagax*). Coastal pelagic finfish are highly mobile pelagic species that are unlikely to benefit directly from MPAs within state waters. Fishing for these species by hand is unlikely to damage habitat, and hook and line gear, dip-nets, ~~and~~ round haul nets, and cast nets do not typically contact the seafloor. However, round haul nets have the potential to damage rocky reef habitats and associated structure forming invertebrates if they come in contact with the bottom. Catch records collected by the Pacific Fisheries Management Council, (PFMC 2009) indicate that bottom contact is infrequent (an average of 6% of hauls contained some benthic algae or invertebrates), and incidental take is low and comprised almost entirely of other highly mobile schooling fish. The mobile nature of the target species and low incidental take of resident species indicate that take of coastal pelagic finfish is likely to have little impact on the resident ecosystem.

Indirect impacts: Coastal pelagic finfish feed on a variety of planktonic organisms and smaller fish. Both coastal pelagic finfish and their prey are highly mobile and incidental catch is low and comprised mainly of other highly mobile species, thus the indirect ecosystem impacts of take are predicted to be low.

Level of protection: **High**

Eulachon (dip net):

Direct impacts: Eulachon (*Thaleichthys paci cus*) are a large anadromous smelt that breeds in rivers and streams within the NCSR. As ocean-going adults, eulachon are believed to school well offshore near the outer continental shelf at depths of 45-225 m (Sweetnam *et al.* 2001). Although the movement patterns of eulachon in the marine environment have not been extensively studied, their schooling habits suggest sufficient mobility that they are unlikely to benefit directly from MPAs within state waters. It is also unclear whether eulachon exhibit breeding site fidelity to their natal streams. A genetic study of eulachon populations revealed substantial genetic variation across their range, but did not identify genetically distinct populations linked to individual rivers or geographic areas (McLean *et al*. 1999). The level of uncertainty about the mobility and spawning site fidelity of eulachon lead to the conclusion that eulachon fishing may temporarily alter the local abundance of eulachon within an MPA, but is unlikely to result in a chronic or long term reduction in the local population.

Eulachon are generally targeted with dip nets in estuarine and fresh waters when they return to rivers to breed. Because this fishing activity occurs in shallow (wading depth) fresh or brackish waters and targets the densest aggregations of spawning eulachon, the level of incidental take of resident marine species in this fishery is likely to be quite low although catch records were not available for analysis.

Indirect impacts: Eulachon feed mainly on euphausid shrimps, copepods, and other crustaceans and are, in turn, preyed upon by a variety of fish including salmon, halibut, cod, and sturgeon (Sweetnam *et al.* 2001). Unlike surf and night smelt, spawning aggregations occur primarily in fresh water and thus are unlikely to provide an important food source for the local nearshore marine ecosystem, thus the removal of eulachon is unlikely to impact community structure.

Level of protection: **High**

Pacific halibut (hook and line):

Direct impacts: Take of Pacific halibut (*Hippoglossus stenolepis*) by hook and line is unlikely to damage habitat, though some bottom contact may occur. Movement studies on Pacific halibut are very limited, but their movement patterns appear to be similar to those of California halibut. For example, Thompson and Herrington (1930) tagged Pacific halibut in Alaska and British Columbia and found that the majority of fish move less than ten miles, though a few individuals move great distances. Given their potential to move only short distances, the abundance of Pacific halibut may be altered by take relative to an SMR.

Associated catch on trips targeting Pacific halibut in the north coast includes a variety of soft bottom and rocky reef-associated species (see Appendix C2). The relatively high associated catch of rocky reef species (nearly 40% of total catch) may be due to the practice of targeting this species in cobble-bottom habitats. Unfortunately, the available catch records do not allow distinction between incidental take and secondary targeting of rockfish or other reef species. In addition to altering the abundance of Pacific halibut, fishing for this species may substantially alter the abundance of associated catch species including reef fish such as rockfish, lingcod, and cabezon, and demersal sharks, skates and rays.

Indirect impacts: Pacific halibut are important predators in the benthic ecosystem. Furthermore, Pacific halibut occur over both sandy and rocky bottoms, and fishing over rocky bottoms increases the likelihood of associated catch of resident rocky reef species. Therefore, fishing for Pacific halibut has the potential to alter the benthic community structure in an area.

Level of protection: **Moderate-Low**

Pacific lamprey (H&L, hand, spear, bow and arrow, dip net):

Direct impacts: Pacific lamprey (*Lampetra tridentate*) are an anadromous fish that breed in rivers and streams within the NCSR. Lampreys are commonly known as “eels” or “freshwater eels” in the study region as a result of their long eel-like bodies. Lampreys likely spend 3 or more years in the marine environment before returning to their natal streams to breed (Beamish 1980) and have been found more than 100 km from the coast and at depths up to 800 m (Kan 1975). Although little is known about the movement patterns of lamprey in the marine environment, evidence suggests that they are sufficiently mobile that they are unlikely to benefit directly from MPAs within state waters.

In California, lampreys are primarily targeted in estuarine and freshwater environments when they return to breed. Hook and line gear and dip nets are common methods of take although hand, spear, and bow and arrow gear may also be used. In the estuarine and freshwater environments where lampreys are targeted the risk of incidental take of resident marine organisms is low.

Indirect impacts: In the marine environment, Pacific lamprey are parasitic, feeding on the blood of larger fish including salmon and marine mammals. As both lamprey and their prey are highly mobile, MPAs are likely to have little impact on the local abundance of these species. Thus, the indirect marine ecosystem impacts of lamprey take are predicted to be low.

Level of protection: **High**

Pelagic finfish (hook and line, troll, spearfishing):

Direct impacts: Pelagic finfish[4] are highly mobile species that are unlikely to benefit directly from MPAs within state waters. The most common species of pelagic finfish targeted in the NCSR are salmon (*Oncorhynchus* spp.) discussed separately below, however several of the smaller species encompassed in this group (anchovy, Pacific herring, jack mackerel, and Pacific mackerel) are also targeted within the study region, and several of the larger species, including tunas and pelagic sharks may be targeted during favorable warm-water conditions. Spearfishing gear is used selectively by divers and does not damage habitat. Hook and line gear, deployed by both troll and non-troll methods, does not typically contact the seafloor and thus is unlikely to damage habitat. Both troll and non-troll hook and line modes of fishing are conducted with similar gear, but trolling is characterized by continuous movement under power, and non-troll fishing is conducted while drifting or at anchor.

Fishing for pelagic finfish with spearfishing gear requires visual contact with the target, thus the incidental catch in this fishery is likely to be minimal. As in the case of salmon, non-target catch associated with hook and line and troll gear is likely to vary as a function of depth and fishing mode (troll vs. drift), with a greater risk of incidental take of rock-associated species in shallower waters or with slow moving drift fishing gear. General trends in the catch data for salmon, the most commonly targeted pelagic finfish in the study region, suggest that fishing for pelagic finfish with both troll and non-troll gear in waters deeper than 50 meters is unlikely to alter the abundance of any species relative to an SMR. The risk of incidental catch of resident species increases slightly with troll gear in waters shallower than 50 meters, but is unlikely to result in a substantial change in abundance of any species. With non-troll hook and line in waters shallower than 50 meters, however, the increased risk of incidental take has the potential to substantially alter the abundance of resident species including rockfish and lingcod.

Indirect impacts: Pelagic finfish generally feed on mobile forage species such as uch as small schooling fishes, crab larvae, squid, shrimps and planktonic organisms. As both pelagic finfish and their prey are highly mobile, MPAs are likely to have little impact on the local abundance of these species. Thus, the indirect ecosystem impacts of pelagic finfish take are predicted to be low. Many of the resident species that may be taken in association with pelagic finfish (rockfishes, lingcod, greenlings), however, play an important predatory role in the nearshore ecosystem. Thus, the level of indirect ecosystem impacts scales with the likelihood of incidental take of resident species.

Level of protection: **High** for spearfishing at any depth
High for both non-troll and troll hook and line in waters greater than 50 meters depth
Moderate-high for troll hook and line in waters less than 50 meters depth
Moderate for non-troll hook and line in waters less than 50 meters depth.

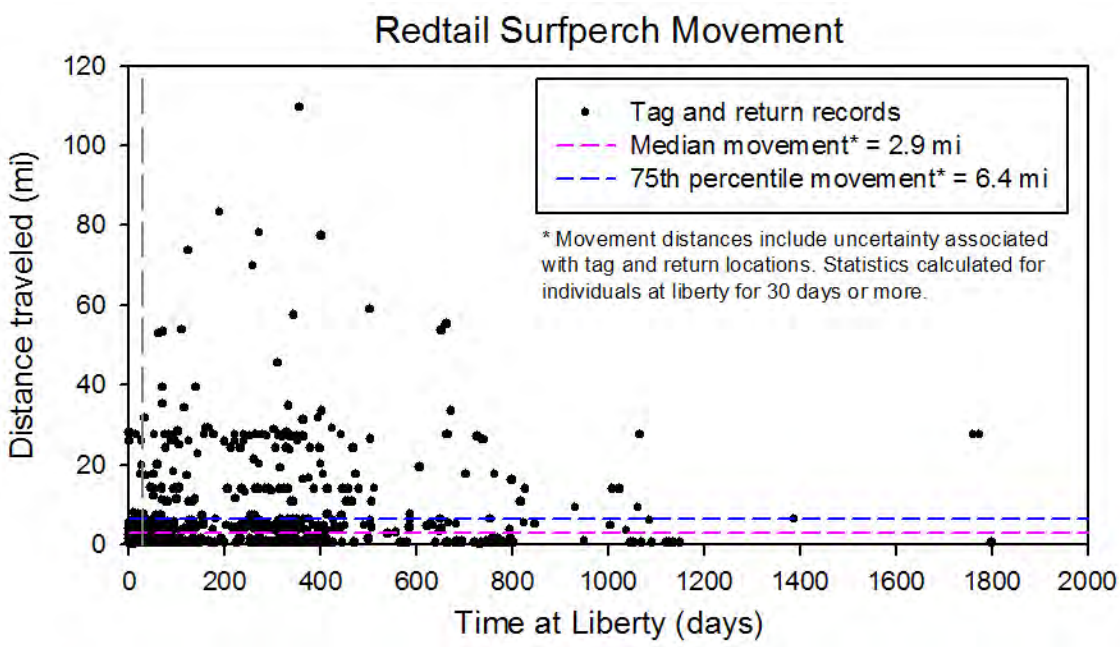
[4] The grouping "pelagic finfish" includes: northern anchovy (Engraulis mordax), barracudas (Sphyraena spp.), billfishes* (family Istiophoridae), dolphinfish (Coryphaena hippurus), Pacific herring (Clupea pallasi), jack mackerel (Trachurus symmetricus), Pacific mackerel (Scomber japonicus), salmon (Oncorhynchus spp.), Pacific sardine (Sardinops sagax), blue shark (Prionace glauca), salmon shark (Lamna ditropis), shortfin mako shark (Isurus oxyrinchus), thresher sharks (Alopias spp.), swordfish (Xiphias gladius), tunas (family Scombridae), and yellowtail (Seriola lalandi). *Marlin is not allowed for commercial take.

Redtail surfperch (hook and line from shore):

Direct impacts: Fishing for redtail surfperch (*Amphistichus rhodoterus*) from shore using hook and line gear may cause some disturbance to the intertidal, but is unlikely to significantly alter habitat. Redtail surfperch occur in a narrow band of shallow waters along the coast, primarily over soft bottoms, and give birth to small numbers of live young (Love 1996, Eschmeyer and Herald 1983). Redtail surfperch are primarily targeted during the breeding season when they aggregate in the surf zone of beaches to give birth and breed. During this birthing period, female surfperch may be especially susceptible to fishing, as they may abort their young when caught, leading to the death of underdeveloped embryos (Allen, pers. com.).

There is little published information about the movements of redtail surfperch, however a ~~tagging~~ study conducted by the Oregon Department of Fish and Wildlife (Pruden 2000) collected tag and recapture information for more than 700 redtail surfperch but reports movements for only 12 selected fish. Although this study did not explicitly evaluate the movements of tagged surfperch, data were made available to MLPA staff for analysis. Results of the movement analysis indicate that a substantial proportion of redtail surfperch (46%) were recovered at the same location where they were tagged more than a month and up to 5 years after the tag date (Figure 3-2). The median movement distance for redtail surfperch tagged in this study was 2.9 miles (results limited to individuals that were at liberty for 30 days or more) although some individuals moved much greater distances (up to 100 miles) in the same time period. Unfortunately, tag and recapture locations were recorded by location name only, which limited the resolution of the movement analysis in some areas and may have artificially inflated movement distances for some individuals. Never-the-less, the movement information derived from this tagging data indicates that redtail surfperch may remain within the confines of a single beach for an extended period of time. This limited movement combined with viviparous reproduction indicates that the abundance of redtail surfperch could be substantially altered by take relative to an SMR.

Figure 3-2. Movements of Redtail Surfperch Derived from Tagging Data Collected in Oregon (Pruden 2000)



Indirect impacts: Redtail surfperch are a key component of the commercial fishery of the north coast study region, and they compose approximately 73% of the commercial surfperch catch in

California (Love 1996). Redtail surfperch eat a wide variety of prey and are eaten by a number of predators, however, the impact of their removal on the resident ecosystem is likely to be mitigated by several factors: 1) fishing from shore leaves a portion of the redtail surfperch habitat inaccessible to fishing, 2) the turbulent surf zone in which they live and forage is a dynamic habitat with high turnover of short-lived benthic invertebrates, and 3) several other surfperch species play a similar ecosystem role. These three mitigating factors lead the SAT to conclude that the removal of redtail surfperch by hook and line from shore is unlikely to substantially alter the community structure of the nearshore sandy bottom habitat.

Level of protection: **Moderate**

Rockfishes, Cabezon and other sculpins, lingcod and other greenlings, California moray eels, wolf eels, and monkeyface and rock pricklebacks (hook and line, spearfishing, trap, hand, bow and arrow):

Direct impacts: Rockfishes (many species, *Sebastes* spp.), cabezon (*Scorpaenichthys marmoratus*) and other sculpins (family Cottidae), ~~and~~ lingcod (*Ophiodon elongatus*) and other greenlings (*Hexagrammos decagrammus* and *Oxylebius pictus*), California moray eels (*Gymnothorax mordax*), monkeyface and rock pricklebacks (*Cebidichthys violaceus* and *Xiphister mucosus*), and wolf eels (*Anarrhichthys ocellatus*) are important members of rocky reef communities. They have low adult mobility, thus their abundance is likely to be substantially altered by catch relative to an SMR. Associated catch for any of these species could include other reef fishes with low mobility. Hand harvest, spearfishing, or bow and arrow fishing for these species does not involve bottom contact. Fishing with hook and line gear (including longlines) could involve bottom contact and traps contact the bottom, but these methods likely cause little habitat disturbance. It is important to note that a level of protection was determined for rockfishes, cabezon and other sculpins, lingcod and other greenlings, California moray eels, monkeyface and rock pricklebacks, and wolf eels individually. Since all ~~four~~ of these species or groups received the same level of protection for the same reasons, they are being presented here as a group.

Indirect impacts: Rockfishes, cabezon and other sculpins, lingcod and other greenlings, California moray eels, monkeyface and rock pricklebacks, and wolf eels are important predators in rocky reef ecosystems. Lingcod, in particular, are high trophic level predators and play a key role in structuring rocky reef communities (Beaudreau 2009). Wolf eels are also known to prey on herbivorous sea urchins which may indirectly influence algal abundance. Decreasing the abundance of any of these species through take could have strong indirect impacts on rocky reef trophic systems and community structure.

Level of protection: **Moderate-Low**

Salmon (hook and line, troll):

Direct impacts: Salmon (*Oncorhynchus* spp.) are highly mobile pelagic species that are unlikely to benefit directly from MPAs within state waters. Hook and line gear, deployed by both troll and non-troll methods, does not typically contact the seafloor and thus is unlikely to damage habitat. Both troll and non-troll hook and line modes of fishing are conducted with similar gear, but trolling is characterized by continuous movement under power, and non-troll fishing is conducted while drifting or at anchor.

To understand the direct impacts of salmon fishing, the SAT workgroup examined catch records from the Commercial Passenger Fishing Vessel (CPFV) fleet logbooks and observer data from the California Recreational Fisheries Survey (CRFS). Both of these sources distinguish between troll

and non-troll fishing modes and depths fished. However, neither information source allows reliable identification of secondary targets, meaning that at least some of the trips may have included fishing targeted at non-salmon species. Data limitations preclude an accurate estimate of the magnitude of incidental take in the salmon fishery, however, catch records may be used to examine the relative trends in and the species composition of associated catch across different depth zones and gear types.

Conceptually, fishing in shallower water, where fishing gear is closer to the seafloor, increases the likelihood that resident, bottom-associated species will be captured incidentally. This is one of several conclusions generated at a workshop on benthic-pelagic coupling that involved fishermen and scientists (Grober-Dunsmore et al. 2008). At that workshop there was general agreement that 50 meters depth was the appropriate delineation between deep waters (where incidental catch is likely to be low) and shallow waters (with likely higher rates of incidental catch). Likewise, fishing with slow-moving gear (i.e. non-troll or drift methods) increases the likelihood that resident species that hunt in a localized area or ambush their prey will be captured incidentally. The available catch records from both the CPFV and CRFS sources appear to support these hypotheses, but datasets are small and show a dramatic variation in associated catch from year to year (see Appendix C2), so conclusions drawn from them are necessarily equivocal.

General trends in the catch data suggest that salmon fishing with both troll and non-troll gear in waters deeper than 50 meters is unlikely to alter the abundance of any species relative to an SMR. The risk of incidental catch of resident species increases slightly with troll gear in waters shallower than 50 meters, but is unlikely to result in a substantial change in abundance of any species. With non-troll hook and line in waters shallower than 50 meters, however, the increased risk of incidental take has the potential to substantially alter the abundance of resident species including rockfish and lingcod.

Indirect impacts: Salmon generally feed on mobile forage species such as anchovies, krill, crab larvae, herring, sardines, squid, sand lance, and planktonic organisms (Hunt et al. 1999, Merkel 1957). As both salmon and their prey are highly mobile, MPAs are likely to have little impact on the local abundance of these species. Many of the resident species that may be taken in association with salmon (rockfishes, lingcod, greenlings), however, play an important predatory role in the nearshore ecosystem. Thus, the level of indirect ecosystem impacts scales with the likelihood of incidental take of resident species.

Level of protection: **High** for both non-troll and troll hook and line in waters greater than 50 meters depth
Moderate-high for troll hook and line in waters less than 50 meters depth
Moderate for non-troll hook and line in waters less than 50 meters depth.

Sharks, skates, and rays (hook and line, spear, harpoon, bow and arrow):

Direct impacts: Take of sharks, skates, and rays (numerous species) using hook and line, spear, harpoon, or bow and arrow is unlikely to damage habitat. Sharks, skates, and rays are a diverse group of cartilaginous fishes (in the subclass Elasmobranchii) that includes the ocean's top predators. Most elasmobranchs are relatively slow growing with late sexual maturation and low reproductive potential. Many elasmobranchs bear live young with litter sizes ranging from 1 to roughly 30 young per year, while others lay a small number of "egg cases" from which the young hatch fully formed. Although most elasmobranchs are highly mobile, there are several species in the north coast study region, including leopard sharks (*Triakis semifasciata*) and bat rays (*Myliobatis californica*) that primarily inhabit estuarine waters and aggregate in estuaries to breed, during which time they are especially vulnerable to fishing. Due to the high mobility of elasmobranchs along the open coast, their abundance is unlikely to be altered relative to an SMR if this take occurs in non-

estuarine waters. In estuarine waters, however, targeting aggregations of breeding elasmobranchs may alter the local abundance of these species and have impacts on coast-wide populations. Furthermore, take by spear, harpoon, or bow and arrow is likely to have little associated catch, since these methods target individual fishes within view. The use of hook and line, however, has the potential for similar associated catches as other hook and line fisheries, and therefore hook and line methods receive a lower level of protection than the methods with directed projectiles.

Indirect impacts: Sharks, skates, and rays are important predators in oceanic and estuarine ecosystems. They are nearly always apex predators in their habitats, and if they are not, it is likely that another elasmobranch is their only predator. As estuarine residents, species such as leopard sharks (*Triakis semifasciata*) and bat rays (*Myliobatis californica*) are important members of the ecosystem; bat rays are known to have impacts on benthic community structure simply through their feeding activites (Karl and Obrebski 1977). Bat rays use estuaries as pupping and feeding grounds (e.g. Martin and Cailliet 1988), and Humboldt Bay has been found to be an important pupping site in the north coast study region (Gray et al. 1997). Removal of these species from the estuarine ecosystem could have indirect impacts on the community structure of these habitats.

Level of protection: **Moderate-high** for spear, harpoon, bow and arrow in non-estuarine waters
Moderate for hook and line in non-estuarine waters
Moderate-low for hook and line, spear, harpoon, bow and arrow in estuarine waters

Shiner surfperch (hook and line, dip net, cast net):

Direct impacts: Fishing for shiner surfperch (*Cymatogaster aggregata*) using hook and line, dip net, or cast net is unlikely to significantly alter habitat, although dip nets and cast nets can contact the bottom.

All of the commonly caught surfperch species in the north coast live primarily in a narrow band of shallow waters along the coast, and give birth to small numbers of live young (Love 1996, Eschmeyer and Herald 1983). During the birthing period, female surfperch may be especially susceptible to fishing, as they may abort their young when caught, leading to the death of underdeveloped embryos (Allen, pers. com.).

The movements of surfperch have not been extensively documented, but several studies indicate that mobility is quite low, especially for reef associated species. A competition experiment conducted on black and striped surfperch found little emigration between populations of these reef-associated species separated by short distances of sand (Schmitt and Holbrook 1990). Beach-associated surfperch such as redtail and calico surfperch are known to move greater distances (Pruden 2000), but at least some beach associated species are known to remain in a small area for long periods of time (Carlisle et al. 1960). Unlike most surfperch species, shiner surfperch are known to utilize multiple habitats, including shallow estuarine areas and protected embayments (Eschmeyer and Herald 1983), but little is known about their movements.

Due to the limited movements of some surfperch species and viviparous reproductive strategy it is possible that the abundance of shiner surfperch could be substantially altered by take relative to an SMR, though studies specific to shiner surfperch have not been conducted. Since shiner surfperch frequently swim in loose schools that may contain other fish species, the potential exists for increased associated catch of non-target species, particularly using dip nets or cast nets.

Indirect impacts: Shiner surfperch are microcarnivores that feed on wide variety of invertebrate prey and are eaten by a number of predators. The indirect impact of shiner surfperch take on the resident ecosystem is likely to be relatively low.

Level of protection: **Moderate-low**

Surf and night smelt (dip net, a-frame net, cast net):

Direct impacts: Take of surf and night smelt (*Hypomesus pretiosus* and *Spirinchus starksi*, respectively) by dip net, a-frame net, or cast net is unlikely to damage the dynamic beach habitat in which this activity occurs. Smelt fishing occurs during the spring and summer months when the fish aggregate along coarse sand and gravel beaches to spawn. Likely because this fishing activity occurs in shallow (wading depth) waters and targets the densest aggregations of spawning smelts, the level of incidental take in this fishery is reportedly quite low. Limited catch records from the CRFS database confirm reports of low incidental take in the smelt fishery.

Little is known about the adult movements or spawning site fidelity of surf and night smelt, so it is unclear how take of these species may alter their long-term local abundance. Surf and night smelt are known to frequent the same spawning beaches year after year, but the locations of spawning aggregations shift along the beaches from night to night and it is unclear whether individual smelt return to the beach where they were spawned, or simply spawn at any one of many beaches that provide appropriate spawning habitat. In Puget Sound, the Washington Department of Fish and Wildlife suggests that surf smelt populations may be dependent on a single beach or handful of beaches (Penttila 2007), but does not substantiate this statement. The level of uncertainty about the mobility and spawning site fidelity of smelt lead to the conclusion that smelt fishing may temporarily alter the local abundance of smelt within an MPA, but is unlikely to result in a chronic or long term reduction in the local population.

Indirect impacts: Smelts and their eggs provide food for a wide variety of species including other fish, marine birds and mammals. Predictable seasonal spawning aggregations may provide an important food source for the local nearshore ecosystem, thus the removal of smelts may impact community structure by reducing this food resource.

Level of protection: **Moderate-high**

Surfperch (hook and line from shore, hook and line):

Direct impacts: Fishing for surfperch (family Embiotocidae) from using hook and line gear either from boats or from shore is unlikely to significantly alter habitat.

The most commonly caught species of surfperch in the North Central Coast study region are redtail surfperch (*Amphistichus argenteus*, discussed above), striped surfperch (*Embiotoca lateralis*), calico surfperch (*Amphistichus koelzi*) and walleye seaperch (*Hyperprosopona argenteum*). Of these species, redtail and calico surfperch are primarily found along beaches, while striped surfperch tend to be associated with rocky substrate and walleye surfperch occupy multiple habitats. All of the commonly caught surfperch species in the north coast live primarily in a narrow band of shallow waters along the coast, and give birth to small numbers of live young (Love 1996, Eschmeyer and Herald 1983). During the birthing period, female surfperch may be especially susceptible to fishing, as they may abort their young when caught, leading to the death of underdeveloped embryos (Allen, pers. com.).

The movements of surfperch have not been extensively documented, but several studies indicate that mobility is quite low, especially for reef associated species. A competition experiment conducted on black and striped surfperch found little emigration between populations of these reef-associated species separated by short distances of sand (Schmitt and Holbrook 1990). Beach-associated surfperch such as redtail and calico surfperch are known to move greater distances (Pruden 2000),

but at least some beach associated species are known to remain in a small area for long periods of time (Carlisle et al. 1960).

Due to the limited movements of some surfperch species and viviparous reproductive strategy it is possible that the abundance of surfperch could be substantially altered by take relative to an SMR. Fishing for surfperch over rocky reef habitats may also result in the associated catch of other resident reef species such as rockfish and greenlings. The change in abundance of surfperch and associated catch species is likely to be less substantial when take occurs only from shore as some portion of the population is likely to be inaccessible to fishing.

Indirect impacts: Surfperch are microcarnivores that feed on wide variety of invertebrate prey and are eaten by a number of predators. The impact of surfperch take on the resident ecosystem is likely to scale with the spatial extent of take. If surfperch are fished from shore only, some portion of their population is likely to remain unfished reducing the ecosystem impacts of this take relative to boat-based fishing.

Level of protection: **Moderate-low** for hook and line
Moderate for hook and line from shore only

Trout other than steelhead rainbow trout (hook and line):

Direct impacts: Take of trout (including cutthroat trout *Oncorhynchus clarkii* and others) by hook and line is unlikely to damage habitat. The group of fishes known as “trout” includes a number of primarily freshwater species and a few anadromous species from the Family Salmonidae. Anadromous species behave like salmon, returning to their natal streams after several years at sea, and some freshwater species spend time in estuaries. Unlike salmon, however, cutthroat trout do not die after spawning and can thus reproduce for multiple years. Since these species are not usually resident in estuaries and coastal waters, their abundances are unlikely to be altered by take relative to an SMR.

Indirect impacts: Trouts prey on a wide variety of crustaceans, insects, and other fishes, and are in turn prey for a number of fishes, birds, and mammals. Since cutthroat trout do not die after spawning and return to natal streams to reproduce, there is the potential that their removal could have an impact on community structure.

Level of protection: **Moderate-high**

White sturgeon (hook and line)

Direct impacts: Fishing for white sturgeon by hook and line is unlikely to damage habitat directly, although gear frequently comes in contact with the bottom.

White sturgeon (*Acipenser transmontanus*) are the largest anadromous fish in North America and inhabit fresh, estuarine, and marine waters in the north coast study region. White sturgeon can live more than 100 years, are slow growing with females not reaching sexual maturity until 15 years of age or more, and reproduce only every 3-5 years (Emmett *et al.* 1991). The slow growth, late maturity, and infrequent reproduction of white sturgeon make them especially vulnerable to over-exploitation. Some populations of white sturgeon are land-locked, while others utilize estuarine and marine waters during their life cycle (Haynes and Gray 1981). Little is known about the movement patterns of adult sturgeon in estuarine and marine waters, but tagging studies in fresh water have shown seasonal site fidelity combined with seasonal migrations (Parsley *et al.* 2008). This combination of vulnerable life history characteristics and seasonal site fidelity indicate that take of

white sturgeon may alter the abundance of this species relative to an SMR. Furthermore, fishing for white sturgeon occurs close to the substrate, which increases the likelihood of incidental take of resident species.

Indirect impacts: White sturgeon are opportunistic bottom-feeders and scavengers that prey on a variety of marine and freshwater fish and invertebrates including sculpins, lamprey, smelt, dead fish, mollusks and crustaceans. Due to their generalist feeding habits, removal of white sturgeon is unlikely to have a substantial impact on community structure.

Level of protection: **Moderate**

LOP Designations for Invertebrates

Abalone (free-diving hand harvest):

Direct impacts: Take of abalone (*Haliotis* spp.) using hand collection techniques is unlikely to damage habitat. Abalone are relatively sedentary organisms, so their local abundance will likely be substantially altered by take relative to an SMR. Because divers harvest selectively, there is little or no catch of non-target species, with the exception of other invertebrates attached to the abalone themselves. However, divers sometimes accidentally remove sub-legal size individuals, which may kill the animal even though it is often immediately replaced. High numbers of scuba divers at local access sites has been shown to lead to localized habitat impacts (Schaegger et al. 1999), and the same may be true for free-divers. Divers may also cause behavioral responses in mobile species (Parsons and Eggleston 2006).

Indirect impacts: Abalone are important detritivores and grazers in the nearshore rocky environment. Adult abalone feed primarily on drift algae (Lowry and Pearse 1973) but both more mobile juveniles and sedentary adults also feed on attached algae (Tutschulte and Connell 1983). The direct impacts of abalone on algal communities is unclear, however, abalone may exert an indirect effect on algal communities through competition with sea urchins for space and food (Tegner and Dayton 2000). The complexity of interactions between abalone, urchins, and algal communities indicate that removal of this species is likely to have impacts on community structure within an MPA. In some areas of California, abalone have deep-water refugia generally beyond free-diving depths. In the north coast study region, however, rocky reefs frequently do not extend to depths beyond the range of free-divers, therefore eliminating the potential for deep-water refugia in many areas. Furthermore, localized depletion of shallow adult spawning stocks within an MPA, combined with short larval dispersal distances, could reduce the local availability of young abalone as prey to small predators even in areas where these deep-water refugia exist. In the case of the (currently closed) commercial abalone fishery, use of diving or “hookah” gear may reduce the deep water abalone refugia thereby increasing the potential for local depletion of adult spawning stocks.

Level of protection: **Moderate-low**

Clams (intertidal hand harvest):

Direct impacts: Take of clams (numerous species) is unlikely to permanently alter habitat in the dynamic soft bottom environments where harvest takes place. Clams are relatively sedentary animals with limited adult home ranges, thus their local abundance is likely to be substantially altered by take relative to an SMR.

Indirect impacts: Clam digging may alter the behavior of local shorebirds and marine mammals, and could kill non-target infaunal species, including improperly placed sublegal clams. Though clams

are an important food source for a variety of fishes and elasmobranchs, hand harvest is unlikely to have a large impact on community structure, since it only occurs in the intertidal zone, thereby leaving a large proportion of the clam population unharvested.

Level of protection: **Moderate**

Coonstripe shrimp and spot prawn (trap):

Direct impacts: Take of coonstripe shrimp (*Pandalus danae*) or California spot prawn (*Pandalus platyceros*) with traps involves bottom contact but is unlikely to alter habitat.

Spot prawns are moderately mobile species (Boutillier and Bond 2000) which may benefit directly from MPAs within state waters. Tagging studies of spot prawns from British Columbia show that individuals remain within a mile or two of their release location over several months (Boutillier, unpublished data). This finding is supported by a study that found significant differences in parasite loads between populations separated by only 10s of kilometers (Bower and Boutillier 1990). The moderate adult movement of spot prawn indicates that the abundance of spot prawn could potentially to be substantially lower in a fished area as compared to a no-take marine reserve. Though no movement studies have been conducted on coonstripe shrimp, they are ecologically similar to spot prawns, so they could be reasonably assumed to have similar adult movement distances. Recent surveys conducted by CDFG indicate that coonstripe shrimp aggregate in areas of mixed mud and rocky bottom where densities can be quite high (20-30 per square meter) (Prall pers. comm.). These observations of aggregations and apparent feature association are consistent with moderate mobility for coonstripe shrimp. No data on associated catch for the spot prawn fishery were examined, but data from other trap fisheries (e.g. Dungeness crab) indicates that bycatch in the trap fishery is likely to be low, thus the fishing activity is unlikely to alter the abundance of any non-target species.

Both spot prawns and coonstripe shrimp are protandrous hermaphrodites, meaning that most individuals hatch, grow, and spend their first several breeding years as males before transitioning to females (Larson 2001, Warner and Larson 2001). Due to the larger size of females, they are a highly valued component of the catch. This life history strategy may make coonstripe shrimp and spot prawn especially vulnerable to fishing pressure, because large reproductive females are directly targeted by the fishery.

Indirect impacts: Spot prawn and coonstripe shrimp are micro-predators, feeding on other shrimp, plankton, small mollusks, worms, sponges, and fish carcasses (Larson 2001, Warner and Larson 2001). In turn, these species are one of many available prey items for fishes and marine mammals. Any change to ecological interactions caused by reduced abundance of spot prawns or coonstripe shrimp is likely to have only minor impacts on community structure within an MPA.

Level of protection: **Moderate**

Crabs other than Dungeness crabs (hand, trap, hoop net):

Direct impacts: Take of crabs (several species of rock crabs and shore crabs including *Cancer productus, C. anthonyi, C. antennarius, C. gracilis,* and *Hemigrapsus nudus*) using hand collection, trap, or hoop net is unlikely to damage habitat, though traps and hoop nets contact the bottom. Rock crabs are important predators and scavengers in the benthic marine ecosystem of California, and shore crabs play a pivotal role as scavengers, predators, and prey in the rocky intertidal. A tagging study from central California showed rock crabs (*C. antennarius*) to have low mobility as adults; almost half of the recovered tagged crabs were found at their original release site up to 18 months

after release, and 7 km was the maximum distance any crab traveled (Carroll 1982). Additionally, data from southern California shows that in Santa Monica Bay, which is closed to rock crab fishing, crabs are larger, size frequencies are broader, and experimental catch rates are higher than in areas open to crab fishing (Leet et al. 2001). These studies indicate that rock crab abundance is likely to be altered by take relative to an SMR. Though no studies have been directly conducted on shore crab home ranges, their construction of home burrows, combined with their position in the food web primarily as scavengers indicates that they have relatively small home ranges, particularly when compared to the minimum MPA size guidelines established by the Science Advisory Team.

Indirect impacts: Rock crabs play an important ecosystem role as scavengers and predators, and are a prey for a variety of other predators. Shore crabs also play a key ecosystem role as scavengers, predators, and prey. The removal of these crabs from the ecosystem is likely to impact community structure.

Level of protection: **Moderate-low**

Dungeness crab (trap, hoop net, diving, hand):

Direct impacts: Traps used to catch Dungeness crab (*Cancer magister*) contact the bottom, but they likely cause little habitat disturbance. Hoop nets, diving, and hand collection are unlikely to damage habitat. Dungeness crab are a moderately mobile species, with potential movements on the order of 10-15 km (Smith and Jamieson 1991), indicating that the abundance of Dungeness crab may be altered by take relative to an SMR, but likely not substantially. An example of the effect of a spatial closure on the abundance [catch per unit effort (CPUE)] and size distribution of Dungeness crabs can be found in studies at the mouth of the Glacier Bay National Park fishing closure (Taggart et al. 2004). Both the abundance (CPUE) and size of legal-sized male crabs in this area increased relative to that within the Park prior to closure and outside the Park after the closure. Sample sites were located 15-20 km outside of, and 10-20 km inside of, the closure boundary (at the mouth of Glacier Bay). However, the oceanography, bathymetry and large size of the spatial closure were likely key factors in determining that outcome, and the applicability of those results to the north coast study region is probably limited. Commercial fishing is known to remove a substantial fraction (up to 90%) of legal-sized male crabs (Methot and Botsford 1982) which reduces the ecosystem-wide abundance and alters the size distribution, and sex ratio of Dungeness crabs. These changes in abundance, however, are likely not substantial on the local scale of MPAs relative to dramatic ecosystem-wide population fluctuations that may occur from one year to the next (McKelvey et al. 1980, Hankin 1985).

Other species landed in the Dungeness crab fishery comprise less than 1% of the total catch and include rock crabs, octopus, sea stars, and female Dungeness crabs in low numbers (Appendix C2). Crab traps and associated buoys may also present an entanglement hazard for marine mammals. Several incidents of humpback whale entanglement in crab traps along the California coast have been reported in local news sources, but no information is available about the frequency of such incidents. Although crab traps may have impacts on non-target organisms, the magnitude of these impacts is likely to be low.

Indirect impacts: Dungeness crabs are key predators in the benthic environment and their abundant larvae and small juveniles provide food for a variety of species including salmon, flatfishes, lingcod, cabezon, rockfishes, octopuses, and larger crabs (Hankin and Warner 2001). Crabs are opportunistic feeders consuming large numbers of sessile and sedentary benthic invertebrates and fishes. Removal of the largest male crabs could decrease predation pressure, which may have an effect on the invertebrate populations and community structure in an area.

Level of protection: **Moderate-high**

Ghost shrimp (hand harvest):

Direct impacts: Take of ghost shrimp (*Neotrypaea californiensis*) alters habitat by removing these important habitat engineers from the ecosystem.

Ghost shrimp are a relatively sedentary species that create branched burrows in mudflats in estuaries and bays. They are important bioturbators and their burrows create habitat for a wide variety of species, including pea crabs, gobies, and burrowing clams. Additionally, they are a significant portion of the biomass in some mudflats and are important prey for some fishes and birds.

The local abundance of ghost shrimp is likely to be altered by take relative to an SMR for two reasons. First, adults have limited home ranges, so local abundance is sensitive to the removal of individuals. Second, the trampling associated with collecting ghost shrimp may amplify the decrease in shrimp abundance. For example, Wynberg and Branch (1994) found a 70% population decline of a similar ghost shrimp species when only 10% of the population was actually removed. They attributed the difference to smothering in collapsed burrows caused by trampling on the surface.

Indirect impacts: Since ghost shrimp are important habitat engineers and modify their environment to the benefit of other species, their removal could limit the available habitat for a suite of associated species, thereby altering mudflat community structure. Additionally, the trampling associated with ghost shrimp collection could reduce other macrofauna populations (Wynberg and Branch 1997) and could kill non-target infaunal species.

Level of Protection: **Low**

Limpets (hand harvest):

Direct impacts: Take of limpets (many species) using hand collection techniques is unlikely to damage habitat. Limpets are relatively sedentary organisms, so their local abundance will likely be substantially altered by take relative to an SMR. Because they are harvested selectively, there is little or no catch of non-target species, with the exception of other invertebrates or algae attached to the limpets themselves.

Indirect impacts: Limpets are important grazers in the rocky intertidal of California and are prey for a variety of organisms including oystercatchers, sea stars, crabs, and fishes. Limpets can have tremendous impacts on the community structure of rocky shores by “bulldozing” or ingesting other invertebrates from the rock, thereby keeping patches of rock open and free of sessile invertebrates (e.g. Miller and Carefoot 1990). Additionally, some limpets, such as the giant owl limpet *Lottia gigantea*, are sequential hermaphrodites, meaning they change from males to females as they grow. This results in a population with large females and small males, and since the largest limpets are usually targeted during harvests, this could lead to either skewed sex ratios or populations with relatively smaller (and therefore less fecund) females (Wright 1989). Given the important role they play in structuring the rocky intertidal and the potential impacts harvest could have on population structure, limpets receive a moderate-low level of protection.

Level of protection: **Moderate-low**

Market squid (hook and line, round-haul net, dip net, cast net, hand)

Direct impacts: Market squid (*Loligo opalescens*) are a highly mobile pelagic species that is unlikely to benefit directly from MPAs within state waters. Fishing for squid frequently targets the species during spawning aggregations, however squid grow quickly and spawn only once, making

the population less vulnerable to spawning-targeted fishing than other species. Hook and line gear, dip-nets, and cast nests may contact the bottom, but are unlikely to directly alter substrate. Round haul nets, however, have the potential to damage rocky reef habitats and associated structure forming invertebrates if they come in contact with the bottom. Catch records collected by the Pacific Fisheries Management Council, (PFMC 2009) indicate that bottom contact is infrequent (an average of 6% of hauls contained some benthic algae or invertebrates), and incidental take is low and comprised almost entirely of highly mobile schooling fish. The mobile nature of the target species and low incidental take of resident species indicate that take of market squid is likely to have little direct impact on the resident ecosystem.

Indirect impacts: Squid are an important prey item for a variety of marine mammals, birds, and fishes. Although adult squid are highly mobile and thus unlikely to benefit from MPAs, the location of breeding aggregations may be predictable from year to year, providing a reliable influx of food in the form of "spawned out" adult squid to the resident marine ecosystem. Consequently, fishing activities that target breeding aggregations of squid may have some impact on the resident marine ecosystem by reducing the availability of squid as a seasonally important prey source.

Level of protection: **Moderate-high**

Mussels (hand harvest):

Direct impacts: Take of mussels (*Mytilus californianus*, *M. galloprovincialis, and M. trossulus*) by hand is unlikely to directly damage the rocky substrate to which they attach. However, mussels are a functionally sessile species, so their local abundance is likely to be substantially altered by take relative to an SMR.

Indirect impacts: Mussels create important biogenic habitat for a huge variety of species (e.g. Suchanek 1992; Lohse 1993) and are an important prey item for numerous rocky shore predators. Their removal significantly alters the species community at that given location.

Level of protection: **Low**

Native oysters (hand harvest):

Direct impacts: Take of native oysters (also known as Olympia oysters, *Ostreola conchaphila*) using hand collection techniques has the potential to damage the hard substrate to which oysters attach. Oysters are also biogenic habitat themselves and are frequently some of the only hard substrate found in soft-bottomed estuaries in the Pacific Northwest. Though they do not form major reefs like oysters in areas such as Chesapeake Bay, they have the potential to create a significant amount of habitat. Since they are sessile, the local abundance of native oysters will likely be altered by take relative to an SMR. In fact, historical records provide some evidence that native oyster abundances can be significantly altered by take, particularly given the limited areas of suitable habitat (shallow estuaries) available (Cook et al. 2000; Kirby 2004).

Indirect impacts: Native oysters are filter feeders that occur in estuaries throughout the Pacific Northwest. Due to historical overfishing, their current ecological role in the environment is limited, though they provide some of the only hard substrate in soft bottomed estuaries. Their shells provide habitat for a number of other species, including juvenile Dungeness crabs. As filter feeders, their removal could have impacts on estuarine water quality; fewer filter feeders can lead to increased water opacity and thus decreased sunlight to benthic photosynthesizers such as eelgrass. Due to the important and complex role oysters can play in west coast estuaries, they receive a low level of protection.

Level of protection: **Low**

Octopus (hand or hook and line):

Direct impacts: Take of octopi (*Octopus rubescens, O. bimaculoides,* and *Enteroctopus dofleini*) using hand collection techniques or hook and line is unlikely to damage habitat. Octopi are important predators in rocky reef ecosystems, even venturing into the intertidal. Octopi usually have relatively small home ranges. Studies of *E. dofleini* have shown they have very small home ranges (maximum 250m^2 in Mather et al. 1985), and one study in Hawaii found that *Octopus cyanea* individuals traveled on average only 14m from their dens (Ivey 2007). Therefore, octopus abundance is likely to be altered by take relative to an SMR.

Indirect impacts: Octopi are important predators in the subtidal and lower intertidal, feeding on snails, crabs, limpets, and other invertebrates. As important high-level predators in the ecosystem, their removal could result in changes to the trophic system and community structure of their rocky reef habitats.

Level of protection: **Moderate-low**

Rock scallop (diving hand harvest)

Direct impacts: Hand collection of rock scallops (*Crassadoma gigantea*) is done in one of two ways. Either the diver cuts the scallop from its shell underwater, leaving the shell attached to the rock, or the diver pries the scallop, shell and all, from the rock. Either method causes some habitat disturbance, but prying the shell from the rock causes damage to the reef as well as removing the habitat formed by the scallop shell. The removal of rock scallops is likely to have an impact on community structure by altering reef structure and habitat for benthic invertebrates.

Rock scallops are a sessile bivalve that inhabits rocky reefs. Due to their sessile nature rock scallops are likely to benefit directly from MPAs within state waters, therefore harvest of rock scallops is likely to alter their abundance relative to an SMR. Because divers harvest selectively, there is little or no catch of non-target species.

Indirect impacts: Rock scallops are planktivores and prey to sea stars and shell borers in the nearshore rocky environment. Removal of this species is likely to have moderate impacts on community structure within an MPA.

Level of protection: **Low**

Sea urchin (diving hand harvest):

Direct impacts: Commercial red sea urchin fishing uses hand rakes to fish urchins. Rake collection of urchins may cause some rocky habitat damage (divers may also move rocks to better remove the urchins), but these habitat effects are unlikely to alter community structure significantly.

Several species of sea urchins inhabit shallow rocky reefs along the coast of California. The two most abundant species on shallow rocky reefs throughout the north coast of California are the red and purple sea urchin (*Strongylocentrotus franciscanus* and *S. purpuratus*, respectively). The red urchin is the only urchin species taken commercially in California waters. Both red and purple sea urchins are relatively sedentary. Thus, the abundance of red sea urchins within an area may be altered by take relative to an SMR, depending on the rates of predation by other sea urchin predators. Divers harvest sea urchins selectively so there is little or no take of non-target species.

Indirect impacts: Urchins are ecologically important species in most shallow rocky ecosystems (Lawrence 1975, Harrold and Pearse 1987, Rogers-Bennett 2007). They are important herbivores, prey, competitors and facilitators of other species in nearshore rocky habitats. In many parts of their range, populations of sea urchins can impact (decrease) the abundance of macroalgae, thereby altering both the total abundance of macroalgae, the relative abundance of species of macroalgae in a kelp forest, and the abundance of invertebrates and fishes associated with habitats created by macroalgae (Graham 2004, Graham et al 2008). However, in the north coast study region, there is little evidence to suggest that unfished urchin populations create “urchin barrens” with no kelp, devoid of fleshy algae and dominated by encrusting coralline algae (L. Rogers-Bennett, in prep).

Adult sea urchins are eaten by several predators on shallow rocky reefs in the north coast study region, including the wolf eel, *Anarrhichthys ocellatus*, sunflower sea star, *Pycnopodia helianthodes*, and other species. Small sea urchins are eaten by other predators (e.g., other sea stars, crabs and other species). In particular, predation by the sunflower sea star has been shown to be important in controlling sea urchin populations in cold water ecosystems similar to those founding the north coast study region (Duggins 1983). For example, predation rates on tethered purple sea urchins at 10 sites spanning the warm and cold water kelp forest ecosystems of the Channel Islands National Marine Sanctuary revealed that urchin mortality was in fact greatest at cold water sites (San Miguel and Santa Rosa) where sunflower sea stars were observed to be the dominant urchin predator, relative to the warm water sites (Anacapa and Santa Cruz) where spiny lobster (*Panulirus interruptus*) and sheephead (*Semicossyphus pulcher*) were the dominant urchin predators (Salomon et al. 2009). In the colder water kelp forest ecosystems off British Columbia, Canada, similar sea urchin predation studies suggest that Pycnopodia is the dominant red sea urchin predator on these subtidal rocky reefs (Salomon pers com 2010).Furthermore, sunflower sea stars are not a fishery target, so their natural populations likely remain high in areas with sufficient prey resources. In addition, at high densities, sea urchins in southern California may experience high mortality from disease (Behrens and Lafferty 2004), which can reduce local sea urchin abundance, however, this has not been observed in the north coast study region.

Sea urchins compete with other herbivores for both drift and intact algae. They also compete with other species for refuge from predators in cracks and crevices. In particular, sea urchins may compete with adult abalone for both drift algae and refuge space (Karpov et al. 2001). In contrast, red sea urchins serve as nursery sites for other small invertebrates, protecting them from predators during their vulnerable life stages. Young abalone seek shelter beneath the spines of red sea urchins and the density of abalone recruits can be greater in northern California MPAs where red sea urchins are protected from take (Rogers-Bennett and Pearse 2001). Red sea urchins act as habitat for juvenile red sea urchin and a suite of other small invertebrates including snails, crabs and invertebrates particularly in shallow habitats in northern California (Rogers-Bennett et al. 1995) and elsewhere in the world. The protection afforded by red sea urchin spines might be even more important for abalone recruits and other invertebrates in the north coast study region, due to the stronger storms and overall shallower rocky reefs of the region, particularly in comparison to other study regions.

These life history features can be used to determine the level of protection for sea urchin harvest in the north coast study region. The lack of evidence that unfished sea urchin populations will form “urchin barrens” in the north coast study region, the sedentary lifestyle of sea urchins, the abundance of important sea urchin predators that are not themselves fishery targets, and sea urchins acting as biogenic structure result in the level of protection for sea urchin harvest in the north coast study region being Moderate-low.

Level of protection: **Moderate-Low**

Turban snails (hand harvest):

Direct impacts: Take of turban snails (*Chlorostoma* [formerly *Tegula*] *funebralis and C. brunea*) using hand collection techniques is unlikely to damage habitat. Turban snails are relatively sedentary organisms, so their local abundance will likely be altered by take relative to an SMR. Because snails are harvested selectively, there is little or no catch of non-target species.

Indirect impacts: Turban snails are detritivores and grazers in the nearshore rocky environment. Their predators include sea stars, crabs, oystercatchers, octopi, and fishes, though no predator specializes on turban snails. Turban snails have been shown to play an important role in intertidal rocky ecosystems, potentially altering community structure through their grazing activities (Nielsen 2001).

Level of protection: **Moderate-Low**

LOP Designations for Algae

Bull kelp (hand harvest):

Direct impacts: Take of bull kelp (*Nereocystis luetkeana*) by hand is unlikely to damage the substrate. However, harvest of bull kelp involves removing the fronds and occasionally the entire pneumatocyst, therefore reducing the alga's reproductive and photosynthetic potential (Springer et al. 2007). Nicholson (1970) found that complete removal of fronds caused all further growth to cease while partial frond removal reduces frond growth rates. Since bull kelp are sessile and likely have limited spore dispersal, reduced reproductive output could lead to a decrease in local bull kelp recruitment. In one study, Roland (1985) found a significant reduction of reproductive output by bull kelp individuals that had been harvested even once during the season. Given their sessile habits and the potential for reduced local recruitment due to harvest, the abundance of bull kelp is likely to be altered by take relative to an SMR.

Indirect impacts: Bull kelp can form extensive beds that provide habitat for a wide variety of other species. In addition to being important to a wide variety of invertebrates, several studies have shown that bull kelp beds are important habitats for both juvenile and adult fishes (e.g. Leaman 1980; Bodkin 1986; Haldorson and Richards 1987; Calvert 2005). In addition to showing bull kelp beds to be important habitat, two of these studies (Leaman 1980; Calvert 2005) experimentally manipulated bull kelp canopy cover and found that most fish populations, especially those of demersal species, decreased in areas with reduced kelp canopy. Though limited in number, these studies suggest that the removal of bull kelp canopy can impact local community structure, therefore the indirect impacts of bull kelp harvest could be substantial.

Level of protection: **Low**

Marine algae other than bull kelp and sea palm (intertidal hand harvest):

The current focus of commercial, recreational and cultural take in northern California is on 'edible' seaweeds. However, many species of marine macroalgae are also harvested from wild populations internationally and nationally for industrial applications as they are the primary sources of alginates, agar, and caregeenans. There is also interest in exploring the use of macroalgae (especially kelps or members of the order Laminariales) for the production of biofuels. Neither Oregon nor Washington currently allow commercial take of benthic marine macroalgae, making California the most likely location for growth in commercial take.

Current regulations on method and amount of commercial take in California are minimal; they do not reflect well established, biological knowledge of benthic marine macroalge and plants nor do they adequately distinguish among species creating the potential for masking the effects of human take (i.e., serial depletion of species). Benthic marine macroalgae and plants include species from 4 major divisions (= phyla) with a large diversity of growth forms and life histories making generalizations challenging. In defining levels of protection for the commercial and recreational take of benthic marine macrolage and plants the focus is on ecological roles and functions. Two species have individual levels of protection, reflecting their important ecological role, current commercial importance and/or availability of data on the impacts of commercial take (the kelp forest-forming species *Nereocystis luetkeana* and the intertidal sea palm *Postelsia palmaeformis*).

Direct impacts: Take of marine algae (for species lists, see LOP designations below) is unlikely to damage the non-biogenic habitat. However, all algae are sessile, so their abundance is likely to be substantially altered by take relative to an SMR, and the dispersal shadows of spores and seeds are very limited in spatial extent, typically less than 1 km (e.g. Kinlan and Gaines 2003).

Indirect impacts: Benthic macroalgae and plants form biogenic habitat. Habitat can take the form of large kelp forests in subtidal habitats (typically formed by *Nereocystis luetkeana* in northern California), surfgrass meadows, and canopy- and turf-forming algal beds in the intertidal zone. Additionally, all macrophytes serve as food either directly or indirectly (as drift, wrack or particulates) for a wide range of herbivores (such as abalone and urchins), suspension feeders (such as mussels and barnacles) and detritivores (such as wrack-associated amphipods and insects).

Thus the removal of any benthic macroalgae will remove biogenic habitat. However, whether or not the removal of that habitat leads to substantial changes in community structure depends on the nature of the species being removed. The removal of canopy forming species substantially alters community structure.

The removal of turf-forming and foliose algae may also result in substantial changes to community structure since they provide habitat for a diversity of small crustaceans and other invertebrates (Dean and Connell 1987) that are, in turn, prey for fishes. For many temperate fishes, these understory algae may be as important for successful recruitment as some of the canopy-forming species (Levin and Hay 1996, Levin 1994). Commercially collected ~~turf-forming and foliose~~ non-canopy forming algae include: *Chondrocanthus/Gigartina exasperata* (Turkish Towel), *Mastocarpus spp.* (Mendocino Grapestone), *Porphyra spp.* (Nori, Laver), and *Ulva spp.* (Sea Lettuce). The latter species (*Porphyra* spp. and *Ulva* spp.) are thin, ephemeral, fast-growing sheet algae that form only limited habitat. *Chondrocanthus/Gigartina exasperata* (Turkish Towel) and *Mastocarpus spp.* (Mendocino Grapestone), however, are longer-lived, slower-growing species that can form complex habitats. Due to their differences in life histories and morphologies, these non-canopy forming algae are divided into two groups, as shown below.

Level of protection: **Low** for canopy forming algae [Alaria spp. (Wakame), Lessonioposis littoralis (Ocean Ribbons), Laminaria spp. (Kombu), Saccharina/Hedophyllum sessile ('Sweet' Kombu), Egregia menzeisii (Feather Boa), and Fucus spp. (Bladder wrack or Rockweed)]
Moderate-Low for Chondrocanthus/Gigartina exasperata (Turkish Towel) and Mastocarpus spp. (Mendocino Grapestone)
Moderate ~~for turf-forming and foliose algae [Chondrocanthus/Gigartina exasperata (Turkish Towel), Mastocarpus spp. (Mendocino Grapestone)~~for Porphyra spp. (Nori, Laver) and Ulva spp. (Sea Lettuce)

Sea palm (intertidal hand harvest):

Direct impacts: Take of sea palms (*Postelsia palmaeformis*) by hand is unlikely to cause habitat damage. However, sea palms are sessile and their abundance is likely to be substantially altered by take relative to an SMR. Commercial hand harvesters tend to only take fronds, but this reduces canopy cover and will reduce spore production if done after June or more than once per year (Thompson et al. *submitted*), which in turn can reduce population size in subsequent years (Nielsen & Knoll *in prep*). In addition, complete removal of all plants in a population prior to the onset of spore production can lead to localized extinction if the population is > 5 m from an adjacent population (Nielsen & Knoll *in prep*).

Indirect impacts: Sea palms form extensive canopy in the high intertidal zone; the presence of algal canopy is well known to ameliorate high temperatures, high light levels and desiccation for understory species in the high intertidal, providing a refuge from these stressful physical conditions for some organisms. Therefore, removal of plants, thinning of plants, and removal of fronds have effects on other species and habitat availability below the sea palm canopy. These effects include: reducing the amount of bare space or available habitat for colonization (created when sea palms are dislodged by waves), altering the abundances of several common understory macroalgae (in the genera: *Corallina, Microcladia* and *Hymenina*), and increasing the diversity of understory species (Blanchette 1994). Some of these changes persist even after take has ceased, including reduced abundance of sea palms due to spore limitation (Blanchette 1994; Thompson et al. *submitted*; Nielsen & Knoll *in prep*).

Level of protection: **Low**

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4. Habitat Representation Analyses (Goals 1 and 4)

Status of this chapter: The SAT approved this chapter on June 29, 2010.

Identification of Key and Unique Habitats for the MLPA North Coast Study Region

The Marine Life Protection Act (MLPA) provides guidance that marine protected areas (MPAs) should encompass a variety of marine habitat types and communities, across a range of depths and environmental conditions. This chapter identifies the key and unique habitats in the North Coast Study Region, as required by the MLPA. The methods for evaluating MPA proposals with respect to representation of key and unique habitats are described in detail later in the chapter.

Habitats Identified in the MLPA and the Master Plan for MPAs

Subsequent to provisions in the MLPA, the master plan further refines the list of “key” habitats (listed below). The SAT recognizes estuaries as a critical California coastal habitat; consequently, estuaries were added to the list of key habitats in the master plan. The master plan further subdivides habitats identified in the MLPA by substrate type or depth, identifying the following key habitats: sand beach, rocky intertidal, estuary, shallow sand, deep sand, shallow rock, deep rock, kelp, shallow canyon, and deep canyon. Because changes in species composition occur across depth zones, even over the same substratum, the SAT has subsequently refined the habitat definitions to include five depth zones (intertidal, intertidal to 30 meters (m), 30 m to 100 m, 100 m to 200 m, and deeper than 200 m). Key habitat types provide benefits by harboring a particular set of species or life stages, having special physical characteristics, or being used in ways that differ from other habitats. The SAT also recommends the representation in MPAs of oceanographic features that represent specific pelagic habitats, such as upwelling centers, estuary waters, river plumes, fronts, and retention zones.

Key Habitats in the MLPA North Coast Study Region

The set of habitats described in the MLPA and master plan can be expanded or reduced by the SAT to reflect representative habitats for each study region. In addition to the habitat types delineated in the MLPA, the SAT notes that key habitat types such as rocky reefs, intertidal zones, and kelp forests are actually broad categories that include several types of habitat and that special consideration in design planning should be given to habitats that are uniquely productive (e.g. upwelling centers or kelp forests) or aggregative (e.g. fronts) or those that sustain distinct use patterns. All of the key habitats except sea mounts occur in the MLPA North Coast Study Region within state waters, although some, such as pinnacles, are not well mapped.

Considering guidance from the MLPA and master plan, the SAT has identified the following “key” marine habitats in the MLPA North Coast Study Region (m = meters, * = mapping data limitations, † = habitat is rare within the study region):

- rocky shore
- sandy beach
- surfgrass*
- coastal marsh
- tidal flats*
- estuarine waters
- eelgrass*
- kelp*

- rocky reef 0-30m*
- rocky reef 30-100m
- rocky reef 100-200m†
- rocky reef >200m†
- soft bottom 0-30m*
- soft bottom 30-100m†
- soft bottom 100-200m†
- soft bottom >200m†
- submarine canyons*†
- pinnacles*
- upwelling centers
- retention zones*
- river plumes
- fronts*

Several of the key habitats indicated above with an asterisk (*) are subject to mapping limitations that may restrict habitat evaluations. Further detail on the methods used to evaluate inclusion of these habitats in MPA proposals is provided below. Other key habitats indicated with a dagger symbol (†) are rare or unevenly distributed within the study region, and thus may be difficult to replicate within MPAs.

Pelagic Habitats

Several pelagic habitats are included in the list of key habitats for the MLPA North Coast Study Region: namely upwelling centers, retention zones, river plumes, and oceanographic fronts. These pelagic habitats, are created by water movement, and are necessarily fluid and difficult to demarcate with fixed boundaries. Furthermore, processes like upwelling and terrestrial runoff occur as events in response to winds or rainfall, so features are impermanent, although they may be recurrent. Thus, while it is important to recognize these habitats, they are difficult to map and evaluate for habitat representation and replication. The SAT habitat workgroup has developed maps of the major upwelling centers and river plumes in the NCSR that will be available in MarineMap and can be used to inform MPA design, but will not be used in any MPA evaluation at this time. It is important to note that areas outside of the mapped upwelling centers may experience episodic upwelling events, but the mapped upwelling centers demarcate the areas of most persistent upwelling. Maps of river plumes demarcate the zones for the 5 largest rivers in the north coast that are likely to be influenced by river-borne sediments and freshwater during periods of peak flow. These mapped river plume zones are scaled to the peak river flow, while the mouths of smaller rivers and streams within the study region are represented as a 1-mile buffer around river mouths to indicate potential river plumes of limited spatial extent.

The SAT recommends that MPAs should be distributed across pelagic habitats (i.e. inside and outside of upwelling centers), but due to the dynamic nature of these pelagic habitats and the fact that they overlay mapped benthic habitats, their inclusion should be a secondary consideration in MPA siting.

Upwelling centers: The upwelling habitat layer identifies areas where water properties are those of recently upwelled waters: colder, clearer, higher in nutrients, low pH, and lower in phytoplankton as compared to coastal waters elsewhere in the study region. These areas include the major upwelling centers at Cape Blanco, Cape Mendocino, and Point Arena and adjacent waters, mostly the upwelling plumes downstream of the centers. The shape of this layer is based on satellite sea-surface temperature data, combined with knowledge of the processes and patterns of upwelling from oceanographic studies (e.g., Largier et al 1993) and professional insight on nearshore circulation. This entire region is characterized by upwelling, thus areas outside the demarcated upwelling zones may also experience recently upwelled waters at times. However, in general waters outside of the demarcated upwelling centers are warmer, lower in nutrients and higher in phytoplankton

concentrations with reduced offshore flow at the surface. While water may be detained in these other areas, there are no true retention zones in this region.

River Plumes: The plume habitat layer identifies areas that are subject to strong land runoff effects following winter rainfall events. This includes low-salinity, high levels of suspended particles, high sedimentation, and low light (and potential exposure to land-derived contaminants). The plume zones associated with the 5 rivers with maximum winter flows are mapped, whereas the smaller plumes associated with rivers with lower flow are marked by a small buffer around their origin. After heavy rain, these smaller plumes may also be distinctly visible but their extent is less (smaller than MPA size) and they persist for shorter periods. The extent of the mapped plumes of the Smith, Klamath, Mad, Eel, and Mattole Rivers is based on one day of flow at the 90-percentile level (a flow that is exceeded 36.5 days a year) and understanding of plume behavior is primarily drawn from a study of the Eel River plume (Geyer et al 2000). The extent and shape of plumes is influenced by shoreline topography (e.g., effect of Pt St George on Klamath River plume), however, plume zones are primarily north of river mouths as alongshore currents and winds are northward during periods of strong runoff. Furthermore, if plumes persist into periods of northerly (upwelling favorable) winds, they tend to be separated from the shore due to the upwelling effect. The plume shapes demarcated in the layer indicate a typical plume zone, with individual plume events exhibiting variations on this theme (i.e. sometimes larger, or smaller, or more southerly, or more northerly).

Rocky Intertidal Habitats

Rocky intertidal habitats in the North Coast Study Region occur both on the mainland and on numerous offshore rocks, sea stacks and small islands. These offshore rocks are especially abundant in the study region and are formed through the erosive action of waves that buffet the shore and whittle away the coastal cliffs, leaving isolated stands of the most resistant rock. Offshore rocks vary in size from just a few square yards to several acres and may occur as far as several miles from the mainland coast. Due to their relative isolation from human disturbance, offshore rocks provide important breeding and resting sites for a wide variety of seabirds and marine mammals. Offshore rocks also support a variety of marine algae and invertebrates, especially those adapted to a high-energy wave environment. Offshore rocks may also contribute to the availability of shallow water rocky reef habitat (0-30m depth) in the study region. To adequately represent the habitat contribution of offshore rocks, both the intertidal length and the nearshore subtidal habitat (especially for those rocks that occur in depths greater than 30 meters) must be considered. For the purpose of evaluating MPA proposals, the shoreline length of offshore rocks will be considered as a subset of rocky shores. However, the shoreline length of offshore rocks will only be assessed for those rocks that are sufficiently large to be accurately mapped (greater than 1000 square meters area) and rocks of any size that occur sufficiently far from shore to be non-contiguous with the existing mapped intertidal shoreline habitat (greater than 100m from shore). In evaluating habitat representation, the SAT will assess representation of mainland rocky shores and offshore rocks separately. In evaluating habitat replication and spacing the shoreline length of offshore rocks and mainland rocky intertidal will be combined.

Subtidal Rocky Reef and Soft Bottom Habitats

Substrate across the majority of the north coast study region has been mapped using high resolution multi-beam sonar techniques. This dataset, developed by the California Seafloor Mapping Program, represents a substantial advance in our ability to identify the location and extent of subtidal rocky reef and soft bottom habitats. Unfortunately, most areas shallower than 10 meters depth (33 feet) remain unmapped due to safety and logistical considerations associated with data collection in those areas. Throughout the north coast, 99% of the area deeper than 30m depth and 72% of the area shallower than 30m depth is mapped and classified as rocky reef or soft bottom habitat. In order to

best accommodate nearshore mapping gaps and reflect the strong depth-dependence of marine communities within the 0-30m depth zone, the SAT has developed a linear measure of substrate in the 0-30m zone called the 0-30m proxy line. This proxy line reflects the best readily available information about substrate within the 0-30m zone, including the areas mapped using multibeam sonar techniques and information from the shoreline [NOAA's Environmental Sensitivity Index (ESI) shoreline] and offshore rock [California Coastal National Monument] datasets. Because marine community composition and the relative abundance of species varies strongly with depth in nearshore areas, nearshore habitats that span the full range of depths from 0-30m are most likely to encompass the full range of biodiversity associated with these habitats. In this respect, a reef or soft bottom area that falls steeply from shore to 30m depth, would likely support a similar level of biodiversity as a gradually sloping reef that spans the 0-30m depth zone over a much larger area. Due to the depth-dependence of nearshore communities, the linear proxy for nearshore rocky reef and soft bottom habitats is scaled to the proportion of soft and hard bottom habitats within the 0-30m depth zone.

As developed, the nearshore proxy line is a line drawn roughly parallel to shore at 12-15m depth. This line is divided into short segments 1/10th of a minute of latitude north-south, and the estimated proportion of hard and soft bottom in the 0-30m zone is associated with each segment. To estimate the proportion of hard and soft bottom in each 1/10th minute segment, the mapped proportion is combined with an estimate from the unmapped areas. The latter value is calculated as the average of offshore and onshore borders of the unmapped areas. For example, if the shoreline is 100% rock and the offshore margin is 50% rock, the unmapped zone between the two would be approximated as 75% rock. This estimate of substrate in the unmapped zone is then scaled to area, and combined with the mapped substrate to generate an overall estimate of rock and sand in the 0-30m zone.

Rivers and estuaries

The study region contains a number of large rivers and smaller streams that provide important spawning habitat for anadromous fish species. The lower reaches of these streams provide estuarine nursery habitat for a variety of marine fishes and are contained within the North Coast Study Region. Many rivers along the north coast have dynamic mouths characterized by shifting sand bar and beach habitat such that the location of the river's outflow may change from year to year. The dynamic beaches and sand bars provide important haul-out sites for marine mammals and nesting sites for shorebirds including the endangered snowy plover. In cases where MPAs are located on the open coast near the outflows of these dynamic rivers, the SAT recommends that MPAs encompass the full range of historical river outflow locations to ensure that connectivity between the MPA and adjacent estuarine habitat is not lost to future shifts in the river mouth location.

Several of the rivers in Mendocino County are characterized by narrow channels surrounded by the steep Mendocino Range and extensive zones of tidal and marine influence. Due to their steep sides, these drowned river valleys do not contain extensive areas of coastal marsh, tidal flats, or eelgrass, however, they provide estuarine habitats in close association with one another and support a variety of marine life. The drowned river valleys in the North Coast Study Region include the estuarine portions of the following rivers:

- Noyo River
- Big River
- Albion River
- Navarro River

Humboldt Bay is the largest estuary in the north coast study region and second-largest estuary in California, after San Francisco Bay. This large and rich habitat supports a wide variety of fish and invertebrate species and serves as a nursery area for open coast species including, English sole,

Pacific herring, lingcod, Dungeness crab, rock crabs, some surfperches, and some rockfishes (Barnhart et al. 1992). Approximately 40% of the known eelgrass in California occurs in Humboldt Bay (Schlosser et al. 2009). Large, dense beds occur throughout all of South Bay, Central Bay, and North Bay. South Bay beds are more dense, contain greater biomass compared to the rest of the bay and South Bay eelgrass beds have been recognized as one of the most important locations of eelgrass growth on the U.S. west coast (Phillips 1984). Due to the richness of marine life supported by Humboldt Bay, the SAT recommends that MPA arrays for the North Coast include representation the full variety of habitats contained within it.

Summary of Guidelines and Evaluation Methods: Habitat Representation

The master plan guidelines with respect to habitat protection are as follows:

1. For an objective of protecting the diversity of species that live in different habitats and those that move among different habitats over their lifetime, every 'key' marine habitat should be represented in the MPA network."
2. "'Key' marine habitats (defined above) should be replicated in multiple MPAs across large environmental and geographic gradients to protect the greater diversity of species and communities that occur across such gradients, and to protect species from local year-to-year fluctuations in larval production and recruitment."

Guidance in the MLPA closely mirrors these guidelines in the master plan with one key difference: the MLPA specifically indicates that state marine reserves (SMRs) are an important component of habitat protection.

To assess how the key and unique habitats defined here are represented across a range of environmental conditions, the SAT has identified two distinct bioregions within the MLPA North Coast Study Region (see Chapter 2). Because the key habitats within these bioregions support different marine life communities, the SAT recommends that MPA proposals represent key habitats across both bioregions.

In evaluating habitat representation the SAT considers:

- the quality of habitat maps,
- the availability of habitats across the entire study region,
- the availability of habitats within the two bioregions defined by the SAT,
- the percentage of available habitat protected in MPAs across all six levels of protection, and
- the distribution of habitat protection across the two bioregions in the MLPA North Coast Study Region.

Several of the key and unique habitats named above have limited distribution in the study region or are poorly mapped (see below for more detailed discussion of habitat map quality). In consideration of data limitations, the SAT conducts a full evaluation of habitat representation (including area and percent of habitat protected) only for habitats that are adequately mapped. For habitats that are not comprehensively mapped, the SAT will conduct simplified evaluations of habitat representation.

Consideration of Habitat Map Quality

The quality of habitat mapping influences the way in which habitat representation can be assessed. For habitats that are comprehensively mapped, it is possible to accurately assess both the amount of habitat encompassed by a proposed MPA and the percent of available habitat protected.

Unfortunately, many of the habitat maps are subject to one or more of the following limitations: 1) mapping is not of consistent quality across the entire study region, 2) mapped data does not allow assessment of the extent of habitat protected (aerial or linear extent), or 3) mapping does not accurately reflect presence or absence of habitats.

Table 4-1. Habitat mapping quality

This table summarizes the limitations of habitat maps and recommendations for use of habitat data in habitat evaluations.

Habitat	Source	Review Summary	Recommended Method of Habitat Assessment
rocky shore	NOAA Environmental Sensitivity Index (ESI) shoreline - 1994	Shoreline types are comprehensively and consistently mapped across the state. resolution may be insufficient to resolve intermixed habitats (e.g. beaches interspersed with rocky outcrops) in some areas.	Appropriate for assessing both the length and proportion of habitat included in MPA proposals.
offshore rocks	California Coastal National Monument (CCNM)	Offshore rocks are comprehensively mapped across the state, but rocks that occur further offshore are not well mapped. There are some inconsistencies in the size and location of mapped rocks as compared to satellite imagery. Larger rocks also mapped in the ESI shoreline file were removed from this dataset to avoid duplication.	A subset of the offshore rocks layer filtered to avoid redundancy with existing mapped intertidal areas may be used for assessing the length and proportion of habitat included in MPA proposals, but the accuracy of these estimates may vary by area.
sandy beach	NOAA ESI shoreline - 1994	Shoreline types are comprehensively and consistently mapped across the state. resolution may be insufficient to resolve intermixed habitats (e.g. beaches interspersed with rocky outcrops) in some areas.	Appropriate for assessing both the length and proportion of habitat included in MPA proposals.
surfgrass	*no current data available in digital format*		
coastal marsh	NOAA Coastal Change Assessment Program (CCAP) 2007	Coastal marsh areas are comprehensively and consistently mapped across the state using remote sensing data.	Appropriate for assessing both the area and proportion of habitat included in MPA proposals.
tidal flats	NOAA ESI shoreline - 1994	Shoreline types are comprehensively and consistently mapped across the state, however dynamic estuarine shorelines are not accurately represented in this older dataset. May not provide accurate or consistent assessment of tidal flat habitat availability.	May be used for assessing the length and proportion of habitat included in MPA proposals, but the accuracy of these estimates may vary by location.

Habitat	Source	Review Summary	Recommended Method of Habitat Assessment
estuaries	National Wetlands Inventory (NWI), The Nature Conservancy (TNC), satellite imagery, expert opinion	A combination of data sources and expert opinion have allowed staff to comprehensively map all tidally influenced enclosed water bodies in the study region, including man-made harbors.	Appropriate for assessing both the area and proportion of habitat included in MPA proposals.
eelgrass	PSMFC, SeaGrant, local studies and reports	Eelgrass is not comprehensively mapped across the study region, and high resolution mapping appropriate for assessing area is only available for Humboldt bay. Staff have confirmed eelgrass presence/ absence for all major estuaries in the study region.	Appropriate for assessing area in Humboldt Bay only. Additionally, presence/ absence data will allow assessment of the proportion of known eelgrass locations protected.
kelp	DFG aerial surveys (from 1989, 1999, 2002-05, and 2008)	Bull kelp, the dominant canopy-forming species in the region, does not form extensive surface canopies, thus the extent of kelp is not well documented by overflight surveys. Multiple years of overflight data allow assessment of locations that are likely to support kelp forests.	A linear measure of kelp derived from the composite of survey data years is appropriate for assessing length and proportion of habitat included in MPA proposals, but may contain some inaccuracies.
rocky reef 0-30m	CSUMB Seafloor mapping, DFG aerial kelp surveys	High resolution mapping of the substrate does not include most areas shallower than 10m depth. Combination of this data with kelp canopy and shoreline type information allows assessment of locations that are likely to contain rocky reef across a substantial portion of the 0-30m depth range.	A linear measure of nearshore rocky reef derived from multiple information sources is appropriate for assessing length and proportion of habitat included in MPA proposals.
rocky reef in the 30-100m, 100-200m, and >200m depth zones	CSUMB Seafloor mapping	High resolution mapping of the substrate is comprehensive and consistent across the study region.	Appropriate for assessing both the area and proportion of habitat included in MPA proposals.
soft bottom 0-30m	CSUMB Seafloor mapping	High resolution mapping of the substrate does not include most areas shallower than 10m depth. Combination of this data with shoreline type information allows assessment of locations that are likely to contain soft bottom across a substantial portion of the 0-30m depth range.	A linear measure of nearshore soft bottom derived from multiple information sources is appropriate for assessing length and proportion of habitat included in MPA proposals.
soft bottom in the 30-100m, 100-200m, and >200m depth zones	CSUMB Seafloor mapping	High resolution mapping of the substrate is comprehensive and consistent across the study region.	Appropriate for assessing both the area and proportion of habitat included in MPA proposals.

Habitat	Source	Review Summary	Recommended Method of Habitat Assessment
submarine canyons	G. Green	Mapping of canyons is comprehensive across the state, but area measurements may not be consistent.	May be used for assessing the area and proportion of habitat included in MPA proposals, but the accuracy of these estimates may vary by location.
pinnacles	*unmapped*		
upwelling centers	J. Largier	Major upwelling centers are comprehensively mapped across the study region, but mapping of this dynamic habitat does not reflect the complexity of temporal and spatial variation.	May be used for informational purposes, but not appropriate for assessing area or percentage of habitat protected.
retention areas	*currently unmapped*		
river plumes	J. Largier	Major and minor river plumes are mapped across the study region, but mapping of this dynamic habitat does not reflect the complexity of temporal and spatial variation.	May be used for informational purposes, but not appropriate for assessing area or percentage of habitat protected.
oceanographic fronts	*currently unmapped*		

Works Cited in Chapter 4

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Schlosser, S., and A. Eicher. 2007. Humboldt Bay Cooperative Eelgrass Summary Report April 2004 to November 2007. National Fish and Wildlife Foundation Report. UC Sea Grant Extension Program, Eureka.

5. Habitat Replication Analyses (Goals 1, 2, 3, 4 and 6)

Status of this chapter: Approved June 30 by SAT

The MLPA's Guidelines Regarding Habitat Replication Analyses

The *Master Plan* guidelines with respect to habitat replication are as follows:

1. "Key" marine habitats (defined above in Chapter 4.0) should be replicated in multiple marine protected areas (MPAs) across large environmental and geographic gradients to protect the greater diversity of species and communities that occur across such gradients, and to protect species from local year-to-year fluctuations in larval production and recruitment.
2. For an objective of providing analytical power for management comparisons and to buffer against catastrophic loss of an MPA, at least three to five replicate MPAs should be designed for each habitat type within a biogeographical region [e.g., Point Conception to Oregon].

Replication of habitats in MPAs addresses goals 1, 2, 3, 4 and 6 of the Marine Life Protection Act (MLPA) as well as other requirements and guidance in the act, including habitat replication within state marine reserves (SMRs). Replication of habitats contributes to achievement of the MLPA goals in the following ways: 1) by ensuring that protected habitats are distributed across environmental and geographic gradients to protect the full diversity of marine life in California's waters, and 2) by distributing protection across multiple areas to reduce the likelihood that a single catastrophic event or localized disturbance will disrupt MPA function state-wide. Evaluations of habitat replication include the number of replicates in SMRs, and also the replication of habitats in state marine conservation areas and state marine parks at the various levels of protection.

Guidance in the *Master Plan* requires that habitats be replicated in three to five MPAs in the biogeographic region. However, spacing guidelines (see Chapter 7.0) may require greater replication of habitats. The SAT also recommends that key marine habitats be replicated in at least one MPA in each of the two bioregions (see Chapter 2.0) contained within the NCSR. This guidance only applies to habitats that occur in both bioregions in sufficient abundance for replication to be feasible. Because the divide between northern and southern bioregions in the North Coast Study Region is not a strong ecological break, but rather a gradual transition zone between areas with different habitat distributions and ecological assemblages, MPAs that fall on this divide could reasonably be assigned to either of the two bioregions. In cases where an MPA falls on the bioregional divide, the SAT will divide habitat replicates across the two bioregions (1/2 replicate in each) to indicate that these habitat replicates occur in the transitional zone and could reasonably be assigned to either bioregion.

Benefits of MPAs are largely dependent on the habitat contained in them. An MPA that does not contain appropriate habitat for an ecosystem or particular species (e.g. kelp forest) provides insufficient benefits to that ecosystem or species.

In evaluating habitat replication, the SAT considers:

- The overall size of each MPA or cluster of MPAs (contiguous MPAs with different allowed uses) at the three highest levels of protection, and
- the extent of each habitat contained within the MPA or MPA cluster.

Only MPA clusters above the minimum size (nine square miles[5]) were considered for habitat replication (with the exception of estuarine habitats). The SAT considered an MPA to include a specific habitat if the MPA encompassed a critical amount of the habitat. This critical amount was defined as an area or length sufficient to encompass 90% of the species that occur in the habitat in sufficient abundance to be ecologically represented (see Figure 5-1.)

To determine the estimated amount of habitat needed, the SAT examined biological survey data from a variety of habitat types present in the study region. Only datasets that had the following features were used: (1) sampling allowed for estimation of species richness, (2) sampling was spatially explicit (the location, depth and area were known), (3) sufficient replication to allow for robust resampling, (4) asymptotic area by richness curves, (5) absence of meaningful design bias, such as would exist if only certain taxa were targeted. Using a resampling procedure and accumulation functions (including Michaelis-Menten) the SAT then estimated the amount of habitat area needed to encompass 90% of the species likely to occur in each habitat (see Figure 5-1).

[5] Unless otherwise noted, all distance measurements are measured in statute miles and all area measurements are measured in square statute miles. Depths are reported in meters (m).

Figure 5-1. Estimated Proportion of Species per Amount of Habitat

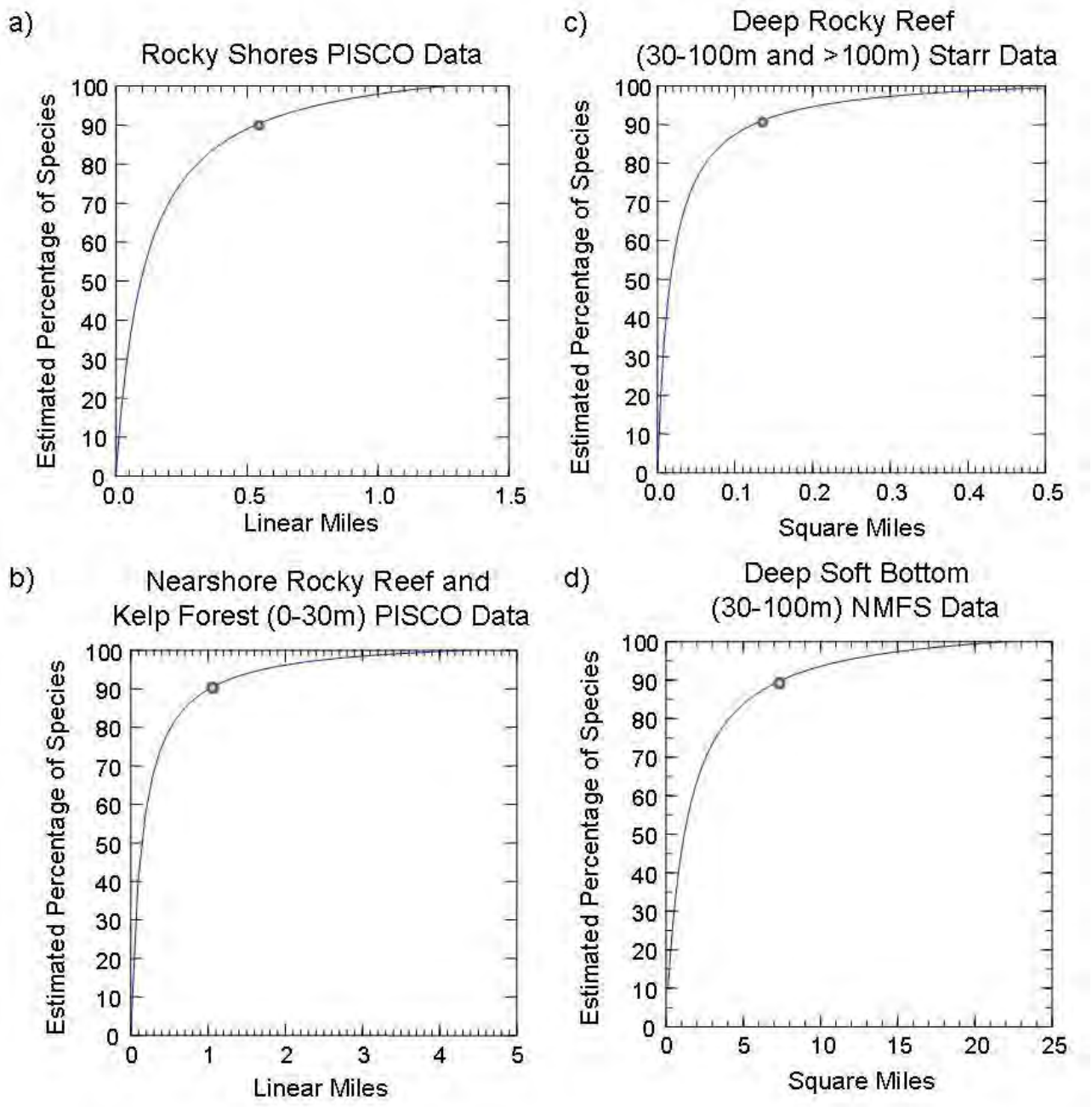

Table 5-1. Amount of habitat in an MPA necessary to encompass 90% of local biodiversity

Habitat	Amount of habitat needed to encompass 90% of biodiversity	Data Source
Rocky shores and offshore rocks	0.55 linear miles	PISCO Biodiversity
Nearshore rocky reefs and kelp forest (0-30 m)	1.1 linear miles *including the full 0-30m depth zone*	PISCO Subtidal
Rocky reef 30-100 m	0.13 square miles	Starr Surveys
Rocky reef 100-3000 m	0.13 square miles	Starr Surveys
Beaches	1.1 linear miles	*See below*
Soft bottom 0-100 m [a] *(includes replicates of 0-30m and 30-100m soft bottom)*	7 square miles total mapped soft bottom Distributed across depth zones including at least: 1.1 mi 0-30m 5 sq mi 30-100m	NMFS trawl surveys 1997-2007
Soft bottom 0-30 m *when not combined with other depth zones*	1.1 linear miles *including the full 0-30m depth zone*	*See below*
Soft bottom 30-100 m *when not combined with other depth zones*	7 square miles	NMFS trawl surveys 1997-2007
Estuarine Habitats [b]	0.12 square miles (77 acres) total estuarine area Distributed across estuarine habitats including at least: 0.04 sq mi coastal marsh (25 acres) 0.04 sq mi eelgrass (25 acres)	SONGs sampling

[a] *Trawl survey data indicate that large amounts of soft bottom habitat are required to encompass 90% of biodiversity if each depth zone is replicated independently. Since soft bottom associated species tend to utilize multiple depth zones, the SAT recommends that soft bottom habitats across multiple depth zones are included in the same MPA or MPA cluster.*

[b] *Estuarine habitat replication thresholds are based upon data from small coastal estuaries in the south and central coast regions and may not be applicable to the large estuarine areas in Humboldt Bay.*

Rocky Shores: Rocky shores in the north coast study region include the mainland shoreline and numerous offshore rocks, sea stacks, and small islands that have been mapped by the California Coastal National Monument. The combined length of rocky intertidal habitat occurring on the mainland and offshore rocks (filtered to reduce redundancy) are combined for the purposes of evaluating replication.

Surfgrass: Surfgrass occurs in shallow and intertidal rocky habitats along the coast of the study region. Few organisms live exclusively in surfgrass habitat but many intertidal and shallow rock species benefit from its presence. There is currently no data available in digital format for the distribution or extent of surfgrass in the north coast study region. The SAT will therefore not evaluate surfgrass explicitly, and rather evaluate rocky intertidal habitat as potential surfgrass habitat.

Nearshore habitats (0-30m): Nearshore habitats in the 0-30m depth zone include kelp forests, 0-30m soft bottom, and 0-30m rocky reef. These habitats are evaluated using a linear proxy that approximates the coastline length of these habitats and assumes that protection extends across the entire 0-30m depth zone. To achieve replication of nearshore habitats, an MPA must encompass the entire 0-30m depth zone.

Kelp: The aerial images used by CDFG to estimate kelp coverage do not reliably capture presence of the dominant kelp species in the north coast study region, bull kelp (*Nereocystis luetkeana*). Therefore, kelp coverage estimates for the region are low and indicate large gaps between kelp patches. Kelp occurs over shallow rocky substrate (0-30 m), so adequate protection of shallow rock habitat should ensure protection of kelp even where it does not appear on the maps. In places where kelp does appear on CDFG maps, the SAT guideline for replication is the same as that for shallow rocky reef, 1.1 miles.

Beaches and 0-30m soft bottom: No data were available to make a scientific assessment of the relationship between shoreline length and biodiversity for beaches or 0-30m soft bottom habitats. Most species that live exclusively in nearshore sandy habitats are associated with the surf zone, thus linking the two habitats. In the absence of surf zone community surveys, the SAT used the species-area relationship derived from nearshore rocky reefs as a proxy. Hence, the SAT considers beach and 0-30 m soft bottom habitats present if an MPA includes at least 1.1 miles these habitats.

Soft-bottom habitats: Trawl survey data from soft bottom habitats indicate that if each soft bottom depth zone were protected individually (i.e. one depth zone per MPA) large areas would be required to ensure protection of representative biodiversity. In some cases these areas greatly exceed the minimum size guidelines for MPAs. Soft bottom associated species, however, tend to utilize multiple depth zones, thus there is substantial overlap in the species composition of adjacent depth zones, although the relative abundance of these species may vary with depth. For example, 53% of the species found in surveys from >100m depths are also found in surveys from the 30-100m depth zone. Results from the trawl surveys indicate that the most efficient way to protect the full range of biodiversity associated with soft bottom habitats in the NCSR is to protect soft bottom habitats across the full range of depths within a contiguous area of protection (i.e. one MPA or MPA cluster).

Soft bottom 0-100 m: In some sections of the NCSR, the study region does not include areas deeper than 100m. In these areas where >100m soft bottom habitats are not available, the SAT recommends that an MPA include a total of 7 square miles of mapped soft bottom habitat, including at least 1.1 miles of 0-30m soft bottom and 5 square miles of 30-100m soft bottom. The total area of 7 sq mi was derived from NMFS trawl data and the distribution of depth zones derived from the distribution of depth zones in the NCSR.

Soft bottom 30-3000 m: In some sections of the NCSR, it may be desirable to target deepwater features for protection with MPAs that do not include nearshore or shoreline habitats. In these areas, the SAT recommends that an MPA include a total of 7 square miles of mapped soft bottom habitat, including at least 5 square miles of 30-100m soft bottom and at least 1 square mile of >100m soft bottom. The total area of 7 sq mi was derived from NMFS trawl data and the distribution of depth zones derived from the distribution of depth zones in the NCSR.

Estuarine Habitats: As noted above, estuaries are not included in the general rule that replication of habitat needs to be within an MPA cluster that is at least nine square miles. This is because estuarine habitats very often are not adjacent to coastal rocky habitats and a requirement for co-location could greatly restrict the location of MPA clusters.

The habitat size guidelines for estuarine replication presented in the table above are based upon data from small coastal estuaries in the south and central coast regions and may not be applicable to the large estuarine areas in Humboldt Bay. In the absence of specific habitat size guidelines for Humboldt Bay, the SAT recommends that proposals consider proportional representation of the three estuarine sub-habitats in MPAs both within the bay and across the study region.

The SAT recommends that wherever possible, a mixture of estuarine sub-habitats be protected in close proximity to one another to allow for the movement of species among sub-habitats. Estuarine

sub habitats include eelgrass[6], tidal flats, and coastal marsh. Additionally, protection of areas close to the mouth of an estuary is likely to have great benefit for species that use both estuarine and open-coast habitats.

[6] Mapped eelgrass in the north coast study region is available for Humboldt Bay only. The SAT will evaluate eelgrass area for Humboldt Bay and conduct an eelgrass presence/absence analysis for all other locations in the study region.

6. MPA Size

Status of this chapter: The SAT approved this chapter on March 16, 2010.

The Master Plan Guidelines Regarding Size Analyses

Size guidelines were developed to provide for the persistence of important bottom-dwelling fish and invertebrate groups within marine protected areas (MPAs); (MLPA goals 2 and 6).

Guidance on size in the *California Marine Life Protection Act Master Plan for Marine Protected Areas* (Master Plan) states:

1. "For an objective of protecting adult populations, based on adult neighborhood sizes and movement patterns. MPAs should have an alongshore span of five to ten kilometers (3-6 miles or 2.5-5.4 nautical miles) of coastline, and preferably 10-20 kilometers (6-12.5 miles or 5.4-11 nautical miles). Larger MPAs would be required to fully protect marine birds, mammals and migratory fish."
2. "For an objective of protecting the diversity of species that live at different depths and to accommodate the movement of individuals to and from shallow nursery or spawning grounds to adult habitats offshore, MPAs should extend from the intertidal zone to deep waters offshore."

The first guideline for MPA size arises primarily from data on the movement of adult and juvenile fish and invertebrates. Since MPAs will be most effective if they are substantially larger than the distance that individuals move within their home ranges, larger MPAs provide benefit to a wider diversity of species.

A summary of existing scientific studies of adult movement shows that adult movement varies greatly among California's marine species (Table 6-1). A recent synthesis and analysis of movement information for west coast rocky reef fishes indicates that the range of movement for 75 percent of individuals of a species (the 75th percentile movement range) was three kilometers (km) or less for 85% of the 26 species for which data are available (Freiwald 2009)

. However, the majority of movement data are from shallow dwelling reef fishes (depth < 30-50 meters). This synthesis also shows that movement distance was not correlated with days at liberty for eleven species for which data are available, indicating that movement of these species was unlikely a diffusive process (i.e. increasing range with time). The analysis also showed that movement distances for deeper dwelling species (n= 6, 75th percentile = 35 km) were significantly greater than for shallower dwelling species (n= 18, 75th percentile = 2 km).

Therefore, the choice of any MPA size determines the subset of species that could potentially benefit. For species with average movement distances of 100s to 1000s of miles, MPAs are unlikely to be a source of significant protection (except when they protect critical locations, e.g. spawning or nesting grounds). As a result, the *Master Plan* guidelines focus on species in the first three movement categories in Table 6.1. The minimum size guideline of five to 10 km (three to six miles) targets species in the first two categories. The preferred size range of 10 to 20 km (six to 12.5 miles) provides substantially more benefit to the important group of species in the third category (10 - 100 km movement). This group includes a number of important rockfishes from the California coast. Therefore, MPAs that meet the preferred size guideline should protect more biological diversity than MPAs that meet the less stringent minimum guideline.

Table 6-1. Scales of adult movement for California coastal marine species

	0-1 km	1-10 km	10-100 km	100-1000 km	>1000 km
Invertebrates	abalone, mussel, octopus, sea star, snail, urchin		Dungeness crab**		jumbo squid**
Rockfishes	black & yellow, brown, copper, gopher, grass*, kelp, quillback, starry, treefish, vermilion	black, China, greenspotted*, olive, yelloweye	blue, bocaccio, yellowtail	canary	
Other Fishes	cabezon, eels, greenlings, giant seabass, black, striped, and pile surfperches, pricklebacks	walleye surfperch*	California halibut, lingcod, starry flounder	anchovy, big skate, herring, Pacific halibut, sablefish**, salmonids**, sole, sturgeon	sardine, shark**, tunas**, whiting**
Reptiles					turtles**
Birds			gulls, cormorants	gulls**	albatross**, pelican**, shearwater**, shorebirds**,terns**
Mammals			harbor seal, otter	porpoise, sea lion**	dolphins, sea lion**, whales**

**Studies of this species included fewer than 10 individuals*

***Seasonal migration*

The second size guideline above arises from the consideration of ecological connections between habitats across depth ranges. Many marine species spend different parts of their life cycle in different habitats that may span a range of depths; if these different habitats are connected in a single MPA, species that move among contiguous habitats likely will benefit.

This guideline reflects the SAT's recommendation that MPAs extend from the shore to the boundary of state waters (three nautical miles offshore). Extending MPA boundaries to the edge of state waters has the added benefit of allowing for connections with any potential future MPA designations in federal waters. The combination of these two guidelines forms the basis for SAT evaluation of MPA size.

In evaluating the size of MPAs, the SAT considers both the area of individual MPAs and clusters of contiguous MPAs. The MPA size guidelines in the *Master Plan* specify that MPAs should cover an alongshore span of at least three to six statute miles (preferably six to 12 statute miles) and extend from the coast to deep waters offshore. Because state waters extend only three nautical miles (3.45 statute miles) offshore, the SAT considers an MPA or cluster of MPAs that extend to the offshore limit of state waters to meet the offshore size guideline. The SAT combines and simplifies alongshore and offshore guidelines from the *Master Plan* by using a minimum size threshold of nine square statute miles, while recognizing that the state waters extend three nautical miles offshore rather than three statute miles as used in the area calculations. No MPA that is smaller than nine square miles could meet both the alongshore and onshore-offshore size guidelines mentioned

above. Thus, for the purpose of SAT analyses, MPA clusters with areas nine to 18 square miles are considered to fall within the minimum size range, and those 18 to 36 square miles fall within the preferred size range. The guidelines for minimum and preferred areas of proposed MPAs will receive priority above the individual guidelines for alongshore and offshore spans. Additionally, the SAT recommends consideration of the configuration of proposed MPAs. Configurations with maximum area-to-perimeter ratios (e.g., three by three statute miles) are more likely to achieve greater protection for a variety of adjacent habitats and associated species than particularly narrow or long MPAs (e.g., one by nine statute miles).

In evaluating the size of MPAs, the SAT:

- combines contiguous MPAs at or above a given level of protection into “MPA clusters,” with size analyses conducted at three different levels of protection: “moderate-high,” “high,” and “very high”; and
- tabulates the number of MPA clusters in each size range (below minimum, minimum size range, preferred size range).

Note that estuarine MPAs are not evaluated with respect to size. Because species and life stages that inhabit estuaries rarely stray from the favorable estuarine habitat, the overall size of the MPA is less important than protecting the entire estuarine system. Thus, the SAT recommends that MPAs encompass entire estuaries, if feasible, but does not evaluate the size of estuarine MPAs relative to the size guidelines.

Works Cited in Chapter 6

Freiwald, J. 2009. Causes and consequences of the movement of temperate reef fishes. PhD Dissertation, University of California, Santa Cruz.

7. MPA Spacing

Status of this chapter: The SAT approved this chapter on March 16, 2010. Changes from the March 16, 2010 version are in underline and strikeout.

Spacing guidelines were developed to provide for the dispersal of important bottom-dwelling fish and invertebrate groups between marine protected areas (MPAs) and to promote connectivity in the network (Goals 2 and 6 of the Marine Life Protection Act (MLPA)).

Connectivity

Connectivity between different places in the north coast study region was evaluated using known life history characteristics of fish and invertebrate larvae in conjunction with models of potential movement. Connectivity estimates are based on the University of California, Santa Cruz (UCSC) implementation[7] of the Regional Ocean Modeling System (ROMS) for the California Current System. The region that is modeled extends from the middle of the Baja Peninsula to Vancouver Island and offshore over 1,000 km. The baseline model is driven by the output from the Coupled Ocean Atmosphere Mesoscale Prediction System (COAMPS) and lateral boundaries are derived from the global ocean state estimate provided by ECCO (Estimating the Circulation and Climate of the Ocean). Connectivity matrices are calculated from numerical trajectories of model floats that follow the 3-dimensional circulation described in the model. Our calculations represent multi-year averages (January 1999 - July 2007) for various spawning periods and pelagic larval durations.

The model has been evaluated using several types of observations, including remotely sensed sea surface temperature (SST), hydrographic data from CalCOFI, and temperature and velocity measurements from nearshore moorings supported by both Monterey Bay Aquarium Research Institute (MBARI) and the Partnership for Interdisciplinary Studies of Coastal Oceans (PISCO). In addition, the UCSC scientists compared modeled estimates of surface eddy kinetic energy and bulk horizontal diffusivities with those estimated from drifters. Modeling studies that describe related implementations of this physical model and float calculations are found in Veneziani et al. (2009), Petersen et al. (2009), and Drake and Edwards (2009).

Modelers used ocean circulation from the ROMS simulation together with known life history characteristics of representative fishes and invertebrates (Table 7-1) to predict expected dispersal patterns throughout northern California. The modelers created “dispersal kernels” or expected dispersal by simulating the release of approximately a million particles from each location throughout northern California. Particles, which simulate larvae, were released in suitable habitats during the appropriate spawning period and for the period of larval duration for all representative species. Particles were passively transported by the simulated currents, and limited behavior (e.g. maintaining depth at a convergent front or edge of an eddy) was incorporated in the model. For each representative species, the model calculated numbers and locations of particles (or model larvae) reaching suitable habitat for settlement and growth at the end of their period of larval duration. ROMS has limited ability to predict small-scale water movement near shore, which may contribute to local retention of larvae. As a consequence, the model likely underestimates self-replenishment.

[7] Researchers are C. Edwards et al., at the University of California, Santa Cruz.

Table 7-1. Life history characteristics of representative fish and invertebrates

Species	Common Name	Spawning Season	Larval Duration
Sebastes melanops	Black rockfish	Jan-May	4-6 months
Sebastes auriculatus	Brown rockfish	Dec-Jun in NCSR	1-2 months
Scorpaenichthys marmoratus	Cabezon	Nov-Mar	3-4 months
Metacarcinus magister	Dungeness crab	Nov-Feb	3-4 months
Haliotis rufescens	Red abalone	Apr-Jul	4-7 days
Strongylocentrotus franciscanus	Red sea urchin	Dec-Mar	50-120 days

Although connections tend to be stronger within bioregions, there is some connectivity between bioregions. In other words, bioregions may be influenced to some extent by movement of animals, nutrients, pollutants, etc., which may be transported from adjacent regions.

Connectivity is different for different species. Dispersal patterns are strongly influenced by seasons and interannual variation. Ocean circulation and resulting movement of particles respond to dominant wind patterns and are not the same from season to season or year to year (although there are underlying patterns). Collectively, the larval dispersal kernels from the ROMS simulations provide a framework for understanding how different parts of the north coast study region are connected.

Spacing of MPAs in the North Coast Study Region

Guidance on spacing of adjacent MPAs, excerpted from the draft *Marine Life Protection Act Master Plan for Marine Protected Areas* (January 2008) (Master Plan), is:

> "For an objective of facilitating dispersal of important bottom-dwelling fish and invertebrate groups among MPAs, based on currently known scales of larval dispersal, MPAs should be placed within 50-100 kilometers (31-62 miles or 27-54 nautical miles) of each other."
>
> Note that neighboring MPAs placed closer than 50 km (31 miles) apart also meet the guideline for spacing for the goal of designing a network of MPAs.

This guideline arises from a number of studies that examine the persistence of marine populations with a network of marine reserves (Botsford et al. 2001, Gaines et al. 2003, Gaylord et al. 2005), and its connection to larval dispersal. The spacing distances arise from a number of recent syntheses of data on larval dispersal in marine fish, invertebrates and seaweeds (Shanks et al. 2003, Kinlan and Gaines 2003, Kinlan et al. 2005) and advances in modeling of larval transport (Siegel et al 2003, Cowan et al 2006). As with adult movement, scales of larval movement vary enormously among species (meters to hundreds of kilometers). In contrast to adult movement, however, short-distance dispersers pose the biggest challenge for connections between MPAs.

Since the MPA spacing guidelines are intended to help ensure connectivity between marine life populations, and populations only occur in suitable habitat, spacing analyses must consider the habitats encompassed by each MPA. Thus, the SAT conducts a separate spacing analysis for each key habitat, including estuarine habitats (Chapter 4). Only MPAs that meet the minimum size guidelines (Chapter 6) and contain at least the critical extent of a habitat (Chapter 5) are counted as replicates of that habitat. The spacing analysis is conducted by measuring the distance between

"replicate" MPAs or MPA clusters for each key habitat. Additionally, the spacing analysis is conducted for the three highest levels of protection afforded by MPAs: at least "moderate-high" protection; at least "high" protection; and, only MPAs with "very high" levels of protection. The spacing evaluation does not incorporate information derived from the connectivity models, but rather evaluates the spacing of habitats relative to the spacing guidelines only. In round one evaluations spacing ~~is~~ was measured as the straight line distance between the edges of two adjacent MPAs that contain replicates of the same habitat. In subsequent evaluations, spacing will be measured as the shortest "over-sea" path (i.e. path that does not cross land) between the edges of two adjacent MPAs. In the north coast study region, spacing will be measured between MPAs that contain replicates of the same habitats, extending from the nearest MPA established in the north central coast study region to the California - Oregon border.

To summarize the evaluation of MPA spacing, the SAT:

- tabulates the maximum gaps between MPAs or MPA clusters in relation to the SAT spacing guidelines of 31-62 statute miles,
- considers spacing for each key habitat separately,
- considers only MPAs or MPA clusters that are of sufficient size to contain adult movement ranges (i.e. meet the minimum size guideline),
- considers only MPAs or MPA clusters that include a sufficient extent of habitat to be counted as meaningful biological replicates, and
- considers only MPAs or MPA clusters that have the three highest levels of protection.

Results of the spacing evaluation will consider the distribution of habitats across the study region and note where naturally occurring gaps between habitats render it impossible for spacing guidelines to be met. In cases where spacing guidelines cannot be met, the SAT recommends that MPA configurations minimize gaps between protected habitats.

Integrated Evaluation of Alternative MPA Proposals

The SAT will use spatially explicit models to evaluate contributions of proposed MPAs to conservation value (biomass or population persistence) and economic value (fishery catch or profit; Chapter 8 – Bioeconomic Modeling). Evaluations using models consider the actual size and spacing of alternative MPA proposals without imposing minimum thresholds levels for these characteristics. The models integrate spatial data on habitat, fishery effort, and proposed MPA locations and regulations and ultimately predict spatial distributions of fish abundances, fishery yields, and (for one model) fishery profits generated for each proposed network of MPAs.

To summarize the SAT evaluation of proposed MPAs using spatially explicit population models, the models can:

- integrate spatial data on habitat, fishery effort, and proposed MPA locations and regulations;
- consider potential contributions of proposed MPAs, regardless of size or spacing;
- consider potential impacts of allowed uses in proposed MPAs, regardless of the level of protection;
- predict biomass and larval supply (a proxy measure of population sustainability) for representative species, across space; and
- predict fish yield for the representative species, across space.

Additional details about the modeling evaluation are provided in Chapter 8.

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8. Bioeconomic Modeling

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For marine protected areas (MPAs) to function effectively as a network that satisfies various goals of the Marine Life Protection Act (MLPA), they must (1) provide adequate protection from harvest to the portion of a species' (adult) population resident in the MPA, and (2) include a sufficient fraction of the populations' total larval production for populations to persist. The science guidelines for MPA design in the *California Marine Life Protection Act Master Plan for Marine Protected Areas* (Master Plan) support general evaluation of the efficacy of MPAs as refugia and connectivity within alternative MPA proposals, but do not evaluate potential population effects or account for several variables, including conditions outside the MPA proposal (i.e., harvest), spatial structure of the seascape, realistic connectivity across space, and fishing pressure on different species.

Spatially explicit population models account for these factors and facilitate more comprehensive and spatially explicit evaluation of the consequences of MPA design for a proposal's ability to satisfy various goals of the MLPA. Spatially explicit models developed for evaluation of alternative MPA proposals go beyond the current scope of the scientific guidelines in the Master Plan to calculate whether populations will persist and how the proposed MPAs will affect fishery yield and profit. The models include, for example, potential contributions from MPAs that do not satisfy all scientific guidelines, the status of populations outside of MPAs (which depends on fishery management), and the potential costs, in terms of fishery yield, associated with achieving a desired conservation outcome. Further, the models allow us to detect potential situations in which MPAs are sited efficiently, so conservation is gained at minimal cost (or perhaps even a benefit) to consumptive users.

This document briefly describes the key inputs and outputs of two models well-suited for analysis of alternative MPA proposals. Also described are the evaluations that will be performed by these models. Finally, an analysis of genetic connectivity, based on model outputs and designed to complement the MPA spacing evaluation (Chapter 6), is described.

Description of Models

In the MLPA North Central Coast Study Region and MLPA South Coast Study Region planning processes of the MLPA Initiative, two models were developed, vetted, and utilized to evaluate alternative MPA proposals; those models have been extended for use in the MLPA North Coast Study Region (NCSR). The models are the University of California, Davis "Spatial Sustainability and Yield" model (UCD model) and the University of California, Santa Barbara "Flow, Fish, and Fishing" model (UCSB model). The two models use the same input data and parameter values and are structurally quite similar, but differ in a few small details. Because both models report consistent results, the SAT modeling work group determined that a single model (UCSB model and hereafter referred to as "the model") could be used to evaluate MPA proposals, with two sets of assumptions that reflect the key differences between the UCSB and UCD models. Beginning with the evaluations for the second round of NCSR proposals, only the UCSB model will be used to produce two sets of results, one using the original UCSB model formulation and a second using a set of assumptions that is similar to the UCD model formulation ("UCD home range formulation). While the first set of results will serve as the primary output for evaluation, the second set of results will provide multi-model inference, allowing users to gauge the sensitivity of model results to the particular model assumptions being made.

The model utilizes spatial data on habitat, fishery effort, and proposed MPA locations and regulations to simulate the population dynamics of fished species and generate predicted spatial distributions of species abundances, yields, and profits for each alternative MPA proposal. The model considers each fished species separately, and focuses on sustainability of fished populations under each MPA proposal using a range of assumptions regarding future fishery management success. The model focuses on the tradeoffs between fisheries performance (profits) and fish abundance. Importantly, it incorporates the population dynamic consequences of spatially explicit fishing regulations. The model has the ability to be run for the initial 'transient' period immediately after MPA implementation or to a long-term, steady-state equilibrium. Simulating the transient period requires data on the starting abundance, across space, of multiple species; lacking these data, the model is not used in this way. In equilibrium mode, the model predicts the state of the system over the long term rather than its dynamics over time[8].

The two original models (UCD and UCSB) differed in details regarding, for example, how specifically population dynamics are modeled, how the steady-state impacts of fisheries outside of protected areas are parameterized, and what units are used to express conservation and economic values. Although they differ in these details, the two models were structurally similar and gave closely agreeing results in the South Coast Study Region and the first round of evaluations for the North Coast Study Region. Based on the latter set of model results, it was clear that one key structural difference in the models was the method for simulating the movement of adult fishes and invertebrates. Therefore, the UCSB model is currently run for both the original set of assumptions and in a second mode that emulates the UCD approach to simulating home range movement (the UCD home range formulation).

The model includes the following structural elements: (a) larval connectivity across patches driven by ocean currents, pelagic larval duration, and spawning season, (b) larval settlement regulated by species density in available habitat, (c) growth and survival dynamics of the resident (adult) population, (d) reproductive output increasing with adult size, (e) adult movement (e.g., home ranges), and (f) harvest in areas outside of MPAs.

Key Changes to Models

The model was enhanced during the South Coast Study Region process. Some of these enhancements were driven by differences in biogeography between the two regions (e.g., more heterogeneous flow patterns in southern California), and some were driven by new methods or data (e.g., the desire to integrate data on fisherman behavior into the models). The key changes in the models are:

- Larval dispersal kernel: The models now use output from Regional Ocean Modeling System (ROMS)-based oceanographic models[9] to predict connectivity, rather than assuming homogeneous Gaussian kernels along the coastline.
- Spatial dimension: The models represent the coastline as a two-dimensional map (in contrast to the one-dimensional representation used in the north central coast study region process).

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[8] Note that equilibrium models do not account for the costs incurred during the time required to reach steady state.

[9] The ROMS model has been developed by oceanographic investigators University of California, Santa Cruz (UCSC), who provided model outputs for use by the spatially explicit population models described in this document. See Chapter 7 – Spacing for additional information on the ROMS model.

This permitted more realistic modeling of complex habitat patterns and offshore islands in the Southern California Bight. A one-kilometer by one-kilometer grid was used for the patches. This grid-scale will be retained for the north coast study region process.

- Fleet dynamics: In the South Coast Study Region process, a version of both models was parameterized with data from Ecotrust's surveys of commercial fisheries in southern California to account for the increased costs of fishing far from shore, rather than assuming the fleet responds only to changes in fish density. The details of the fleet model are given in Appendix A2. Due to limited time and resources, it was not possible to conduct a similar effort for the North Coast Study Region. Therefore, the fleet in the current version of the model responds to the spatial distribution of profit, which depends solely on fish abundance.
- Species: A list of model species has been assembled that covers a wide range of life history and fishery traits of species that occur in northern California (Appendix A3).

Caveats Associated with Model Interpretation

All models necessarily make simplifying assumptions about the nature of real-world processes. The bioeconomic model relies upon a series of key assumptions about the structural elements (Appendix A1). As such, model results should be interpreted with awareness of the assumptions, although these actually are less restrictive than those required by the verbal and mathematical models that form the basis of the MPA size and spacing guidelines in the Master Plan. For example, the ROMS model used to estimate larval dispersal patterns in the bioeconomic models has limitations in its ability to resolve nearshore circulation, yet is more realistic than the spatially homogenous pattern of connectivity implicitly assumed by the MPA size and spacing guidelines (see "Chapter 7 - Spacing" for more information on the ROMS).

Model outputs also depend on the particular parameter values chosen for each species, so the predictions of the models will be most accurate when appropriate parameter values are known. The SAT modeling work group searched the biological literature for the best estimates of the necessary life history parameters for each model species (Appendix A3). Appendix A3 was circulated among SAT members and outside experts to ensure that the best parameter estimates have been used.

The spatial distributions of larval settlement and adult biomass predicted by the models are driven by two sets of assumptions: 1) larval dispersal is driven by oceanography as predicted by the ROMS model, and 2) the suitability of a particular location for the settlement and growth of a species is determined by the presence of habitat appropriate for that species. The available habitat maps represent habitat in a binary fashion; that is, habitat is either hard- or soft-bottom. Using a rasterized version of these maps, the models consider the fraction of the one square kilometer cell which is suitable habitat (either hard or soft substrate of the appropriate depth, depending on species) to be a continuous measure of habitat availability in the cell. The maximum density of individuals in a cell (carrying capacity) is proportional to this measure of habitat availability.

A final caveat is that model results are highly sensitive to the level of fishing outside of MPAs. Because the model is intended to predict a future equilibrium state, it is necessary to predict future fishing levels, an area of high uncertainty. Moreover, the performance of a species under a certain level of fishing also is highly sensitive to the shape of the settler-recruitment relationship (see Table A1 in Appendix A1), which is itself highly uncertain. The precise relationship between fishing effort and the shape of the settler-recruit curve is complex and not perfectly understood, especially in a model such as this with considerable spatial complexity. In general, however, it is possible to represent the joint uncertainty in the shape of the settler-recruit curve (biological uncertainty) and in future harvest scenarios (management uncertainty) relative to each other. Specifically, the models describe the shape of the settler-recruit curve in terms of a compensation ratio or critical

replacement threshold (CRT), and harvest is described in terms of its effect on the lifetime egg production (LEP) of a species.

For a given value of the CRT, the model results depend roughly on the relative values of CRT and LEP rather than on the particular CRT chosen. In general, the management scenario depends on whether harvest causes lifetime egg production to exceed or fall short of the critical replacement threshold set by the settler-recruit relationship. Expressing the effects of harvest in terms of lifetime egg production also reduces some of the dependence of model results on uncertainty about adult life-history parameters. Therefore, it is possible to represent both biological and management uncertainty by choosing a particular value for the CRT for each species and then simulating population dynamics under several different fishery management regimes relative to that CRT. The models will simulate three fishery management regimes that approximate (1) unsuccessful management, (2) MSY-like management, and (3) conservative management, given that CRT. Thus, the model results can illustrate a range of possible performance for each species. For concise interpretation (i.e., coming up with several summary results for each alternative MPA proposal) it may be desirable to weight results across species or possibly weight the probability of different future management outcomes.

SAT Recommendations for Using the Bioeconomic Model to Compare Alternative MPA Proposals

Because the bioeconomic model is built on the best available science, the SAT recommends that the model be among the principal modes of evaluation for each alternative MPA proposal in the MLPA North Coast Study Region. In making this recommendation, the SAT emphasizes that the models' conceptual principles are consistent with those upon which existing MPA size and spacing guidelines are based, and yield similar general conclusions: MPA size relative to adult movement strongly determines MPA effectiveness, and MPA spacing relative to larval dispersal distance strongly determines the ability of MPAs to function as a network. Spatially explicit modeling is more comprehensive because it integrates the effects of MPA size and spacing, habitat distribution, level of fishing, and adult and larval movement to quantify the effectiveness of alternative MPA proposals. Moreover, a spatially explicit model is not susceptible to threshold-related sensitivity that can arise from evaluation based on the size and spacing guidelines (i.e., specific sizes and spacing (or ranges of these) are adequate, but others are not). Rather the bioeconomic model estimates the conservation and economic consequences of each proposed spatial configuration of MPAs, so that these can be evaluated directly.

The model produces a range of outputs that can be used to evaluate these conservation and economic consequences. Primarily, the model produces a measure of *conservation value* (e.g. increases in biomass or population sustainability), and a measure of *economic return* (e.g. yield or fishery profitability). Both conservation value and economic return can be described study-region wide (a single number, Appendix A, Figures A4.1 and A4.2) or can be made spatially explicit (a map or table, Figures 8.1 and 8.2 and Appendix A, Table A4.1). The models calculate each output at three spatial scales: Individual one kilometer by one kilometer cells, the entire study region, and at the sub-region scale. Conservation value is essentially a measure of the effectiveness of an alternative MPA proposal at meeting MLPA goals 1, 2, and 6[10], while economic return reflects the expected changes to fishing yields of implementing MPAs. Specifically, the model will output:

1. Conservation Value

[10] Subsections 2853(b)(1), (b)(2), and (b)(6), Fish and Game Code.

   a. [Biomass and larval supply of representative species, across space, under each alternative MPA proposal (including “No Action”)
   b. If A=Conservation Value under Proposal X, and B=Biomass under No Action, then the quotient: (A-B)/B provides a measure of the percentage increase in conservation value compared with No Action.

2. Economic Return
   a. Fishery yield for the representative species, across space, for each alternative MPA proposal (including “No Action”)
   b. Again, by comparing to “No Action”, one can generate a measure of the percentage increase or decrease in economic return from the proposal.

The SAT proposes that each alternative MPA proposal be evaluated by compiling the following outputs:

1. Spatial effects on Conservation Value (as percentage changes versus No Action, presented as a spatial map and averages for each sub-area)
   a. For each model species
   b. For an average of all model species
2. Region-wide effects on Conservation Value
   a. For each model species
   b. For an average of all model species
3. Spatial effects on Economic Return (presented as a spatial map and averages for each sub-area)
   a. For each model species
   b. For an average of all model species
4. Region-wide effects on Economic Return
   a. For each model species
   b. For an average of all model species
5. Spatial fishing intensity
   a. For each model species
   b. For an average of all model species
6. Connectivity diagrams: The larval dispersal kernel shows the intensity of connections from all source to all destination locations.
7. Tradeoff curves: Plot of Conservation Value against Economic Return for each MPA proposal

All analyses will take place over a range of fishing intensities, and will be calculated using the UCSB model. The UCD home range module of the UCSB model also will be run for comparison to determine whether model results are robust to assumptions about adult movement, but only a summary of results for that module will be produced.

Using Model Outputs to Improve Each MPA Network Proposal

In addition to the outputs being used to compare alternative MPA proposals, the model also produces outputs which can be used to evaluate the strengths and weaknesses of each design. These outputs are intended provide feedback during the iterative design process so that proposals can be adjusted to improve their performance in terms of conservation value and (if desired) economic value.

Three kinds of feedback are provided for each species:

- The models calculate how much biomass is in each MPA and, what fraction of the larvae arriving in that MPA were produced within the MPA (self-recruitment). The first metric will allow a determination of which MPAs are in locations that support large populations of the target species and which are poorly placed to protect that species. The second metric (self-recruitment) allows a determination of the extent to which each MPA is seeded with larvae originating elsewhere, as opposed to being replenished primarily by larvae spawned within that MPA. Examples of these outputs are given in Table A4.2 in Appendix A4.
- The model calculates how conservation value and economic value would vary for an alternative MPA proposal if one of the proposed MPAs was not implemented, Appendix 4, Table 4A.3. That is, the model is run for a particular alternative MPA proposal, which contains *m* individual MPAs. Then *m* additional model runs are made. In each run, one of the MPAs is 'deleted' from the proposal. The outcome of these deletion runs is then compared to the run with the full proposal. By comparing the performance of the proposal with and without each individual MPA, the relative importance of each MPA can be determined. If the proposal with a particular MPA removed performs similarly to the whole, intact proposal, then the given MPA is not contributing greatly to various MLPA goals, and could be altered to improve its effectiveness at meeting those goals. Alternatively, if removing an MPA causes a decrease in overall performance, then that MPA is performing well at meeting those goals and should probably not be reduced in size or repositioned.
- The models calculate the change in larval supply to each spatial cell under each alternative MPA proposal. This value is calculated as the percentage change in larvae settling in a cell in a given proposal, relative to the number of larvae settling in that cell under the "No-Action" Alternative, or Proposal 0. This statistic reveals which portions of the study region are expected to experience an increase (or decrease) in larval replenishment as a result of MPA implementation. Additionally, the model results also display the locations where those additional larval settlers were spawned; i.e., the locations where MPAs increase the production of successful larvae ("successful" larvae are those that actually disperse to another cell within the study region). This statistic quantifies the degree to which a given MPA actually increases the replenishment of itself, other MPAs, and the fished areas outside of MPA boundaries. This statistic can be compared across MPA proposals to determine which MPA configurations lead to the greatest increase in successful larval production. Examples of these outputs are given in Figure A4.3 of Appendix A4.

In interpreting these outputs, it is important to recognize that the performance of an alternative MPA proposal or a particular MPA within that proposal is determined by the interplay of multiple factors, often in nonlinear ways. Therefore "improving" the performance of a particular MPA could be accomplished by varying any one of a number of factors (including size, shape, coverage of habitat in the vicinity, distance to neighboring MPAs, position relative to oceanographic retention zones, etc.). However, lessons drawn from simpler models of population dynamics within MPAs (e.g,, Crowder et al. 2000, Botsford et al. 2001, 2009, Gaines et al. 2003, Kaplan and Botsford 2005, Kaplan 2006, Moffitt et al. 2009) do suggest the consequences of adjusting different MPA features. In general, MPAs will afford better protection to a species if it is made larger relative to the home range radius of that species. An MPA is more likely to be self-sustaining and independently

persistent if it is larger (so that a greater fraction of larvae produced within that MPA return to replenish the population within the MPA) and if it is positioned in a location with higher oceanographic retention (larger values on the diagonal of the larval connectivity matrix). MPAs also may support large populations if they are situated such that they receive large inputs of larvae from 'upstream' locations, although then the performance of the 'downstream' MPA is tied to the persistence of the population in the 'upstream' location. Similarly, it may be advantageous to locate MPAs such that they export many larvae to 'downstream' locations (determined by looking at the off-diagonal elements of the connectivity matrix in the horizontal rows corresponding to that MPA as a larval origin). However, the successful export of larvae still will depend on whether the 'source' MPA maintains a large, persistent population.

Using Models to Evaluate Genetic Connectivity

The science guidelines for MPA spacing are to place MPAs no more than 50-100 km apart for an objective of facilitating dispersal of important bottom-dwelling fish and invertebrate groups among MPAs, based on currently known scales of larval dispersal (From the Master Plan). This threshold guideline is easy to use for design of MPAs, but it has two substantial limitations. First, the threshold-based guideline is discrete and does not provide information about contributions of MPAs that are close to the maximum spacing. For example, MPAs that are 99 km apart fall within the range of the guideline, while MPAs 101 km apart do not. The 50-100 km value was chosen based on examination of empirically-determined larval dispersal distances with the understanding that connectivity decreases monotonically with increasing distance. However, the use of threshold guidelines can be misconstrued by non-experts to suggest that connectivity is maximized below that range and negligible at greater distances. In reality, some locations may be more connected based on geographic, physical and oceanographic characteristics, while other may be less connected than the threshold guidelines suggest. Additionally, the MPA spacing guideline is a proxy measure that does not account for spatial variability in dispersal (such as the existence of breaks or discontinuities in larval dispersal) or better sources of information on dispersal, such as numerical ocean circulation models.

The SAT has noted that a bioeconomic model can directly calculate the levels of demographic connectivity. That is, the bioeconomic model provides additional information about connectivity between MPAs that is complementary to the MPA spacing evaluation. Moreover, the bioeconomic model provides continuous measures of the ecological effects of MPA proposals (i.e., it is not threshold-based) and it can explicitly account for spatial heterogeneities in dispersal. However, although the bioeconomic model in its current form takes dispersal and connectivity into account, it does not directly evaluate whether MPAs are functioning as a network. As an extreme example of this distinction, consider an MPA array made of up several large MPAs separated by large distances. If those MPAs are self-persistent, the bioeconomic model would reveal that the MPA array is demographically sustainable and would persist through time, despite low or no connectivity between MPAs. However, in a fragmented MPA array, genetic information would not be able to pass from one sub-population in an MPA to another protected sub-population, making the overall population less able to respond to and adapt to changing conditions (e.g., climate change). To operate as an ecological network, MPAs should be connected by the exchange of alleles. For this reason, the existing bioeconomic modeling framework has been adapted to explicitly calculate patterns of genetic connectivity.

The genetic connectivity extension of the existing bioeconomic models represents dynamics in patches that have a maximum carrying capacity of 100 individuals in *N* patches (the same number of patches used in the standard bioeconomic model). The results are sensitive to the value used for carrying capacity, but consistent results are obtained across model runs as long as the carrying capacity is held constant. The model tracks the allele frequency of a single haploid locus in each

patch. Genetic connectivity between patches is assessed by assuming that all patches are homozygous for a single allele *A*, except for patch *i,* which is homozygous for an alternative allele, *B*. The time it takes (in generations) for one copy of allele *B* to arrive in every other patch is a measure of the genetic connectivity between *i* and all other patches. This metric is calculated for each of the *N* patches in turn. That is, each patch is considered to be the initial origin of allele B and transmission times are calculated to each of the other patches, which are assumed to start out as homozygous A. This iterative procedure provides a pairwise estimate of connectivity among all the patches. This model maintains a finite, integer number of individuals in the population (rather than operating in units of population density), so in each timestep, some number of individuals (and the alleles they carry) are randomly lost from the population due to mortality. This introduces stochastic genetic drift into the model, so multiple model runs are used to approximate the long-term probability of genetic connectivity.

The model operates at the steady-state equilibrium obtained from the original demographic model. That is, all life-history parameters, habitat, fishing rates, etc., are assumed to be constant at their equilibrium levels for the duration of the genetic connectivity simulations. The genetic connectivity between each pair of patches is calculated for each of the fishery management scenarios (unsuccessful management, MSY-type management, and/or conservative management) and for the unfished scenario. Connectivity is reported as the difference in connectivity afforded by a proposed network of MPAs (or MPA array), relative to the unfished state. If C_{ij}(F) is the connectivity (average number of generations) between patches *i* and *j* under fishing conditions *F*, then the percent change in connectivity for an MPA array is:

$$Z_{ij} = [\ 1- C_{ij}(\text{fished})/C_{ij}(\text{unfished})\ ]\times 100$$

Values of *Z* near zero indicate that the proposed network of MPAs (or MPA array) maintains the same level of connectivity found in an unfished population. More negative values indicate that gaps in MPA spacing may be causing a loss in connectivity in the network. Note that Z_{ii} is undefined because $C_{ii} = 0$, and that $Z_{ij} = 0$ if there is no connectivity between *i* and *j* in the unfished state (i.e., a natural connectivity barrier). Visual inspection of a plot of *Z* values typically reveals where genetic breaks have arisen and can be used to gauge where MPA spacing may be adjusted to prevent this break in the network of MPAs.

Figure 8-1. Example of spatial map of biomass generated by the bioeconomic model

The map from the MLPA North Coast Study Region shows the equilibrium biomass for one species black rockfish in each model cell.

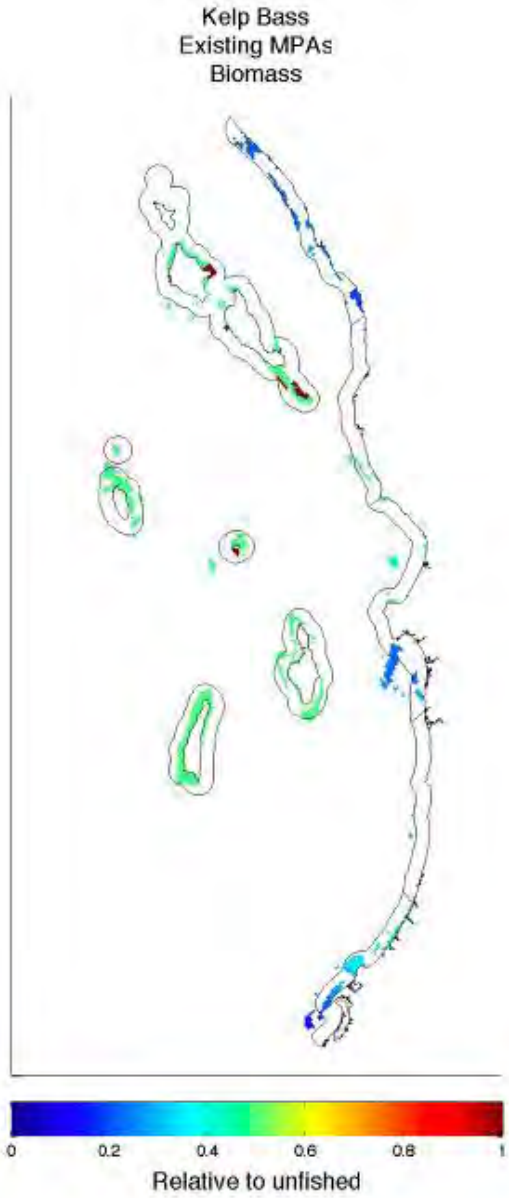


Figure 8-2. Example of spatial map of fishery yield generated by the bioeconomic model

The map shows the equilibrium yield for one species brown rockfish in each model cell in the MLPA Nouth Coast Study Region.

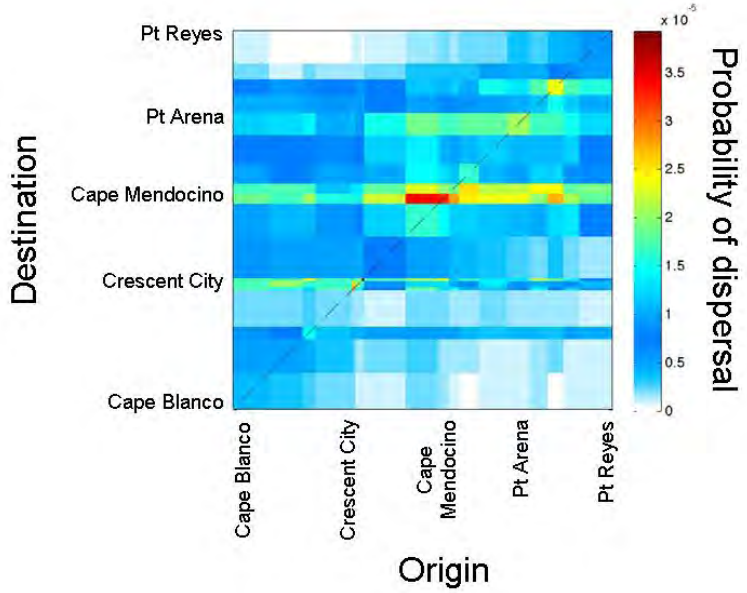
Kelp Bass
Existing MPAs
Larval recruitment
0
0.2
0.4
0.6
0.8
1
Relative to unfished

Figure 8-3. Example of spatial map of fishing generated by the bioeconomic model

The map from the MLPA North Coast Study Region shows the equilibrium fishing rate for one species brown rockfish in each model cell.

Figure 8-4. Example of connectivity matrix used by models

Color intensity at each point shows the probability of dispersal of black rockfish larvae (average from 2000-2006) from an origin patch (along horizontal axis) to a destination patch (along vertical axis). Points are grouped geographically for the MLPA North Coast Study Region. Matrix: C. Edwards and P. Drake, UCSC



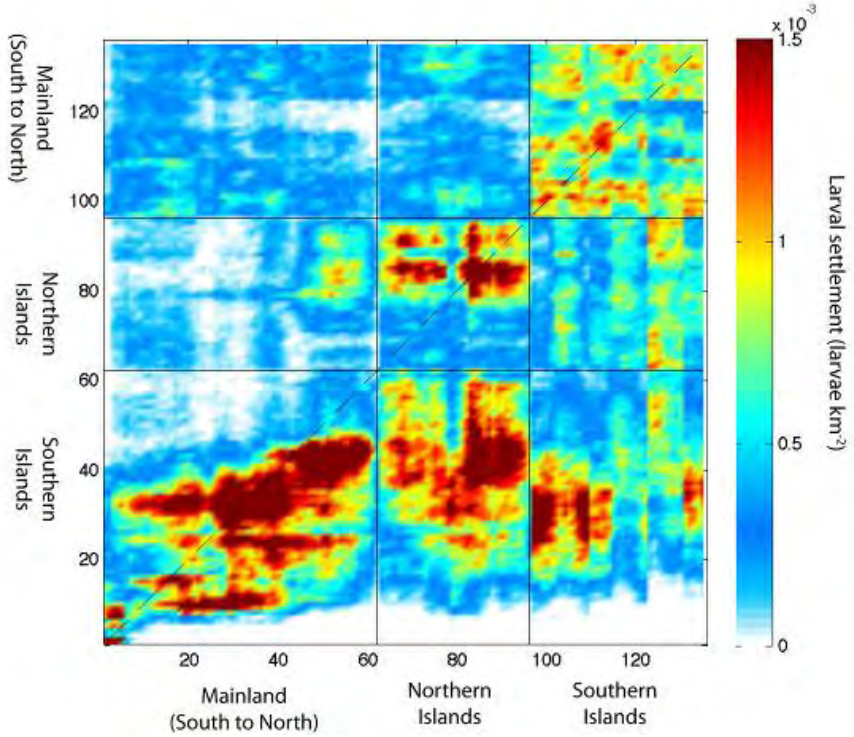
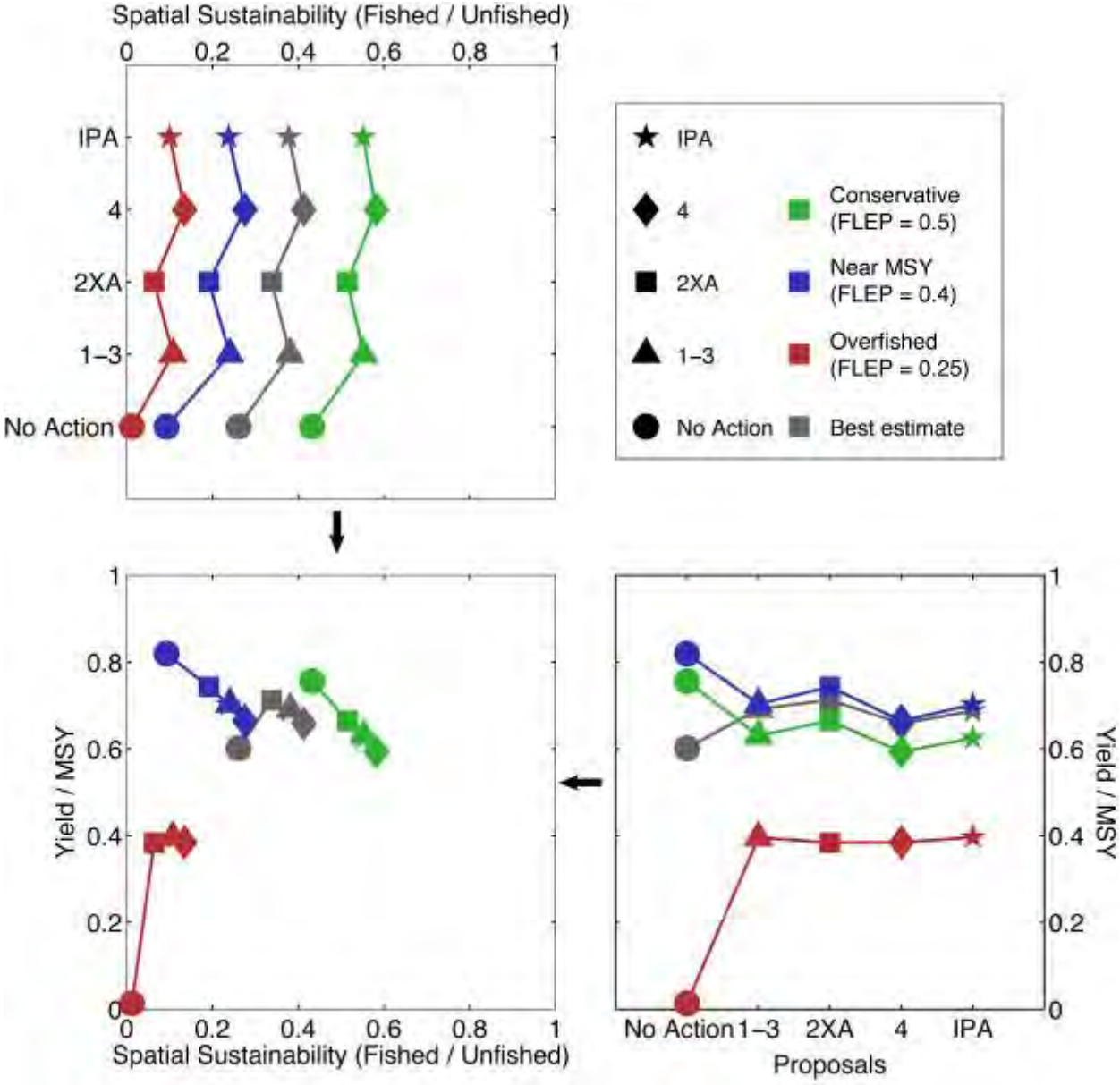


Figure 8-5. Example of tradeoff curve produced by models

This example shows a comparison of eight external MPA arrays and the no action alternative (Proposal 0) from the MLPA North Coast Study Region. The horizontal axis is the Conservation Value metric (total biomass as a proportion of biomass in a scenario without fishing for each proposal) and the vertical axis is the Economic Value metric (total fishery yield as a proportion of maximum sustainable yield under Proposal 0). This figure illustrates the tradeoff curve for both metrics for each proposal. Model results were generated using three different assumptions about the future success of fishery management outside of MPAs: conservative management (not shown), MSY-type management (top panel), and unsuccessful management (middle panel). Results for all three scenarios are plotted in the bottom panel in green, blue, and red, representing conservative, MSY-type and unsuccessful management, respectively. Marker shapes indicate different external MPA arrays; the Proposal 0.



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9. Protection of Marine Birds and Mammals

Status of this chapter: SAT approval June 30.

Marine protected areas (MPAs) may benefit marine birds and mammals by 1) potentially reducing human disturbance at roosting/haul-out sites and breeding colonies/rookeries, 2) protecting their forage base and 3) reducing bycatch (e.g., gray whales interacting with fishing gear). To evaluate the protection afforded by proposed MPAs to birds and mammals the SAT does the following:

- identifies proposed MPAs or special closures[11] that contribute to protection of birds and mammals
- identifies species likely to benefit from MPAs and for which data are available
- identifies important breeding and foraging hot spots for marine birds and mammals
- estimates the proportion (of total numbers of individuals) of breeding birds at colonies and the number of rookeries potentially benefiting by proposed MPAs
- estimates the number and size of marine bird roost sites and proportion (of total numbers of individuals) of mammals at haul-outs potentially benefiting by proposed MPAs
- estimates the proportion of available near-colony foraging areas protected by proposed MPAs, defined by evaluating protection of buffered areas around colonies
- estimates the proportion of available neritic foraging 'hot spots' protected by proposed MPAs, defined by at-sea densities of marine birds and mammals
- estimates the proportion of estuarine and coastal beach habitats protected and diversity and density of shorebirds and waterfowl protected by proposed MPAs

This evaluation focuses on birds, including seabirds, shorebirds and waterfowl, and on pinnipeds (seals and sea lions) and cetaceans (harbor porpoise and gray whales)[12]. Population, as used in this evaluation, refers to the number of animals that use a site for breeding or resting. Evaluations are focused on the study region as a whole. Evaluations include numbers of species (species diversity), numbers of individual birds or mammals, number of roosts or haulouts and percentages of populations breeding within individual proposed MPAs and within all proposed MPAs that contribute to the protection of birds and mammals. Species evaluated are limited to those identified as likely to benefit from MPAs and special closures.

The SAT evaluation for marine birds and mammals focuses on:

1. Protection of seabird breeding colonies and pinniped rookeries based on population size, location and species composition

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[11] Special closures are not MPAs, but could restrict access to discrete areas to prevent human disturbance to colonies, rookeries, haul-outs and roosts. Special closures may be included in future rounds of the marine birds and mammals evaluations if included in MPA proposals; they would be evaluated with regard to marine birds and mammals using similar methods as used for MPAs.

[12] Cetaceans are included only in foraging analyses (i.e., 4 and 5 below), because there are limited data about fine-scale use patterns.

This analysis examines whether MPAs and special closures proposals will benefit the species identified as likely to benefit. Evaluations are based on the numbers of animals in the MLPA North Coast Study Region, and the proportion of breeding colonies and number of rookeries within each proposed MPA or special closure area. For each colony within a proposed protection area, the SAT considers the likely effect of the specific protections or regulations identified (e.g. no-entry zones) that would reduce human disturbance, and whether the MPA or special closure area affects significant numbers of animals. Special closure areas will provide maximum benefit by minimizing disturbance caused by boats, irrespective of vessel type, but will not afford shore-based protection above the mean high tide line. MPAs that restrict fishing or other activities in waters surrounding colonies would provide less benefit than no-entry zones but likely would provide a benefit by reducing the numbers of boats approaching and lingering near colonies. Possible benefits of reduced disturbance include increased bird/mammal productivity, colony/population size, and species diversity (Carney & Sydeman 1999) (Rojek et al. 2007).

Data used for these assessments comes from the National Oceanic and Atmospheric Administration (NOAA)/U.S. Fish and Wildlife Service (USF&WS) bird colony database[13], from pinniped data compiled from Mark Lowry (NOAA Fisheries), and other sources. Count data were gathered when the maximum numbers of animals were expected to be at the sites. The SAT evaluates total counts of seabirds and pinnipeds, and the proportion breeding by species, and for all species combined, within each proposed MPA or special closure. The sizes of special closures vary, but usually range between 300 and 1000 feet.

2. Marine bird and mammal population hot spots

This analysis evaluates whether proposed MPAs or special closures overlap important seabird and marine mammal population hot spots. For seabirds, SAT has identified a population hot spot as seabird islands with more than 10,000 nesting birds recorded. Population hot spots for seabirds in the north coast study region are:

- Castle Rock
- False Klamath Rock
- Green Rock
- Flatiron Rock
- False Cape Rocks
- Steamboat Rock
- Rockport Rocks
- Cape Viscaino

For marine mammals, the SAT has identified a population hot spot as rookeries with recorded Steller sea lions or other pinniped haulout/rookeries with 500 or more pinnipeds present. Population hot spots for marine mammals in the north coast study region are:

- Southwest Seal Rock
- Sugarloaf Island

[13] Original data is from Carter et al. 1992 and Sowles et al.1980. These data were then updated in 2004.

- Vicinity of Castle Rock, Crescent City
- South Bay, Humboldt Bay
- Arcata Bay, Humboldt Bay
- Mouth of the Eel River

3. Marine bird and mammal resting (roost/haulout/raft) locations based on population size, location and species composition

In addition to reproduction, many marine birds and pinnipeds require areas close to foraging locations where they can safely come to shore to rest, sleep, dry (i.e., cormorants, pelicans), or molt (some pinnipeds). Frequent disturbance at resting sites results in high levels of energy expenditure that can lead to poor body condition and/or cause animals to abandon the area (Carney & Sydeman 1999, Rojek et al. 2007).

The methods the SAT uses to assess roosting areas and haulout sites are similar to those used for colonies/rookeries. For seabirds, the SAT uses data on major Brown Pelican roosts, which also serve as a surrogate for other species. For pelicans, roosts have been categorized as low, medium, or high importance based on maximum counts of: 1) never more than 100 birds; 2)100-500 birds; and 3) > 500 birds, respectively. For pinnipeds, total numbers and the proportion are calculated for each species and for all species combined, and sites used by each species are evaluated based on these proportions.

4. Marine bird and pinniped near-colony/rookery foraging concentrations based on population size, location, and species composition

As upper-trophic-level predators, marine birds and mammals require an abundance of resources for survival and reproduction. With long life expectancies (>20 years), low annual productivity, and high site fidelity, these animals are subject to population level impacts from reduced prey supplies or disturbance at foraging areas. High levels of disturbance at foraging areas may cause increased energy expenditure leading to poor body condition; this may be especially detrimental for species with long migration routes (e.g., Brown Pelican, waterfowl, shorebirds), which may not have sufficient energy reserves to complete migration. Thus, protection of important prey species and foraging areas could have benefits, especially to species with limited foraging distributions.

For breeding species, the SAT will focus on four seabird and two marine mammal species most likely to benefit based on limited foraging ranges. For birds, this analysis focuses on the Pelagic Cormorant, Brandt's Cormorant, Pigeon Guillemot, and Common Murre. For pinnipeds, this analysis focuses on the harbor seal and the Steller sea lion. These species mainly forage in nearshore waters within a few miles of colonies during the breeding season. However, other species are likely to benefit (e.g. Double-crested Cormorant, Black Oystercatcher, loons and grebes, waterfowl, California sea lion).

Evaluations of benefits to marine birds and mammals near colonies are based on whether or not proposed regulations may benefit forage species (Table 9-1) or foraging habitats, how much foraging area will be protected near breeding areas, and how many animals stand to benefit. Zones extending three miles alongshore and to three miles offshore (the main foraging range of these species when breeding) from breeding colonies/rookeries are used to examine the numbers of birds/mammals utilizing the area within the proposed MPA.

5. Marine bird and mammal neritic foraging based on location, density, and species composition

There are hydrographic features within the neritic zone of state waters that concentrate prey of many marine birds and mammals. Retention areas and thermal fronts adjacent to upwelling centers and river plumes are known to concentrate prey. These areas are often referred to as 'hot spots', or areas of high trophic transfer, as they provide essential foraging opportunities to upper trophic level predators. While the types of prey typically found at hot spots are highly mobile (e.g. anchovies, squid, and krill), they may benefit from MPAs protecting hot spots as they have a high probability of being concentrated in these areas. Any protection given to hot spots will likely ultimately translate into added marine bird and mammal benefits. A composite map of at-sea densities based on transect surveys will be plotted over proposed MPAs and special closures to determine the area of neritic foraging hot spots protected for seabirds and pinnipeds. Hot spots are identified as areas with the top 10% density for each of seven groups of species in the analysis. The seven groups of species are:

- Loons, Grebes, and Scoters
- Pigeon Guillemots and Pelagic Cormorants
- Marbled Murrelets
- All other seabirds
- All pinnipeds
- Harbor Porpoise
- Gray Whales

Gray whales typically migrate past the northern California coast in the late fall and early spring as they travel between their northern Arctic feeding grounds and their southern Mexican breeding and calving grounds. The north coast region is significant to gray whales because there is a small population (~200 whales) of gray whales that forgo their full northern migration and spend summers foraging south of the Bering and Chuckchi seas (Calambokidis et al. 2002). These animals are part of the Pacific Coast Feeding Aggregation and the southern terminus of their range is in the northern California waters. These gray whales depend on the nearshore habitat during this time to feed in order to procure enough resources to successfully overwinter while fasting in Mexico. In addition to the at-sea analysis, a map of near shore densities for gray whales surveyed from shore sites will be plotted over proposed MPAs and special closures to determine the area of near shore foraging hot spots protected.

6. Estuarine and coastal beach protection for resident and migrant shorebirds and waterfowl

There are many human activities, including hunting, that take place within estuaries and have adverse effects on shorebird and waterfowl populations. Estuaries provide critical resting and foraging habitat for resident and migrant birds and seals. Protecting both estuarine and coastal beach habitat, even if limited to below mean high tide, will have direct benefit to these populations. The SAT evaluates whether proposed MPAs and special closures provide protection to the avian inhabitants of estuarine areas using three analyses. The first analyses evaluate the level of protection to the habitat by identifying, five habitat types: estuarine waterways, tidal flat, coastal marsh, coastal beach and eelgrass in Humboldt Bay. The analysis will investigate the amount of available habitat and number of estuaries protected within proposed MPAs and special closures.

The second analysis evaluates the protection provided to wintering waterfowl and shorebirds in north coast estuaries. This evaluation is based on maximum winter counts from aerial annual

surveys conducted by the California Department of Fish and Game. Each estuary is rated high, medium or low based on the range of maximum winter counts for each species group among all estuaries. For waterfowl and shorebirds, the number of groups and estuary rating by group that are represented in proposed MPAs are evaluated. The analysis reports on six groups of species, as follows:

- Dabbling Ducks
- Diving Ducks
- Geese
- Sea Ducks
- Shorebirds
- Swans

The third analysis evaluates the protection specifically provided to shorebirds in Humboldt Bay. Humboldt Bay is a significant site for migratory and wintering shorebirds (Danufsky and Colwell 2003). Intertidal mud flat areas in Humboldt Bay provide important feeding habitat for a variety of species supporting consistently large populations of shorebirds. Nineteen mud flat sites throughout Humboldt Bay were systematically sampled and baseline data for species densities were recorded. For shorebirds, the species density and diversity for each proposed MPA containing one of the 19 survey sites are evaluated. The number of survey sites in proposed MPAs in Humboldt Bay are reported for each proposal. Proposed MPAs that capture the western shore of Arcata Bay and/or one of the three higher density Marbled Godwit areas are noted.

Consideration of MPAs in analyses 1 through 6

The bird and mammal analysis focuses only on benefits provided by proposed MPAs and special closures. The SAT recognizes that many other marine bird and mammal protections exist outside the MLPA, such as the Marine Mammal Protection Act and the Migratory Bird Treaty Act. All current protections outside the MLPA affect all proposals equally, and therefore are not considered separately from or in addition to proposed MPAs and special closures in these analyses. The focus of all six analyses outlined above will be on special closures and state marine reserves (SMRs), with the recognition that special closures will provide greater protection than SMRs. However, the SAT recognizes some activities have greater impacts than others and state marine conservation areas (SMCAs) permitting certain activities should be considered independently during each analysis. Mills et al. (2005) provide summaries of fisheries activities with potential impacts to marine bird populations. Table 9.2 defines which activities an SMCA can allow and still be considered for a given analysis. For analyses of breeding and resting sites, the ultimate goal is to reduce all human activities around those areas. Table 9.2 is the criteria for level or protection specific to seabirds based on activities that put user groups in close proximity to the species breeding and resting areas. Specifically, activities which allow harvest close to or on islands will not be included in any analysis. For example, MPAs allowing recreational and/or commercial salmon fishing in depths greater than 50m are included in some evaluations, since virtually all islands occur in shallower waters in this region, but only MPAs allowing commercial salmon trolling an commercial trap crabbing) in waters less than 50m deep are included in some evaluations, since the large commercial boats generally stay clear from islands or rocks. Another example would be MPAs allowing hand harvest of algae and mussels limited to the mainland shoreline. These MPAs would be included in the breeding and foraging analyses, whereas no shore-based activities are included in the estuary/beach analysis,

since these activities would likely affect birds and mammals on shore. Finally, fisheries interactions with marine mammals have been less studied in those areas than those with seabirds. Given this, only special closures and SMRs will be included in the marine mammal analyses.

Table 9-1. Known important prey items of Brandt's Cormorant, Pelagic Cormorant, Common Murre, Pigeon Guillemot, harbor seal, Steller sea lion, harbor porpoise and gray whale

Note: Most fish taken by seabirds are in the juvenile stage.

Species	Prey	Preferred Foraging Habitat
Brandt's Cormorant	Fish	Soft bottom
	Osmerid smelt	
	Short-belly rockfish *Sebastes jordani*	
	Yellowtail rockfish *Sebastes flavidus*	
	Other rockfish *Sebastes* spp.	
	Pacific sandlance *Ammodytes hexapterus*	
	Speckled sanddab *Citharichthys stigmaeus*	
	Northern anchovy *Engraulis mordax*	
	Pacific herring *Clupea pallasi*	
	Pacific staghorn sculpin *Leptocottus armatus*	
	Hemilepidotus spp. (Cottidae)	
	Other sculpins (Cottidae)	
	Pacific tomcod *Microgadus proximus*	
	Northern Pacific hake *Merluccius productus*	
	Shiner perch *Cymatogaster aggregata*	
	Pacific tomcod *Microgadus proximus*	
	Spotted cusk-eel *Chilara taylori*	
	Butter sole *Isopsetta isolepis*	
	Rex sole *Glyptocephalus zachirus*	
	English sole *Parophrys vetulus*	
	Invertebrates	
	Market squid *Loligo opalescens*	
Common Murre	Fish	
	Osmerid smelt	
	Northern Anchovy *Engraulis mordax*	
	Pacific herring *Clupea pallasi*	
	Market squid *Loligo opalescens*	
	Juvenile rockfish (esp. Short-belly *Sebastes jordani*)	
	Pacific sanddab *Citharichthys sordidus*	
	Juvenile Salmonids	

Species	Prey	Preferred Foraging Habitat
Pelagic Cormorant	Fish	Submerged reefs
	Short-belly rockfish *Sebastes jordani*	
	Yellowtail rockfish *Sebastes flavidus*	
	Other rockfish *Sebastes* spp.	
	Sculpins (Cottidae)	
	Coryphopterus nicholsii	
	Chilara taylori	
	Invertebrates	
	Shrimp *Spirontocaris* spp.	
Pigeon Guillemot	Fish	Submerged reefs
	Rockfish *Sebastes* spp.	
	Pacific sanddab *Citharichthys sordidus*	
	Blennies (Clinidae)	
	Sculpins (Cottidae)	
	Gunnels (Pholidae)	
	Spotted cusk-eel *Chilara taylori*	
	Invertebrates	
	Red octopus *Octopus rufescens*	

Species	Prey	Preferred Foraging Habitat
Harbor seal	Fish	
	Rockfish *Sebastes* spp.	
	Pacific sandlance *Ammodytes hexapterus*	
	Plainfin midshipman *Porichthys notatus*	
	Speckled sanddab *Citharichthys stigmaeus*	
	Northern anchovy *Engraulis mordax*	
	Pacific herring *Clupea pallasi*	
	Pacific staghorn sculpin *Leptocottus armatus Hemilepidotus* spp. (Cottidae)	
	Other sculpins (Cottidae)	
	Pacific tomcod *Microgadus proximus*	
	Northern Pacific hake *Merluccius productus*	
	Shiner perch *Cymatogaster aggregata*	
	Spotted cusk-eel *Chilara taylori*	
	Butter sole *Isopsetta isolepis*	
	Rex sole *Glyptocephalus zachirus*	
	English sole *Parophrys vetulus*	
	Salmonid	
	Lamprey *Lampetra tridentata*	
	Hagfish *Entatretus* spp.	
	Walleye Pollock *Theragra chalcogramma*	
	Starry flounder, *Platichthys stellatus*	
	Pile perch, *Rhacochilus (Damalilicthys) vacca*	
	Invertebrates	
	Shrimp Spirontocaris spp.	
	Market squid *Loligo opalescens*	
	Octopoda spp.	
	Crustacea	
	Bivalve mollusk	
Steller sea lion	Fish	
	Pacific Hake *Merluccius productus*	
	Pacific Lamprey *Lampetra tridentata*	
	Pacific herring *Clupea pallasi*	
	Rockfish *Sebastes* spp.	
	Smelt (*Osmeridae*)	
	Sculpins (*Cottidae*)	
	Sandlance *Ammodytes hexapterus*	
	Capelin *Mallotus villosus*	
	Pacific cod *Gadus macrocephalus*	
	Salmon *Oncorhynchus* spp.	
	Flatfishes	
	Invertebrates	
	Market squid *Loligo opalescens*	
	Octopus spp.	
	Squid spp.	

Species	Prey	Preferred Foraging Habitat
Harbor porpoise	Fish	
	Northern anchovy *Engraulis mordax*	
	Spotted cusk eel *Chilara taylori*	
	Rockfish *Sebastes* spp.	
	Pacific hake *Merluccius productus*	
	Pacific sardine *Sardinops sagax caeruleus*	
	Pacific herring *Clupea pallasi*	
	Plainfin midshipmen *Porichthys notatus*	
	Pacific sanddab *Citharichthys sordidus*	
	Pacific tomcod *Microgadus proximus*	
	Invertebrates	
	Market squid *Loligo opalescens*	
Gray whale	Invertebrates	Sandy bottom, rock bottom
	Diastylopsis dawsoni	
	Atylus tridens	
	Jassa spp.	
	Ischyrocerus spp	
	Gammaridean spp.	
	Thysanoessa spinfera	
	Crab larvae (zoea stage)	
	Neomysis rayii	

Sources for Table 9-1: Data on seabird prey items from Ainley, D.G., C.S. Strong, T.M. Penniman, and R.J. Boekelheide. 1990. The feeding ecology of Farallon seabirds. Pp. 51-127 in (D.G. Ainley and R.J. Boekelheide, eds.), Seabirds of the Farallon Islands: Ecology, Dynamics, and Structure of an Upwelling-system Community. Stanford University Press, Stanford, California. Data on harbor seal prey items from Harvey JT, Helm R, Morejohn G. (1995) Food habits of harbor seals inhabiting Elkhorn Slough, California. Calif. Fish and Game. 81:1-9; Antonelis, G.A. and C.H. Fiscus. 1980. Steller Sea Lion Diet from Pitcher 1981, Fish. Bull., Gray whale prey from Jenkinson 2002 MS thesis HSU.

Table 9-2. Proposed activities that will qualify (Yes) or disqualify (No) an SMCA for inclusion in each seabird analysis

Activity	Breeding Colony/Hot Spots Analysis	Roost Analysis	Near-colony Foraging Analysis	Neritic Foraging Analysis	Estuary / Beach Analysis
Coonstripe shrimp and spot prawn (trap)	No	No	No	No	Yes
Pacific halibut (H&L)	No	No	No	No	Yes
Surf and night smelts (dip net, a-frame net, cast net)	Yes	Yes	Yes	Yes	No
Salmon – Recreational (H&L or troll in waters >50m depth)	Yes	Yes	No	No	Yes
Salmon – Commercial (H&L or troll in waters >50m depth)	Yes	Yes	Yes	No	Yes
Salmon – Recreational (troll in water <50m depth)	No	No	No	No	Yes
Salmon – Commercial (troll in water <50m depth)	Yes	Yes	Yes	No	Yes
Salmon – Recreational (H&L in waters <50m depth)	No	No	No	No	Yes
Salmon – Commercial (H&L in waters <50m depth)	No	No	No	No	Yes

Activity	Breeding Colony/Hot Spots Analysis	Roost Analysis	Near-colony Foraging Analysis	Neritic Foraging Analysis	Estuary / Beach Analysis
Coastal pelagic finfish (H&L, round-haul net, dip net)	Yes	Yes	No	No	No
Dungeness crab – Recreational (trap, hoop-net, diving)	No	No	No	No	Yes
Dungeness crab – Commercial (trap, hoop-net, diving)	Yes	Yes	Yes	No	Yes
Smelt (H&L, dip net)	Yes	Yes	No	No	No
Redtail surfperch and other surfperch (H&L from shore)	Yes	Yes	Yes	Yes	No
Surfperch (H&L)	No	No	No	No	No
California halibut (H&L)	No	No	No	No	No
Clams (intertidal hand harvest)	Yes	Yes	Yes	Yes	No
Turf algae (intertidal hand harvest)	Yes	Yes	Yes	Yes	No
Lingcod, cabezon and rockfishes and greenlings (H&L, spearfishing, trap)	No	No	No	No	No
Red abalone (free-diving)	No	No	Yes	Yes	No
Urchin (diving)	No	No	No	No	?
Rock scallop (diving)	No	No	No	No	No
Mussels (hand harvest)	Yes	Yes	Yes	Yes	No
Bull kelp (hand harvest)	No	No	No	No	No
Ghost shrimp (hand harvest)	Yes	Yes	Yes	Yes	No
Sea palm (intertidal hand harvest)	No	No	No	Yes	No
Canopy-forming algae (intertidal hand harvest)	No	No	No	Yes	No

Works Cited in Chapter 9

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10. Water and Sediment Quality

Status of this chapter: The SAT approved this chapter on October 13, 2010.

The SAT water quality work group has prepared the draft methods for evaluating water and sediment quality concerns within proposed marine protected areas (MPAs) in the north coast study region (NCSR) for approval by the full SAT.

While water quality is not subject to management under the MLPA, it may be an important consideration in designing MPA proposals. Living marine resources may be substantially affected where water quality is significantly compromised, and may be subject to changes in key population (e.g., abundance, growth, reproduction, and mortality), and community parameters (e.g., energetic, diversity, structure and organization).

Considering Water Quality in MPA Design

Water bodies that do not meet state water quality standards are placed on California's list of "impaired water bodies" according to Section 303(d) of the Clean Water Act. Water quality impairments are designated for a variety of purposes, some of which do not directly affect marine life (e.g., human health due to contact recreation and seafood consumption) and are not a concern for the MLPA. The SAT determined that MPAs may be placed in or near areas of threatened water quality if there are other reasons (e.g. meeting the guidelines for habitat representation and replication or MPA size and spacing) to place MPAs in such areas.

Water quality evaluations are not mandated by the MLPA, and should therefore be considered secondary to other MPA network design guidelines. Other established SAT guidance, including bioregions, habitat representation and replication, and MPA size and spacing, should be used as the primary mechanisms to drive the design of alternative MPA proposals consistent with the Master Plan. Water quality considerations should be incorporated if other guidelines and criteria have been met.

Areas of Water Quality Opportunities and Concern

The Marine Managed Areas Improvement Act (MMAIA; Stats. 2000, Chapter 385), which is complementary to the MLPA, does address water quality concerns with the establishment of state water quality protection areas (SWQPAs). Areas of special biological significance (ASBSs), which were established through the California Ocean Plan, are a subset of SWQPAs. SWQPAs, inclusive of ASBSs, must be designated by the State Water Resources Control Board. These areas are protected from waste being discharged into them, affording better and more natural water quality. MPAs proposed within ASBSs should have the potential to benefit from protection beyond that offered by standard waste discharge restrictions and other measures, due to the strict water quality protections in ASBSs (ASBSs in the NCSR are listed in Table 10-4). Where possible the SAT recommends siting MPAs in ASBSs. The SAT recommends avoiding, where possible, water quality concern areas, including areas containing or impacted by:

1. Storm water runoff from developed urban or agricultural watersheds, other non-point sources such as ports, harbors or marinas, and disturbances from dredge disposal activities.

2. Municipal sewage or industrial outfalls.

In the South Coast Study Region the SAT recommended avoiding cooling water intake sites for power plants. In the NCSR, there is only one major coastal power plant currently using once-through cooling, the Humboldt Bay Power Plant which is owned by Pacific Gas and Electric Company. However, the plant is completing a re-powering project in early 2010 to fully convert to closed cycle cooling by the end of 2010. There are therefore no cooling water intakes that should be avoided in the NCSR.

Both the SWQPAs and water quality concern areas have been identified on the water quality maps which accompany the guidance document titled “California MLPA Master Plan Science Advisory Team draft recommendations for considering water quality and marine protected areas in the MLPA North Coast Study Region”.

The SAT strongly recommends that the following sites are undesirable locations for MPA placement because they contain water quality conditions that will most likely compromise MPA performance and potentially the ability of an MPA to meet the goals of the MLPA:

- Samoa Pulp Mill Outfall
- Crescent City Harbor
- Trinidad Harbor
- Eureka Harbor and other developed harbors in Humboldt Bay
- Shelter Cove Harbor
- Fort Bragg Noyo Bay Harbor

The SAT has also identified two areas where dredge disposal activities occur. The SAT recommends avoiding, when possible, placing an MPA adjacent to the Whaler Islands dredge disposal site and adjacent to the Crescent City Harbor and the Humboldt Open Ocean Disposal Site (HOODS) which is located three nautical miles off the mouth of Humboldt Bay. MPAs located adjacent to Whaler Island may experience periodical disturbances from sedimentation and turbidity caused by dredge disposal activities, which could disturb benthic communities. Additionally, MPAs may be minimally affected by dredge disposal activities if they were located adjacent to HOODS and for his reason it would be best to avoid this area, if possible, during the MPA planning process. For more detailed information and on these two sites please see Question # 9 in the document titled “California MLPA Master Plan Science Advisory Team Responses to Science Questions Posed during the June 29-30, 2010 MLPA Master Science Advisory Team Meeting” which was released during the July 29th and 30th NCRSG meeting.

Evaluation Methodology

Scoring for Open Coastal MPAs

The SAT determined that the best way to evaluate potential impacts of water quality on proposed MPA networks is to assign scores based on presence or absence of water quality concerns and opportunities. A matrix will be established based on whether or not a proposed MPA includes either of the two water quality concern areas listed above. SWQPAs also will be included in this matrix, and will act as a positive influence on the score when co-located with MPAs. Final scores for each MPA and the MPA network proposal will be an average for each of the category scores. The scores for each water quality concern category are weighted according to the level of concern. Weights are based on the expert opinion that storm water and nonpoint source discharges will have a greater impact on MPA performance than wastewater discharges.

Urban and agricultural storm runoff is known to be toxic to larvae of marine fish and invertebrates; storm water plumes from developed areas may extend over an appreciable area following major rainstorms. Additionally, ports, harbors and marinas, may contain nonpoint source contaminants at levels unsuitable for MPA placements. Treated wastewater effluents are less of a concern because they are controlled through permits with effluent limitations; however, they still present a pollution threat if effluent limits are violated, and also because sediments in their immediate vicinity may have elevated contaminant concentrations. There is only one major wastewater effluent discharge in the NCSR from the Samoa Pulp Mill, but there are several intermediate and small discharges. An impact zone of 0.5 mile radius should be given for major wastewater outfalls and 0.25 mile radius for intermediate wastewater outfalls, and it is advisable that small wastewater outfall points (impact "points") should not be included in an MPA.

Co-location with urban or agricultural stormwater runoff or other nonpoint source discharge sites such as ports, harbors or marinas, and dredge disposal sites will reduce the score by 1.0. Co-location with an impact zone around a wastewater discharge outfall will reduce the score by 0.5. MPAs that do not include water quality concern areas will receive a positive score of 1.

An MPA that is co-located with a SWQPA scores a maximum of 1.0. This score will be weighted based on the percentage of shoreline extent of the SWQPA that overlaps the proposed MPA. For example, if 60% of the MPA's shoreline is within the boundaries of an SWQPA, then that MPA will receive a 0.6 score under the SWQPA category. If an MPA is not co-located with a SWQPA then it scores 0 for that category. Table 10-1 summarizes the scoring system for each category.

Table 10-1. Scoring table for evaluating water quality in coastal MPAs

Water Quality Concern Area	Scores: Co-located with Water Quality Concern Area	Scores: Not Co-located with Water Quality Concern Area
Stormwater/Nonpoint Source Discharge/Dredge Disposal	-1.0	1.0
Wastewater Discharge	-0.5	1.0
Water Quality Protection Area	Co-located with SWQPA	Not Co-located with SWQPA
SWQPA/ASBS	Between 0 and 1, based on the % of shoreline coverage	0
Final score for each MPA	Average of scores for each category, weighted by multiplying by ratio of MPA shoreline to regional proposal total shoreline for coastal MPAs	
Final score for regional MPA proposal (coastal MPAs only)	Sum of the final score for each MPA within the proposal	

Maximum score for each category is 1.0.

The scores for the three water quality categories will be averaged to obtain a score for each proposed MPA. Individual MPA scores will be weighted by the ratio of the shoreline length of a proposed MPAs to the shoreline of the proposed MPAs in the NCSR. This will provide a water quality score for each coastal MPA in the proposal, which potentially ranges from a low of 0.17 for MPAs with high overlap with areas of water quality concern, to 1.0 for MPAs avoiding water quality concerns while having high overlap with areas of water quality opportunity.

Scoring for MPAs in Estuaries, Lagoons, and Bays

All MPA proposals likely will include estuaries, lagoons, and/or bays, due to the important role these play in marine ecosystems and because they include one or more of the many key habitats that should be included in MPA proposals as described in the *Master Plan*. Embayments are productive and essential to the marine ecosystem in part because of their enclosed, protected structure at the mouths of coastal streams. High productivity in embayments is related to natural nutrient deposition from coastal streams. However, the influence of development in watersheds and bays (such as urban development, agriculture, timber harvest, aquaculture and harbors) also makes them vulnerable to pollution. Anthropogenic eutrophication from developed watersheds can alter the natural nutrient balance in embayments. Toxic pollutants, also derived from watershed runoff and from anthropogenic activities in bays and on the shoreline, adhere to the sediments in bays and estuaries. Therefore, the greater the number of bay and estuary MPAs included in a proposal, the greater the chance that the proposal's overall score will be reduced. However, not all bay and estuary MPAs are considered impacted enough to receive a reduced water quality score.

The SAT recognizes differences between embayments (estuaries, lagoons, and bays) and open coastal MPAs in terms of water quality issues. Whereas water pollution enters open coastal waters from a nearshore discharge point and disperses toward the open ocean, discharges into enclosed bays and estuaries tend not to disperse quickly and can be retained through several tidal cycles. In addition, there are no SWQPA/ASBSs currently designated in enclosed bays and estuaries. Using the same scoring system would unequally weight scores for enclosed bays and estuaries relative to the open coast. For all these reasons, the SAT will provide, for each MPA proposal, separate evaluations of open coastal MPAs and MPAs located in bays and estuaries. Table 10-2 summarizes the scoring system for each water quality concern area for bays and estuaries.

Table 10-2. Scoring table for evaluating water quality concerns in embayment and estuarine MPAs

Water Quality Concern Area	Co-located with Water Quality Concern Area Scores	Not Co-located with Water Quality Concern Area Scores
Stormwater/Nonpoint Source Discharge/Dredge Disposal	-1.0	1.0
Wastewater Discharge	-0.5	1.0
Final score for each embayment MPA	Average of scores for each category, weighted by multiplying by ratio of MPA area to total area of all proposed MPAs in embayments and estuaries.	
Final score for regional MPA proposal (coastal MPAs only)	Sum of the final score for each MPA within the proposal	

Maximum score for each category is 1.0

Each of the two water quality categories will be averaged to obtain a score for each individual MPA. These individual MPA scores will be combined by obtaining a weighted average based on the ratio of the area of a specific MPA to the sum of area for all the bay/estuary MPAs in the entire proposal. This will provide a water quality score for each bay/estuarine MPA in the proposal, which potentially ranges from a low of 0.25 for MPAs with high overlap with areas of water quality concern, to a high of 1.0 for MPAs without overlap with these areas of concern.

Scoring for MPAs Proposals

After a weighted average score has been determined for each of the individual coastal and embayment MPAs within a proposal, a weighted average score is then determined for the entire proposal. The weighted average is a single comprehensive score for water quality of the entire MPA proposal (average MPA score within a proposal) multiplied by (MPA size/total area or shoreline length in a proposal). This equation is done for each MPA and then summed across all MPAs to get the weighted average score, example provided below.

In the example proposal below (Table 10-3), MPAs One, Two and Three are coastal MPAs, and Four, Five and Six are embayment MPAs. For the coastal MPAs, MPA One was not placed in any areas of water quality concerns, such as stormwater/nonpoint source or wastewater discharges, therefore a score of 1 was placed under each of these two categories. Additionally, MPA One had a shoreline that was 100% co-located with an SWQPA/ASBS and followed the guidelines listed above for water quality protection area scoring. Therefore, a 1 was placed under that category. MPA One scored the highest possible score (1.0) across all categories. MPA Two did not score as well due to co-locating the MPA with a major or intermediate wastewater discharge. MPA Three did not score well due to co-locating with a stormwater/nonpoint source. MPAs Two and Three also did not receive any additional credit for being co-located with water quality protection areas.

Example MPA Four was not placed in any areas of water quality concerns, such as stormwater/nonpoint source or wastewater discharges, and therefore MPA Four scored the highest possible score for an embayment MPA across all categories. MPA Five did not score as well due to co-locating the MPA with a major or intermediate wastewater discharge. MPA Six scored even worse due to co-locating with both a stormwater/nonpoint source and a wastewater discharge, and received the worst score of all MPAs in the proposal.

In summary for this hypothetical proposal, Example MPAs One and Four received the highest scores (1.0). Example MPAs Two, Three, Five and Six scored low and improvements could be made it is possible to adjust their locations to better meet the water quality guidelines.

Table 10-3. Example of water quality evaluations for a hypothetical proposal

	Shoreline Length (Mi)	Stormwater/ Nonpoint Source Discharge Zone/Dredge Diposal	Wastewater Discharge Zone	Co-Located with an SWQPA/ASBS	MPA Average Score	MPA Shoreline ratio	MPA Score Weighted Average
			Coastal MPAs				
Example MPA One	5	1	1	1	1	0.42	0.42
Example MPA Two	3	1	0.5	0	0.5	0.25	0.13
Example MPA Three	4	0	1	0	0.33	0.33	0.11
Proposal Average Scores [a]	12	0.66	0.83	0.33	0.61		0.66
			Bay/Estuarine MPAs				
Example MPA Four	10	1	1		1	0.3	0.3

	Shoreline Length (Mi)	Stormwater/ Nonpoint Source Discharge Zone/Dredge Diposal	Wastewater Discharge Zone	Co-Located with an SWQPA/ASBS	MPA Average Score	MPA Shoreline ratio	MPA Score Weighted Average
Example MPA Five	15	1	0.5		0.75	0.45	0.34
Example MPA Six	8	0	0.5		0.25	0.24	0.06
Proposal Average Scores [a]	33	0.66	0.66		0.66		0.7

[a] *Shoreline length, MPA area, and final weighted score are summed and not averaged.*

Table 10-4. Names and shoreline lengths of water quality protection areas in the NCSR

SWQPA	Area (mi^2)	Alongshore Span (miles)
Redwood National Park ASBS	97.88	35.9
Trinidad ASBS	0.46	2.0
King Range ASBS	39.15	33.0
Jughandle Cove ASBS	0.32	1.5

11. Commercial and Recreational Fishery Impacts

Status of this chapter: The SAT approved this chapter on February 11, 2010. Changes from the February 11, 2010 version are in underline and strikeout.

While fishery impacts are not the focus of the MLPA, they may be considered in designing alternative MPA proposals. The evaluation of maximum potential recreational and commercial fishery impacts utilizes region-specific data collected by MLPA contractor Ecotrust on areas of importance. To evaluate the potential recreational and commercial fishery impacts, MLPA Initiative staff and contractors do the following:

- Conduct local knowledge interviews with recreational and commercial fishermen, using an interactive, custom computer interface, to collect geo-referenced information about the extent and relative importance of study region commercial and recreational fisheries.
- Organize impact analyses by port, fishery, and/or user group.
- Evaluate and summarize the maximum potential impacts on commercial, commercial passenger fishing vessel (CPFV), and recreational fishing grounds both in terms of total area and value affected, with results summarized for both study region fishing grounds and total fishing grounds[14].
- Conduct an impact analysis for commercial and CPFV fisheries.
- Consider or identify “outliers” (i.e., fisheries and individual fishermen likely to experience disproportional impacts).
- Assess the effect of existing fishery management area closures and other constraints on fishing grounds.

Background

In order to conduct an analysis of the relative effects of MPA proposals on fisheries that are conducted in the MLPA North Coast Study Region (NCSR), we use data layers characterizing the spatial extent and relative stated importance of fishing grounds for key commercial, commercial passenger fishing vessel (CPFV), and recreational fisheries. This information was collected during interviews in the summer and fall months of 2009 (June through October), using a stratified, purposeful sample of 219 commercial fishermen and stratified, solicited samples of 22 CPFV operators and 574 recreational fishermen. Individual responses regarding the relative importance of ocean areas for each fishery were standardized using a 100-point scale and normalized to the reported fishing grounds.

Using the normalized data described above, we assess the potential effects of any MPA proposal using a variety of analyses (see Table 12-1).

We report results for the commercial and CPFV fisheries at both the study region and port group levels. We report results for the recreational fisheries by user group (i.e. private vessel, kayak, and dive) and by port group (see Table 12-2).

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[14] *Impact analyses represent a “worst case scenario” in which fishermen cannot fish in a different location.*

Table 11-1. Reported results

	Commercial	CPFV	Recreational
Potential impacts on fishing grounds (area and stated value)	X	X	X
Potential net economic impacts	X	X	
Potential gross economic impacts	X		
Disproportionate impacts on fisheries	X	X	
Disproportionate impacts on individuals	X		

Table 11-2. Summary of results by sector

	Commercial	CPFV	Recreational
# of fisheries	10 species	5 species	5 species
Level of analysis	Port-fishery combinations	Port-fishery combinations	Results reported by user group (private vessel, kayak, dive) and by port

Port groups for the commercial fisheries are defined as Crescent City, Trinidad, Eureka, Shelter Cove, Fort Bragg, and Albion[15]. Port groups for the CPFV fisheries are defined as Crescent City, Trinidad, Eureka, Shelter Cove, and Fort Bragg. Port groups for the recreational fisheries are defined as Crescent City, Trinidad, Eureka, Shelter Cove, and Fort Bragg/Albion.

It should be noted that, with respect to the recreational fishery analysis, the use of a stratified, solicited sample limits the use of traditional statistical measures (e.g., confidence intervals), meaning they may not deliver their advertised precision. Nevertheless, this approach does allow us to make broad generalizations about preferences of the overall recreational fishing population and the three user groups within the study area (i.e., private vessel, kayak, and dive), adding increased thematic resolution to the MLPA decision-making process.

Impact on Commercial Fishing Grounds: Methods

Marine protected area (MPA) proposals typically vary according to their spatial extent and the commercial fisheries they affect. More specifically, MPAs often vary by the number and types of fisheries permitted within their boundaries. Furthermore, study area fisheries themselves vary in spatial extent and frequently overlap. Many of them are conducted in fishing grounds that extend beyond the state waters of the NCSR, and because of this we report potential impacts both in terms of total fishing grounds and those that fall within the study area (i.e., zero to three nautical miles from shore). Since any one MPA may have different effects on different fisheries, and different fisheries may be affected differently by all MPAs, it is necessary to consider single MPAs and single fishery

[15] *In contrast to other commercial fisheries, seaweed harvesters do not have landings data associated with a port. Therefore, based on spatial harvest patterns we define three harvest complexes within the study region: the Crescent City and Trinidad complex, the Fort Bragg and Albion complex, and the Elk complex.*

uses independently. Note that because current fishery closures affect all proposals equally, they have no differential effect.

A key assumption of this analysis is that each of the MPA proposals completely eliminates fishing opportunities in areas closed to specific fisheries and that fishermen are unable to adjust or mitigate in any way. In other words, the analysis assumes that all commercial fishing in an area affected by an MPA would be lost completely, when in reality it is more likely that effort would shift to areas outside the MPA. The effect of such an assumption is most likely an overestimation of the impacts, or a “worst case scenario.”

Potential Impacts on Area and Stated Value

We conduct an overlay of each MPA with each fishery considered in this study. MPAs are grouped according to level of protection, using the same levels of protection as elsewhere in the SAT evaluations. In other words, for each MPA and protection level within each proposal, we assess the commercial fisheries that would be affected.

We compile results in a series of spreadsheets, summarizing the effects of the various MPA proposals on commercial fisheries, both in terms of the area affected and the relative value lost. We use the same analytical methods as those developed and used in previous iterations of the MLPA process (Scholz et al. 2006; 2008; 2010), creating a weighted surface that represents the stated importance of different areas for each fishery. More specifically, we multiply these stated importance values by the proportion of in-study region landings (by landing port and by fishery). The percentage of area and value affected is calculated based on grounds identified within only the NCSR, not within the whole state of California. These estimates then feed into the economic impact assessment (described in Appendix B).

The percentage change in area and value for each of the commercial fisheries (both for the study region and for each port group) is determined by the intersection of each MPA proposal and the fishing grounds specific to that fishery. Each MPA within a proposal is classified by whether it would affect the fishery or not. If a fishery is affected by a MPA, the area and value are summarized and then divided by the total area and value for the entire fishing grounds as derived from interviews with fishermen, and the total study area. The total percentage of area and value affected for the total fishing grounds and the grounds inside the study area are then summarized by proposal for all MPAs affecting each fishery.

The percentage change in area and value for each of the commercial fisheries (both for the study region and for each port group) are determined by the intersection of each MPA proposal and the fishing grounds specific to that fishery. Each MPA within a proposal is classified by whether it would affect the fishery or not. If a fishery is affected by an MPA, the area and value are summarized and then divided by the total area and value for the entire fishing grounds as derived from interviews with fishermen, and the total study area. The total percentage of area and value affected for the total fishing grounds and the grounds inside the study area are then summarized for all MPAs affecting each fishery per proposal.

For the commercial fisheries, we also evaluate the additional impacts that potentially occur when considering the existing fishery management area closures and/or fishery exclusion zones. The fishing grounds, as defined by the fishermen through the interview process, represent the total area and value regardless of these existing or potential fishery management closures and/or fishery exclusion zones. In order to evaluate the effect of such closures, the fishing grounds that fall inside those areas are removed, and the value associated with the removed area redistributed to the remaining fishing grounds outside the closed areas. In other words, values are redistributed across only what could be considered the available fishing grounds in proportion to their relative value as

derived from the interviews. Using the same method described above, we determine the percentage change in value by the intersection of each MPA proposal with the total fishing grounds now constrained to areas not inside the closed areas (i.e. the "available fishing grounds").

Potential Primary Impacts on Ex-Vessel Value

In order to estimate the impacts to the commercial fishery sector associated with each of the MPA proposals, we estimate a "worst-case scenario" or maximum potential economic impact of each MPA proposal[16]. To accomplish this, we use methods similar to those in Scholz et al. (2008), which are based on methods utilized in the MLPA Central Coast Study Region process by Wilen and Abbott (2006). The modified analysis in Scholz et al. (2008), however, differs in a very important respect, that is, by having original survey data on fishermen's operating costs collected through the interview process.

As part of the fishermen interview process in the NCSR, field staff asked several questions related to operating costs, including:

- What percentage of your gross revenue goes towards crew share or labor?
- What percentage of your gross revenue goes towards fuel?
- What percentage of your gross revenue goes towards other costs?

With the opportunity to interview NCSR fishermen directly, information specific to the study region is gained. There is also the opportunity for data resolution regarding types of costs fishermen face. Using data from the interviews, two cost categories are created: fixed and variable. Fixed costs include costs that are independent of the number of trips a fishing vessel makes or the duration of these trips. For example, vessel repairs and maintenance, insurance, and mooring and dockage fees are typically considered fixed costs. On the other hand, variable costs include costs that are dependent on the number of trips a vessel makes or the duration of these trips. Variable costs typically include fuel, maintenance, crew share, and gear repair/replacement. For the purpose of this study, crew wages and fuel costs are assumed to be variable costs. All other costs are assumed to be fixed costs.

The net economic impact (NEI) of each MPA proposal is calculated for each port group, and for the NCSR as a whole. The NEI results are presented as revenue reductions in both dollar terms ($ 2007) and percentage terms. The starting point for calculating NEI is baseline gross economic revenue (Baseline GER), which is gross revenue for the fishery in question absent any MPA proposal. Baseline GER is based on an eight-year average (2000–07) converted to 2007 dollars. The baseline net economic revenue (Baseline NER) is found by subtracting the fishery-specific fixed and variable costs from the Baseline GER. A similar net economic revenue calculation is performed for each MPA proposal and is then compared with Baseline NER to yield NEI.

Potential Disproportionate Impacts on Fisheries

We also use the results of our analysis to evaluate whether there are commercial port-fishery combinations that may be disproportionately affected by each of the MPA proposals. To assess these impacts, we use a box plot analysis to identify outliers within each fishery (calculated using estimated impacts on the stated value of total fishing grounds). In a box plot analysis, outliers are

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[16] *For a detailed description of the methods used, please see Scholz et al. (2008), which can be found at http://www.ecotrust.org/mlpa/Ecotrust_FinalReport_NCCSR_080701.pdf.*

defined as extreme values that deviate significantly from the rest of the sample. Box plot analysis results can also inform convergence among MPA proposals within a fishery and/or relative potential impacts between fisheries.

Potential Disproportionate Impacts on Individuals

For the individual impact analysis, we evaluate if there are individual fishermen who would be disproportionally affected by each MPA proposal (i.e., 100% or a large portion of their grounds are inside a proposed MPA that would restrict fishing). To assess these impacts, we first overlay each fisherman's fishing grounds weighted by ex-vessel revenue (for each fishery in which the individual participates) with those areas being considered for closure under each proposal. We then summarize the potential impact on each fisherman's ex-vessel revenue across all fisheries in which the individual participates. The "worst-cast scenario" still applies in that fishermen are assumed not to adjust to different fishing grounds.

We then use a box plot analysis to identify individual outliers. In a box plot analysis, outliers are defined as extreme values that deviate significantly from the rest of the sample. This analysis not only identifies individual outliers, but is able also to describe the relative impacts of proposals on individual fishermen.

Impact on CPFV and Recreational Fishing Grounds: Methods and Approach

Potential Impacts on Area and Stated Value

The methods and approach used to assess the impact of the various MPA proposals on CPFV and recreational fisheries are identical to those used to assess the impact on commercial fisheries (please refer to Appendix B for a description of those methods) with one exception. While the stated importance values of the commercial fishing grounds are weighted by each fisherman's relative contribution to the total ex-vessel value of in-study region landings (both by landing port and by fishery), no weighting occurs in the calculation of CPFV and recreational fishing grounds[17]. Rather, the analysis is done using only stated importance values from the interviews.

The recreational data should be used with the following caveats:

- The data are not representative of the entire population of recreational fishermen due to the less than desirable (less than statistically significant) sample size (CPFV not included).
- The data should only be considered at the port/landing level, not at the entire study region level.
- The data represent interviewees' areas of value, not areas of effort.
- The data represent areas that are important to interviewees over their entire recreational fishing experience, not necessarily the areas that are important to them currently.

That said, based on conversations with leaders of the recreational fishing community, we believe that the data and the manner in which they were acquired allow us to produce results that speak

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[17] *No weighting occurs for the obvious reason that ex-vessel values do not exist for CPFV or recreational fishery landings.*

broadly to the preferences of the overall recreational fishing population and also each user group and port/landing.

As in the commercial fisheries impact analysis, the percentage change in area and value for each of the recreational fisheries (only for the port/landing) is determined by the intersection of each MPA proposal and the fishing grounds specific to that fishery.

Potential Primary Impacts on Value

Similar to the analysis of the commercial fisheries, we calculate the potential net economic impact for the CPFV fisheries as the average reduction in net economic revenue across all species considered. Please see the section on commercial fisheries for a description of the methods we use.

Potential Disproportionate Impacts on Fisheries

For the CPFV fisheries, we also evaluate whether there are port-fishery combinations that may be disproportionately affected by each MPA proposal. Please see the section on commercial fisheries for a description of the methods we use.

Works Cited in Chapter 11

Scholz, A. J., C. Steinback, S. Kruse, J. Bonkoski, S. Hetrick, N. Lyman, S. Lloyd, and L. Weiss. 2010. Commercial and recreational fishing grounds and their relative importance off the South Coast of California. Report submitted to California Marine Life Protection Act Initiative (forthcoming).

Scholz, A. J., C. Steinback, S. Kruse, M. Mertens and M. Weber. 2008. Commercial and recreational fishing grounds and their relative importance off the North Central Coast of California. Report submitted to California Marine Life Protection Act Initiative (June 30).

Scholz, A. J., C. Steinback and M. Mertens. 2006. Commercial fishing grounds and their relative importance off the Central Coast of California. Report submitted to California Marine Life Protection Act Initiative (May 4).

Wilen, J. and J. Abbott. 2006. Estimates of the Maximum Potential Economic Impacts of Marine Protected Area Networks in the Central California Coast. Final report submitted to the California Marine Life Protection Act Initiative in partial fulfillment of Contract #2006-0014M (July 17).

Appendix A. Bioeconomic Modeling

A1. Model Assumptions for Key Structural Elements in the Spatially Explicit Bioeconomic Model

Table A1-1. Assumptions of the University of California, Santa Barbara (UCSB) bioeconomic model

UCSB Model Assumptions
Larval Dispersal: Adults of representative species in each 1 km x 1 km habitat cell throughout the study region spawn larvae that are randomly distributed within that cell. The probability of larvae moving from that cell to any other in the study region is calculated using output from the ROMS, for which larvae are assumed to behave as passive, neutrally buoyant particles. Dispersal pathways are calculated by averaging across several years of ROMS circulation output. For each species, dispersal pathways are calculated using known spawning seasons and pelagic larval durations for the species. ROMS dispersal probabilities are calculated for five km radius circles distributed along the coastline of the study region; these data are mapped onto the 1 km x 1 km habitat grid used in the population models. Successful settlement for larvae 'arriving' at each model cell is contingent on the presence of suitable habitat in that cell.
Larval Settlement: Settling larvae experience intra-cohort density-dependent mortality. That is, the mortality rate of settlers depends on the density (fish per square meter) of other settlers arriving at that location, reflecting competition for habitat and predator refuges that is typical of the species being modeled. Because this density-dependence represents competition for habitat and refuges, its strength depends on the proportion of the cell that is suitable habitat. For a given number of settling larvae, more will survive to adulthood in a cell with abundant suitable habitat than in a cell with mostly poor habitat.
Adult Growth and Reproduction: Growth for each species is based on previously published growth curves. Survival is independent of fish age and is based on published estimates of mortality in the absence of fishing. Egg production is assumed to be proportional to the total weight of adult fish.
Adult Movement: Each year a fraction of the fish of each age class in each cell leave the cell and are distributed evenly among all neighboring habitable cells. We assume, for each species, that this fraction is proportional to the typical diameter of a home range of an individual of that species, and that the probability of an adult settling in nearby cells is a Gaussian function of the distance from the source cell. The model is reasonably insensitive to the scaling of this diffusive movement rate, and produces similar results when adult home ranges are assumed to be fixed.
Fishing Pressure: We assume that fishers are acting to maximize their own profits. Assuming a large number of fishers acting independently, this means that fishing effort will be distributed such that at the end of each season marginal profits are the same in all cells.

A2. Summary of Methods for Parameterizing Fishing Fleet Component of the Spatially Explicit Bioeconomic Model

Note: These methods are currently under development.

Both the economic and conservation outcomes of implementing an MPA network will depend on how areas outside of the MPAs are fished. The UCSB and UCD models therefore predict not only how MPAs will change fish populations but also how fishing effort will be distributed throughout the region. Because of the broad spatial scale and the large number of fishers involved, the models do

not seek to predict decisions made by individual fishers but instead to predict the aggregate distribution of fishing effort for each species.

The description of the spatial distribution of fishing effort in the bioeconomic models can take on several forms, of increasing complexity. The simplest description is a uniform distribution of fishing effort (except in MPAs, where effort is restricted or prohibited). A somewhat more realistic description is to allow fishing effort to be redistributed across space as a function of profit. This approach is based on the expectation that effort on each species will be distributed across patches so that marginal yield from fishing the species is the same in all fished patches. If this was not the case, and one patch had higher marginal profits than another, fishers would be expected to reduce effort in the less profitable patch and allocate more effort to the more profitable patch. To calculate the level of fishing effort that equalizes marginal profits in each patch, the models need to know how yield in each patch varies as a function of fishing effort.

A3. Summary of Life History Parameters Used in Models

Life-history parameters for each modeled species are obtained by searching the published scientific literature, stock assessments, and the 2000 Pacific States Marine Fisheries Commission report prepared by G. Cailliet et al. These parameters will be vetted by the SAT modeling work group and a panel of experts on northern California fish and kelp forest ecosystems, including other SAT members.

Parameters Used

Movement: Because management with MPAs involves creating differences in conditions (i.e., fishing mortality rate) over space, the effects of individual movement have a critical effect on sustainability and yield. Two kinds of biological movement are important, dispersal during the larval stage and swimming movement during juvenile and adult stages.

Juvenile/Adult Swimming: Most of the species that will be protected and sustained by MPAs either have limited adult movement or move within a specified home range. For some of these species, the sizes of the home ranges have been estimated using acoustic tags. This type of movement can be considered well known for species that have been studied in this way. In general, home range size is reported in terms of diameter, which facilitates implementation in a one-dimensional model. There is greater confidence in estimates derived from acoustic tagging studies than from simple tag-recapture studies.

Larval Dispersal: The models use estimates of larval dispersal derived from the ROMS-based Lagrangian particle-tracking model developed by C. Edwards and P. Drake at the University of California, Santa Cruz (UCSC). In this approach, each species is characterized by pelagic larval duration (PLD) and spawning season.

Life History: Both reproduction and yield depend on the sizes of individuals, which depends on how fast they grow through life. Here, the relationship of body size versus age is presented in terms of the dependence of length on age in the most commonly used form, a von Bertalanffy growth function. The parameter L_∞ represents the mean length for very old individuals, the parameter k represents the growth rate at young ages, and the parameter t_0 essentially describes the length of an individual at age 0. The relationship of body size versus age also is presented in terms of weight, which is calculated from size via an allometric relationship, $W = aL^b$. The values of a and b are given for each species.

Reproduction depends on the age of maturity and fecundity. Fecundity, *f*, the number of eggs produced by a female of a certain age or size in a year, is commonly assumed to be proportional to weight, but is sometimes also calculated from an allometric (or other) relationship with length.

Mortality consists of two components, fishing mortality and natural mortality. Here we present instantaneous natural mortality rates.

The size ranges that are available to be caught by the fishery are either specified by regulation or estimated from fishery or other data.

Compensation Ratio / Critical Replacement Threshold: Species persistence, and thus all model results, depends heavily on the shape of the settler-recruit relationship. This relationship describes the per-capita mortality of settlers as a function of settler density; settlers surviving this initial bout of post-settlement mortality are considered 'recruits' into the benthic population. This curve is generally described in terms of the slope at the origin; it is assumed that the curve has a Beverton-Holt functional form and that the asymptotic maximum density can be made non-dimensional by scaling all model results to the baseline unfished case.

The settler-recruit curve is analogous to the stock-recruit curves utilized in non-spatial fishery models. The slope at the origin of the stock-recruit curve can be described as a non-dimensional compensation ratio, which is the ratio of per-capita settler survival at very low densities (settlers = 0) to per-capita survival of settlers at the highest possible density in the unfished state. The inverse of this number (1/CR) also is referred to as the critical replacement threshold (CRT) because it is the fraction of lifetime egg production (FLEP) below which the population is not persistent. That is, if CR = 5, CRT = 1/5 = 0.2, and if fishing reduces lifetime egg production below 20% of its unfished maximum, the population will collapse. Estimates of the CR generally are difficult to obtain except for species that have been fished below the CRT and therefore collapsed. As a consequence the CR is known for only a few fished species. Dorn (2002) estimated a CR of approximately 3 for several collapsed species of north Pacific rockfishes. This CR is likely to be a conservative estimate, especially since some species are likely to be somewhat more resilient than those rockfish species. Therefore, both models use a reasonable but nonetheless conservative estimate of CR = 4 (CRT = 0.25) for the settler-recruit curves for each species.

Although the choice of CR will affect the model results, by far the largest effect will be on the sensitivity of the population to fishing. This effect on sensitivity to fishing largely should be accounted for by the methods used to choose fishing effort outside of reserves. Because fishing effort in each of the future fishing scenarios is chosen as some constant fraction of CRT (or MSY, in the case of the UCSB model), the potential for the choice of CR to affect model outcomes should be much reduced.

Species Notes

The effects of alternative MPA proposals will be evaluated for a suite of seven species in the north coast study region: black rockfish, brown rockfish, cabezon, redtail surfperch, red abalone, red sea urchin, and Dungeness crab. The text and tables that follow provide the life history parameters used for each model species and the literature source for that parameter. Unless otherwise noted, all distances are in kilometers, all organism body lengths are in centimeters, and all masses are in kilograms. A literature search for parameter estimates is currently underway for redtail surfperch. Dungeness crab is not well represented in the model because fishing targets only the males and the model does not explicitly track the sexes separately. We will produce a limited number of modeling results for Dungeness crab, modeling only the males and assuming that fishing cannot reduce larval production.

Table A3-1. Black rockfish (*Sebastes melanops*)

Parameter	Value	Source
Pelagic larval duration	4-6 mo	Love et al. 2002, Laroche and Richardson 1980
Spawning season	Jan-May	Leet et al. 2001
Home range diameter	9-16 km	Mathews and Barker 1984, Culver et al. 1987, Starr and Green 2007
Length-at-age (cm TL) von Bertalanffy equation: $L(t) = L_\infty\left(1-\exp\left(-k\left(t-t_0\right)\right)\right)$		Bobko and Berkeley 2004
L_∞	44.2	
k	0.33	
t_0	0.075	
Weight-at-length (cm, kg) $W = \acute{a}L^{\hat{a}}$		Ralston and Dick 2003
$\acute{a}$	1.68×10^{-5}	
$\hat{a}$	3	
Maximum age	50 yr	Love et al. 2002
Age at maturity	7 yr	Bobko and Berkeley 2004
Natural mortality rate	0.14	Ralston and Dick 2003, Sampson 2007
Available to fishery	4 yr	CDFG Regulations

Table A3-2. Brown rockfish (*Sebastes auriculatus*)

Parameter	Value	Source
Pelagic larval duration	1-2 months	
Spawning season	Dec-Jun in NCSR	
Home range diameter	< 2 km	Lea et al 1999
Length-at-age (cm TL) von Bertalanffy equation: $L(t) = L_\infty\left(1 - \exp\left(-k(t - t_0)\right)\right)$		Love and Johnson 1998
L_∞	51.4	
k	0.16	
t_0	-0.55	
Weight-at-length (cm, kg) $W = áL^{â}$		Love and Johnson 1998
$á$	4.4×10^{-5}	
$â$	2.74	
Maximum age	20	Stein and Hassler 1989
Age at maturity	4	Love and Johnson 1998
Natural mortality rate	0.112	Gowan 1983
Available to fishery	?	

Table A3-3. Cabezon (*Scorpaenichthys marmoratus*)

Parameter	Value	Source
Pelagic larval duration	3-4 mo	Cope and Punt 2005
Spawning season	Nov-Mar	Leet et al. 2001
Home range diameter	60 m	C. Merelis et al., unpublished data
Length-at-age (cm TL) von Bertalanffy equation: $L(t) = L_\infty\left(1 - \exp\left(-k\left(t - t_0\right)\right)\right)$		Cope and Punt 2005
L_∞	62.12	
K	0.18	
t_0	-1.06	
Weight-at-length (cm, kg) $W = áL^{â}$		Cope and Punt 2005
A	9.2×10^{-6}	
A	3.187	
Maximum age	13 yr	Cope and Punt 2005, Love 1996
Age at maturity	3 yr	Cope and Punt 2005
Natural mortality rate	0.25	Cope and Punt 2005
Available to fishery	4 yr	CDFG Regulations

Table B3-4. Retail Surfperch (*Amphistichus rhodoterus*)

Parameter	Value	Source
Pelagic larval duration	0 months	Bennett and Wydoski 1977.
Spawning season	September to December in NSCR	Bennett and Wydoski 1977.
Home range diameter		E. Saarman and Oregon DFW, unpublished data
Length-at-age (cm TL)		
von Bertalanffy equation:	2.57 km	
$L(t) = L_\infty\left(1 - \exp\left(-k(t - t_0)\right)\right)$		Calculated from data in Bennett and Wydoski 1977. Consistent with love 1996
L_∞	47.3	
k	0.1375	
t_0	-1.186	
Weight-at-length (cm, kg)		
$W = á L^{â}$		Bennett and Wydoski 1977
á	1.2023*10^-6	
â	3.12	
Maximum age	9	Bennett and Wydoski 1977, Baltz 1984
Age at maturity	3	Love 1996
Natural mortality rate	0.46	Calculated from data in Bennett and Wydoski 1977.
Available to fishery	4	CDFG regulations

Table A3-4. Red abalone (*Haliotis rufescens*)

Parameter	Value	Source
Pelagic larval duration	4-7 d	Prince et al. 1987
Spawning season	Apr-July	Leet et al. 2001
Home range diameter	100 m	Ault and Demartinit 1987
Length-at-age (cm TL) von Bertalanffy equation: $L(t) = L_\infty\left(1 - \exp\left(-k(t - t_0)\right)\right)$		Tegner et al. 1992
L_∞	19.24	
k	0.217	
t_0	0	
Weight-at-length (cm, kg) $W = á L^{â}$		Ault 1982
$á$	1.69×10^{-4}	
$â$	3.02	
Maximum age	30 yr	Leaf 2005
Age at maturity	3 yr	Rogers-Bennett et al. 2004
Natural mortality rate	0.15	Tegner et al. 1989
Available to fishery	8 yr	CDFG Regulations

Table A3-5. Red sea urchin (*Strongylocentrotus franciscanus*)

Parameter	Value	Source
Pelagic larval duration	7-19 wk	Leet et al. 2001
Spawning season	Dec-Mar	Rogers-Bennett et al. 1995
Home range diameter	10 m	Rogers-Bennett et al. 1995
Length-at-age (cm TL) von Bertalanffy equation: $L(t) = L_\infty\left(1 - \exp\left(-k\left(t - t_0\right)\right)\right)$		Morgan 1997, Morgan et al. 2000
L_∞	11.8	
k	0.22	
t_0	0	
Weight-at-length (cm, kg) $W = \acute{a}L^{\hat{a}}$		
$\acute{a}$	1	
$\hat{a}$	3	
Maximum age	30 yr	Morgan 1997, Morgan et al. 2000
Age at maturity	3 yr	Morgan 1997, Morgan et al. 2000
Natural mortality rate	0.08	Morgan 1997, Morgan et al. 2000
Available to fishery	5 yr	CDFG Regulations

Table A3-6. Dungeness crab (*Cancer magister*)

Parameter	Value	Source
Pelagic larval duration	3-4 mo	Leet et al. 2001
Spawning season	Nov-Feb	Leet et al. 2001
Home range diameter	5-10 km	
Length-at-age (cm TL) von Bertalanffy equation: $L(t) = L_\infty\left(1 - \exp\left(-k(t - t_0)\right)\right)$		L. Botsford, unpublished data
L_∞	24	
k	0.345	
t_0	0.068	
Weight-at-length (cm, kg) $W = á L^{\hat{a}}$		
$á$	3.165×10^{-4}	
$\hat{a}$	2.76	
Maximum age	7 yr	
Age at maturity	4 yr	
Natural mortality rate	0.2	
Available to fishery	4 yr (males only)	CDFG Regulations

A4. Examples of Bioeconomic Model Output to Be Used as Feedback on Individual MPA Performance (examples taken from the MLPA North Coast Study Region)

The following figures are examples of model outputs that will be provided as part of the evaluation of alternative MPA proposals from the MLPA North Coast Study Region. These example results were

produced by the UCSB model based on the Round 2 draft MPA proposals for the North Coast Study Region. Proposals are the existing MPAs (P0), Ruby 1 (RU1), Ruby 2 (RU2), Sapphire 1 (SA1) and Sapphire 2 (SA2).

Figure A4-1. Conservation value

Total biomass as a fraction of unfished biomass for the North Coast Study Region under three scenarios of future fishery management: Unsuccessful, Maximum Sustainable Yield (MSY) type and conservative management. The model assumptions were that all consumptive uses were prohibited until specifically identified by species and gear type.

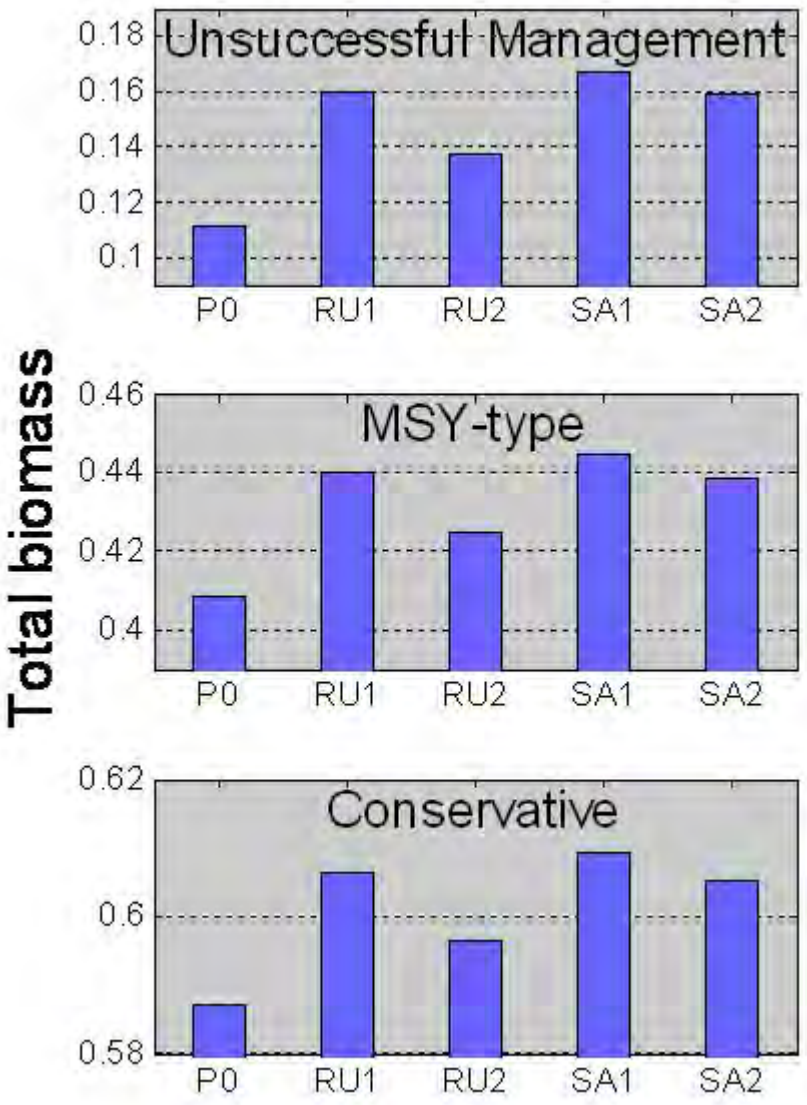

Figure A4-2. Economic value

Total yield with MPAs as a fraction of maximum sustainable profit without MPAs for the north coast study region under three scenarios of future fishery management: Unsuccessful, Maximum Sustainable Yield (MSY) type and conservative management. The model assumptions were that all consumptive uses were prohibited until specifically identified by species and gear type.

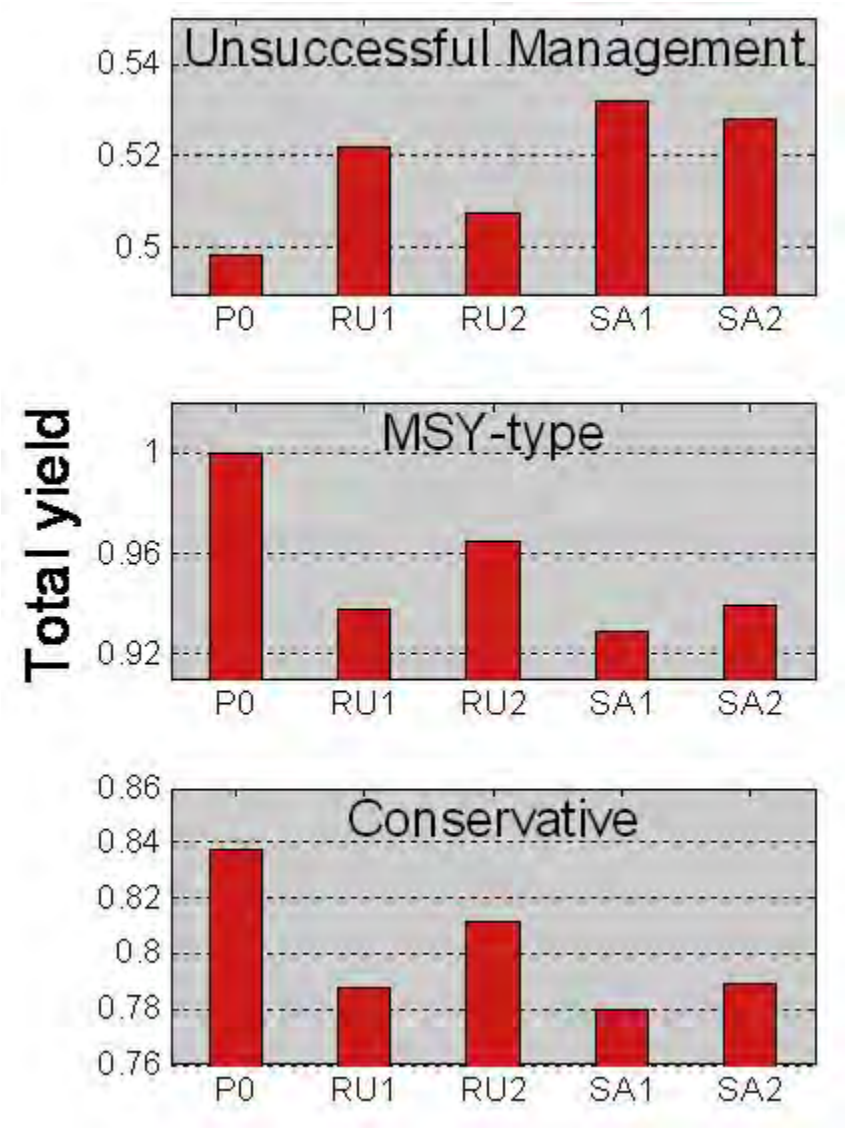

Figure A4-3. Change in larval production and larval supply for an MPA proposal

Left panel: Percent change in the production of successfully dispersing brown rockfish larvae, relative to Proposal 0 (both under unsuccessful fishery management scenario). Right panel: Percent change in larval settlement, relative to Proposal 0. The successful larval settlers depicted in the right panel were produced at the locations depicted in the left panel.

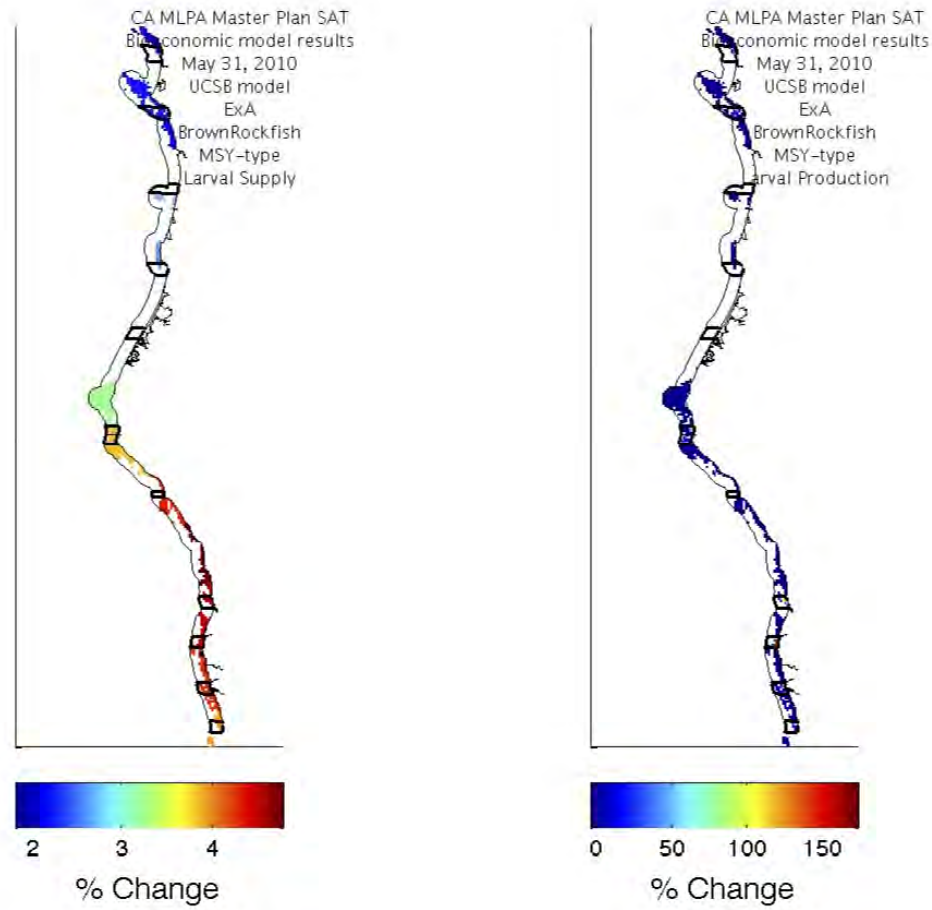

Table A4-1. Total Biomass and Total Fishery Yield for each Model Species.

Total biomass and fishery yield predicted for each of seven species for evaluations of round 2 Ruby draft marine protected area (MPA) proposal 1 (RU1) were estimated using UCSB bioeconomic model. A complete table of all proposed MPAs for all Round 2 draft MPA proposals is posted to the MLPA North Coast Study Region website. The total biomass of each species is estimated at equilibrium for each square kilometer of the study region. Values are scaled relative to total unfished biomass such that values of 0 indicate no biomass and values of 1 indicate maximum unfished biomass. Total fishery yield is the total harvest of each species relative to maximum sustainable yield (MSY) of the species with the existing MPAs (proposal 0). For round 2 evaluations, seven species were modeled: Black rockfish, brown rockfish, cabezon, redtail surfperch, Dungeness crab, red abalone and red sea urchin. Model results were calculated for 3 different fishery management scenarios; the results in this table are from the MSY-type management scenario. Total biomass and yield are the average across the six core model species, excluding Dungeness crab.

Round 2 Draft MPA Proposal	Species	Total Biomass	Total Fishery Yield
RU1	Black Rockfish	0.48	0.97
RU1	Brown Rockfish	0.45	0.92
RU1	Cabezon	0.41	0.95
RU1	Red Abalone	0.42	0.98
RU1	Red Sea Urchin	0.43	0.93
RU1	Redtail Surfperch	0.46	0.87
RU1	Dungeness Crab	0.3	0.96

Table A4-2: Biomass and self-recruitment

Example of model outputs for biomass and self-recruitment for a single proposed marine protected area (MPA) in the round 2 Ruby draft MPA proposal 1 (RU1) for the north coast study region (NCSR) were estimated from the University of California, Santa Barbara (UCSB) bioeconomic model. A complete table of all proposed MPAs for all Round 2 draft MPA proposals is posted to the MLPA North Coast Study Region website. Values reported in this table were calculated under the maximum sustainable yield (MSY)-type management scenario. Values of biomass are scaled relative to total unfished biomass such that values of 0 indicate no biomass and values of 1 indicate maximum unfished biomass. Self-recruitment is the proportion of settling larvae in an MPA that were produced within that MPA. This metric provides information on the relative isolation of the MPA from other larval sources. Values of self-recruitment are between 0 and 1, where a value of 0 indicates that a population is totally isolated. For round 2 evaluations, seven species were modeled: Black rockfish, brown rockfish, cabezon, redtail surfperch, Dungeness crab, red abalone, and red sea urchin. Due to the unique characteristics of the Dungeness crab fishery, this species is not included below.

Round 2 Draft MPA Proposal	MPA Name	Species	Biomass	Self-recruitment
RU1	Petrolia Lighthouse SMR	Black Rockfish	0.0266	0.0236
RU1	Petrolia Lighthouse SMR	Brown Rockfish	0.0377	0.0384
RU1	Petrolia Lighthouse SMR	Cabezon	0.0161	0.0173
RU1	Petrolia Lighthouse SMR	Red Abalone	0.0145	0.1034
RU1	Petrolia Lighthouse SMR	Red Sea Urchin	0.0338	0.0216
RU1	Petrolia Lighthouse SMR	Redtail Surfperch	0.0143	1
RU1	Ten Mile SMCA	Black Rockfish	0.0044	0.0039
RU1	Ten Mile SMCA	Brown Rockfish	0.0071	0.0094
RU1	Ten Mile SMCA	Cabezon	0.0127	0.0109
RU1	Ten Mile SMCA	Red Abalone	0.0155	0.0707
RU1	Ten Mile SMCA	Red Sea Urchin	0.0067	0.0048
RU1	Ten Mile SMCA	Redtail Surfperch	0.0111	1

Table A4-3. Deletion analysis for external proposed MPA arrays

This table shows the biomass increase and biomass increase per area for each MPA proposed in the round 2 Ruby draft marine protected area (MPA) proposal 1 for the Marine Life Protection Act (MLPA) Initiative north coast study region (NCSR). A complete table of all proposed MPAs for all four Round 2 draft MPA proposals is posted to the MLPA North Coast Study Region website. Results are derived from the UC Santa Barbara (UCSB) bioeconomic model. To explore a range of assumptions, the UCSB model runs this analysis assuming maximum-sustainable yield (MSY)-type management outside of the MPAs, and again assuming unsuccessful management outside of the MPAs. The ***biomass increase*** is the contribution of an individual proposed MPA to the overall biomass in the external MPA array, expressed as a percentage of the equilibrium biomass with the full proposed MPA array. A biomass increase of 1 indicates that the MPA is contributing 1% to the overall biomass in the study region (for example, allowing fishing within that MPA would reduce biomass by 1%). ***Biomass increase per area*** is the contribution of an individual proposed MPA to the overall biomass in the external MPA array, accounting for the area of the MPA. This is calculated as the percent increase in biomass per square kilometer of habitat protected. For both metrics, negative numbers indicate that the MPA is reducing equilibrium biomass. Negative numbers are rare but can occur when opening an MPA draws fishing effort away from other, more productive, locations. For deletion analysis for revised round 1 evaluations, the Master Plan Science Advisory Team (SAT) modeled populations of six species: Black rockfish, brown rockfish, cabezon, redtail surfperch, red abalone, and red sea urchin. Biomass increase and biomass increase per area are averaged across these species.

Round 2 Draft MPA Proposal	MPA Name	Biomass increase MSY scenario	Biomass increase per area MSY scenario	Biomass increase management fails scenario	Biomass increase per area management fails scenario
RU1	False Klamath Cove SMCA	0.9506	0.2777	5.0085	1.4629
RU1	Mattole Canyon SMR	0.6432	0.4615	3.7591	2.6974
RU1	Petrolia Lighthouse SMR	2.3848	0.3361	11.0432	1.5566
RU1	Point Cabrillo SMCA	0.387	0.6845	1.1079	1.9595
RU1	Point St. George Reef SMCA	0.3238	0.2881	1.0493	0.9335
RU1	Pyramid Point SMCA	-0.0002	-0.0052	0.081	1.9285
RU1	Pyramid Point SMR	0.7812	0.1524	3.4326	0.6696
RU1	Reading Rock Nearshore SMCA	0.02	0.0827	0.1412	0.5852
RU1	Reading Rock Offshore SMCA	0.9357	0.2003	4.8741	1.0435
RU1	Samoa SMCA	0.2626	0.1076	1.3555	0.5553
RU1	South Cape Mendocino SMR	0.6857	0.1367	3.157	0.6296
RU1	Ten Mile SMCA	0.9764	0.5232	3.6122	1.9355
RU1	Ten Mile SMR	1.121	0.5237	3.8509	1.799
RU1	Vizcaino SMCA	2.1075	0.46	9.3754	2.0465

Appendix B. Impact Assessment Methods

In order to estimate the socioeconomic impact to the commercial fishery sector associated with each of the MPA proposals, staff from Ecotrust, contractor to the MLPA Initiative, will estimate the maximum potential impact for each of the MPA proposals using methods developed in the Central Coast process (Wilen and Abbott 2006) and refined in the North Central Coast and South Coast processes (Scholz et al. 2008; 2010). The analysis assumes that each of the MPA proposals completely eliminates fishing opportunities in areas closed to specific fisheries and that fishermen are unable to adjust or mitigate in any way (Wilen and Abbott 2006). The results can be considered by each group (i.e., stakeholders, SAT, BRTF, Initiative staff, FGC) as trade-offs for protections relative to socioeconomic impacts and can be weighed in siting and evaluating the various MPA proposals. The remainder of this paper describes the steps needed to complete the maximum potential impact analysis in the North Coast Study Region.

1: Generate Baseline Estimates of Gross Economic Revenue

The first step involves calculating a baseline estimate 1) from which to derive estimates of the socioeconomic impact associated with changes in commercial fisheries that might be induced by each MPA alternative and 2) against which to compare those estimates. The baseline estimate is generated using gross fishing revenues from California Department of Fish and Game landing receipts reported for ports in the North Coast Study Region. A nine-year average (2000–08) derived from the regional landing receipts and converted into current dollar values (i.e., $2008) is used.

The first step involves calculating a baseline estimate 1) from which to derive estimates of the socioeconomic impact associated with changes in commercial fisheries that might be induced by each MPA alternative and 2) against which to compare those estimates. The baseline estimate is generated using gross fishing revenues from California Department of Fish and Game landing receipts reported for ports in the North Coast Study Region. A nine-year average (2000–08) derived from the regional landing receipts and converted into current dollar values (i.e., $2008) is used.

More specifically, to generate baseline estimates of gross economic revenue (GER), for any fishery, *f*, $BGER_f$ is the average ex-vessel value of the fishery in 2008 dollars, where

$BGER_f = \sum_{p \in P} BGER(f, p)$, the sum of the baseline estimates of GER for this fishery over all ports.

Staff also define the fisheries specific to each port, or in other words, create a baseline estimate of gross economic revenue for each port. For a specific port, *p*, being considered in the North Coast Study Region, the baseline estimate ($BGER_p$) can be calculated as the sum of the baseline estimates of GER for this port over all fisheries:

$$BGER_p = \sum_{f \in F} BGER(f, p).$$

The baseline gross economic revenue ($BGER_{TOT}$) for <u>all</u> commercial fisheries ($f \in F$) being considered in the North Coast Study Region is therefore:

$BGER_{TOT} = \sum_{f \in F} BGER_f = \sum_{f \in F} \sum_{p \in P} BGER(f, p)$ or equivalently,

$$BGER_{TOT} = \sum_{p \in P} BGER_p = \sum_{p \in P} \sum_{f \in F} BGER(f, p).$$

2: Generate Gross Economic Revenue for the Various MPA Alternatives

The next step involves using results from the Ecotrust mapping exercise, specifically stated importance indices for the fishing grounds, to estimate the socioeconomic impact associated with changes in the commercial fisheries that might be induced by each MPA alternative. For a description of the methods used to create stated importance indices, please see Scholz et al. (2006).

For any fishery, *f*, port, *p*, and any MPA alternative, *a*:

$$GER(f, p, a) = BGER(f, p) - GEI(f, p, a)$$

where $GEI(f, p, a)$ is the estimated gross economic impact on fishery, *f*, at any port, *p*, under any alternative, *a*.

Therefore,

$$GER_f(a) = \sum_{p \in P} GER(f, p, a) \text{ and } GER_p(a) = \sum_{f \in F} GER(f, p, a)$$

as well as

$$GEI_f(a) = \sum_{p \in P} GEI(f, p, a) \text{ and } GEI_p(a) = \sum_{f \in F} GEI(f, p, a).$$

Gross economic revenue under any alternative, *a*, ($GER_{TOT}(a)$), for <u>all</u> commercial fisheries ($f \in F$) being considered in the North Coast Study Region can be calculated as:

$$GER_{TOT}(a) = \sum_{f \in F} GER_f(a) = \sum_{p \in P} GER_p(a) = \sum_{f \in F} \sum_{p \in P} GER(f, p, a) = \sum_{p \in P} \sum_{f \in F} GER(f, p, a)$$

From this it can be said that, for any MPA alternative, *a*,

$$GEI_{TOT}(a) = BGER_{TOT} - GER_{TOT}(a)$$

where GEI_{TOT_a} is defined as the total gross economic impact on all commercial fisheries under any alternative, *a*. Therefore,

$$GEI_{TOT}(a) = \sum_{f \in F} GEI_f(a) = \sum_{p \in P} GEI_p(a) = \sum_{f \in F} \sum_{p \in P} GEI(f, p, a) = \sum_{p \in P} \sum_{f \in F} GEI(f, p, a).$$

3: Generate Baseline Estimates of Net Economic Revenue

In order to compute net economic benefits, staff 1) estimate the share of gross fishing revenues represented by costs and 2) scale the baseline estimate (i.e. gross fishing revenues) calculated in Step 1 using the estimated cost shares. In the Central Coast process, an estimate of 65% was used across all fisheries (Wilen and Abbott 2006). For the North Coast process, several cost related questions are asked during interviews with fishermen in an effort to improve on this estimate as well

as allow for the ability to account for cost variability among different fisheries. After all interviews are completed, the cost data are broken out by fishery or fisheries. For example, cost data for a fisherman who fished both salmon and crab would be aggregated with only other interviewees participating in both those fisheries. A mean cost estimate will then be calculated for each category.

Costs will be broken into two categories: fixed costs and variable costs. Fixed costs include costs that are independent of the number of trips a vessel makes or the duration of these trips. For example, vessel repairs and maintenance, insurance, and mooring and dockage fees are typically considered fixed costs. On the other hand, variable costs include costs that are dependent on the number of trips a vessel makes or the duration of these trips. Variable costs typically include fuel, maintenance, crew share, and gear repair/replacement. For the purpose of this study, crew wages and fuel costs will be considered variable costs. All other costs will be considered fixed costs.

For any fishery, *f*, net economic revenue is calculated as:

$$BNER_f = BGER_f - C_{X_f} - C_{V_f}$$

where C_{X_f} is the fixed cost associated with any fishery, *f*, and is set as a fixed dollar value, and C_{V_f} is the variable cost associated with any fishery , *f*, and is a fixed percentage of $BGER_f$.

Baseline net economic revenue ($BNER$) for <u>all</u> commercial fisheries ($f \in F$) being considered in the North Coast Study Region can be calculated as:

$$BNER_{TOT} = \sum_{f \in F} BNER_f$$

4: Generate Estimates of Net Economic Revenue for the Various MPA Alternatives

In order to compute net economic revenue for each of the various MPA alternatives, staff (1) estimate the share of gross fishing revenues represented by costs under each MPA alternative, and (2) scale the estimated gross fishing revenues for that alternative accordingly. Costs are calculated using the methods described in Step 3.

For any fishery, *f*, and any MPA proposal, *a*,

$$NER_f(a) = GER_f(a) - C_{X_f} - C_{V_f} \quad .$$

For any MPA alternative, *a*, net economic revenue for <u>all</u> commercial fisheries ($NER_{TOT}(a)$) can be calculated as:

$$NER_{TOT}(a) = \sum_{f \in F} NER_f(a)$$

5: Generate Estimate of the Potential Primary Net Economic Impact for the Various MPA Alternatives

Using the results from the previous steps, the potential primary net economic impact (NEI) of a particular MPA alternative, *a,* on a particular fishery, *f,* can then be calculated as:

$$NEI_f(a) = BNER_f - NER_f(a).$$

The potential primary NEI of any MPA alternative, *a,* on all commercial fisheries ($f \in F$) can then be calculated as:

$$NEI_{TOT}(a) = BNER_{TOT} - NER_{TOT}(a).$$

6: Generate Estimate of the Potential Primary Gross Economic Impact for the Various MPA Alternatives

Using the results from steps 1–5, the potential primary gross economic impact (GEI) of a particular MPA alternative, *a,* on a particular fishery, *f,* can then be calculated as:

$$GEI_f(a) = BGER_f - GER_f(a).$$

The potential primary GEI of any MPA alternative, *a,* on all commercial fisheries ($f \in F$) can then be calculated as:

$$GEI_{TOT}(a) = BGER_{TOT} - GER_{TOT}(a).$$

Example of Estimate Costs

For fishery *f*, assume the following proportion of gross economic revenue goes to the following costs:

20% = fixed costs

20% = crew wages

10% = fuel costs → 30% = variable costs

Assume that baseline gross economic revenue equals $10,000. Under the baseline, fixed costs equal $2,000 and variable costs equal $3,000, resulting in total costs of $5,000. Assume that under MPA alternative *a,* gross economic revenue now equals $5,000. Under this alternative, fixed costs will still equal $2,000; however, variable costs will be recalculated as:

$5,000 * 0.3 = $1,500

This results in total costs of $3,500 under MPA alternative *a.*

Works Cited in Appendix B

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