California MLPA Master Plan Science Advisory Team

**Methods Used to Evaluate Draft MPA Proposals in the
North Coast Study Region (DRAFT)
Chapters 6 and 7: Size and Spacing**
January 18, 2010

6. Size (Goals 2 and 6)

Status of this chapter: Pending approval by the SAT.

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[1]. 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

---

[1] Jan Freiwald, unpublished dissertation.

California MLPA Master Plan Science Advisory Team
Methods Used to Evaluate Draft MPA Proposals in the North Coast Study Region (DRAFT)
Chapters 6 and 7: Size and Spacing
January 18, 2010

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 perch, pricklebacks	walleye perch*	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

California MLPA Master Plan Science Advisory Team
Methods Used to Evaluate Draft MPA Proposals in the North Coast Study Region (DRAFT)
Chapters 6 and 7: Size and Spacing
January 18, 2010

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.

California MLPA Master Plan Science Advisory Team
Methods Used to Evaluate Draft MPA Proposals in the North Coast Study Region (DRAFT)
Chapters 6 and 7: Size and Spacing
January 18, 2010

7. Spacing (Goals 2 and 6)

Status of this chapter: Pending approval by the SAT.

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 study region was evaluated using known life history characteristics of fish and invertebrate larvae in conjunction with models of potential movement. The model used to predict connectivity is based on realistic Regional Ocean Modeling System (ROMS) simulations[2]. The model assumes larvae and young behave as Lagrangian particles transported through ocean circulation. The ROMS simulations of ocean circulation are driven by realistic winds and currents at lateral open boundaries (Conil & Hall 2006) (Dong & McWilliams 2007). The lateral-boundary conditions are derived from Simple Ocean Data Assimilation (SODA) (Carlton & Cao 2000) (Carlton et al 2000), while the wind field is calculated from the Fifth-Generation Pennsylvania State University-National Center for Atmospheric Research Mesoscale Model (MM5) (Hughes et al 2008). The circulation model for the north coast study region is based on data gathered during the period of XXXX-XXXX.

ROMS simulations were validated through a series of comparisons with other types of data (Dong et al. In review), including data from the National Data Buoy Center's Acoustic Doppler Current Profilers (ADCP), high frequency radar, California Cooperative Oceanic Fisheries Investigations (CalCOFI), and Advanced Very High Resolution Radiometer (AVHRR). The mean ocean circulation and variations based on ROMS simulations show high levels of agreement with other types of observations. 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.

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. Modelers explored the full range of potential movement based on release of particles every one kilometer throughout the study region and every six hours for a period of XXXX-XXXX. Particles were passively transported by the simulated currents, and

---

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

California MLPA Master Plan Science Advisory Team
Methods Used to Evaluate Draft MPA Proposals in the North Coast Study Region (DRAFT)
Chapters 6 and 7: Size and Spacing
January 18, 2010

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.

Table 7-1: Life History Characteristics of Representative Fish and Invertebrates

Species	Common Name	Spawning Season	Larval Duration
	Black rockfish		
	Brown rockfish		
	Cabezon		
	Burrowing shrimp		
	Dungeness crab		
	Red abalone		
Strongylocentrotus *franciscanus*	Red sea urchin	Dec-Feb	40-60 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 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.

California MLPA Master Plan Science Advisory Team
Methods Used to Evaluate Draft MPA Proposals in the North Coast Study Region (DRAFT)
Chapters 6 and 7: Size and Spacing
January 18, 2010

This guideline arises from a number of studies that examine the persistence of marine populations with a network of marine reserves[3,] 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[4] 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 (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.

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,

- 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.

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,

---

[3] Botsford et al 2001, Gaines et al 2003, Gaylord et al 2005

[4] Shanks et al 2003, Kinlan et al 2003, Kinlan et al 2005

California MLPA Master Plan Science Advisory Team
Methods Used to Evaluate Draft MPA Proposals in the North Coast Study Region (DRAFT)
Chapters 6 and 7: Size and Spacing
January 18, 2010

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 about 10 representative species, across space; and

- predict fish yield for the representative species, across space.

Additional detail about the modeling evaluation is provided in Chapter 8.

Chapter 7 References

Botsford, L.W., Hastings, A., and Gaines, S.D. 2001. Dependence of sustainability on the configuration of marine reserves and larval dispersal distance. *Ecology Letters* 4: 144-150.

California. Journal of Climate 19: 4308–4325

Carlton, J., G. Chepurin and X. Cao. 2000. A Simple Ocean Data Assimilation Analysis of the Global Upper Ocean 1950–95. Part II: Results. *Journal of Physical Oceanography* 30(2): 311–326.

Carlton, J., G. Chepurin, X. Cao and B. Giese. 2000. A Simple Ocean Data Assimilation Analysis of the Global Upper Ocean 1950–95. Part I: Methodology. *Journal of Physical Oceanography* 30(2): 294–309.

Conil S., and A. Hall. 2006. Local Modes of Atmospheric Variability: A case study of Southern California. *Journal of Climate* 19: 4308–4325

Cowen, R. K., C. B. Paris, A. Srinivasan. 2006 Scaling of connectivity in marine populations. *Science*. 311:522-527.

Dever, E., M. Hendershott, and C. Winant. Statistical aspects of surface drifter observations of circulation in the Santa Barbara Channel. *Journal of Geophysical Research-Oceans*, 103(C11):24781–24797, OCT 15 1998.

Dong, C., and J. McWilliams. 2007. *Vorticity Generation and Evolution in the Shallow-Water Island Wake.*

Dong, C., E. Icida and J. McWilliams. Circulation and Multiple-Scale Variability in the Southern California Bight. *Progress in Oceanography*. In review.

Gaines, S. D., B. Gaylord, and J. Largier. 2003. Avoiding current oversights in marine reserve design. *Ecological Applications*. 13:S32-46

Gaylord, B., S. D. Gaines, D. A. Siegel, M. H. Carr. 2005. Consequences of population structure and life history for fisheries yields using marine reserves. *Ecological Applications*. 15:2180-2191.

California MLPA Master Plan Science Advisory Team
Methods Used to Evaluate Draft MPA Proposals in the North Coast Study Region (DRAFT)
Chapters 6 and 7: Size and Spacing
January 18, 2010

Hughes M., A. Hall, R.G. Fovell. 2008. Blocking in areas of complex topography, and its influence on rainfall distribution. *Journal of Atmospheric Science*. Accepted.

Kinlan, B., and S. D. Gaines. 2003. Propagule dispersal in marine and terrestrial environments: a community perspective. *Ecology*. 84:2007-2020.

Kinlan, B., S. D. Gaines, and S. Lester. 2005. Propagule dispersal and the scales of marine community process. *Diversity and Distributions*. 11:139-148.2005.

Shanks, A.L., Grantham, B.A. & Carr, M.H. 2003. Propagule dispersal distance and the size and spacing of marine reserves. *Ecological Applications*, 13, S159–S169.

Siegel, D., B. P. Kinlan, B. Gaylord and S. D. Gaines. 2003. Lagrangian descriptions of marine larval dispersion. *Marine Ecology Progress Series*. 260:83-96.