Size and Spacing of Marine Reserves Workshop Report

Prepared by Selina Heppell and Jack Barth, Science and Technical Advisory Committee
and
Heather Reiff, Marine Resource Management Program, Oregon State University

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Acknowledgements

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Overview – why did we meet and what did we accomplish?

At the request of the Marine Reserves Working Group (MRWG), the Science and Technical Advisory Committee (STAC) of Oregon's Ocean Policy Advisory Council (OPAC) held a workshop on marine reserve size and spacing to address the need for guidelines that can be used in the site proposal process. Thirty-one scientists and advisors, along with 5 support staff, met at the Oregon Institute of Marine Biology (OIMB) in Charleston on April 10, and half the day on April 11. The workshop was open to the public, but public comment was not solicited due to time constraints. Meeting participants included marine biologists, oceanographers, fishermen with nearshore experience, and scientists who were directly involved with the development of marine reserve design recommendations in California (Appendix D).

This was a scientific meeting to discuss what we know about nearshore oceanography, habitats, and species. Due to our time constraints, the expertise of the attendees, and specific requests from OPAC's Marine Reserves Working Group, this workshop did not cover issues on specific sites for reserves, nor on ways to minimize social or economic impacts of reserves. Research needs to assess the economic or social impacts of reserves in state waters will be the subject of a future meeting or workshop.

The primary objective of our workshop was to produce a consensus document for OPAC that reviews existing science and provides recommendations for reserve size and spacing guidelines for Oregon. We accumulated a large amount of information at the workshop and in subsequent analyses, many of which are on-going. This document serves as our final meeting report to MRWG that reviews presentations made at the meeting, an overview of scientific issues discussed by the workshop participants, and addresses the specific questions asked in the request letter received April 5, 2008. We also provide tables of species by habitat type, available information on movement rates and depths, species-area curves, and habitat maps. Finally, we provide a list of short- and long-term research needs that may be used in planning discussions.

By the end of our 1.5 day meeting, we had accomplished the majority of our goals: connecting scientists and fishermen with a broad knowledge of the biological and physical characteristics of Oregon's nearshore zone, identifying the main scientific issues and concerns with marine reserve planning, reviewing the size and spacing guidelines used in California and their applicability to Oregon's nearshore, and developing a list of short- and long-term research needs for evaluation and monitoring of reserve sites. We agreed that a follow-up meeting to evaluate existing data would be valuable for recommending specific guidelines based on Oregon species and habitats, if time and resources permitted. Several meeting participants agreed to continue their involvement in the process as reviewers and/or future meeting participants.

Workshop discussion summary and recommendations

Responses to STAC request letter

The STAC was initially charged with addressing 4 questions (see Memo to STAC from Marine Reserves Working Group in the Appendix B):

The MRWG is requesting the STAC to recommend guidelines for the marine reserve nomination process based on available biological and ecological data at your next planned workshop. In recognition of the limited time available before the nomination process for marine reserves, the MRWG requests the STAC provide their best guidance on the following questions:

- *How do we identify "special places" in nearshore Oregon, such as biodiversity hotspots, unique habitat features etc. using available habitat maps and biological information.*

“Special places” in Oregon waters include areas with high biological diversity, rare or specific oceanographic characteristics, and rare or distinctive habitats. Because we have excellent descriptive data on the types of habitat and depths where species are found, we can confidently use each type of habitat to represent a list of species that are likely to be found there. Thus, as a “first cut” for evaluating the likely diversity of organisms found in a proposed reserve site, we can use the number and diversity of habitat types found in an area. Regions with high variability in habitat types and/or depths are more likely to exhibit characteristics of “special places” for diversity reasons. These regions can be determined from existing maps of bottom habitats and from future surveys. Rocky outcrops, headlands, submarine banks and canyons may influence biological diversity, coastal circulation and productivity, and serve as boundaries between biogeographic regions. Some of the physical features in state waters that may exhibit or influence biological diversity are Simpsons Reef and Cape Arago, the lee of Cape Lookout, the inshore side of the Heceta and Stonewall Banks complex, and inshore areas to the south of Cape Blanco including the reefs near Port Orford. A unique feature of the Oregon coast that is likely to affect the distribution of organisms is the long stretch of sandy bottom between Florence and Coos Bay (about 75 km, 40.5 nautical miles alongshore). Another region of sandy bottom, although much shorter, is between Seaside and the Columbia River (about 28 km, 15 nautical miles alongshore). Other natural features of special interest are regions where seasonal hypoxic bottom waters are found (over and inshore of Heceta Bank) (Grantham et al. 2004; Chan et al., 2008) and where Harmful Algal Blooms are generated or persist (Trainer et al., 2002). Lastly, proximity to state or federal protected areas on land makes adjacent ocean areas distinctive, as they may have reduced pollution or sedimentation compared to areas that are adjacent to highly populated ports, towns or agriculture.

- *What guidelines should we use for minimum size and spacing for reserves (i.e. networks or systems) to meet our stated goals and objectives, and what is the relationship between reserve properties (size, configuration, habitat-types, depths) and the likelihood of meeting those objectives?*

Each potential place for a marine reserve is unique and the size, shape and design should be tailored to each site. In this report, we provide information to allow managers and the public to consider the potential species or ecosystem benefits of a range of potential marine reserve sizes, and apply that knowledge in the context of the Oregon marine reserve goals, objectives, and mandates.

To the extent practicable, we recommend that proposed sites be placed or sized to maximize the habitat types and depth ranges available in the chosen area. This should maximize the diversity per area, provided that patches of habitat are large enough to provide space for the species that live in that habitat.

There was strong consensus by the meeting attendees on the need for multiple reserve sites distributed along the entire coast to assure replication for scientific evaluation and to have some insurance against natural or man-made catastrophes that might damage habitats in particular areas. There was somewhat less agreement (3 to 8 abstentions out of approximately 30 attendees) for recommending very specific size and spacing guidelines, with suggestions for more discussion to assure that those guidelines clearly match Oregon's specific reserve objectives, and analysis of existing data on our nearshore oceanography, habitats and species. Much of our existing knowledge is summarized in this report and ODFW's Nearshore Strategy, and could be refined with additional analyses by scientists and people with local knowledge of Oregon species and habitats.

Some of the criteria suggested here are consistent with and patterned after those developed during the California Marine Life Protection Act. The general consensus of the group was that, based on the California process, the guidelines for reserve size and spacing in California are not likely to change when the species list is refined to include only Oregon species (see section below on Application of California guidelines to Oregon's reserve planning process). We have compiled information on Oregon species and habitats to show the expected relationship between reserve size and potential benefits to species, as shown in Table 2 and Figures 32 and 33.

Size:

- For the objective of protecting the greatest diversity of species, marine reserves should include a range of habitat-types and depths.
- Based on a synthesis of data from marine protected areas worldwide, long-term studies of multiple reserves in temperate regions, and recent data from reserves in California, it is clear that the number of species that can achieve their natural densities and size structure increases with the size of a protected area. The species that benefit most are those that are fished heavily, top predators, and those with small home ranges.
- To maximize diversity, a reserve should be of sufficient size to contain at least 90% of species characteristic of the habitats therein. The area of habitat required to do that can be

determined from species-area curves developed for various west-coast ocean habitats, but analysis of existing Oregon nearshore data would be optimal.

– A minimum size guideline of 5-10km alongshore distance (2.7-5.4 nautical miles), based on analysis of species movement rates given in the California Marine Life Protection Act (MLPA), was agreed to by most workshop attendees, with a small number of abstentions.

Spacing:

– The unique geomorphology of the Oregon coast and alongshore differences in bottom habitat and water-column characteristics (currents, stratification, primary production) should be taken into account when deciding the spacing of marine reserves.
– For the objective “to protect key types of marine habitats in multiple locations along the coast to enhance resilience of nearshore ecosystems to natural and human-caused effects,” marine reserves should be distributed along the full Oregon coast and in each biogeographical region.
– Larvae released from a reserve will be dispersed up and down the coast, depending on season and distance from shore. Larvae with short planktonic larval durations (PLD), up to about one week, will tend to reseed reserves of 5-10 km (2.7-5.4 nautical miles) in size, while larvae with longer pelagic larval durations, for example around 30 days, will seed greater than or equal to 25 km (13.5 nautical miles) to either side of the reserve (Shanks et al., 2003). The spacing guideline used in the MLPA of 50-100km apart alongshore (27-54 nautical miles) was generally agreed to as a starting point, with the caveat that long stretches of sand habitat in the center of the coast would have to be considered.

Shape (configuration):
– The design and shape should take into account the adjacent habitat types and the cross-shelf extent of habitat types.
– Shape should maximize habitat complexity.
– For a homogeneous habitat, minimizing the perimeter-to-area ratio will maximize protection within a reserve, and minimize vulnerability to edge effects and spillover loss
– To enhance protection of species that move to greater depths as they grow, which includes approximately 2/3 of managed groundfish species that occur in state waters, habitat protection should extend from the intertidal zone to deep waters offshore (potentially extending beyond state boundaries). However, contiguous reserves may not be necessary where particular habitat-types are patchy, such as areas with rock habitat that does not extend into deep water.

- *What research data are available and what is known and not known with respect to physical, biological and ecological information that contributes to these recommendations?*

There is a substantial amount of scientific information published on the biological responses observed in marine reserves, larval transport, and theoretical models of marine reserve design and potential effects (Appendix A). There is also a fair amount of literature on nearshore species that occur in Oregon and their habitats, although gaps exist in our knowledge of movement patterns for many fish species and abundance patterns of many invertebrates. Likewise, there are papers on species interactions and the response of fish and invertebrates to changes in physical ocean conditions. Time constraints prevent us from providing a thorough review and analysis of all available biological information that is applicable to guidelines on reserve size and spacing; thus, many of the "recommendations" are quite general and based on conclusions drawn in similar nearshore systems. Finally, because there are no true "no-take" reserves in Oregon, there are no area-specific data to help predict the precise responses in populations, habitats or biological communities that may occur in future Oregon reserves. There is also little information on the effects of fishing in Oregon's nearshore, so the "treatment effect" that may occur with reserve designation is likely to be variable, even if areas are well-enforced.

- *Can you provide us with other supporting information which the STAC considers relevant for the placement of marine reserves, development of coastwide reserve planning guidelines, or evaluation of publicly nominated sites?*

  - We reiterate that the biogeographical region represented by the Oregon territorial sea south of Cape Blanco extends into northern California.
  - Marine reserves in state waters would benefit from being linked to protected areas in deeper federal waters immediately offshore.
  - To buffer against catastrophic loss of a marine reserve and to provide sufficient statistical power for analyzing their effects, the final reserve design for Oregon should include "replicates" of each habitat type within a biogeographical region (with the understanding that these are unlikely to be true "statistical replicates" due to variation in habitat and location). A goal suggested by workshop attendees was 3-5 occurrences of each habitat type within reserves in each biogeographical region, in patches large enough to include 90% or more of the expected species diversity for that habitat type.
  - To analyze the effects of marine reserves, each site should be paired with nearby reference sites with similar habitat content in unprotected regions.

Applicability of California guidelines to Oregon reserve planning

Extensive analyses of available data on fish, invertebrates, and habitats were conducted by the Science Advisory Team in California to identify scientifically defensible guidelines for the size and spacing of marine protected areas (MPAs) in the state waters of California's central coast. Because most of the species researched for those analyses also occur in Oregon state waters, and the habitat types are generally similar, we can learn much from the efforts of that group of scientists. It is important to note that the **recommendations for MPA design in California (Appendix D) are viewed as guidelines, not requirements**.

Because we were asked to advise on size and spacing guidelines for Oregon reserves in the absence of time and resources for a thorough evaluation of available local data, the workshop attendees discussed the applicability of the California guidelines at length. In all cases of a "vote," which serves as expert opinion of the attendees, the majority agreed that the recommendations from California were scientifically defensible when applied to Oregon. There was consensus on size recommendations (alongshore distance of 5-10km, or 2.7 - 5.4 nm and preferably 10-20km, or 5.4 – 10.8 nm), due to the overlap of CA and OR fish species (23 of 28 fish species studied, mostly hard-bottom species). There were more abstentions by participants voting on precise spacing recommendations based on larval transport, due to uncertainties in transport mechanisms (oceanography), habitat heterogeneity, and larval duration. However, the spacing guideline used in the MLPA of 50-100km apart alongshore (27-54 nautical miles) was generally agreed to as a starting point, with the caveat that long stretches of sand habitat in the center of the coast would have to be considered. Attendees agreed that multiple reserve sites spaced some distance from one another improve the likelihood of meeting OPAC's objectives.

When we removed California-only species from the species movement table, there was little change in the number and types of species in each home range category (compare Figure 3, page 16, and Table 2, page 51). Our new plots showing typical movement and depths for different species (Figure 32 and 33, page 51-53) should clarify the potential benefits of small and large reserves to many Oregon species.

Nearshore Oregon oceanography is most similar to that of Northern California, in terms of upwelling activity and transport processes. Specific oceanographic characteristics were not included in the original analyses by the Science Advisory Team in California; we may be able to improve predictions of area connectivity in our state with data generated by oceanographers at the College of Oceanic and Atmospheric Sciences at Oregon State University (see Presentation 5, page 31).

Important differences exist between the Oregon and California considerations of marine protected areas. These differences were discussed at the workshop and developed further as this report was written.

1) There is better habitat information for Oregon than was widely available in California, which should allow for more precise evaluation of changes in proposed reserve boundaries.

2) The California process was developed in the context of California's specific marine reserve goals, objectives, and mandates. There are two specific differences between the Oregon objectives given by OPAC and the objectives of the MLPA (Appendix D);
    a. recommendations in California were for MPA designations, not restricted to no-take reserves as was the Oregon condition at the time of our meeting; and
    b. nearshore fisheries are more intense in California, and potential fishery benefits were included in the analysis of MPA site proposals (see Presentation 2, page 21).

These differences do not negate the *general* applicability of the California methods and guidelines to Oregon, **and the workshop attendees agreed that the methods of analysis were scientifically defensible.** However, improving the guidelines with Oregon-specific information and with Oregon's specific objectives in mind is highly desirable and could be done by biological and physical scientists using existing information. However, improving the guidelines with Oregon-specific information is highly desirable and could be done by biologists and physical scientists using existing information if resources were made available.

Critical research needs

We recommend that resources be identified to support the following short-term data synthesis needs, which have direct relevance to refining the guidelines listed here:

- Conduct initial "ground-truthing" of habitat maps with assistance from local agency scientists, academic institutions, fishermen, divers, and other resource users
- Develop "species-area curves" for nearshore habitats under consideration, using existing Oregon-specific data
- Identify potential "retention areas" for fish and invertebrate larvae, based on ocean circulation models
- Map human use patterns in the nearshore to identify areas that are (or were) more heavily impacted by fishing
- Compile a map of current and past scientific research (biological and physical)
- Evaluate the utility of incorporating spatially-explicit models of species dispersal and fishing activity into coastwide protected area planning

For sites proposed for consideration as marine reserves or protected areas:

- Determine the amount of distinct habitat-types through existing maps and new surveys
- Identify data sources that may provide "baseline" information, such as previous or on-going research in the area
- Identify adjacent or nearby areas of similar habitat and depth that can serve as "reference sites" for effects evaluation
- Conduct seasonal surveys to determine the variability of species abundance and diversity in the area, as well as physical properties. The length and extent of "baseline" information needed will depend on the objectives of a particular site and any previously collected data that can contribute to an assessment of the past or current conditions in the area.

Workshop Presentation summaries

1. Science-Based Design for Effective Marine Reserves: Lessons from the California Marine Life Protection Act Initiative

presentation by Rick Starr, University of California Sea Grant, and Mark Carr, University of California, Santa Cruz

The design of marine reserves needs to match the goals and objectives for management or conservation of the area. The CA Marine Life Protection Act of 1990 has 6 goals, 4 of which are directly addressed with marine protected area (MPA) design:

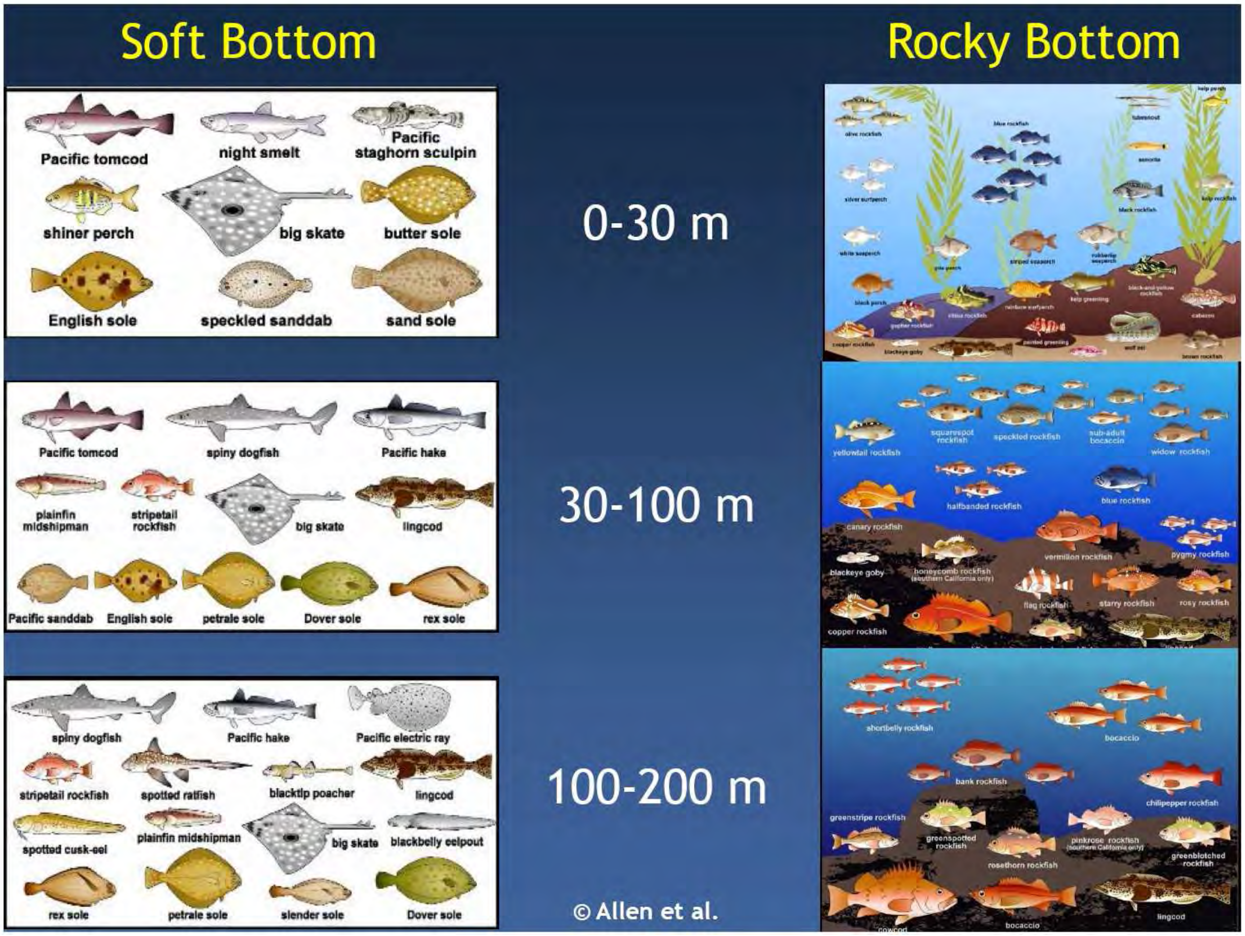
1. Protect natural diversity and ecosystem functions
2. Sustain and restore marine life populations
3. Protect representative and unique habitats
4. Ensure that MPAs are designed and managed as a network

The Marine Life Protection Act Science Advisory Team (SAT), composed of scientific advisors appointed by California Department of Fish and Game, provided the scientific support for the Marine Life Protection Act Initiative and developed the information found here.

Key habitats were identified using:
• Bottom type and depth
• Biogenic habitat
• Oceanographic features

Species were identified according to their affiliation with the key habitats (Figure 1).

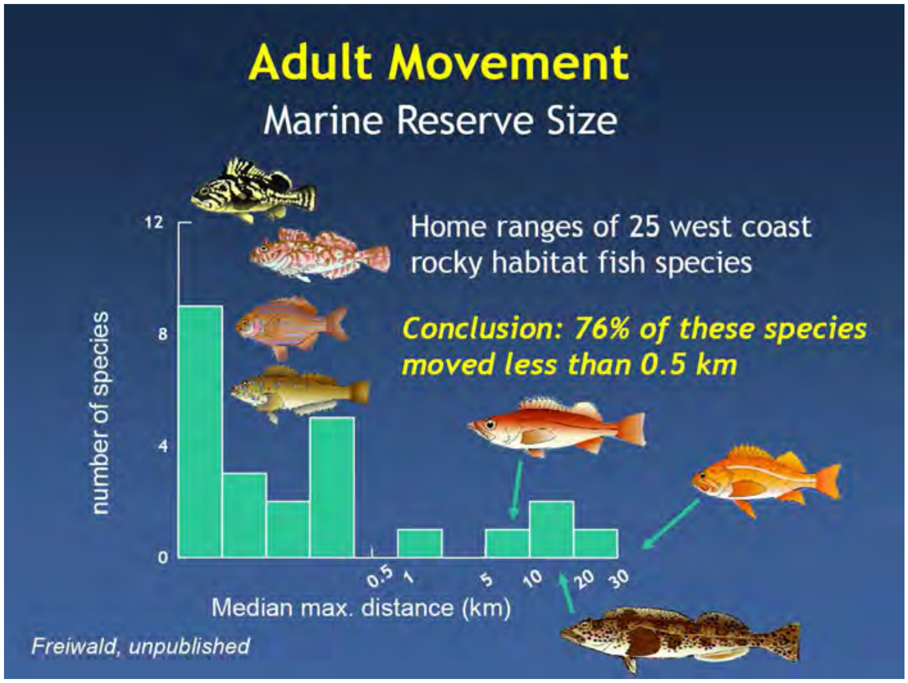
Figure 1. Fish species commonly associated with hard and soft bottom habitats in nearshore California.



Size of reserves should be based on range of adult movement.

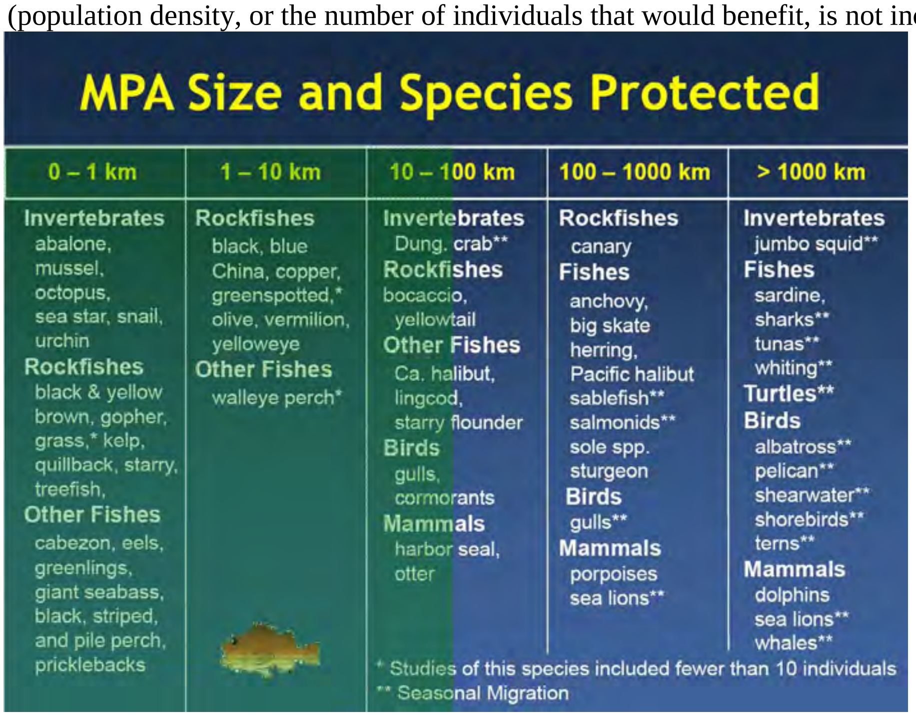
In order to effectively protect individuals of a species, marine protected areas or marine reserves should be large enough to assure that at least some individuals will stay within them for most of their natural lifespan. In California, reserve size was set according to the median maximum or 75th percentile of the maximum range of adult movement for different species, primarily because adults are the targeted size class of fisheries. Data for this analysis came primarily from published studies that used information on movement from tagged fish (Figure 2).

Figure 2. Chart showing the median of the maximum movement distance for each of 25 species of nearshore California fishes.



Once movement and home ranges have been identified for a variety of species, a chart of what species can be protected for different sized reserves can be rendered (Figure 3):

Figure 3. Species that are likely to benefit from reserves of increasing size, based on California species lists. Each species is categorized by its home range distance according to the typical movements of that species (population density, or the number of individuals that would benefit, is not included).



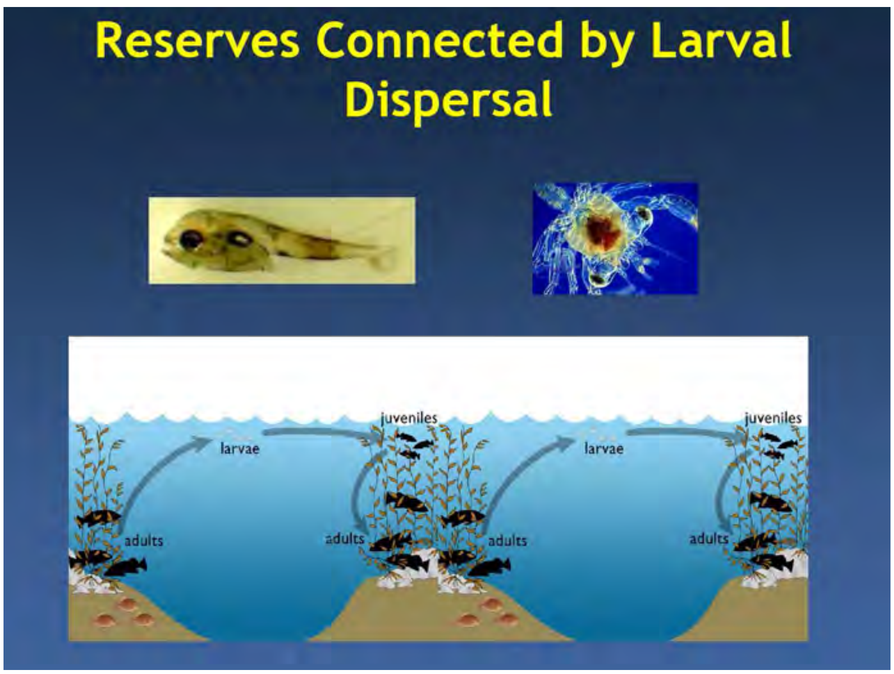
From this process, the California MLPA size guidelines to meet stated goals and objectives were determined to be:

• Minimum alongshore span of 5-10 km (2.7-5.4 nautical miles)
• Preferably 10-20 km (5.4 – 10.8 nm)
• Extend from the intertidal zone to the offshore boundary of state waters (3 miles offshore)

Most of the species listed in these figures and tables are found in Oregon state waters.

Marine reserve spacing should be based on larval dispersal
MPAs should be spaced far enough apart to maximize the length of coastline replenished by larvae produced within MPAs, but close enough together that larvae have the potential to be exported from one to the next (Figure 4):

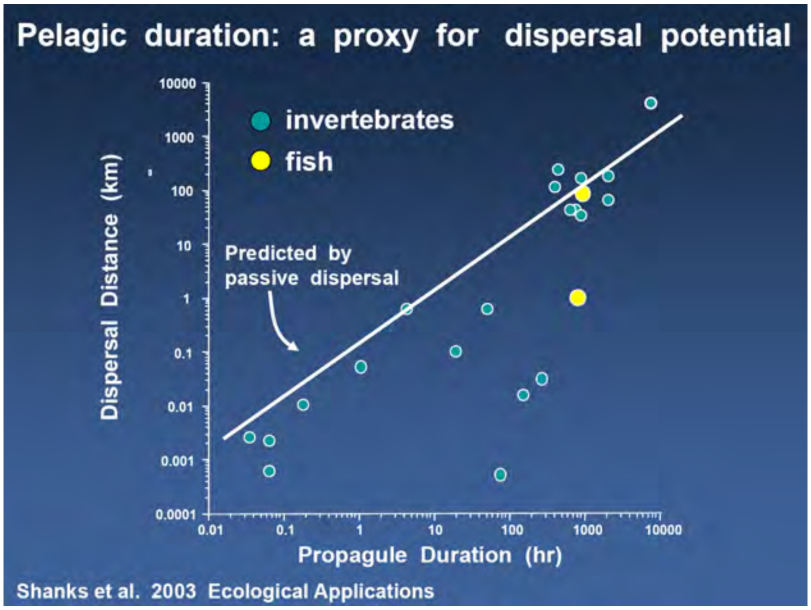
Figure 4. Conceptual model of how local fish populations contribute to the replenishment of one another, connected by the transport of larvae by currents.



Dispersal distance can be estimated by the length of time larvae spend in the pelagic stage. As shown in Figure 5, the longer larvae spend in the pelagic stage, the farther they go:

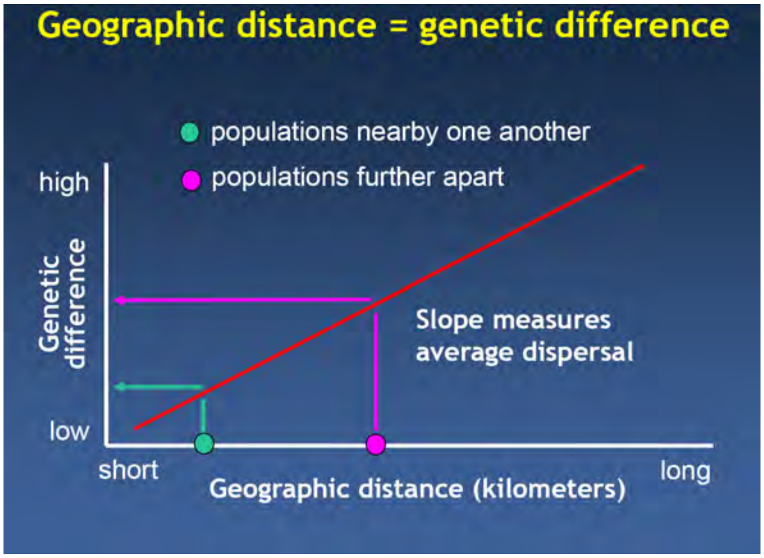
Figure 5. Plot showing a significant positive correlation between larvae (propagule) duration in the pelagic stage and dispersal distance (km).

1 km = 0.54 nautical miles, 0.62 statute miles



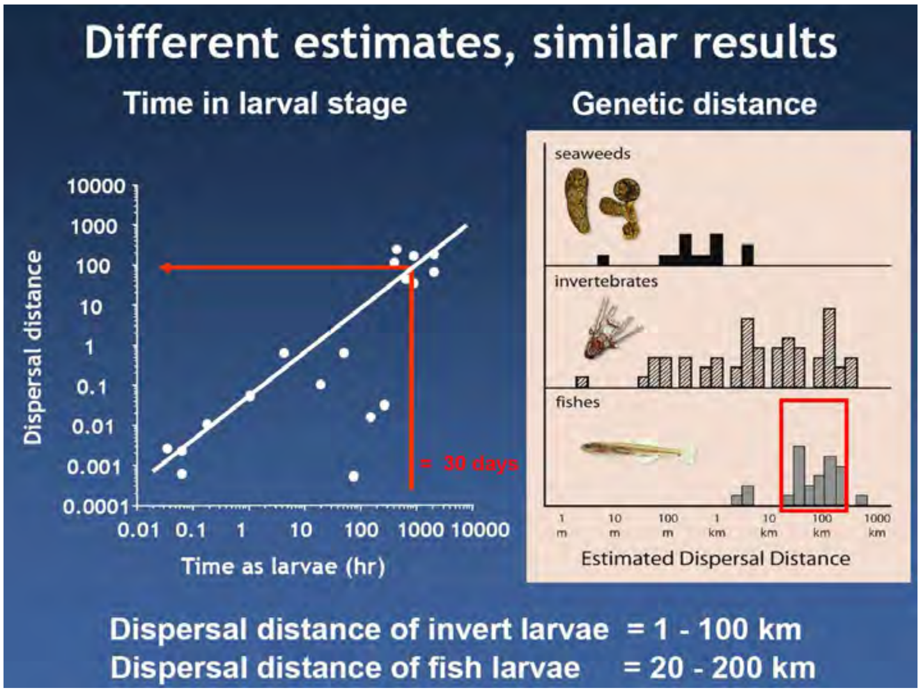
An additional method used to confirm dispersal distance is genetic differences. Genetic tests can be performed to see how closely related two organisms or populations are. The slope of the relationship between geographic distance and genetic difference can estimate the distance that larvae of a species are dispersed (i.e. transported by currents). The lower the slope, the longer the average dispersal distance (Figure 6).

Figure 6. Conceptual graph of how genetic difference relates to geographic distance. For a given average dispersal distance (indicated by the slope of the line), populations further apart show greater genetic difference than close by populations.



Based on genetic data, generalizations of larval dispersal can be made for invertebrates and fish (Figure 7). The estimates of larval dispersal from genetic studies are similar to the estimates from the time spent in the pelagic stage. This similarity reinforces the estimates.

Figure 7. Estimates of larval dispersal distances for invertebrates and fish species based on genetic evidence.



By combining size information and spacing information, guidelines for size and spacing were developed. To aid the process, the SAT developed minimum and preferred guidelines.

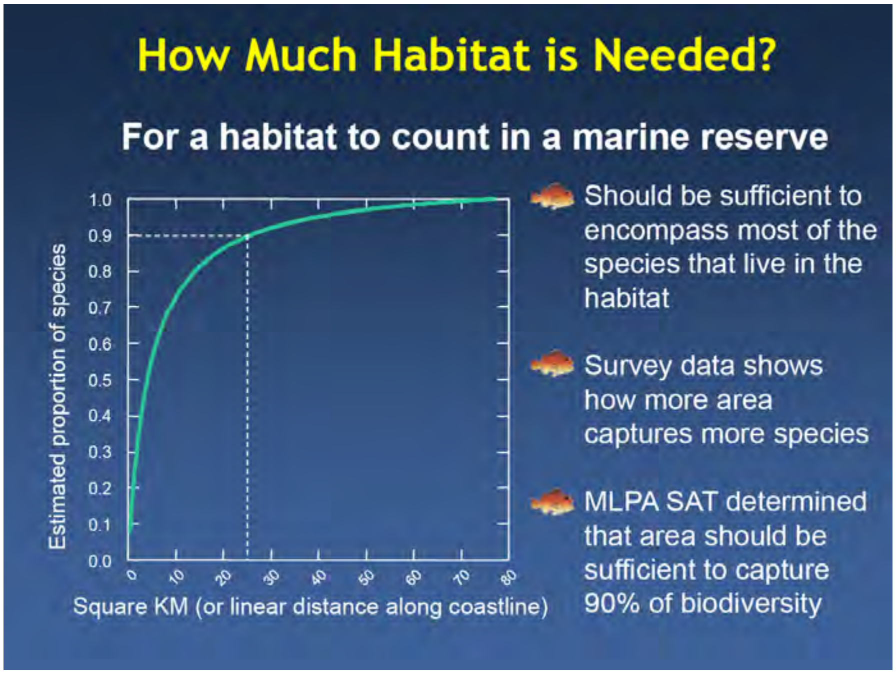
Size guidelines:
• 5-10 km, minimum
• 10-20 km, preferred
• Intertidal to deep waters

Spacing guidelines:
• 50-100 km apart

Size and spacing are inter-related
• Smaller MPAs should be closer together
• Larger MPAs may be spaced farther apart

Finally, the CA MLPA Scientific Advisory Team explored the issue of how much habitat should be present within a protected area to qualify as sufficient to contribute to a network and be considered as a replicate of that habitat. Most areas considered for MPAs included multiple habitat types; this is desirable, because it increases the diversity of species that would be within a protected area. Guidelines for minimum habitat area needed to protect biodiversity were developed based on species-area relationships (Figure 8). The graphs show the accumulation of possible species in a habitat as the size of the habitat area increases.

Figure 8. Guidelines for minimum habitat area needed to protect biodiversity developed by the CA MLPA Scientific Advisory Team.



The presentation ended with emphasis on how these analyses were used as guidelines for the stakeholders to make decisions. These science-based results were used as guidelines, but stakeholders drew actual lines of the MPAs.

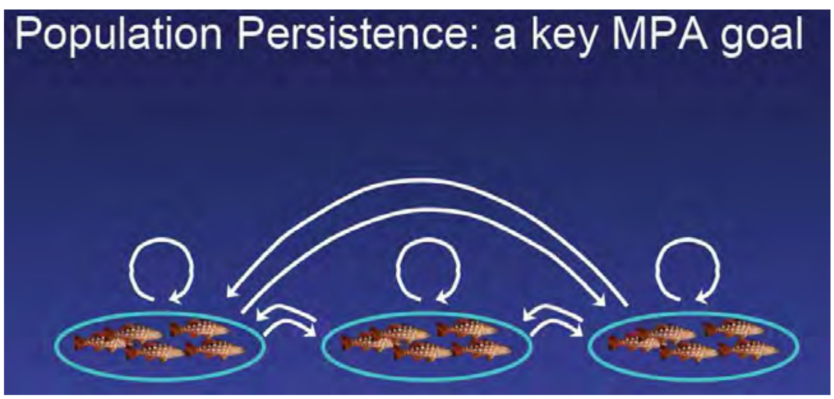
2. Persistence and Yield in MPA Networks: Results from Spatially Explicit Population Models

presentation by J. Wilson White (presenter) and Louis W. Botsford, University of California, Davis

Models of species persistence and fishery yield in marine protected area (MPA) networks are an important tool to help understand how MPAs affect fish and fisheries. The purpose of our research is to use models to identify changes in fishery yield and fish population distribution and persistence in nearshore California. Because the Oregon MPAs will not be specifically designed as fishery management tools, some aspects of these models may not be relevant to evaluation of reserve size and spacing here in Oregon. Nevertheless, the removal of fishing pressure is a primary effect of any MPA, and our models can provide insight into how populations of fished species will respond to MPAs and how multiple MPAs can interact as a network connected by larval dispersal.

In California, most goals of the Marine Life Protection Act (MLPA) implicitly require that MPAs support persistent populations (Figure 9).

Figure 9. Diagram of population persistence in a network of MPAs, with larvae retained within natal MPAs and also settling in neighboring MPAs

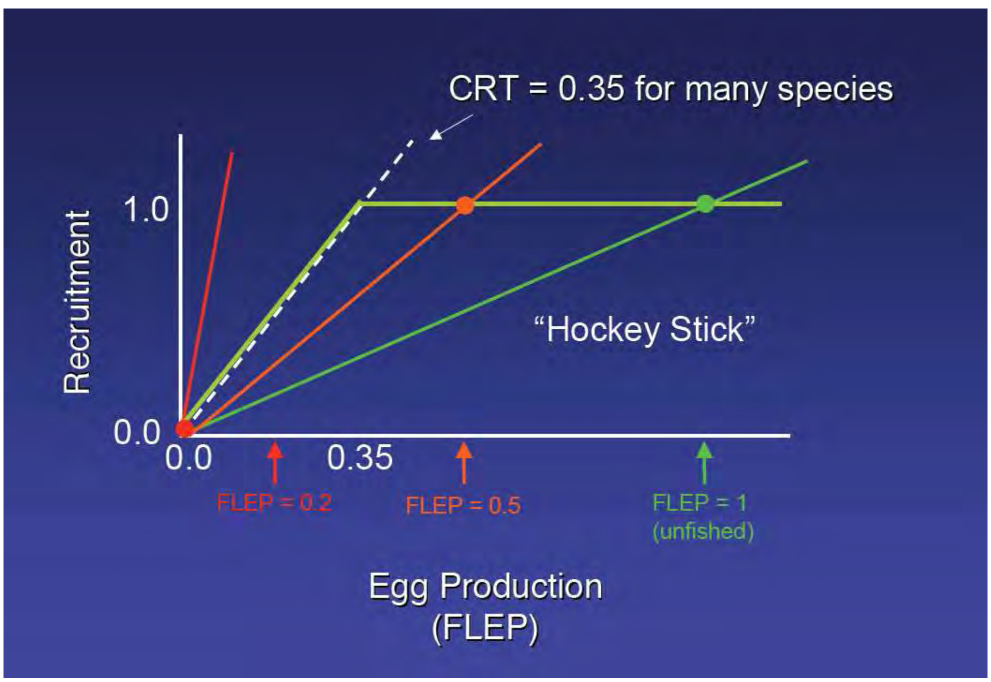


The criterion for population persistence is replacement. Just as in a human population, persistence requires that each fish replace itself with at least one offspring (a ‘recruit’) over its entire lifetime. In most fish populations it is difficult to keep track of offspring during the larval phase (when mortality and dispersal are both quite high), so the replacement concept is described in terms of the number of eggs that each fish much produce in its lifetime in order to ensure that at least one survives to recruit.

In a natural fish population, the expected lifetime egg production (LEP) for a new recruit is calculated by summing the expected egg production at each age (which increases with age) times the probability of surviving to that age (which decreases with age). In a fished population, individuals are less likely to reach older ages (the age distribution of the population is truncated), so LEP decreases. We can thus describe the intensity of fishing effort in terms of the fraction of natural egg production (FLEP) that results. If FLEP is low enough, fish are no longer producing enough eggs to replace themselves, so the population is no longer persistent. The value of FLEP at which this occurs is termed the critical replacement threshold (CRT). For many fish populations, the CRT is found at FLEP = 0.35 (35% of natural lifetime egg production), and we use that value in our models. Using FLEP as a "common currency" for evaluation of population persistence obviates the need to use many (difficult to estimate) parameters and allows us to identify the best configurations of reserve size and spacing for a wide range of taxa given a particular level of fishing.

The general relationship between FLEP and recruitment is shown by the yellow curve in Figure 10. For high values of FLEP, recruitment stays at the unfished maximum of 1 (individuals are replacing themselves); as FLEP decreases below 0.35, recruitment decreases to zero (replacement is insufficient). The long-term, steady state levels of recruitment for several levels of fishing are shown by the colored dots. The location of the dot is found by plotting a line with slope 1/FLEP and finding the intersection of that line with the yellow curve. Notice that if FLEP < 0.35, the dot approaches zero and the population goes extinct. In this figure we have used an angular "hockey stick" curve to illustrate the FLEP-recruit relationship; this is just an approximation of the real curve, which would be smoother and less angular.

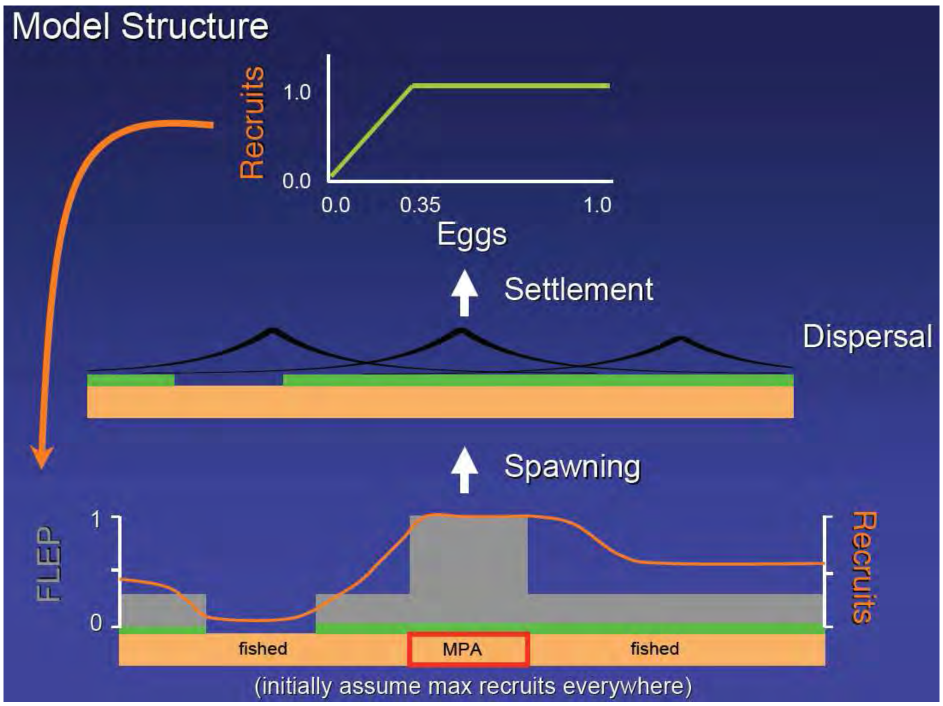
Figure 10. Diagram of the "hockey stick" relationship between the fraction of natural egg production (FLEP) and recruitment. FLEP can be used as a common currency to characterize the relationship between fishing pressure and population replenishment.



In a coastal population, neighboring subpopulations may exchange larvae with each other. In this case, any given subpopulation may not retain enough larvae for each fish to replace itself directly, but may be replenished by larvae arriving from neighboring subpopulations. Thus, larval exchange can allow a network of subpopulations to persist, even if any one subpopulation would not persist in isolation. We term this a network effect.

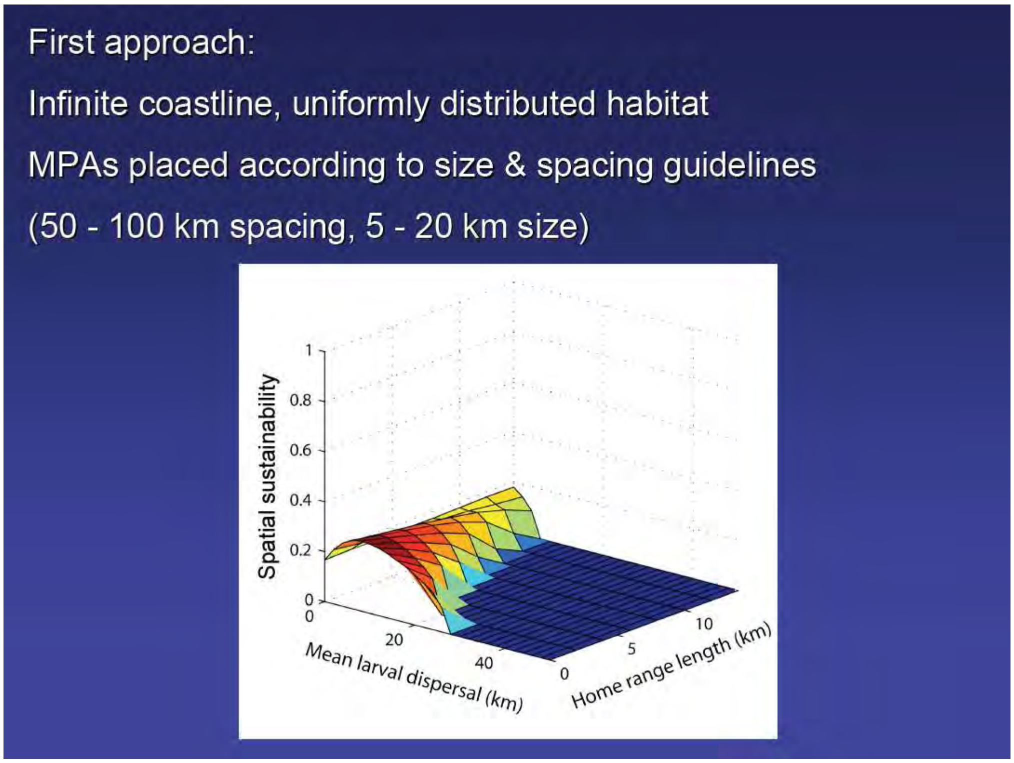
Network effects may be especially important in the presence of MPAs, because egg production in unfished areas (where FLEP is high) can replenish fished areas (where FLEP is low). Likewise, MPAs that are too small to persist in isolation may be replenished by larvae dispersing from neighboring MPAs or fished areas (Figure 11).

Figure 11. Diagram showing the model structure of dispersal, FLEP and recruit effects in fished and MPA areas



For populations along the California coastline, a reasonable first approximation is to model a one-dimensional linear coastline. In an initial modeling effort, we evaluated the effectiveness of the California size and spacing guidelines for networks of MPAs along an infinite coastline with uniformly distributed, homogenous habitat. In general, MPAs that conformed to the guidelines supported persistent populations of species with moderate to low larval dispersal distances and home range widths (Figure 12). Home range width often had a stronger effect on persistence than larval dispersal distance, so it may be desirable to create wider reserves to accommodate species with large home ranges.

Figure 12. Modeling results for an infinite coastline with uniformly distributed habitat with and MPA network that met the recommended CA size and spacing guidelines. The response surface indicates the fraction of the coastline supporting a persistent population for different combinations of larval dispersal distance and adult home range width. Results indicate that species with shorter larval dispersal and smaller home ranges are more likely to have persistent populations within this type of MPA network.

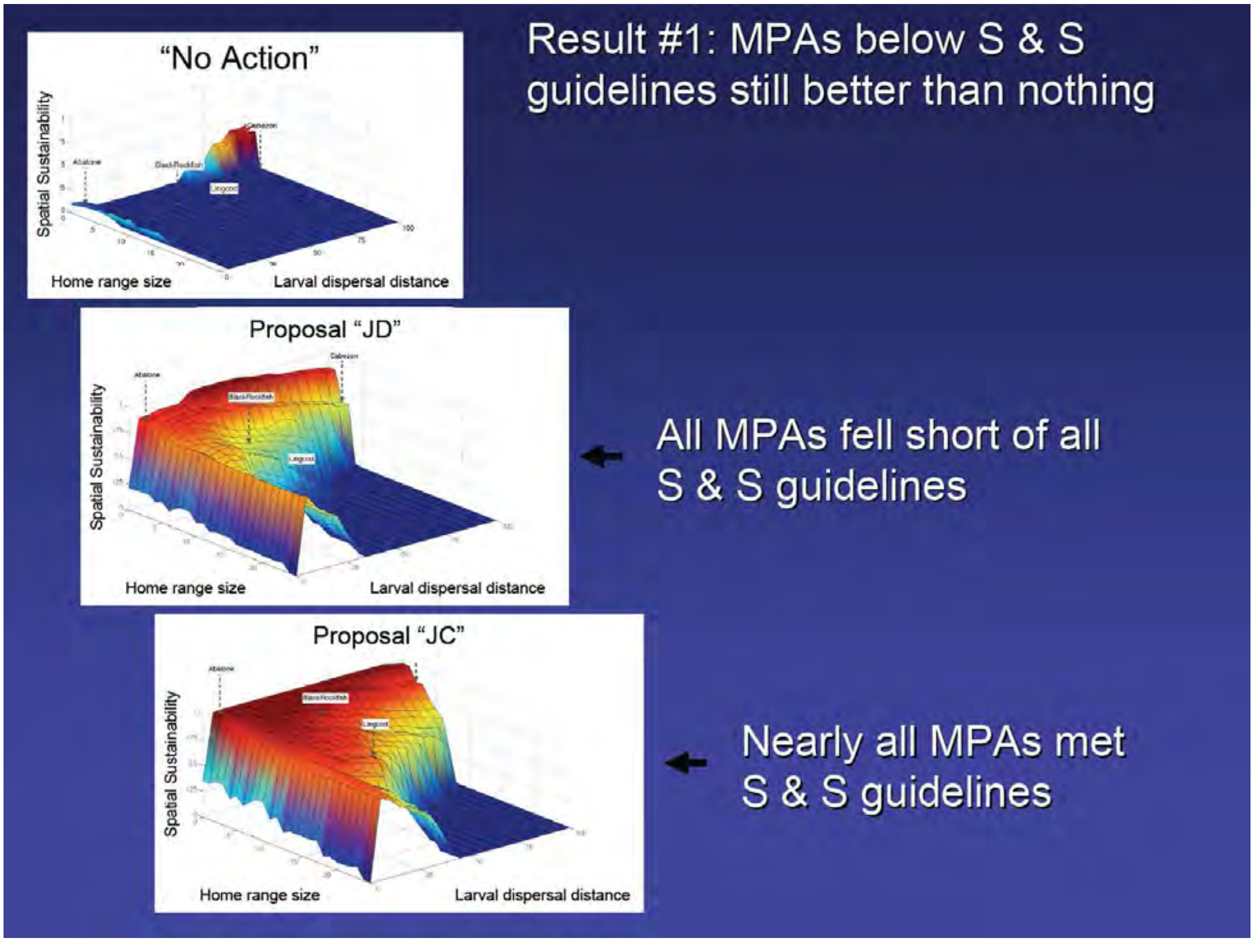


To evaluate MPAs for the North Central Coast Study Region (between Pigeon Pt and Pt Arena), we developed models that incorporated the spatial distribution of habitat in the study region and simulated population dynamics for 8 commercially important species. The goals of this effort were to:

- Evaluate proposed MPAs for persistence and yield
- Compare each proposal to the "no action" scenario (current regulations only)

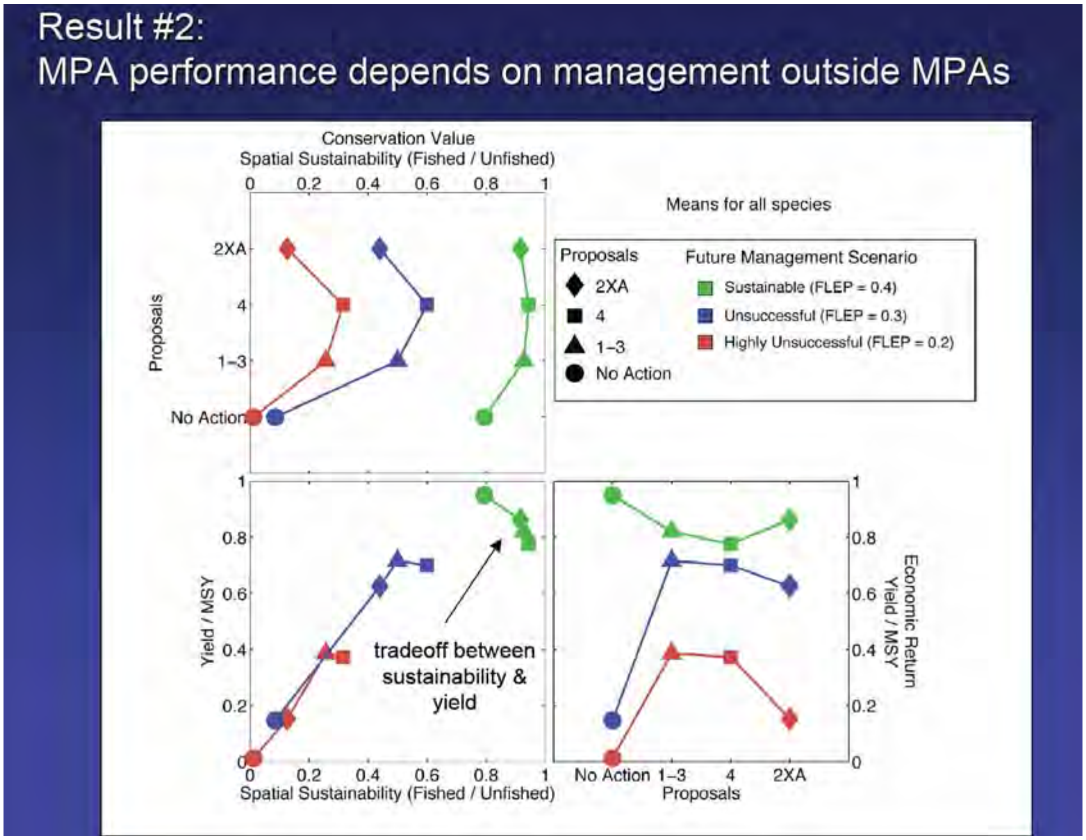
The model results for several representative MPA proposals reveal the essential lessons from this effort (Figure 13). Proposals in which most MPAs fell short of the size and spacing guidelines still performed better than the No Action scenario. However, proposals that more closely matched the preferred size and spacing guidelines supported persistent populations for a wider range of larval dispersal distances and adult home range widths. Once again, species with wider home ranges were the least likely to sustain persistent populations.

Figure 13. Results for several representative MPA proposals from the North Central Coast of California. The axes of each figure are the same as in Fig. 12.



Another factor determining MPA performance is the management of fisheries outside of the MPAs (Figure 14). If fisheries are managed poorly ("overfishing"), MPAs may be necessary to sustain persistent populations, and increasing the area dedicated to MPAs may actually increase fishery yield. However, if fisheries are managed sustainably, MPAs are less important to persistence, there are fewer benefits to increasing MPA area, and MPAs may impose economic costs by reducing fishery harvests. Consequently, a reliable assessment of the performance of a particular MPA proposal requires decision makers to specify what sort of management will occur outside MPA boundaries.

Figure 14. The effect of fishery management on MPA performance. Each panel shows the performance of 4 MPA proposals (symbols) under 3 different management scenarios (sustainable, unsustainable, or highly unsustainable fishing). MPAs are evaluated based on the ability to support persistent populations (upper left), fishery yield (bottom right), and the trade-off between those two factors (bottom left).



The general conclusions of our modeling efforts are:

1. Species that move in large home ranges as adults are not protected well by MPAs
2. Increasing MPA size is more useful than reducing spacing in terms of improving persistence and fishery yield (especially for species with high adult movement)
3. Spatially explicit models can be valuable tools to determine if conservation and economic targets are being met
4. MPA success depends on current and future fishery management *outside* MPAs
5. Decision makers must specify their beliefs about future and/or commitment to managing fisheries

In general, we recommend using size and spacing guidelines as a starting point for designing MPAs, but emphasize that models such as these should be used to compare different MPA proposals in order to quantify their ability to support populations and fisheries.

3. Invertebrates in Near-shore Oregon

presentation by Craig Young, Oregon Institute of Marine Biology

Marine Reserve discussions tend to stray away from invertebrates, but invertebrates are responsible for most marine animal diversity worldwide. In Oregon, invertebrates far outnumber all marine birds, mammals, fish and algae combined.

Oregon has:

- Over 200 marine plants
- More than 3,000 marine invertebrate species
- About 500 species of marine fish
- 155 bird species
- 26 mammal species

Smith and Light's Manual (2007 edition, J. Carlton, ed.) lists 3,700 intertidal invertebrates between central CA and the northern border of OR. Most invertebrates disperse as pelagic larvae and the diversity of these larval forms is amazing. Although actual dispersal distances have been measured for only a few species, dispersal potential of invertebrates may often be inferred from development mode and egg size. Thanks to a strong tradition of embryological studies established by the students of R. L. Fernald at the University of Washington, the Pacific Northwest has the most complete data base on developmental mode for any region on earth, including all other areas where marine reserves have been established. Interestingly, the invertebrate with the longest known larval dispersal time is *Fusitriton oregonensis*, the Oregon state shell. A number of scientists in Oregon are actively working on the mechanisms by which larval invertebrates are transported by currents.

Only a few marine invertebrates, including clams and crabs, are commercially important in Oregon but invertebrates provide food for many of the harvested fishes, and some modify habitats that are used by fisheries species. Any discussion of community-wide species diversity in marine reserves must focus in large measure on the invertebrate fauna.

4. Propagule duration and dispersal distance

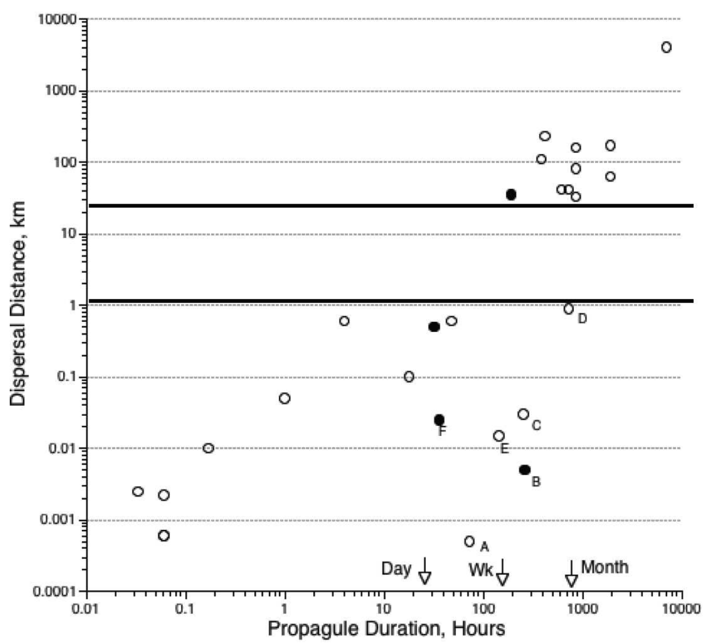
presentation by Alan Shanks, Oregon Institute of Marine Biology

The distance and time that propagules (eggs, embryos, larvae, spores, etc.) spend in the planktonic stage is an important factor for the size and spacing of marine reserves. Knowledge of larval dispersal distances can help estimate an optimal size for reserves as well as the distance between marine reserves. This will allow propagules with short pelagic durations (PLD) to sustain populations within a reserve and larvae with longer PLD's from one marine reserve to disperse and settle in another marine reserve.

Propagules spend from seconds to months in the plankton. The length of time larvae spend in the plankton is related to distance traveled. The longer larvae spend in the plankton, the further they can potentially go. Additionally, larvae are not passively distributed, as was once believed. For example, some stay close to the bottom where currents are slower and they are therefore more likely to be retained in close proximity of their starting point.

There is a gap in dispersal distance between 1 and 25 km (0.54 and 13.5nm) and no matter how many data points are collected, the gap remains (Figure 15). It is possible that the gap may fill in as more species are studied. However, the lack of species with propagule dispersal distances of 1-25 km may also reveal a strategy for species to stay close (within 1 km) or go very far (beyond 25 km) from where they were born.

Figure 15. Graph of larval dispersal distances showing a gap between 1 and 25 km. (0.54 – 13.5 nautical miles) Modified from Shanks, Grantham and Carr (2003).



Shanks, Grantham and Carr, 2003

A marine reserve could be designed to maintain populations of organisms whose larvae disperse short distances (< 1 km); a reserve 5 to 10 km in diameter should be adequate to allow these kinds of populations to be sustained. A marine reserve would not, however, be designed to retain larvae that disperse over 25 km. The larger values could be used to estimate how closely reserves should be spaced. A minimum spacing of about 25 km, or 25-50 km (13.5 – 27 nm) alongshore distance might be appropriate based on the current data.

There are differences in the patterns of reproduction and dispersal of larvae of nearshore species and shelf/slope species. Nearshore fish larvae start their pelagic period around April 1 and end around mid-September, whereas shelf/slope fish larvae begin their pelagic period near the end of December and end around the beginning of September (Figure 16). The implications of these differences are important. Larvae of nearshore species are in the water only during the upwelling season, whereas larvae of shelf/slope species are in the water during both the Davidson Current season and the upwelling season. The timing of reproduction by some shelf/slope species suggests that the currents are moving the larvae north and then south along the shelf, with possibly little net movement along the coast (Figure 17).

Figure 16. Graphs showing the difference in nearshore and shelf/slope fish species with respect to time of year larvae are dispersed (Shanks and Eckert, 2005).

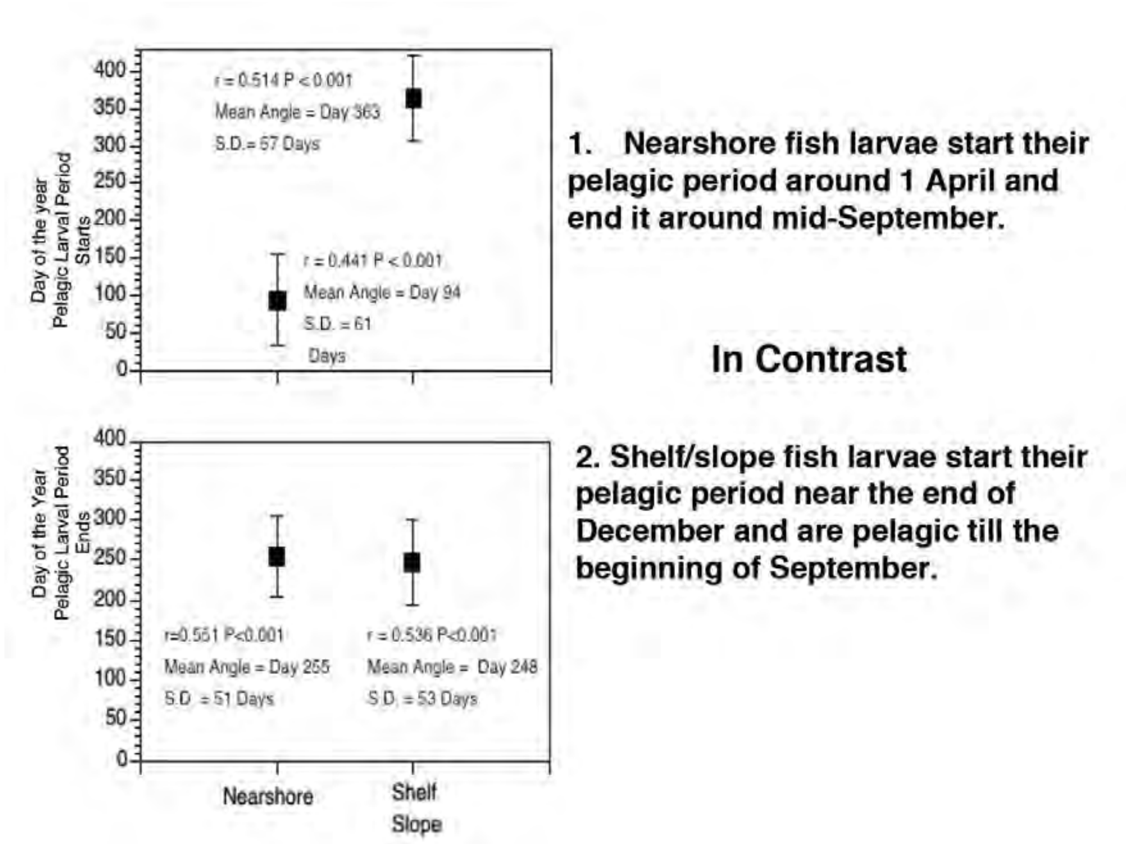
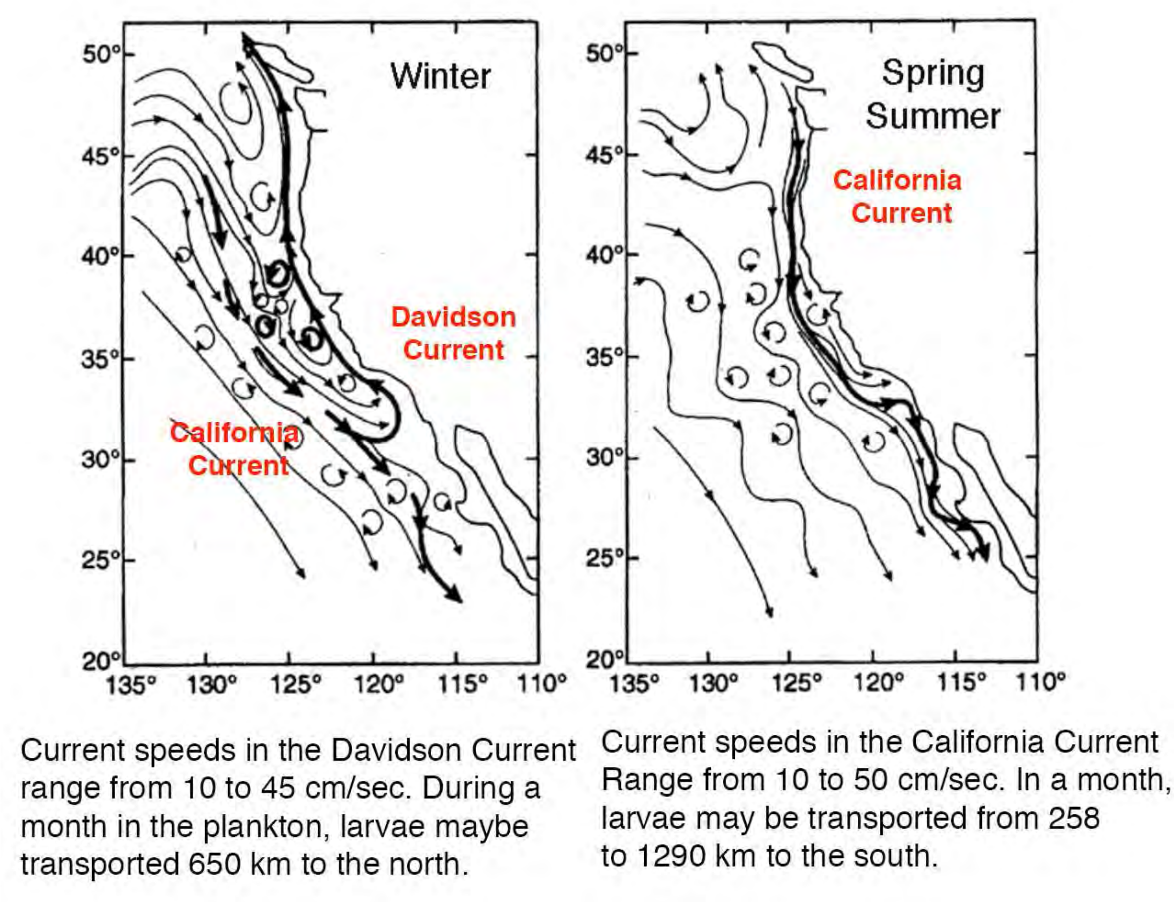


Figure 17. Diagrams illustrating the differences in the California and Davidson currents between the winter and spring/summer seasons with implications for larvae dispersion.



Other research has been conducted to help confirm travel distances of larvae and juvenile fish. Studies of black rockfish otoliths (ear bones of fish which can show chemical changes, water conditions and other environmental factors as well as age of a fish) suggest a maximum dispersal distance of only 120 km (64.8 nm) — a smaller distance than previously thought (Miller and Shanks, 2004).

The overall conclusions indicate two main concepts:

1. For species with short dispersal distances (< 1km, 0.54nm), a reserve one to a few miles in diameter may support self-sustaining populations. Enough larvae spawned in the reserve will recruit back into the reserve to sustain the populations in the reserve.
2. For species with larval with longer dispersal distances (e.g., > 25 km, 13nm), larvae may be dispersed along the coast over distances from 10-20 or even several hundred miles. Larvae spawned in a reserve will settle over a broad area of the coast contributing to populations both inside and outside of a network of reserves. Given the variability in ocean currents, it is possible that some of these larvae will actually settle near where they were spawned.

5. Physical Oceanography Affecting Reserve Size and Siting Issues

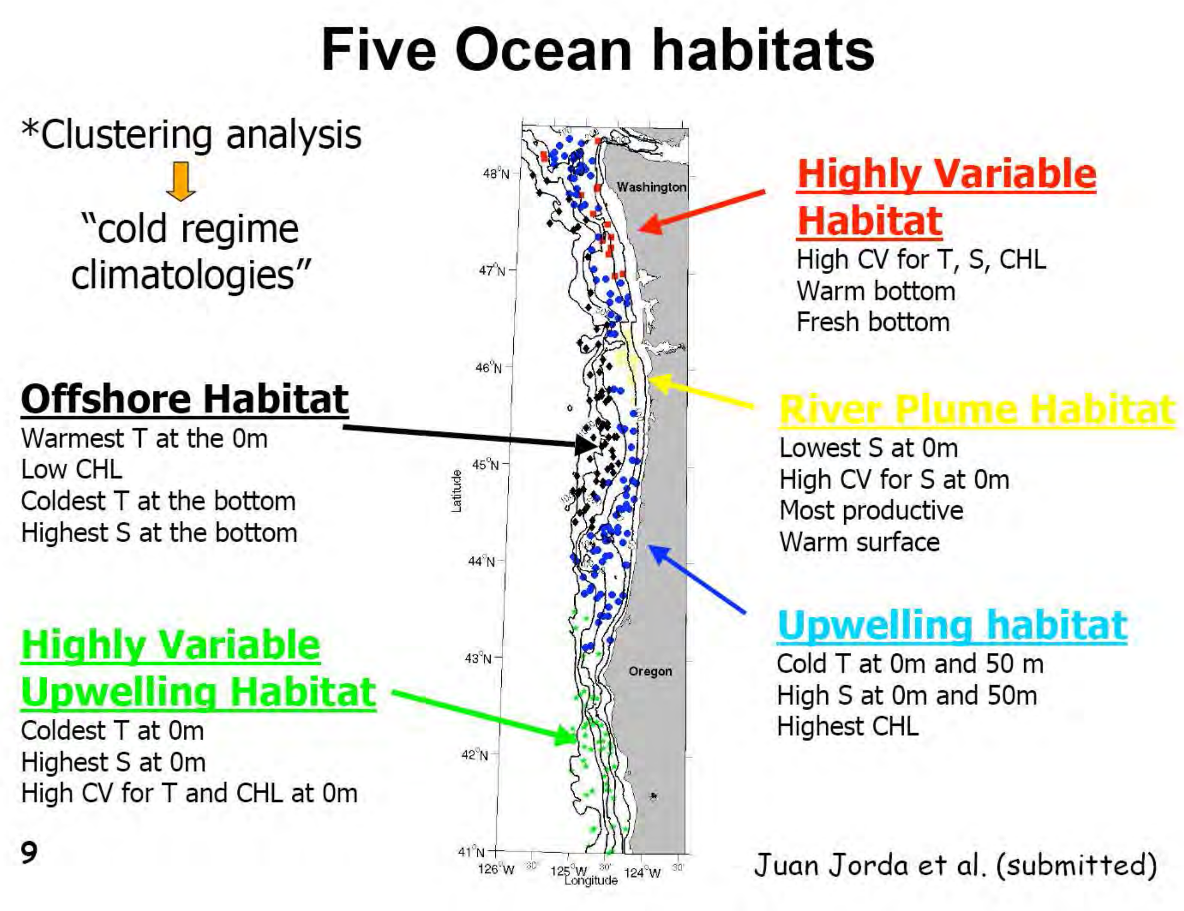
presentation by Mike Kosro and Hal Batchelder, Oregon State University

Mike Kosro:

There are many oceanographic instruments in current use that enable physical oceanographers to gather pertinent data including salinity, temperature, chlorophyll levels, downwelling and upwelling, surface current mapping, surface properties, sea level, etc.

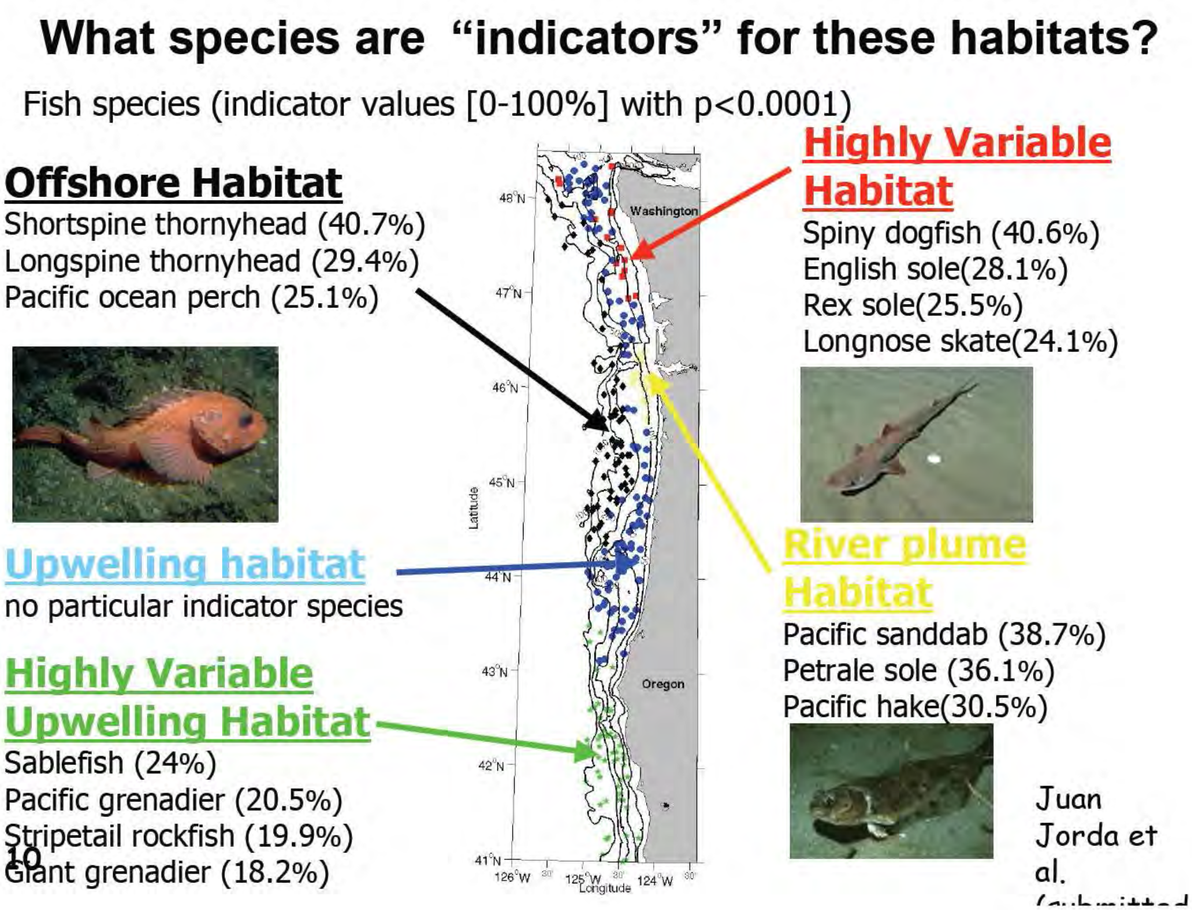
Knowledge of fish species and oceanographic data can be combined and analyzed to see how they correlate in time and space. There are generally five ocean habitats defined by currents and water column properties along the West Coast of the United States (Figure 18). These are highly variable habitat, river plume habitat, upwelling habitat, offshore habitat and highly variable upwelling habitat. These habitats vary in salinity, temperature and other properties.

Figure 18. Diagram of locations and characteristics of the five general ocean habitats for the West Coast.



Some fish species have a high affinity to specific habitats and can be considered “indicators” of a habitat type (Figure 19). For example, the distribution of catches of a fish with a high affinity for upwelling zones can indicate the likely presence of that habitat type. Likewise, oceanographic data can be used to identify likely biological hotspots, such as the Strait of Juan de Fuca.

Figure 19. A diagram of indicator species for the five general habitats along the West Coast



Daily and monthly fluctuations in surface currents and upwelling or downwelling can be identified over large spatial scales along the Oregon coast using a variety of instruments and remote sensing from satellites. Links have been made between oceanographic data and salmon catches. For example, upwelling conditions in 2005 were weak. This year (2008) salmon catches were low and many researchers believe this is due to the weak upwelling conditions in 2005.

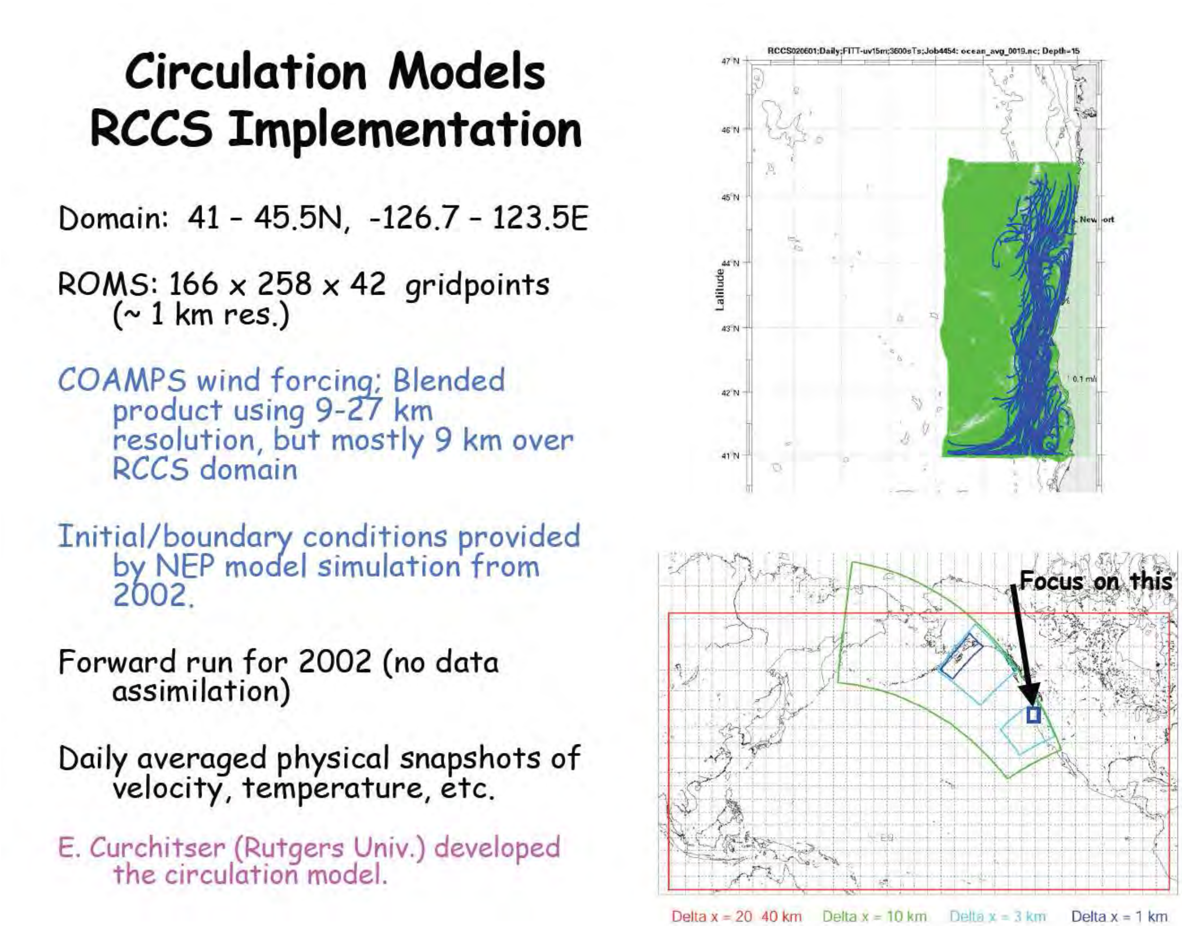
In conclusion, surface currents provide scientists with important information about ocean conditions, which are related to water properties that define habitat. Additionally, current data can allow scientists to estimate dispersion statistics, which indicate transport mechanisms for fish and invertebrate larvae. These statistics will change by location and will be affected by seasonal and interannual variability.

Hal Batchelder:

Computer simulations can be used to study circulation and other oceanographic processes. Physical circulation models of the region from Northern California to Tillamook, OR (Figure 20—upper figure) have been run using the best available high resolution wind forcing for calendar year 2002, and with initial conditions and boundary conditions provided by a lower-resolution, larger-domain model (10 km (= 5.4 nm)) region outlined in green in Figure 20—lower figure).

Figure 20. Circulation model results for the Oregon coast.

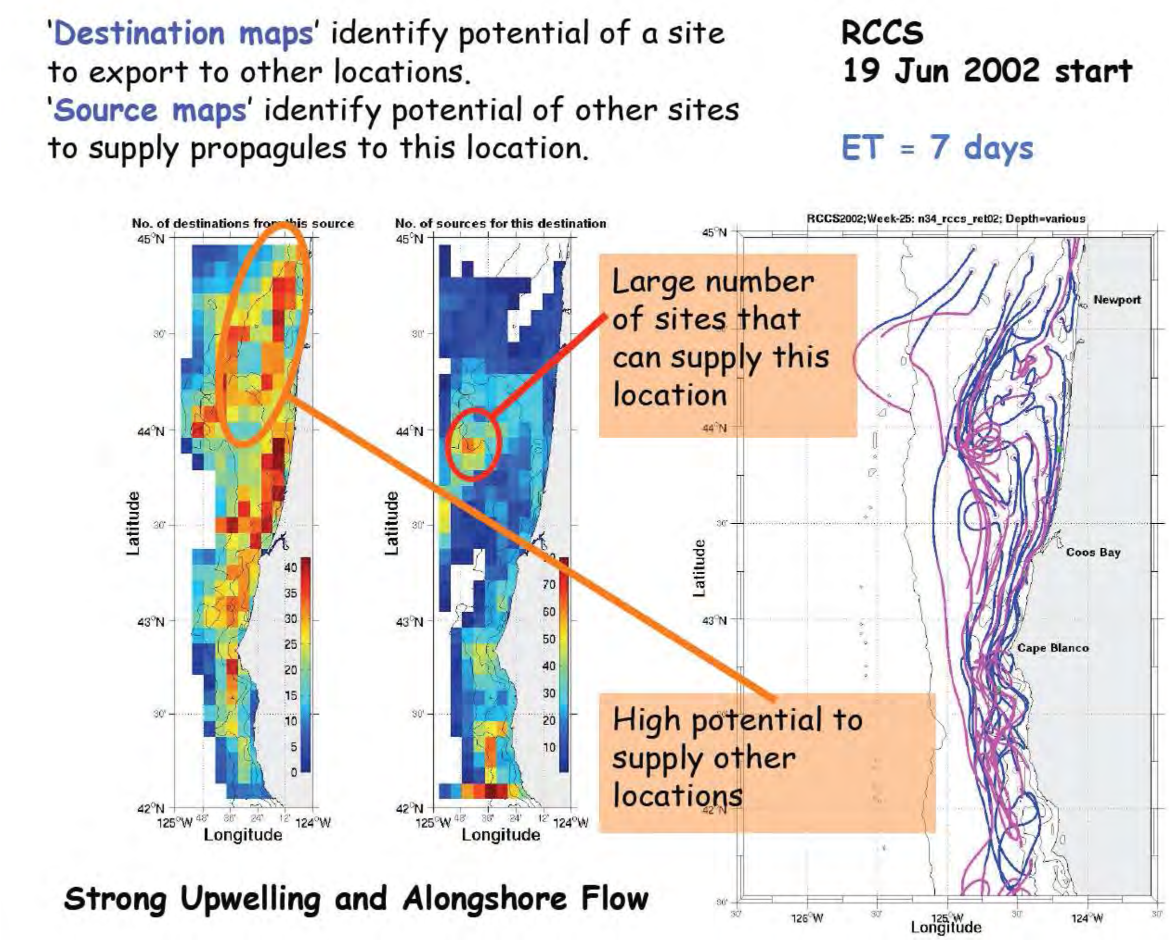
Top panel: The region modeled at 1 km resolution, from Northern California to Tillamook Bay. Bottom panel: various nested model domains showing the small region off Oregon-California and larger regions modeled at lower horizontal resolution.



Lagrangian particle tracking was used to examine trajectories of particles as they experience the seasonally-variable wind forcing. New simulations were initiated weekly and particles tracked for 15 days or until they exited the model domain. Using the particle positions, it was possible to quantify spatial and temporal patterns of retention times of particles that originated on the Oregon shelf. Statistics derived from the Lagrangian experiments revealed that the Heceta Bank region, and especially the near-coastal waters inshore of Heceta Bank have longer retention times (more sluggish flow), suggesting that these may be areas of self-recruitment for marine species with short (<14 d) pelagic larval durations.

Using these Lagrangian experiment results, other metrics of potential value to siting and evaluation of marine protected areas may be derived. Of particular note are “destination maps” and “source maps”. Destination maps identify sites with a high potential to export larvae to many other locations. Source maps identify areas that might receive new individuals (young; recruits) from many other regions (Figure 21). The model domain was subdivided into regions of approximately 10 km by 10 km for calculating these statistics. Regions in Figure 21 that are in warm colors (reds and yellows) are regions that have high potential for providing young to many other sites (destination map; left panel) or receive young from many other sites (source map; center panel). For the examples shown here, ca. 50000 particles were tracked for each simulation. If greater numbers of particles are tracked, and or particles are seeding into the nearest shore regions only, it would be possible to provide maps of retention, destinations and sources at higher (ca. 1 km) resolution.

Figure 21. Diagram of destination and source maps for potential particle dispersal. Destination areas are identified with red.



In conclusion, the coupling of high-resolution models of ocean circulation using realistic bathymetry and wind forcing produce circulation fields that can be explored using particle tracking experiments to estimate some metrics, such as retention times, destination and source maps, that provide key transport-related information regarding the potential ability of specific regions to recover from overfishing, or of regions to serve as exporters of young to other regions, or to self-seed. For now, these simulations are of limited use because only one year of data (2002) has been analyzed and only a portion of the coast has been thoroughly investigated. Using Lagrangian experiments to analyze multiple years of ocean simulations would enable better statistics of these processes—esp. how they vary seasonally, spatially and interannually. Future simulations need to be done with a larger model domain, which will allow better spatial description, but also allow for longer duration Lagrangian experiments. Currently, the duration of Lagrangian experiments is limited by the desire not to have individual particle interactions with the boundary of the physical model domain.

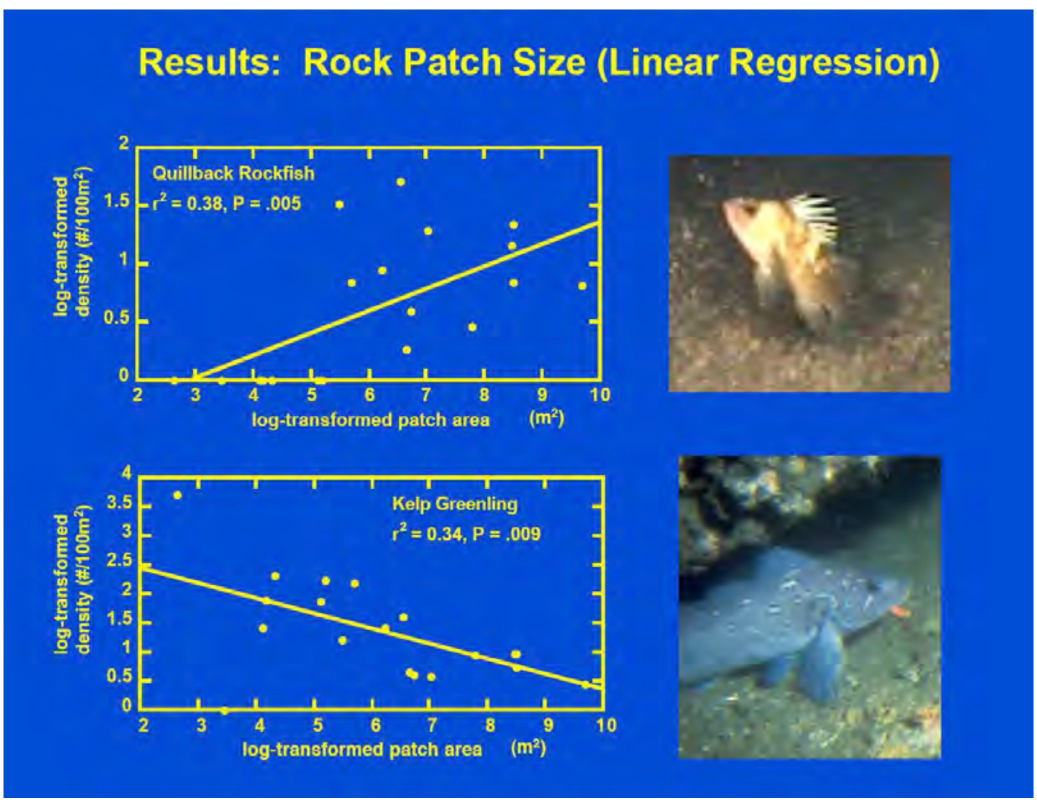
6. Nearshore Rocky Reef Habitat and Rockfish Site Fidelity

presentation by Dave Fox, Oregon Department of Fish and Wildlife

Analyses of fish-habitat relationships can be made using high-resolution maps that combine sonar images of the habitat with visual surveys of fish taken by remotely operated vehicles. Rock patch structure, size and relief can be an indicator of fish density and distribution, as well as community composition. Two examples are presented from Cape Perpetua and Orford Reef.

By using side-scan sonar at Cape Perpetua, you can see about 60 distinct small patch reefs, which can be an indicator of fish distribution. There are about 8 rockfish species commonly found in this area and we can see how the fish are distributed in these patches. For example, Quillback rockfish distribution on the patches at Cape Perpetua shows an increase in fish density with habitat patch size (Figure 22). The x-axis is surface area of the habitat patch and the y-axis indicates the density measure of the fish. A linear regression was fit to the data, but it was a poor regression with a lot of scatter. The results of this indicate that there were no Quillback on very small patches less than 5.5 m^2. In contrast, Kelp Greenling were found on smaller rock patches, starting at around 4 m^2, and actually decreased in density as patch size increased.

Figure 22. Linear regression of Quillback rockfish and Kelp Greenling sampled on rock patch reefs at Cape Perpetua, indicating there were no Quillback on very small rock patches, but there were Kelp Greenling on smaller patches.

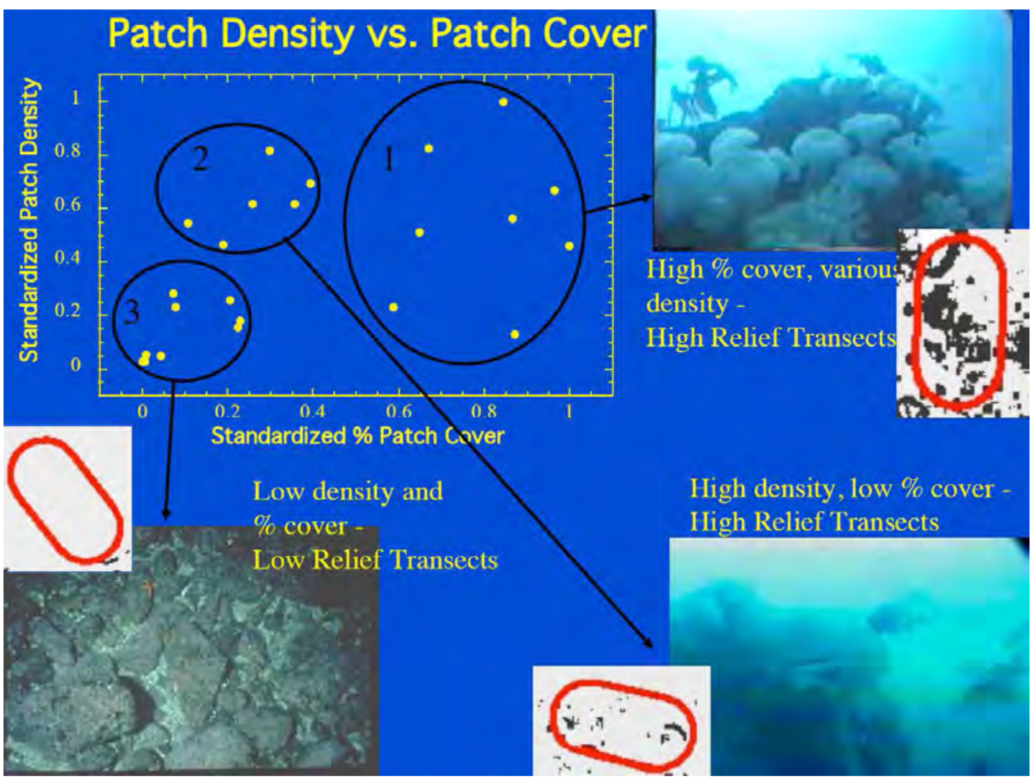


The fish density data appeared to be a showing a “threshold” phenomenon. There were no fish or very low densities on very small rock patches, then once you reached a certain patch size densities increased dramatically but did not increase further as patch size increased. The overall trend seen in several distributions of this type was similar. Rock patches as small as approximately 10 by 20 m have abundant concentrations of fish. Small rock patches are significant in the number of fish they can hold, are common in Oregon’s nearshore area, and should not be over looked simply because they are small.

At Orford Reef, vertical relief was found to be an important factor for fish abundance. There was a significant, but weak, positive correlation between vertical relief as represented by mean slope of rock surfaces and fish densities. High slope areas consistently had high concentrations of fish, while low mean slope areas had completely variable fish densities. This finding indicates that there is likely some other important factor coming into play. Habitat patches were then defined by variation in depth with buffer areas around transects. Portions of each buffer area with high depth variation were classified as high-relief habitat patches. The patches were then described with two-variables: percent cover of all high relief patches within a buffer area and density of individual patches (regardless of the size) within the buffer area. These analyses lead to a plot of patch density versus patch cover (Figure 23). Three patterns stand out:

1. High percent cover of habitat patches, including large outcroppings of rock yielded high fish densities —this result is similar to high slope areas
2. High density of small rock outcrops, but low percent cover yielded high density of fish
3. Low percent cover and low relief area yielded a low density of fish

Figure 23. Diagram of relationship between patch density and patch cover in relation to fish densities



The second and third pattern occur in areas with low mean slope, helping to explain why low mean slope areas had both high densities and low densities of fish. While it is often assumed that rock patches are important if they are large and unimportant if they are small, the occurrence of many small habitat patches and the relative landscape position in the patches helps explain the overall abundance of fish on a reef. This type of landscape analysis is needed to fully define habitat quality and species diversity.

To further research site fidelity of fish species in rock patches, several species of fish were acoustically tagged at Siletz Reef off of Lincoln City and Black rockfish were specifically studied at Seal Rock. Siletz Reef is an area mapped with side scan and multibeam sonar. The tags had the ability to measure depth and other information on the fishes' location. The results of this tagging were approximately as follows:

- o Quillback, Tiger, Vermillion and Yelloweye—high site fidelity
- o Black rockfish—high to intermediate site fidelity
- o Canary—low site fidelity

Overall, there is quite a bit of variation of what fish will do—some will leave the grid completely, some make short forays in and out of an area and many other combinations of movement. Figures 24 and 25 shows examples of high and low site fidelity, respectfully, by different species.

Figure 24. Map showing an example of high site fidelity by yelloweye rockfish from individual acoustic tag data.

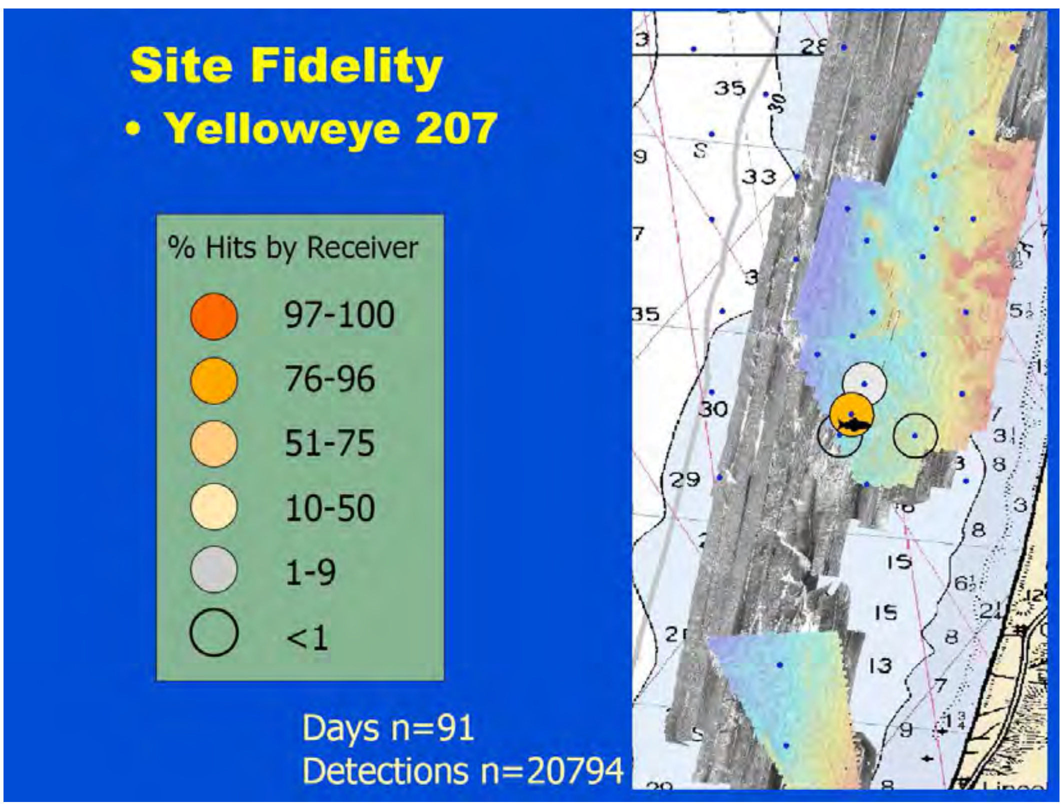
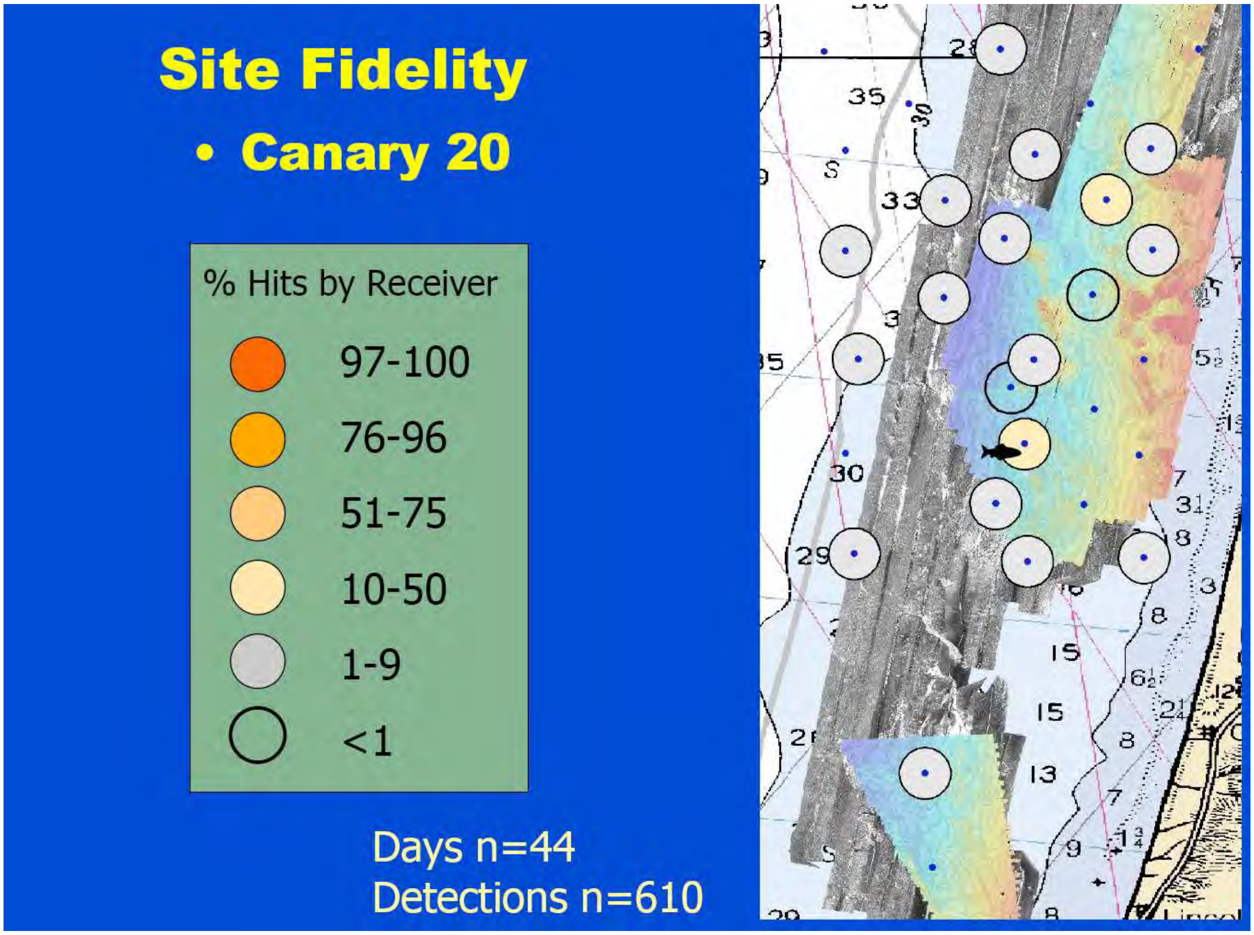


Figure 25. Map showing an example of low site fidelity by yelloweye rockfish from individual acoustic tag data.



The implications of these data to marine reserve design are as follows:

- With rocky reef habitat—don't oversimplify reef types, there can be a lot of differences among rocky reefs and they should not be over generalized
- Isolated small rocky habitat patches can be important habitat
- Relative "value" of rocky reef to fish is not a simple relationship to habitat relief; there are several scales of relief which can affect fish populations
- The response of fish species will depend on their site fidelity
- High resolution seafloor mapping is necessary to better understand rocky reefs

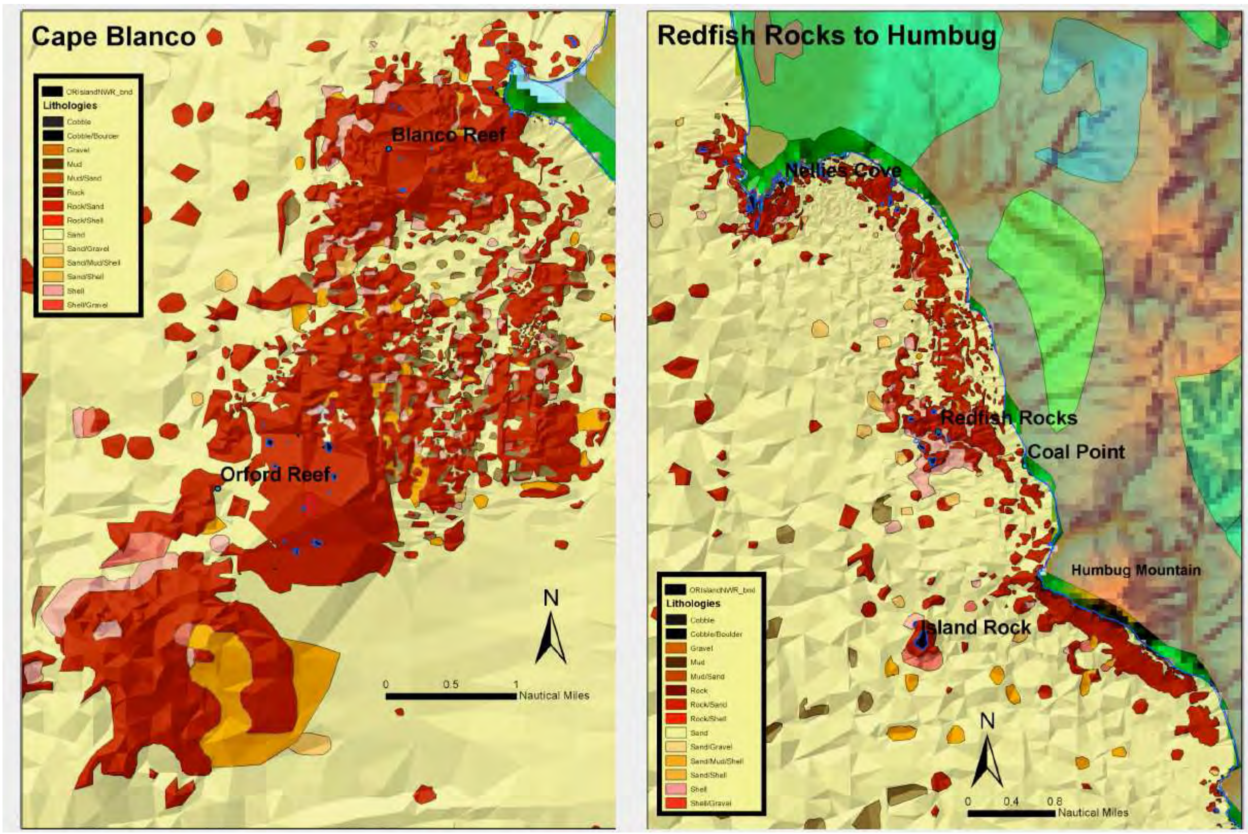
7. Seafloor mapping off the Oregon coast

presentation by Chris Goldfinger, Oregon State University

Approximately 5-7 % of Oregon's territorial sea has been mapped in high resolution. The current regional maps available until now are the best maps that could be made with the very limited existing data. When the mapping team set out in September to create these maps, they came upon a gold mine of bottom sample data dating back to 1858. These data were older USCGS (now NOS) sample data that had never had never been digitized for Oregon and Washington. They included ~ 9,300 bottom samples that were digitized and combined with existing data (Figure 26). From the combined data set, a new surficial geologic habitat map was constructed encompassing the Oregon Territorial Sea. Lithologic interpretation included rock, sand, mud, gravel, shelly and mixed sediments. Kelp mapped from aerial surveys was used as a proxy for a rocky bottom type and augmented the sample data. The density of this sampling is not likely to ever be recreated, and can be used to help ground truth future high resolution mapping efforts. While the data span 150 years, the navigation and data quality are remarkably good. Typical navigational accuracy is less than 30 meters, determined by comparing the surveyed positions of offshore rocks to modern data.

Figure 26. Map of Cape Blanco and Redfish Rocks areas created from digitized bottom sample data from NOS archives.

Note that detailed maps like this one are available for most of the nearshore through the PacCOOS interactive mapping web site http://nwioos.coas.oregonstate.edu/ and www.oregonmarinereserves.net.



Summary of Scientific Issues for Oregon Marine Reserve Planning

Diversity and Habitat

The Oregon coast is home to a rich array of species, from seaweeds to invertebrates, fish and mammals – one of the richest areas of species diversity in cold waters around the world. Species of fish and invertebrates tend to be associated with particular habitats. Habitat may be defined by structure, depth, bottom-type, and currents or wave action. These abiotic (= non-living) factors have a strong influence on organisms that create habitat themselves, such as kelp, other seaweeds, and invertebrates that remain on the bottom – sea anemones, sponges, and coral-like animals. Because we have excellent descriptive data on the types of habitat and depths where species are found, we can confidently use each type of habitat to represent a list of species that are likely to be found there. Thus, as a "first cut" for evaluating the likely diversity of organisms found in a proposed reserve site, we can use the amount and diversity of habitat types found in an area.

The STAC recommended that the following habitat types be represented in Oregon marine reserves, based on available physical and biological data:

Intertidal

***Sandy or gravel beaches**
***Rocky intertidal and cliff**

Kelp forest

Soft bottom

***0-25 meters (0-82 feet)**
***greater than 25 meters (out to 3 miles)**

Hard bottom

***Low relief (0-25 m, 0-82ft)**
***High relief (0-25 m, 0-82 ft))**
***Low relief (over 25 m (82 ft) depth, out to 3 miles)**
***High relief (over 25 m (82 ft) depth, out to 3 miles)**

These categories are more general than those specified in California, and may warrant modification now that additional information on bottom types has been assembled with historical data (see "Seafloor mapping off the Oregon coast", Presentation 7, page 40).

More diversity of habitats and depths in an area will increase the chances that a larger number of species will utilize it. Scientists use "species-area curves" to determine the amount of area needed to encompass the diversity of organisms that occur in a given area or habitat. A species-area curve describes the percent of total possible species for a habitat that can be found in an "island" of increasing size. Species-area curves may be different for different habitats and can show us the minimum size of an area that would be required to find 80%, 90% or 95% of species that are associated with that habitat (Figures in the Data Summary, page 46-47). Data on the occurrence of species in an area or habitat can be obtained through visual surveys (SCUBA, remotely-operated vehicle video) or trapping methods that do not bias the sample by attracting fish from adjacent areas. There is an increase in the proportion of total species identified as sampling area increases, in square kilometers or linear kilometers. Optimally, these curves would be constructed for habitats in nearshore Oregon waters, and eventually, for specific sites proposed as reserves.

Because of these strong relationships between habitat, depth and species, reserve sites that include **multiple habitat types and depths are likely to encompass a larger number of species**. A smaller reserve with more diversity of habitat will probably include more species than a larger reserve over only one habitat-type. Species-area curves can help define the minimum area of a habitat-type required to be considered "protected" in a marine reserve.

Area size and home ranges of mobile species

The amount of space required to encompass most of the species that are commonly found in a particular habitat can be relatively small. However, the total amount of each habitat-type in a protected area will affect the total number of animals present in a site, as well as the chances that they will remain within the area for a long time period. The number of individuals protected from fishing by a reserve will depend on the maximum density that species will tolerate (how "crowded" they are willing to be) and how far individuals typically move. The abundance of fish species depends on the amount of fishing pressure and on the quality of the habitat, such as how much food or shelter is available there. The abundance of invertebrates may depend on the frequency of natural or human-caused habitat disturbance. Maximum densities of species that sit on the bottom can be estimated with survey data, but we do not have "unfished" areas at present to make reliable calculations of maximum densities that might be achieved in reserves. Maximum densities of mobile species are more difficult to obtain. All populations of plants, invertebrates, and fish are likely to vary over time in response to changes in their environment.

A "home range" is defined as the typical area that an individual animal will use for most of the year. It is not easy to get home range information for marine species, because this requires tagging and monitoring of individual animals. However, some data on fish movement rates are available for Oregon species, including recent work by ODFW on rockfishes. ODFW has also been compiling information on fish density in different habitats, based on video surveys with Remotely Operated Vehicles. The size of a marine reserve or protected area can be considered with the home range of different species in mind. In general, small reserves will protect fewer individuals and only those fished species that have small home ranges. **Larger reserves have potential to protect species with larger home ranges, and a larger number of individuals of a species.** Most nearshore species that have been studied extensively occur in rocky or hard bottom habitats. There are very few studies on movement rates of sandy and soft bottom species. **In general, it appears that soft bottom species are more mobile** (Table 2, page 51; Figures 32-33, page 51-53**).**

Many animals utilize more than one habitat type or depth, either seasonally or year-to-year. It is important to recognize that reserves in Oregon state waters, which typically include depths of 60m (30 fathoms) or less (Figure 30) will be home to some species during only part of the year or part of their life cycle (Table 3, page 55). "Ontogenetic shifts" are changes in habitat that individual animals make as they grow. In our nearshore environments, several species live in one habitat as small juveniles, another habitat as larger juveniles, and sometimes a third habitat as adults. Most groundfish, for example, move into deeper water as they grow. Black rockfish juveniles settle in estuaries and very shallow rocky areas, school in rockpiles in the summer, and often move to deeper rocky areas as they get larger. Juvenile crab and flatfish use estuaries as nursery areas and move into near shore, then deeper areas as they grow. Crabs also make seasonal migrations between shallow and deeper water. It is important to consider ontogenetic shifts and seasonal migrations in marine reserve planning, because it is unlikely that a single protected area would encompass all life stages of many, if not most, species. “Refuge areas” created by marine reserves or protected areas can reduce mortality risk for large juvenile or adult animals that are targets of fishing, even if those individuals do not reside in the reserve boundaries all the time. The effects on smaller fish or non-targeted species are likely to vary, and may depend on interactions with predators and prey.

Species Interactions

One of the primary goals of reserves is the protection of diversity across the biological community, which requires consideration of interactions among species. Predation and competition tend to reduce the productivity of one or all of the interacting species. Unharvested species may do well outside reserves and spill over to negatively affect competing or prey species inside reserves. Therefore, considering species interactions often leads to a requirement for larger reserves than might be predicted when considering a species in isolation. In addition, some species, particularly prey or competitors of harvested species, will likely decline after establishment of a reserve as part of the natural community response. Monitoring of a variety of species is therefore necessary to fully understand the response of entire biological community.

One example of potential species interactions in the context of Oregon reserves is the potentially negative effect of rockfish predators (e.g., lingcod, sea lions). Cascading effects of decreasing prey in response to increasing predators may occur if the predators are harvested before reserve establishment. However, the common tendency for fish predators to consume smaller individuals within a prey population reduces the likelihood of such prey biomass decreases in reserves, particularly when both the prey and predator are harvested before reserve establishment. Recent examination of lingcod diets off Oregon’s southern and central coasts suggest that rockfish are generally a small component of their diet, unlike the observed diets of lingcod in Puget Sound. Sea lion and harbor seal distribution and attraction of these predators to reserve areas will require monitoring, as the effects of these mammals on flatfish and rockfish may be substantial near their haulout sites.

Some combinations of species interactions may drive the existence of alternative community structures, where different sets of species may dominate a community (e.g., large top predators, scavengers or small forage species) and species interactions create positive feedback loops that help maintain each state over time. These types of changes in the communities of fish and invertebrates have been observed in some temperate (cold water) marine reserves. In these cases, a potential benefit of reserves is to enhance the resilience of the more ecologically natural and socioeconomically desirable state by providing a buffer against both natural and human disturbances.

Larval transport and connectivity – how many sites and how far apart?

The idea of multiple reserves and reserve “networks” stems from two principles: preserving multiple areas to hedge against uncertainty and environmental change, and spacing areas to promote “connectivity” through the transport of larvae or juveniles from one reserve to another.

Because of uncertainty in our understanding of nearshore ecosystems, and the variability in these environments caused by oceanography and climate, it is important to have some replication of protected habitats. This “avoid putting all of your eggs in one basket” strategy also enables adaptive management.

Bioregions are areas identified to have distinct physical and/or biological characteristics. Oceanographers and biologists studying genetics of fishes and the ranges of different species have identified the Columbia River and Cape Blanco as significant physical barriers affecting currents and the movement of various organisms; this supports option 3 of the three bioregion proposals considered by OPAC (Figure 31). The area south of Cape Blanco extends into Northern California, to Cape Mendocino. While it may be impossible to fully replicate the amount and types of habitat preserved in marine reserves within the two major bioregions, **hard- and soft-bottom habitats should be represented in reserves north and south of Cape Blanco** because there is a reduced chance of connectivity across that barrier.

In general, capes are important geological features that can concentrate or retain particles in the water column, including the eggs and larvae of nearshore organisms and the plankton that they feed on. Further research is needed to identify which capes have the largest effect on where and when larvae are transported to the nearshore environment. However, it is likely that prominent features such as the larger capes and some subsurface structures do affect the movement of larvae and the connectivity between populations of some organisms. Likewise, the large expanses of sandy bottom in the middle of our coast may reduce connectivity between rocky habitats north of Florence and south of Coos Bay.

Larvae released from a reserve will be dispersed up and down the coast. The length of time spent in the water column can affect the likelihood that a fish or invertebrate larva produced in one location will settle in another location. A number of transport models and studies of population genetics support the relationship between larval duration (the time spent moving in the currents as a larva) and distance travelled before settling to the bottom. However, this is very simplistic; variation in currents, temperature, and even larval behavior can influence the likelihood of connecting reserves through larval transport. Coastal oceanographers note that during some months of the year, a larva could be transported from Astoria to Bandon in a few days. Larvae with short pelagic larval durations, up to about one week, will tend to reseed reserves of 5-10 km (2.7 - 5.4 nm) size, while larvae with longer pelagic larval durations, for example around 30 days, will seed areas located greater than or equal to 25 km (13.5 nm) to either side of the reserve. Additional research is needed in existing reserve networks, such as those in California, and on the physical processes affecting our coastal currents before a strong recommendation for reserve spacing can be made based on connectivity of the reserves through larval transport. However, this does not negate the need for **multiple sites for each habitat type**, and the suggestion from California for **spacing of 50-100 km (27-54 nautical miles) apart** for each habitat type assures that reserves are distinct but potentially connected preservation areas.

Data summary for Oregon nearshore species

See also Appendix C – Life stages and habitats of Oregon Nearshore species, compiled by Cristen Don, ODFW

Species-area curves generated for Heceta Bank and CA nearshore

Methods for Heceta Bank Species-Area Curves

Provided by Brian Tissot, WSU Vancouver

Data were collected from observations made during 27 dives using the ROV ROPOS on Heceta Bank, OR in June of 2000 and 2001. Both fishes and megafaunal invertebrates were enumerated at 22 survey sites across the bank within habitat patches at 70-400 m (230-1312 feet) depths. Only taxa that could be identified to the species level (fishes and most invertebrates), or to single taxa within a genus or family (some invertebrates) were used in the analysis. A total of 23,758 fishes from 40 species were observed over a linear distance of 48.4 k and an area of 73.6 hectares; 236,762 invertebrates from 27 species were observed over 35.2 k and 54.8 h. Species-area curves were calculated with PRIMER software by using 300 random permutations of sample ordering. Cumulative species curves were plotted against average habitat patch distance and fitted using a power function to estimate the minimum distance needed to account for 90% and 95% of all species, respectively. ***Note that this analysis is for areas outside of OR State waters, and additional work is needed to accurately translate transect information to square area.***

Figure 27. Invertebrate species-area curves generated for Heceta Bank.

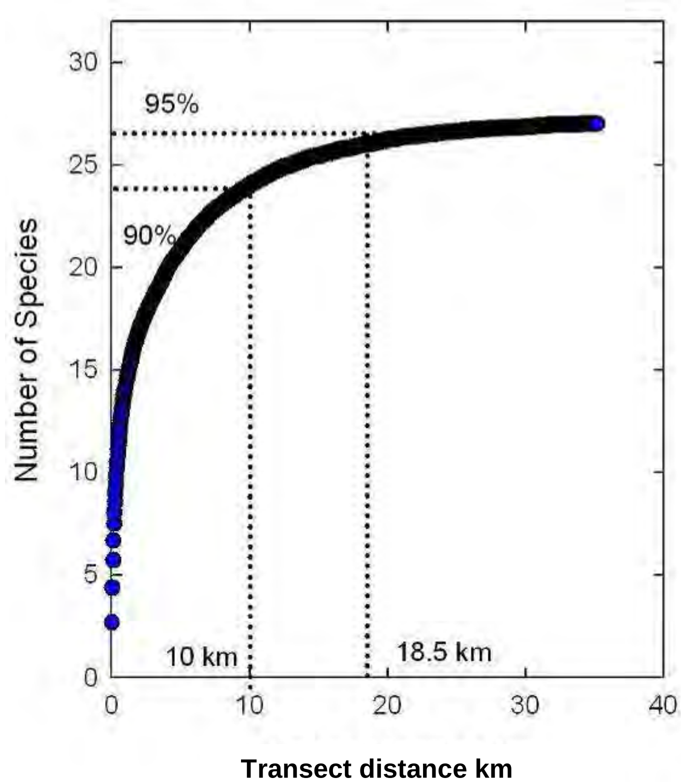


Figure 28. Fish species-area curves generated for Heceta Bank.

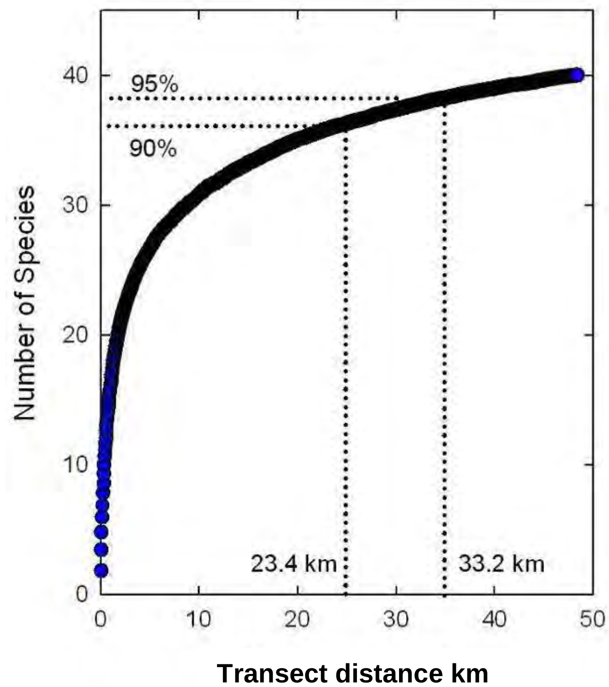


Figure 29. Species-area curves generated for different nearshore habitats in California used by the Science Advisory Team to set minimum habitat areas for representation in MPAs.

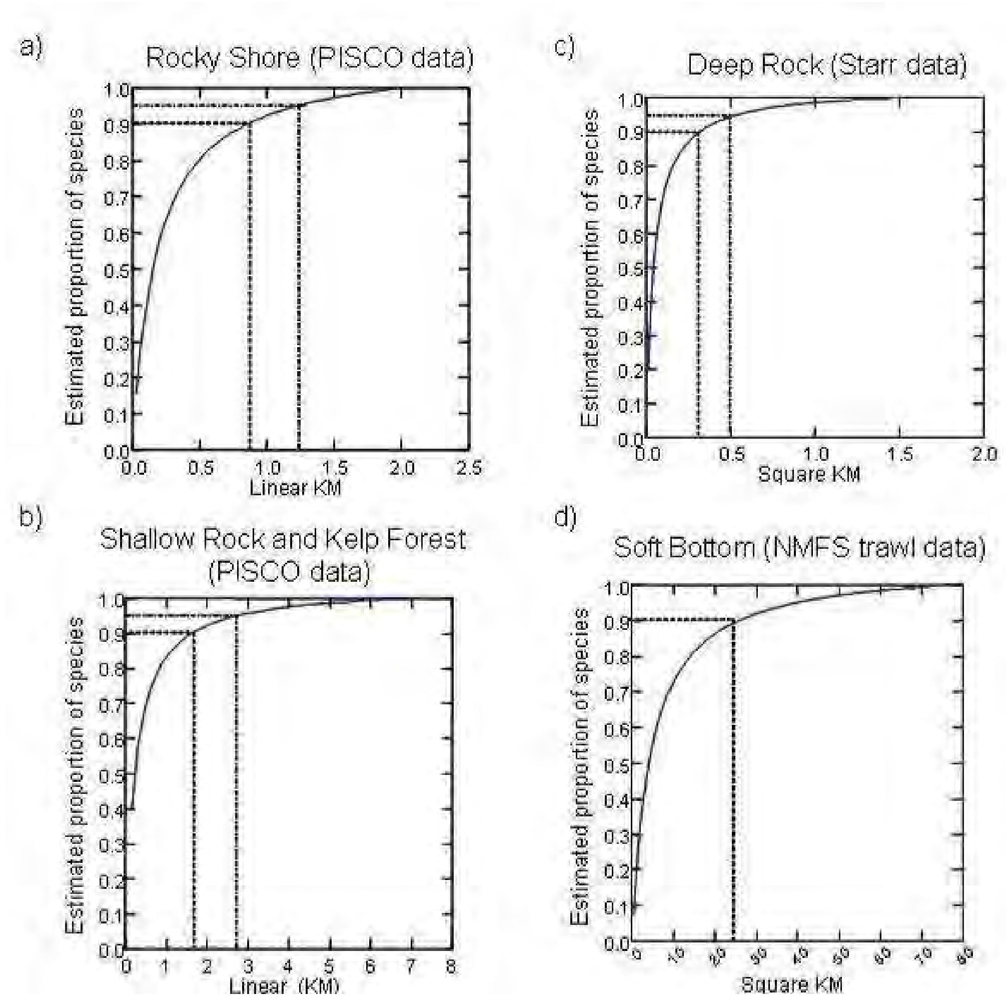


Table 1. California guidelines on the amount of habitat in an MPA necessary to encompass 90% of local biodiversity.

PISCO = Partnership for Integrated Study of the Coastal Ocean.

Habitat	Representation needed to encompass 90% of biodiversity	Data Source
Rocky Intertidal	~0.5 linear miles	PISCO Biodiversity studies
Shallow Rocky Reefs/Kelp Forests (depth 0-30 meters, 0-98 feet)	~1 linear miles	PISCO Subtidal studies
Deep Rocky Reefs (depth 30-100 m, 98-328 ft)	~0.1 square miles	Starr surveys (CDFG/CA SeaGrant)
Sandy Habitat (depth 30-100 m, 98-328 ft)	~10 square miles	NMFS triennial trawl surveys 1977-2007
Sandy Habitat (depth 0-30 m, 0-98ft)	~1 linear miles	Based on shallow rocky reefs

Depths, bioregions and habitats of Oregon's nearshore

Figure 30. Bathymetry and location of the Territorial Sea (3 mile limit) for nearshore Oregon. Figure also shows location of major hard structure. From ODFW Nearshore Strategy, http://www.dfw.state.or.us/MRP/nearshore/index.asp.

Nearshore and offshore rock substrate as interpreted by sidiescan sonar imagery (Chris Goldfinger, Oregon State University) and bull kelp aerial surveys (1990, ODFW).

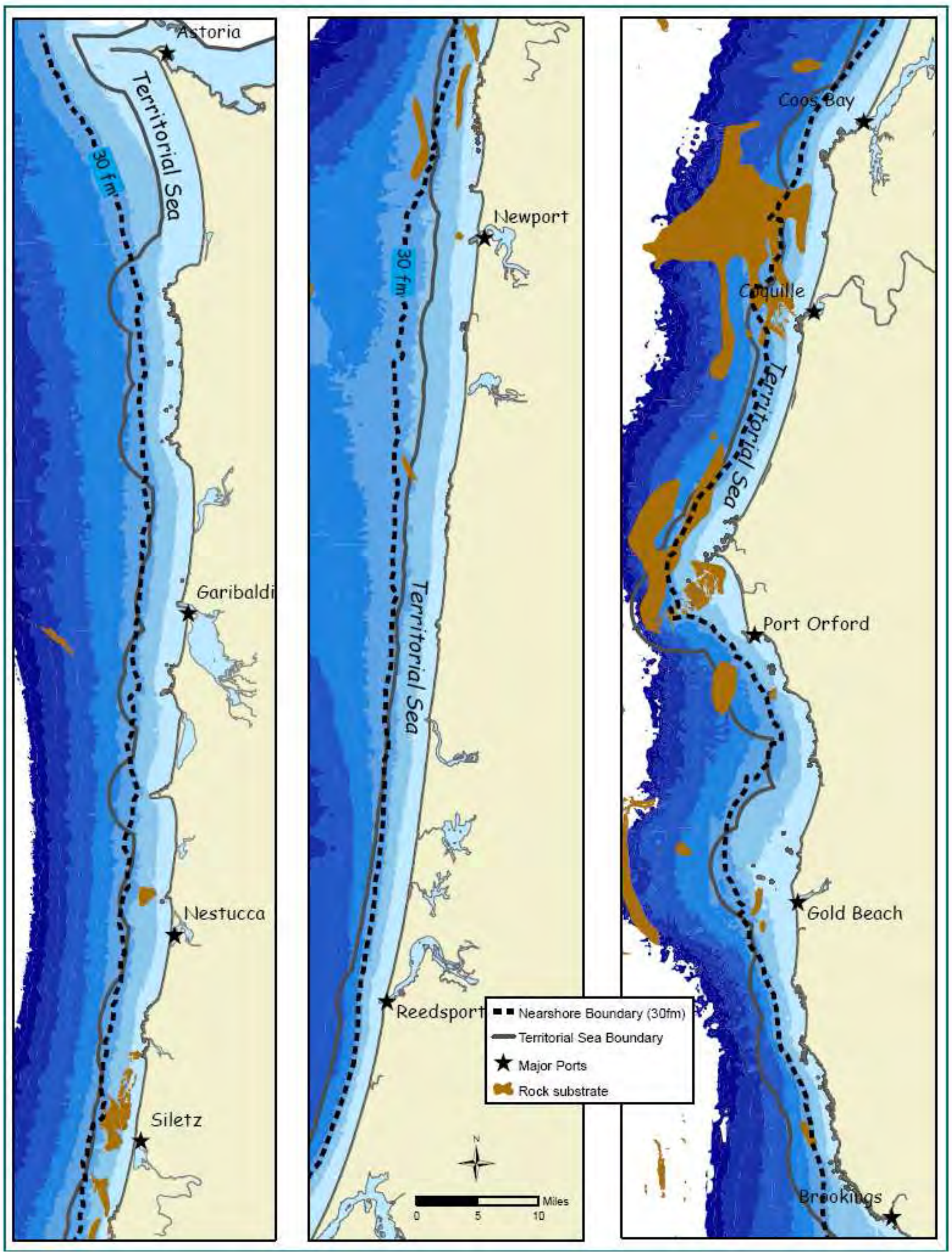
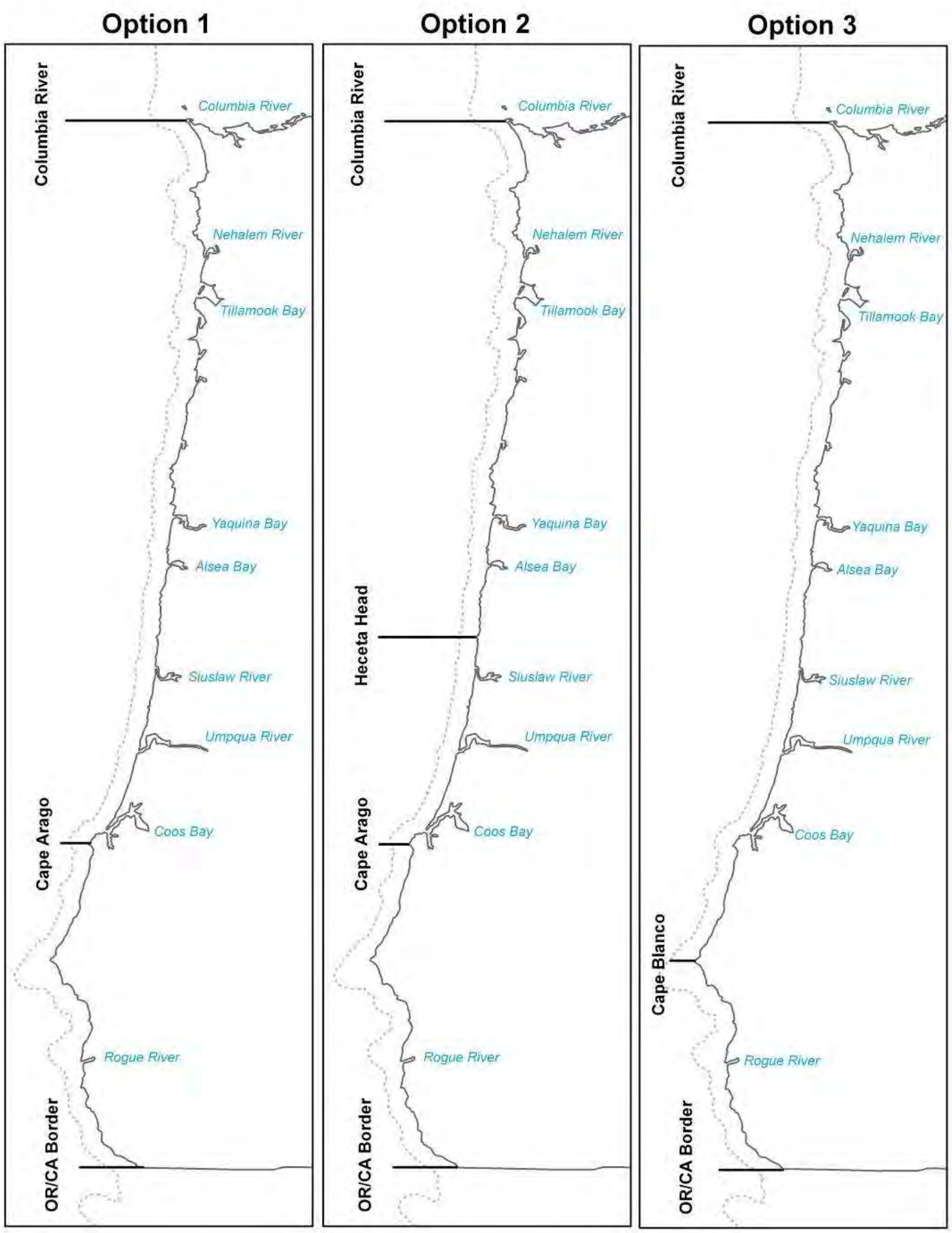


Figure 31. Preferred bioregion options presented to OPAC.

Option 3 is supported by workshop attendees, who note that the region south of Cape Blanco extends into Northern California.



Home range and typical depth information – Oregon species

Table 2. Oregon nearshore species "home range" estimates. This table is modified from the California Marine Life Protection Act Guidelines to include only Oregon species. "Home range" refers to typical movement by adults; larval dispersal or juvenile movement may be greater.1 km = 0.54 nautical miles, 0.62 statute miles

0-1 km	1-10 km	10-100 km	100-1000 km	> 1000 km
Invertebrates	**Invertebrates**	**Invertebrates**	**Invertebrates**	**Invertebrates**
abalone, barnacle, mussel, clams, sea stars, snails, red and purple urchin, sponges	octopus	Dungeness crab**, red/brown/sand crab, prawns, sea cucumber		jumbo squid**
Rockfishes	**Rockfishes**	**Rockfishes**	**Rockfishes**	
black and yellow, brown, gopher, grass*, quillback	China, copper, vermillion, yelloweye	Black, blue	canary	
Other Fishes	**Other fishes**	**Other fishes**	**Other fishes**	**Other fishes**
cabezon, eels, greenlings, striped and pile surfperch, pricklebacks	walleye surfperch	starry flounder, lingcod, yellowtail, sculpin, English and rock sole, redtail surfperch, giant wrymouth	anchovy, big skate, herring, Pacific halibut, salmonids**, sole spp, sturgeon	sardine, sharks**, tunas**, whiting**

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

(next page)

Figure 32. Plot of Oregon nearshore species arranged by typical depth and adult movement rates – rock and hard-bottom species.

Names in **bold** denote commonly fished or collected species. RF = rockfish. Figures prepared by S. Heppell, Oregon State University Department of Fisheries and Wildlife with assistance from H. Reiff , K. Thomas, and K. Thompson; reference list available on request; some movement rates are based on limited study.

Rock, hard bottom, structure

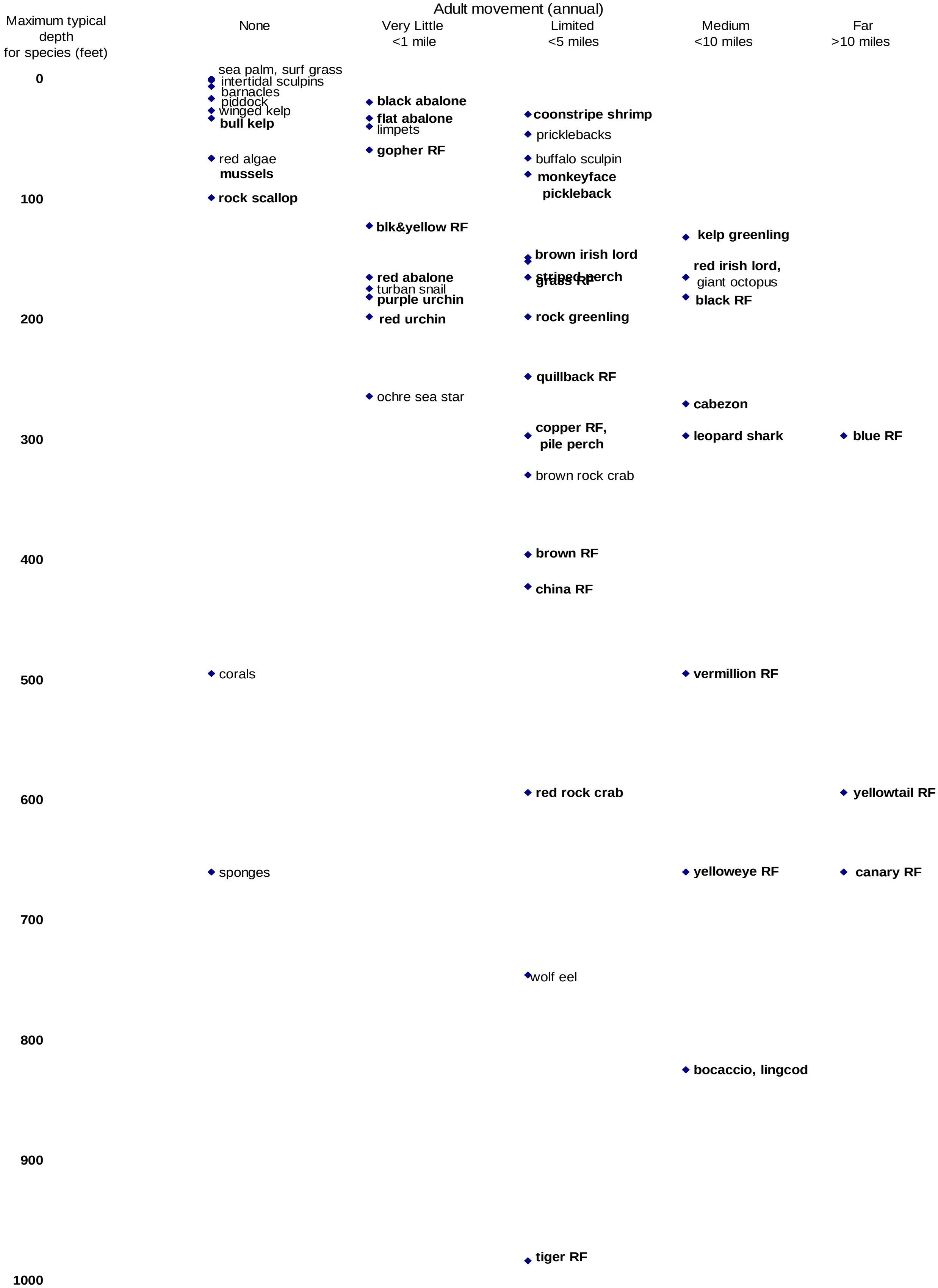


Figure 33. Plot of Oregon nearshore species arranged by typical depth and adult movement rates - Sand and soft-bottom species.

Names in **bold** denote commonly fished or collected species. Figures are based on preliminary analysis of available data prepared by S. Heppell, Oregon State University Department of Fisheries and Wildlife with assistance from H. Reiff , K. Thomas, and K. Thompson; reference list available on request.

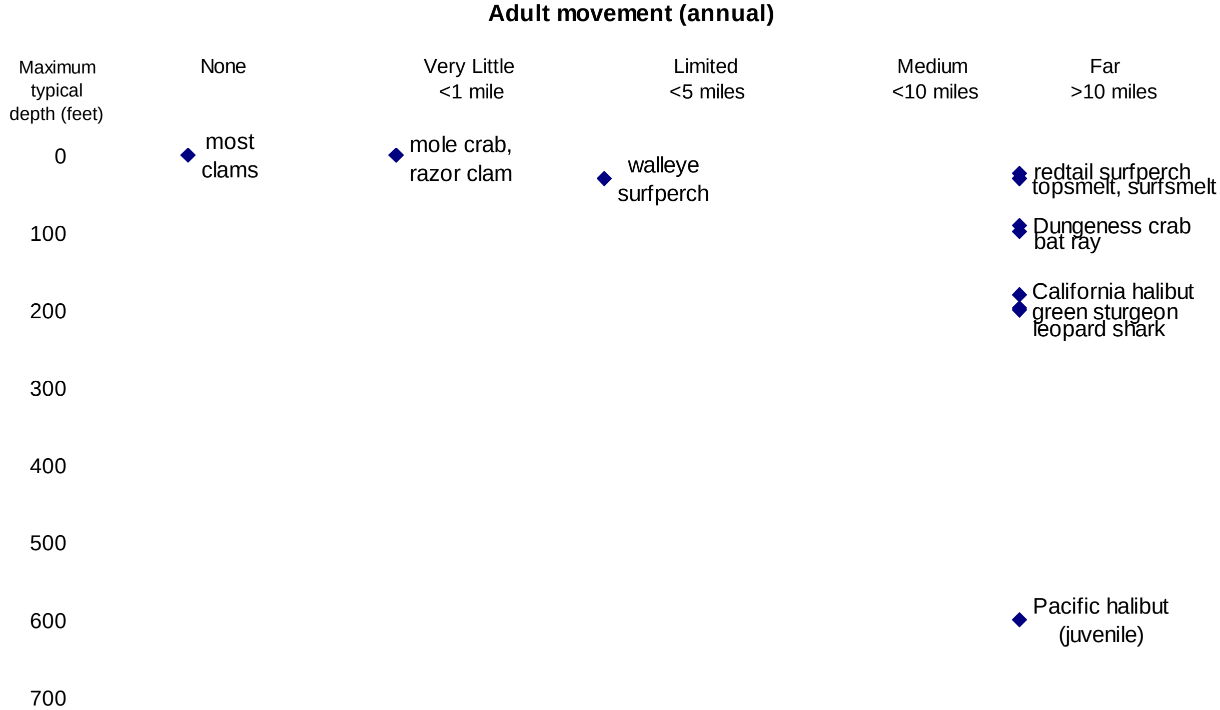


Table 3. Oregon nearshore strategy species categorized by time or life stage spent in nearshore waters.

Information is not available for all species, and this table should be considered preliminary until additional synthesis of biological data is complete. Prepared by C. Don, Oregon Department of Fish and Wildlife; species list based on ODFW Nearshore Strategy, www.dfw.state.or.us/MRP/nearshore/index.asp

Residency in nearshore waters (< 60 meters)	**Categories:** 1 - Full time resident 2 - Seasonal resident/migrant 3 - Juvenile resident 4 - Occasional resident (range mostly includes deeper waters) 5 - Occasional migrant (e.g., pelagic)	
Species	**Category**	**Comments**
abalone, black	1	Current and historic occurrence in Oregon (south coast) uncertain.
abalone, flat	1	
abalone, red	1	Southern Oregon (Cape Argo) northern extent of species range. Do not mate at northern end of range.
algae, red	1	
anchovy, northern	2	
barnacles, gooseneck	1	
Cabezon	1	Small juveniles mixed nearshore and offshore waters.
clam, littleneck (tomales bay cockle)	1	
clam, razor	1	
corals	1	
crab, brown rock	1, 3	Unknown whether makes seasonal migrations.
crab, dungeness	1, 2, 4	
crab, red rock	1, 3	Unknown whether makes seasonal migrations.
crab, sand (mole)	1	
dogfish, spiny	5	North-south and on-shore offshore movements
eel, wolf	1	
elephant seal, northern	2	
eulachon	2	Spawning occurs in freshwater.
flounder, starry	1, 2	Adults move inshore in winter and spring and offshore come summer.
greenling, kelp	1	Adults not a migratory species. Newly hatched larvae move out of estuaries or shallow nearshore into open waters.
greenling, rock	1	
halibut, California	1	May use bays and estuaries as nursery grounds.
herring, Pacific	2	Spawning grounds are typically in sheltered inlets, sounds, bays, and estuaries rather than along open coastlines.
kelp, bull	1	
kelp, winged	1	
lance, pacific sand	1	No spawning migrations have been observed; however, offshore-onshore movements occur before spawning in the fall (Robards et al. 1999)
limpets	1	
lingcod	1, 3	Unclear whether most adults make extensive migrations.
lord, red irish	1	
mussels, native	1	
octopus, giant	1	Inshore migration for mating, no along shore migrations.
other intertidal algal species	1	
piddock, flap-tipped	1	
porpoise, harbor	3, 5	
prawn, spot	1	

Residency in nearshore waters (< 60 meters)	**Categories:** 1 - Full time resident 2 - Seasonal resident/migrant 3 - Juvenile resident 4 - Occasional resident (range mostly includes deeper waters) 5 - Occasional migrant (e.g., pelagic)	
Species	**Category**	**Comments**
prickleback, monkeyface	1	
prickleback, rock	1	
ratfish, spotted	4	
ray, bat	5	
rockfish, black	1	Juveniles in estuaries and intertidal
rockfish, black-and-yellow	1	Southern Oregon is northern extent of species range. Reproduction not known to occur in Oregon.
rockfish, blue	1, 3	9-18m depth for juveniles
rockfish, bocaccio	3	Move into deeper water with size and age. 18-30m typical depth for juveniles
rockfish, brown	1, 3	Adults mixed nearshore and offshore (to 135 m). Juveniles move into deeper water as they mature.
rockfish, canary	3	Juveniles as shallow as intertidal
rockfish, chilipepper	3	Nearshore -300m juveniles
rockfish, china	1	
rockfish, copper	1, 3	May move inshore to release young. Little movement once settled.
rockfish, darkblotched	3	55-200m depth for juveniles
rockfish, gopher	1	Southern Oregon (Cape Blanco) northern extent of specie range. Parturition not known to occur in Oregon.
rockfish, grass	1	Central Oregon (Yaquina Bay) is northern extent of species range.
rockfish, greenstriped	3	40m depth for juveniles
rockfish, Pacific ocean perch	3	0-37m depth for juveniles
rockfish, pygmy	3	44-200m depth for juveniles
rockfish, quillback	1, 3	20-60m depth for juveniles
rockfish, silvergray	3	20m depth for juveniles
rockfish, splitnose	3	Juveniles only in nearshore depths
rockfish, squarespot	3	30m juveniles only; adults deeper
rockfish, stripetail	3	15m juveniles only; adults much deeper
rockfish, tiger	1,3	10 m depth for juveniles
rockfish, vermillion	3	6-36m depth for juveniles
rockfish, yelloweye	3, 4	Adults generally in deeper water
rockfish, yellowtail	3, 4	Juveniles as shallow as intertidal; adults much deeper
rockfish, widow	3	10-140m depth for juveniles
sanddab, Pacific	2, 3	Inshore migration during summer. Unknown whether makes along-coast movements.
sardine, Pacific	5	
scallop, rock	1	
sculpin, buffalo	1	
sculpin, Pacific staghorn	1	Mostly estuaries
sea cucumber, CA	1	
sea lion, California	2	
sea lion, Steller	2	
sea palm	1	
Sea star, ochre	1	
sea stars	1	

Residency in nearshore waters (< 60 meters)	**Categories:** 1 - Full time resident 2 - Seasonal resident/migrant 3 - Juvenile resident 4 - Occasional resident (range mostly includes deeper waters) 5 - Occasional migrant (e.g., pelagic)	
Species	**Category**	**Comments**
seal, harbor	1	
shark, blue	5	
shark, brown smoothhound	5	
shark, leopard	1	
shark, Pacific angel	4	
shark, salmon	5	
shark, shortfin mako	5	
shark, soupfin	5	
shark, white	5	
shrimp, coonstripe/dock	1	
skate, big	3, 4	
smelt, surf	1	
smelt, top-	1	Spawning occurs in estuaries.
snail, turban	1	
sole, butter	2, 4	Mature fish move inshore to spawn (Love 1996).
sole, English	2, 3	
sole, flathead	2	Adults migrate from deep waters in the winter to shallow waters in spring and early summer.
sole, rock	2, 3	Adults move to deeper waters in winter to spawning grounds, and shallower waters to feed in summer. Move into deeper water with increased size.
sole, sand	2, 3, 4	May move into shallow nearshore waters in early winter to spawn, then south and offshore in summer to feed. Move to deeper waters with increased size and age.
squid, market	2	Juveniles are carried from the spawning grounds by currents and adults move inshore to spawn.
sturgeon, green	2	Highly migratory up and down the coast. Spawns in freshwater.
sturgeon, white	2	Spawns in freshwater. Not usually any along shore migration.
surfperch, calico	1	
surfperch, pile	1	Estuaries and nearshore
surfperch, redtailed	1	Seasonal movement to estuaries for reproduction; >20 mile tag recoveries; Cape Arago a possible dispersal barrier
surfperch, shiner	1	Estuaries and nearshore
surfperch, striped	1	
surfperch, walleye	1	
surfperch, white	1	
thresher, common	5	
triton, Oregon	1	
turbot, Curlfin	4	
urchin, purple	1	
urchin, red	1	
whale, gray	2	

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*Species and habitat database

Appendix A: Bibliographies

A list of species reference papers can be obtained from the authors (Selina.Heppell@oregonstate.edu) and through the ODFW website on the Nearshore Strategy

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Appendix B: Size and Spacing Meeting Information

Meeting Agenda

Final Agenda (updated 04/10/08)

April 9 (Wednesday) EVENING SOCIAL starts at 7pm in the Dining Hall

Day 1 Thursday, April 10
Breakfast in the Dining Hall and coffee provided

8:30 am Welcome, Introductions and Overview of our task at hand

Welcome to OIMB	Craig Young, OIMB
OPAC process: how we got here	Greg McMurray, OPAC
STAC roles and current requests from Marine Reserves Working Group	Selina Heppell, OSU
Review of draft goals and objectives approved by OPAC Work Plan for this meeting	Jack Barth, OSU

Questions, discussion

BREAK to load presentations

9:30 am Short presentations – please limit to 20 minutes

Review of the "rules of thumb" developed for reserve siting in CA	Rick Starr, Moss Landing Marine Lab and Mark Carr, UCSC
Review of theoretical approaches	Will White, UCDavis
Review of data on invertebrates and larval dispersal	Alan Shanks and Craig Young, U Oregon
Review of available data and maps	
Physical oceanography: chemistry, currents and dispersion models	Mike Kosro and Hal Batchelder, OSU
Fine-scale habitat mapping and species associations	Dave Fox, ODFW
Habitat Maps	Chris Goldfinger, OSU

LUNCH at OIMB
2pm – Work Session begins

Issue #1: Size and configuration?

- Review of existing synthesis documents on relationship between reserve size and biological response – what responses can be expected for reserves of different size?
- Review available data on home range, movement of adults and juveniles of local species
- Review habitat types and maps, discuss need to extend shore-based reserves to deeper water
- Discuss approaches, recommendations that can be made with existing data, certainty of those recommendations, and what additional synthesis or research could be done over the short- and longer-term

BREAK

Issue #2: Spacing?

- Review data and theory on network concepts, connectivity
- Review dispersal information, habitat distribution, and physical oceanography of the Oregon coast
- Discuss approaches, recommendations that can be made with existing data, certainty of those recommendations, and what additional synthesis or research could be done over the short- and longer-term

Additional discussion as needed. Break around 5:30.

DINNER at OIMB 6:30 pm

Day 2 Friday, April 11
Breakfast in the Dining Hall and coffee provided

8:30 am Synthesis: Matching Oregon's objectives to what we know

- What can be recommended, based on available information?
- Is there short-term (< 1 year) data gathering or synthesis that could contribute?
- How do size and spacing recommendations vary according to goals and objectives?
- Develop consensus statements for report to OPAC

BREAK

Continue Synthesis Discussion and outline report to OPAC
Next Steps

Conclusion of the Workshop – noon on April 11.

Workshop request memo from OPAC to STAC

MEMO

DATE: April 4, 2008

TO: STAC

FROM: OPAC Marine Reserves Working Group

SUBJECT: Request for information on size, spacing and other attributes of marine reserves in Oregon's Territorial Sea.

The MRWG is requesting the STAC to recommend guidelines for the marine reserve nomination process based on available biological and ecological data at your next planned workshop. In recognition of the limited time available before the nomination process for marine reserves, the MRWG requests the STAC provide their best guidance on the following questions:

- How do we identify "special places" in nearshore Oregon, such as biodiversity hotspots, unique habitat features etc. using available habitat maps and biological information.

- What guidelines should we use for minimum size and spacing for reserves (i.e. networks or systems) to meet our stated goals and objectives, and what is the relationship between reserve properties (size, configuration, habitat-types, depths) and the likelihood of meeting those objectives?

- What research data is available and what is known and not known with respect to physical, biological and ecological information that contributes to these recommendations?

- Can you provide us with other supporting information which the STAC considers relevant for the placement of marine reserves, development of coastwide reserve planning guidelines, or evaluation of publicly nominated sites?

List of Meeting Participants and Contact Information

Participants

	Name	e-MAIL ADDRESS	Affiliation
1	Satie Airame	airame@msi.ucsb.edu	Channel Islands Marine Sanctuary, PISCO
2	Jack Barth	barth@coas.oregonstate.edu	OSU Oceanography, STAC
3	Marissa Baskett	mbaskett@nceas.ucsb.edu	UC Davis Ecology
4	Hal Batchelder	hbatchelder@coas.oregonstate.edu	OSU Oceanography
5	Ric Brodeur	Rick.Brodeur@noaa.gov	NW Fisheries Science Center
6	Mark Carr	carr@biology.ucsc.edu	UC Santa Cruz, PISCO
7	Lorenzo Ciannelli	lciannelli@coas.oregonstate.edu	OSU Oceanography
8	Michael Donnellan	michael.d.donnellan@state.or.us	ODFW
9	Jeff Feldner	jeff.feldner@oregonstate.edu	OR Sea Grant, STAC
10	Dave Fox	David.S.Fox@state.or.us	ODFW
11	Chris Goldfinger	gold@coas.oregonstate.edu	OSU Oceanography
12	Kirstin Grorud--Colvert	grorudck@science.oregonstate.edu	OSU PISCO
13	Don Gunderson	dgun@u.washington.edu	UW Fisheries
14	Selina Heppell	selina.heppell@oregonstate.edu	OSU Fisheries, STAC
15	Mark Hixon	hixonm@science.oregonstate.edu	OSU Zoology
16	Mike Kosro	kosro@coas.oregonstate.edu	OSU Oceanography
17	Mike Lane	no e-mail	Reedsport Fisherman
18	Aaron Longton	alongton@harborside.com	Port Orford Fisherman
19	Scott McMullen	smcmullen@ofcc.com	Astoria Fisherman, OPAC
20	Greg McMurray	gregory.mcmurray@state.or.us	DLCD, OPAC
21	Jessica Miller	Jessica.Miller@oregonstate.edu	OSU Fisheries
22	Jay Rasmussen	jay.rasmussen@oregonstate.edu	OR Sea Grant, OPAC, STAC
23	Gil Rilov	rilovg@science.oregonstate.edu	OSU PISCO
24	Steve Rumrill	steve.rumrill@dsl.state.or.us	South Slough National Estuarine Research Reserve
25	Alan Shanks	ashanks@darkwing.uoregon.edu	U of Oregon Ecology
26	Rick Starr	starr@mlml.calstate.edu	CA Sea Grant
27	Brian Tissot	tissot@vancouver.wsu.edu	Washington State U. Ecology
28	Craig Young	cmyoung@uoregon.edu	U of Oregon Ecology
29	Waldo Wakefield	waldo.wakefield@noaa.gov	NW Fisheries Science Center
30	Will White	jwwhite@ucdavis.edu	UC Davis Ecology
	Support Staff		
31	Laurel Hillman	Laurel.Hillmann@state.or.us	Oregon State Parks
32	Andy Lanier	Andy.Lanier@state.or.us	DCLD
33	Heather Reiff	hreiff@coas.oregonstate.edu	OSU and DCLD
34	Emily Saarman	emily@biology.ucsc.edu	PISCO
35	Kayla Thomas	thomas.kayla@gmail.com	OSU

Appendix C: List of Oregon nearshore species (mostly fishes) and their habitats

Prepared by C. Don, Oregon Department of Fish and Wildlife; species list based on ODFW Nearshore Strategy, http://www.dfw.state.or.us/MRP/nearshore/index.asp

				Habitat Type(s)									
	Common Name	**Scientific Name**	**Life History Stage**	**Hard Bottom Subtidal (no kelp)**	**Hard Bottom Subtidal (with kelp)**	**Soft Bottom Subtidal**	**Pelagic**	**Estuarine**	**Rocky Intertidal**	**Soft Bottom Intertidal**	**Habitat Unknown**	**Predominately Nearshore, Offshore, or Mixed?**	**Habitat Notes**
1	**Big skate**	*Raja binoculata*	Adults			**x**						mixed	
			Juveniles			**x**						nearshore	
			Lg Juveniles	**na**	**na**	**na**	**na**	**na**	**na**	**na**	**na**	na	
			Larvae	**na**	**na**	**na**	**na**	**na**	**na**	**na**	**na**	na	
2	**Black rockfish**	*Sebastes melanops*	Adults	**x**	**x**		**x**	**x**				nearshore	High-relief rocky reefs. Boulder fields. Midwater.
			Juveniles	**x**	**x**	**x**	**x**	**x**	**x**			nearshore	Nearshore sand-rock interface. High rock. Seagrass beds. Midwater. Tidepools.
			Lg Juveniles	**x**	**x**	**x**	**x**	**x**	**x**			nearshore	
			Larvae				**x**					mixed	
3	**Black-and-yellow rockfish**	*Sebastes chrysomelas*	Adults	**x**	**x**	**x**						nearshore†	† Species does not occur throughout Oregon (Cape Blanco northern extent of range). Spawning not known to occur in Oregon waters.
			Juveniles	**x**	**x**	**x***			**x**			nearshore†	* Not known to occur over soft bottom habitats in Oregon waters.
			Lg Juveniles	**x**	**x**	**x**						nearshore†	
			Larvae		**x***		**x***					*	* Not known to occur in Oregon waters.
4	**Blue rockfish**	*Sebastes mystinus*	Adults	**x**	**x**							mixed	
			Juveniles	**x**	**x**		**x**		**x**			nearshore	
			Lg Juveniles	**x**	**x**	**x**						nearshore	
			Larvae				**x**					nearshore	
5	**Bocaccio**	*Sebastes paucispinis*	Adults	**x**	**x**	**x**						offshore	
			Juveniles	**x**	**x**	**x**	**x**	**x**				nearshore	
			Lg Juveniles	**x**	**x**	**x**						mixed	
			Larvae				**x**	**x**				mixed	

				Habitat Type(s)									
	Common Name	**Scientific Name**	**Life History Stage**	**Hard Bottom Subtidal (no kelp)**	**Hard Bottom Subtidal (with kelp)**	**Soft Bottom Subtidal**	**Pelagic**	**Estua-rine**	**Rocky Inter-tidal**	**Soft Bottom Inter-tidal**	**Habitat Un-known**	**Predom-inately Nearshore, Offshore, or Mixed?**	**Habitat Notes**
6	**Brown rockfish**	*Sebastes auriculatus*	Adults	**x**	**x**			**x**				mixed	
			Juveniles	**x**	**x**			**x**				nearshore	
			Lg Juveniles	**na**	**na**	**na**	**na**	**na**	**na**	**na**	**na**	na	
			Larvae					**x**					
7	**Bull kelp**	*Nereocystis luetkeana*	Adults		**x**							nearshore	
			Juveniles	**na**	**na**	**na**	**na**	**na**	**na**	**na**	**na**	na	
			Lg Juveniles	**na**	**na**	**na**	**na**	**na**	**na**	**na**	**na**	na	
			Larvae	**na**	**na**	**na**	**na**	**na**	**na**	**na**	**na**	na	
8	**Cabezon**	*Scorpaenichthys marmoratus*	Adults	**x**				**x**				nearshore	
			Juveniles	**x**	**x**		**x**	**x**	**x**			mixed	
			Lg Juveniles	**x**				**x**				nearshore	
			Larvae				**x**	**x**				mixed	
9	**California mussel**	*Mytilus californianus*	Adults	**x**					**x**			nearshore	Rock. Exposed. Attached. Located in high wave energy areas.
			Juveniles	**x**					**x**			nearshore	
			Lg Juveniles	**na**	**na**	**na**	**na**	**na**	**na**	**na**	**na**	na	
			Larvae				**x**						
10	**California sea lion**	*Zalophus californianus*	Adults	**x**	**x**		**x**	**x**	**x**	**x**		nearshore	Only males found in Oregon. Haul-out on land and man made structures. California sea lions do not breed in Oregon.
			Juveniles	**x***	**x***		**x***		**x***	**x***		*	* Do not occur in Oregon (pups stay with females).
			Lg Juveniles	**x**	**x**		**x**		**x**	**x**			
			Larvae	**na**	**na**	**na**	**na**	**na**	**na**	**na**	**na**	na	
11	**Canary rockfish**	*Sebastes pinniger*	Adults	**x**								offshore	
			Juveniles	**x**	**x**	**x**	**x**		**x**			mixed	Sand, mud, and gravel. Low rock and cobble.
			Lg Juveniles	**x**								mixed	
			Larvae				**x**					mixed	

				Habitat Type(s)									
	Common Name	**Scientific Name**	**Life History Stage**	**Hard Bottom Subtidal (no kelp)**	**Hard Bottom Subtidal (with kelp)**	**Soft Bottom Subtidal**	**Pelagic**	**Estua-rine**	**Rocky Inter-tidal**	**Soft Bottom Inter-tidal**	**Habitat Un-known**	**Predom-inately Nearshore, Offshore, or Mixed?**	**Habitat Notes**
12	**China rockfish**	*Sebastes nebulosus*	Adults	**x**								nearshore	Rock and cobble.
			Juveniles	**x**			**x**					nearshore	
			Lg Juveniles	**na**	**na**	**na**	**na**	**na**	**na**	**na**	**na**	na	
			Larvae				**x**					nearshore	
13	**Copper rockfish**	*Sebastes caurinus*	Adults	**x**	**x**			**x**				nearshore	
			Juveniles		**x**	**x**	**x**	**x**				nearshore	Seagrass. Low growing algae. Rock and cobble. High-relief rock. Sand and low rock.
			Lg Juveniles	**x**	**x**			**x**				nearshore	
			Larvae					**x**					
14	**Dungeness crab**	*Cancer magister*	Adults			**x**		**x**		**x**		mixed	Sand. Occasionally mud. Eelgrass.
			Juveniles			**x**		**x**		**x**		mixed	Sand, mud. Eelgrass.
			Lg Juveniles	**na**	**na**	**na**	**na**	**na**	**na**	**na**	**na**	na	
			Larvae				**x**					mixed	Upper 20 m of water column. Larvae are carried offshore by surface currents during late winter and spring.
15	**Eulachon**	*Thaleichthys pacificus*	Adults				**x**	**x**			**x**		Anadromous.
			Juveniles				**x**				**x**		
			Lg Juveniles	**na**	**na**	**na**	**na**	**na**	**na**	**na**	**na**	na	
			Larvae				**x**	**x**			**x**		Carried downstream and out to sea.
16	**Flat abalone**	*Haliotis walallensis*	Adults		**x**				**x**			nearshore	Kelp. Rocky reefs.
			Juveniles		**x**				**x**			nearshore	Crevices. Rocky reefs, rocks, boulders.
			Lg Juveniles	**na**	**na**	**na**	**na**	**na**	**na**	**na**	**na**	na	
			Larvae				**x**					nearshore	
17	**Giant octopus**	*Octopus dofleini*	Adults	**x**		**x**			**x**			nearshore	Prefer rocky substrates. Rock, sand, mud.
			Juveniles				**x**					nearshore	
			Lg Juveniles	**x**					**x**			nearshore	Rocks, crevices, rocky substrate.
			Larvae	**na**	**na**	**na**	**na**	**na**	**na**	**na**	**na**	na	

				Habitat Type(s)									
	Common Name	**Scientific Name**	**Life History Stage**	**Hard Bottom Subtidal (no kelp)**	**Hard Bottom Subtidal (with kelp)**	**Soft Bottom Subtidal**	**Pelagic**	**Estua-rine**	**Rocky Inter-tidal**	**Soft Bottom Inter-tidal**	**Habitat Un-known**	**Predom-inately Nearshore, Offshore, or Mixed?**	**Habitat Notes**
18	**Gopher rockfish**	*Sebastes carnatus*	Adults	**x**	**x**	**x**						nearshore†	† Species does not occur throughout Oregon (Cape Blanco northern extent of range). Spawning not known to occur in Oregon waters.
			Juveniles	**x**	**x**	**x**	**x***		**x**			nearshore†	* Pelagic juveniles not known to occur in Oregon waters.
			Lg Juveniles	**na**	**na**	**na**	**na**	**na**	**na**	**na**	**na**	na	
			Larvae		**x***		**x***					*	* Not known to occur in Oregon waters.
19	**Grass rockfish**	*Sebastes rastrelliger*	Adults	**x**	**x**							nearshore†	† Species does not occur throughout Oregon (Yaquina Bay northern extend of range).
			Juveniles	**x**	**x**	**x**			**x**			nearshore†	Low growing algae. Tidepools.
			Lg Juveniles	**na**	**na**	**na**	**na**	**na**	**na**	**na**	**na**	na	
			Larvae				**x**						
20	**Gray whale**	*Eschrichtius robustus*	Adults		**x**	**x**	**x**	**x***				nearshore	* Breeding occurs in bays in Baja.
			Juveniles			**x**	**x**	**x***				nearshore	* Breeding occurs in bays in Baja.
			Lg Juveniles	**na**	**na**	**na**	**na**	**na**	**na**	**na**	**na**	na	
			Larvae	**na**	**na**	**na**	**na**	**na**	**na**	**na**	**na**	na	
21	**Green sturgeon**	*Acipenser medirostris*	Adults			**x**		**x**			**x**	nearshore	
			Juveniles					**x**				nearshore	Migrate to sea during second year.
			Lg Juveniles	**na**	**na**	**na**	**na**	**na**	**na**	**na**	**na**	na	
			Larvae										Freshwater rivers.
22	**Harbour porpoise**	*Phocoena phocoena*	Adults			**x**	**x**				**x**	mixed	
			Juveniles				**x**				**x**		
			Lg Juveniles	**na**	**na**	**na**	**na**	**na**	**na**	**na**	**na**	na	
			Larvae	**na**	**na**	**na**	**na**	**na**	**na**	**na**	**na**	na	
23	**Kelp greenling**	*Hexagrammos decagrammus*	Adults	**x**	**x**			**x**				nearshore	
			Juveniles	**x**	**x**		**x**	**x**				mixed	
			Lg Juveniles	**x**	**x**			**x**				nearshore	
			Larvae				**x**	**x**				mixed	Newly hatched larvae move out of estuaries or shallow nearshore into open waters.

				Habitat Type(s)									
	Common Name	Scientific Name	Life History Stage	Hard Bottom Subtidal (no kelp)	Hard Bottom Subtidal (with kelp)	Soft Bottom Subtidal	Pelagic	Estua-rine	Rocky Inter-tidal	Soft Bottom Inter-tidal	Habitat Un-known	Predom-inately Nearshore, Offshore, or Mixed?	Habitat Notes
24	**Lingcod**	*Ophiodon elongatus*	Adults	x	x	x		x				mixed	
			Juveniles	x	x		x	x				nearshore	
			Lg Juveniles	x	x	x		x				nearshore	
			Larvae				x	x				nearshore	
25	**Northern anchovy**	*Engraulis mordax*	Adults				x					mixed	
			Juveniles				x					nearshore	
			Lg Juveniles	na	na	na	na	na	na	na	na	na	
			Larvae				x					mixed	
26	**Northern elephant seal**	*Mirounga angustirostris*	Adults	x	x		x			x		mixed	Generally do not breed in Oregon. Cape Arago State Park (Coos Bay) is only spot where elephant seals haul-out year-round in Oregon. Supratidal on sandy and gravel beaches.
			Juveniles							x		nearshore	Weaners stay mainly on land, with short periods of time spent in the water.
			Lg Juveniles	x	x		x			x		mixed	The majority of the elephant seals seen in Oregon are sub-adult animals that come to shore to molt.
			Larvae	na	na	na	na	na	na	na	na	na	
27	**Ochre sea star**	*Pisaster ochraceus*	Adults	x					x			nearshore	Rocky shores. Exposed and protected areas.
			Juveniles	x					x			nearshore	Found in crevices and under rocks. Little known.
			Lg Juveniles	na	na	na	na	na	na	na	na	na	
			Larvae				x					nearshore	
28	**Pacific harbor seal**	*Phoca vitulina*	Adults	x	x		x	x	x	x		nearshore	
			Juveniles		x		x	x		x		nearshore	Also on land.
			Lg Juveniles	na	na	na	na	na	na	na	na	na	
			Larvae	na	na	na	na	na	na	na	na	na	
29	**Pacific herring**	*Clupea pallasii*	Adults				x	x				mixed	
			Juveniles				x	x					
			Lg Juveniles	na	na	na	na	na	na	na	na	na	
			Larvae					x					

				Habitat Type(s)									
	Common Name	**Scientific Name**	**Life History Stage**	**Hard Bottom Subtidal (no kelp)**	**Hard Bottom Subtidal (with kelp)**	**Soft Bottom Subtidal**	**Pelagic**	**Estua-rine**	**Rocky Inter-tidal**	**Soft Bottom Inter-tidal**	**Habitat Un-known**	**Predom-inately Nearshore, Offshore, or Mixed?**	**Habitat Notes**
30	**Pile perch**	*Rhacochilus vacca*	Adults	**x**	**x**	**x**						nearshore	Surfgrass.
			Juveniles		**x**	**x**		**x**				nearshore	Surfgrass.
			Lg Juveniles	**na**	**na**	**na**	**na**	**na**	**na**	**na**	**na**	na	
			Larvae	**na**	**na**	**na**	**na**	**na**	**na**	**na**	**na**	na	
31	**Purple sea urchin**	*Strongylocentrotus purpuratus*	Adults	**x**	**x**				**x**			nearshore	Rocky shores. Strong wave action.
			Juveniles	**x**	**x**				**x**			nearshore	
			Lg Juveniles	**na**	**na**	**na**	**na**	**na**	**na**	**na**	**na**	na	
			Larvae				**x**						
32	**Quillback rockfish**	*Sebastes maliger*	Adults	**x**	**x**			**x**				mixed	
			Juveniles	**x**	**x**	**x**	**x**	**x**				nearshore	
			Lg Juveniles	**x**	**x**			**x**				nearshore	
			Larvae				**x**	**x**				nearshore	
33	**Razor clam**	*Siliqua patula*	Adults			**x**				**x**		nearshore	Exposed/open sandy beaches.
			Juveniles			**x**				**x**		nearshore	
			Lg Juveniles	**na**	**na**	**na**	**na**	**na**	**na**	**na**	**na**	na	
			Larvae				**x**					nearshore	Eggs and larvae are dispersed by ocean currents. Free swimming in water column near bottom.
34	**Red abalone**	*Haliotis rufescens*	Adults		**x**				**x**			nearshore†	† Species does not occur throughout Oregon (Cape Arago northern extent of range). Exposed/open. Boulders and rocky reefs.
			Juveniles		**x**				**x**			nearshore†	Settle on coralline red algae. Found inbetween rocks and boulders.
			Lg Juveniles		**x**				**x**			nearshore†	Rock crevices.
			Larvae				**x***					nearshore†*	* Do not mate at northern end of range (Cape Arago, OR). Pelagic until developing shell becomes too heavy.
35	**Red sea urchin**	*Strongylocentrotus franciscanus*	Adults	**x**	**x**				**x**			nearshore	
			Juveniles	**x**	**x**				**x**			nearshore	
			Lg Juveniles	**na**	**na**	**na**	**na**	**na**	**na**	**na**	**na**	na	
			Larvae				**x**				**x**		

				Habitat Type(s)									
	Common Name	**Scientific Name**	**Life History Stage**	**Hard Bottom Subtidal (no kelp)**	**Hard Bottom Subtidal (with kelp)**	**Soft Bottom Subtidal**	**Pelagic**	**Estua-rine**	**Rocky Inter-tidal**	**Soft Bottom Inter-tidal**	**Habitat Un-known**	**Predom-inately Nearshore, Offshore, or Mixed?**	**Habitat Notes**
36	**Redtail surfperch**	*Amphistichus rhodoterus*	Adults			**x**						nearshore	Shallow surf and sandy bottoms.
			Juveniles					**x**					
			Lg Juveniles	**na**	**na**	**na**	**na**	**na**	**na**	**na**	**na**	na	
			Larvae	**na**	**na**	**na**	**na**	**na**	**na**	**na**	**na**	na	
37	**Rock greenling**	*Hexagrammos lagocephalus*	Adults	**x**	**x**							nearshore	
			Juveniles	**x**	**x**		**x**					nearshore	
			Lg Juveniles	**na**	**na**	**na**	**na**	**na**	**na**	**na**	**na**	na	
			Larvae				**x**				**x**		
38	**Rock scallop**	*Hinnites giganteus*	Adults	**x**					**x**			nearshore	Protected rocky shores. Rock crevices. Attached to hard substrate.
			Juveniles	**x**			**x**		**x**			nearshore	Protected outer coast.
			Lg Juveniles	**x**					**x**			nearshore	
			Larvae				**x**						
39	**Sea palm**	*Postelsia palmaeformis*	Adults						**x**			nearshore	High energy areas only.
			Juveniles	**na**	**na**	**na**	**na**	**na**	**na**	**na**	**na**	na	
			Lg Juveniles	**na**	**na**	**na**	**na**	**na**	**na**	**na**	**na**	na	
			Larvae	**na**	**na**	**na**	**na**	**na**	**na**	**na**	**na**	na	
40	**Shiner perch**	*Cymatogaster aggregata*	Adults	**x**	**x**	**x**		**x**				nearshore	
			Juveniles					**x**				nearshore	
			Lg Juveniles	**na**	**na**	**na**	**na**	**na**	**na**	**na**	**na**	na	
			Larvae	**na**	**na**	**na**	**na**	**na**	**na**	**na**	**na**	na	
41	**Spiny dogfish**	*Squalus acanthias*	Adults	**x**		**x**	**x**	**x**				mixed	
			Juveniles				**x**	**x**				mixed	
			Lg Juveniles	**x**		**x**	**x**	**x**				mixed	
			Larvae	**na**	**na**	**na**	**na**	**na**	**na**	**na**	**na**	na	
42	**Starry flounder**	*Platichthys stellatus*	Adults			**x**		**x**				nearshore	Gravel, sand, and mud.
			Juveniles					**x**				nearshore	
			Lg Juveniles	**na**	**na**	**na**	**na**	**na**	**na**	**na**	**na**	na	
			Larvae				**x**	**x**				mixed	

				Habitat Type(s)									
	Common Name	Scientific Name	Life History Stage	Hard Bottom Subtidal (no kelp)	Hard Bottom Subtidal (with kelp)	Soft Bottom Subtidal	Pelagic	Estua-rine	Rocky Inter-tidal	Soft Bottom Inter-tidal	Habitat Un-known	Predom-inately Nearshore, Offshore, or Mixed?	Habitat Notes
43	**Steller sea lion**	*Eumetopias jubatus*	Adults	**x**	**x**		**x**	**x**	**x**			mixed	
			Juveniles	**x**	**x**		**x**		**x**			nearshore	
			Lg Juveniles	**x**	**x**		**x**		**x**			mixed	
			Larvae	**na**	**na**	**na**	**na**	**na**	**na**	**na**	**na**	na	
44	**Striped perch**	*Embiota lateralis*	Adults	**x**	**x**		**x**	**x**				nearshore	
			Juveniles	**x**	**x**			**x**				nearshore	Shallow water reefs amongst algae.
			Lg Juveniles	**na**	**na**	**na**	**na**	**na**	**na**	**na**	**na**	na	
			Larvae	**na**	**na**	**na**	**na**	**na**	**na**	**na**	**na**	na	
45	**Surf grass**	*Phyllospadix spp.*	Adults	**x**	**x**				**x**			nearshore	
			Juveniles	**na**	**na**	**na**	**na**	**na**	**na**	**na**	**na**	na	
			Lg Juveniles	**na**	**na**	**na**	**na**	**na**	**na**	**na**	**na**	na	
			Larvae	**na**	**na**	**na**	**na**	**na**	**na**	**na**	**na**	na	
46	**Surf smelt**	*Hypomesus pretiosus*	Adults				**x**	**x**			**x**	nearshore	Little is known about habits in ocean.
			Juveniles				**x**				**x**	nearshore	Little known of juvenile habits.
			Lg Juveniles	**na**	**na**	**na**	**na**	**na**	**na**	**na**	**na**	na	
			Larvae				**x**				**x**	nearshore	Little known about.
47	**Tiger rockfish**	*Sebastes nigrocinctus*	Adults	**x**								mixed	
			Juveniles	**x**			**x**				**x**		
			Lg Juveniles	**na**	**na**	**na**	**na**	**na**	**na**	**na**	**na**	na	
			Larvae				**x**				**x**		
48	**Topsmelt**	*Atherinops affinis*	Adults	**x**	**x**	**x**	**x**	**x**				nearshore	Surfgrass.
			Juveniles	**x**	**x**		**x**	**x**				nearshore	
			Lg Juveniles	**na**	**na**	**na**	**na**	**na**	**na**	**na**	**na**	na	
			Larvae				**x**	**x**				nearshore	
49	**Vermilion rockfish**	*Sebastes miniatus*	Adults	**x**	**x**	**x**						mixed	Rocky shelf and boulder fields.
			Juveniles	**x**	**x**	**x**	**x**					nearshore	Nearshore sand-rock interface. Rocky shelf.
			Lg Juveniles	**na**	**na**	**na**	**na**	**na**	**na**	**na**	**na**	na	
			Larvae				**x**					nearshore	

				Habitat Type(s)									
	Common Name	**Scientific Name**	**Life History Stage**	**Hard Bottom Subtidal (no kelp)**	**Hard Bottom Subtidal (with kelp)**	**Soft Bottom Subtidal**	**Pelagic**	**Estua-rine**	**Rocky Inter-tidal**	**Soft Bottom Inter-tidal**	**Habitat Un-known**	**Predom-inately Nearshore, Offshore, or Mixed?**	**Habitat Notes**
50	**White sturgeon**	*Acipenser transmontanus*	Adults			**x**		**x**			**x**	nearshore	
			Juveniles					**x**				nearshore	
			Lg Juveniles	**na**	**na**	**na**	**na**	**na**	**na**	**na**	**na**	na	
			Larvae					**x**				nearshore	Carried downstream to estuaries.
51	**Wolf-eel**	*Anarrhichthys ocellatus*	Adults	**x**	**x**							mixed	
			Juveniles				**x**					mixed	
			Lg Juveniles	**x**	**x**							mixed	
			Larvae				**x**				**x**		
52	**Yelloweye rockfish**	*Sebastes ruberrimus*	Adults	**x**								mixed	
			Juveniles	**x**			**x**					nearshore	
			Lg Juveniles	**na**	**na**	**na**	**na**	**na**	**na**	**na**	**na**	na	
			Larvae				**x**				**x**		
53	**Yellowtail rockfish**	*Sebastes flavidus*	Adults	**x**		**x**	**x**					mixed	
			Juveniles	**x**	**x**	**x**	**x**		**x**			mixed	
			Lg Juveniles	**x**		**x**	**x**					nearshore	
			Larvae				**x**					nearshore	

Appendix D. California MPA Guidelines – excerpt from Marine Life Protection Act

CALIFORNIA MARINE LIFE PROTECTION ACT INITIATIVE

MLPA MASTER PLAN FRAMEWORK

Adopted by the
California Fish and Game Commission
August 18, 2005

California Department of Fish & Game
August 22, 2005

Section 3. Considerations in the Design of MPAs
Accomplishing MLPA goals and objectives to improve a statewide network of MPAs will require the consideration of a number of issues, some of which are addressed in the MLPA itself. These are as follows:

- Goals of the Marine Life Protection Program
- MPA networks
- Types of MPAs
- Settling goals and objectives for MPAs
- Geographical regions
- Representative and unique habitats
- Species likely to benefit from MPAs
- Enforcement considerations in setting boundaries
- Information used in the design of MPAs
- Monitoring and evaluation strategies and resources
- Other activities affecting resources of concern

Each of these issues is discussed below.

Goals of the Marine Life Protection Program
The foundation for achieving the goals and objectives of the MLPA is a Marine Life Protection Program (Program), which must be adopted by the Commission. The MLPA sets the following goals for the Program [FGC subsection 2853(b)]:
(1) To protect the natural diversity and abundance of marine life, and the structure, function, and integrity of marine ecosystems.
(2) To help sustain, conserve, and protect marine life populations, including those of economic value, and rebuild those that are depleted.
(3) To improve recreational, educational, and study opportunities provided by marine ecosystems that are subject to minimal human disturbance, and to manage these uses in a manner consistent with protecting biodiversity.
(4) To protect marine natural heritage, including protection of representative and unique marine life habitats in California waters for their intrinsic value.
(5) To ensure that California's MPAs have clearly defined objectives, effective management

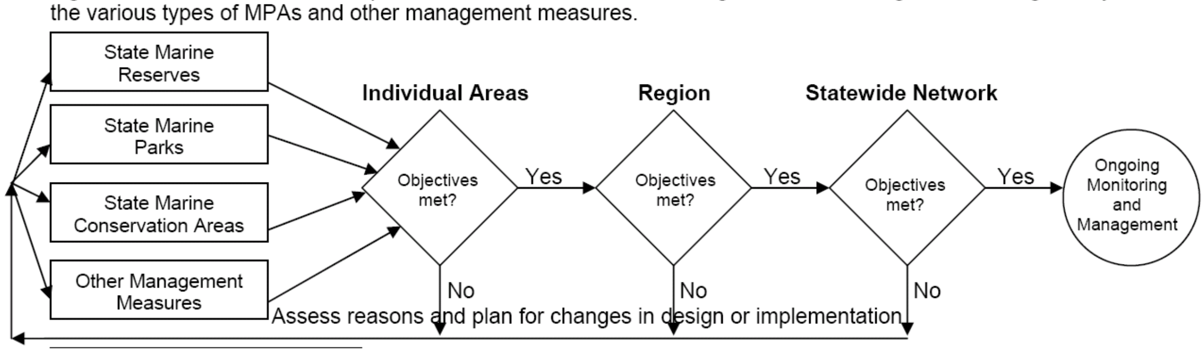
measures, and adequate enforcement, and are based on sound scientific guidelines.
(6) To ensure that the state's MPAs are designed and managed, to the extent possible, as a network.
The goals, objectives, management, monitoring, and evaluation of an MPA network must be consistent with the MLPA goals and objectives.

The goals of the MLPA go beyond the scope of traditional management of activities affecting living marine resources, which has focused upon maximizing yield from individual species or groups of species. For example, the first goal emphasizes biological diversity and the health of marine ecosystems, rather than the abundance of individual species. The second goal recognizes a role of an MPA system as a tool in fisheries management. The third recognizes the importance of recreation and education in MPAs, and balances these with the protection of biodiversity. The fourth recognizes the value of protecting representative and unique marine habitats for their own value. The fifth and sixth goals address the deficiencies in California's existing MPAs that the MLPA identifies elsewhere in the law.

The MLPA also states that the preferred siting alternative for MPA networks, which the Department must present to the Commission, must include an "improved marine life reserve[4] component" and must be designed according to all of the following guidelines:
(1) Each MPA shall have identified goals and objectives. Individual MPAs may serve varied primary purposes while collectively achieving the overall goals and guidelines of this chapter.
(2) Marine Life Reserves in each bioregion shall encompass a representative variety of marine habitat types and communities, across a range of depths and environmental conditions.
(3) Similar types of marine habitats shall be replicated, to the extent possible, in more than one marine life reserve in each biogeographical region.
(4) Marine life reserves shall be designed, to the extent practicable, to ensure that activities that upset the natural functions of the area are avoided.
(5) The MPA network and individual MPAs shall be of adequate size, number, type of protection, and location to ensure that each MPA meets its objectives and that the network as a whole meets the goals and guidelines of the MLPA.

Overall, proposed MPAs in each region must meet their individual goals and objectives, and the collection of MPAs and other management measures in each region and throughout the State must meet the goals and objectives of the MLPA. A simple decision tree for examining this is shown in Figure 3. This diagram indicates how the various types of MPAs along with other management measures work together to meet individual goals, regional goals, and the goals of the MLPA.

Figure 3. Flowchart of the review process to determine if individual, regional, and MLPA goals are being met by the various types of MPAs and other management measures.



[4] As noted previously, marine life reserve in the context of the MLPA is synonymous with a state marine reserve.

MPA Networks

One of the goals of the Marine Life Protection Program calls for improving and managing the state's MPAs as a network, to the extent possible. Although neither statute nor legislative history defines "network," the ordinary dictionary usage contemplates *interconnectedness* as a characteristic of the term. The first finding of the MLPA highlights the fact that California's MPAs "were established on a piecemeal basis rather than according to a coherent plan" [Fish and Game Code Section 2851(a)]. The term "reserve network" has been defined as a group of reserves which is designed to meet objectives that single reserves cannot achieve on their own (Roberts and Hawkins, 2000). In general this definition may infer some direct or indirect connection of MPAs through the dispersal of adult, juvenile, and/or larval organisms or other biological interactions. In most cases, larval and juvenile dispersal rates are not known and oceanography or ocean current patterns may be combined with larval biology to help determine connectivity.

Portions of the overall network will likely differ in each region of the state. The MLPA also requires that the network as a whole meet the various goals and guidelines set forth by the law and contemplates the adaptive management of that network [Fish and Game Code Section 2857(c)(5)]. In order to meet those goals a strict interpretation of an ecological network across the entire state, based on biological connectivity, may not be possible.

As stated above, the MLPA also requires that MPAs be managed as a network, to the extent possible. This implies a coordinated system of MPAs. MPAs might be linked through biological function as in the case of adult and juvenile movement or larval transport. MPAs managed as a network might also be linked by administrative function. The important aspects of this interpretation are that MPAs are linked by common goals and a comprehensive management and monitoring plan, and that they protect areas with a wide variety of representative habitat as required by the MLPA. MPAs should be based on the same guiding principles, design criteria, and processes for implementation. In this case, a statewide network could be one that has connections through design, funding, process, and management. At a minimum, the master plan should insure that the statewide network of MPAs reflects a consistent approach to design, funding and management. The desired outcome would include components of both biological connectivity and administrative function to the extent each are practicable and supported by available science.

Because of the long-term approach of the MLPA Initiative, the statewide network of MPAs called for by the MLPA will be developed in phases, region by region. Within each region, components of the statewide network will be designed consistent with the MLPA and with regional goals and objectives. Each component ultimately will be presented as a series of options, developed in a regional process involving a regional stakeholder group and a subgroup of the science team. Each will include a preferred alternative identified by the Department and delivered to the Commission. Another application of phasing may be an incremental implementation of a portion of the statewide MPA network within a single region. This type of phasing could allow for the completion of baseline surveys or the time necessary to secure additional funding for enforcement and management. Final proposals should include an explanation of the timing of implementation.

Science Advisory Team Guidance on MPA Network Design

The MLPA calls for the use of the best readily available science, and establishes a science team as one vehicle for fostering consistency with this standard. The MLPA also requires that the MPA network and individual MPAs be of adequate size, number, type of protection, and location as to ensure that each MPA and the network as a whole meet the objectives of the MLPA. In addition, the MLPA requires that representative habitats in each bioregion be replicated to the extent possible in more than one marine reserve.

The availability of scientific information is expected to change and increase over time. As with the rest of this framework, the following guidelines should be modified if new science becomes available that indicates changes. Additionally, changes should be made based on adaptive management and lessons learned as MPAs are monitored throughout various regions of the state.

The science team provided the following guidance in meeting these standards. This guidance, which is expressed in ranges for some aspects such as size and spacing of MPAs, should be the starting point for regional discussions of alternative MPAs. Although this guidance is not prescriptive, any significant deviation from it should be consistent with both regional goals and objectives and the requirements of the MLPA. The guidelines are linked to specific objectives and not all guidelines will necessarily be achieved by each MPA. For each recommendation below, detailed references are provided in the bibliography with notation linking them to the appropriate section.

Overall MPA and network guidelines:
• The diversity of species and habitats to be protected, and the diversity of human uses of marine environments, prevents a single optimum network design in all environments.
• 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.
• 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.
• For an objective of protecting adult populations, based on adult neighborhood sizes and movement patterns, MPAs should have an alongshore span of 5-10 km (3-6 m or 2.5-5.4 nm) of coastline, and preferably 10-20 km (6-12.5 m or 5.4-11 nm). Larger MPAs would be required to fully protect marine birds, mammals, and migratory fish.
• 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 km (31-62 m or 27-54 nm) of each other.
• 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.
• For an objective of lessening negative impact while maintaining value, placement of MPAs should take into account local resource use and stakeholder activities.
• Placement of MPAs should take into account the adjacent terrestrial environment and associated human activities.
• For an objective of facilitating adaptive management of the MPA network into the future, and the use of MPAs as natural scientific laboratories, the network design should account for the need to evaluate and monitor biological changes within MPAs.

1. MPAs should be in different marine habitats, biogeographical regions and upwelling cells *(See references noted "A" in literature cited)*
The strong association of most marine species with particular habitat types (e.g., sea grass beds, submarine canyons, shallow and deep rock reefs), and variation in species composition across latitudinal, depth clines and biogeographical regions, implies that habitat types must be represented across each of these larger environmental gradients to capture the breadth of biodiversity in California's waters.

Different species use marine habitats in different ways. As a result, protection of all the key habitats along the California coast is a critical component of network design. A 'key' habitat type is one that provides distinctive benefits by harboring a different set of species or life stages, having special physical characteristics, or being used in ways that differ from the use of other habitats. In addition, many species require different habitats at different stages of their life cycle - for example, nearshore species may occur in offshore open ocean habitats during their larval phase. Thus, protection of these habitats, as well as designs that ensure connections between habitats, is critical to MPA success. Individual MPAs that encompass a diversity of habitats will both ensure the protection of species that move among habitats and protect adjoining habitats that benefit one another (e.g., exchange nutrients, productivity). Habitats with unique features (educationally, ecologically, archeologically, anthropologically, culturally, spiritually), or those that are rare should be targeted for inclusion. Habitats that are uniquely productive (e.g. upwelling centers or kelp forests) or aggregative (e.g., fronts) or those that sustain distinct use patterns (e.g. dive training centers, fishing or whale watching hot spots) should also get special consideration in design planning.

2. Target species are ecologically diverse *(See references noted "B" in literature cited)*
MPAs protect a large number of species within their borders, and these species can have dramatically different requirements. As a result, MPA networks cannot be designed for the specific needs of each individual species. Rather, design criteria need to focus on maximizing collective benefits across species by minimizing compromises where possible. Commonly, it is more practical to consider protecting groups of species based on shared functional characteristics that influence MPA function and design (e.g., patterns of adult movement; patterns of larval dispersal; dependence on critical locations such as spawning grounds, mammal haul out areas, bird rookeries). It is also reasonable to emphasize protection of ecologically and economically dominant species groups when siting MPAs. The former play the largest roles in the function of coastal ecosystems, and the latter often experience the greatest impacts from human activities. In addition, knowledge of the distribution of rare, endemic, and endangered species should supplement the use of species groups. Generally, MPAs should not be used solely to enhance single-species management goals.

3. ***Uses of marine and adjacent terrestrial environments are diverse*** *(See references noted "C" in literature cited)*
The way people use coastal marine environments is highly diversified in method, goals, timing, economic objectives, spatial patterns, etc. The wide spectrum of environmental uses should be a part of decisions comparing alternatives networks of MPAs. The heterogeneity of uses, both between and within consumptive and non-consumptive categories make it unlikely that any one design will satisfy all user groups. The design will need to make some explicit provisions for trading off between the various negative and positive impacts to user groups. Placement of MPAs should also take into account the adjacent terrestrial environment and associated human activities. Freshwater runoff can be an important source of nutrients but also a potential source of contaminants to the adjacent marine environment. Terrestrial protected areas (e.g., preserves, parks) can regulate human access, restrict discharge of contaminants and provide enforcement support to adjoining MPAs.

4. MPA permanence is especially critical for long lived animals
Two clear objectives for establishing self-sustaining MPAs are to protect areas that are important sources of reproduction (nurseries, spawning areas, egg sources) and to protect areas that will receive recruits and thus be future sources of spawning potential. To meet the first objective of protecting areas that serve as sources of young, protection should occur both for areas that historically contained high abundances and for areas that currently contain high abundances. Historically productive fishing areas, which are now depleted, are likely to show a larger, ultimate response to protective measures if critical habitat has not been damaged. Protecting areas where targeted populations were historically abundant alone is insufficient, however, because the pace of recovery may be slow, especially for species with relatively long life spans and sporadic recruitment (for example, top marine predators). Including areas with currently high abundances in an MPA network helps buffer the network from the inevitable time lag for realizing the responses of some species. The biological characteristics of longevity and sporadic recruitment also suggest that the concept of a rotation of open and closed areas will probably not work well for the diversity of coastal species in California.

5. Size and shape guidelines *(See references noted "D" in literature cited)*
To provide any significant protection to a target species, the size of an individual MPA must be

large enough to encompass the typical movements of many individuals. Movement patterns vary greatly among species. Some are completely immobile or move only a few meters. Others forage widely. The more mobile the individuals, the larger the individual MPA must be to afford protection. Therefore, minimum MPA size constraints are set by the more mobile target species. Because some of California's coastal species are known to move hundreds of miles, MPAs of any modest size are unlikely to provide real protection for these species. Fortunately, tagging studies indicate that net movements of many of California's nearshore bottom-dwelling fish species, particularly reef-associated species, are on the order of 5-20 km (3-12.5 m or 2.5-11 nm) or less over the course of a year. These individual adult neighborhood or home range sizes must be combined with knowledge of how individuals are distributed relative to one another (e.g., in exclusive versus overlapping neighborhoods) to determine how many individuals a specific MPA design will protect. Current data suggest that MPAs spanning less than about 5-10 km (3-6 m or 2.5-5.4 nm) in extent along coastlines may leave many individuals of important species poorly protected. Larger MPAs, spanning 10-20 km (6-12.5 m or 5.4-11 nm) of coastline, are probably a better choice given current data on adult fish movement patterns. With MPAs of this size, pelagic species with very large neighborhood sizes will likely receive little protection unless the MPA network as a whole affords significant reductions in mortality during the cumulative periods that individuals spend in different MPAs, or unless other ecological benefits are conferred (e.g., protection of feeding grounds, reduction in bycatch). Protection for highly mobile species will come from other means, such as state and federal fisheries management programs, but MPAs may play a role.

Less is known about the net movements of most of the deeper water sedentary and pelagic fishes, especially those associated with soft-bottom habitat, but it is reasonable to suspect that the range of movements will be similar or greater than those of nearshore species. One cause of migration in demersal fishes is the changing resource/habitat requirements of individuals as they grow. Thus, individual ranges can reflect the gradual movement of an individual among habitats, and MPAs that encompass more diverse habitat types will more likely encompass the movement of an individual over its lifetime. Although fisheries may not target younger fish, offshore MPAs that include inshore nursery habitats increase the likelihood of replenishment of adult populations offshore. Such MPAs would also protect younger fish from incidental take (i.e. by-catch). Fish with moderate movements, especially those in deeper water, will require larger MPA sizes. Because several species also move between shallow and deeper habitat, MPAs that extend offshore (from the coastline to the three-mile offshore boundary of State waters) will accommodate such movement and protect individuals over their lifetime. Typically, the relative amount of higher relief rocky reef habitat decreases with distance from shore. In such situations, a MPA shape that covers an increasing area with distance offshore (i.e. a wedge shape) may be an effective design. This shape also better accommodates the greater movement ranges of deeper water and soft-bottom associated fishes and the larval/juvenile stages of nearshore species which may occur offshore during their planktonic phase of life. However, this may conflict with the optimum design for enforcement purposes of using lines of latitude and longitude for boundaries.

Coupling of pelagic and benthic habitats is an important consideration in both offshore and nearshore MPA design. The size of a protected area should also be large enough to facilitate enforcement and to limit deleterious edge effects caused by fishing adjacent to the MPA. MPA shape should ultimately be determined on a case-by-case basis using a combination of information about bathymetry, habitat complexity, and species distribution and relative abundance.

6. Spacing between MPAs *(See references noted "E" in literature cited)*
The exchange of larvae among MPAs is the fundamental biological rationale for MPA "networks". Larval exchange has at least three primary objectives: to assure that populations within MPAs are not jeopardized by their reliance on replenishment from less protected populations outside MPAs; to ensure exchange and persistence of genetic traits of protected populations (e.g., fast growth, longevity); and to enhance the independence of populations and

communities within MPAs from those outside MPAs for the use of MPAs as reference sites. For MPAs to act as reference sites for comparison with less protected populations or communities, MPAs must act independently from areas with less protected populations. Independence is enhanced for MPAs whose replenishment is contributed to by other MPAs. Movement out of, into and between MPAs by juveniles, larvae or spores of marine species depends on their dispersal distance. Important determinants of dispersal distance are the length of the planktonic period, oceanography and current regimes, larval behavior, and environmental conditions (e.g., temperature and sources of entrainment). As with adult movement patterns, the dispersal of juveniles, larvae and eggs varies enormously among species. Some barely move from their natal site. Others disperse vast distances. MPAs will only be connected through the dispersal of young if they are close enough together to allow movement from one MPA to another. Any given spacing of MPAs will undoubtedly provide connectivity for some species and not for others. The challenge is minimizing the number of key or threatened species that are left isolated by widely spaced MPAs.

Based on emerging genetic data from species around the world, larval movement of 50-100 km appears common in marine invertebrates. For fishes, larval neighborhoods based on genetic data appear generally larger, ranging up to 100-200 km. For marine birds and mammals, dispersal of juveniles of hundreds of km is not unusual, but for some of these species, return of juveniles to natal areas can maintain fine-scale population structure. For MPAs to be within dispersal range for most commercial or recreational groundfish or invertebrate species, they will need to be on the order of no more that 50-100 km apart. Otherwise, a large fraction of coastal species will gain no benefits from connections between MPAs.

Current patterns, retention features such as fronts, eddies, bays, and the lees of headlands may create “recruitment sinks and sources”. Such spatial variation in recruitment habitat may be predictable - dispersal distances will be shorter where retention is substantial (e.g., lees of headlands). As a result, MPAs may need to be more closely spaced in these settings. Although dispersal data appear to be valid for a wide range of species, there are only a small number of coastal marine species in California that allow these estimates of larval neighborhoods to be made with confidence. Nonetheless, it is the distribution of dispersal distances across species that really drives network design rather than the specific patterns for any particular species.

7. Minimal replication of MPAs

MPAs in a particular habitat type need to be replicated along the coast. Four major reasons for this are: to provide stepping-stones for dispersal of marine species; to insure against local environmental disaster (e.g. oil spills or other catastrophes) that can significantly impact an individual, small MPA; to provide independent experimental replicates for scientific study of MPA effects; and for the use of MPAs as reference sites to evaluate the effects of human influences on populations and communities outside MPAs. Ideally at least five replicates (but a minimum of three) containing sufficient representation or each habitat type, should be placed in the MPA network within each biogeographical region and for each habitat to serve these goals. For large biogeographical regions, fulfilling the critical stepping stone role may require even more MPA replicates. The spacing criteria discussed above will drive the number of replicates in this situation. To ensure that the effects of MPAs can be quantified, the network should be designed in a way that facilitates comparison of protected and unprotected habitats, and between different degrees of consumptive and non-consumptive uses.

8. Human activities ranges and MPA placement

The geographic extent of human activities is suggestive of size and placement of MPAs. Fishing fleets and other user groups typically have a finite home range from ports and access points along the coast. Many activities, especially in central California, are day-based and conducted from motor, sail or hand powered crafts with ranges between 1 and 29 miles (1 and 25 nautical miles). Historical patterns of fishing activity may have been concentrated much closer to ports than is true today because of declines in target species abundance from activities in the past. If MPAs are designed to limit consumptive uses, MPAs located farthest away from access points will tend to be associated with lower costs. However, MPAs often become magnets for fishing along their edges. These situations create a net benefit for consumptive users by locating MPAs close to ports and coastal access points. Similarly, MPAs designed to facilitate certain non-consumptive types of activities such as diving may be more effective closer to ports and coastal access points. As a general rule, locating MPAs at the outer reaches of the maximum range of any given user group will tend to minimize the impacts on that group, both negative (loss of opportunity) and positive (creation of opportunity). The balance between these influences must be evaluated for specific locations. In addition, if MPAs restrict transit they will carry higher social, economic and, potentially, safety costs for users seeking access to sites beyond the MPA.

9. Human activity patterns and portfolio effects

Human activities have distinct hotspots where effort is concentrated. For example, in the northern California urchin fishery, economists at the University of California at Davis have documented are-based fishing strategies around a dozen fishing locations. It is likely that there are a threshold number of these locations below which the fishery would not be feasible. Because an MPA larger than the typical harvest area could potentially eliminate a fishing location, these spatial use patterns should be part of design considerations, especially if establishing one particular MPA would spell the end of a particular activity along the entire coastline.

Consideration of Habitats in the Design of MPAs *(See additional references noted "F" in literature cited)*

The first step in assembling alternative proposals for MPAs in a region and in the context of a statewide MPA network is to use existing information to the extent possible to identify and to map the habitats that should be represented. The MLPA also calls for recommendations regarding the extent and types of habitats that should be represented.
The MLPA identifies the following habitat types: rocky reefs, intertidal zones, sandy or soft ocean bottoms, underwater pinnacles, seamounts, kelp forests, submarine canyons, and seagrass beds. The Master Plan Team convened in 2000 reduced this basic list by eliminating seamounts, since there are no seamounts in state waters. The team also identified four depth zones as follows: intertidal, intertidal to 30 meters, 30 meters to 200 meters, and beyond 200 meters. Several of the seven habitat types occur in only one zone, while others may occur in three or four zones.

The science team recommends expanding these habitat definitions in four ways:
1. Based on information about fish depth distributions provided in a new book on the ecology of California marine fishes (Allen et al. in press), the science team recommends dividing the 30-200 m depth zone into a 30-100 m and a 100-200 m zone. This establishes five depth zones for consideration:

• Intertidal
• Intertidal to 30 m (0 to 16 fm)
• 30 to 100 m (16 to 55 fm)
• 100 to 200 m (55 to 109 fm)
• 200 m and deeper.

2. The habitats defined in the MLPA implicitly focus on open coast ecosystems and ignore the critical influence of estuaries. California's estuaries contain most of the State's remaining soft bottom and herbaceous wetlands such as salt marshes, sand and mud flats, and eelgrass beds. Ecological communities in estuaries experience unique physical gradients that differ greatly from those in more exposed coastal habitats. They harbor unique suites of species, are highly productive, provide sheltered areas for bird and fish feeding, and are nursery grounds for the young of a wide range of coastal species. Emergent plants filter sediments and nutrients from the watershed, stabilize

shorelines, and serve as buffers for flood waters and ocean waves. Given these critical ecological roles and ecosystem functions, estuaries warrant special delineation as a critical California coastal habitat.

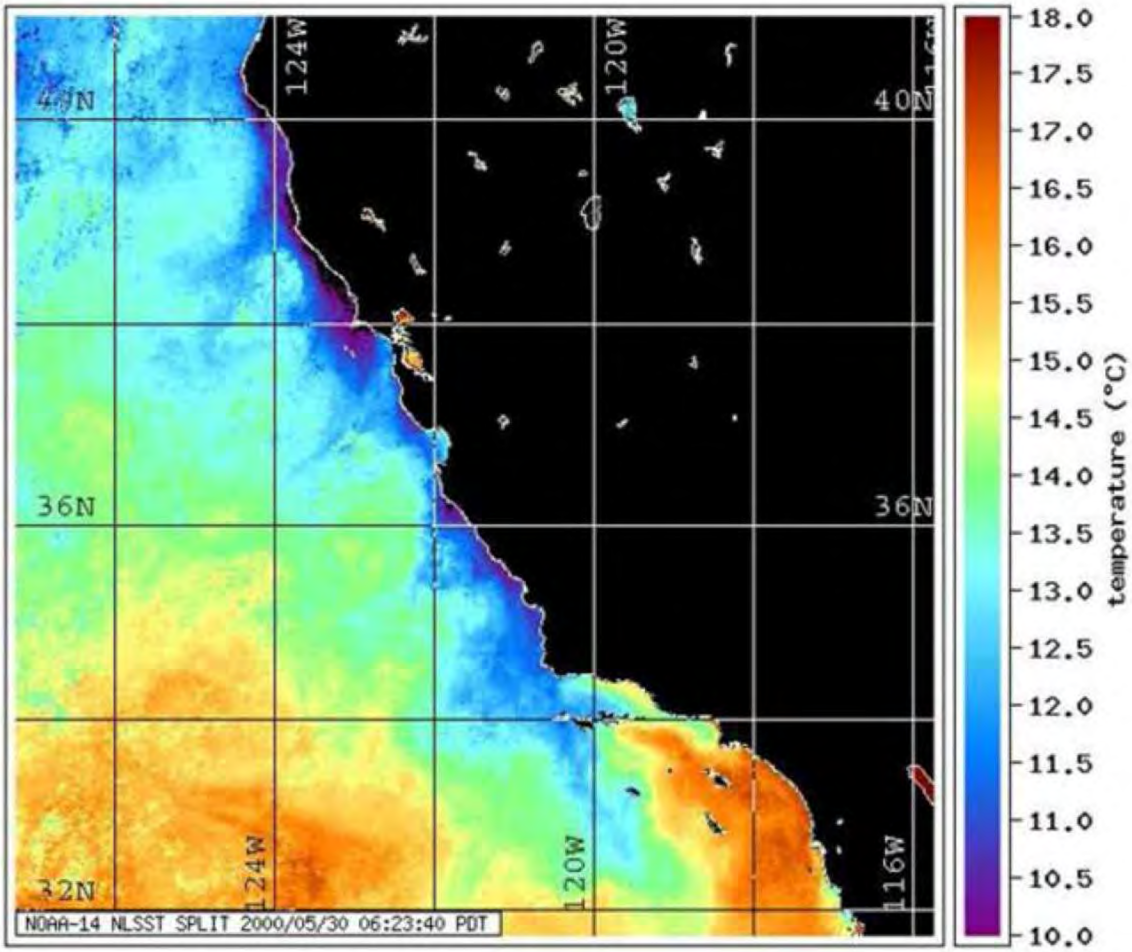
3. Three of the habitats defined in the MLPA – rocky reefs, intertidal zones, and kelp forests – are generic habitat descriptions that include distinct habitats that warrant specific consideration and protection. In the case of rocky reefs and intertidal zones, the type of rock that forms the reef greatly influences the species using the habitat. For example, granitic versus sedimentary rock reefs harbor substantially different ecological assemblages and should not be treated as a single habitat. Similarly, the term kelp forest is a generic term that subsumes two distinct ecological assemblages dominated by different species of kelp. Kelp forests in the southern half of the state are dominated by the giant kelp, *Macrocystis pyrifera.* By contrast, kelp forests in the northern half of the state are dominated by the bull kelp, *Nereocystis luetkeana*. In central California, both types of kelp forests occur. These two types of kelp forests harbor distinct assemblages and should be treated as separate habitats.

4. Habitat definitions in the MLPA should be expanded to include ocean circulation features, because habitat is not simply defined by the substrate. Seawater characteristics are analogous to the climate of habitats on land, and play a critical role in determining the types of species that can thrive in any given setting. Just as features of both the soil and atmosphere characterize habitats on land, features of both the substrate (e.g., rock, sand, mud) and the water that bathes it (e.g., temperature, salinity, nutrients, current speed and direction) characterize habitats in the sea. No one would argue that a sand dune at the beach and a sand dune in the desert are the same habitat. Similarly, rocky reefs in distinct oceanographic settings are different habitats that can differ fundamentally in the species that use the reefs.

The oceanography of the California coastline is dominated by the influence of the California Current System. On the continental shelf and slope this system consists of two primary currents - the California Current, which flows toward the equator, and the California Undercurrent, which flows toward the North Pole (Hickey, 1979; 1998). When present, the undercurrent occurs beneath the southward flowing California Current. North of Pt. Conception, the undercurrent may reach the surface as a nearshore, poleward flowing current that is best developed in fall and winter (Collins et al., 2000; Pierce et al., 2000). These currents vary in intensity and location, both seasonally and from year to year.
Organisms will also be affected by the circulation induced by tidal currents. For those living in shallow water habitats very close to shore, inshore of the surf zone, the dominant influence on transport of planktonic eggs and larvae will be the circulation generated by breaking waves.
As can be seen in a satellite image of ocean temperature along the California coastline (Figure 4), the circulation and physical characteristics of the California Current System are exceedingly complex and variable. This is not the image one would expect if ocean currents were analogous to northward or southward flowing rivers in the sea. Rather, ocean flows are greatly modified by variation in the strength and direction of winds, ocean temperatures and salinity, tides, the topography of the coastline, and the shape of the ocean bottom, among several other factors. The end result is a constantly changing sea of conditions.

The patterns are not completely random, however. Many aspects of ocean climates vary somewhat predictably in space, especially ones that are tied to key features of the coastline – points and headlands, river mouths, etc. Locations that share similar ocean climates are typically more similar in the types of species they harbor. Therefore, defining habitats for the MLPA and MPA networks must include habitats defined by coastal oceanography as well as the composition of the seafloor.

Figure 4. An example of sea surface temperature in the California coastal waters, May 30, 2000.



Although a wide range of oceanographic habitats could be defined for the California coastline, the science team suggests that three prominent habitats stand out because of their demonstrated importance to different suites of coastal species:

- Upwelling centers
- Freshwater plumes
- Retention areas

Upwelling Centers

Upwelling is one of the most biologically important circulation features in the ocean. Upwelling occurs when deep water is brought to the surface. On average deep water is colder and more nutrient rich than surface waters. When upwelling delivers nutrients to the sunlit waters near the surface, it provides the fuel for rapid growth of marine plants, both plankton and seaweeds. Ultimately the added nutrients can energize the productivity of entire marine food webs. Upwelling regions are the most productive ocean ecosystems. The west coast of North America is one of the few major coastal upwelling regions on the entire planet (Chavez and Collins, 2000; Hickey, 1998). The major driver of upwelling along the California coastline is wind. Winds that blow from the north and northwest parallel to California's generally northsouth coastline drive currents at the surface. Because of the complicated effects of friction and the rotation of the earth, surface water is pushed to the right of the direction of the wind (the Coriolis Effect). With winds blowing from the north and northwest, this effect pushes surface waters away from shore. As water is pushed offshore, it is replaced by water that is upwelled from below.

The rate of upwelling depends on many features that vary spatially along the coastline – the strength and direction of the wind, the topography of the shoreline, and the shape of the continental shelf are three of the most important. Capes and headlands play a key feature in all of these drivers of upwelling. They accelerate alongshore winds, and they channel coastal currents in such a way that upwelling intensity can increase dramatically in their vicinity. As a result, major headlands and capes from Pt. Conception north are commonly centers of upwelling associated with strong rates of offshore transport of surface waters, greatly elevated nutrient concentrations, and enhanced productivity offshore (Pickett and Paduan, 2003). Since major capes and headlands tend to be fairly regularly spaced along the California coastline, with an average spacing between 150 and 200 km (93 and 124 m or 81 and 108 nm), these upwelling centers drive cells of ocean circulation with relatively predictable patterns of flow. Enhanced offshore flow and upwelling emanates from headlands, versus eddies and locations of more frequent alongshore flow in the regions between headlands. These filaments of upwelled water are readily identified emanating from key headlands in most satellite images of ocean temperature or biomass of phytoplankton. Because the upwelling centers are locations of more frequent and intense offshore flow near the surface, which moves larvae and other plankton away from shore, and elevated nutrients, which fuels much more rapid algal productivity, these locations represent a distinct oceanographically driven coastal habitat with substantially different species composition and dynamics compared to other coastal locations.

Freshwater Plumes
A second coastal habitat driven by features of the water column is generated by the influence of rivers. Freshwater emerging from watersheds alters the physical characteristics of coastal seawater (especially salinity), changes the pattern of circulation (by altering seawater density), and delivers a variety of particles and dissolved elements, such as sediments, nutrients, and microbes. These effects all arise from the land and can have a profound influence on the success of different marine species. The mouths of watersheds set the locations of low salinity plumes, and the size and shape of the plume vary over time as functions of the volume of flow from the watershed, the concentration of particles, and the nature of coastal circulation into which the water is released. The location of California's freshwater plume habitats can be defined by both satellite and ocean-based measurements.

Larval Retention Areas
Since connectivity and movement of larvae, plankton, and nutrients play such an important role in the impact of MPAs on different species, changes in the speed and direction of coastal currents can create very different ecological settings. A number of circulation features can greatly limit the coastal particles. In particular, features characterized by rotational flows, such as eddies, can greatly enhance the length of time that a particle or larval fish stays in a general region of the coastline. Such retentive features have been shown to significantly affect the species composition of coastal ecosystems (Largier, 2004). Since many retention areas are tied to fixed features of coastal topography (e.g., eddies in the lee of coastal headlands or driven by bottom topography), they define unique regions of coastal habitat that can be predictably defined.

Experience in California and elsewhere demonstrates that individual MPAs generally include several types of habitat in different depth zones, so that the overall number of MPAs required to cover the various habitat types can be smaller than the number of total habitats. The Master Plan Team convened in 2000 also called for considering adjacent lands and habitat types, including seabird and pinniped rookeries. Since marine birds and mammals are protected by federal regulations, they are not a primary focus of the MLPA. Nonetheless, these species can play important ecological roles and their success may be impacted by changes in other components of California's coastal ecosystems that are a primary focus of MLPA. Therefore, MPA planning needs to coordinate with other efforts focused on marine birds and mammals. As noted regarding the design of MPAs, this guidance should be the starting point for regional discussions regarding representative habitats in a region. Although this guidance is not prescriptive, any significant deviation from it should be explained.

Species Likely to Benefit from MPAs

Recommending the extent of habitat that should be included in an MPA network will require careful analysis and consideration of alternatives. These recommendations may vary with habitat and region, but should be based on the best readily available science. One aspect of determining appropriate levels of habitat coverage is the habitat requirements of species likely to benefit from MPAs in a region. At Fish and Game Code subsection 2856(a)(2)(B), the MLPA requires that the master plan identify “select species or groups of species likely to benefit from MPAs, and the extent of their marine habitat, with special attention to marine breeding and spawning grounds, and available information on oceanographic features, such as current patterns, upwelling zones, and other factors that significantly affect the distribution of those fish or shellfish and their larvae.”

The Department prepared a master list of such species, which appears in Appendix G. This list may serve as a useful starting point for identifying such species in each region during the development of alternative MPA proposals. With the assistance of the science team, the Department should develop a list of species specific to each study region of the state, as they are determined, for use by the appropriate regional stakeholder group. The list will indicate which species are of critical concern and why. This regional list then can assist in evaluating desirable levels of habitat coverage in alternative MPA proposals. Although the statewide list will be all inclusive, it is not likely that all species on the list will benefit from the establishment of new, or the expansion of existing, MPAs. For example, a species may be in naturally low abundance within this portion of its geographical range.

The Department, with the assistance of the science team, will develop scientifically based expectations of increases in abundance of focal species for each MPA. These expectations, while not hard targets or performance goals, will help managers determine the efficacy of MPAs. If expected increases are not realized, the process of adaptive management will allow for changes in the MPA design.

Biogeographical Regions

In calling for a statewide network of MPAs, to the extent possible, the MLPA recognizes that the state spans several biogeographical regions, and identified these, initially, as follows [FGC subsection 2852(b)]:

- The area extending south from Point Conception,
- The area between Point Conception and Point Arena, and
- The area extending north from Point Arena.

In the same provision, the MLPA provides authority for the master plan team required by FGC subsection 2855(b)(1) to establish an alternate set of boundaries. The Master Plan Team convened by the Department in 2000 determined that the three regions identified in the MLPA were not zoogeographic regions; scientists recognize only two zoogeographic regions between Baja California and British Columbia with a boundary at Pt. Conception. Instead of the term “biogeographical region,” the team adopted the term “*marine region*” and identified four *marine regions*:

- North marine region: California-Oregon border to Point Arena (about 210 linear miles or 183 linear nautical miles of coastline);
- North-central marine region: Point Arena to Point Año Nuevo (about 180 linear miles or 156 linear nautical miles of coastline);
- South-central marine region: Point Año Nuevo to Point Conception (about 233 linear miles or 203 linear nautical miles of coastline); and
- South marine region: Point Conception to the California-Mexico border, including the islands of the southern California Bight (about 280 linear miles or 243 linear nautical miles of coastline).

Three of the above four regions (those north of Pt. Conception) fall within the larger zoogeographic region accepted by scientists. These sub-regions were used more or less as subdivisions of the greater zoogeographic region by the former Master Plan Team. Technically, the requirement of replicate state marine reserves encompassing a representative variety of habitat types and depths would only apply to the two recognized zoogeographic regions within the state. However, based on the concept of a network of MPAs, in whatever way it is defined, and the fact that it would likely require unusually and unacceptably large state marine reserves to incorporate a wide variety of habitat types if only two (the minimum definition of "replicate") state marine reserves were established in each zoogeographic region, it is likely that a statewide network will contain more than two state marine reserves in each biogeographical region.

MPAs in different biogeographical regions will affect different suites of species. Thus replication and network design may be considered separately for relatively distinct stretches of coastline. Biogeographical regions can be distinguished based upon data of two types: 1) the location of species' borders along the coastline; and 2) surveys of species' distribution and abundance. Historically, the locations of species' borders, i.e., places where multiple species terminate their ranges, have been used to define biogeographical regions or provinces. However, regional boundaries typically are set by only small subset of the species distributed up and down coast from these "breakpoints".

The abundances and diversity of species at locations along the coast are much more reflective of differences in biological communities and provide the best evidence of biologically distinct regions from both structural and functional standpoints. Historically, such data on abundance and biological diversity have not been available at enough locations along most coastlines for broad scale, geographic analyses. As a result, definitions of biogeographical regions have been forced to rely on a less meaningful measure of biological differences – the location of species' borders.

Biogeographers have divided all major oceans into large *biogeographic provinces*. California's coastline spans two of these large-scale provinces – the Oregonian and the Californian Provinces – with a boundary in the vicinity of Point Conception. This prominent biogeographical boundary has been recognized for more than half a century. More detailed analyses of species' borders also have led to the identification of regional scale boundaries between biogeographical sub-provinces.

Biogeographers commonly have used distributional data for subgroups of taxonomically related species (e.g., snails, seaweeds, or fish) to set biogeographical boundaries; interestingly, the boundaries for sub-provinces often differ among taxonomic groups because different types of species respond to different physical and biological characteristics in different ways (Airamé et al. 2003). Two locations, however, emerge as prominent boundaries for key coastal species. Seaweeds, intertidal invertebrates, and nearshore fishes have comparable numbers of species' borders in the vicinity of Monterey Bay as they do at Point Conception. In addition, coastal fishes have an important sub-province boundary at Cape Mendocino. Scientific data do not support a significant biological break between biogeographical regions at Point Arena, as identified in earlier MLPA documents. Therefore, on the basis of the distribution of species' borders for key coastal species groups, there are three biogeographical regional boundaries and four regions along the California coast:
1. The Mexican border to Pt. Conception,
2. Point Conception to Monterey Bay,
3. Monterey Bay to Cape Mendocino, and
4. Cape Mendocino to the Oregon border.

In the past decade, detailed data have become available on species abundances and diversity from a large number of locations along California's coast. This wealth of information on actual species assemblages now provides the opportunity to define biogeographical regions on the basis of actual ecosystem compositions, rather than the presumed composition of ecosystems inferred from species' borders. These ecosystem-based data are a better scientific fit with the goals of the MLPA. Summaries of species abundance and diversity data, especially for shallow water species (<30 m depth), suggest that there are four points of transition along the California coastline that demarcate distinct marine assemblages: Point Conception, Monterey Bay, San Francisco Bay, and Cape Mendocino.

Three of these locations are identical to those defined above solely on the basis of species' borders for prominent groups. The new boundary that emerges from abundance and biodiversity data is San Francisco Bay. The region between Monterey Bay and Cape Mendocino has two distinct biological assemblages on coastal reefs even though this is not a region characterized by large numbers of species' borders. The difference in assemblages on either side of San Francisco Bay appears to be caused by changes in the types of rock that form nearshore reefs. Since the type of rock is used to defined bottom habitats for MPA designation, this transition in species composition could be addressed in MPA designs using habitat considerations or, alternatively by designating the Monterey Bay to San Francisco Bay segment as a distinct biogeographical region.

Based on this review, there are four possible definitions of the biogeographical regions that will serve as the basic structure of the statewide network of MPAs. These options are as follows:
1) The three biogeographical regions defined in the MLPA;
2) The two *biogeographic provinces* recognized by many scientists with a boundary at Point Conception;
3) The four *marine regions* identified by the former Master Plan Team, with boundaries at Pt. Conception, Pt. Año Nuevo, and Pt. Arena; and
4) The biogeographical regions recognized by scientists who have identified borders based on species distributional patterns or on abundance and diversity data with boundaries at Pt. Conception, Monterey Bay and/or San Francisco Bay, and Cape Mendocino.

Accepting the strong scientific consensus of a major biogeographical break at Point Conception, the MLPA Blue Ribbon Task Force recommends that the Commission adopt the two biogeographic provinces as the biogeographical regions for purposes of implementation of the Marine Life Protection Act. The Task Force recommends that the more refined information on other breaks be used in designating study regions and in designing networks of MPAs.

Types of MPAs
The MLPA recognizes the role of different types of MPAs in achieving the objectives of the Marine Life Protection Program [FGC subsection 2853(c)]. While the MLPA does not define the different types, the Marine Managed Areas Improvement Act (MMAIA) does define state marine reserve, state marine park, and state marine conservation area. (See Appendix B for the text of the MMAIA as amended.)