A Biogeographic Assessment of the Channel Islands National Marine Sanctuary

A Review of Boundary Expansion Concepts for NOAA's National Marine Sanctuary Program

November 2005

prepared for the

National Marine Sanctuary Program

and

Channel Islands National Marine Sanctuary

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Editors

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NOAA/NOS/NCCOS
1305 East West Highway, SSMC-4, NSCI 1
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ABOUT THIS DOCUMENT

This biogeographic assessment represents the continuation of an ongoing partnership between the National Marine Sanctuary Program (NMSP) and the National Centers for Coastal Ocean Science (NCCOS). The purpose of this collaboration is to provide sanctuary managers with basic information on the distribution of marine flora and fauna relevant to the national marine sanctuaries they manage. This particular work, conducted in collaboration with the Channel Islands National Marine Sanctuary (CINMS) and members of the local research community, builds on a previous assessment developed for California's other three national marine sanctuaries (NOAA, 2003). These efforts were undertaken specifically to support the management plan revision process mandated for each sanctuary. This process evaluates the degree that each sanctuary is meeting its goals and allows an opportunity for the public to determine if there are new directions or issues that they feel the sanctuary should address. One issue raised by the public during the CINMS management plan revision process was whether the sanctuary boundaries should be expanded. A significant portion of this document, therefore, is devoted toward providing a biogeographic assessment of the differing boundary concepts previously developed by CINMS in conjunction with the Sanctuary Advisory Council and general public. This was accomplished by a thorough analysis of the biogeographic datasets provided to the analytical team by the local research community. Additionally, the data gathered, analyses performed, and patterns of distribution observed should provide invaluable information to support science, education, and support other spatially-explicit management decisions.

The results of this assessment are available via both hard copy and CD-ROM. Also available on the CD-ROM are the data utilized to develop the Habitat Suitability Models along with the ArcGIS project files used to develop many of the figures within this report (e.g. species distribution, substrate and oceanographic maps). For more information on this effort please visit the NCCOS Biogeography Team webpage dedicated to this project at: http://ccma.nos.noaa.gov/ecosystems/sanctuaries/chanisl_nms.html or direct questions and comments to:

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EXECUTIVE SUMMARY

The priority management goal of the National Marine Sanctuaries Program (NMSP) is to protect marine ecosystems and biodiversity. This goal requires an understanding of broad-scale ecological relationships and linkages between marine resources and physical oceanography to support an ecosystem management approach. The Channel Islands National Marine Sanctuary (CINMS) is currently reviewing its management plan and investigating boundary expansion. A management plan study area (henceforth, Study Area) was described that extends from the current boundary north to the mainland, and extends north to Point Sal and south to Point Dume. Six additional boundary concepts were developed that vary in area and include the majority of the Study Area. The NMSP and CINMS partnered with NOAA's National Centers for Coastal Ocean Science Biogeography Team to conduct a biogeographic assessment to characterize marine resources and oceanographic patterns within and adjacent to the sanctuary. This assessment includes a suite of quantitative spatial and statistical analyses that characterize biological and oceanographic patterns in the marine region from Point Sal to the U.S.-Mexico border. These data were analyzed using an index which evaluates an ecological "cost-benefit" within the proposed boundary concepts and the Study Area.

The sanctuary resides in a dynamic setting where two oceanographic regimes meet. Cold northern waters mix with warm southern waters around the Channel Islands creating an area of transition that strongly influences the regions oceanography. In turn, these processes drive the biological distributions within the region. This assessment analyzes bathymetry, benthic substrate, bathymetric life-zones, sea surface temperature, primary production, currents, submerged aquatic vegetation, and kelp in the context of broad-scale patterns and relative to the proposed boundary concepts and the Study Area. Boundary cost-benefit results for these parameters were variable due to their dynamic nature; however, when analyzed in composite the Study Area and Boundary Concept 2 were considered the most favorable.

Biological data were collected from numerous resource agencies and university scientists for this assessment. Fish and invertebrate trawl data were used to characterize community structure. Habitat suitability models were developed for 15 species of macroinvertebrates and 11 species of fish that have significant ecological, commercial, or recreational importance in the region and general patterns of ichthyoplankton distribution are described. Six surveys of ship and plane at-sea surveys were used to model marine bird diversity from Point Arena to the U.S.-Mexico border. Additional surveys were utilized to estimate density and colony counts for nine bird species. Critical habitat for western snowy plover and the location of California least tern breeding pairs were also analyzed. At-sea surveys were also used to describe the distribution of 14 species of cetaceans and five species of pinnipeds. Boundary concept cost-benefit indices revealed that Boundary Concept 2 and the Study Area were most favorable for the majority of the species-specific analyses. Boundary Concept 3 was most favorable for bird diversity across the region. Inadequate spatial resolution for fish and invertebrate community data and incompatible sampling effort information for bird and mammal data precluded boundary cost-benefit analysis.

The final chapter integrates data and analyses from each of the preceding chapters utilizing two separate approaches. Cost-benefit indices were ranked for each biological group and for the oceanographic/physical parameters to provide a consistent and comprehensive evaluation of the boundary concepts. The Study Area and Boundary Concept 2 (see Chapter 1) ranked highest for the bird, fish, and mammal groups, as well as all the data in composite. The Study Area also ranked highest for macroinvertebrates. Second, select spatial data were integrated, based on data compatibility and spatial range, to identify areas of spatial coincidence which may reflect ecosystem "hotspots". Habitat suitability models for fish and macroinvertebrates, along with bird and mammal sightings information were utilized to evaluate this spatial coincidence. Areas of highest spatial coincidence most closely resemble the spatial delineation for the Study Area and also include a broad area from the mainland south through San Clemente Island.

Integration results highlight the Channel Islands and the area extending north to the mainland to Point Conception as an important ecosystem that supports a diverse array of biological communities. The boundary concepts that were favorably ranked incorporated large areas of the coastal mainland, due in part to the nearshore affinity exhibited by many of the analyzed species. Deep offshore environments away from the Channel Islands were correspondingly less favorable. Both the Study Area and Boundary Concept 2 are characterized by areas of increased upwelling, dynamic surface currents and eddies, and persistent thermal fronts. These concepts also include large areas of important habitats such as kelp, seagrasses, and wetlands along with a mixture of deep and shallow waters that many species depend on for all or part of their life cycles.

In compliance with the National Environmental Policy Act, the National Marine Sanctuary Program will incorporate this assessment with cultural and socio-economic analyses to prepare a Supplemental Environmental Impact Statement to fully analyze boundary change concepts.

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CHAPTER 1 INTRODUCTION

Chris Caldow, Julie Kellner, M. James Allen, Satie Airamé, Steve Gaines

1.1 PROJECT BACKGROUND

The National Marine Sanctuary Program (NMSP) is currently updating and revising the management plans for each of its 13 sanctuaries. This process, which is open to the public, enables each site to revisit the reasons for sanctuary designation and assess whether they are meeting their goals, as well as to set new goals consistent with the mandates of the National Marine Sanctuaries Act. Issues raised by the public during this process are evaluated and a determination is made as to whether they will be incorporated into the updated plan. Many of these issues focus on topics such as the implementation of marine zoning or sanctuary boundary adjustments, both of which require information on the distribution of resources within and around the sanctuary. Recognizing this, NMSP and NOAA's National Centers for Coastal Ocean Science (NCCOS) formalized an agreement to collaborate in the revision process by developing such information through a series of biogeographic assessments conducted in selected sanctuaries. The resulting products are then supplied to sanctuary managers and staff for use in the policy and decision making process. This collaborative effort began along the west coast of the U.S. with the Cordell Bank, Gulf of Farallones, and Monterey Bay national marine sanctuaries, and is herein centered on the Channel Islands National Marine Sanctuary (CINMS).

The current CINMS boundaries (Figure 1.1.1) were selected to provide adequate protection of local marine plants and animals given the nature of adjacent human uses and based on the limited information on the spatial distribution of threats, biota, and habitats that were available in 1980, the year the sanctuary was created. However, the CINMS management plan has not been updated since 1983 and new management issues have subsequently arisen, as has the availability of pertinent biological information. As a result, CINMS was one of the first sanctuaries to begin the management plan review process, which was initiated along with the formation of the Sanctuary Advisory Council in 1998. This was followed by a series of seven "public issue" scoping meetings along the coast of southern California and Washington D.C. in 1999.

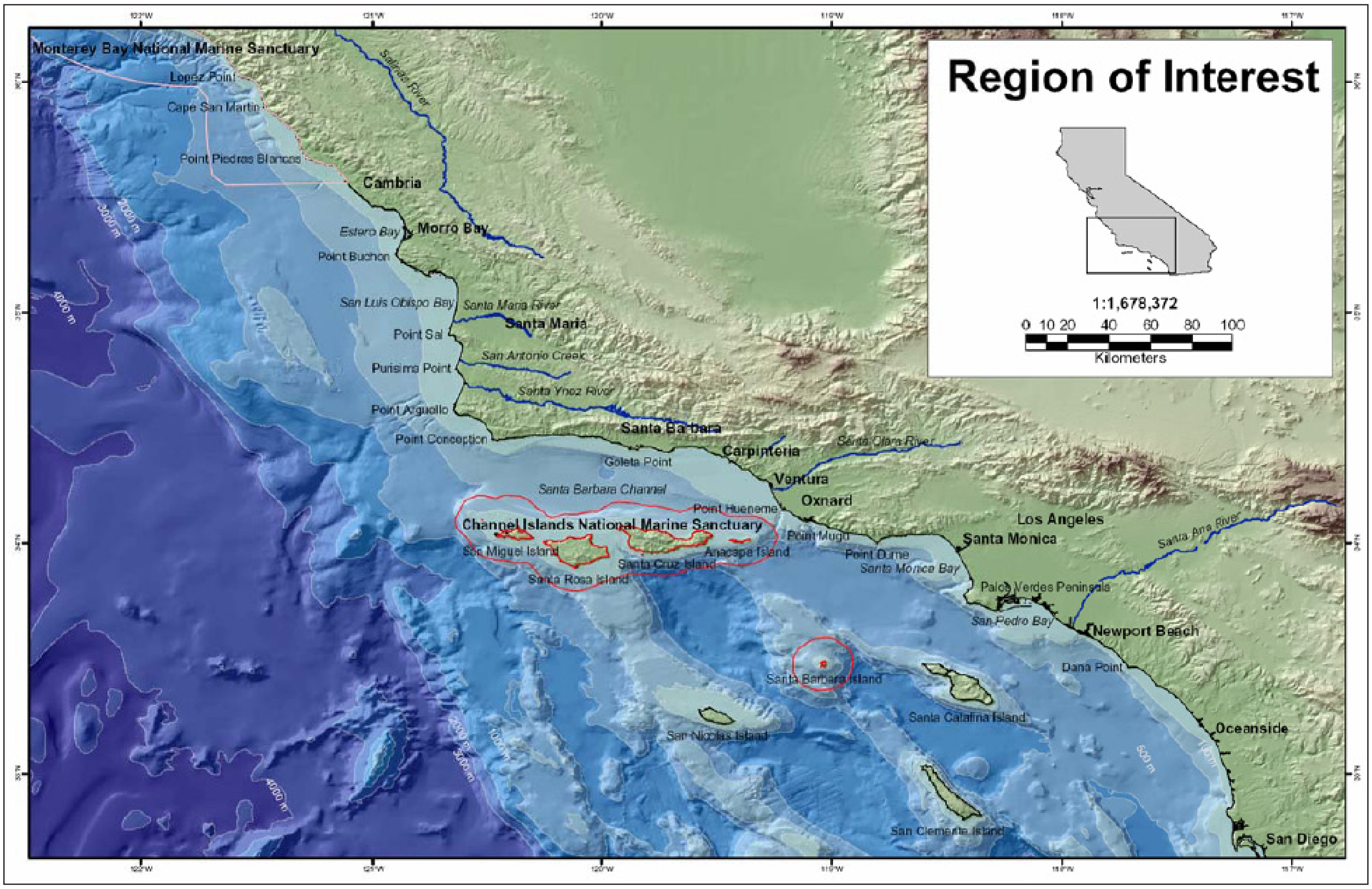

Figure 1.1.1. Map of the Channel Islands and specific coastal locations in the surrounding region of interest. The red lines indicate the current boundaries for the Channel Islands National Marine Sanctuary and the pink line to the north is the southern boundary of the Monterey Bay National Marine Sanctuary.

Three main factors have driven the sanctuary's interest in considering a change to the CINMS boundaries: 1) an emerging understanding of how the sanctuary's living resources are integrally connected to marine areas outside the CINMS boundary, 2) heightened awareness of human activities occurring outside the sanctuary that could pose threats to CINMS resources, and 3) high public interest in boundary expansion as expressed clearly during the 1999 public scoping meetings. These factors have been considered as the sanctuary's management plan review process has evolved.

The issue of expanding the sanctuary's boundary was first raised during public scoping meetings held in 1999, and has been an issue of continued interest to numerous constituents. A large number of scoping comments received suggested that sanctuary boundaries be expanded to incorporate more of the regional marine ecosystem and to allow CINMS to better address management issues associated with coastal watersheds, oil and gas development, water quality, and military activity. Other comments received were not in support of boundary expansion.

Following the scoping meetings, sanctuary staff worked closely with the Sanctuary Advisory Council and other constituents to better understand and assess issues underlying the possible need for expanding CINMS boundaries. In 2000, a literature review was commissioned to help understand the geographic range of ecological linkages among species and habitats found within the sanctuary (McGinnis, 2000). As a result of this assessment, the author recommended the area from Point Mugu northward to Point Sal (Figure 1.1.2a) as a connective unit. This area is referred to as the Study Area throughout this assessment.

A range of initial boundary "concepts" then emerged from meetings and workshops held with the Sanctuary Advisory Council in 2000 and 2001. In assisting with the design of boundary concepts, Sanctuary Advisory Council members considered the known locations of key or unique habitats, oceanographic processes, marine species, marine and coastal human activities, potential threats to sanctuary resources, ease of boundary identification, and other factors. The resulting six boundary concepts ranged in scope from the existing CINMS boundary, the "No Action Concept" (NAC), to an expansion to the coastal mainland extending from Point Sal in the north to Point Mugu to the south (Figure 1.1.2a).

The current CINMS boundary was designated under the authority of Title III of the Marine Protection, Research and Sanctuaries Act of 1972, now known as the National Marine Sanctuaries Act, and has remained unaltered since its establishment. The sanctuary is located in the Southern California Bight, 40 kilometers off the coast of Santa Barbara, California. It encompasses 3,745 km^2 of seawater, and extends from the mean higher high water line to six nautical miles offshore around the northern Channel Islands (San Miguel, Santa Rosa, Santa Cruz and Anacapa) and Santa Barbara Island (Figure 1.1.1).

Boundary Concept 1 includes the entire Study Area recommended by McGinnis (2000), plus an additional portion over part of the Santa Lucia Bank. As the largest boundary concept, it encompasses the widest range and variety of habitats. Human uses encompassed include oil and gas exploration and development, commercial and recreational fishing, other types of recreation, harbors, watersheds and military use. This is the only concept that includes coastal areas adjacent to harbors. Concept 1a resembles Concept 1, except for the exclusion of offshore oil and gas leases and coastal ports and harbors (Figure 1.1.2a).

Concept 2 incorporates much of the Study Area, and its area contains 62% of Concept 1. Unlike Concepts 1 and 1a, the mainland coastal component of Concept 2 begins at Gaviota and extends slightly north of Point Sal thereby excluding the more urbanized areas of the mainland coast. Unlike the larger boundary concepts, the northward boundary of Concept 3 does not incorporate Point Arguello. It extends from the southern boundary of Vandenberg Air Force Base, south past Point Conception and east past Cojo Anchorage. The mainland coast component of Concept 3 extends to a small fraction of the mainland coastline including Point Conception, without overlapping state or federal oil and gas leases and without adjoining any urban coastal areas (Figure 1.1.2a).

Concepts 4 (Figure 1.1.2a) and 5 (Figure 1.1.2b) include only offshore areas and do not include habitats associated with the mainland coast, such as mainland kelp beds, wetlands, and linkages to coastal watersheds. Concept 4 encompasses a larger area than the existing CINMS boundary, providing a contiguous connection between the northern Channel Islands and Santa Barbara Island. Concpet 5 is closest among the concepts to the existing sanctuary boundary, and essentially squares off the curved sanctuary boundary to aid in boundary

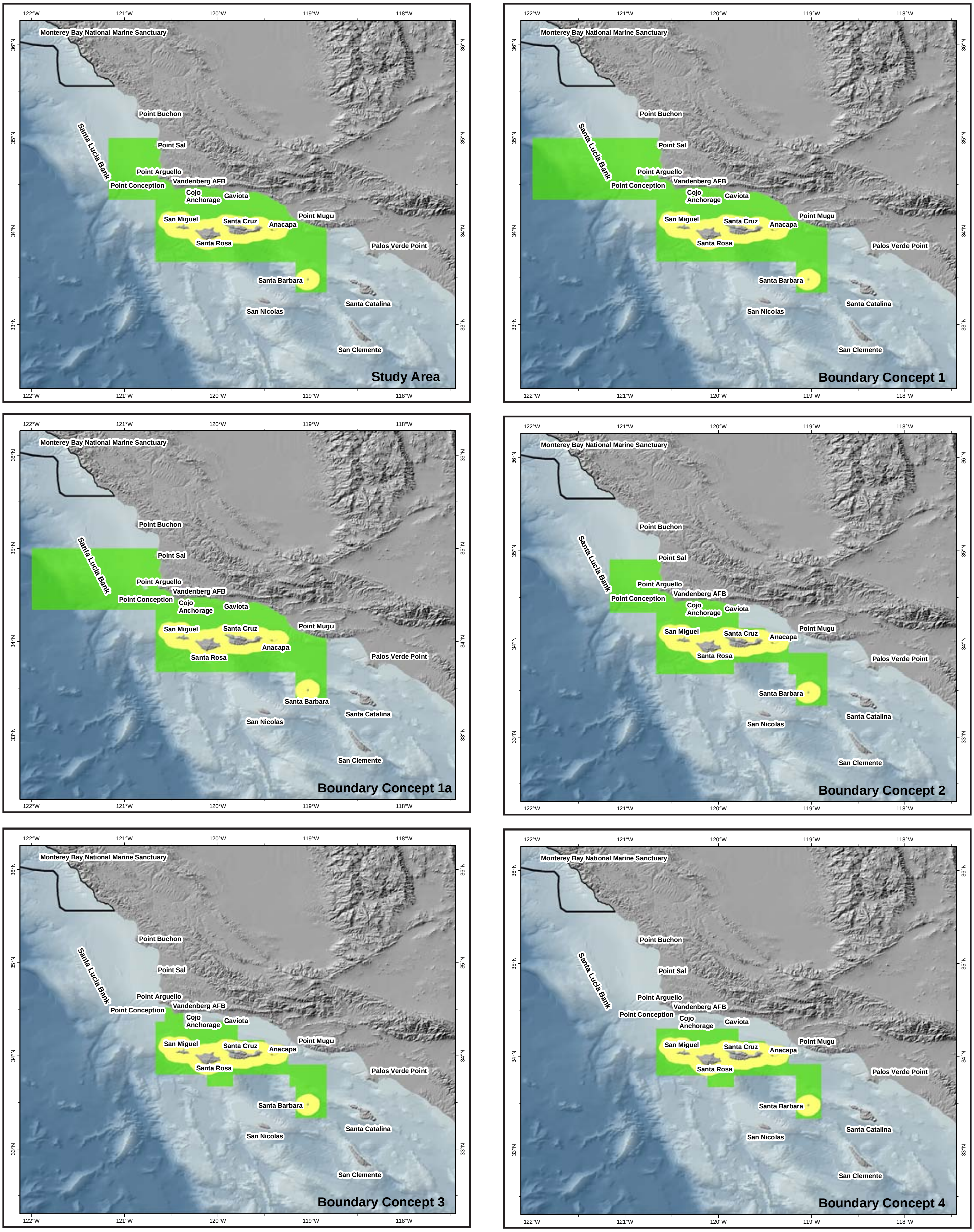

Figure 1.1.2a. Spatial delineations for the Study Area and boundary Concepts 1-4.

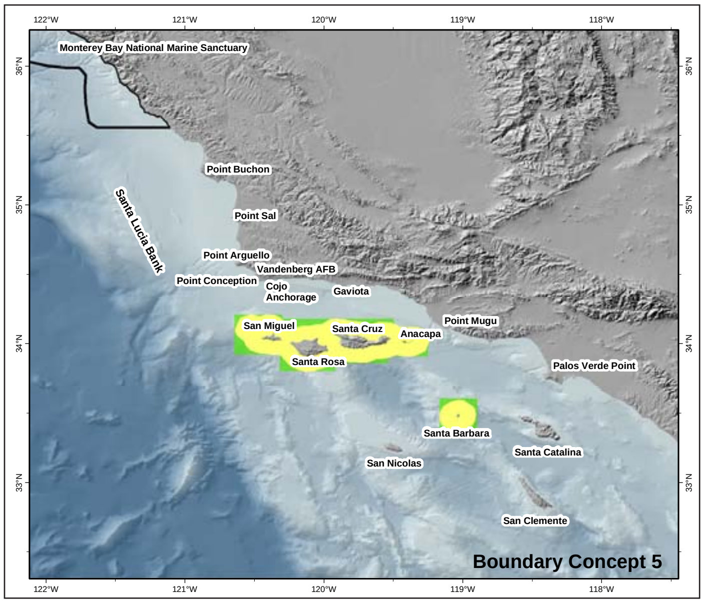

Figure 1.1.2b. Spatial delineation for boundary Concept 5.

Table 1.1.1. Total area, perimeter, and amount of mainland coastline included for the NAC, Study Area, and six boundary concepts.

	Area (km^2)	Perimeter (km)	Mainland Coastline (km)
NAC	3745	653.34	0.00
5	4536	708.72	0.00
4	7981	831.00	0.00
3	9044	903.67	20.32
2	13736	1074.90	140.02
1	22613	1220.10	277.64
1a	22591	1239.23	277.64
SA	*17093*	*1069.52*	*277.64*

identification for enforcement, charting and navigation purposes. Total area and amount of mainland coastline are displayed in Table 1.1.1.

In 2001, the Sanctuary Advisory Council was unable to reach a consensus on which of the six boundary concepts to endorse, and the issue remained controversial with a variety of stakeholders. In 2002, following the Advisory Council discussions, the NMSP in consultation with the NOAA Administrator determined that there was a need to conduct additional data collection and analyses in order to make an appropriately informed decision on boundary expansion. In particular, it was determined that a detailed study of the Channel Islands regional biogeography was needed and would be conducted by NCCOS. Hence, the revised draft management plan and associated Draft Environmental Impact Statement (DEIS) do not contain an analysis of the boundary concepts discussed herein.

In 2003, NCCOS was asked by the NMSP to evaluate (from a biogeographic perspective) the six boundary concepts that had been previously developed by sanctuary staff and the Advisory Council, including the NAC. Identifying how these alternatives correspond to the distribution of critical biotic and habitat resources is a necessary component of assessing the qualities of one alternative over another. However, it is important to note that this biogeographic study is not a decision-making document for NOAA; rather, this study will help inform any future decision-making on sanctuary boundary change.

Currently, the NMSP plans to incorporate and build on this biogeographic study, as well as previous work, to prepare a Supplemental Environmental Impact Statement (SEIS) that will present and fully analyze boundary change concepts (including the option of not changing the boundary). In compliance with the National Environmental Policy Act (NEPA), the potential environmental and socioeconomic impacts associated with any boundary change will be analyzed in the SEIS and made available for public review and comment. The process will be open and transparent to the public, involving significant discussion and input from the Advisory Council and other interested agencies and parties. After consideration and incorporation of comments received on the SEIS, a final agency determination on sanctuary boundary change will follow. Additional information about the public process conducted from 1999-2001 that led to the development of the seven boundary concepts analyzed in this report is currently available on the CINMS web site at the following locations: General background on the boundary change issue-http://channelislands.noaa.gov/manplan/boundaries.html; Sanctuary Advisory Council involvement with this issue-http://channelislands.noaa.gov/manplan/history.html; McGinnis (2000) report-http://www.channelislands.noaa.gov/manplan/documents.html.

This biogeographic assessment was made possible by a wealth of studies, local assessments (e.g., marine reserves analyses), and advancements in remote sensing that have provided a variety of new spatial data that can be used to support selection of a boundary. This work complements and builds upon a similar effort recently completed by NCCOS for three sanctuaries in central and northern California (Cordell Bank, Gulf of the Farallones, and Monterey Bay national marine sanctuaries; NCCOS, 2003). The biogeographic assessment for these three sanctuaries was conducted to identify important biological zones, time periods, and ecological linkages within an area that extends from Point Arena in the north to Point Sal in the south. The overlap in flora and fauna as well as the expertise of the research community allowed NCCOS to take advantage of contacts and data sources already developed through this earlier work. In addition, a supplemental report was developed for this prior assessment which describes the key ecosystems, species, and interactions occurring within that study region (Airamé *et al*., 2003). While the focus of the report was on central and northern California, it describes the surrounding regions as well. As a result, much of the current study draws on the information gathered and analyses conducted as part of that effort. With the addition of this report and biogeographic assessment, there is now integrated biogeographic information compiled for the California coastline from Pt. Arena south to the U.S. – Mexico border. This framework provides for future broad-scale analysis that goes well beyond the boundaries of individual sanctuaries and provides a strong foundation for managing sanctuaries not as isolated areas but as a network of interconnected habitats.

This assessment was conducted for the marine waters surrounding California's Channel Islands and represents the culmination of a 24-month collaboration between NCCOS and CINMS. It was greatly assisted by the generous support of time and data provided by numerous researchers along the entire west coast. While the immediate focus of this assessment was to evaluate a series of boundary expansion concepts for the sanctuary, a biogeographic study such as this one should help to inform managers who need to make other spatially explicit management decisions for this region. Additionally, this assessment represents a summary of existing comprehensive, large-scale data sets. Missing Taxa or areas not covered may provide the driving force for future research necessary to fill these gaps. This assessment only considers biological, geological, and physical oceanographic data, and does not include other boundary analysis criteria (e.g. socioeconomics, management feasibility) that will be utilized by the NMSP management to make the ultimate decision in selecting a boundary alternative from the SEIS.

1.2 INTRODUCTION TO BIOGEOGRAPHY

Biogeography is the study of the geographic distribution of species. More specifically, it is the study of the relationship of species' distribution patterns relative to geographical differences in the environment. It focuses on large-scale patterns in species distributions and classifies them into biogeographic regions, provinces, and life zones. Biogeographic regions are related to global climatic zones, with latitudinal differences in ranges of temperature, day length, and primary production. These are all important variables affecting distribution. Biogeographic provinces are biotically distinct geographic areas within a biogeographic region, and hence have similar ranges of day length and temperature but are distinct in other environmental characteristics. Life zones in the ocean generally represent major changes of environmental conditions (e.g., estuarine, coastal, open ocean) or bathymetric zones (with decreasing temperature and ambient light and increasing pressure occurring with increasing depth) (Hedgpeth, 1957; Allen and Smith, 1988; Allen, in press). Biogeographic provinces and life zones are adaptive, in that species living there must have specific adaptations to the environmental characteristic of the province or zone (e.g., to temperature range, seasonality of production, bathymetric pressure, light levels, etc.). Hence, the biota of these provinces and zones has developed over evolutionary time (Briggs, 1974; Allen, 1982a; Briggs, 1995).

Throughout a biogeographic province, one might expect to find the same set of species occurring in a given habitat in a given life zone (Allen, 1982a; b). Similarly in an adjacent biogeographic province, one would find a somewhat different set of species in the same habitat in the same life zone (Allen, in press). While some species would be unique to each province, some broadly ranging species would occur in both provinces (Allen and Smith, 1988). Where two adjoining provinces (or life zones) meet, there is an ecotonal region where species common in each are found in lower abundance. With distance from the ecotone center these incidental species become less important and predictable to a community in a given habitat.

It is important to understand the relative fidelity to and abundance of a species in a specific area. The distribution of biogeographic provinces has been relatively stable since the last ice age, although the location of boundaries between provinces varies somewhat with large-scale periodic and aperiodic climate changes (e.g., Pacific decadal oscillation, El Niño) (Allen *et al*., 2004). A species is typically more common and abundant within the main part of the biogeographic province(s) where it occurs. It occurs less frequently with greater variation of abundance near the end or outside of its typical biogeographic province (Andrewartha and Birch, 1954).

Biogeographic assessments are important because they focus on the large-scale distribution of species rather than on local occurrences of species and hence provide the basis for predicting biota for a given habitat within a biogeographic province. Assessments of specific species involves mapping nursery grounds, spawning areas, feeding areas, migratory routes, and areas where they are fished (NOAA, 1990). This provides valuable information for determining essential habitat for protection. In addition to the information these assessments provide on a single species, they can provide information on the distribution of species diversity and richness of biota. Furthermore, these assessments help to identify which species form assemblages or communities, and how population and community measures, such as species diversity and richness, vary in the region.

Biogeographic assessments are useful to coastal managers because they provide a basis for determining components of the biota that are typical of an area and are appropriate for management of species or habitats. Local assemblages are composed of species that are representatives of the biogeographic community and species that are incidental to the area (Allen, 1982a; b). In the former case, because of their persistence in the population, representative species can be more readily managed. In the latter case, incidental species are likely to vary greatly over time, either by chance or in response to climatic change, making management less likely to be successful in the long term.

1.3 BIOGEOGRAPHY OF THE WEST COAST

A number of biogeographic provinces and life zones occur along the California coast. There are two coastal biogeographic provinces: Oregonian and San Diegan. The Oregonian Province primarily extends from southeastern Alaska to Point Conception, and is part of the Eastern Boreal Pacific Region (Briggs, 1974; 1995). The Oregonian Province also extends southward beyond Point Conception along the outer islands of southern California, and in part reappears in upwelling areas off Baja California (Hubbs, 1949). The San Diegan Province (part of the warm-temperate California region, which also includes the Cortez Province of the Gulf of California) extends from Point Conception, California to Magdalena Bay, Baja California Sur (Briggs, 1974). However, in warm-regime years, some San Diegan species extend their ranges northward. Offshore are two provinces of the cold-temperate Oceanic Boreal Pacific Region. Offshore are two provinces of cold-temperate Ocean Boreal Pacific Region (McGowan, 1971). The Subarctic Province extends south along the California coast to Cape Mendocino, and the Transition Zone extends south from Cape Mendocino to Magdalena Bay.

Several pelagic and benthic life zones occur in this region (Allen and Smith, 1988). Pelagic life zones consist of the Neritic Zone (water column over shelf to 200 m isobath) and three oceanic zones (over slope and basins): Epipelagic Zone (surface to 200 m); Mesopelagic Zone (200-1000 m); and Bathypelagic Zone (1000-4000 m; Figure 1.3.1). Benthic life zones (Allen, In press) include Intertidal, Inner Shelf (0-30 m), Middle Shelf (30-100 m), Outer Shelf (100-200 m), Mesobenthal (Upper) Slope (200-500 m), and Bathybenthal Slope (500-1000 m; Figure 1.3.2). A separate Estuarine Zone consists of both water-column and benthic species (Hedgpeth, 1957).

Coastal biogeographic provinces differ in their distribution with depth, with the Oregonian Province extending further south with each successive benthic life zone (Allen, In press). In some cases, submergence occurs, with species occurring in shallow depth zones in central and northern California occurring in deeper life zones in southern California (Hubbs, 1949; Allen, In press).

The Channel Islands lie at the intersection between the warm-temperate San Diegan biota and the cold-temperate Oregonian biota. The California Current (which largely defines the California part of the Oregonian Province), flows south on the outer edge of the Southern California Bight (SCB) below Point Conception as the coast of southern California turns abruptly eastward. This current intersects the coast near Cape Colnett, Baja California (forming the southern end of the SCB). Part of the current flows north into the SCB, forming a large eddy, with warm water dominating the inner part of the SCB. This warm water zone comprises the southern California part of the San Diegan Province, whereas the outer islands of the SCB (San Miguel, Santa Rosa, and San Nicolas islands) largely have an Oregonian biota. Santa Cruz Island (eastern part), Anacapa Island, Santa Barbara Island, Santa Catalina Island, and San Clemente Island largely have a San Diegan biota (particularly the latter two islands). In a recent report by Airamé *et al*. (2003) describing the biogeography and ecological linkages of

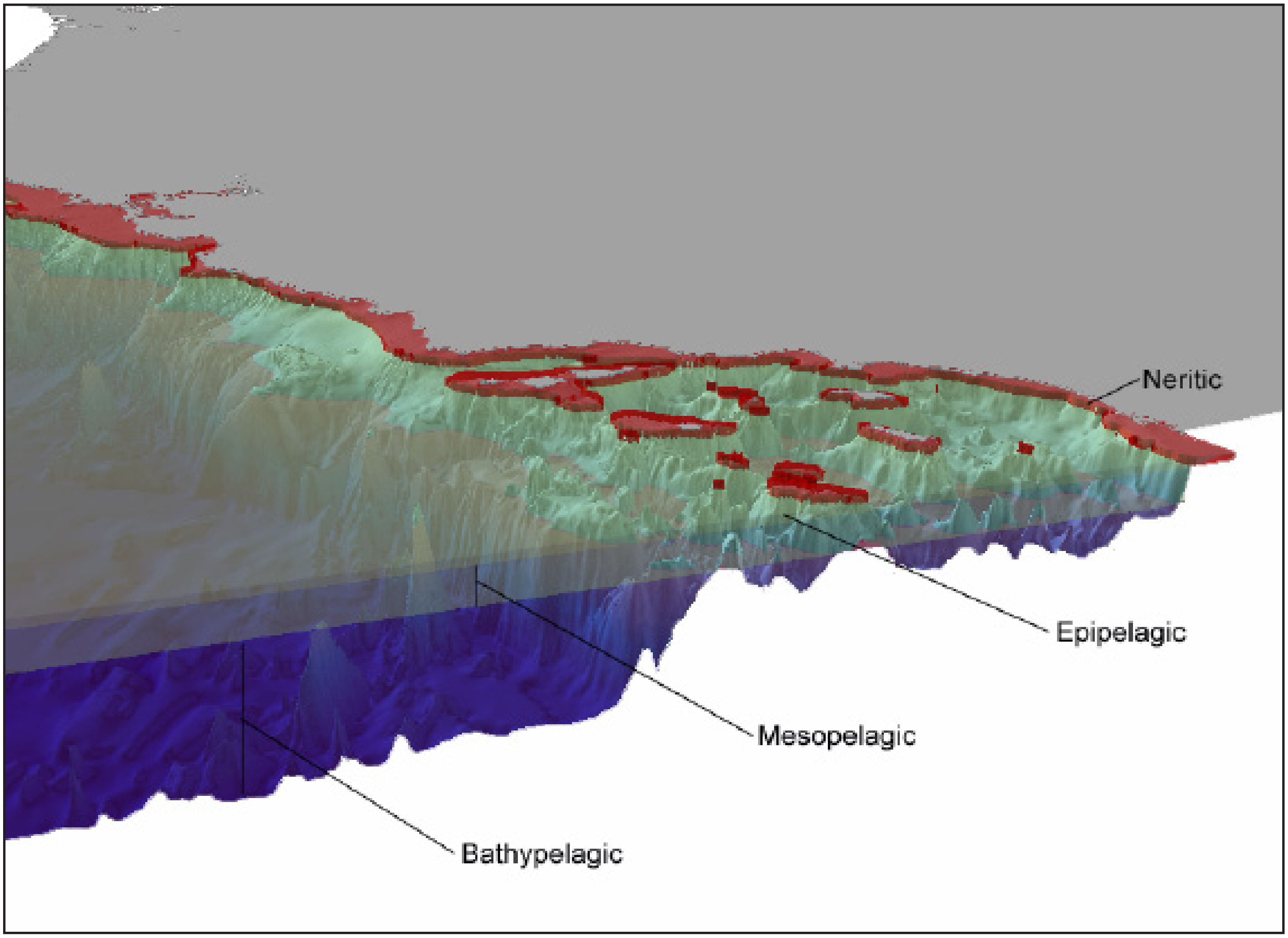

Figure 1.3.1. Pelagic life-zones off southern California.

marine and estuarine ecosystems of central and northern California, a range endpoint analysis was conducted on eastern Pacific marine invertebrates, fishes, birds, and mammals to look for biogeographic breaks in their distributions along the west coast of North America. The transition zone between the Oregonian and San Diegan provinces, which is located within the region of interest, is emphasized as a result of these analyses. A short discussion of the results is presented below.

Latitudes where the northern or southern extent of many species' ranges end often corresponded to major oceanographic features. For example, at Point Conception (a known biogeographic boundary described above), the cool water of the California Current intersects with the relatively warm water of the California Countercurrent, which flows north along the coast of southern California. These areas were highlighted graphically in Figures 1.3.3-1.3.6, where the longer bars equate to a greater number of species with range termini at the given latitude. The portion of the graphs enclosed by a black box highlight range endpoints within the region of interest. Analyzing latitudinal trends in this manner is a common technique applied to examine patterns of distribution, diversity, and structure in marine populations (Horn and Allen, 1978; Roy *et al*., 1994; Dawson, 2001). This type of information can, in turn, be used to identify distinct regions or transitional zones in the marine environment and allow managers a better understanding of their resources when making informed place-based management decisions.

Marine Benthic Invertebrates

The database used in this analysis (Figure 1.3.3) included 539 species of marine benthic invertebrates from the coast of California (G. Eckert, unpublished data). Information about each species was gathered from the primary literature and included the northern and southern range endpoints to the nearest 0.5° latitude. Results indicate significant transitions in fauna occurring at San Diego (32.5°N), the Channel Islands/Pt. Conception (33-34.5°N),

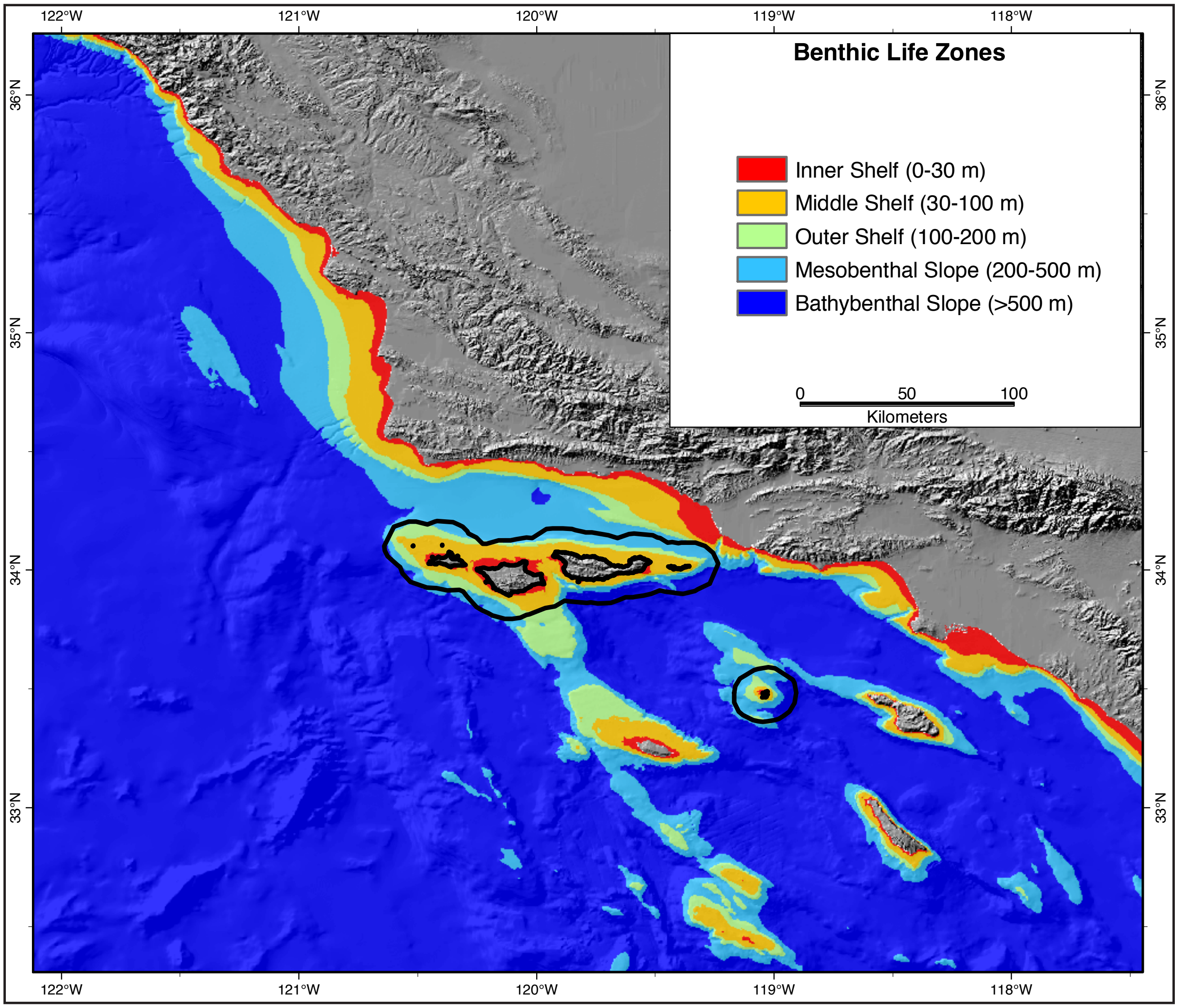

Figure 1.3.2. Benthic life-zones off southern California.

and Monterey Bay (36.5°N) with additional biogeographic breaks at Vancouver Island (49.5°N) and the Aleutian Islands (53°N). The large number of range endpoint peaks (both northern and southern) within the region of interest indicate that this is a transition zone where southern species are reaching their northern limits and are being replaced by northern species at their southern limits. Historical studies also support the findings shown here. Major barriers for eastern Pacific mollusks from Alaska to Baja California were found to occur at Vancouver Island (48-49°N), the northern Channel Islands (34.4°N), and Punta Eugenia (28.2°N) (Roy *et al*., 1994). Within California, Point Conception and Monterey Bay are recognized as biogeographical boundaries for ascidians, crabs, and shallow-water benthic mollusks (Hayden and Dolan, 1976; Valentine, 1966). Within southern California Newell (1948) found concurrent range endpoints at both San Clemente Island (33°N) and the northern Channel Islands (34°N) for marine mollusks.

Marine Fishes

Northern and southern range endpoints of 294 Pacific coast fishes obtained from Eschmeyer *et al*., (1983) are shown to the nearest 0.5° latitude (Figure 1.3.4). The overwhelming majority of range endpoints occur along the central and southern California coasts. The four major biogeographic transitions starting in the south occur at San Diego (32.5°N), the Channel Islands/Pt. Conception (33.5-34°N), Monterey Bay (36.5°N) and finally San Francisco/Point Reyes (37.5°N). A few minor shifts in species composition occurred at Cape Mendocino (40.5°N), Vancouver Island (49.5°N), the Aleutian Islands (54°N), Kodiak Island (57.5°N) and Prince William Sound (60.5°N). As in the case of benthic marine invertebrates, the large number of range endpoint peaks (both northern and southern) within the study area indicate that this is a transition zone where southern species are reaching their northern limits and are being replaced by northern species at their southern limits. The two dominant orders within this sample of fishes, Perciformes (N=122) and Scorpaeniformes (N=78), exhibit different biogeographic patterns. Perciform fishes are generally distributed south of Point Reyes, which is the most distinct

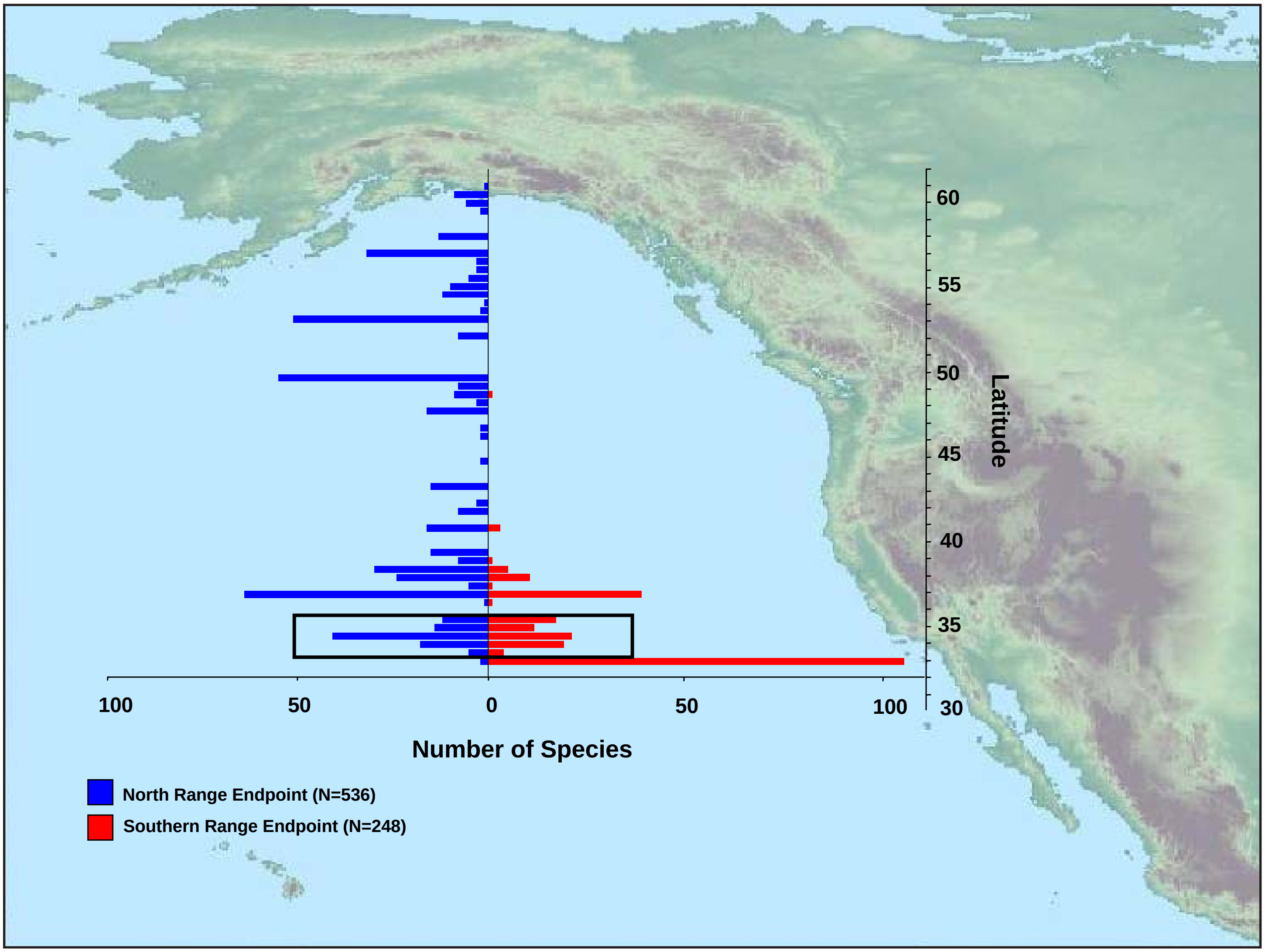

Figure 1.3.3. Latitudinal range endpoints for 539 species of marine benthic invertebrates.

biogeographic transition among members of this taxon. In contrast, Scorpaeniform fishes are distributed widely along the western coast of North America, from Baja California to the Bering Sea. A comprehensive analysis of the distribution of 500 species of marine fishes conducted by Horn and Allen (1978) also supports the results found here. The authors identify Point Conception as the most significant biogeographic boundary which could extend as far south as 30°S latitude. The authors note that Point Conception appears to be a more distinct boundary for southern species than northern species, which is consistent with results presented here.

Seabirds and Shorebirds

Distribution information used for this analysis was extracted from Peterson (1990), and included 132 shorebird and seabird species (Figue 1.3.5). Information on northern and southern range endpoints were summarized into 2° latitudinal bins. The resulting histogram shows small breaks in central and southern California. Central California is the northern endpoint for the distribution of four species (black-vented shearwater, least bittern, black storm-petrel, and clapper rail) and the southern endpoint for five species (glaucous gull, fork-tailed storm-petrel, Barrow's goldeneye, harlequin duck, and yellow-billed loon). While southern California is the northern endpoint for only three species (gull-billed tern, royal tern, and least storm-petrel), it is the southern endpoint for eight species (horned and red-necked grebes, mew gull, black scoter, common murre, pigeon guillemot, tufted puffin, and marbled murrelet). Overall, the distributions of most seabird and shorebird species found in the region of interest were wide ranging. Most of the northern range limits occurred in the Gulf of Alaska and Bering Sea, whereas most of the southern range limits occurred in Mexico. Although the coast of California does not present a significant biogeographic barrier for most seabirds and shorebirds, nearly ten percent of the species examined had a range terminus near southern California.

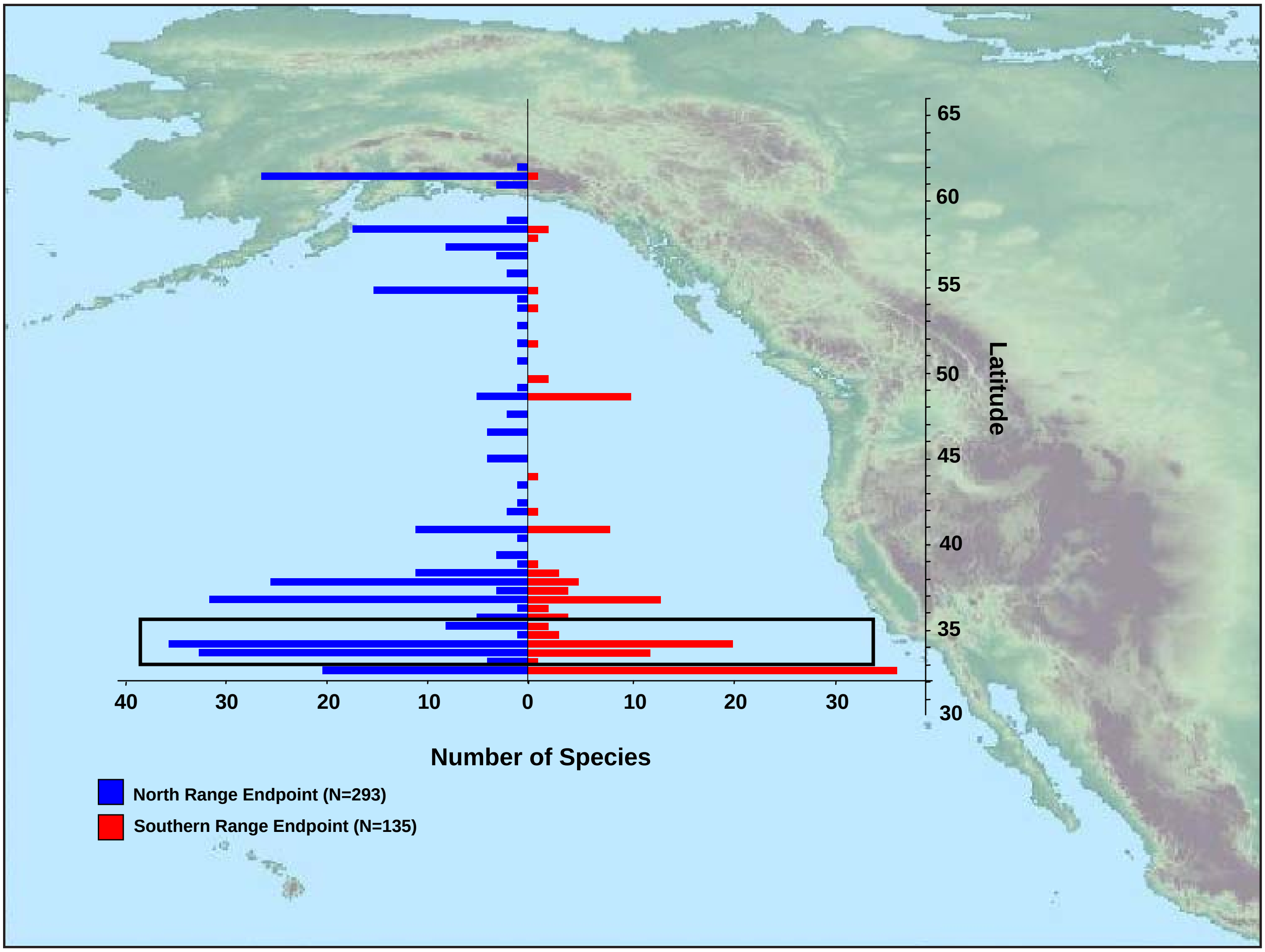

Figure 1.3.4. Latitudinal range endpoints for 294 species of marine fishes.

Marine Mammals

49 marine mammal species were included in this range endpoint analysis. Information about each species was obtained from Burt and Grossenheider (1976) and included the northern and southern range endpoints in 2° latitudinal bins (Figure 1.3.6). The most significant boundary in California occurs near Point Conception. A few delphinid species, including the melon-headed whale, pygmy killer whale, false killer whale, short-finned pilot whale, and striped dolphin are found primarily south of this promontory, while others such as the northern right whale dolphin, Dall's porpoise, harbor porpoise, Hubb's beaked whale, and Stejneger's beaked whale are found primarily north. This represents over twenty percent of the species examined in this study which is significant given that local oceanographic patterns and habitat features generally do not constrain the distributions of large marine mammals. The majority of marine mammals examined however, were widely distributed along the western coast of North America. Pinnipeds also exhibited wide distributions from Alaska to central or southern California and Baja California with no biogeographic breaks occurring in the region. Harbor seals are widespread in coastal habitats of the northern hemisphere. California sea lions are found from Vancouver Island to the southern tip of Baja California. Most of the population of Steller sea lions is in the Gulf of Alaska and the Bering Sea, but small populations are found along the coast as far south as central California. Northern elephant seals are distributed from the Aleutian Islands to Baja California. Although most of the worldwide population of northern fur seals is found on the Pribilof Islands, a small number of northern fur seals are found on Bogoslof Island in the southern Bering Sea, San Miguel Island off southern California, and the Farallon Islands off central California.

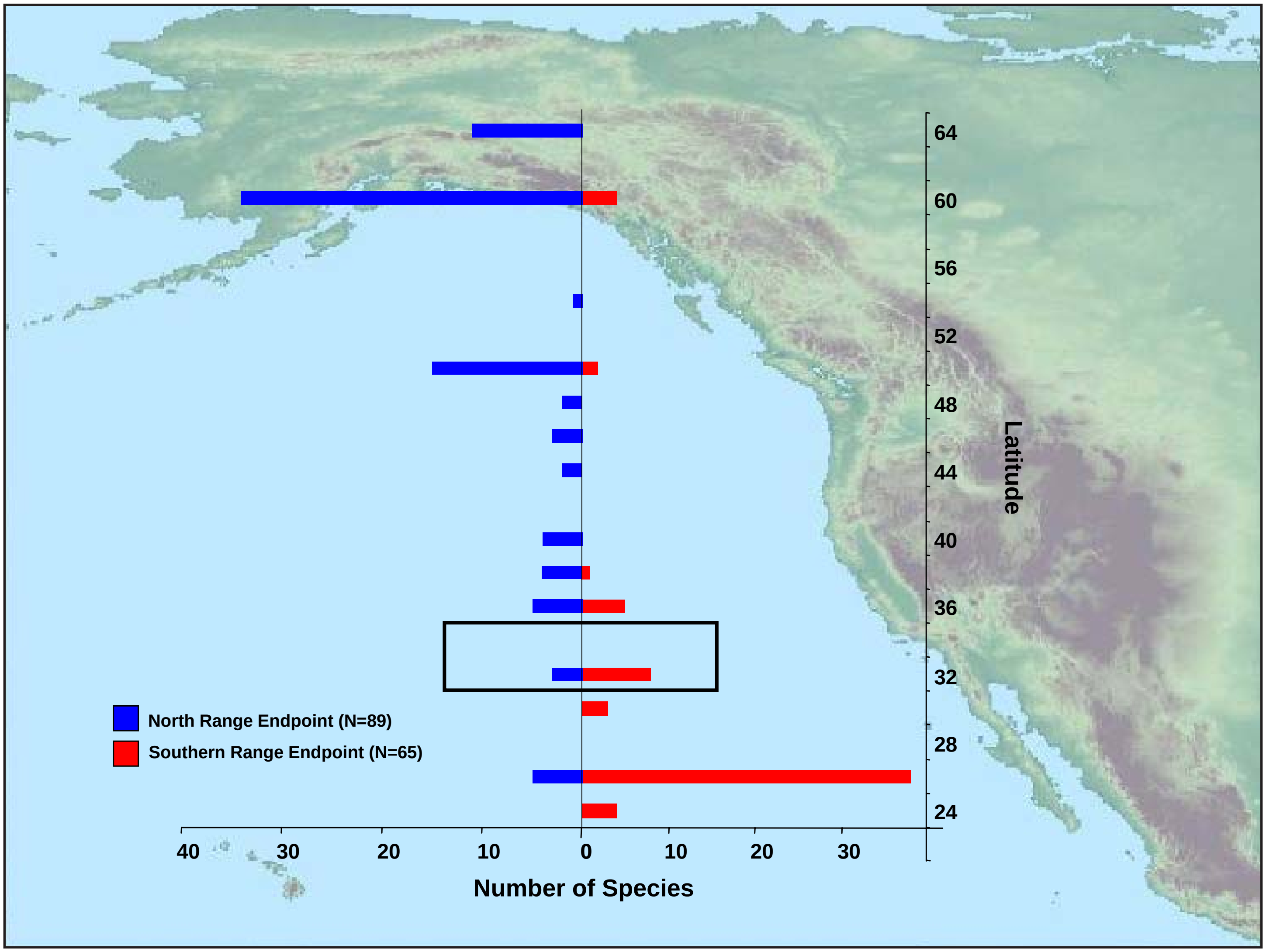

Figure 1.3.5. Latitudinal range endpoints for 132 shore and seabird species.

1.4 THE FOUR-STEP ASSESSMENT PROCESS

Species Selection

The initial step in the biogeographic assessment presented in the following chapters involved the identification of key species and the collection of relevant biological and physical data sets in the region of interest necessary to conduct spatial analyses. Recently, the state of California underwent a process to evaluate the region around the Channel Islands in order to determine which areas would be delineated as marine protected areas (MPA). One component of that process involved the identification of species whose distributions would be the biological focus of the decision. A working group was formed that developed a set of criteria to define species of interest around the Channel Islands. The list of species selected with these criteria includes: (1) species of economic and recreational importance, (2) keystone or dominant species, (3) candidate, proposed, or species listed under the Endangered Species Act, (4) species that have exhibited long-term or rapid declines in harvest and/or size frequencies, (5) habitat forming species, (6) indicator or sensitive species, and (7) important prey species. The list excludes species that are: (1) incidental, (2) at the edge of their ranges, or (3) highly migratory. The criteria by which the species were selected for the MPA effort were equally relevant for an analysis of the regional biogeography. However, the final species list for the biogeographic assessment was shortened, primarily for fish and invertebrates, due to the lack of sufficient spatial biological data.

Data Collection and Synthesis

Over 50 researchers along the west coast from federal and state agencies, non-governmental organizations, and academia were contacted in an effort to assemble all existing distributional data pertinent to the species selected above as well as their associated habitats. Once a data set was identified its utility was evaluated through exami-

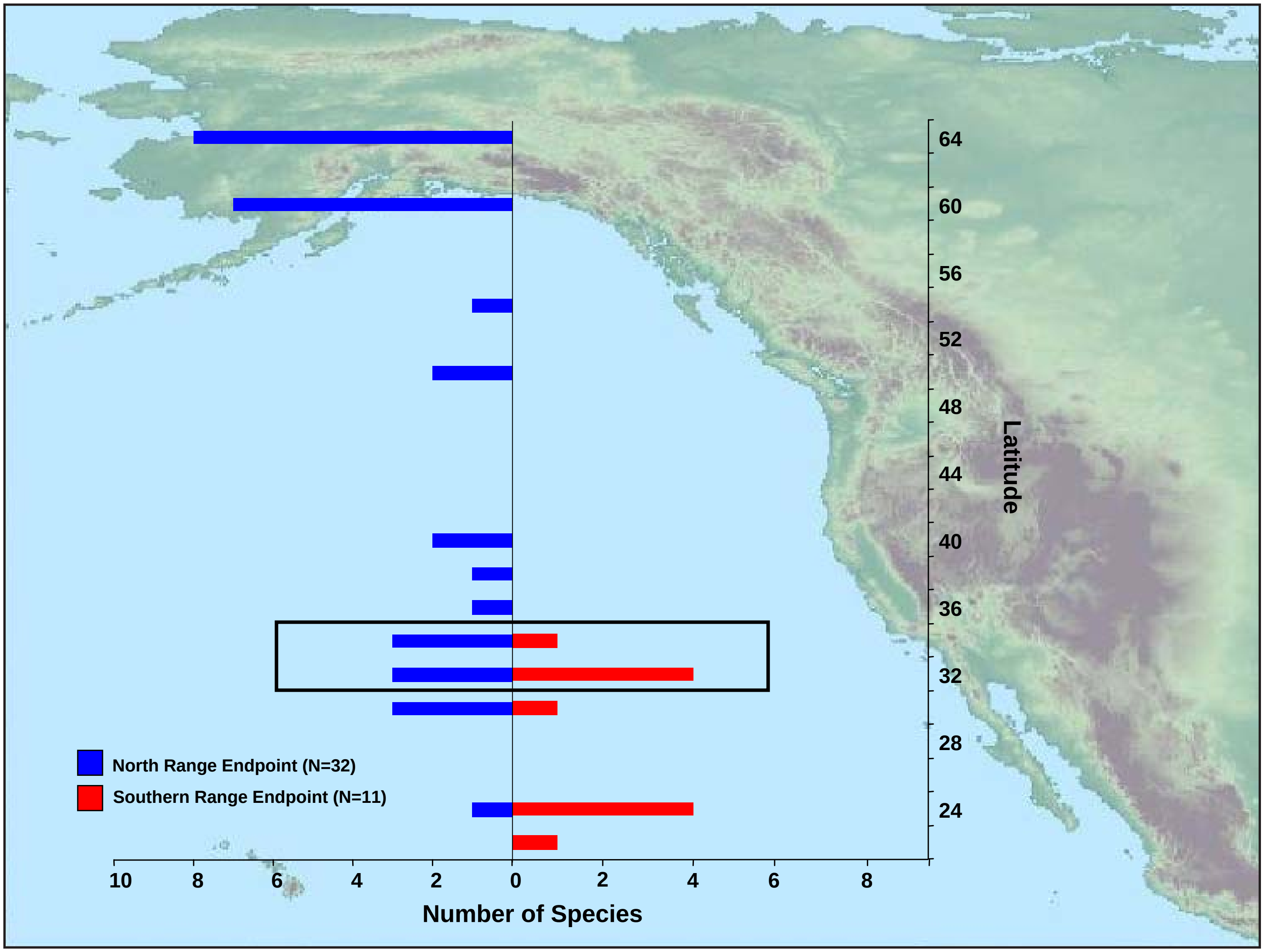

Figure 1.3.6. Latitudinal range endpoints for 49 marine mammal species.

nation of its spatial extent and quantity of information provided. As this study was dependent on pre-existing data rather than the collection of data specific to the questions asked, the type and quality of information collected was extremely variable from one data set to the next. Among the complexities of working with these inherently variable data were varying spatial and temporal coverages, as well as different methodologies employed in data collection. To the extent that differences precluded data sets from being combined and analyzed together, they were kept separate. Appendix B lists the data sets used in this assessment (as well as some that were identified, but not used) and the contact information for the data providers.

Broad-scale patterns were identified in the distribution of taxa based on species presence and absence, as well as abundance information where available. This step began by combining each unique data set into a common spatial framework within a Geographical Information System (GIS). An aggregate look across multiple species was conducted through examination of community metrics such as diversity and richness. In some cases, data were sufficient to perform clustering analyses to examine the co-occurrence of species at various locations. Patterns in the analyses conducted were then set in the context of the physical data layers (oceanography, bathymetry, and sediment). These layers were also utilized for modeling the potential distributions of specific invertebrates and fishes as existing data on individual species within those taxa was insufficient.

The next step in the process was the evaluation of the six boundary concepts with respect to resource distribution.

Metric Development

The choice of an appropriate metric for comparison of the different boundary concepts is a difficult one, and involves implicit value judgments. Since such judgments are policy decisions, and inherently beyond the scope of a biogeographic assessment, we have chosen to present three separate metrics along with a discussion of their biases and implied values. In each chapter, we present an absolute metric (count), a relative metric (density or mean), and the Optimal Area Index (OAI) for each boundary alternative. The absolute and relative metrics are provided because they are simple and intuitive. However, because these two metrics show biases for larger and smaller alternatives respectively, we have also chosen to present the OAI (explained below), which attempts to balance these two tendencies. None of these metrics is objectively better than another, and a thorough comparison of the boundary concepts will require consideration of all of them.

A fundamental distinction can be made between metrics which are based on absolute quantity and those based on relative quantity. Examples of absolute metrics include the total number of blue whale observations recorded in boundary Concept 5, or the total area of above average bird density falling within the current CINMS boundaries. Examples of relative metrics include the number of blue whale observations/km^2 recorded in boundary Concept 5, or the average bird density within the current CINMS boundaries. Although the difference in wording is subtle, under many circumstances the results of absolute and relative metrics can be completely opposite.

Consider a situation (illustrated in Figure 1.4.1) in which the area of greatest conservation value is concentrated in one location and that value declines with distance from this center. A set of hypothetical boundary concepts exist such that each boundary is centered on the location of highest conservation value, and each successively larger boundary encompasses the smaller. In this situation, absolute metrics will inherently favor the largest boundary. This is because, for absolute metrics, more is necessarily better (or at least no worse) when the smaller options are a subset of the larger ones. In our hypothetical example, relative metrics will inherently favor the smallest boundary. Since all boundaries are centered on the region of highest conservation value, expanding from the smallest can only add areas of relatively lower conservation value, thus reducing the magnitude of relative metrics such as means or densities. These relationships are illustrated in Figure 1.4.2.

For many of the species and community metrics discussed in this assessment, the hypothetical example above is an apt description of the situation. The current boundary of the CINMS was chosen in part because for many species it encompasses an area of optimal habitat. The smaller boundary concepts are also generally subsets of the larger concepts, with all options encompassing the current boundaries. To the extent that each species or community metric matches the hypothetical situation, absolute metrics will be biased toward the larger boundary concepts and relative metrics will favor the smaller.

Because of the inherent biases of absolute and relative metrics, we have included a third metric which attempts to provide a more balanced gauge of the relative merits of different boundary concepts. This third metric (the OAI) represents the relative increase in some measure of ecological value, divided by the relative increase in area compared to the current boundaries. The OAI is calculated using the formula:

$$OAI=(B_1-B_0/B_0)/(A_1-A_0/A_0)$$

where B_1 and B_0 refer to the value of the ecological metric (e.g. sightings, diversity, richness, etc.) within the boundary concept and the current boundaries respectively, and A_1 and A_0 are the respective areas. In the OAI, the terms representing the difference in ecological value (numerator) and the difference in area (denominator) are both calculated relative to the current boundaries. This provides some balance against the previously discussed biases, but may not eliminate them entirely.

Maps and spatial metrics of the boundary concepts evaluated using the above metrics are provided in Figure 1.1.2. After evaluating the six boundary concepts provided by the sanctuary, the data was further examined to determine if areas of high biological significance within the study region were absent from those options but should be considered as candidate regions for incorporation.

Analyses Review

All analyses completed as part of the biogeographic assessment were reviewed. All data providers, together with others familiar with the data sets, and selected members of the CINMS Sanctuary Advisory Council, were consulted to obtain consensus on the analytical methodology utilized and to ensure accurate interpretation of the resulting patterns.

1.5 ASSESSMENT OUTLINE

This assessment begins with a discussion of the physical setting (Ch. 2). The study area is described in this section in terms of the physical environment (geology, climate and meteorology, physical oceanography). Included in this chapter is a discussion of regional sea surface temperature patterns, chlorophyll, currents, and bathymetry as they are related to the boundary concepts. This places into context the four subsequent analytical chapters: marine invertebrates (Ch. 3), fishes (Ch. 4), birds (Ch. 5), and marine mammals (Ch. 6). Where data was sufficient, each of these chapters includes an analysis of community structure as well as a look at the individual species identified by the sanctuary as being of high importance. The marine mammal chapter is further refined with a section on pinnipeds and sea otters and another on cetaceans. Each chapter includes four major sections. The first section describes in detail the data and methodology used in the analysis of that particular taxa. The second includes an analysis of broad-scale patterns looking over the entire range for which data was available in the given data set. Following this, the focus is on the study area and the boundary concepts. Finally, a summary section discuses the resulting patterns uncovered in the analyses. Chapter 7, the integration, summarizes all the results and looks across all taxa for consistent patterns and contains an evaluation of how the different boundary concepts compare.

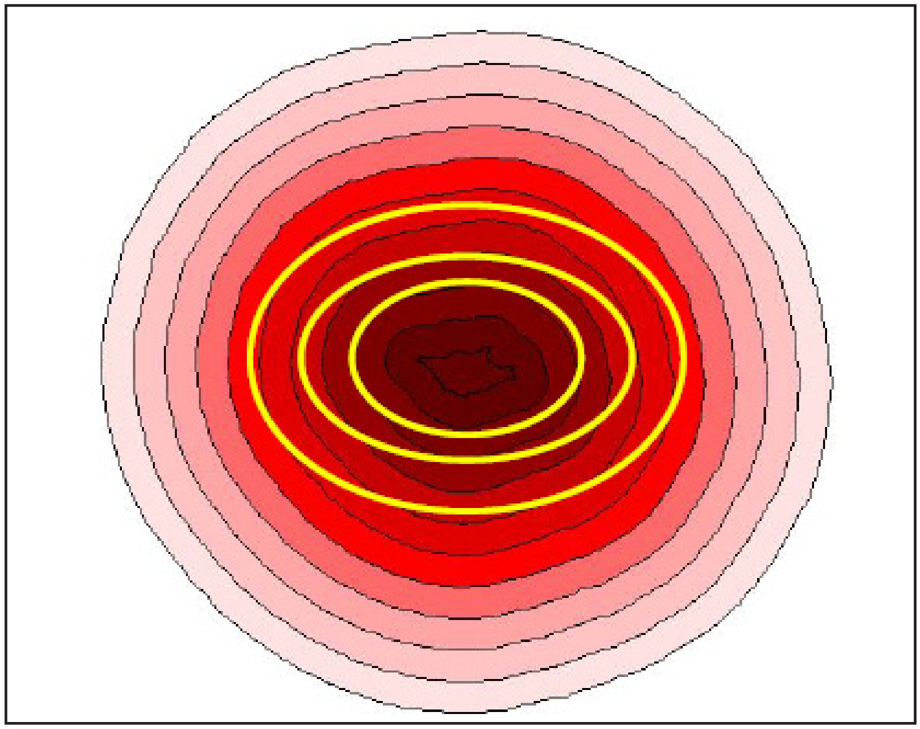

Figure 1.4.1. A hypothetical set of three boundary concepts (yellow lines), and the ecological value (red circles, with darker colors representing greater values) of the area contained within them.

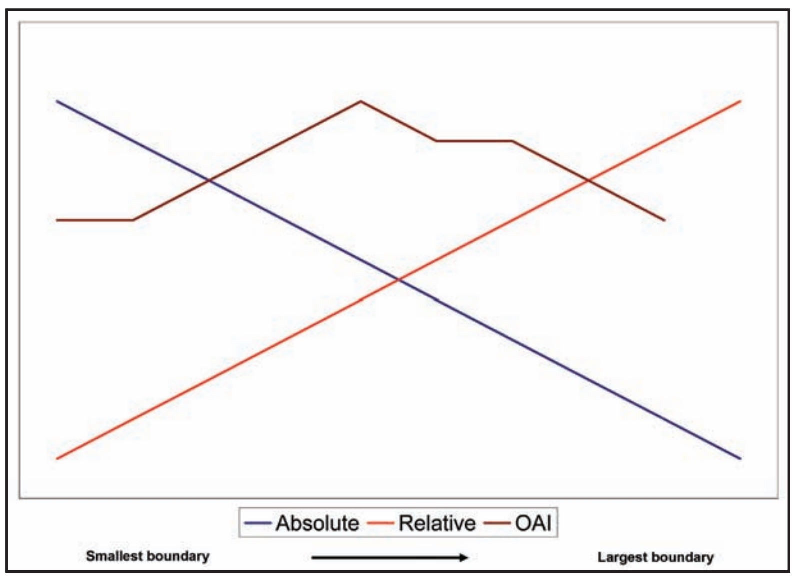

Figure 1.4.2. Trend in values of absolute and relative metrics and the OAI (rescaled for display) for the hypothetical example shown in Figure 1.4.1.

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CHAPTER 2 PHYSICAL AND OCEANOGRAPHIC SETTING

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2.1 PHYSICAL ENVIRONMENT AND GEOLOGY

The following sections provide a brief overview of the physical and oceanographic environment for the region of interest. Much of the material is excerpted or summarized from the *Draft Environmental Impact Statement for Channel Islands Marine Sanctuary* (CINMS, 2000) and *Ecological Linkages: Marine and Estuarine Ecosystems of Central and Northern California* (Airamé *et al*., 2003a) reports. This section describes the physical, climatic and oceanographic setting near the Channel Islands and supplements the subsequent analytical chapters which provide spatially-articulated assessments of both dynamic and static habitats of the region.

Figure 2.1.1 shows the geologic and bathymetric features for the region of interest. The four northern Channel Islands (San Miguel, Santa Rosa, Santa Cruz and Anacapa) parallel the east-west trend of the coast, and vary from 20 to 40 km offshore. Santa Barbara Island lies about 64 km south of Point Mugu, California. These islands are all located within a unique oceanographic region known as the Continental Borderland (Norris and Webb, 1990).

The Continental Borderland is located offshore of California between Point Conception and Punta Banda in Baja California (Mexico). Continued large-scale overriding of the North American Plate by the Pacific Plate in southern California caused movement along the San Andreas Fault System (Dailey *et al*., 1993). The Continental Borderland, with its wide shelf (up to 483 km seaward) and series of laterally shifted blocks, resulted from this movement (Dailey *et al*., 1993). Unlike most wide continental shelves that consist of gently sloping platforms interrupted by low banks and occasional canyons, the Continental Borderland is a region of basins and elevated ridges. The Channel Islands are the portions of the ridges that rise above sea level. The highest point in the Channel Islands is Picacho Diablo on Santa Cruz Island, with an elevation of 747 m. The seaward edge of the Continental Borderland is the Patton Escarpment, a true continental slope that descends 4,000 m to the deep ocean floor (Norris and Webb, 1990). Basin slopes account for 63% (49,753 km^2) of the borderlands area (Norris and Webb, 1990). Basin floors represent 17% of the total area (13,260 km^2), while the islands only comprise 1.1% of the total (880

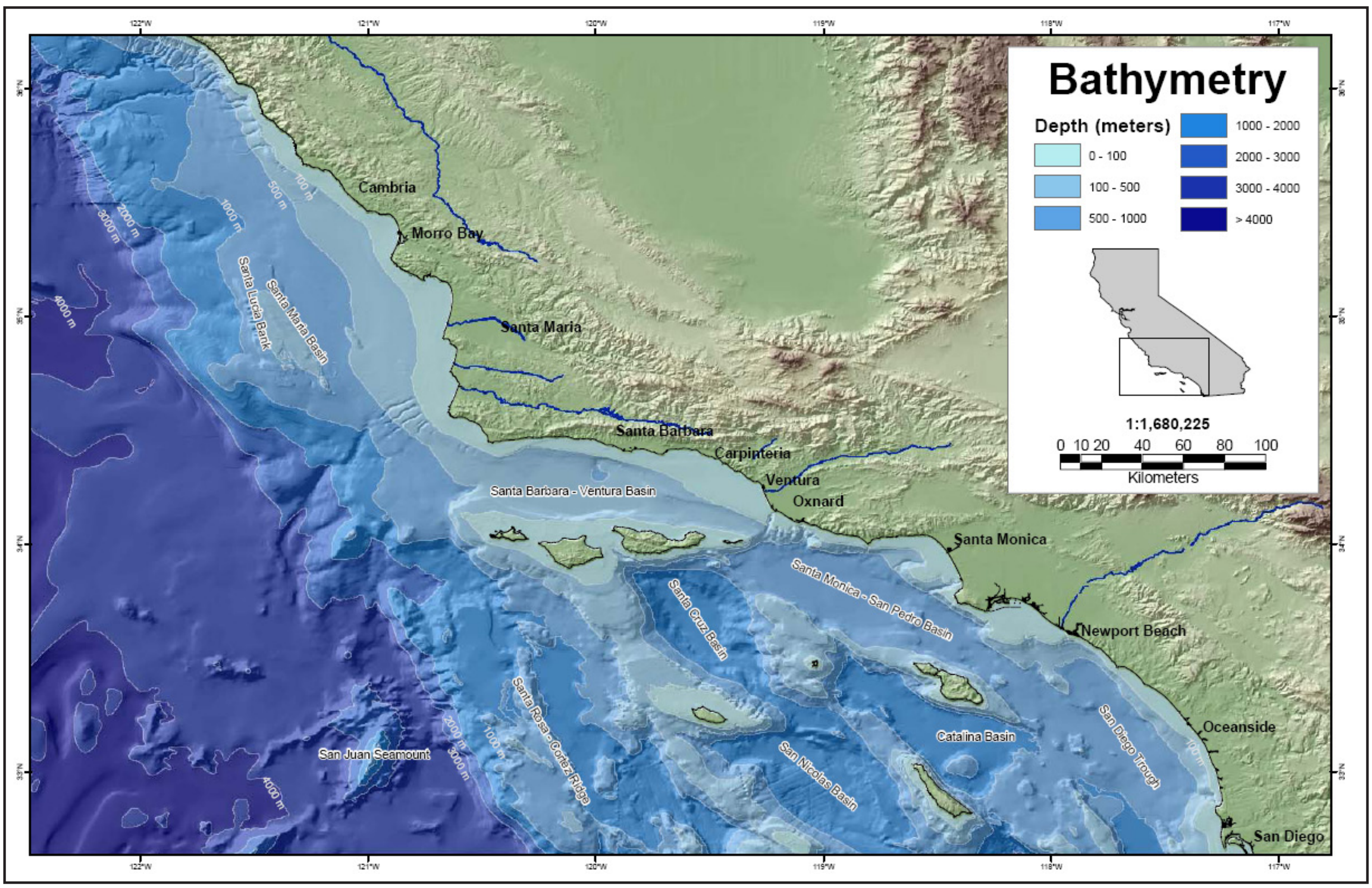


Figure 2.1.1. Bathymetric and geologic features of the region of interest.

km^2). The basins nearest the mainland have the shallowest depths, flattest floors and thickest sediment fills and range in depth from 500 to 2,500 m.

The Santa Barbara-Ventura Basin, oriented east-west in parallel with the coastline and the islands, lies between the islands and the mainland, and is approximately 500 m deep, 297 km long, up to 88 km wide, and approximately 13,000 km^2 in area. This basin is located within the Transverse Ranges Province, which also includes the Santa Ynez and Santa Monica Mountains, and the Channel Islands. The submerged portion of the Santa Barbara-Ventura Basin, an area of 5,179 km^2 and approximately 97 km in length from Point Conception to Port Hueneme, is commonly referred to as the Santa Barbara Channel. The western entrance to the channel is approximately 97 km wide with a sill depth of about 450 m, whereas the Anacapa Passage, the eastern entrance to the channel, is more limited with a width of 19 km and a shallower sill depth of 200 m (Dever, 2004). The remaining basins in the Southern California Bight, such as the Santa Cruz Basin to the south of the northern Channel Islands and the Santa Monica-San Pedro Basin to the southeast, trend northwest-southeast.

North of the Continental Borderland, the offshore Santa Maria Basin abuts the Santa Barbara-Ventura Basin at a location known as the “Amberjack High”. This basin extends north-northwest from Point Conception to Point Buchon and is approximately 160 km in length, 16 to 80 km wide, and approximately 7,769 km^2 in size. It is bounded on the east by the Hosgri and related fault zones, and on the west by Santa Lucia Bank.

There are at least 32 submarine canyons in the Continental Borderlands. Along the mainland coast are six prominent canyons that are thought to be related to the modern shoreline. Other coastal canyons appear to be related to the shoreline and lower sea levels during the Ice Age that ended approximately 12,000 years ago (Norris and Web, 1990). There are also canyons cut into offshore basins in the region (Dailey *et al*., 1993).

2.2 CLIMATE AND METEOROLOGY

Santa Barbara County has a Mediterranean climate characterized by mild winters, when most rainfall occurs, and warm, dry summers. The regional climate is dominated by a strong and persistent high-pressure system that frequently lies off the Pacific coast (generally referred to as the Pacific High). The Pacific High shifts northward or southward in response to seasonal changes or the presence of cyclonic storms. In its usual position to the west of Santa Barbara County, the Pacific High produces an elevated temperature inversion. Coastal areas are characterized by early morning southeast winds, which generally shift to northwest later in the day. Transport of cool, humid marine air onshore by these northwest winds causes frequent fog and low clouds near the coast, particularly during night and morning hours in the late spring and early summer months.

The terrain around Point Conception, combined with the change in orientation of the coastline from north-south to east-west, can cause counterclockwise circulation (eddies) to form east of the point. These eddies fluctuate from time to time and place to place, leading to highly variable winds along the southern coastal strip. Point Conception also marks the change in the prevailing surface winds from northwesterly to southwesterly.

During the fall and winter months, the region is subject to Santa Ana winds, which are warm, dry, strong, and gusty winds that blow northeasterly from the inland desert basins through the mountain valleys and out to sea. Wind speeds associated with Santa Ana conditions are generally 24 to 32 km/h, although they can reach speeds in excess of 96 km/h.

2.3 PHYSICAL OCEANOGRAPHY

The oceanography in the Study Area is closely tied to the processes of the California Current System which forms the eastern portion of the clockwise North Pacific Subtropical Gyre and extends 3,000 km from the Straight of Juan de Fuca (Vancouver Island) to Baja California Sur. The California Current is predominantly a wind-driven system and encompasses three major currents: the equatorward California Current, the poleward California Undercurrent and the poleward Southern California Countercurrent (which occasionally combines with the Davidson Current north of Point Conception).

In the Study Area, currents in the Santa Barbara Channel include patterns of warm, saline water from the Southern California Countercurrent and the colder water from the California Current. Upwelling often occurs where these water masses meet near the headlands of Point Arguello and Point Conception, as well as along much of the California coast, depending on the season. Upwelling plumes expand southward from headlands and frequently enter the Santa Barbara Channel on the southern side of the western mouth (Atkinson *et al*., 1986). There can be a channelwide response to upwelling north of Point Conception (Auad *et al*., 1998). Oceanographic thermal fronts are abundant in the Santa Barbara Channel and form as a consequence of upwelling and current shear between the two primary currents (Harms and Winant, 1998).

Offshore Ocean Currents

Offshore circulation in the Study Area is dynamic and results from the interaction of large-scale ocean currents, local geography, and the unique basin and ridge topography of the ocean bottom in the Southern California Bight. The prevailing wind system of the North Pacific Ocean is the mid-latitude Westerlies, a belt of winds that blow from west to east between 30ºN and 60ºN. These westerly winds create the North Pacific Current that pushes water away from Asia towards the west coast of North America. As this trans-Pacific flow converges toward the North American coastline, it is deflected equatorward forming the eastern boundary of the California Current. This surface current is dominant year round, and appears as a slow, broad southeastern flow that transports cool, fresh, nutrient and oxygen-rich subarctic water equatorward. The California Current extends from the shelfbreak to an offshore distance of approximately 1,000 km, with strongest speeds at the surface and extending to at least 500 m in depth (Hickey, 1998), while the inshore section of the current is limited to the upper 200 m over the continental slope (Hickey, 1979). North of Point Conception, the core lies about 100-200 km from the coast, with maximum equatorward velocities of 5-10 cm/s (Chelton, 1984). South of Point Conception, the core of the California Current flows further from the coast between 300-400 km offshore (Lynn and Simpson, 1987) with average speeds generally less than 25 cm/s (Reid and Schwatzlozse, 1962). Seasonal maxima in current speeds occurs in the summer to early fall.

South of Point Conception, a portion of the California Current turns shoreward into the Southern California Bight both north and south of the Channel Islands. Near San Diego, a larger branch of the California Current bends poleward into the SCB, where it is known as the Southern California Countercurrent. This nearshore countercurrent dominates the mean water circulation in the Southern California Bight during summer and winter (Hickey, 1993) at poleward speeds of 10-20 cm/s (Oey, 1999). Huyer *et al*. (1989), Harms and Winant (1998) and Oey (1999) have suggested that this countercurrent is caused by equatorward weakening of the wind curl south of Point Conception.

The Southern California Countercurrent draws warmer water from the south and forces the water northwest through the southern Channel Islands and the Santa Barbara Channel (Dailey *et al*.,1993). Additionally, some of the countercurrent is deflected west into the California Current south of the northern Channel Islands, resulting in a seasonal counterclockwise gyre in the Southern California Bight called the Southern California Eddy (Lynn and Simpson, 1987, Hickey, 2000). In spring, when the countercurrent is at its minimum northward flow, equatorward surface flow prevails in the Southern California Bight (Hickey 1993). Hickey (1979) suggested that the Southern California Countercurrent may combine with the poleward Davidson Current north of Point Conception, the latter having peak flows during winter.

Underlying the California Current and the Southern California Countercurrent is a subsurface flow called the California Undercurrent, a narrow (10-40 km) poleward flow that extends the length of the coastline from Baja California to at least 50ºN (Hickey, 1998). Originating in the eastern equatorial Pacific, the California Undercurrent can be characterized by a warm, saline, oxygen and nutrient-poor signature (Neander, 2001). Peak northward speeds of 30-50 cm/s usually occur in summer to early fall, being stronger at depths 100-300 m, and can be continuous over distances of more than 400 km along the continental slope (Collins *et al*., 1996; Pierce *et al*., 2000) or can break into separating, mesoscale jets (Cornuelle *et al*., 2000; Barth *et al*., 2000).

Circulation in the Study Area is also influenced by coastal upwelling, a process regulated by prevailing winds and the orientation of the coastline. In the northern hemisphere, Ekman transport causes surface water to move ~45 degrees to the right of the wind direction. Where surface water is pushed away from the coastline, deeper nutrient rich water rises to the surface creating an upwelling current. Along the north-south oriented coast of California, winds blowing from the north move surface water westward, away from the coastline, creating upwelling currents that bring colder water to the surface (San Francisco State University, 2000). North of Santa Cruz (>37ºN), a strong seasonal contrast in winds results in favorable upwelling conditions in summer contrasted by downwelling during winter storms (Strub and James, 2000). From 35-37ºN, modest storm activity results in monthly mean winds that remain upwelling-favorable year round (Strub and James, 2000). In contrast, upwelling is rare along the mainland coast of the Santa Barbara Channel because the headlands at Point Conception shelter the east-west oriented channel from the strong northwesterly winds that generate upwelling (Love *et al*., 1999). Point Conception is the southernmost major upwelling center on the west coast of the United States, and marks a transition zone between cool surface waters to the north and warm waters to the south (Love *et al*., 1999). However, upwelled water from regions north of the Bight appears to enter the western end of the Santa Barbara Channel and move eastward along its southern boundary (Hickey, 2000).

The currents and upwelling effects, with their varying water temperatures, create at least three climatic/habitat zones in the Santa Barbara Channel and the surrounding region. Waters north of Point Conception and offshore and south of the Channel Islands are cool, and have biotic assemblages characteristic of northern and central California (Oregonian Biogeographic Province) (Airamé *et al*., 2003b). San Miguel Island is primarily influenced by the cool water of the California Current, and also lies in the Oregonian Biogeographic Province. The warm waters of the California Countercurrent dominate the Santa Barbara Channel and Santa Barbara and Anacapa Islands. These areas belong to the Californian Biogeographic Province (Airamé *et al*., 2003b). Eastern Santa Rosa Island and Santa Cruz Island occupy a transition zone between the cold and warm water provinces, and should be considered a third biogeographic region (Seapy and Littler, 1980; Airamé *et al*., 2003b)

Within the Santa Barbara Channel, a localized cyclonic gyre circulation pattern exists year-round (Hendershott and Winant, 1996; Lagerloef and Bernstein, 1988) with seasonal variations in intensity. In general, cool water enters the channel from the west and flows eastward along the Channel Islands, while warm water enters the channel from the east and flows westward along the coast. Harms and Winant (1998) identify six distinct variations; *Upwelling, Relaxation, Cyclonic; Propagating Cyclones, Flood East, and Flood West*. In the *Upwelling* pattern, there is a strong south and southeastward flow of cool water from Point Conception and along the north sides of the Channel Islands, and a weak warm water flow toward the northwest along the mainland. In the *Relaxation* pattern, there is a strong northwestward flow of warm water into the channel from the east, and a weak inflow of cold water from the west. The *Cyclonic* pattern is an elongated, closed pattern created when the central eddy is strongest, and there is little flow into the channel from either the west or the east. In the *Propagating Cyclones* pattern, small, tight circular flow cells form in the center of the Channel and drift toward the west. These four patterns form in spring, summer and fall, but the cyclonicity is strongest in summer and weakest in winter. In the winter, directional flow patterns form. The winter *Flood East* pattern consists of a strong eastward flow into the Channel along the coastline, and lesser eastward inflow along the Channel Islands. The winter *Flood West* pattern has a strong northwestward flow along the coast, and a weaker northwest flow along the islands.

Two opposing forces generate the cyclonic flow patterns: a poleward pressure gradient and an equatorward wind stress (Nishimoto and Washburn, 2002). In the warm waters of the Southern California Bight, sea level is higher than in the cold, upwelled waters north of Point Conception. This difference in sea level creates a poleward pressure gradient that draws water westward through the channel. Upwelling-favorable winds tend to drive strong eastward flow, opposing the westward pressure gradient. When the effects of wind equal that of the pressure gradient, the cyclonic flow patterns form. Imbalances in the two competing forces create the pattern variations described above.

Nishimoto and Washburn (2002) found that the eddy circulation in the Santa Barbara Channel extended to depths of at least 650 feet (200 m), or nearly half the total channel depth, and suggest that persistent cyclonic eddies play an important role in maintaining marine populations through climate changes. Cold water uplifted in the center of the eddy may provide an additional source of nutrients during a shift to a warm-water regime, increasing primary productivity and the amount of food available for fish. Nishimoto and Washburn (2002) found large aggregations of juvenile fishes concentrated in an eddy in the Santa Barbara Channel, and suggest that high food availability and feeding success contributed to faster growth and higher survivorship of these fishes. Nishimoto and Washburn (2002) also noted that the fishes were entrained in the eddy current in their larval stages and remained there until they passed the juvenile stage, when they grew strong enough to escape the circulating current.

Hickey (2000) found that the sediments in ocean basins of the SCB are near anoxic to anoxic, and that the anoxic area is increasing. Expansion of the anoxic areas reduces the ability of the basin sediments to support marine life. The high ridges between the basins essentially prevent influx of oxygen-bearing water into the basins, which is important for maintaining oxygen levels. The events that bring oxygen to the basins are associated with processes in the upper water column. Strong upwelling and southeastward flow from the Santa Barbara Channel into the Santa Monica Basin appear to drive cold, denser water over the ridges into the basins, where it mixes with the ambient water confined within. Influxes of oxygen-bearing cold water occur only for a few days at a time, after intervals of several years (Hickey, 2000). The Santa Barbara Basin, which lies between the Channel Islands and the mainland, is relatively shallow (1,640 ft/500 m). An intense coastal upwelling event off Point Conception caused rapid renewal of the water in this basin (Hickey, 1993). Within the last 40 years, water in the Santa Barbara Channel has overturned several times (Hickey, 1993).

Waves

Waves in the Santa Barbara Channel are produced by seasonal swells crossing the open ocean, the sheltering effect of Point Conception and the Channel Islands, the variable wind fields that arise from the mountainous coastal and island topography, and the complex shallow water bathymetry within the channel (O'Reilly *et al*., 2000). Deep water swells from winter storms typically enter the channel from the west or west-southwest, for the most part unbroken by the Channel Islands. West swells produce high waves along the south-facing coastline just south of Point Conception and at the eastern end of the channel south of Ventura. A massive fan of sediment deposited on the shelf by the Ventura and Santa Clara rivers concentrates much of the wave energy traveling eastward down the channel onto a narrow section of coastline near the mouth of the Santa Clara River channel (O'Reilly *et al*., 2000). When the deep water swell originates more from the west-southwest, this focusing zone shifts directly northward into the Ventura area. West swells can also produce large waves at Rincon Point west of Ventura, and at the south end of Santa Monica Bay near Redondo Beach. Wave heights increase along portions of the Channel Islands that border the south side of the channel (O'Reilly *et al*., 2000).

In the summer, deep water swells originate in the south Pacific, and encounter the Channel Islands as they move north toward California. The islands shelter most of the channel and the south-facing coast from summer swells, significantly limiting wave heights. South swells from storms near New Zealand enter the western end of the channel, while those originating further east near South America are almost entirely obstructed. South swells travel past Anacapa Island and reach the coast near Ventura and Rincon Point. Rare swells originating from the southeast can reach the coast at Santa Barbara (O'Reilly *et al*., 2000).

Long-Term Climate Perturbations

Longer term climatic phenomena influencing the region include El Niño, Pacific Decadal Oscillation, and global warming. The recurring El Niño-Southern Oscillation pattern is one of the strongest in the ocean-atmosphere system. El Niño is defined by relaxation of the trade winds in the central and western Pacific, which can set off a chain reaction of oceanographic changes in the eastern Pacific Ocean. Off the coast of California, El Niño events are characterized by increases in ocean temperature and sea level, enhanced onshore and northward flow, and reduced coastal upwelling of deep, cold, nutrient-rich water. During this period, survivorship and reproductive success of planktivorous invertebrates and fishes decrease with plankton abundance. Marine mammals and seabirds, which depend on these organisms for food, suffer food shortages, leading to widespread starvation and decreased reproductive success.

Every 20-30 years, the surface waters of the central and north Pacific Ocean (20°N and poleward) shift several degrees from the mean temperature. Such shifts in mean surface water temperature, known as the Pacific Decadal Oscillation, have been detected 5 times during the past century, with the most recent shift in 1998. The Pacific Decadal Oscillation impacts production in the eastern Pacific Ocean and, consequently, affects organism abundance and distribution throughout the food chain. Ocean waters off the coast of California have warmed considerably over the last 40 years. It is not clear if this warming is a consequence of an interdecadal climate shift or global warming. In response to these three phenomena, some species have shifted their geographic ranges northward, altering the composition of local assemblages.

2.4 PHYSIOGRAPHIC COMPLEXITY

Data and Methods

The rationale behind examining physiographic complexity is to provide potential linkages to spatial patterns described in other chapters, and to provide a measure of context for subsequent discussions of observed regional biogeographic patterns. For example, offshore circulation patterns in the region result, in part, from the interaction of large-scale ocean currents, local geography, and the unique basin and ridge topography of the ocean bottom of the Southern California Bight (Airamé *et al*., 2003a). As discussed in chapter 2.2, these currents influence the distribution of living marine resources in the region. Furthermore, many taxa, particularly fishes, are known to exhibit a strong affinity for areas of high structural complexity (Yoklavich *et al*., 2000, 2002; Hixon *et al*., 1991; Hixon and Tissot, 1992; Field *et al*., 2002; Starr, 1998; and Williams and Ralston, 2002). The analyses presented here are provided as a proxy for quantifying structure in the region (i.e., mesoscale rugosity), and should be interpreted with care, as they represent an estimate for only one neighborhood range (1 km). Similar analyses can be performed for an infinite set of ranges, each resulting in similar patterns with dimensions proportionate to the prescribed neighborhood.

The maps of physiographic complexity presented here were derived using a bathymetric grid produced by the California Department of Fish and Game (CDFG) in August 2000 (Figure 2.1.1-Chapter 2.1.1). This bathymetric grid was made from 75 tiled digital elevation models (DEM) that were mosaicked into a single grid, and resampled to a 200 m resolution. DEM's were developed by the Teale Data Center under contract with CDFG, and have a geographic domain ranging from 31.9^{o} to 42.5^{o} north latitude. Physiographic complexity was calculated from these bathymetric data using a neighborhood statistical function in ArcView 3.2 (GIS), and represents the degree of variation in water depth (bathymetry) within a prescribed (and constant) area for the entire seascape. In this analysis, a standard deviation of water depth was calculated within a 1 km radius "moving-window". The calculated standard deviation was then assigned to the centroid of that neighborhood. This analysis was performed by centering the moving window on each individual bathymetric grid cell in the source data, and resulted in an estimate of the standard deviation of bathymetry at a scale of 1 km for the entire region (Figure 2.4.1, mapped range is 32^{o} to 39^{o}N). This measure of complexity was chosen over calculating a standard slope value because it not only captures areas of high slope, but also highlights areas that typify the unique basin and ridge topography of the ocean bottom in the Southern California Bight.

To analyze patterns of physiographic complexity in relation to proposed boundary concepts, average variance was calculated inside each of the boundaries. The assumption of this analysis was that encompassing an area of higher average complexity is preferred, and that this complexity likely provides a more diverse complement of potential habitats (niches) for living marine resources. Average complexity within each concept was then used in calculating an Optimal Area Index (OAI). Since the average is a relative measure of physiographic complexity, we also provide an analysis of the absolute area of high complexity captured within each concept. In this analysis, results of the complexity map were classified into standard deviations, with areas in red representing locations where the complexity was equal to or greater than 2 standard deviations above the mean deviation (henceforth "high"; stippled area in Figure 2.4.1). The total area of high complexity contained within each concept was then estimated for use in the absolute OAI calculations.

Broad-scale Patterns

The spatially-articulated estimate of physiographic complexity resulted in a map that highlights areas of steep slopes, as well as regions of ridge and basin topography. Stippled areas in Figure 2.4.1 indicate where average complexity was classified as high. A continuous northwest-southeast trending area of high complexity can be seen running along the entire coastline. This area represents the continental slope, and is generally centered on the 2,000 m isobath (shown in green). The large reticulated area of physiographic complexity that is evident throughout the Southern California Bight generally consists of the ridge and basin topography first described in chapter 2.1. In fact, nearly all of the high complexity areas contained within the current Channel Islands sanctuary boundary can be attributed to these unique geologic features of the continental borderland rather than to continental slope per se.

Results indicate that the complement of sanctuaries along the California coastline (Gulf of the Farallones, Cordell Bank, Monterey Bay, and Channel Islands) capture large areas of high estimated complexity, with each sanctuary comprised of at least 20% high complexity area. In this analysis (ranging from 31.9^{o} to 32.5^{o} north latitude), the total area identified as high complexity was 95,255 km^2. Roughly 8,251.1 km^2 (8.7%) of this area is contained within the four California sanctuaries, with 1.4% of the total falling inside the current boundaries of the Channel Islands National Marine Sanctuary. A total of 36% of the area contained within CINMS boundaries was classified as having high complexity. This is the second largest proportion of any California sanctuary (Gulf of the Farallones-21.5%, Cordell Bank-30.5%, and Monterey Bay-42%). Most of the complex area contained within the Gulf of the Farallones, Cordell Bank, and Monterey Bay national marine sanctuaries is comprised of continental slope. In the Monterey Bay sanctuary, much of the physiographic variance is attributed to the Monterey, Soquel, Carmel Canyon complex.

The continental slope drops steeply from the edge of the continental shelf (~200 m) to depths of approximately 3,000-4,000 m, where it reaches the abyssal plain. Waters of the continental slope are dark, cold, and under very high pressure. In general, the community structure of invertebrates and fishes along the continental slope vary markedly with depth (Airamé, *et al*., 2003a; NCCOS, 2003). This same trend is evident in the analysis of fish community structure presented in chapter 4.2, including those communities found in the ridge and basin structure of continental borderland in the Southern California Bight. Rockfishes (*Sebastes* spp.) and flatfishes (Pleuronectiformes) are some of the most common benthic fishes found inhabiting the region (Airamé, *et al*., 2003a). Because many ecologically and commercially important fishes and invertebrates exhibit a strong affinity for physiographic complexity (Gabriel and Tyler, 1980; Matthews and Richards, 1991; Sullivan, 1995; Williams and Ralston, 2002; Love *et al*., 2002; Field *et al*., 2002; NCCOS, 2003), and their community structure is often classified by ecologists based on the underlying metric (bathymetry), we consider higher complexity to be a benefit in this analysis. Overall, it is likely that concepts characterized by a wide range of depths, coupled with a high degree of complexity, would exhibit the greatest potential to support a diverse faunal assemblage. As such, optimal area index (OAI) values presented in here are designed to highlight concepts with the highest relative complexity.

Analysis of Boundary Concepts

Results of this analysis highlight expansive and interconnected areas of physiographic complexity throughout the Southern California Bight – an expression of the ridge and basin topography that dominates the regional geology. Nearly all of the high complexity areas contained within the current Channel Islands NMS boundary (No Action Concept; NAC) can be attributed to these unique features. A total of 24% of the area contained within current CINMS boundaries was classified as having high physiographic complexity. The optimal area index (OAI) values calculated for each concept suggest that only concept 5 provides greater benefit (in terms of physiographic variance), as it is the only boundary that resulted in a mean complexity value greater than the NAC.

As discussed in Chapter 1.4, two Optimal Area Index (OAI) values are presented here, the first of which is calculated using the mean complexity inside each of the concepts (henceforth “relative OAI”), and the second using the total area of high complexity captured inside each boundary (henceforth “absolute OAI”). Mean estimated complexity for the NAC was 21.2 with a coefficient of variation (CV) of 103.2%. Mean complexity and CV values for the remaining concepts, ranging from smallest in size to largest, are as follows: Concept 5-21.8, 100.2%; Concept 4-19.3, 110.6%; Concept 3-18.6, 113.7%; Concept 2-16.7, 111.4%; Concept 1a-18.5, 115.6%; and Concept 1-18.5, 115.6% (Figure 2.4.2). Mean complexity for the Study Area boundary (defined in McGinnis, 2000) was estimated to be 16.5 with a CV of 114.3% (Figure 2.4.2). The relatively large CV values resulted from the highly variable nature of the estimate (standard deviation of bathymetry). For example, areas along the continental shelf show relatively little deviation in bathymetry within a 1 km^2 neighborhood, while areas along the continental slope exhibit extreme differences in depth over short distances.

These results exhibit a weak, yet statistically significant (a=0.10) inverse relationship to concept size. This relationship is shown in Figure 2.4.3 as a linear regression function between concept area (km^2) and the mean complexity value calculated within the boundary (r^2=0.43, P=0.08). On the other hand, the relationship between concept area and absolute area of high complexity was very predictable (and statistically significant), with larger concepts containing ever larger areas of high complexity. Figure 2.4.3 shows the linear regression function between the total concept area (km^2) and the area of high complexity contained within the boundary (r^2=0.98, $P<0.0001$).

A more balanced metric to use in assessing the relative benefits of each concept as it relates to optimizing for high physiographic complexity is the OAI (Table 2.4.1, also see Chapter 1.4). While this metric decouples the relationships between concept area and the relative and/or absolute estimate to some extent, results of the OAI are still dependent upon the input data, absolute vs. relative measures. As such, we’ve provided OAI results for both mean and total area of high complexity. Results suggest that Concept 5, the minimum expansion concept, provides maximum benefit in terms of the mean complexity calculated for each concept (relative OAI) and in terms of the area of high complexity contained within each concept (absolute OAI). Because the mean OAI incorporated a negative value in the numerator for all boundary concepts except 5 (decreased complexity), the calculated value is necessarily negative.

Summary
• Patterns of mean physiographic complexity highlight areas along the continental slope, as well as areas typical of ridge and basin topography.

• Scientific literature supports the notion that many biological communities exhibit affinities for high complexity, and are often classified based on the underlying bathymetry estimate.

• Of the boundary concepts under consideration, Concept 5 provides relatively large increases in relative and absolute physiographic complexity for its size.

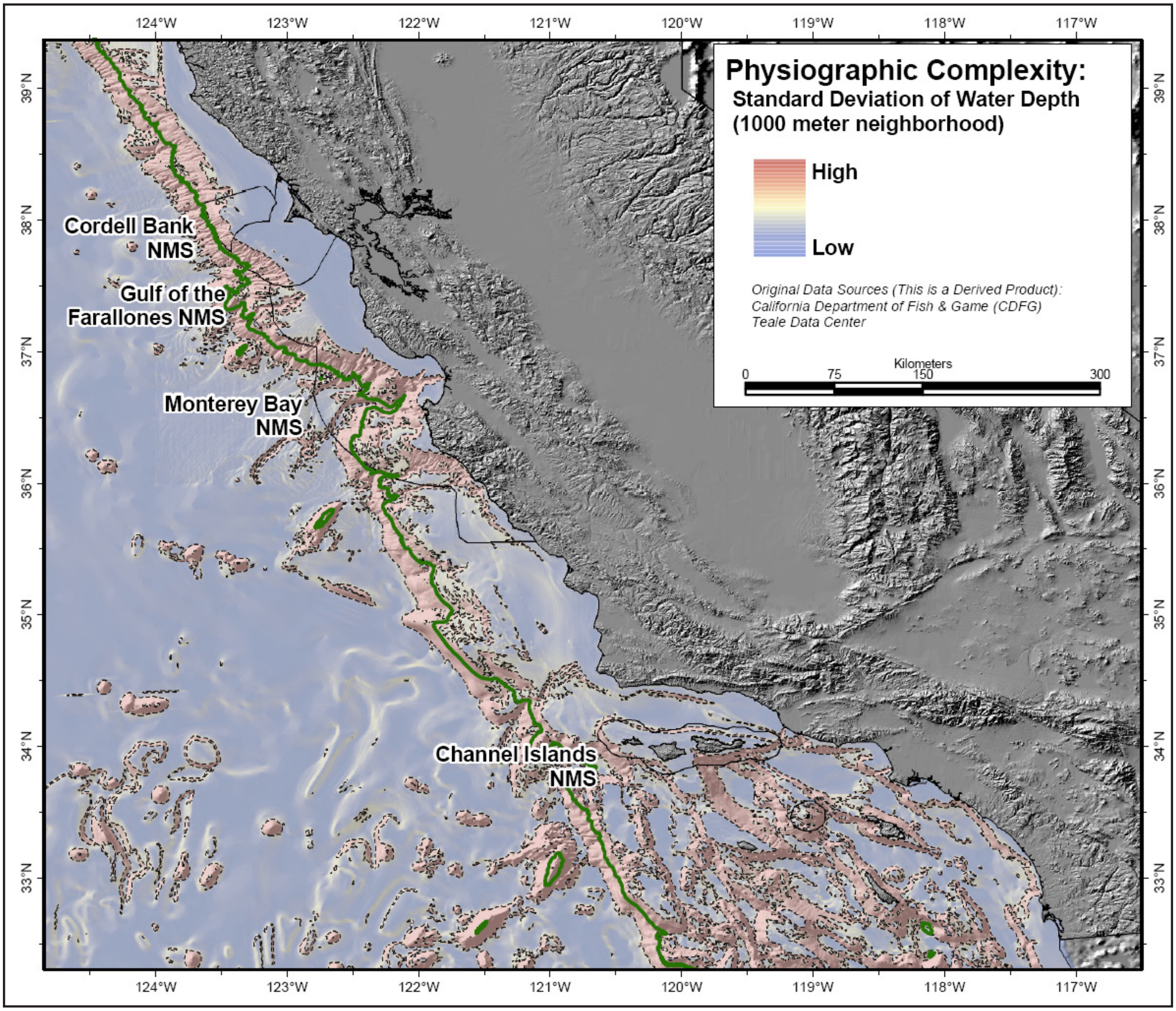


Figure 2.4.1. Map of physiographic complexity along the California coast (ranging from 32° to 39°N). Stippled areas indicate where complexity was >2 standard deviations above the mean. The green line demarcates to 2000 m isobath (a proxy for the continental slope).

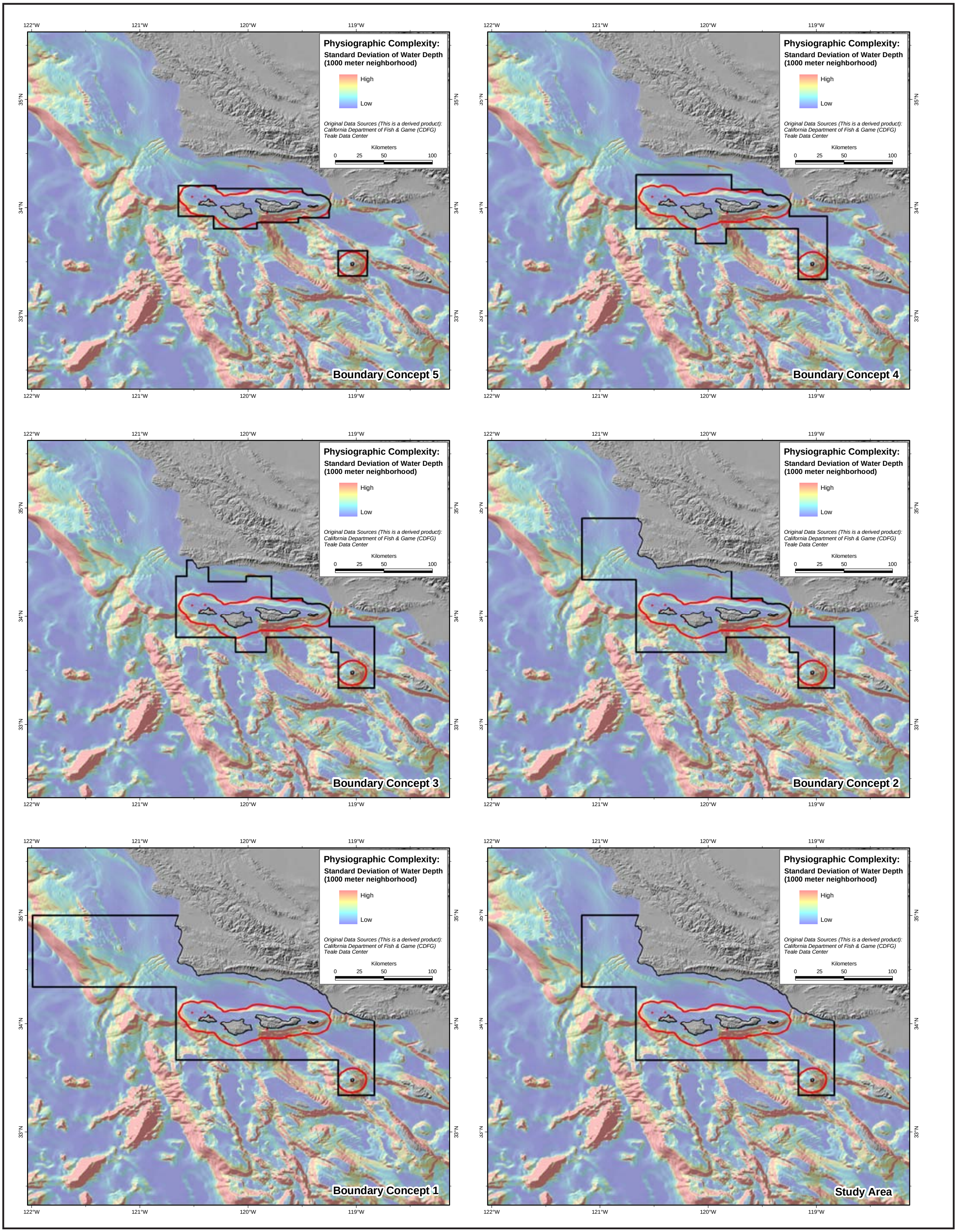


Figure 2.4.2. Physiographic complexity within boundary concepts. The No Action Concept (NAC) is shown as a red line, while the concepts are shown as a black line.

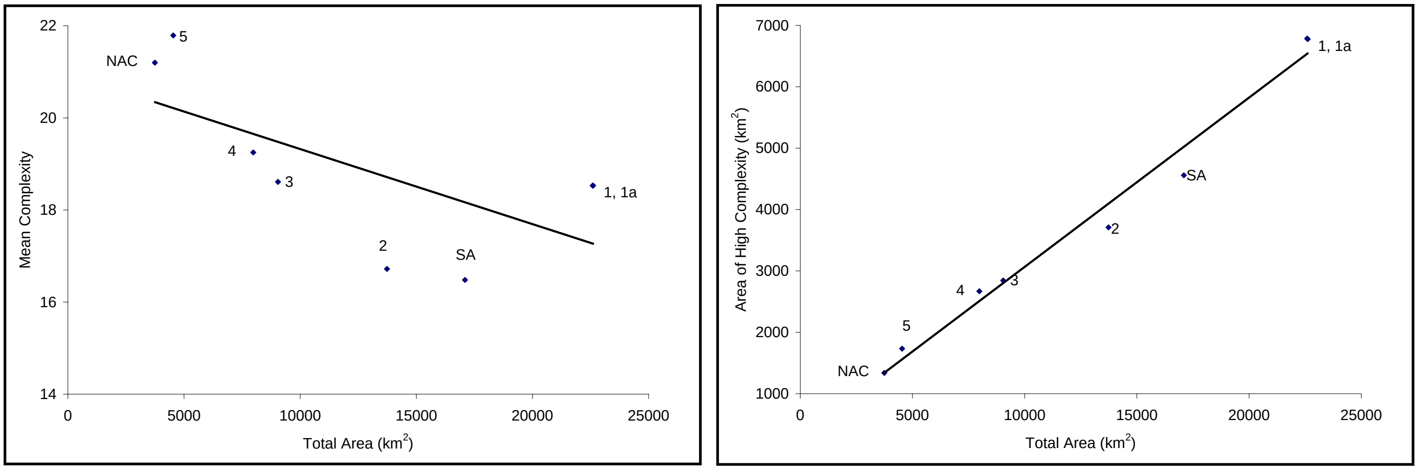


Figure 2.4.3. Linear regression functions between concept area (km²) and mean physiographic complexity (left), and the area (km²) of high physiographic complexity (right).

Table 2.4.1. Analysis of boundary concepts. Numbers in bold indicate an increase in the estimate when compared to the No Action Concept (NAC). Maximum calculated OAI numbers are shaded in gray. Delta (Δ) indicates a rate of change calculation, and is always expressed as a percent change from the NAC.

Concept	Area (km²)	Mean Complexity	High Complexity Area (km²)	Δ Area (%)	Δ Mean Complexity (%)	Δ High Complexity Area (%)	Mean Complexity OAI (relative)	High Complexity Area OAI (absolute)
NAC	3745	21.20	1339	-	-	-	-	-
5	4536	**21.79**	**1734**	21.12	2.78	29.51	0.132	1.397
4	7981	19.25	**2669**	113.11	-9.20	99.31	-0.081	0.878
3	9044	18.61	**2844**	141.50	-12.22	112.37	-0.086	0.794
2	13736	16.72	**3709**	266.78	-21.13	177.00	-0.079	0.663
1a	22591	18.53	**6777**	503.23	-12.59	406.15	-0.025	0.807
1	22613	18.53	**6785**	503.82	-12.59	406.76	-0.025	0.807
SA	*17093*	*16.48*	**4558**	*356.42*	*-22.26*	*240.39*	*-0.062*	*0.674*

2.5 BENTHIC SUBSTRATE

Data and Methods

In this chapter, geologic data for offshore California are analyzed to characterize the distribution of substrate types, and more specifically for the area around the Channel Islands National Marine Sanctuary. Analyses are based upon a comprehensive set of geologic data that were synthesized, classified, and mapped according to substrate and habitat type for the entire U.S. west coast. Benthic features from a variety of sources (side-scan sonar, bottom samples, seismic data, and multibeam bathymetry) were interpreted by geologic mapping experts and subsequently classified according to substrate and habitat type (Greene *et al*., 1999). This task was completed by the National Marine Fisheries Service (NMFS) as part of the development of an Environmental Impact Statement (EIS) that considers the designation of Essential Fish Habitat (EFH) for Pacific coast groundfish (NMFS, 2004).

The substrate data ranges from Washington to the U.S.-Mexico border (32°-48.5° latitude) and from 50-200 km from the shoreline (excluding estuaries). Benthic substrate data for California encompasses nearly 165,000 km² of the continental shelf and slope and are classified into approximately 33 different habitat types (Figure 2.5.1). The level of spatial resolution varies across the dataset based on the quantity and quality of the original data sources used to construct this substrate map. As such, fine scale inaccuracies may exist throughout the range of the data.

In addition to assessing the distribution of substrate types throughout the southern California region, the map was used as an input for deterministic habitat suitability models (HSM) for a select group of fishes and inverte-

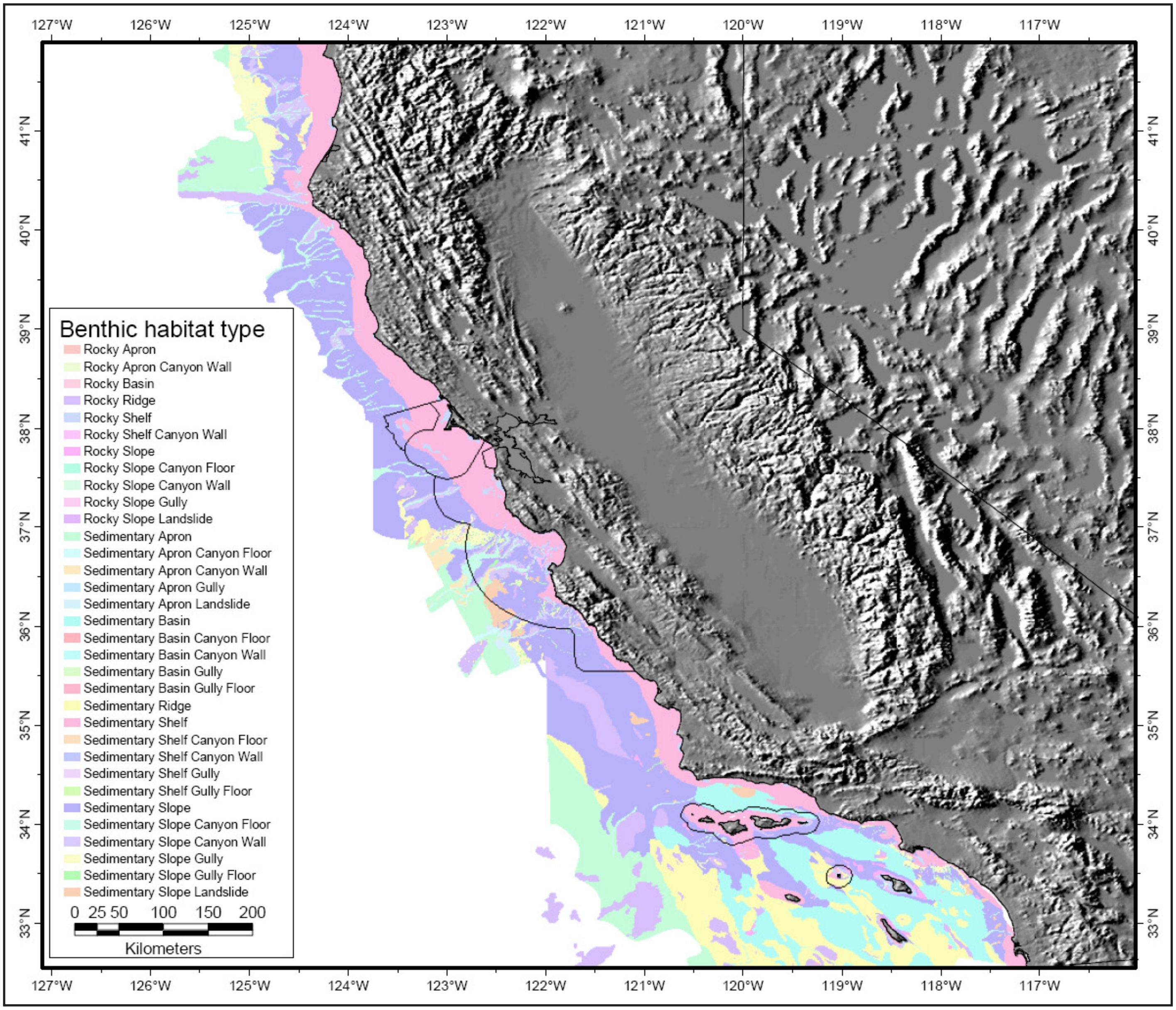


Figure 2.5.1. Benthic habitat types for the marine waters off California (Greene *et a*l., 1999).

brates (Chapters 3.1 and 4.1). Linking the 33 classes of habitat types to species life history information from scientific literature was difficult; thus, a separate substrate attribute was used for habitat suitability modeling which defined the substrate as either hard or soft. Model results for invertebrates were reviewed in June 2004 by a panel of experts. They expressed concern that the map underestimated the amount of hard bottom, most notably at depths between 0-30 m along the mainland south of Point Conception and around the Channel Islands. Additional hard substrate data (MMS, 1987) were then provided by scientists from UCSB who converted non-digital substrate maps developed by the Minerals Management Service (MMS) into a format suitable for use within a GIS. These data extend from Morro Bay to the U.S.-Mexico border and were combined with the NMFS substrate data, resulting in a better estimation of hard substrate in southern California (Figure 2.5.2). Chapter 2.6 provides a more detailed analysis of these data.

Broad-scale Patterns

Figure 2.5.3 displays the distribution of 33 habitat types off the coast of California encompassing a total area of 164,725 km^2. Habitat types shaded in red reflect rocky outcroppings, ridges, reefs, and other hard bottom features. Areas shaded with orange and yellow generally display soft continental shelf substrate, while areas in green indicate soft substrate on the continental slope. The amount of area classified as hard bottom habitat accounts for approximately 10% of the total area, the majority of which is located south of Monterey Bay. The region

Table 2.5.1. Area (km^2) and percentage of total area for habitat types within boundary concepts.

Habitat Type	NAC		Concept 5		Concept 4		Concept 3		Concept 2		Concept 1a		Concept 1		Study Area	
	Area	%	Area	%	Area	%	Area	%	Area	%	Area	%	Area	%	Area	%
Rocky Ridge (hard)	33.9	0.9	44.6	1.0	106.7	1.4	125.0	1.4	158.9	1.2	880.4	3.9	884.3	3.9	201.4	1.2
Rocky Shelf (hard)	135.8	3.6	137.6	3.0	163.5	2.1	187.9	2.1	236.6	1.7	264.9	1.2	263.2	1.2	265.0	1.6
Rocky Slope (hard)	120.6	3.2	157.8	3.5	265.1	3.3	284.5	3.3	325.2	2.4	366.5	1.6	365.4	1.6	366.7	2.1
Rocky Slope Canyon Wall (hard)	0	0	0.1	<0.01	0	0	0	0	0	0	0	0	0	0	0	0
Sedimentary Apron (soft)	0	0	0	0	0	0	0	0	0	0	1338.5	5.9	1333.8	5.9	0	0
Sedimentary Basin (soft)	379.8	10.2	640.6	14.2	2371.8	29.8	2772.8	30.7	3026.6	22.1	3812.2	16.9	3806.1	16.9	3817.1	22.4
Sedimentary Ridge (soft)	235.5	6.3	302.1	6.7	342.9	4.3	347.7	3.8	409.3	3.0	968.9	4.3	965.6	4.3	460.2	2.7
Sedimentary Shelf (soft)	1877.9	50.4	1934.0	42.8	2162.1	27.1	2360.3	26.1	3681.6	26.8	5026.6	22.3	5038.2	22.4	5049.2	29.6
Sedimentary Shelf Canyon Wall (soft)	5.7	0.2	5.7	0.1	5.7	0.1	5.7	0.1	5.7	<0.01	5.7	<0.01	5.7	<0.01	5.7	<0.01
Sedimentary Shelf Gully Floor (soft)	0.7	<0.01	0.7	<0.01	0.7	<0.01	0.7	<0.01	0.7	<0.01	0.7	<0.01	0.7	<0.01	0.7	<0.01
Sedimentary Slope (soft)	832.8	22.4	1167.7	25.8	2313.9	29.0	2596.0	28.8	5330.4	38.8	9222.6	41.0	9214.2	40.9	5309.3	36.9
Sedimentary Slope Canyon Floor (soft)	21.3	0.6	32.3	0.7	88.7	1.1	88.4	1.0	137.1	1.0	137.6	0.6	137.6	0.6	137.8	0.6
Sedimentary Slope Canyon Wall (soft)	81.6	2.2	99.0	2.2	98.8	1.2	110.9	1.2	111.0	0.8	186.9	0.8	186.9	0.8	157.6	0.9
Sedimentary Slope Gully Floor (soft)	0	0	0	0	0	0	0	0	21.2	0.2	18.6	0.1	21.2	0.1	21.2	0.1
Sedimentary Slope Landslide (soft)	0	0	0	0	46.3	0.6	148.8	1.6	277.3	2.0	284.5	1.3	284.3	1.3	284.5	1.7
∑ hard	290.2	7.8	340.2	7.5	537.2	6.7	597.3	6.6	720.8	5.3	1511.8	6.7	1512.8	6.7	833.0	4.9
∑ soft	3435	92.2	4182	92.5	7431	93.3	8433	93.4	13001	94.7	21003	93.3	20994	93.3	16243	95.1

north of Monterey is typically characterized by a broad continental shelf and slope comprised of soft substrate with scattered areas of hard bottom. In southern California, the area appears to be dominated more by sedimentary basins, ridges, and slope habitat. Large features are noticeable throughout the extent of the data: the Gorda Escarpment due west of Cape Mendocino, Cordell Bank west of Point Reyes, and the Davidson Seamount and Santa Lucia Bank southwest of Monterey Bay. In southern California, hard bottom areas are observed comprising features such as the Rodriguez Seamount, San Juan Seamount, Patton Escarpment, Cortes Bank, and Tanner Bank. Soft bottom features that are readily apparent are the basins of Monterey Canyon, Pioneer Canyon, and the Santa Barbara-Ventura Canyon in southern California.

Analysis of Boundary Concepts

Figure 2.5.3 displays benthic habitat types in southern California. Fifteen of the 33 habitat types found across California are found within the study area (Table 2.5.1). Percentages of hard substrates ranged from 5-8% of the total area within concept boundaries. Most hard substrate was located south of San Miguel and Santa Rosa Islands, around Anacapa Island and north of Santa Barbara Island. Concept 1a contained the most hard substrate (1,514 km^2), mostly attributed to the inclusion of the southern portion of Santa Lucia Bank. Soft substrates were mostly comprised of sedimentary shelf, slope, and basin habitat classifications (Table 2.5.1).

Spatial heterogeneity of habitats was quantified using the Shannon Index of diversity, and was compared among boundary concepts. This approach has been recently applied to marine coral reef ecosystems (Jeffrey, 2005). The Shannon index (Shannon and Weaver, 1949) is one of the most commonly used diversity metrics in community ecology (Magurran, 1988). Typically, the index is used to characterize biological communities; however, the same principles apply when analyzing the habitat map. The index attempts to balance habitat richness (the number of unique habitat types) with habitat evenness (the amount of area among the habitat types). For a given number of habitat types, the Shannon index is highest when there are equal areas within each habitat type. The Shannon index (H') was calculated using the formula:

$$H' = -\sum_{i=1}^{S} \left[\left(\frac{n_i}{N}\right) \ln \left(\frac{n_i}{N}\right) \right]$$

where n_i is the total area of the i^{th} habitat type (S) in the sample, and N is the total area of the sample (Magurran, 1988).

We supplement Shannon's Index of diversity with a measurement of evenness calculated using Shannon's equitability index:

$$E = H' / \ln(N)$$

Values of this index range from 0 to 1 and describe the dominance of habitat types; values close to 1 indicate that habitats are evenly distributed.

Figure 2.5.4 shows the calculated habitat diversity for each of the boundary concepts and the Study Area. Habitat diversity was lowest within the current boundary and increased with increasing concept area, with the exception of Concept 2, which had the third lowest diversity. Similarly, habitat richness (the total number of habitat types present) was lowest within the current boundary and increased with increasing concept area (Figure 2.5.5). Concept 2 and the study area exhibited low evenness values and displayed similar trends to diversity values. As expected, habitat richness increased as concept area increased, as well as diversity for 4 of the 6 concepts. Diversity and evenness values for the Study Area and Concept 2 were the lowest (Figure 2.5.5). While the area of new habitats gained for Concept 2 and the study area were large, these gains were dominated by two habitat types. Thus habitat diversity and evenness values were depressed.

Although habitat diversity was greatest within Concept 1a (Figure 2.5.6) and was not statistically significant (r^2=0.44, p<0.17), analysis of diversity using the OAI (Table 2.5.2) indicate that Concept 5, the minimum expansion concept, provides the greatest benefit in terms of the proportional changes in area and diversity.

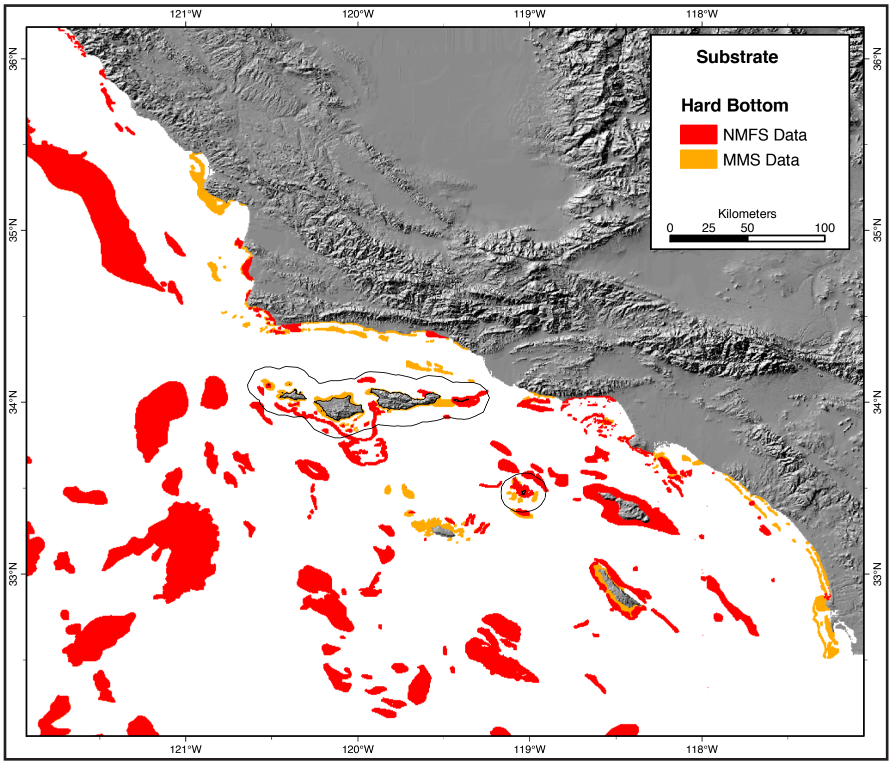


Figure 2.5.2. Location of hard substrate from NMFS and MMS datasets.

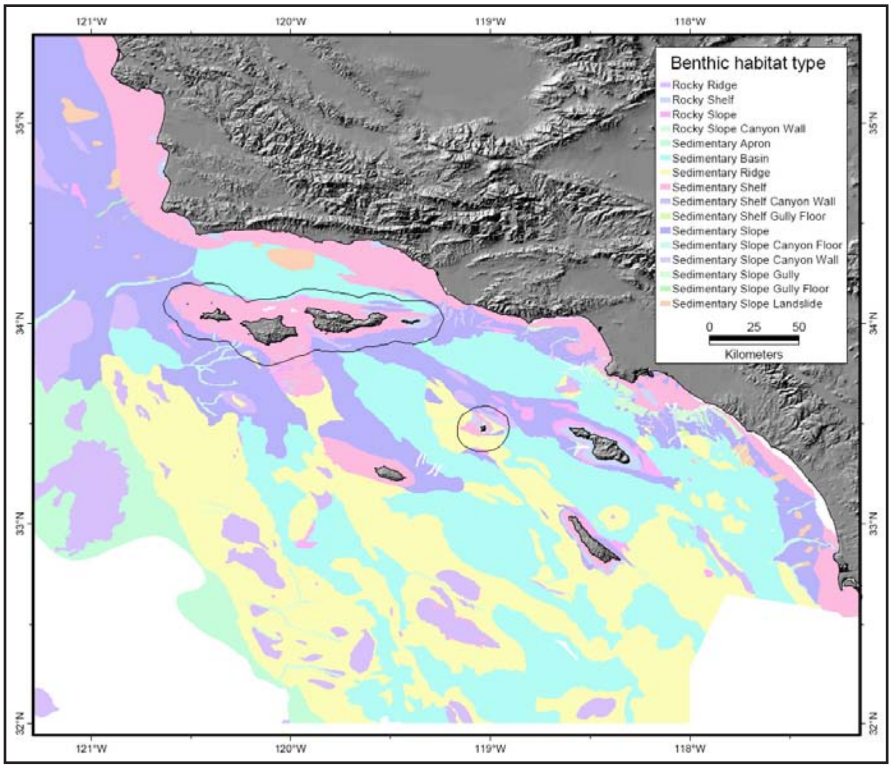


Figure 2.5.3. Benthic habitat types for the marine waters off southern California (Greene *et al*., 1999).

Chapter 2

Summary

• Data presented here provide the most current broad-scale representation of benthic habitats for the contiguous coastline of the western U.S.

• Patterns of habitat diversity and richness were positively correlated with the increasing area of boundary concepts.

• Of the six boundary concepts being considered, Concepts 1 and 1a provided the highest habitat diversity and richness, but Concept 5 ranked highest in the OAI.

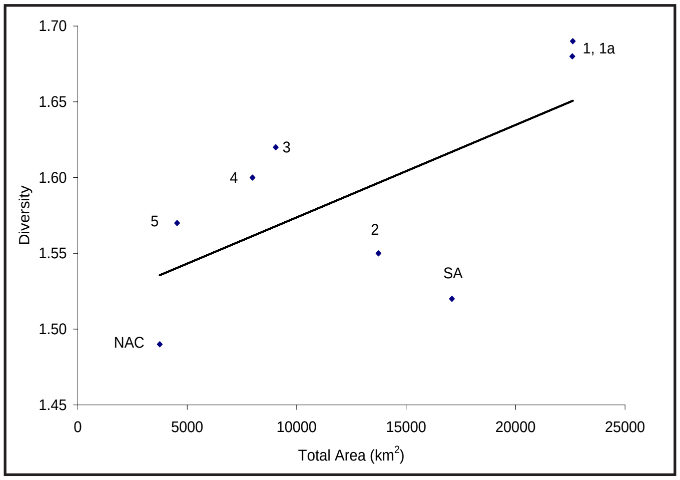


Figure 2.5.4. Regression of habitat diversity and total area for the current and proposed boundary concepts. Numbers indicate concepts and NAC=No Action Concept, SA=Study Area.

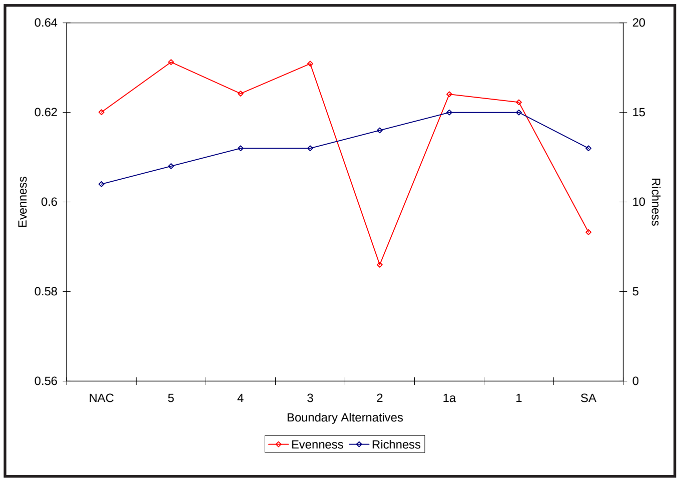


Figure 2.5.5. Evenness and richness estimates for habitat types within boundary concepts. Numbers on the x-axis represent concepts, NAC=No Action Concept, SA=Study Area.

Table 2.5.2. Analysis of habitat diversity within boundary concepts. Numbers in bold indicate an increase in the estimate when compared to the No Action Concept (NAC). Maximum calculated OAI numbers are shaded in gray. Delta (Δ) indicates a rate of change calculation, and is always expressed as a percent change from the NAC.

Concept	Area (km²)	Diversity (H´)	Δ Area (%)	Δ Diversity (%)	OAI (absolute)
NAC	3475	1.49	-	-	-
5	4538	**1.57**	21.12	5.37	0.25
4	7981	**1.60**	113.11	7.38	0.07
3	9044	**1.62**	141.50	8.72	0.06
2	13736	**1.55**	266.78	4.03	0.02
1a	22591	**1.69**	503.23	13.42	0.03
1	22613	**1.68**	503.82	12.75	0.03
SA	*17093*	*1.52*	*356.42*	*2.01*	*0.01*

2.6 BATHYMETRIC LIFE-ZONES

Data and Methods

This section describes the geographic distribution of habitats of southern California classified by substrate type and depth. Within the region, bathymetry ranges from intertidal to over 4,000 m, and four zones have been recognized within this range which contain distinct biological communities (Airamè *et al*., 2003b). Within the top 30 m, light penetrates surface waters, supporting a highly productive nearshore community. Shallow rocky reefs often support kelp forests that provide physical structure and an abundant source of food for subtidal organisms. Soft bottom habitats lack the physical structure and high production associated with kelp forests and rocky reefs and are commonly inhabited by many species of groundfish and invertebrates (Airamé *et al*., 2003a). Many species of rockfish and rock crabs inhabit rocky reefs at depths between 30-100 m, while several species of flatfish and molluscs occupy soft substrates. At depths of 100-200 m, rockfish such as bocaccio and cowcod, are common on rocky reefs, while several species of prawns inhabit soft substrates. Continental slope species such as sablefish, thornyheads, and dover sole inhabit hard and soft substrates at depths >200 m.

The previous section assessed the distribution of substrate types in the vicinity of the Channel Islands National Marine Sanctuary (CINMS). In this section, benthic substrate from the combined NMFS and MMS datasets is used in conjunction with bathymetry contours to provide a two-dimensional assessment of habitats within each boundary concept. Bathymetry is also categorized into four depth categories, according to the classifications described in Airamé *et al*., (2003b):

0-30 m	Shoreline, photic zone
30-100 m	Upper continental shelf
100-200 m	Lower continental shelf
>200 m	Continental slope

Habitat diversity is a measure of both richness (the total number of habitat categories present) and the evenness of their distribution. All eight of the combinations of bathymetry categories (0-30 m, 30-100m, 100-200m, >200m) and substrate groups (hard, soft) are present in the current CINMS boundaries (Airamé *et al*. 2003b), and thus in all of the boundary concepts. Therefore, richness is equivalent in all of the boundary concepts, and we can reduce our analysis to a discussion of the spatial evenness of the eight habitat combinations. Shannon's equitability (E_H) is a common metric used to describe evenness and can be calculated using the formula:

$$\frac{-\sum_{i=1}^{s}\left[\left(\frac{n_i}{N}\right)\ln\left(\frac{n_i}{N}\right)\right]}{\ln(S)}$$

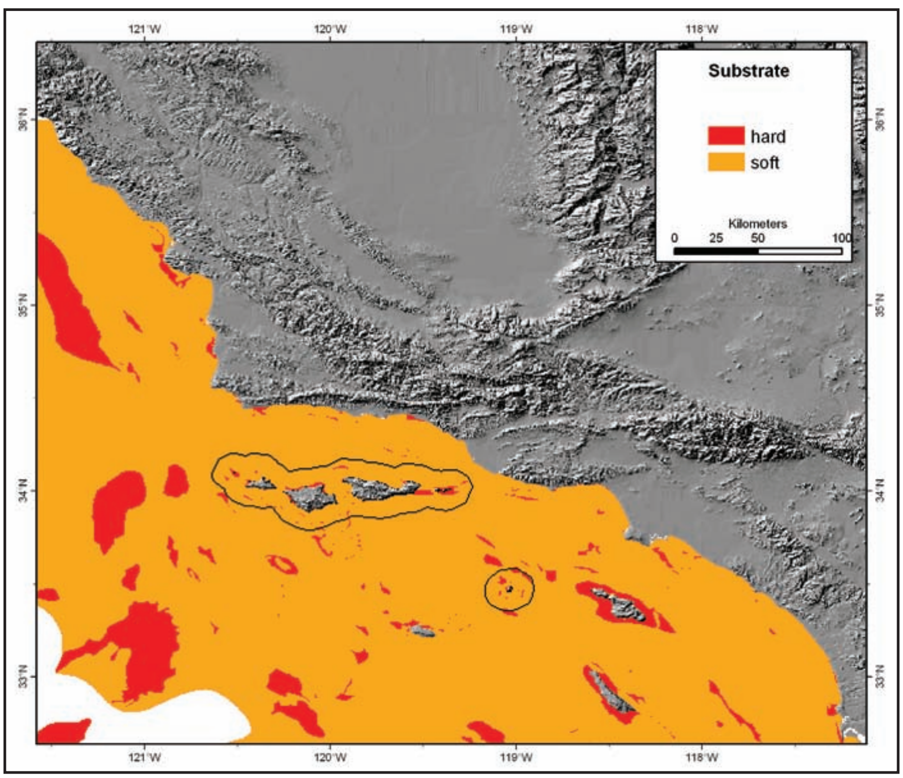


Figure 2.6.1. Distribution of benthic substrate types (hard or soft) off southern California.

where n_i is the area of habitat belonging to the i^{th} habitat type (S) in the boundary concept, and N is the total area of the boundary concept. Thus, n_i/N is the proportion of habitat type i relative to the total area of that boundary concept (Magurran, 1988). Values for Shannon's Equitability range from 0 to 1 with 1 being complete evenness.

Broad-scale Patterns

Rocky habitats are patchy both along the coastline as well as further offshore (Figure 2.6.1); however, much of the nearshore habitat around the Channel Islands is comprised of hard substrate. Depths greater than 200 m are a dominant feature of the broad-scale bathymetry (Figure 2.6.2). Habitats within the upper continental shelf (30-100 m) are

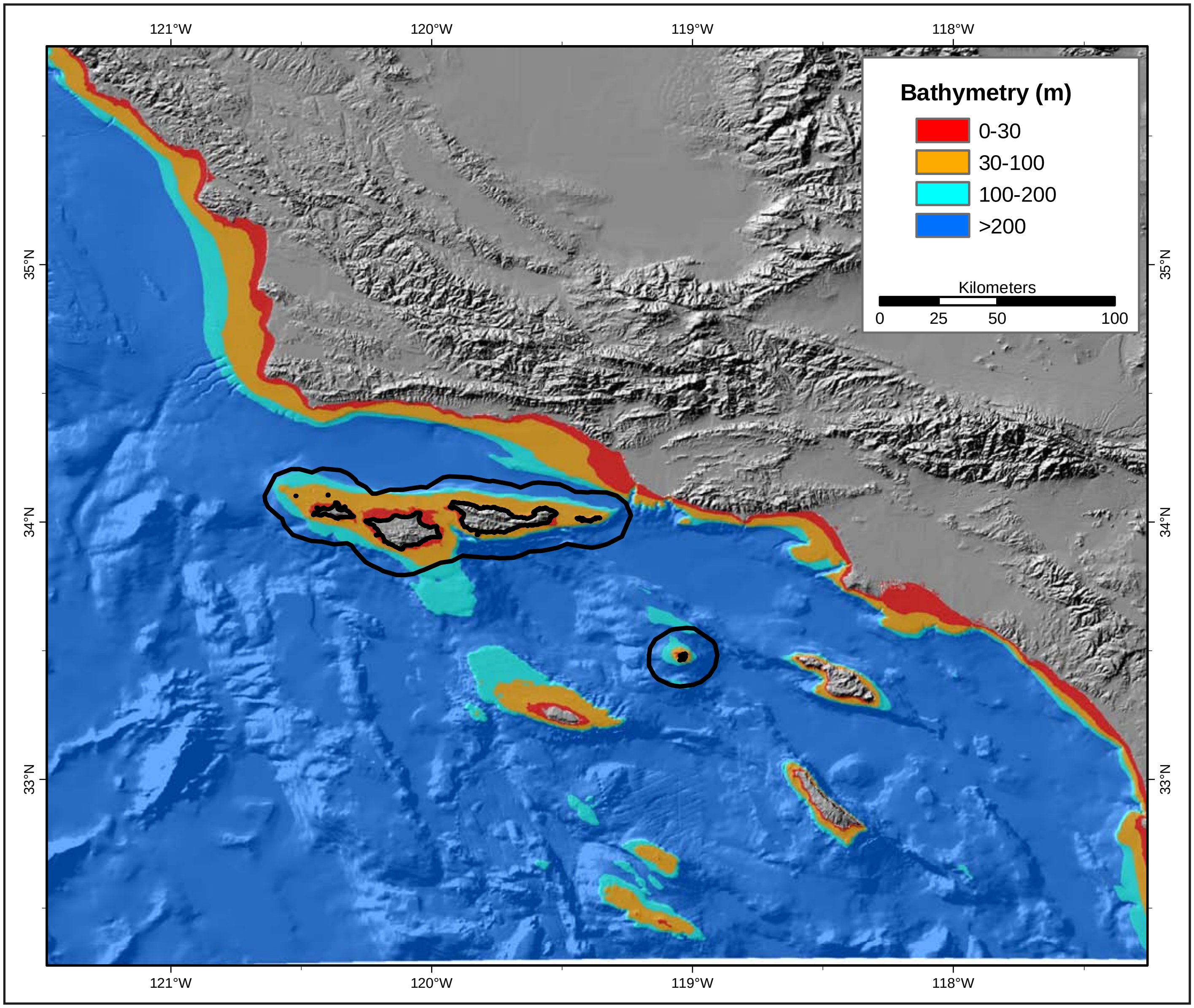


Figure 2.6.2. Distribution of bathymetric zones (m) off southern California.

the second most common, followed by lower continental shelf habitat (100-200 m). Shoreline habitats within the photic zone (0-30 m) are the least abundant.

Analysis of Boundary Concepts

All configurations considered here were dominated by soft substrate, which covered more than 85% of the total area within each concept (Figure 2.6.1). Likewise, depths greater than 200 m were predominant and increased as concept area increased (Figure 2.6.2). These continental slope habitats comprise 43% of the area within the current boundary, 67% of the Study Area, 51% of Concept 5, 68% of Concept 4, 69% of Concept 3, 70% of Concept 2, and 75% of Concepts 1 and 1a. Upper continental shelf followed in habitat dominance ranging from 31% for the current boundary to 12 for Concepts 1 and 1a. Relative abundance also declined with increasing concept area.

Evenness of the eight habitat categories generally declined as area increased, and was greatest for the No Action Concept (Table 2.6.1). This trend is graphically represented in Figure 2.6.3 as a linear regression function between area (km^2) and evenness (r^2=0.66, p=0.01). This trend can primarily be attributed to the disproportionate gain in deeper habitat as more area is incorporated into a boundary concept. The current CINMS boundaries and the smaller concepts 5 and 4 are a more suitable choice based upon evenness alone.

A more balanced metric to use in assessing the relative representation of habitat types and depth is the Optimal Area Index (OAI) (Table 2.6.1). OAI takes into account the proportional change (%) in evenness moving from the NAC to each of the concepts under consideration. It also incorporates the proportional change (%) in area from the NAC. The negative value of the OAI for habitat evenness for all of the boundary concepts under consideration indicates that the current CINMS boundary is preferable. Compared to the other concepts, the NAC contains a more equitable distribution of the 8 habitat categories.

Table 2.6.1. Analysis of life-zone evenness within boundary concepts. Numbers in bold indicate an increase in the estimate when compared to the No Action Concept (NAC). OAI estimates shaded in gray represent maximum observed benefit. Delta (Δ) indicates a rate of change calculation, and is always expressed as a percent change from the NAC.

Concept	Area (km^2)	Evenness	Δ Area (%)	Δ Evenness (%)	OAI (absolute)
NAC	3475	0.78	-	-	-
5	4538	0.73	21.12	-5.69	-0.27
4	7981	0.59	113.11	-23.87	-0.21
3	9044	0.58	141.50	-25.60	-0.18
2	13736	0.56	266.78	-27.80	-0.10
1a	22591	0.53	503.23	-31.27	-0.06
1	22613	0.53	503.82	-31.25	-0.06
SA	17093	0.59	356.42	-24.32	-0.07

Summary

• Upholding ecosystem biodiversity requires protection of a wide variety of representative and unique habitats. Habitat in Central and Southern California can be characterized by a range of substrate types and depths that provide structure for a variety of organisms, including kelp forest, soft bottom and rocky reef communities.

• Similar to the broad-scale patterns, the current boundary of the CINMS encompasses a considerable amount of soft substrate. The bathymetric classes considered here (photic zone, upper and lower continental shelf, and continental slope) are all represented within the region and within the current CINMS boundaries where they are distributed with a relatively high degree of evenness.

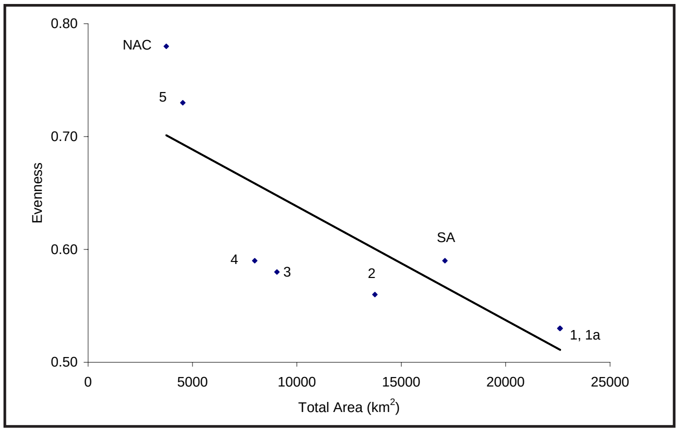


Figure 2.6.3. Regression of habitat evenness and total area for the current and proposed boundary concepts. Numbers indicate concepts and NAC=No Action Concept, SA=Study Area.

• The current CINMS boundary provides a more equal representation of habitats (substrate type and depth) than the proposed boundary concepts.

2.7 SEA SURFACE TEMPERATURE AND FRONTAL BOUNDARIES

Pattens in sea surface temperature (SST) influence the distribution of marine species and habitats, particularly in areas of persistent SST fronts. The convergence of the northern and southern biogeographical provinces near the Santa Barbara Channel result in a dynamic biological and physical transition zone which influences the abundance and distribution of many organisms, including pelagic juvenile fishes, plankton and other microorganisms, benthic macroalgae, seagrasses, and invertebrates. Large-scale shifts in SST, and consequently frontal boundaries, affect the spatial and temporal distribution of these organisms. This chapter provides analysis of SST and frontal boundaries for the region of interest and provides physical context for subsequent biological analyses.

Data and Methods

The sea surface temperature (SST) data presented here were obtained from the NOAA/NASA Pathfinder dataset. SST data are derived from the 5-channel Advanced Very High Resolution Radiometers (AVHRR); multi-purpose imaging instruments attached to the NOAA -7, -9, -11 and -14 polar orbiting satellites. They measure global cloud cover, sea surface temperature, and ice, snow and vegetation cover and characteristics. Daily, 8-day, and monthly averaged data for both the ascending pass (daytime) and descending pass (nighttime) are available on equal-angle grids of 4096 pixels/360 degrees (nominally referred to as the 9 km resolution), 2048 pixels/360 degrees (nominally referred to as the 18 km resolution), and 720 pixels/360 degrees (nominally referred to as the 54 km resolution or 0.5 degree resolution). Monthly averaged 9km data were used here to achieve the greatest possible spatial resolution and to minimize cloudiness (no data values) by averaging cloud-free data values across a month of data. The SST data encompassed 125 months from January 1993-May 2003. The AVHRR Oceans Pathfinder SST data were obtained through the online PO.DAAC Ocean ESIP Tool (POET) at the Physical Oceanography Distributed Active Archive Center (PO.DAAC), NASA Jet Propulsion Laboratory, Pasadena, CA. <http://podaac.jpl.nasa.gov/poet>.

To analyze spatial patterns in relation to proposed boundary concepts, sea surface temperature data for the 125 months (January 1993-May 2003) were averaged across four months (January, April, July, October) representing typical seasonal temperature values, to provide an overall estimate of mean SST along the Pacific margin of the coterminous United States (ranging from 31°-46°N, Figure 2.7.1). Average SST was calculated for each of the months across all years for which data were available. In addition to sea surface temperature, we also present estimated SST variance over time and an analysis of frontal boundaries and their persistence through time as derived from SST data. Variance in SST over time was estimated for each cell by calculating the statistical variance of all data available in that cell from January 1993-May 2003 (Figure 2.7.2). Variance estimates ranged from 0 to 10.6. The resulting map was classified into four equal area quantiles. Two quantiles representing the areas of least variance were highlighted (0-25% and 25-50%).

Frontal boundaries were derived from SST data using a number of tools that make up the Generic Mapping Tool (GMT) software package developed and maintained by Paul Wessel (University of Hawaii) and Walter H. F. Smith (NOAA). GMT is available under the GNU public license and can be downloaded from the University of Hawaii, Honolulu, HI <http://gmt.soest.hawaii.edu>. To derive frontal boundaries, each monthly mean SST dataset was first converted to GMT's grid format using the GMT tool *nearneighbor* (Figure 2.7.3). A slope function was run across each of these monthly SST coverages using GMT *grdgradient* to create new coverages in which the magnitude of the slope was calculated for each cell. In this case, the slope represents areas containing the steepest temperature gradient, or changes in SST, across some geographic extent space. The resulting coverage was then classified into 20 equal areas (5% quantiles) using GMT *grdhisteq* and the quantile with the greatest slope was extracted using GMT *grdclip* to represent the areas with the steepest temperature gradients (Figure 2.7.3). These areas of steep temperature gradient serve as a proxy for SST fronts. The resulting grids were added together using GMT *grdmath* to obtain a final grid containing cells with values representing the number of months during which an SST front occurred in each cell (Figure 2.7.4). This coverage of SST frontal persistence contained cell values ranging from zero to 65 months and was classified into standard deviations. The highest standard deviation (+3 above the mean, or 21-66 of the 125 available months) was considered to represent areas of persistent SST fronts.

Broad-scale Patterns

Broad-scale patterns referred to in this section include consideration of both spatial and temporal scales. It is understood that sea surface temperature patterns and their related features are ephemeral depending on the season, year, and the state of the El Niño-Southern Oscillation (ENSO). However, because sanctuary boundaries do not change seasonally, or with the ENSO, a decision was made to look at the overall spatial and temporal trends through both space and time to evaluate the mean expression of SST and its effects.

Sea surface temperature analysis displays the expected gradient of cold water in the north slowly warming towards the south, ranging from 0° to 23° Celsius. Of particular interest is that seasonal changes that bring warmer water to the north coincide with the onset of coastal upwelling along the northern California coast (Figure 2.7.1). The end result is that water temperatures along the northern California coast remain cool during the summer months and are at times cooler in the summer than during winter months. The expression of this system is most evident in the low variance in SST exhibited along the coast from the northern California border to Point Conception (Figure 2.7.2). This core of cool water provides a relatively stable environment that may contribute to apparent formation of northern and southern biogeographic provinces, and the formation of a transitional zone between them that is often ascribed to the Channel Islands area (McGinnis, 2000).

Analysis of potential SST frontal zones (Figures 2.7.4 and 2.7.5) suggest that the Channel Islands region exhibits a persistent concentration of steep temperature gradients. Persistent concentrations of high frontal density are not present all the time. These frontal systems are defined not as a single persistent front, but as a dynamic region characterized by a persistent high concentration of frontal features. In the analysis (ranging from 31°-47° degrees latitude), the total area defined as having a high concentration of persistent SST fronts was roughly

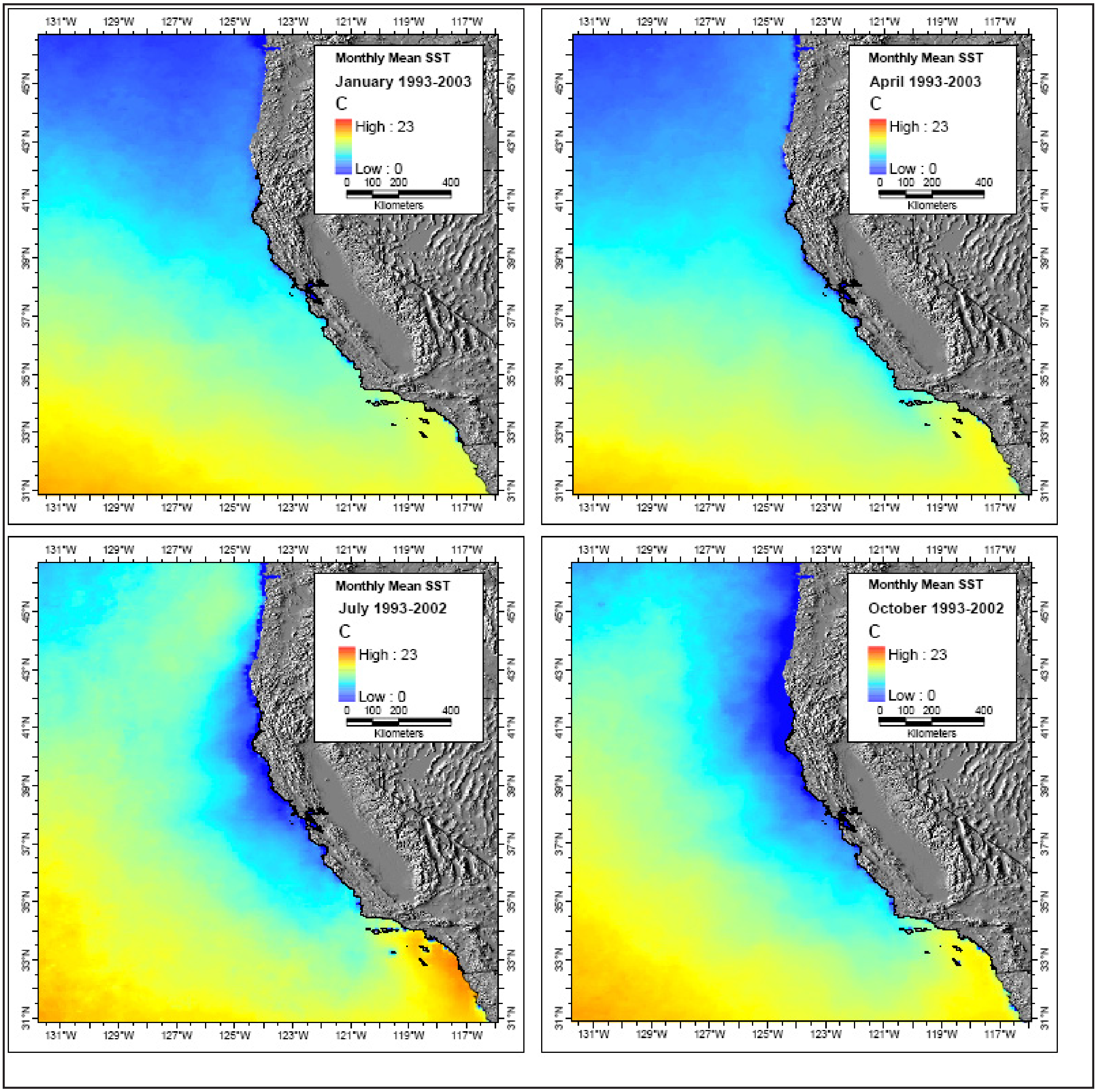


Figure 2.7.1. Seasonal mean sea surface temperature (January, April, July, and October) averaged across years from 1993 to 2003.

70,000 km^2, approximately 2% of the analysis area. Most the high area was confined to the coastline, with the largest area of frontal persistence observed in the area around the Channel Islands, most likely generated by the confluence of the cool south-bound California Current and warmer northbound Davidson Current. Frontal features extending along the northern California coast are generated by coastal upwelling events and the many eddies and gyres that spin out of the upwelling areas as they join the California Current.

Analysis of Boundary Concepts

The preceding discussion identified areas of high SST frontal persistence. Those areas closest to or within the current study area center around Sur Ridge, just south of Monterey Bay, and the Channel Islands. A total of 70% of the area contained within current CINMS boundaries was classified as having high SST frontal persistence. As such, it is important to note that the No Action Concept (NAC, current boundary) captures a large area of high frontal persistence.

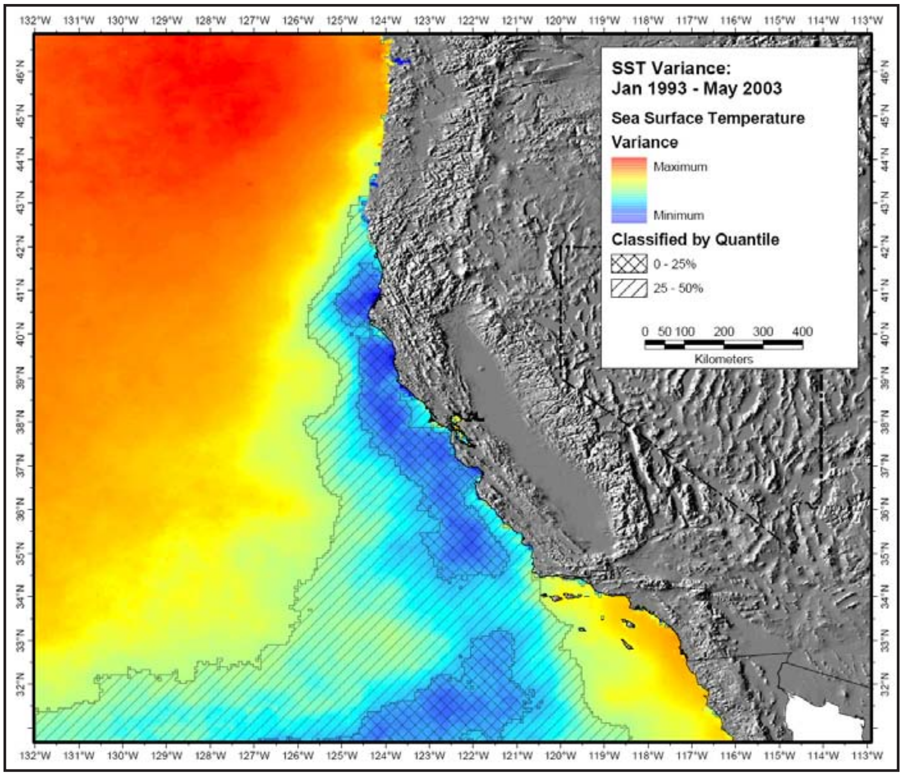


Figure 2.7.2. Sea surface temperature variance, calculated from mean monthly values for the period January 1993 to May 2003. Cool tones represent low SST variance and warm tones represent high SST variance. Hatched area represents the lowest two quantiles.

Mean SST frontal persistence for the NAC was calculated to be 29.6 months. Mean frontal persistence for the remaining concepts, ranging from smallest in size to largest are as follows: Concept 5-27.9 months; Concept 4-23.9 months; Concept 3-23.2 months; Concept 2-20.7 months; Concept 1a and 1-16 months. Mean frontal persistence for the study area boundary (defined in McGinnis, 2000) was estimated to be 19.4 months. Overall, mean SST frontal persistence decreases as area increases (Figure 2.7.6 and Table 2.7.1). Because the area of high frontal persistence is proportionally concentrated around the Channel Islands themselves, as additional areas away from the islands are included, less area of high frontal persistence is captured.

Due to the dynamic nature of SST and frontal boundaries, OAI statistics were not generated for the boundary concepts. However, it is important to note

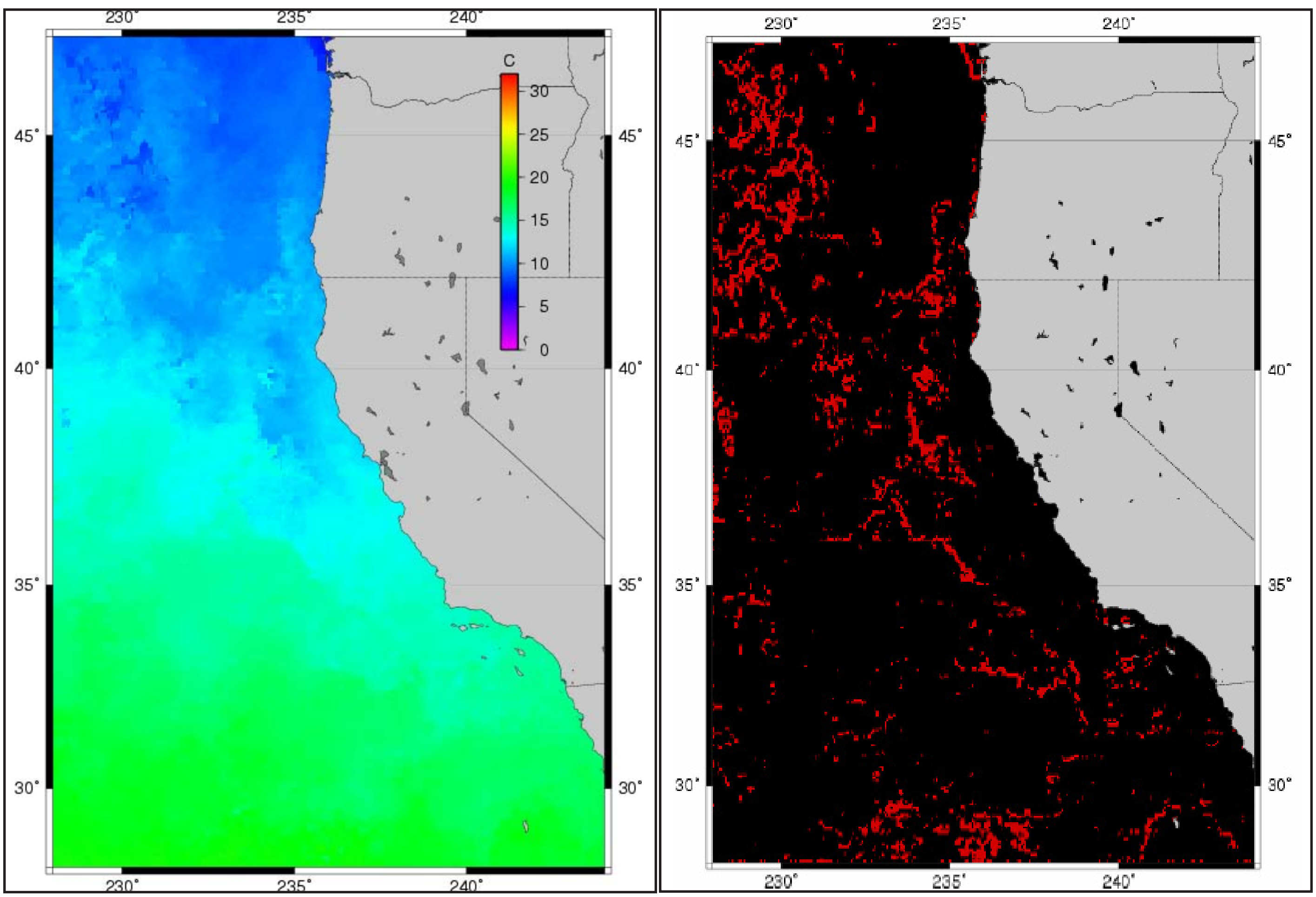


Figure 2.7.3. Left panel shows an example interpolated SST grid from GMT for January 1993. Right panel shows a grid clip of the highest quantile from the January 1993 slope magnitude grid. Red areas indicate the top 5% of values and represent the steepest temperature gradients and are used to identify SST fronts.

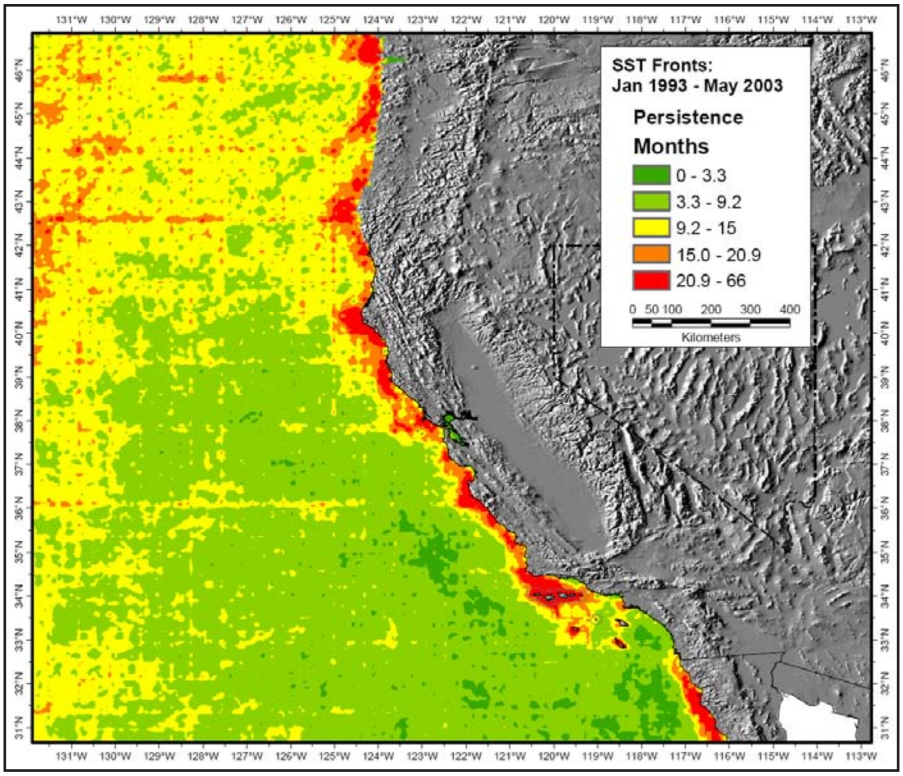


Figure 2.7.4. Persistence of SST fronts through time. Colors indicate number of months during which a front was evident, with green representing fewer months (1 std. dev. below the mean) to red (3 std. dev. above the mean).

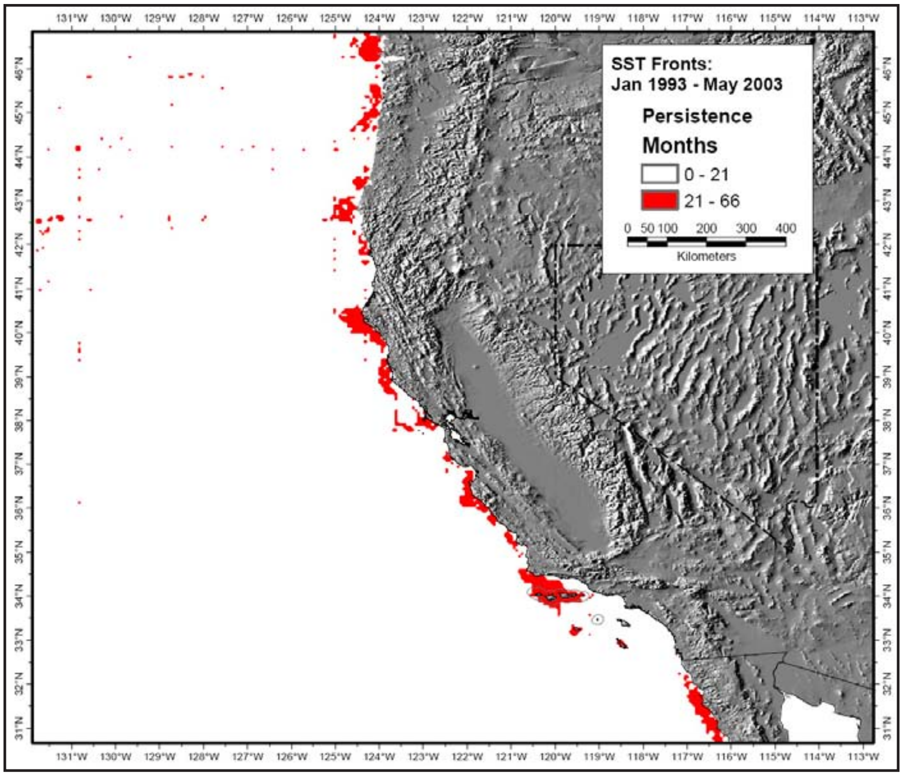


Figure 2.7.5. Areas with greatest SST front activity through time.

that since 1993 the area around the northern Channel Islands has been centered among a large area of SST front activity (Figure 2.7.5). In general, Figure 2.7.7 suggests that there is a point of dimishing returns with regard to additional area protected versus inclusion of more frontal activity (illustrated by the fitted polynomial equation). Concept 2 provides a large increase in SST frontal area, over Concepts 3, 4, and 5, relative to the total area of each. Concepts 1 and 1a, on the other hand, offer only a small increase in SST frontal activity over Concept 2 relative to additional total area.

Summary

• A stable area of sea surface temperatures exists along the California coast, ranging from California's northern border to Point Conception and extending offshore to 200 km.

• The Channel Islands National Marine Sanctuary encompasses a transition zone from cooler waters to the north and warmer waters to the south.

• A large portion of the current boundaries (~70%) include area identified as having persistent SST fronts. Concept 2 provides the greatest increase in persistent SST front area before returns begin to diminish (area of high SST frontal activity versus total area).

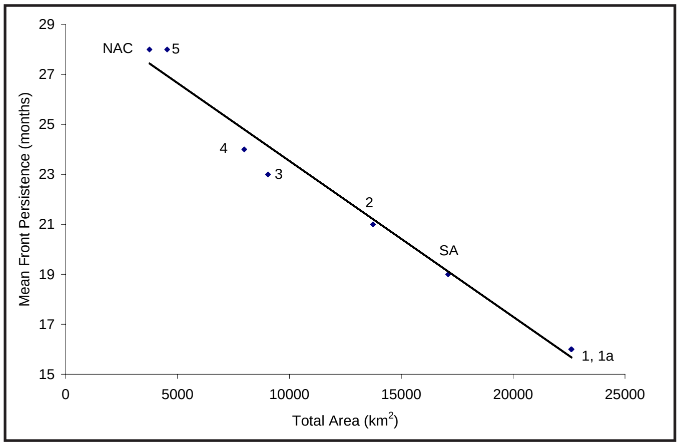


Figure 2.7.6. Linear regression function between concept area (km²) and mean persistence of SST fronts.

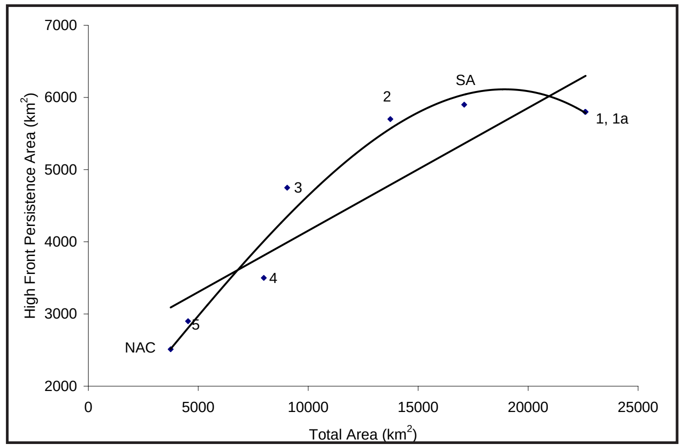


Figure 2.7.7. Linear regression function between total concept area (km²) and area of high SST frontal persistence.

2.8 SURFACE CHLOROPHYLL AND OCEAN CURRENTS

Data and Methods

Pelagic marine food webs, including that of the Southern California Bight and adjacent waters, are supported by phytoplankton production. Throughout the year phytoplankton serve as a food source for protozoans, zooplankton, bivalves, and larval fishes (e.g., anchovies and sardines), which in turn are the foundation of a complex food web that supports all coastal fauna. Analyses of chlorophyll-a and currents presented here are intended to provide context for discussion in subsequent chapters on invertebrate, fish, bird, and mammal biogeography, and to lay the foundation for discussing interconnectivities between oceanographic processes and biogeographic patterns in the region.

The surface chlorophyll data presented here were derived from remotely sensed global chlorophyll-a concentration estimates (mg/m³) acquired using the Sea-viewing Wide Field-of-view Sensor (SeaWiFS). The purpose of SeaWiFS is to provide quantitative data to resolve the magnitude and variability of chlorophyll concentrations, and subsequently to estimate primary production by marine phytoplankton. Presented here are level-3 processed data derived from the first 26 months of acquisition (November 1997-December 1999). This time period was selected because data for these months were readily available. Level 3 data consists of geophysical parameters binned to a 9x9 km (81 km²) global equal-area grid at daily, 8-day, monthly, and annual intervals. Level 3 geophysical parameters consist of five normalized water-leaving radiances (radiance data corrected for atmospheric light scattering and sun angles differing from nadir), and seven geophysical parameters derived from the radiance data. This level categorization was developed by NASA to indicate that the data have been post-processed to contain both geophysical parameters and geographic coordinates.

In addition, to gain a broader understanding of the observed large-scale patterns in surface chlorophyll, estimates of surface current vectors, showing both magnitude and direction are also presented. Current data were derived using ocean surface altimetry collected by the ERS-2 and TOPEX/POSEIDON satellites. Monthly averaged current vectors were developed for identical months and years as described for ocean color, and have a horizontal resolution of 0.25 degrees (~28 km). When superimposed on ocean color, these vectors exhibit clear spatial correlations with patterns in observed chlorophyll concentrations, and are used, in part, to set the oceanographic context for subsequent analyses of ocean color and other biological resource distributions in the region. All data and analyses presented in this section were derived from data made available through the Marine Conservation Biology Institute's (MCBI) Baja California to Bering Sea Conservation Initiative (B2B). More information about MCBI and the Bering to Baja initiative can be found at <http://www.mcbi.org>.

To best achieve the study objectives of analyzing spatial patterns in relation to proposed boundary concepts, ocean color data for 26 months (November 1997-December 1999) were averaged to provide an estimate of mean chlorophyll-a concentration ([ChlA]) along the Pacific coast of the United States (ranging from 28°-49° latitude). Data from 2000 to present were available, however at the time of analysis these data were not post-processed and were not included. While ocean color is variable in all dimensions, a composite estimate (mean [ChlA]) was

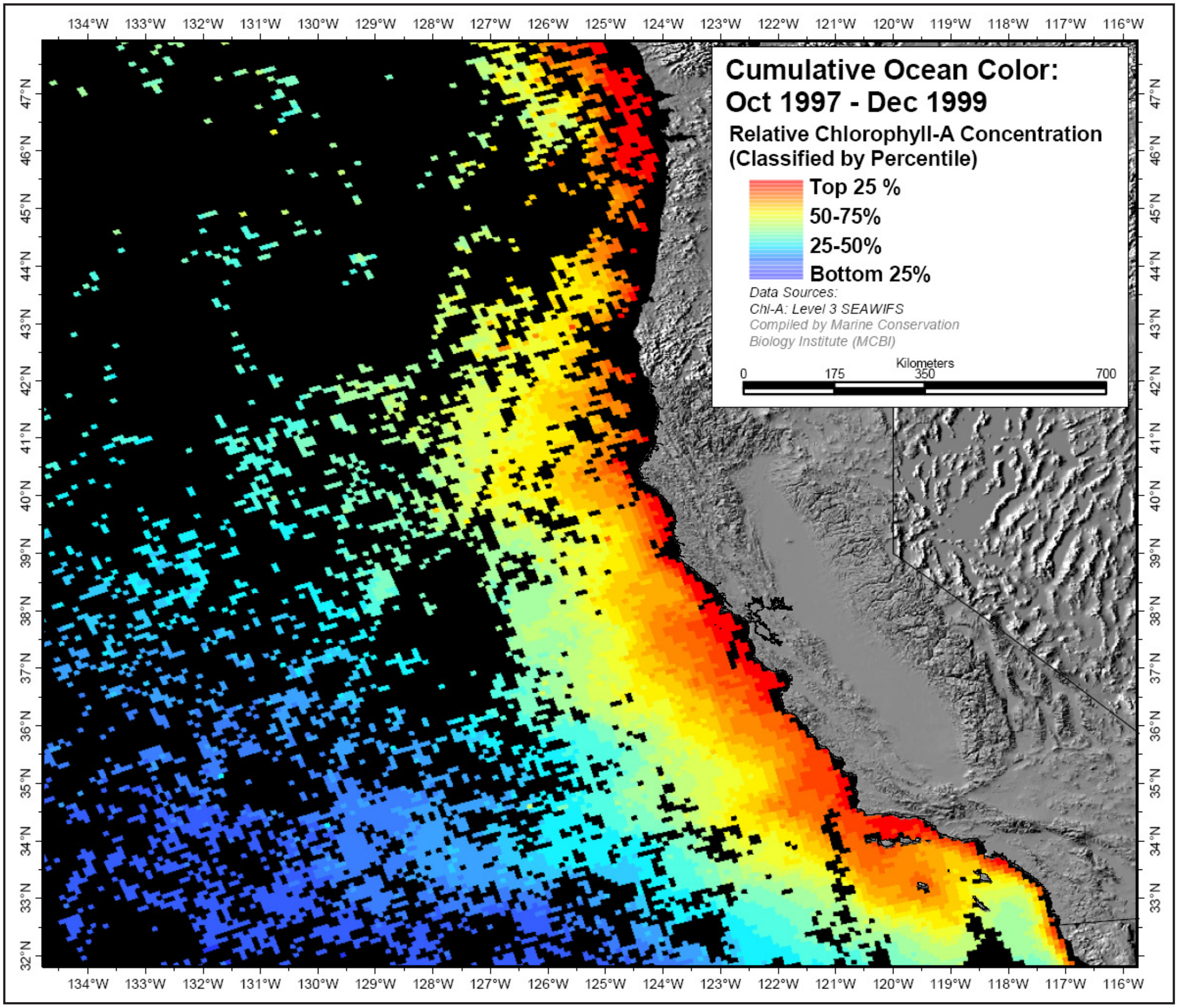


Figure 2.8.1. Average [ChlA] for grid cells in which data was present during November 1997-December 1999. Areas in black indicate grids cells where one or more months were not available. Warm tones indicate high mean [ChlA], while cool tones represent low mean

analyzed as CINMS boundaries will not change in response to monthly variation in oceanographic condition. An average concentration was calculated only for grid cells in which data were present during all 26 months (Figure 2.8.1). Excluding grid cells lacking full temporal coverage was done to minimize biases that may result from a disproportionate expression of seasonal [ChlA], thereby biasing the average value in that cell. Grid cells shaded in black indicate areas where one or more months were not available due to cloud cover, etc. Once calculated, mean values were then used to construct a model to estimate mean [ChlA] throughout the geographic extent using an interpolation technique (kriging) which resulted in a statistically smoothed raster surface (Figure 2.8.2).

To accomplish this, the calculated mean [ChlA] was first assigned to a point at the center of the cell (i.e. the cell centroid). These point data were then tested for significant spatial autocorrelation using the Moran's I and Geary's C statistics (Kaluzny *et al.*, 1998). Significant autocorrelation indicates that points that are nearer to one another tend to have more similar values than points that are far away (Legendre, 1993), and is prerequisite to accurate interpolation. Next, the spatial autocorrelation was described using a variogram, which summarizes the decrease in relatedness between pairs of points as the distance between them increases. Parameters of the resulting variogram were used in the kriging procedure, which provides a surface of predicted values, as well as a standard error map indicating regions of confidence in the accuracy of estimated mean surface chlorophyll. To avoid displaying estimates of modeled surface chlorophyll in areas where we have little confidence, the standard error map was used to clip (mask) the interpolated surface. The resulting map (Figure 2.8.3) displays interpolated mean [ChlA] for those regions where the standard error was in the lowest 30 percent. The modeled accuracy

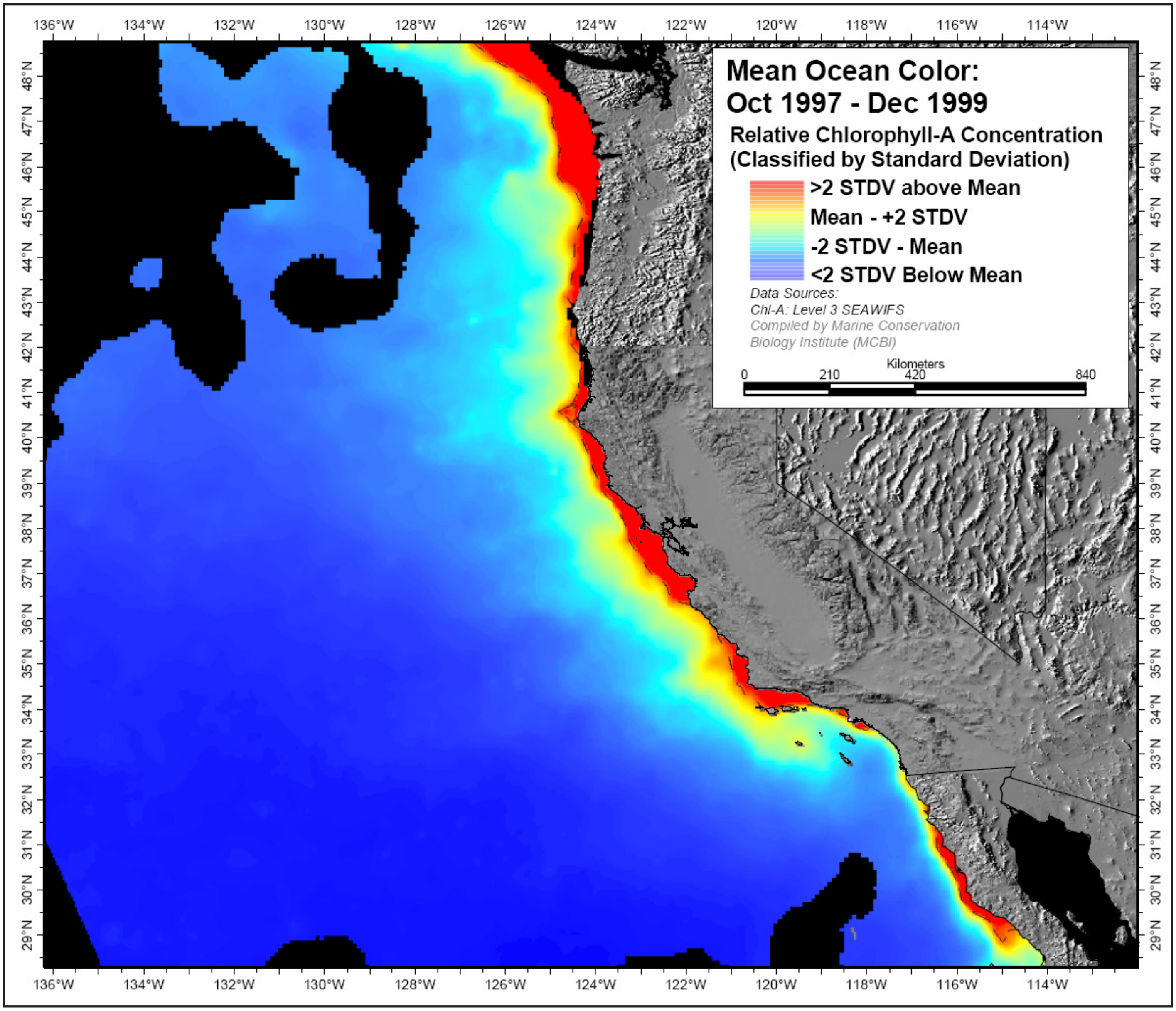


Figure 2.8.2. Interpolated mean chlorophyll concentration [ChlA] for the period between November 1997 and December 1999. Model extent ranges from 28º- 49ºN. Warm tones indicate high mean [ChlA], while cool tones represent low mean [ChlA]. Areas clipped by the model standard error map appear black.

was then assessed using standard cross-validation techniques. Regressing predicted values against observed values yielded a coefficient of determination (r^2) of 0.97 ($p<0.001$).

Estimated patterns of ocean color should be interpreted with care, as they represent a composite of 26 months, some of which were considered by oceanographers to have taken place during a strong El-Niño period. As stated above, surface chlorophyll can be highly variable, and the average surface provided in this report is designed only to highlight areas of relatively persistent high [ChlA]. In addition to the mean [ChlA] map and analysis, mean monthly maps of surface chlorophyll and current vectors are also provided for 1999 (see broad-scale patterns below), but are not individually analyzed relative to the boundary concepts. 1999 was selected from the available years as it represents a relatively "normal" year in the El-Niño-Southern Oscillation (ENSO) cycle (Dandonneau *et al*., 2003).

Broad-scale Patterns

The interpolated 26-month mean surface chlorophyll model resulted in estimated concentrations of near-surface chlorophyll that were higher (warm tones) nearshore than offshore throughout the analysis extent (Figure 2.8.3). Stippled areas on the map indicate areas where average [ChlA] was greater than 2 standard deviations above the mean (henceforth "high"). A conspicuous area of high [ChlA] can be seen centered on the nearshore wa-

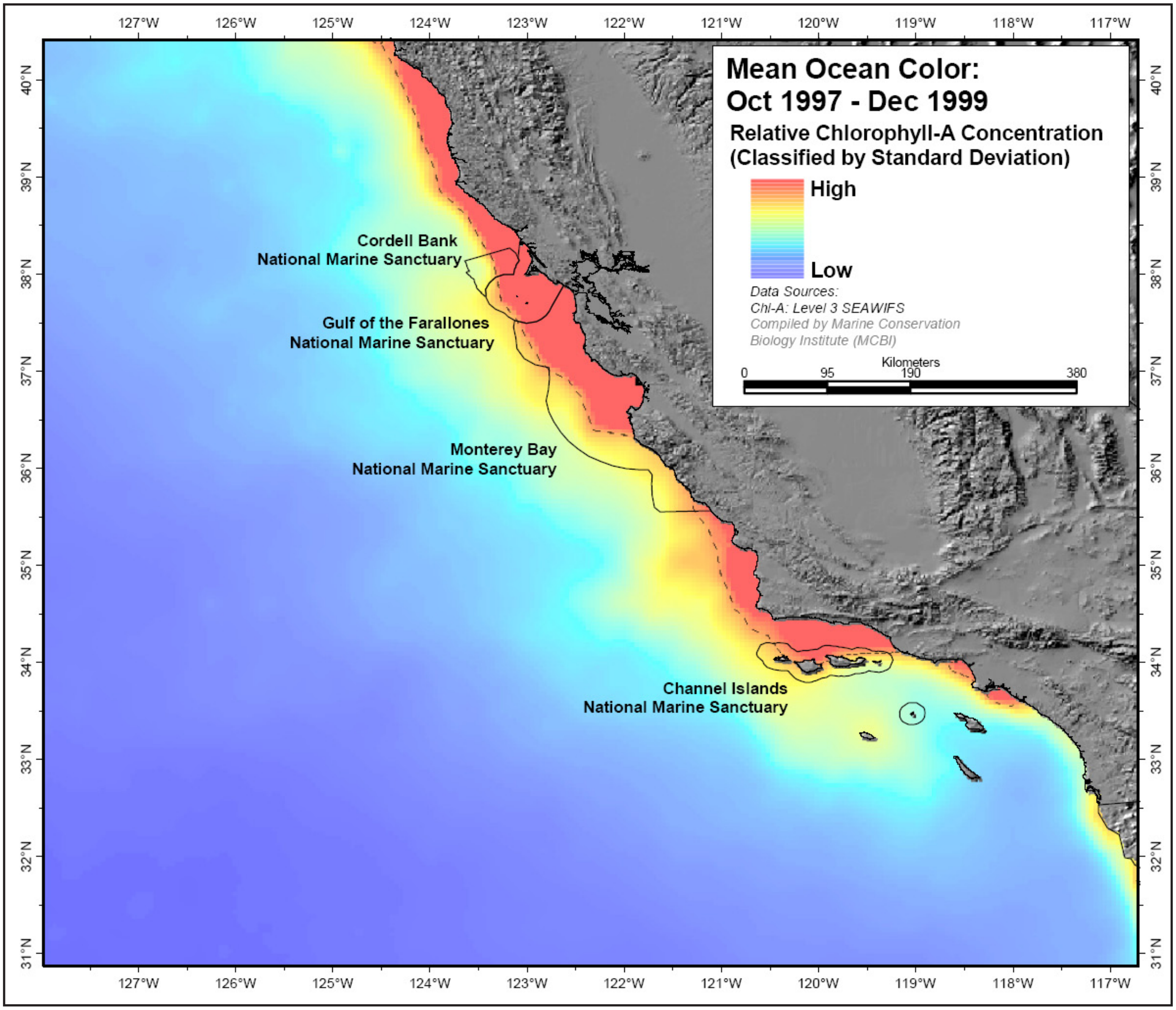


Figure 2.8.3. Interpolated mean chlorophyll concentration [ChlA] for the period between November 1997 and December 1999. Stippled areas on the map indicate where average [ChlA] was greater than 2 standard deviations above the mean. Warm tones indicate high mean [ChlA], while cool tones represent low mean [ChlA].

ters off Points Arguello and Conception, extending northward to Cambria, and eastward into the Santa Barbara Channel (SBC), settling into the Santa Barbara-Ventura Basin (refer to Figure 2.1.1). It is interesting to note that waters exhibiting relatively low [ChlA] can be found in the adjacent Santa Monica-San Pedro Basin which is deeper, and typically fed by warm, less nutrient-rich waters of the northward flowing California countercurrent. A second much larger area of high [ChlA] can be seen extending from just south of Monterey northward through the entire range of the analysis. In both cases, the seaward extension of elevated ocean color averages approximately 50 km, and then attenuates rapidly thereafter.

Two smaller areas of relatively high [ChlA] also can be seen just offshore of Santa Monica and Newport Beach; however, these are likely expressions of nutrient enrichment resulting from allocthonous materials sent downstream of the Santa Anna River, and San Mateo, Malibu, and various other creeks. This may be further exacerbated by agricultural and urban runoff from the densely populated Los Angeles basin. As such, high [ChlA] is clearly not always a sign of a healthy marine environment. Nutrient enrichment (eutrophication) can lead to hypoxia which has the propensity to profoundly affect an ecosystem, and cause physiological stress to associated aquatic organisms. The Committee on Environment and Natural Resources (CENR) released a report in 2003 which indicated that fertilizers and point source pollutants contribute the majority of nitrogen that is exported to marine and estuarine ecosystems in the southern California region (CENR, 2003). As such, it is not surprising to see this expressed in our analysis.

Results also indicate that the complement of sanctuaries along the California coastline (Gulf of the Farallones, Cordell Bank, Monterey Bay, and Channel Islands) captures substantial areas of high estimated mean [ChlA]. In this analysis (ranging from 28° to 49° latitude), the total area identified as high [ChlA] was 97,584 km^2. Roughly 11,728 km^2 (~11%) of this high area is contained within the four California Sanctuaries. Roughly 1% of the high area fell inside the boundaries of the Channel Islands National Marine Sanctuary (NAC). However, this represents 24% of the area contained within current CINMS boundaries. This is the smallest proportion of any California sanctuary (Gulf of the Farallones-85%, Monterey Bay-53%, and Cordell Bank-43%).

Highest phytoplankton biomass in the region has generally been reported to occur in nearshore surface waters, with maxima most frequently occurring during the spring and summer upwelling season when nutrient content of surface waters is relatively high (Airamé *et al*., 2003a). Spatial and temporal trends in ocean color shown here corroborate these findings, with monthly mean [ChlA] maps for 1999 suggesting that peak phytoplankton concentrations occurred between March and June of that year (Figures 2.8.4 and 2.8.5a). Additionally, current vectors suggest that the spatial patterns in [ChlA] are largely controlled by geostrophic flow. This can be clearly seen during the summer months where current jets and filaments can be seen transporting phytoplankton offshore. Thus, many of the region's biological resource distributions are influenced by these surface currents, and by other larger-scale ocean currents such as the southward flowing California Current and northward flowing southern California Countercurrent. This notion is not new, as many scientists have published their findings on the interrelationships between marine fauna and local oceanographic climate (Oedekoven *et al*., 2001; Ainley *et al*., 1994; Allen, 1994; Briggs *et al*., 1987; and Chelton *et al*., 1982).

The current vectors provided here (Figures 2.8.5a,b) reveal the persistent cyclonic flow pattern discussed in section 2.3. These surface currents can be seen during each month south and west of Point Conception. This pattern of surface circulation meandered only slightly through the duration of 1999. It is interesting to note that during the spring and early summer, an anti-cyclonic flow pattern set up along coastal waters centered on Morro Bay. These counter-rotating flows were presumably the result of the convergence of the California Current and southern California Countercurrent. This dynamic system of eddies, gyres, jets, and filaments clearly impact the distribution of observable phytoplankton distribution.

Analysis of Boundary Concepts

The preceding discussion identified a large region of high mean [ChlA] centered on Points Arguello and Conception, ranging from Cambria in the north southward along the shelf to Point Conception, where it then spreads eastward throughout the entire Santa Barbara-Ventura Basin. A total of 24% of the area contained within current CINMS boundaries was classified as having high [ChlA]. As such, it is important to note that the No Action Concept (NAC, current boundary) is reasonably well configured to capture areas of high [ChlA], and a review of the remaining concepts suggests that only boundary concepts 2 and 5 provide viable options in terms of optimizing expansion to capture areas of relatively high average primary productivity (Table 2.8.1). As discussed in Chapter 1.4, two Optimal Area Index (OAI) values are presented here. The first of which is calculated using the mean [ChlA] inside each of the concepts (henceforth "relative OAI"), and the second is calculated using the total area of high [ChlA] captured inside each boundary (henceforth "absolute OAI").

Mean estimated [ChlA] for the NAC was calculated to be 1.22 with a coefficient of variation (CV) of 23.3%. Mean diversity and CV values for the remaining concepts, ranging from smallest in size to largest are as follows: Concept 5-1.23, 24.3%; Concept 4-1.15, 29.0%; Concept 3-1.18, 30.4%; Concept 2-1.26, 29.3%; Concept 1a-1.22, 30.3%; and Concept 1-1.22, 30.3% (Figure 2.8.6). Mean [ChlA] for the study

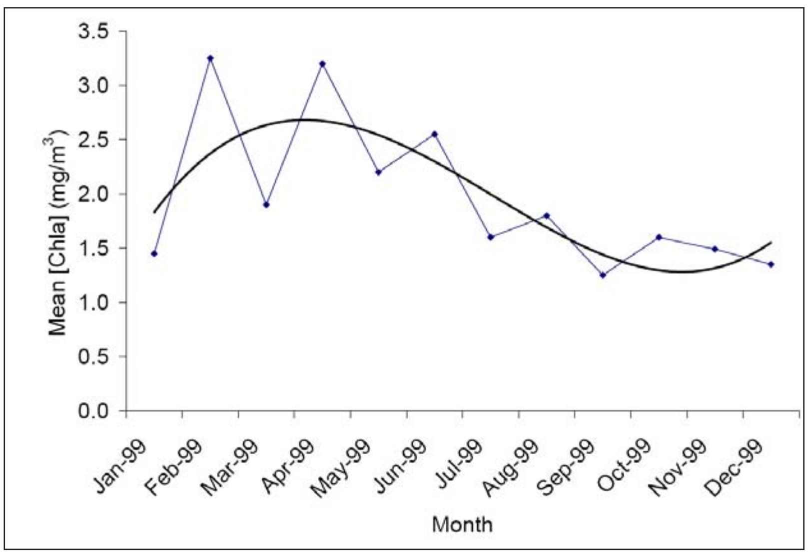
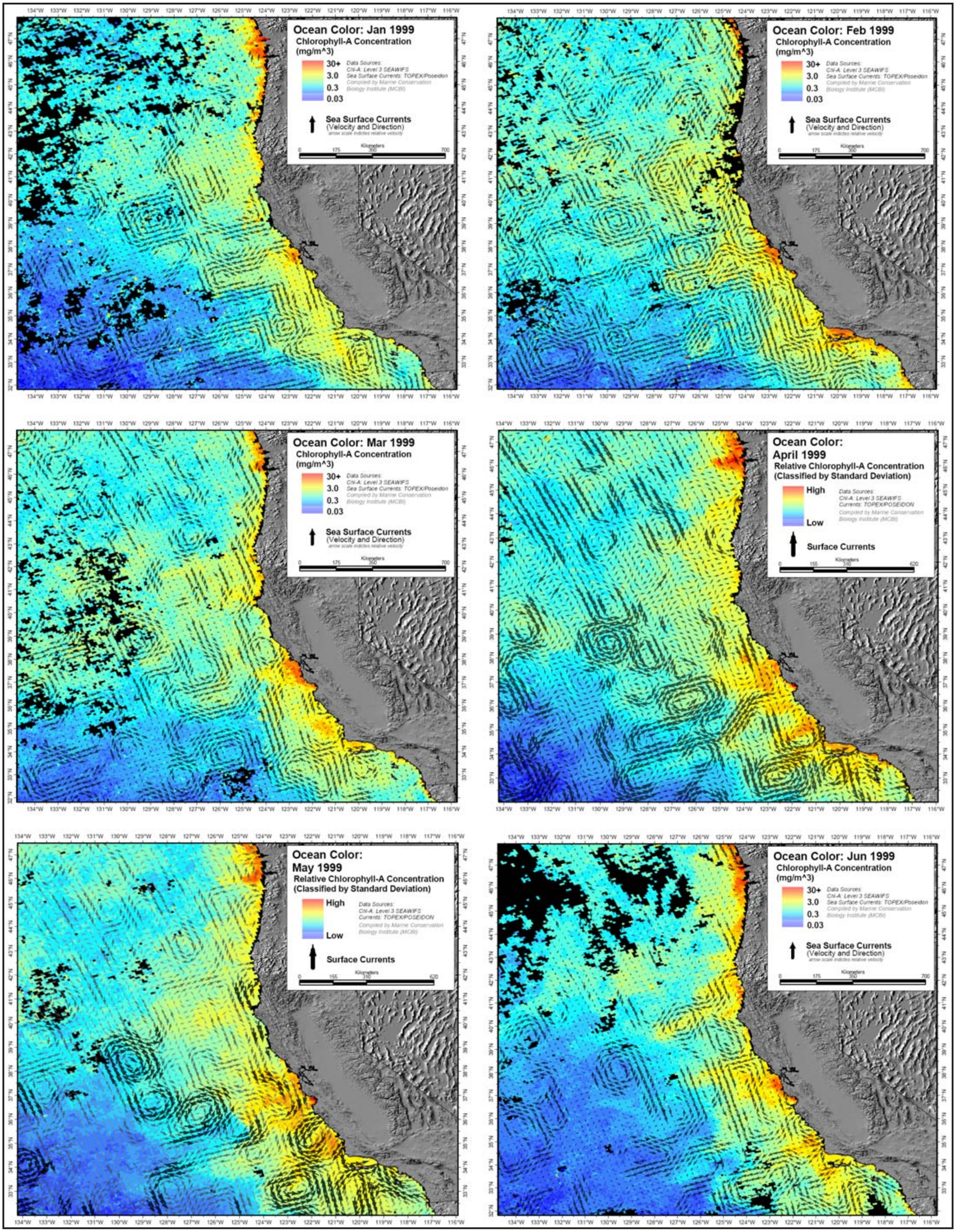
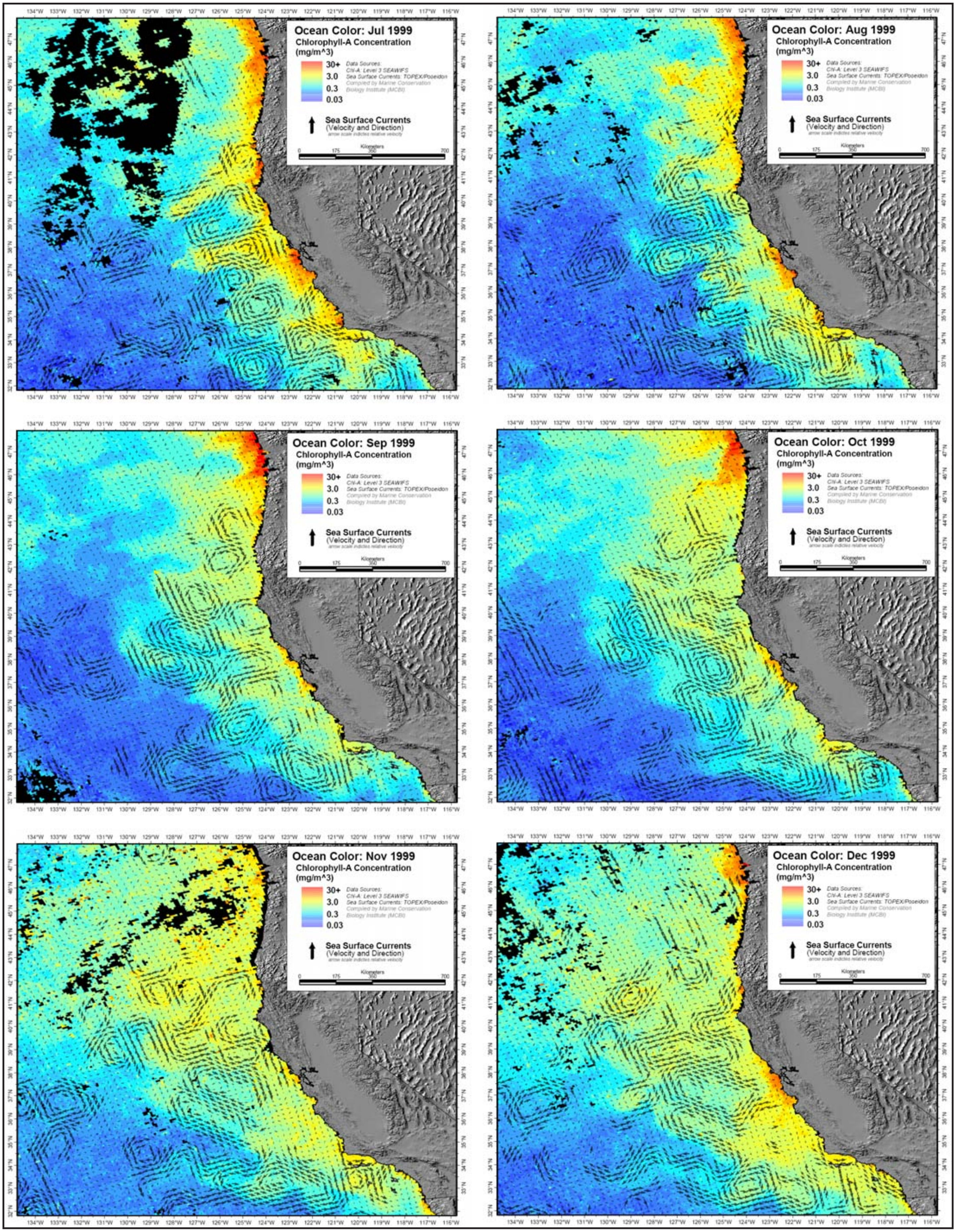


Figure 2.8.4. Monthy mean [ChlA] for 1999. Estimates derived from data contained within the Study Area boundary. Smooth line indicates a third-order polynomial through the observed estimates.



Figures 2.8.5a. Mean chlorophyll concentration [ChlA] for the months January to June 1999 (left to right). Altimetry derived surface current velocity vectors for the same time periods are superimposed on the [ChlA] surface. Large arrows indicate relatively strong flow (greater than mean), while small arrows indicate weak flow.



Figures 2.8.5b. Mean chlorophyll concentration [ChlA] for the months of July to December 1999 (left to right). Altimetry derived surface current velocity vectors for the same time periods are superimposed on the [ChlA] surface. Large arrows indicate relatively strong flow (greater than mean), while small arrows indicate weak flow.

area boundary (defined in McGinnis, 2000) was estimated to be 1.29 with a CV of 30.3% (Figure 2.8.6). Of the concepts in question, only 2 and 5 exhibited a higher mean [ChlA] value than the NAC (Table 2.8.1). It is important to note that the Study Area also resulted in a high relative OAI, but is not currently under consideration as a concept. These results show no statistical relationship to concept size, unlike the predictable relationships discussed in chapter 1.4. This lack of trend is shown in Figure 2.8.7 as a linear regression function between concept area (km^2) and the mean [ChlA] value calculated within the boundary (r^2=0.07, P=0.45). The relationship between concept area and absolute area of high [ChlA] is very predictable (and statistically significant), with larger concepts containing ever larger areas of high [ChlA]. Figure 2.8.8 shows the linear regression function between the total concept area (km^2) and the area of high [ChlA] contained within the boundary (r^2=0.99, P<0.0001).

A more balanced metric to use in assessing the relative benefits of each concept as it relates to optimizing for high [ChlA] is the OAI (Table 2.8.1). While this metric decouples the predictable relationships between concept area and the relative and/or absolute estimate to some extent, results of the OAI are still dependent upon the input data – absolute vs. relative measures. As such, we've provided results of the OAI for both mean and area of high [ChlA]. Again, the OAI takes into account the proportional (%) change in [ChlA] as you step from the NAC to each of the concepts under consideration. It also incorporates the proportional change (%) in area from the NAC. Results suggest that Concept 5, the minimum expansion concept, provides maximum benefit in terms of the mean [ChlA] calculated for each concept (relative OAI), while concept 2 provides the highest absolute OAI value in terms of the area of high [ChlA] contained within each concept. Because the mean OAI incorporated a negative value in the numerator for concepts 1, 1a, 3, and 4 (decreased [ChlA]), the calculated value is necessarily negative.

Table 2.8.1. Analysis of chlorophyll within boundary concepts. Numbers in bold indicate an increase in the estimate when compared to the No Action Concept (NAC). Maximum calculated OAI numbers are shaded in gray. Delta (D) indicates a rate of change calculation, and is always expressed as a percent change from the NAC.

Concept	Area (km^2)	Mean ChlA	High ChlA Area (km^2)	Δ Area (%)	Δ Mean ChlA (%)	Δ High ChlA Area (%)	Mean ChlA OAI (relative)	High ChlA Area OAI (absolute)
NAC	3745	1.223	981	-	-	-	-	-
5	4536	1.233	**1225**	21.12	0.82	24.87	0.39	1.178
4	7981	1.146	**2056**	113.11	-6.30	109.58	-0.056	0.969
3	9044	1.176	**2683**	141.50	-3.84	173.50	-0.027	1.226
2	13736	**1.263**	**4842**	266.78	3.27	393.58	0.012	1.475
1a	22591	1.215	**6437**	503.23	-0.65	556.17	-0.001	1.105
1	22613	1.215	**6414**	503.82	-0.65	553.82	-0.001	1.099
SA	*17093*	*1.291*	*6441*	*356.42*	*5.56*	*556.57*	*0.016*	*1.562*

Summary

- Patterns of mean [ChlA] show highest concentrations in nearshore waters during spring and summer, and in some cases, appear in locations known for upwelling.

- Patterns of mean [ChlA] are clearly related surface current patterns.

- Of the boundary concepts under consideration, Concepts 2 and 5 provide relatively large increases in [ChlA] for their size in comparison to the NAC.

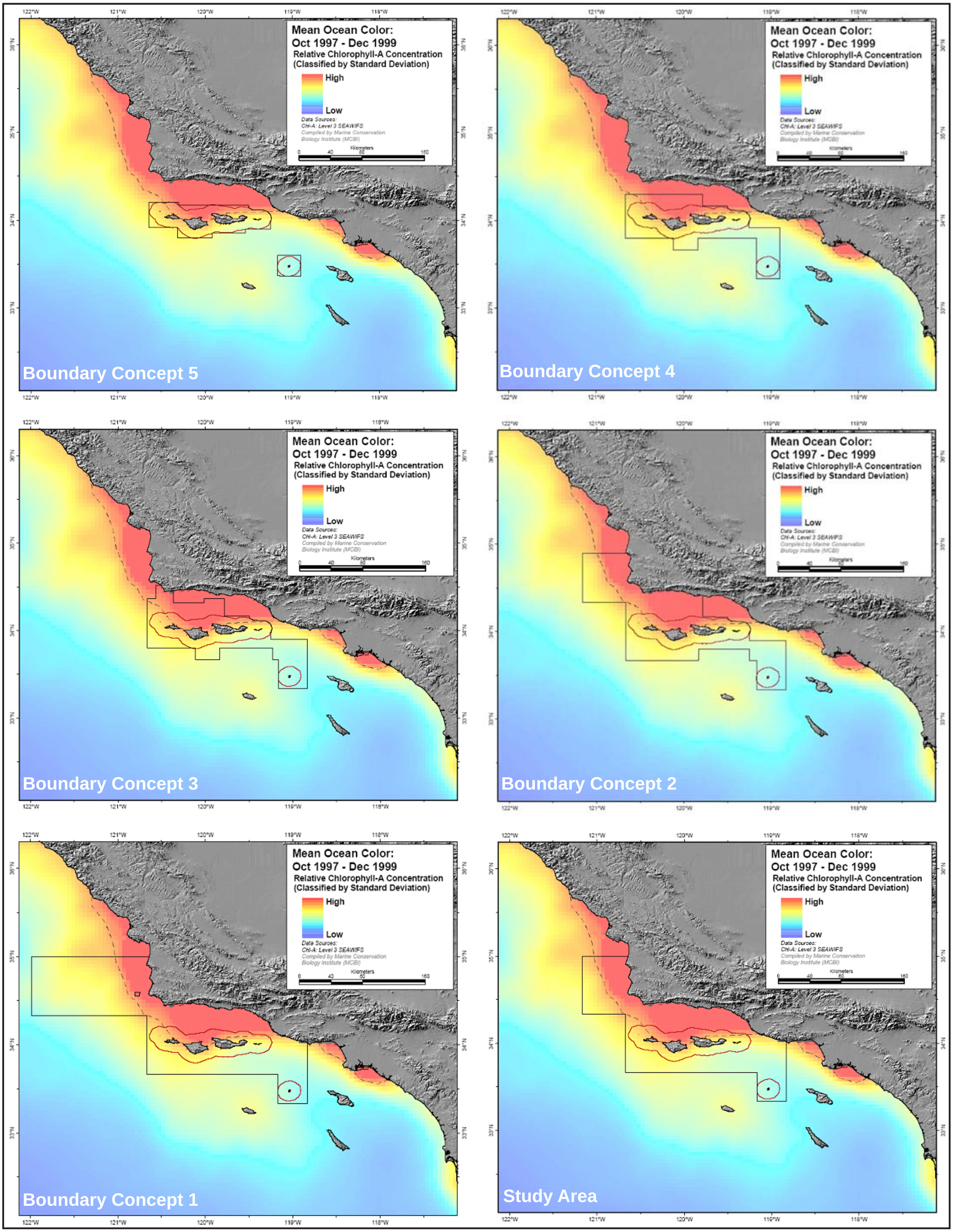


Figure 2.8.6. Interpolated mean chlorophyll concentration [ChlA] for the period between November 1997 and December 1999 with boundary concepts overlain. The No Action Concept (NAC) is shown as a red line, while the concepts are shown as a black line.

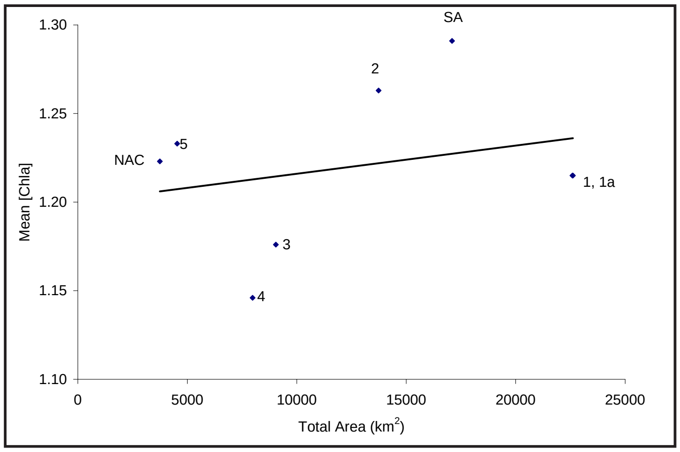


Figure 2.8.7. Linear regression function between concept area (km^2) and mean [ChlA].

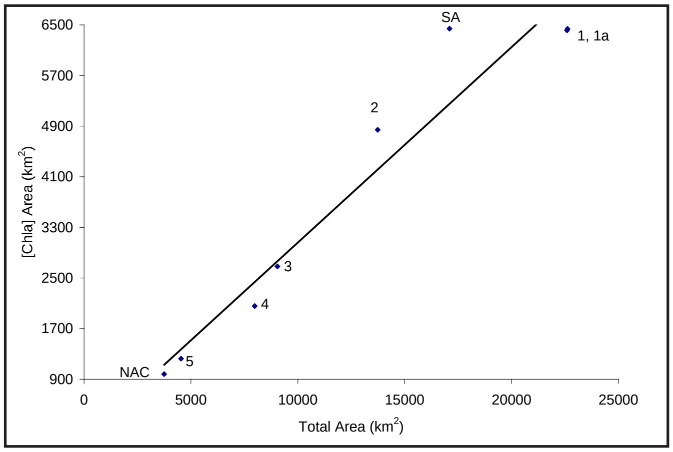


Figure 2.8.8. Linear regression function between the total concept area (km^2) and area of high [ChlA].

2.9 SUBMERGED AQUATIC VEGETATION DISTRIBUTION: EELGRASS AND SURFGRASS

Data and Methods

Data presented here are a compilation of all currently available quality controlled submerged aquatic vegetation (SAV) GIS data sets for the west coast of the United States, ranging from 33^o to 49^o north latitude. The data were compiled from seventeen data sources. These sources were acquired over a large range of time periods, collected at several different spatial resolutions, and were collected using a variety methods, including: 1) aerial photography, 2) videography, 3) multispectral sensors, 4) sonar, and 5) standard field surveys. The temporal range of data used in this composite view of SAV is from 1987 through 2003. Data were originally developed for the Pacific States Marine Fisheries Commission in cooperation with the National Marine Fisheries Service (NMFS) Northwest Region and the Pacific Fishery Management Council to support the designation and conservation of Essential Fish Habitat (EFH) for Pacific Coast groundfishes. Data were consolidated and integrated in a GIS format to support spatially explicit habitat modeling and impact assessment on a coast-wide scale.

This SAV dataset was developed by TerraLogic GIS, Inc., and was published in April 2004. Data developers urge caution when analyzing and interpreting the data, as they merely represent a regional (*i.e.*, not persistent through time) view of SAV locations. It is also important to note that the distribution of SAV's can be quite ephemeral. Areas without mapped SAV may contain seagrass; however, digital data were unavailable during this data compilation. To analyze distributions of SAV in relation to proposed concepts, the total area of SAV was estimated within each boundary. The area calculated represents combined areas of Eelgrass (*Zostera marina*) and surfgrass (*Phyllospadix* spp.).

Z. marina occurs from Alaska to Baja California along the Pacific coast of North America. Eelgrass beds are generally considered to be extremely productive habitats that support a rich assemblage of fish species, and provide refugia for the larval and juvenile stages (Valle *et al*., 1999; Leet *et al*., 2001). Eelgrass habitat also is an important resource for birds, as it has an associated rich benthic faunal community that provides forage species for waterfowl and other marine birds. In California's bays and estuaries north of Monterey Bay, eelgrass also provides spawning habitat for Pacific herring (*Clupea pallasii*). Subsequently, birds such as scooters (*Melanitta* spp.), bufflehead (*Bucephala albeola*), and goldeneyes (*Bucephala clangula*), eat eggs deposited onto eelgrass by *C. pallasii* during the mid-winter spawn. In addition, birds such as surface-feeding ducks and the black brant (*Branta nigricans*) feed directly on eelgrass (Leet *et al*., 2001). Surfgrass (*Phyllospadix* spp.) is also considered to be a highly productive living habitat that provides shelter and resources for a variety of taxa (Stewart and Myers, 1980), including many fishes and invertebrates, such as the California spiny lobster (*Panulirus interruptus*) (Engle, 1979).

Because SAV's provide critical habitat for such a wide range of biological resources, the assumption of this analysis was that boundaries which encompass a larger area of SAV habitat are preferred, and that any addition of this habitat provides the potential for increased habitat and biological diversity. The total area of SAV habitat within each concept was then used in calculating an Optimal Area Index (OAI). Because estimates of SAV density, standing stock, or biomass were unavailable (only the estimated area and distribution were available), only results of the absolute OAI are provided (see Section 1.4 for further discussion on OAI).

Broad-scale Patterns

SAV distribution along the California coastline is patchy and discontinuous, with long stretches of the central coast – from San Francisco Bay south to Morro Bay – generally lacking significant areas of coverage (Figure 2.9.1). It is important to note that the polygons that portray SAV distribution in this map have been greatly exaggerated so that they can be seen at this scale. Data indicate that *Zostera* can be found throughout the range of this analysis, while *Phyllospadix* is generally more abundant south of Point Arguello. Leet *et al*. (2001) reported that SAV's are found to some degree in all of California's larger bays and estuaries, including Humboldt Bay, Tomales Bay, San Francisco Bay, Monterey Bay, Morro Bay, and San Diego/Mission Bay. Furthermore, SAV's are well established in several smaller open estuarine embayments along the coast. Maps presented here corroborate these reports.

In all, a total of 317 km^2 of SAV was mapped along the entire Pacific coastline of the coterminous U.S. Maps indicate that the complement of National Marine Sanctuaries along the California coastline (Gulf of the Farallones, Cordell Bank, Monterey Bay, and Channel Islands) do not capture large areas of SAV. Of the four California sanctuaries, only the Gulf of the Farallones and Channel Islands capture measurable areas of SAV. Gulf of the Farallones NMS contains approximately 22 km^2 (~7% of total mapped), while the CINMS contains approximately 19 km^2 (~6% of total mapped). Of these two sanctuaries, only the Channel Islands contained both *Zostera marina* and *Phyllospadix* spp.

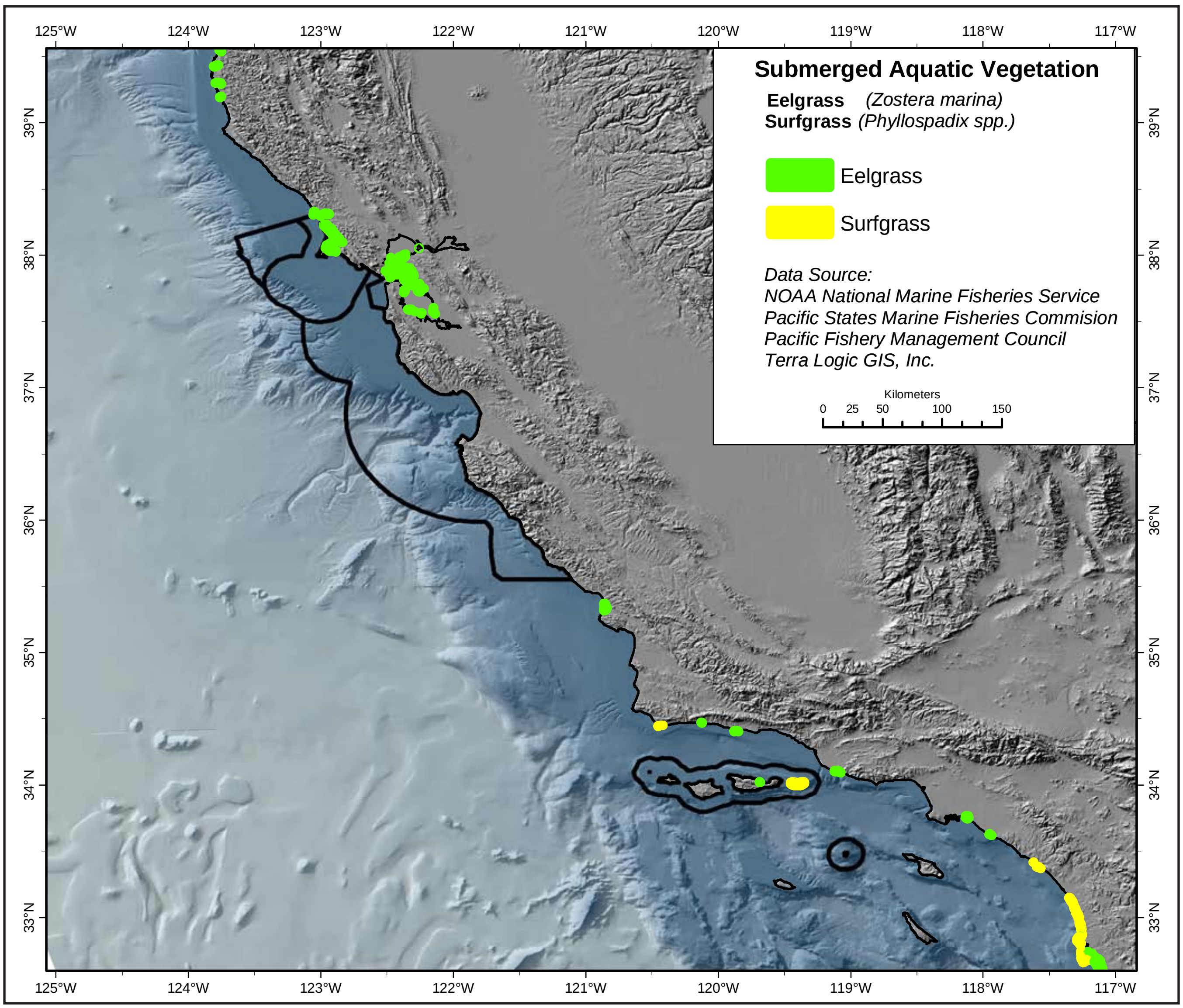


Figure 2.9.1. Distribution of submerged aquatic vegetation within coastal California waters.

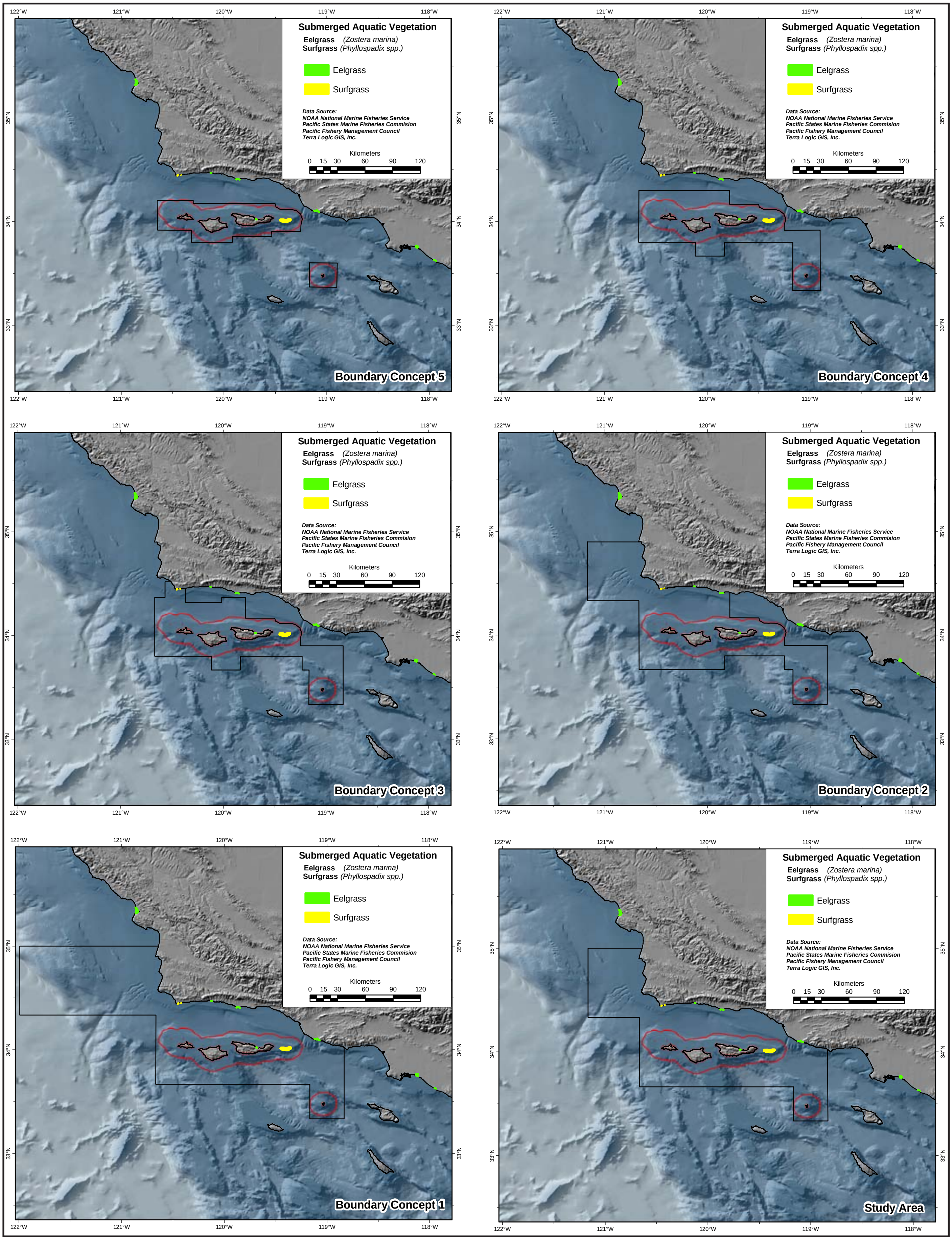


Figure 2.9.2. Distribution of submerged aquatic vegetation within the proposed boundary concepts in southern California.

Analysis of Boundary Concepts

While the total area of SAV within the current sanctuary boundary is modest (Table 2.9.1), it contributes approximately 46% of the total SAV beds contained within National Marine Sanctuaries along the California coast. Concepts 1, 1a, and 2 would encompass an additional 0.41 km^2, as would the study area boundary. This amounts to a 2% increase in area of SAV for concepts 1, 1a, and 2. Concept 3 would capture an additional 0.11 km^2, or an increase of 0.5%. Figures 2.9.2 show the distribution of SAV beds relative to each boundary concept. Results exhibit a predictable and statistically significant positive relationship to concept size (at a=0.05). This relationship is shown in Figure 2.9.3 as a linear regression function between concept area (km^2) and the area of SAV contained within each concept (r^2=0.83, P=0.001).

Table 2.9.1. Analysis of SAV distribution within boundary concepts. Numbers in bold indicate an increase in the estimate when compared to the No Action Concept (NAC). OAI estimates shaded in gray represent maximum observed benefit. Delta (D) indicates a rate of change calculation, and is always expressed as a percent change from the NAC.

Concept	Area (km^2)	SAV Area (km^2)	Δ Area (%)	Δ SAV Area (%)	OAI (absolute)
NAC	3475	19.00	-	-	-
5	4538	19.00	21.12	0.00	0.000
4	7981	19.00	113.11	0.00	0.000
3	9044	**19.11**	141.50	0.58	0.004
2	13736	**19.41**	266.78	2.16	0.008
1a	22591	**19.41**	503.23	2.16	0.004
1	22613	**19.41**	503.82	2.16	0.004
SA	*17093*	*19.41*	*356.42*	*2.16*	*0.006*

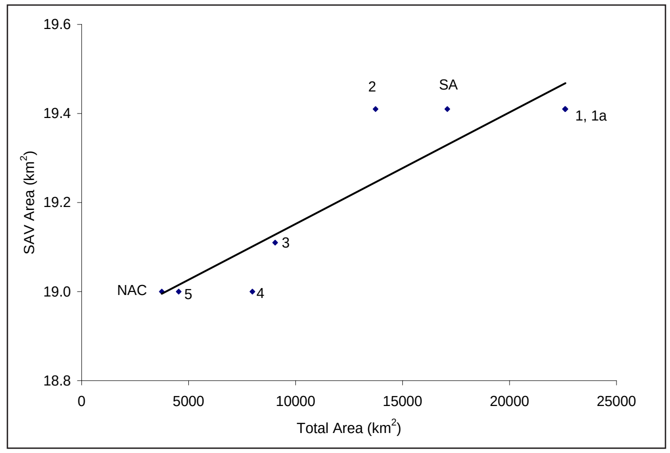


Figure 2.9.3. Linear regression function between area of SAV distribution and total area of boundary concepts.

The optimal area index (OAI) values suggest that concepts 3, 2, 1, and 1a all would result in a net benefit in terms of SAV distributions, and that concept 2 would provide maximum benefit. This is due to the fact that while concepts 1 and 1a are substantially larger, they contain no further SAV beds than what is captured in concept 2.

Summary

• SAV distribution along the coast of California is patchy and discontinuous.

• The Channel Islands NMS presently contributes 46% of all mapped SAV beds contained within all four California sanctuaries.

• Of the boundary concepts under consideration, concept 2 provides relatively large increases in SAV area for its size.

2.10 KELP DISTRIBUTION

Data and Methods

Data presented here delineate kelp bed distribution (primarily *Nereocystis leutkeana* and *Macrocystis* spp.) along the coast of California, ranging from 32°-41° latitude. These data, developed by the California Department of Fish and Game (CDFG) Marine Region, are a subset of an entire west coast dataset that was used to support the National Marine Fisheries Service (NMFS) in the development of an environmental impact statement (EIS) that considers the designation of Essential Fish Habitat (EFH) for Pacific coast groundfish. Kelp data were digitized for use in a GIS from scanned aerial photos (1989 and 1999) and digital multispectral video data (2002). Assessments of accuracy for the abundance and distribution of kelp are uncertain due to the various sampling methods. Additionally, the strong association of kelp and the variability of oceanographic and climatic conditions may affect overall map accuracy. Therefore, kelp bed locations and extent may not reflect current or past conditions; however, the data are useful in identifying general patterns of kelp distribution and to highlight areas that have been known to support kelp growth. In this chapter, kelp data were analyzed to characterize its distribution along the coast of California and to compare spatial kelp coverage within the proposed boundary concepts.

Kelp forests provide habitat that supports a vast trophic web. Species of polychaetes, amphipods, decapods, gastropods, and ophiuroids are common among kelp holdfasts, while sponges, tunicates, anemones, cup corals, and bryozoans are frequently found under kelp canopies. Kelp also provides refuge for many species of young-of-the-year and juvenile fishes, such as señorita (*Oxyjulius californica*) and surfperch (*Brachyistius frenatus*), which are common throughout the canopy. Several species of rockfish are abundant in kelp forests: blue rockfish (*Sebastes mystinus*), olive rockfish (*S. serranoides*), and black rockfish (*S. melanops*). Furthermore, kelp forests provide a large source of prey for piscivorous birds, such as gulls, terns, snowy egrets, great blue herons, and cormorants. At the higher end of the trophic chain, many mammals seek prey items among the kelp structure, including: sea otters, harbor seals, and California sea lions (Airamé *et al*., 2003a).

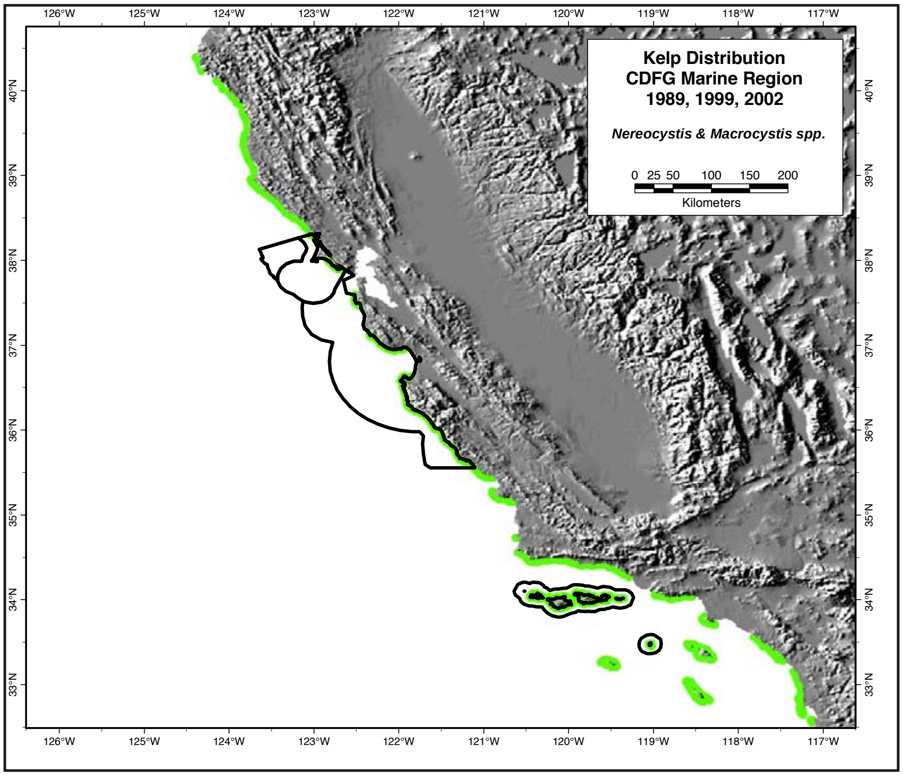


Figure 2.10.1. Kelp distribution based on aerial and multispectral surveys conducted by CDFG during 1989, 1999, and 2002. Kelp polygons have been enlarged for better viewing.

Giant kelp is of significant commercial value in central and southern California, where historically 100,000 tons are harvested annually, most of which comes from southern California (Tarpley, 1992). During the mid 1980's kelp harvesting supported an industry worth $40 million. Few studies examine the potential ecological impacts of intensive and repeated harvesting of kelp. Of these studies performed, results indicate that harvesting does not have a significant effect to kelp abundance and distribution; however, more studies are needed to understand how harvesting affects invertebrate and fish populations (Airamé *et al*., 2003b).

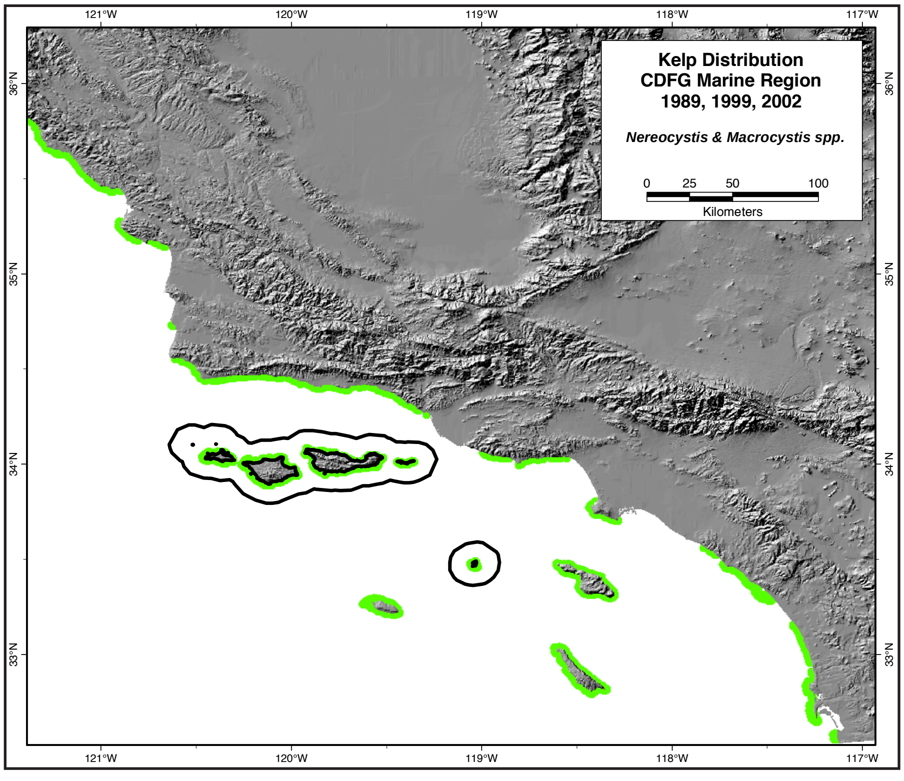


Figure 2.10.2. Kelp distribution off southern California.

Broad-Scale Patterns

Dense forests of kelp grow in rocky nearshore (to 40 m) habitats along the entire California coast (Figure 2.10.1). The GIS kelp data is not segregated by species; however, giant kelp, *Macrocystis pyrifera*, is the predominant species south of Santa Cruz, while bull kelp, *Nereocystis leutkeana*, is more common to the north (Airamé *et al*., 2003a). In central California, kelp beds are typically comprised of narrow bands that parallel the shoreline due to the steepness of the shore. Extensive areas of kelp were found along the shoreline from Cape Mendocino through the Gulf of the Farallones and

Monterey Bay sanctuaries. In southern California extensive kelp beds can extend far offshore along rocky and well stabilized sandy bottoms which have less extreme relief than the region to the north (Miller and Geibel, 1973). Kelp was also broadly distributed in southern California, with large concentrations found from Point Conception to Point Mugu and considerable amounts were contained within the Channel Islands National Marine Sanctuary and southern islands (Figure 2.10.2).

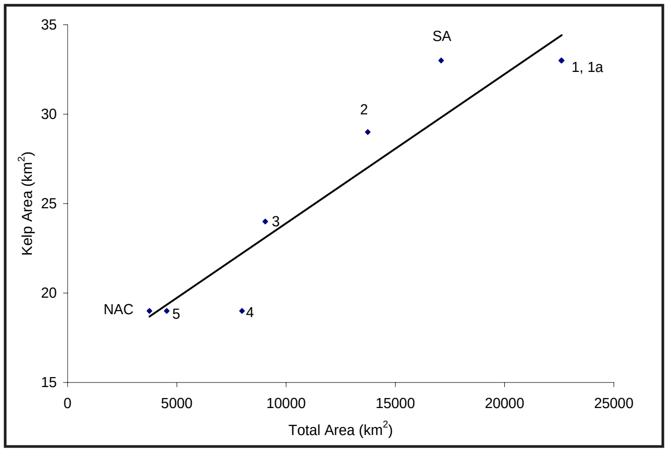


Figure 2.10.3. Regression of kelp area and total area for the current and proposed boundary concepts. Numbers indicate alternatives and NAC=No Action Concept, SA=Study Area.

Analysis of Boundary Concepts

Figure 2.10.2 displays kelp distribution in southern California. Overall, kelp comprised 1% or less of the total area contained within each concept and abundance was significantly greater (r^2=0.90, p>0.0003) within the larger Concepts (1, 1a, 2 and the Study Area) than within Concepts 3, 4, 5 and the NAC (Figure 2.10.3). The OAI was used to compare historic kelp coverage within each boundary concept (Table 2.10.1). Results indicated that the Study Area provided the most favorable gain of kelp habitat, however, this boundary is not considered as a concept. Therefore, Concepts 2 and 3 provide the most benefit in terms of kelp abundance and total area gained relative to the current CINMS boundary.

Summary

- Kelp forests provide habitat that supports many species.

- Patterns of kelp distribution are highly variable and data presented here do not reflect current conditions.

- Results of the OAI suggest that Concept 2 exhibits the greatest benefit among boundary concepts in terms of kelp coverage.

Table 2.10.1. Analysis of kelp distribution within boundary concepts. Numbers in bold indicate an increase in the estimate when compared to the No Action Concept (NAC). OAI estimates shaded in gray represent maximum observed benefit. Delta (D) indicates a rate of change calculation, and is always expressed as a percent change from the NAC.

Concept	Area (km²)	High Kelp Area (km²)	Δ Area (%)	Δ Kelp Area (%)	OAI (absolute)
NAC	3475	19.0	-	-	-
5	4538	19.0	21.12	0.00	0.00
4	7981	19.0	113.11	0.00	0.00
3	9044	**24.0**	141.50	26.32	0.19
2	13736	**29.0**	266.78	52.63	0.20
1a	22591	**33.0**	503.23	73.68	0.15
1	22613	**33.0**	503.82	73.68	0.15
SA	*17093*	*33.0*	*356.42*	*73.68*	*0.21*

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CHAPTER 3 – BIOGEOGRAPHY OF MACROINVERTEBRATES

Randy Clark, Wendy Morrison, M. James Allen, Larry Claflin

Several hundred species of invertebrates inhabit the mainland shelf and slope of southern California. Many of these species are abundant in southern California and have biogeographic breaks near Point Conception and CINMS. Others are more transient and have population centers north or south of the region (Figure 1.1.5). Providing an ecological assessment of all invertebrate species within the region of interest is beyond the scope of this chapter. This chapter examines the potential areas of habitat suitability for important commercial, ecological, and recreational species as determined by the CINMS. Additionally, fisheries independent monitoring data were analyzed to explore macroinvertebrate community structure on the southern California continental shelf.

3.1 SINGLE SPECIES HABITAT SUITABILITY MODELS (HSM)

Data and Methods

Habitat suitability modeling (HSM) is a tool for predicting the adequacy of habitat for a given species or assemblage of species. Models are constructed as a mathematical expression to provide an index of habitat quality as a function of one or more environmental variables. Model development can range from qualitative to quantitative, and is wholly dependent on the type of data being used to model the species in question (Brown *et al*., 2000; Clark *et al*., 2004). These mathematical expressions can then be mapped in a geographic information system (GIS) to portray areas of potential distribution for a given species.

Table 3.1.1. Invertebrate species of interest for the CINMS biogeographic assessment.

Common Name	Scientific Name
rock crabs	*Cancer* spp.
black abalone	*Haliotis cracherodii*
red abalone	*Haliotis rufescens*
white abalone	*Haliotis sorenseni*
California market squid	*Loligo opalescens*
sheep crab	*Loxorhynchus grandis*
spot shrimp	*Pandalus platyceros*
ridgeback rock shrimp	*Sicyonia ingentis*
California spiny lobster	*Panulirus interruptus*
California sea cucumber	*Parastichopus californicus*
warty sea cucumber	*Parastichopus parvimensis*
red sea urchin	*Strongylocentrotus franciscanus*
purple sea urchin	*Strongylocentrotus purpuratus*

In this chapter, deterministic models of habitat suitability were developed based on published ranges of bathymetry, preference for benthic substrate types, and latitudinal gradients for 15 macroinvertebrate species (Table 3.1.1). Where information was adequate, species distributions were mapped using a qualitative measure of suitability: high, medium, and low. For example, the distribution of the black abalone (*Haliotis cracherodii*) was reported to occur primarily from the shallow intertidal to 10 m on hard substrate (Leet *et al*., 2001). Based on these data, high suitability was assigned to hard substrate between 0-10 m, moderate suitability over hard substrates between 10-30 m, and all other habitats and depth zones were considered low suitability. Areas of high habitat suitability for each species were examined relative to the six boundary concepts using the Optimal Area Index (OAI). While there are many invertebrate species distributed throughout southern California (Chapter 1.3), the species listed in Table 3.1.1 were determined by project staff to have a significant commercial, ecological, and/or recreational importance within the southern California region.

Benthic substrate suitability was based on preferences for hard or soft substrates found in scientific literature combined with expert opinion. Preferred bathymetric ranges were rounded to the nearest 10 m interval to integrate with the GIS bathymetry data. The GIS bathymetric layer was developed using various sources and mapped at 10 m increments for the entire west coast of the U.S. Data extend from the shoreline to approximately 4,000 m. Refer to Chapter 2.10 for a more complete description of these data. For some species, information on latitudinal range was not available in the literature and expert opinion was used to provide information on latitudinal breaks.

Typically, fisheries independent monitoring data are used to validate habitat suitability model results (Rubec *et al*., 1999; Clark *et al*., 2004); however, such data were unavailable for invertebrates at the extent and scale needed. Thus, commercial fisheries data (Commercial Master File, CMASTR) provided by California Department of Fish and Game (CDFG) Marine Region GIS Lab were mapped and superimposed over suitability maps for comparison. These provided monthly summaries of abundance or total weight of landings within 10x10 nautical mile grids (Figure 3.1.1). CMASTR data were used for validating models for black, red, and white abalone, purple and red sea urchins, and ridgeback prawn. CMASTR data are landings information (in pounds) recorded at processing docks. Commercial trawl and trap logs recorded by commercial fishermen were used to validate models for California spiny lobster, California and warty sea cucumbers, ridgeback and spot prawns, and rock crabs. Validation data were ranked by 33rd percentile and classified as high, medium, and low to be consistent with model results. Mapped model results were presented at a workshop during May 2004 and reviewed by a panel of invertebrate biologists from CDFG and the University of California, Santa Barbara.

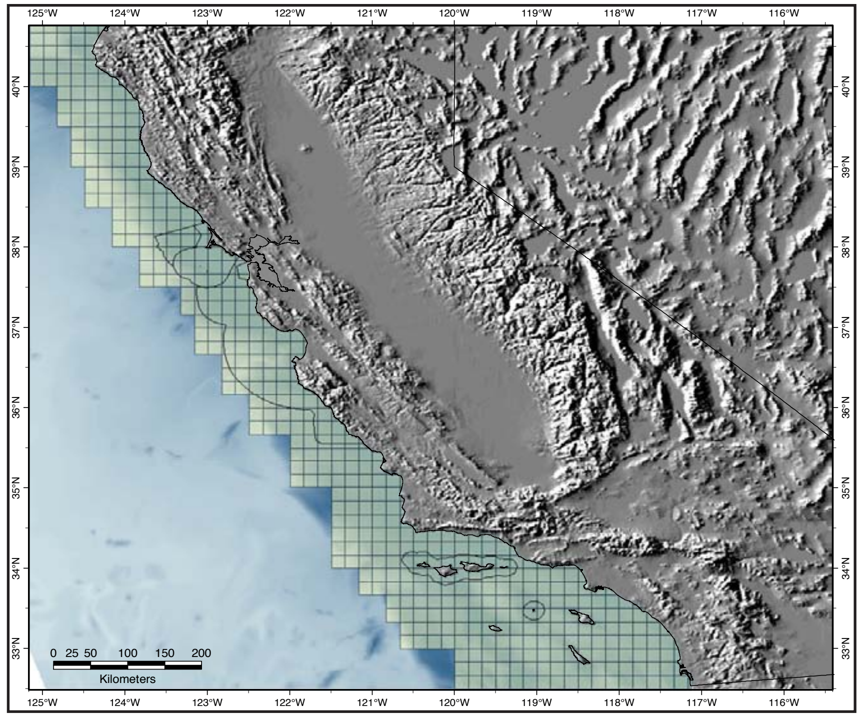

Figure 3.1.1. CDFG commercial 10x10 nm fishery landings grids. Mean monthly landings (pounds) were reported within designated grids from 1996-2002.

Rock crabs *(Cancer* spp.*)*
Three species of rock crab (brown, red, and yellow) were modeled together because their distribution and habitat preferences are reported to be similar (Carroll and Winn, 1989; Leet *et al*., 2001). The brown rock crab occurs from Washington to central Baja California, whereas the red rock crab occurs from Alaska to central Baja California, and the yellow rock crab is found from Humboldt Bay to Magdalena Bay, Baja California. Rock crab abundance is highest from low intertidal levels to subtidal depths (1-60 m), and occur over both hard and soft substrates (Morris *et al*., 1980; Winn, 1985). Red and brown rock crabs are found to depths of 100 m (Schmidt, 1921; Winn, 1985) and the yellow rock crab's depth range may extend to 140 m (Garth and Abbott, 1980; Winn, 1985). Although these species occur together throughout much of their range, brown rock crabs are more abundant in central California, red rock crabs dominate in northern California, and yellow rock crabs are most abundant in southern California (Carroll and Winn, 1989). Migration patterns are not described, though they are known to range randomly over several kilometers. Rock crabs are predators (feeding on a wide variety of invertebrates) and scavengers. Longevity is estimated to be 6 years or more (Leet *et al.,* 2001).

Large-scale commercial harvest of rock crabs using traps began in 1950. Santa Barbara and the Channel Islands represent major fishery areas. A minor sport fishery, using hoop nets and star traps, exists. Rock crab landings through 1991 have steadily increased since the fishery opened, with some fluctuation. Other sources of mortality include predation by fishes, octopus, sea stars, and sea otters. Rock crab populations in the study area have not specifically been assessed; however, experimental trapping has shown that catches are lower in commercially exploited areas (Gotshall and Laurent, 1979; Morris *et al.,* 1980; Leet *et al.,* 2001).

Broad-scale Patterns
High suitability was determined to occur over hard and soft substrate types in waters between 0-60 m. Habitats between 60-90 m were classified as moderately suitable. Habitats at depths between 90-140 m were considered low suitability and habitats at depths greater than 140 m were considered outside the species range and unsuitable. High and moderately suitable habitats are abundant throughout California waters and, when combined, comprise a large portion of the continental shelf (Figure 3.1.2). Considerable amounts of highly suitable habitat were observed within Gulf of the Farallones, Monterey Bay, and Channel Islands National Marine Sanctuaries. Commercial data from CDFG CMASTR landings were limited and model validation was not conducted.

Analysis of Boundary Concepts
Within the current sanctuary boundary approximately 655 km^2 was considered highly suitable habitat for rock crabs (Figure 3.1.3). This area was comprised of nearshore waters around the northern Channel Islands to 70 m. A similar ratio of area was considered to be moderately suitable, while the majority of the area within the current boundary was determined to be low suitability. No additional highly suitable habitat was observed within the

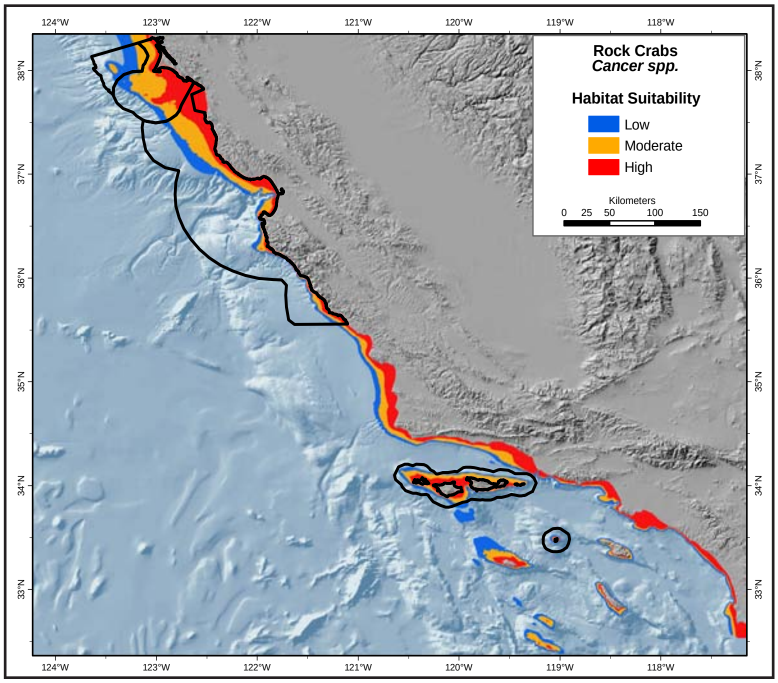

Figure 3.1.2. Rock crab (*Cancer* spp.) habitat suitability off central and southern California.

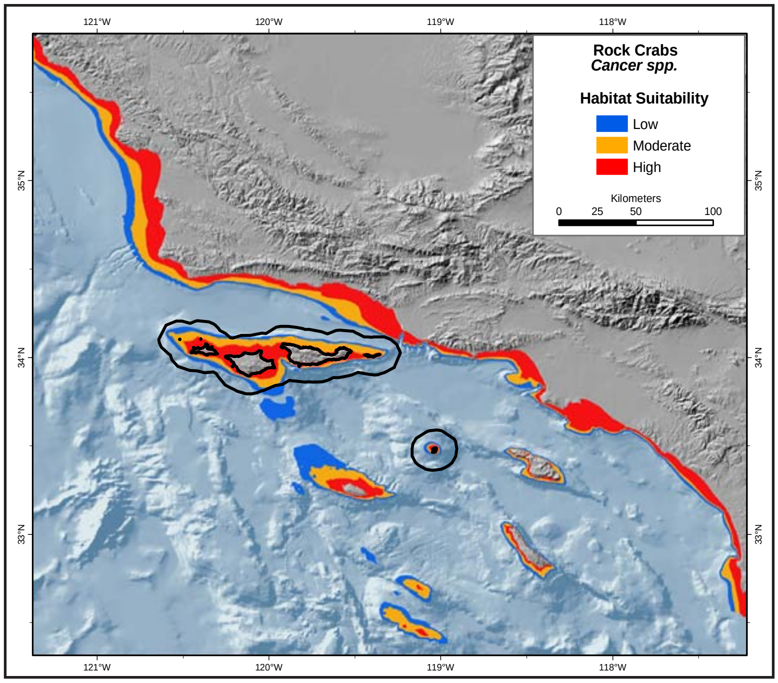

Figure 3.1.3. Rock crab (*Cancer* spp.) habitat suitability off southern California.

larger boundaries of Concepts 4 and 5. A 10% relative increase of highly suitable habitat was seen within Concept 3 as the northern boundary extended partially to the mainland. Significant increases were observed within Concepts 1, 1a, 2 and the Study Area as the northern boundaries contained vast amounts of shallow nearshore waters along the mainland (Figure 3.1.4). Analysis of the absolute OAI calculations for the predicted distribution of highly suitable habitat for rock crabs indicate that the Study Area yielded the greatest increase of highly suitable habitat relative to the increase in area from the No Action Concept (NAC; Table 3.1.2); however, this boundary is not under consideration. Therefore, Concepts 1 and 1a ranked highest for the OAI statistic.

Summary

• Brown, red, and yellow rock crabs share similar habitat preferences; highly suitable habitat was defined to occur over hard and soft substrates between 1-60 m.

• Of the six boundary concepts being considered, Concepts 1 and 1a provide the optimal proportional change of suitable habitat/total area relative to the NAC.

Table 3.1.2. Analysis of rock crab habitat suitability within boundary concepts. Numbers in bold indicate an increase in the estimate when compared to the No Action Concept (NAC). OAI estimates shaded in gray represent maximum observed benefit. Delta (D) indicates a rate of change calculation, and is always expressed as a percent change from the NAC.

Concept	Area (km²)	High Suitability Area (km²)	Δ Area (%)	Δ High Suitability Area(%)	OAI (absolute)
NAC	3475	732	-	-	-
5	4538	**739**	21.12	0.96	0.05
4	7981	**739**	113.11	0.96	0.01
3	9044	**812**	141.50	10.93	0.08
2	13736	**1363**	266.78	86.20	0.32
1	22613	**2150**	503.82	193.72	0.38
1a	22591	**2150**	503.23	193.72	0.38
SA	*17093*	***2150***	*356.42*	*193.72*	*0.54*

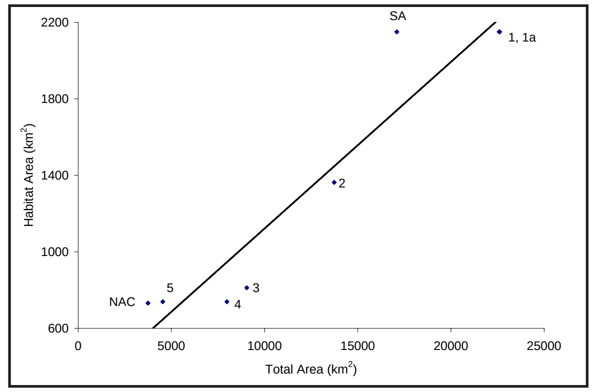

Figure 3.1.4. Regression of highly suitable habitat area for rock crabs and total area for the current and proposed boundary concepts. Numbers indicate concepts and NAC=No Action Concept, SA=Study Area.

Black abalone *(Haliotis cracherodii)*

Black abalone inhabit mid-low intertidal levels to depths of 6 m from Oregon to southern Baja California (Morris *et al*., 1980). They are readily identified by dark, bluish-black coloration, a smooth shell with 5 to 7 open respiratory holes, and relatively small size (5 to 20 cm as adults). Black abalone are relatively sedentary and typically found clustered in wet crevices, under boulders, or on the walls of surge channels along exposed shores. Black abalone are typically found within the intertidal to mid-intertidal zone (1-10 m) and a few may be found at depths of 20 m (Ault, 1985). *H. cracherodii* compete with sea urchins and other crevice-dwellers for space and food (Miller and Lawrence-Miller, 1993; Taylor and Littler, 1979). Where abundant, abalone may be stacked on top of each other, reaching densities of more than 100/m^2 (Douros, 1987; Richards and Davis, 1993). Black abalone are slow-growing and long-lived, with recruitment being low and variable (Morris *et al*., 1980; Van Blaricom *et al*., 1993). Growth rates depend on animal size, location, food availability, reproductive condition, and other factors. Absolute longevity has not been determined, but ages greater than 30 years appear likely based on tagging and other population studies (e.g., Van Blaricom *et al*., 1993).

Although once an important fishery resource throughout the study area, landings peaked in 1973 and declined thereafter (Leet *et al*., 2001). Sport and commercial black abalone fisheries have been closed since 1993. *H. cracherodii* populations in southern California suffered catastrophic declines since the mid-1980s that have resulted in a nearly complete disappearance of black abalone along mainland shores south of Point Conception (Miller and Lawrence-Miller, 1993), as well as at many of the Channel Islands (Lafferty and Kuris, 1993; Richards and Davis, 1993). Mortality was associated with withering syndrome (WS), in which the foot shrinks and weakened individuals lose their grip on rock surfaces (Antonio *et al*., 2000; Friedman *et al*., 1997; Gardner *et al*., 1995). WS has spread to populations north of Pt. Conception in recent years (Altstatt *et al*., 1996). Other sources of mortality include smothering by sand, dislodgment by storm waves, and predation by octopus, sea stars, fishes, and sea otters (Morris *et al*., 1980; Van Blaricom *et al*., 1993). Impacts from oil are little known, but North *et al*. (1965) reported black abalone mortality following a spill in Baja California. Because of low recruitment, slow growth, and already decimated reproductive populations, additional mortality from oil spills would be devastating, and recovery prospects long-term at best. It is important to note that results of the HSM described below do not capture these types of information, rather they identify habitats that are potentially suitable for particular species.

Broad-scale Patterns

Highly suitable habitat for black abalone was determined to occur in nearshore waters ranging from 0-10 m on hard substrates and low on hard substrates between 10-20 m. All habitats at depths greater than 20 m were considered unsuitable. As such, highly suitable habitat for black abalone was limited to nearshore rocky habitats along the mainland and islands of California, especially around the Channel Islands (Figure 3.1.5).

Commercial statistics for black abalone were available from CDFG CMASTR landings data during 1990-1993 (Figure 3.1.6). The majority of landings occurred in southern California, most notably around San Miguel, Santa Rosa, and San Nicolas islands. These data were not sufficient for statistical comparisons with the predicted HSM results however, six of the nine commercial grids that were ranked as high overlapped areas of high habitat suitability, and six of eight grids that were ranked as moderate overlapped high and moderately suitable habitats.

Analysis of Boundary Concepts

Highly suitable habitat for black abalone within the CINMS was spread throughout the islands comprising 66 km² (Figure 3.1.5). An additional 99 km² of area was considered moderately suitable. No additional highly suitable habitat was gained within Concepts 4 and 5. Highly suitable habitat increased within the remaining concepts that have boundaries which include mainland shoreline (Figure 3.1.7). OAI results indicate that Concept 2 provides the greatest proportional change of suitable habitat/total area relative to the NAC (Table 3.1.3).

Summary

- Black abalone have a narrow range of habitat distribution. Highly suitable habitat occurs over hard substrates at depths between 0-10 m.

- Sport and commercial fisheries for black abalone are currently closed.

- Of the six boundary Concepts being considered, Concept 2 provides the optimal proportional change of suitable habitat for black abalone/total area in relation to the NAC.

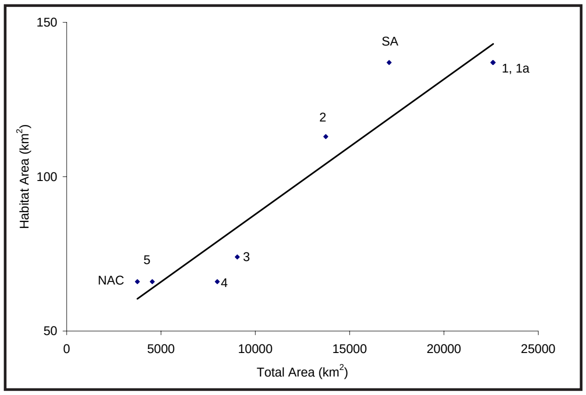

Figure 3.1.7. Regression of highly suitable habitat area for black abalone and total area for the current and proposed boundary concepts. Numbers indicate concepts and NAC=No Action Concept, SA=Study Area.

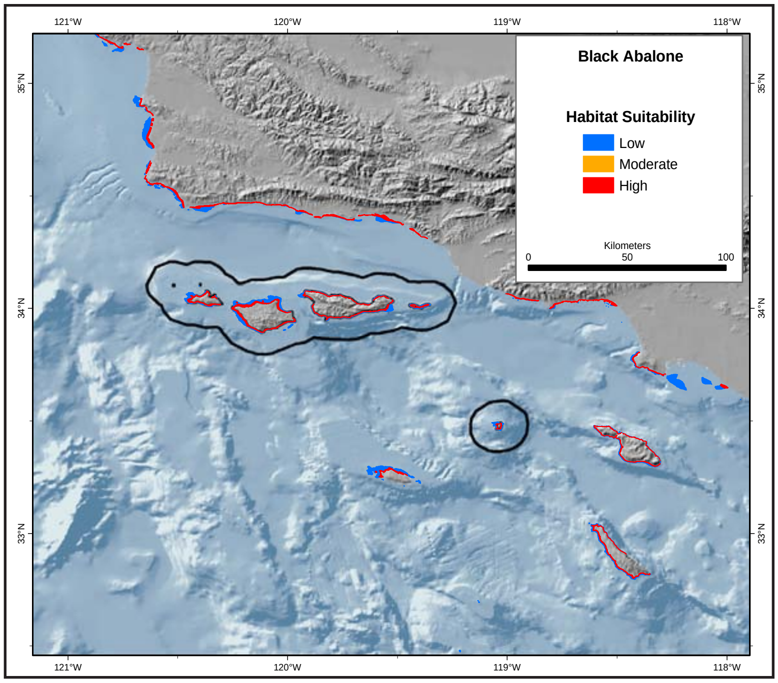

Figure 3.1.5. Black abalone habitat suitability off southern California.

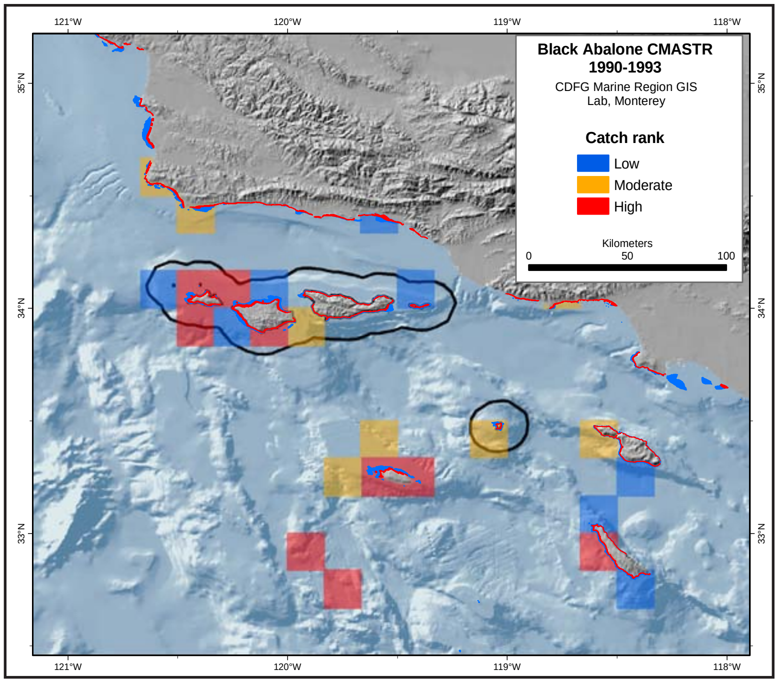

Figure 3.1.6. Black abalone commercial landings data from CDFG CMASTR database, 1990-1993, superimposed over predicted habitat suitability.

Red abalone *(Haliotis rufescens)*

Red abalone prefer to inhabit low intertidal and subtidal rocky substrates to depths of 30 m from Oregon to southern Baja California (Morris *et al*., 1980). In southern California, red abalone are most abundant from the intertidal zone to 30 m with a depth limit of 50 m (Leighton, 1968). This colder-water abalone is relatively sedentary on reef tops or in crevices. They feed on drift algae and, especially when young, on microscopic algal films. This species may live 20 years (Leet *et al*., 2001). Red abalone were once an important fishery in California, with landings peaking in 1967 and steadily declining thereafter (Leet *et al*., 2001). They were common or abundant in the study area, especially along the northwestern islands, but now are uncommon except for areas at Santa Rosa and San Miguel Islands. The red abalone commercial and sport fishery is currently closed, except for sport take by free divers in northern California. Other sources of mortality include predation by crabs, octopus, sea stars, fishes, and sea otters.

Table 3.1.3. Analysis of black abalone habitat suitability within boundary concepts. Numbers in bold indicate an increase in the estimate when compared to the No Action Concept (NAC). OAI estimates shaded in gray represent maximum observed benefit. Delta (D) indicates a rate of change calculation, and is always expressed as a percent change from the NAC.

Concept	Area (km^2)	High Suitability Area (km^2)	Δ Area (%)	Δ High Suitability Area(%)	OAI (absolute)
NAC	3475	66	-	-	-
5	4538	66	21.12	0.00	0.00
4	7981	66	113.11	0.00	0.00
3	9044	**74**	141.50	12.12	0.09
2	13736	**113**	266.78	71.21	0.27
1	22613	**137**	503.82	107.58	0.21
1a	22591	**137**	503.23	107.58	0.21
SA	*17093*	*137*	*356.42*	*107.58*	*0.30*

Broad-scale Patterns

High suitability habitat for red abalone was determined to consist of hard substrates at depths between 0-30 m. Hard substrates between 30-40 m were classified as moderate and low to 50 m. While these high and moderately suitable habitats are intermittently located throughout the nearshore waters of California, it is difficult to display them from a state-wide scale. Thus, results for southern California are displayed in Figure 3.1.8. Warmer waters from the south reduce suitability at locations east of the midpoint of Santa Cruz island (approximately 119.8° W; Barsky, K. pers. comm.), where suitability was defined as moderate on hard substrates between 0-30 m and low at depths between 30-50 m. In southern California, considerable amounts of highly suitable habitat are situated along the mainland west of Santa Barbara and around San Miguel, Santa Rosa, and Santa Cruz Islands. Moderate suitability in the nearshore mainland extends east of Point Mugu and around the southern Channel Islands.

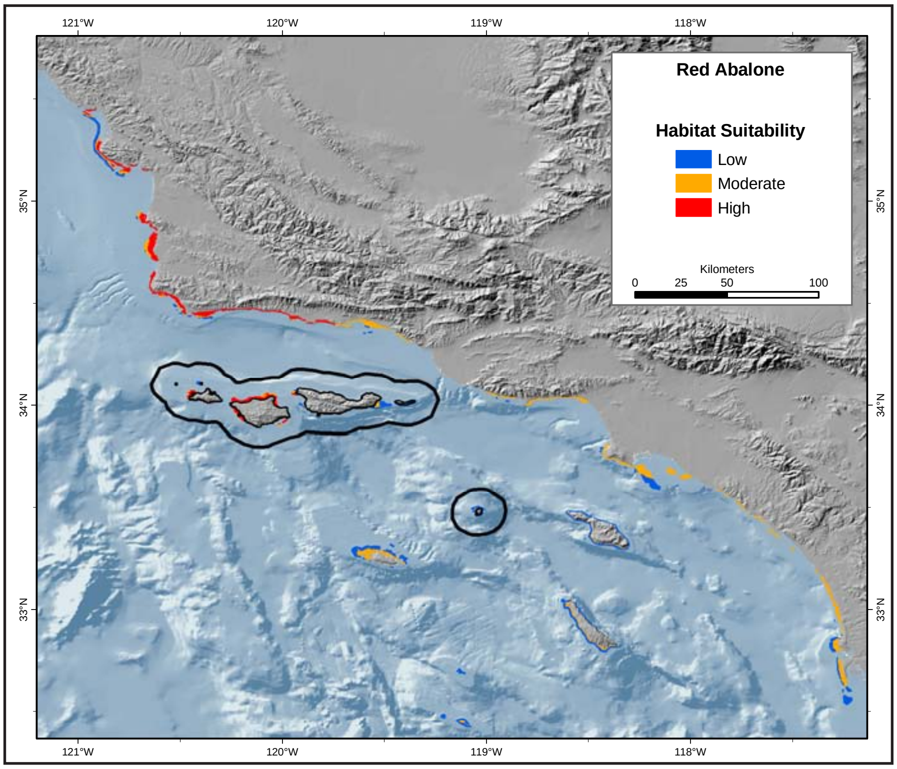

Figure 3.1.8. Red abalone habitat suitability off southern California.

Commercial information for red abalone were available from CDFG's CMASTR landings data from 1990-1999. Although landings occurred from Point Reyes through southern California, viewing the overlap with model results was difficult. Therefore, landings from southern California superimposed over model results are shown in Figure 3.1.9. Chi-square analysis indicated a significant correlation between CDFG landings data and predicted habitat suitability.

Analysis of Boundary Concepts

Highly suitable habitat for red abalone comprises 123 km^2 within the current CINMS boundary (NAC). Although Concepts 4 and 5 increased in size, no additional highly suitable habitat was included. Within these boundaries, areas of high and moderate suitability were found primarily around San Miguel, Santa Rosa, the western half of Santa Cruz, and along the mainland west of Santa Barbara (Figure 3.1.8). Regression analysis revealed significant increases of highly suitable habitat within Concepts 1, 1a, 2, and the Study Area boundary compared to the smaller concepts (Figure 3.1.10). Although Concepts 1 and 1a contained the greatest amount of red abalone habitat, OAI results indicated that Concept 2 offers the most beneficial proportional change of suitable habitat/total area relative to the NAC (Table 3.1.4).

Summary

• Highest habitat suitability for red abalone occurs over hard substrate within 0-30 m.

• Red abalone distribution throughout southern California is broadly dispersed throughout the Channel Islands and along the mainland.

• The commercial fishery for red abalone closed in 1997.

• Of the six boundary concepts being considered, Concept 2 provides the optimal proportional change of suitable habitat for red abalone/total concept area relative to the NAC.

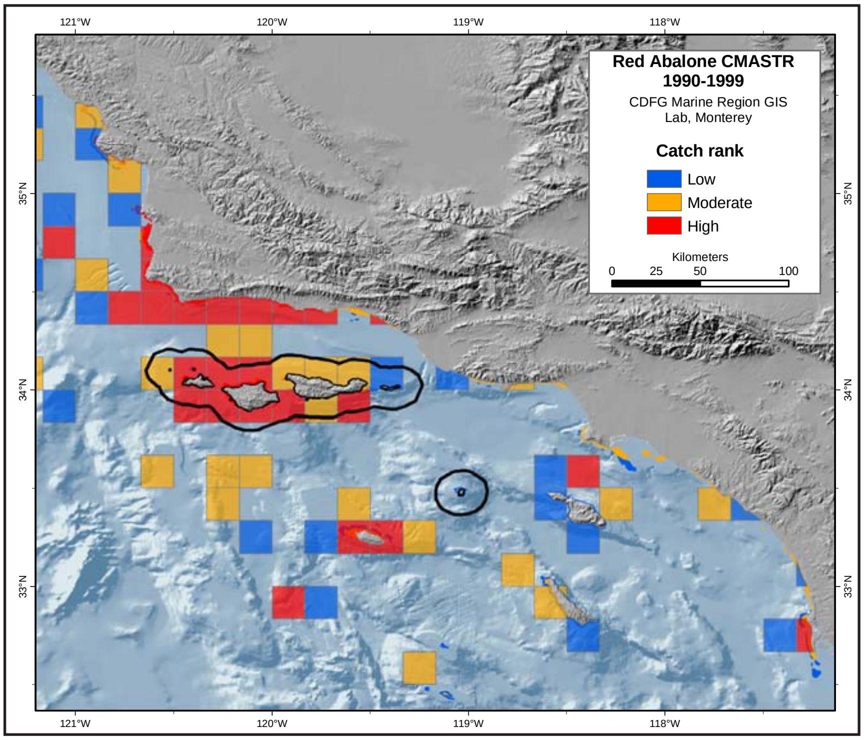

Figure 3.1.9. Red abalone commercial landings data from CDFG CMASTR database, 1990-1999, superimposed over predicted habitat suitability.

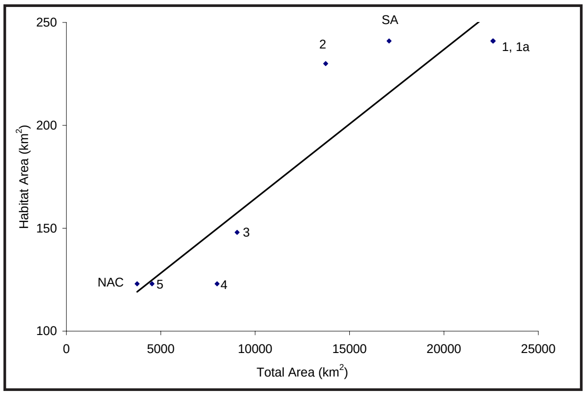

Figure 3.1.10. Regression of highly suitable habitat area for red abalone and total area for the current and proposed boundary concepts. Numbers indicate concepts and NAC=No Action Concept, SA=Study Area.

White abalone *(Haliotis sorenseni)*

Historically, adult and juvenile white abalone were most abundant at depths ranging from 20-60 m in warm waters from southern California to southern Baja California (Morris *et al*., 1980; Leet *et al*., 2001; Lafferty *et al*., 2004). Longevity has been estimated to be 25 years (Gotshall and Laurent, 1979; Davis *et al*., 1996). White abalone are sedentary, inhabiting open, exposed deep-water reefs with a kelp understory. Adults consume drifting and attached macroalgae. Juveniles are cryptic, hiding in crevices and beneath rocks where they feed on microalgal films (Davis *et al*., 1996).

The white abalone fishery developed late due to their preferred depth range (with the first reported commercial landings in 1968). Historically, abundance was highest along the southern and northeastern Channel Islands. Peak landings occurred in 1972 and decreased thereafter (Leet *et al*., 2001). Average density during periods of peak harvest in the 1970s was one abalone/m^2. Density has dramatically decreased since then with recent surveys in the study area suggesting that density has decreased to 0.0001/m^2 (Davis *et al*., 1998). Females must be within a few meters of a male during spawning for fertilization to occur. Present population densities in the study area apparently preclude successful spawning. Although some sections of the white abalone fishery have been closed since 1977 and the entire fishery has been closed since 1993, densities have continued to fall (Davis *et al*., 1998;

Table 3.1.4. Analysis of red abalone habitat suitability within boundary concepts. Numbers in bold indicate an increase in the estimate when compared to the No Action Concept (NAC). OAI estimates shaded in gray represent maximum observed benefit. Delta (D) indicates a rate of change calculation, and is always expressed as a percent change from the NAC.

Concept	Area (km^2)	High Suitability Area (km^2)	∆ Area (%)	∆ High Suitability Area(%)	OAI (absolute)
NAC	3475	123	-	-	-
5	4538	123	21.12	0.00	0.00
4	7981	123	113.11	0.00	0.00
3	9044	**148**	141.50	20.33	0.14
2	13736	**230**	266.78	86.99	0.33
1	22613	**241**	503.82	95.93	0.19
1a	22591	**241**	503.23	95.93	0.19
SA	*17093*	***241***	*356.42*	*95.93*	*0.27*

Carlton *et al*., 1999). Subthreshold breeding density and continued predation (e.g., fish, octopus, and sea stars) suggest that recovery without significant human intervention is unlikely. White abalone are currently a candidate species for protection under the Environmental Species Act. Submersible surveys are being carried out to further evaluate population status and to explore possibilities for collection of specimens for a captive breeding program.

Broad-scale Patterns

Since white abalone prefer warm waters, their distribution is almost the transpose of that for red abalone. Highly suitable habitats occur east of Point Mugu (approximately 119.8°W) over hard substrates between 20-60 m. Hard substrates at depths less than 20 m and between 60-70 m were considered moderate, while hard substrates between 70-80 were low suitability. Hard substrates at depths between 20-70 m west of Santa Barbara were classified as moderate and low at depths from intertidal to 20 m and 60-80 m. The distribution of white abalone are limited to southern California, thus habitats above 35.5°N were considered to be low suitability. Accordingly, 565 km^2 is considered highly suitable for white abalone in southern California (Figure 3.1.11). These habitats are generally found just off the mainland from Santa Barbara to the U.S.-Mexico border. Other areas of high suitability encompass the southern Channel Islands (Santa Catalina, San Clemente Islands, and San Nicolas), Anacapa Island, the eastern half of Santa Cruz Island, and portions of Tanner and Cortez Banks.

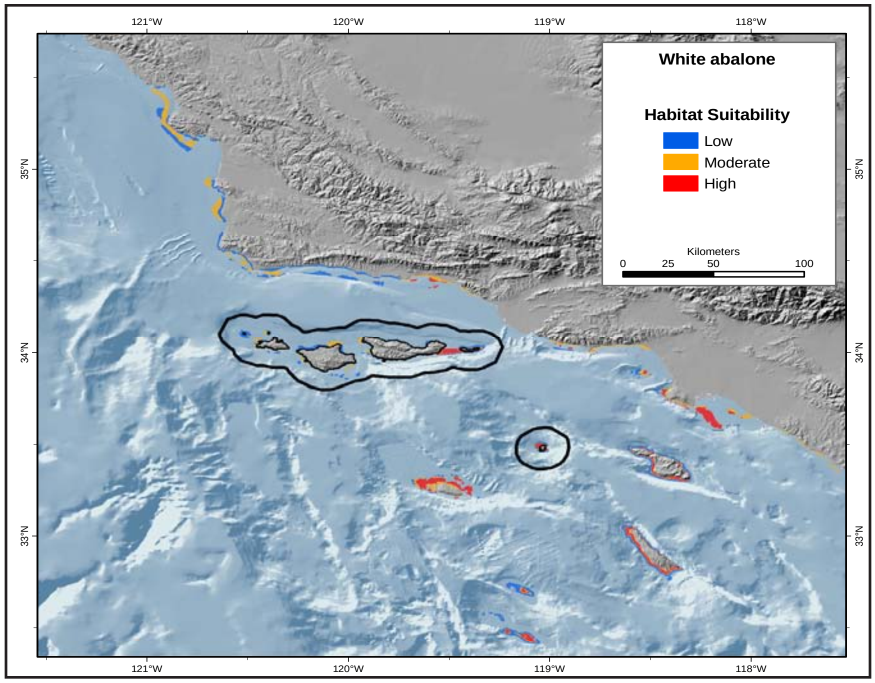

Figure 3.1.11. White abalone habitat suitability off southern California.

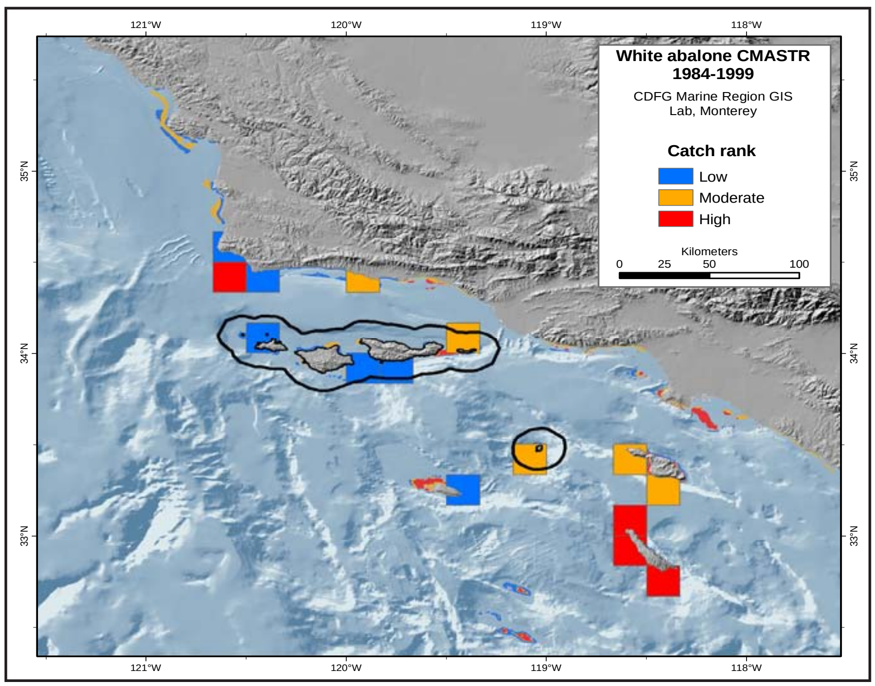

Figure 3.1.12. White abalone commercial landings data from CDFG CMASTR database, 1984-1999, superimposed over predicted habitat suitability.

CDFG's CMASTR landings data from 1984-1999 were compared with HSM results to provide a measure of model validation (Figure 3.1.12). The data were insufficient for statistical analysis; however, visual observation indicates that catch patterns generally agree with model results.

Analysis of Boundary Concepts

Approximately 52 km^2 of habitat was considered highly suitable for white abalone within the current CINMS boundary (NAC). No additional highly suitable habitat was gained within Concepts 2, 3, 4 or 5. Highly suitable habitats located on the mainland east of Santa Barbara were gained within Concepts 1, 1a, and the Study Area (Figure 3.1.13). Most of the habitat classified as highly suitable were located further south and are not included in any of the boundary concepts (Figure 3.1.11). Despite this, OAI results indicate that Concepts 1 and 1a offer the best proportional change in highly suitable habitat area/total area gained relative to the NAC (Table 3.1.5).

Summary

- White abalone is a candidate species under the Endangered Species Act.

- Suitable habitat for white abalone was determined to occur over hard substrate within 20-60 m. The majority of highly suitable habitat occurs south of the proposed boundary concepts.

- Of the six boundary concepts being considered, Concepts 1 and 1a provide the optimal proportional change of suitable habitat for white abalone/total area in relation to the NAC.

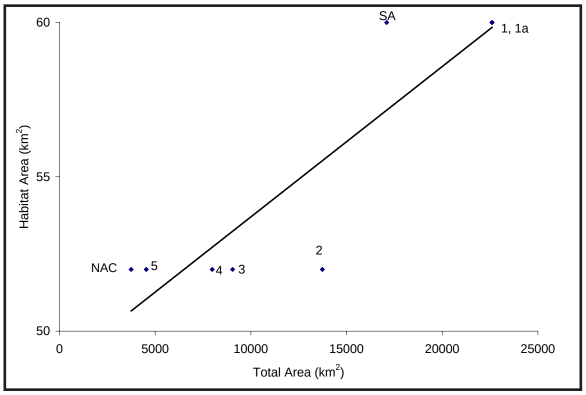

Figure 3.1.13. Regression of highly suitable habitat area for white abalone and total area for the current and proposed boundary concepts. Numbers indicate concepts and NAC=No Action Concept, SA=Study Area.

Table 3.1.5. Analysis of white abalone habitat suitability within boundary concepts. Numbers in bold indicate an increase in the estimate when compared to the No Action Concept (NAC). OAI estimates shaded in gray represent maximum observed benefit. Delta (D) indicates a rate of change calculation, and is always expressed as a percent change from the NAC.

Concept	Area (km^2)	High Suitability Area (km^2)	∆ Area (%)	∆ High Suitability Area(%)	OAI (absolute)
NAC	3475	52	-	-	-
5	4538	52	21.12	0.00	0.00
4	7981	52	113.11	0.00	0.00
3	9044	52	141.50	0.00	0.00
2	13736	52	266.78	0.00	0.00
1	22613	**60**	503.82	15.38	0.03
1a	22591	**60**	503.23	15.38	0.03
SA	*17093*	***60***	*356.42*	*15.38*	*0.04*

California Market Squid *(Loligo opalescens)*

The California market squid occurs off southern Alaska to central Baja California. The market squid is pelagic, inhabiting coastal waters to 800 m (PFMC, 1998). Large numbers of squid gather to spawn in semi-protected bays, usually over a sand bottom with rocky outcroppings. Spawning often occurs from October through May in the study area among squid that are from 1 to 3 years of age; however, spawning may occur at other times in some years (Leet *et al*., 2001). Spawning may occur in deep waters (Roper *et al*., 1984). Eggs are deposited on the bottom in clusters, with juveniles emerging within approximately one month. Adults die after spawning. The diet of squid consists of small pelagic crustaceans, fishes, and benthic worms.

Market squid have been harvested in California since 1863. The California fishery shifted its emphasis to southern California in 1961, where it is currently centered. The fishery has been marked by large-scale fluctuations in landings, with no apparent overall trend. The present status of populations in the this region is unclear and is presently being evaluated by the California Department of Fish and Game. Squid are important prey for numerous fishes, birds, and marine mammals and their eggs are eaten by benthic echinoderms (Morris *et al*., 1980, Leet *et al*., 2001). The market squid is one of the principal diet items of Dall's and Risso's dolphins, pilot whales, sea lions, and elephant seals (Bonnell and Dailey, 1993).

Broad-scale Patterns

Habitat suitability for market squid was considered to be high from 0-200 m, moderate between 201-500 m, and low at depths between 500-800 m. Since market squid are pelagic, suitability for substrate types was not considered. Thus, mapped suitability based on bathymetry results in extensive areas along the continental shelf of California and around the islands in the south (Figure 3.1.14). Smaller areas of moderate suitability extend seaward of high suitability habitats, followed by a broad area of low suitability in deeper (<800 m) waters. Based on the model, approximately 28,000 km^2 of highly suitable habitat occurs off the coast of California.

National Marine Fisheries Service (NMFS) trawl samples from 1999-2002 (N=1,096) were superimposed over the predicted habitat suitability map to test model performance. Suitability values were extracted at the trawl sample location (Figure 3.1.15) and compared using correspondence analysis. A positive relationship was observed with NMFS trawl catches and HSM results ($X^2<0.0001$, $r^2=0.17$). High and moderate catches from the NMFS data were more correlated with high suitability, while low catches were correlated with moderate and low suitability. Some biases must be considered when interpreting these results. The data used for this comparison were taken from NMFS otter trawls, where sampling was not equivalent throughout the bathymetric range of the study area. Also, otter trawls may not effectively capture squid; purse seines are typically used in the squid commercial fishery (NMFS, 1998).

Analysis of Boundary Concepts

Considerable amounts of highly suitable habitat were included within all boundary concepts and more than half of the total area within the current CINMS boundary (NAC) was considered highly suitable for market squid (Figure 3.1.17). Little additional habitat was gained within Concept 5 while an increase of 20% was observed within Concept 4. Significant gains were observed in the larger concepts as their northern boundaries contained habitats near the mainland. Although Concepts 1, 1a, and the Study Area contained greater amounts of highly suitable habitat, comparison of OAI values indicates that Concept 2 provides the optimal proportional change of highly suitable habitat/total area gained relative to that of the NAC (Table 3.1.6).

Summary

•California market squid is one of the most important commercial fisheries in California.

•Market squid are pelagic and highly suitable habitat occurs in waters between 0-200 m.

•Model performance tested well with NMFS trawl data.

•Of the six boundary concepts being considered, Concept 2 provides the optimal proportional change of highly suitable habitat for market squid/ total concept area relative to the NAC.

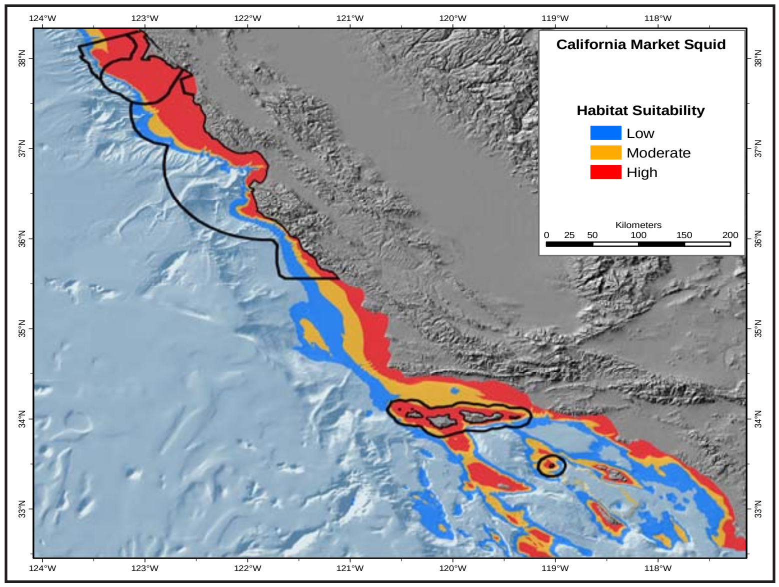

Figure 3.1.14. California market squid habitat suitability off central and southern California.

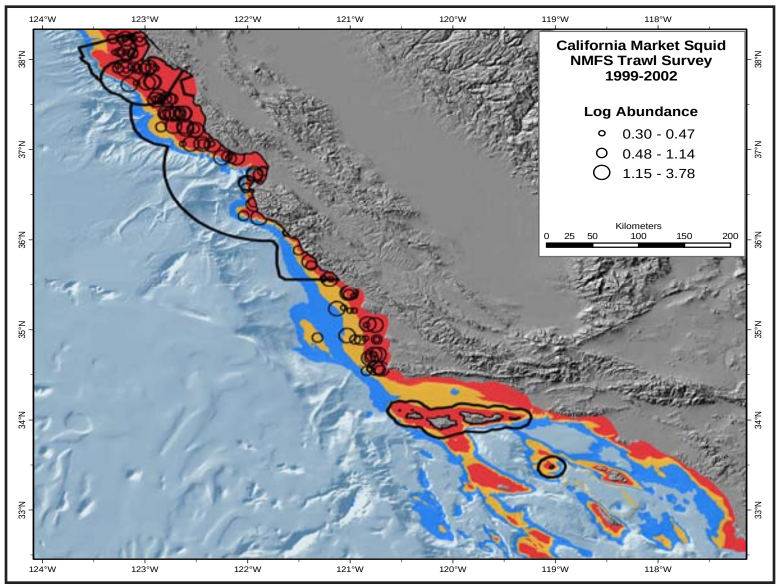

Figure 3.1.15. Location of NMFS trawls (1999-2002) and squid mean log abundance superimposed over predicted habitat suitability.

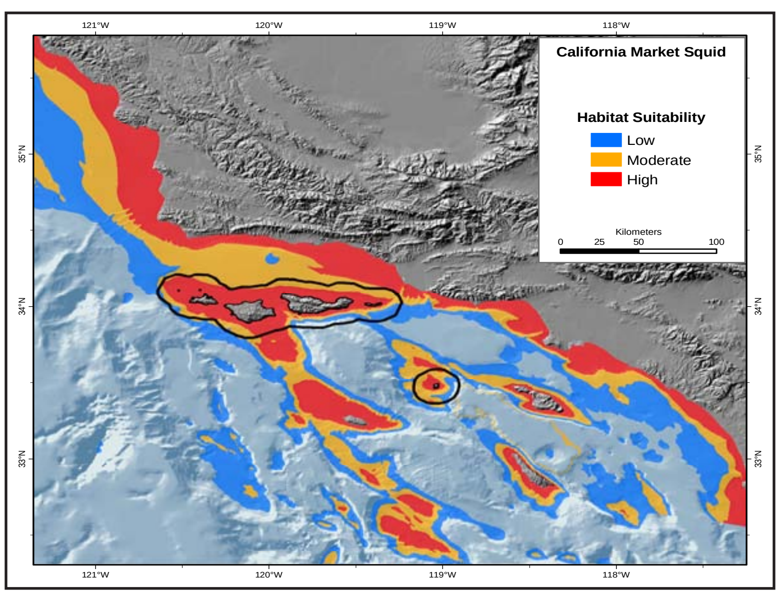

Figure 3.1.16. California market squid habitat suitability off southern California.

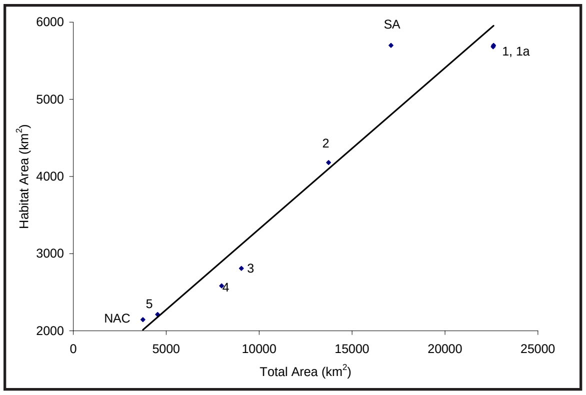

Figure 3.1.17. Regression of highly suitable habitat area for California market squid and total area for the current and proposed boundary concepts. Numbers indicate concepts and NAC=No Action Concept, SA=Study Area.

Table 3.1.6. Analysis of California market squid habitat suitability within boundary concepts. Numbers in bold indicate an increase in the estimate when compared to the No Action Concept (NAC). OAI estimates shaded in gray represent maximum observed benefit. Delta (D) indicates a rate of change calculation, and is always expressed as a percent change from the NAC.

Concept	Area (km^2)	High Suitability Area (km^2)	Δ Area (%)	Δ High Suitability Area(%)	OAI (absolute)
NAC	3475	2145	-	-	-
5	4538	**2212**	21.12	3.12	0.15
4	7981	**2583**	113.11	20.42	0.18
3	9044	**2809**	141.50	30.96	0.22
2	13736	**4181**	266.78	94.92	0.36
1	22613	**5699**	503.82	165.69	0.33
1a	22591	**5681**	503.23	164.85	0.33
SA	*17093*	***5699***	*356.42*	*165.69*	*0.46*

Sheep crab *(Loxorhynchus grandis)*

The sheep crab is the largest member of the California spider crabs, with an adult carapace length ranging from 4-9 inches. They range from Cordell Bank to Baja California in sand or rocky substrate at depths ranging from 3-124 m. Male crabs winter in deep water, but both sexes migrate onshore in early spring to mate (Leet *et al*., 2001).

The Santa Barbara Channel and waters offshore of the northern Channel Islands represent major fishery areas for the sheep crab. Large-scale commercial harvest of sheep crab whole body and claws began in 1984 and the fishery peaked in 1988, with retail values totaling $1.9 million/year. Landings declined after 1990 when the use of gillnets was banned in shallow water, and again in 1994 when gillnets were universally phased out (Leet *et al*., 2001).

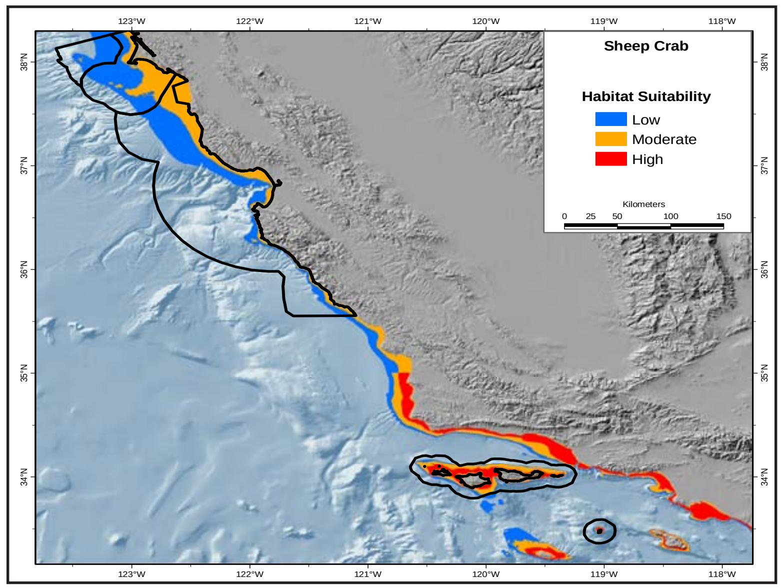

Figure 3.1.18. Sheep crab habitat suitability off central and southern California.

Broad-scale Patterns

Sheep crab suitability was defined as high for both hard and soft substrate at depths from 10-60 m. Moderate suitability extended from intertidal waters to 10 m and between 60-100 m. Habitat suitability was low at depths between 100-130 m. Sheep crabs are most abundant south of Point Conception, thus habitats in waters less than 60 m, above 35°N were considered moderate suitability while remaining habitat was defined as low. Suitability was considered low for all habitats north of Point Reyes. As such, highly suitable habitat is abundant throughout southern California waters, extending along the mainland from Point Conception south to San Diego, and encompassing the Channel Islands (Figure 3.1.18). Moderately suitable habitat extends northward through the central California sanctuaries.

Sheep crab landings data, recorded as mean pounds during 1996-2000, superimposed over HSM results are presented in Figure 3.1.19. During this time period, the commercial fishery was most active in southern California, most notably between the northern Channel Islands and Santa Catalina Island. Landings data were insufficient to compare statistically; however, upon further observation the landings data do not correlate well with HSM results. Landings data indicate that sheep crabs were harvested at depths deeper than that predicted as suitable.

Analysis of Boundary Concepts

Approximately 20% of the total area (739 km^2) within the current CINMS boundary was considered highly suitable habitat for sheep crab (Figure 3.1.20). No highly suitable habitat was gained within the slightly larger Concepts 4 and 5. Concepts 1, 1a, 2, and the Study Area gained substantial amounts of highly suitable habitat with the inclusion of area near the mainland. Concepts 1 and 1a contained nearly three times the amount of highly suitable habitat than the NAC (Figure 3.1.21) and had the highest OAI value (Table 3.1.7).

Summary

• Sheep crab are most abundant from Point Conception south to Baja California; highly suitable habitat was considered to occur over hard and soft substrates at depths between 10-60 m.

• The commercial fishery for sheep crab primarily occurs in southern California.

• Of the six boundary concepts being considered, Concepts 1 and 1a provided the best proportional gain of highly suitable habitat/total area relative to the NAC.

Spot shrimp *(Pandalus platyceros)*

Spot shrimp occur on rocky substrates in deep water (45–487 m) from Alaska to San Diego (Leet *et al*., 2001). Adults are generally found at the deeper end of this range, while juveniles are typically found in shallower waters (Sunada, 1984). The diet of spot shrimp consists of small crustaceans, plankton, molluscs, polychaetes, sponges, and carcasses (O'Clair and O'Clair, 1998). This species may live for more than 6 years.

A commercial fishery using trawling gear and traps began in southern California in 1974 (Leet *et al*., 1992). Spot shrimp populations have not been well studied. Landings have fluctuated

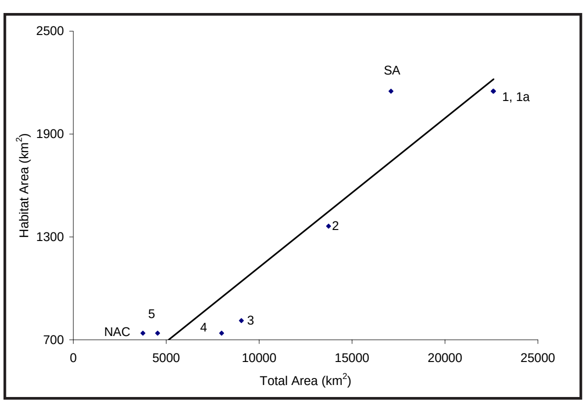

Figure 3.1.21. Regression of highly suitable habitat area for sheep crab and total area for the current and proposed boundary concepts. Numbers indicate concepts and NAC=No Action Concept, SA=Study Area.

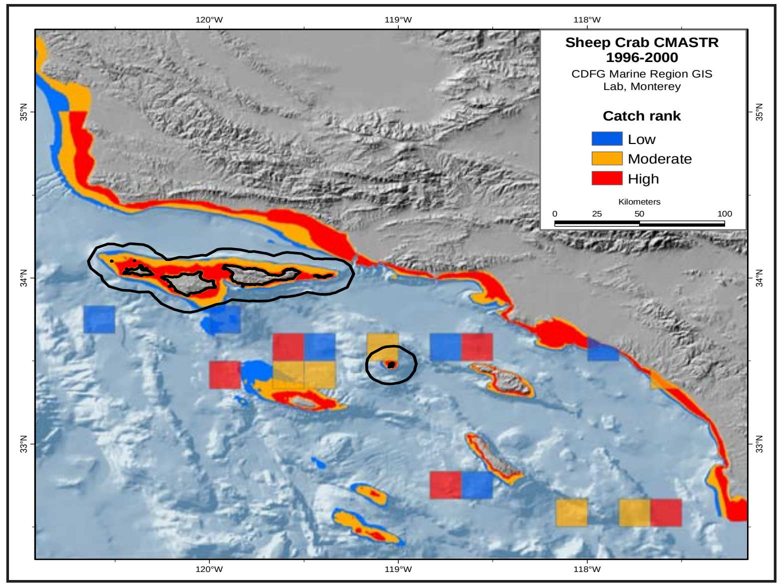

Figure 3.1.19. Sheep crab commercial landings data from CDFG CMASTR database, 1996-2000, superimposed over predicted habitat suitability.

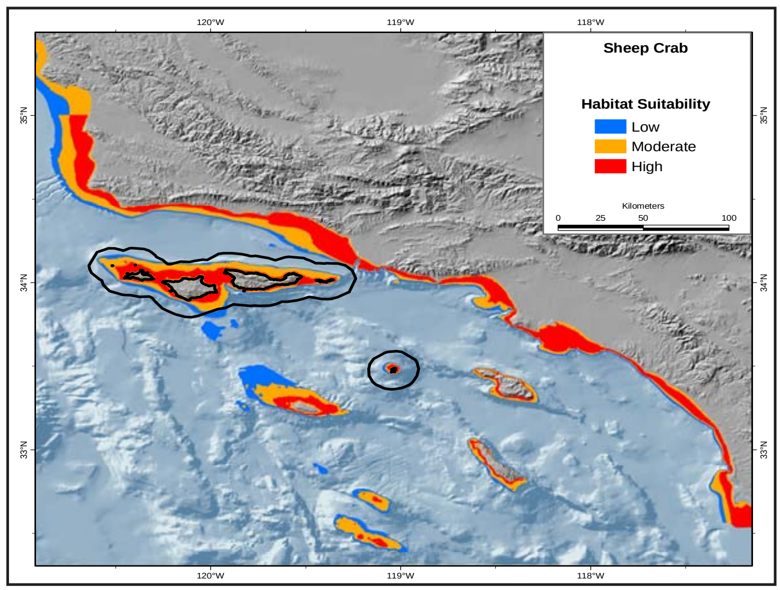

Figure 3.1.20. Sheep crab habitat suitability off southern California.

Table 3.1.7. Analysis of sheep crab habitat suitability within boundary concepts. Numbers in bold indicate an increase in the estimate when compared to the No Action Concept (NAC). OAI estimates shaded in gray represent maximum observed benefit. Delta (D) indicates a rate of change calculation, and is always expressed as a percent change from the NAC.

Concept	Area (km²)	High Suitability Area (km²)	Δ Area (%)	Δ High Suitability Area(%)	OAI (absolute)
NAC	3475	739	-	-	-
5	4538	739	21.12	0.00	0.00
4	7981	739	113.11	0.00	0.00
3	9044	**812**	141.50	9.88	0.07
2	13736	**1363**	266.78	84.44	0.32
1	22613	**2150**	503.82	190.93	0.38
1a	22591	**2150**	503.23	190.93	0.38
SA	*17093*	***2150***	*356.42*	*190.93*	*0.54*

widely, with several good years followed by several poor years. Natural predators include octopus and fish. The northern portion of the Southern California Bight is one of the major population centers for this species (O'Clair and O'Clair, 1998; Leet *et al*., 2001).

Broad-scale Patterns

Highly suitable habitat for spot shrimp was determined to occur on hard and soft substrates within a wide bathymetric range (150-320 m). Moderate suitability extends from 40-150 m and 320-400 m. Low suitability extended from 400-490 m. As such, most of California's continental shelf is suitable habitat for spot shrimp (Figure 3.1.22), and is characterized by a narrow band of highly suitable habitat surrounded by extensive areas of moderate suitability. Considerable amounts of highly and moderately suitable habitat exist in southern California, most notably within the Santa Barbara Channel, the Santa Cruz Basin, and the offshore banks south of the Channel Islands. These areas correspond well with published areas of high abundance (Leet *et al*., 2001).

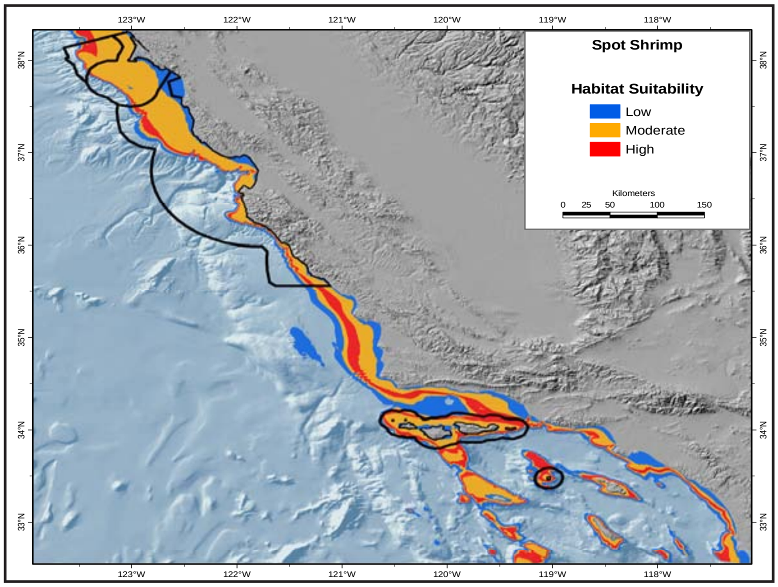

Figure 3.1.22. Spot shrimp habitat suitability off central and southern California.

Model performance was tested with CDFG's commercial trawl and trap logs from 1994-2001. CDFG commercial trap landings primarily occurred in southern California (Figure 3.1.23) around the Channel Islands and along the mainland. Landings in pounds were ranked similar to that for the HSM and compared using correspondence analysis. Chi-square analysis indicated a significant correlation (X^2=0.0072, r^2=0.07). Commercial trawl landings (Figure 3.1.24) were more ubiquitous than trap landings, and chi-square results displayed a statistically significant correlation with model results (X^2<0.0001, r^2=0.17).

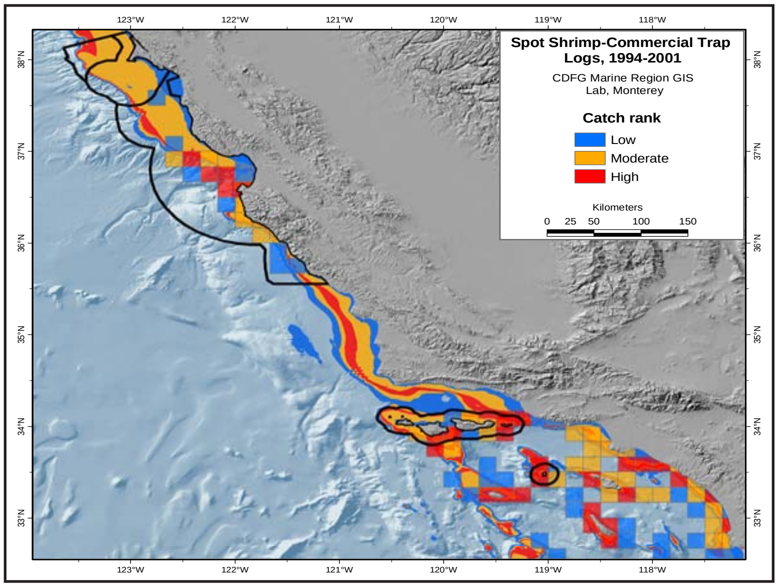

Figure 3.1.23. Spot shrimp commercial landings data from CDFG Commercial Trap Logs, 1994-2001, superimposed over predicted habitat suitability.

Analysis of Boundary Concepts

Approximately 979 km^2 of highly suitable habitat occurs within the current CINMS boundary (Figure 3.1.25). Highly suitable habitat increased relatively by 12% within Concept 5, 50% within Concept 4, and 70% within Concept 3. Significant gains of highly suitable habitat were observed within the large concepts which included areas in the northern portion of the Santa Barbara Channel and around Point Conception. Although Concepts 1 and 1a contained the largest amounts of highly suitable habitat (Figure 3.1.26), OAI results indicate that Concept 5 offered the optimal proportional change of suitable habitat gained/total area gained relative to the NAC (Table 3.1.8).

Summary

• Spot shrimp are typically a deep water species where highly suitable habitat occurs over hard and soft substrates at depths between 150-320 m .

• Comparisons of commercial data and habitat suitability were statistically significant.

• Of the six boundary concepts being considered, Concept 5 provided the optimal proportional change of highly suitable habitat for spot shrimp/total concept area relative to the NAC.

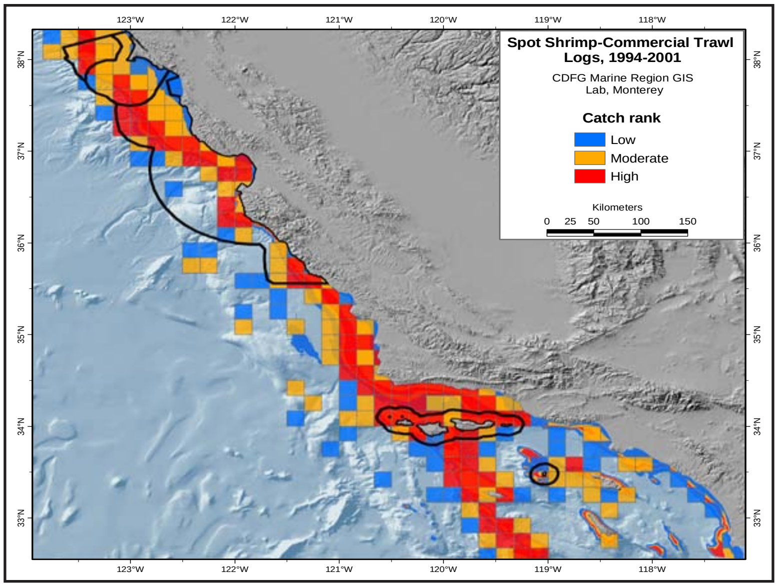

Figure 3.1.24. Spot shrimp commercial landings data from CDFG Commercial Trawl Logs, 1994-2001, superimposed over predicted habitat suitability.

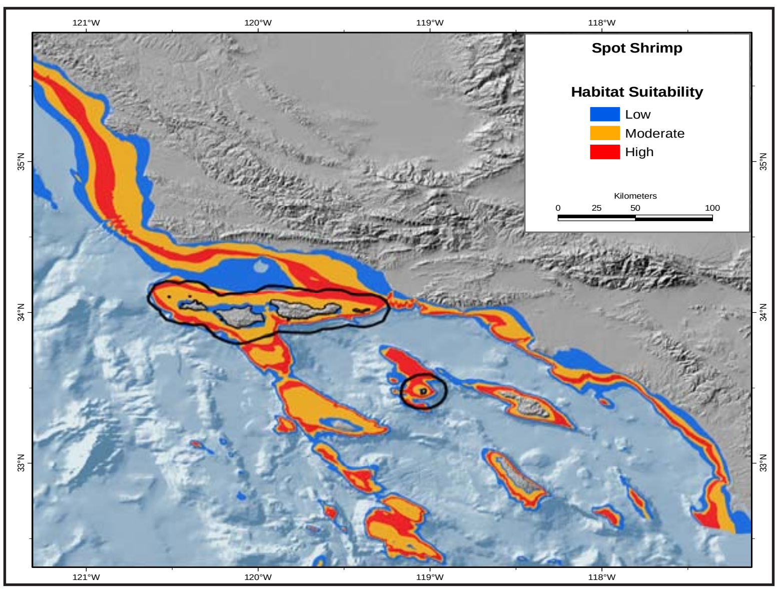

Figure 3.1.25. Spot shrimp habitat suitability off southern California.

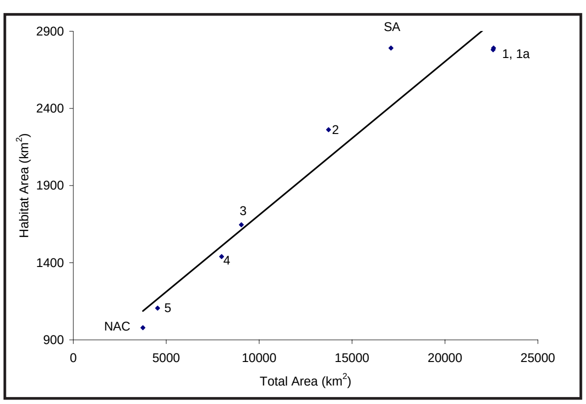

Figure 3.1.26. Regression of highly suitable habitat area for spot shrimp and total area for the current and proposed boundary concepts. Numbers indicate concepts and NAC=No Action Concept, SA=Study Area.

Table 3.1.8. Analysis of spot shrimp habitat suitability within boundary concepts. Numbers in bold indicate an increase in the estimate when compared to the No Action Concept (NAC). OAI estimates shaded in gray represent maximum observed benefit. Delta (D) indicates a rate of change calculation, and is always expressed as a percent change from the NAC.

Concept	Area (km²)	High Suitability Area (km²)	Δ Area (%)	Δ High Suitability Area(%)	OAI (absolute)
NAC	3475	979	-	-	-
5	4538	**1106**	21.12	12.97	0.61
4	7981	**1440**	113.11	47.09	0.42
3	9044	**1646**	141.50	68.13	0.48
2	13736	**2262**	266.78	131.05	0.49
1	22613	**2791**	503.82	185.09	0.37
1a	22591	**2780**	503.23	183.96	0.37
SA	*17093*	***2791***	*356.42*	*185.09*	*0.52*

Ridgeback rock shrimp *(Sicyonia ingentis)*
Ridgeback rock shrimp occur in subtidal depths (5-307 m) from Monterey Bay to central Mexico (Perez-Farfante, 1985). In the Southern California Bight, they are most abundant between 40-160 m (Sunada, 1984). Preferred substrates are sand, shell, and mud (Sunada, 1984; Leet *et al*., 2001). The diet is not well known, though it is suspected to be a detritus feeder as are related species. This species may live about 5 years.

A commercial fishery using trawling gear began in 1966. Landings decreased dramatically from 1985 to 1991 (Leet *et al*., 2001). Surveys by the California Department of Fish and Game confirmed population declines since 1985. The study area includes one of the major population centers for this species (Leet *et al*., 2001).

Broad-scale Patterns
High habitat suitability was determined to occur over hard and soft substrates between 40-160 m. All substrates between 20-40 m and 160-250 m were considered moderate, while substrates at depths between 0-20 m and 250-310 m were defined as low suitability. Leet *et al*., (2001), state that ridgeback rock shrimp distribution begins near Monterey Bay and extends through Mexico and abundance is greater south of Point Conception. Therefore, suitability is higher below 35°N and extends southward. The distribution of high and moderately suitable habitat is similar to that of spot prawn by covering a wide region of the continental shelf and encompassing the Channel Islands (Figure 3.1.27). Highly suitable habitat is also found on the southern offshore banks.

Model performance was tested with trawl data collected by Southern California Coastal Water Research Project (SCCWRP) during 1994 and 1998. During these two years, 520 stations were sampled throughout southern California at depths to 200 m (Figure 3.1.28). Catches were ranked and compared to HSM results using chi-square analysis. Model results and catch rankings grouped well, although moderate catches were more closely correlated with high HSM rankings. Despite this, the comparison was statistically significant ($X^2<0.0001$, $r^2=0.20$).

Analysis of Boundary Concepts
Highly suitable habitat for ridgeback rock shrimp follows the contour of the continental shelf and encompasses a broad area around the Channel Islands (Figure 3.1.29). Approximately 30% of the area within the current CINMS boundary (1,138 km^2) was considered highly suitable habitat for

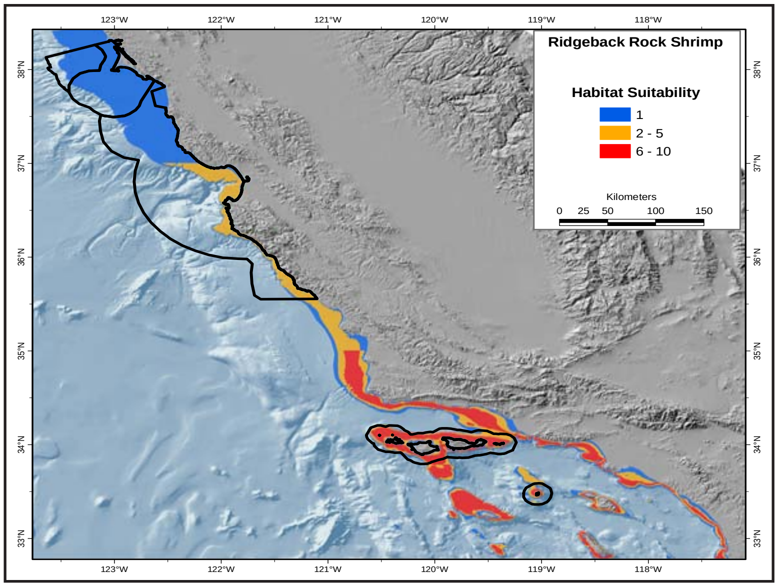

Figure 3.1.27. Ridgeback rock shrimp habitat suitability off central and southern California.

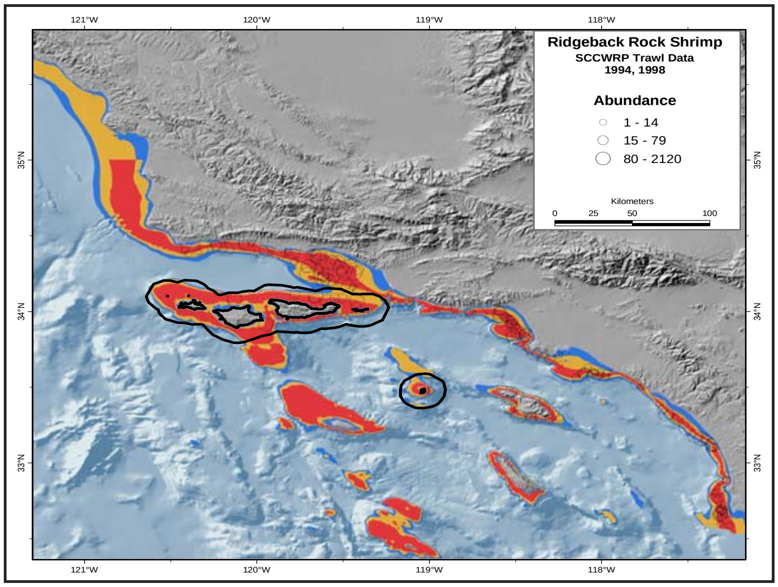

Figure 3.1.28. Location of SCCWRP trawls (1994, 1998) and ridgeback rock shrimp mean abundance superimposed over predicted habitat suitability.

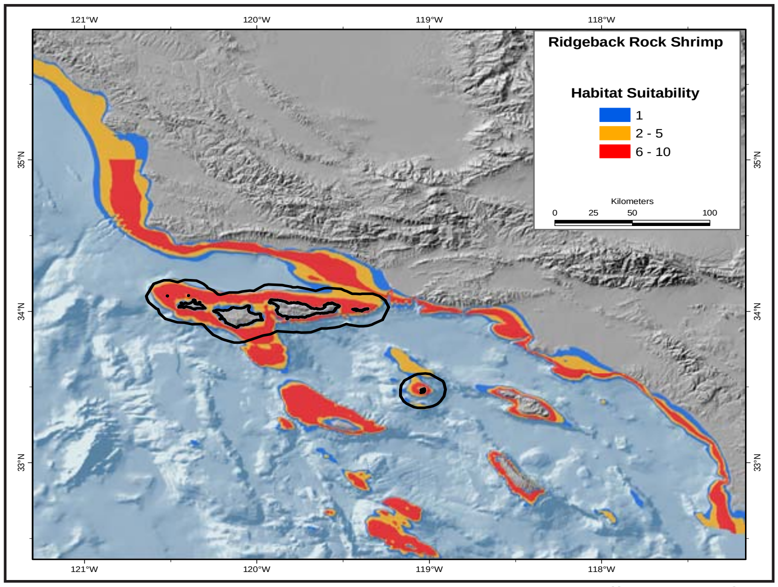

Figure 3.1.29. Ridgeback rock shrimp habitat suitability off southern California.

ridgeback rock shrimp. Areas of suitable habitat increased with increasing concept size (Figure 3.1.30) but exhibited a relative decline in terms of the proportion of total area contained. Highly suitable habitat increased slightly within Concepts 4 and 5, while substantial gains were observed within the remaining concepts. The Study Area, which is not considered as a boundary concept, provided the highest OAI (Table 3.1.9) and Concept 2 produced the highest OAI value for the concepts under consideration.

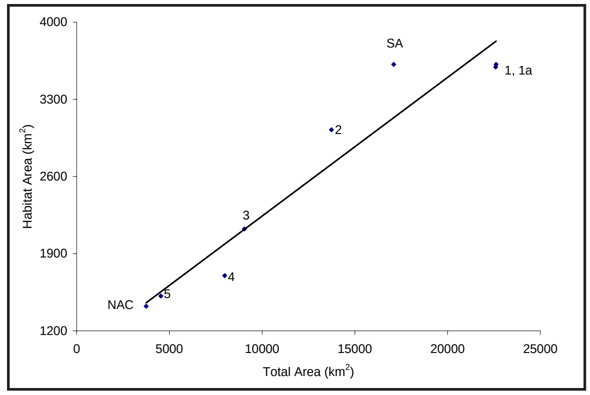

Figure 3.1.30. Regression of highly suitable habitat area for ridgeback rock shrimp and total area for the current and proposed boundary concepts. Numbers indicate concepts and NAC=No Action Concept, SA=Study Area.

Summary

- Highly suitable habitat for ridgeback rock shrimp was considered to occur over hard and soft substrates at depths between 40-160 m and below 35°N.

- The commercial fishery has declined in recent years but landings have been highest in southern California.

- Of the five boundary concepts being considered, Concept 2 provided the optimal proportional change of highly suitable habitat for ridgeback rock shrimp/total concept area relative to the NAC.

Table 3.1.9. Analysis of ridgeback rock shrimp habitat suitability within boundary concepts. Numbers in bold indicate an increase in the estimate when compared to the No Action Concept (NAC). OAI estimates shaded in gray represent maximum observed benefit. Delta (D) indicates a rate of change calculation, and is always expressed as a percent change from the NAC.

Concept	Area (km^2)	High Suitability Area (km^2)	Δ Area (%)	Δ High Suitability Area(%)	OAI (absolute)
NAC	3475	1423	-	-	-
5	4538	**1516**	21.12	6.54	0.31
4	7981	**1701**	113.11	19.54	0.17
3	9044	**2124**	141.50	49.26	0.35
2	13736	**3024**	266.78	112.51	0.42
1	22613	**3617**	503.82	145.18	0.31
1a	22591	**3593**	503.23	152.49	0.30
SA	*17093*	***3617***	*356.42*	*145.18*	*0.43*

California spiny lobster *(Panulirus interruptus)*

California spiny lobster inhabit intertidal and subtidal hard substrates (to 80 m) from Monterey Bay to central Mexico, with most of the population occurring south of Point Conception (Morris *et al*., 1980; Leet *et al*., 2001). Juveniles (under 2 years) utilize shallow (5 m) vegetated reefs, especially surfgrass beds, as nursery habitats (Engle, 1979). Adults inhabit crevices in rocky areas, from which they emerge at night to forage on a wide variety of invertebrates, including worms, molluscs, and sea urchins. Spiny lobsters may live 30 years or more (Leet *et al*., 2001).

Spiny lobsters have been commercially harvested using traps in California for over 100 years. Most of the fishery occurs in water less than 30 m deep, although the fishery has expanded to include deeper habitats. A sport fishery (hand capture) is popular among scuba divers in southern California. Other sources of mortality include predation by octopus and fishes. California spiny lobster populations have not been well studied; however, population levels appear to be fairly stable. Lobster populations are likely maintained by recruitment from Baja California facilitated by warm-water patterns over the past two decades. Landings declined from 1950 to 1975, then increased coincident with the establishment of escape ports for sub-legal sized lobsters in traps and development of the long-term warming trend (Leet *et al*., 2001).

Broad-scale Patterns

Highly suitable habitat for California spiny lobster was considered to occur over hard and soft substrates at depths between 0-30 m. Suitability was defined as moderate between 30-60 m, and low between 60-80 m. Leet *et al*., (2001), report that lobsters are rare north of Point Conception; therefore, suitability was considered moderate around Point Conception from approximately 34.5° N to 35°N and low above 35°N (Figure 3.1.31) to Monterey Bay. As such, highly suitable habitat is distributed primarily along the nearshore of the mainland and around the Channel Islands and offshore banks.

Catch per unit effort (CPUE) data were available from CDFG's commercial lobster fishery during 1998-2002 (Figure 3.1.32). These data were insufficient to compare statistically; however, visual observation shows that most landings grids occurred over habitats that were predicted to have high or moderate suitability; while, some grids with high CPUE occurred over habitats with low suitability. Examination of mean CPUE and maximum HSM value for each grid cell shows increasing CPUE with increasing habitat suitability.

Analysis of Boundary Concepts

Approximately 9% (341 km^2) of the current CINMS area (NAC) was considered highly suitable for spiny lobster (Figure 3.1.33). No additional gains of highly suitable habitat were observed within Concepts 4 and 5. A relative increase of 12% was observed within Concept 3, 55% within Concept 2, and 172% for the larger concepts (Figure 3.1.34). The Study Area provided the greatest proportional increase in suitable habitat/total area gained compared to the NAC; however, this boundary is not being considered as a concept. Of the six concepts under consideration, Concepts 1 and 1a yielded the highest OAI value (Table 3.1.10).

Summary

• Highly suitable habitat for California spiny lobster occurs from Point Conception southward over hard and soft substrates at depths of 0-30 m.

• CPUE data were not consistent with HSM results.

• Of the six boundary concepts being considered, Concepts 1 and 1a provide the optimal proportional gains in highly suitable habitat for California spiny lobster/total area relative to the NAC.

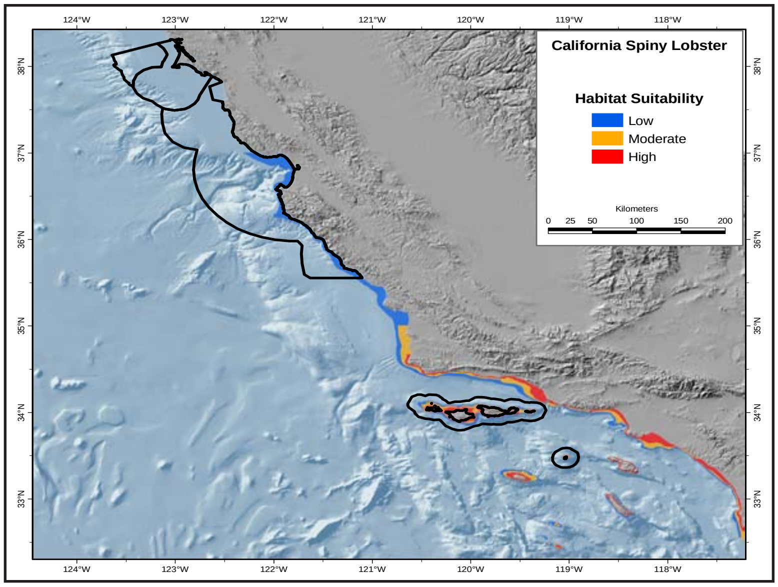

Figure 3.1.31. California spiny lobster habitat suitablity off central and southern California.

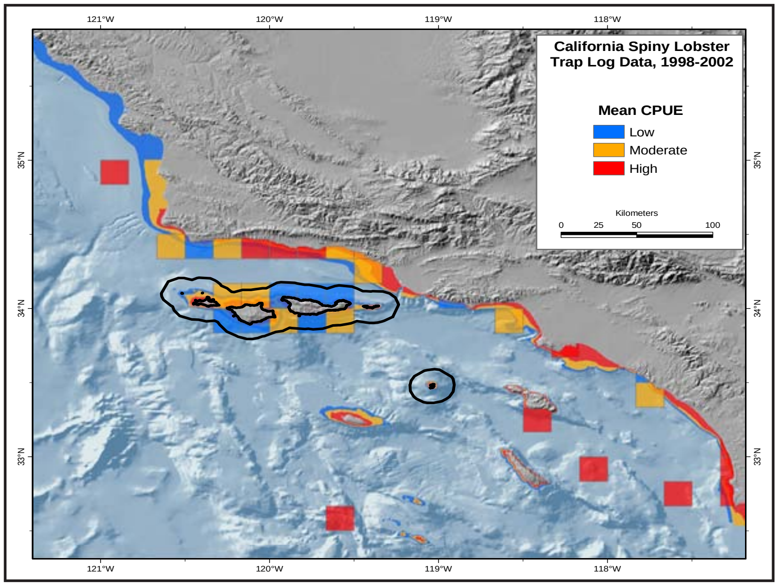

Figure 3.1.32. California spiny lobster commercial landings data from CDFG Commercial Logs, 1998-2002, superimposed over predicted habitat suitability.

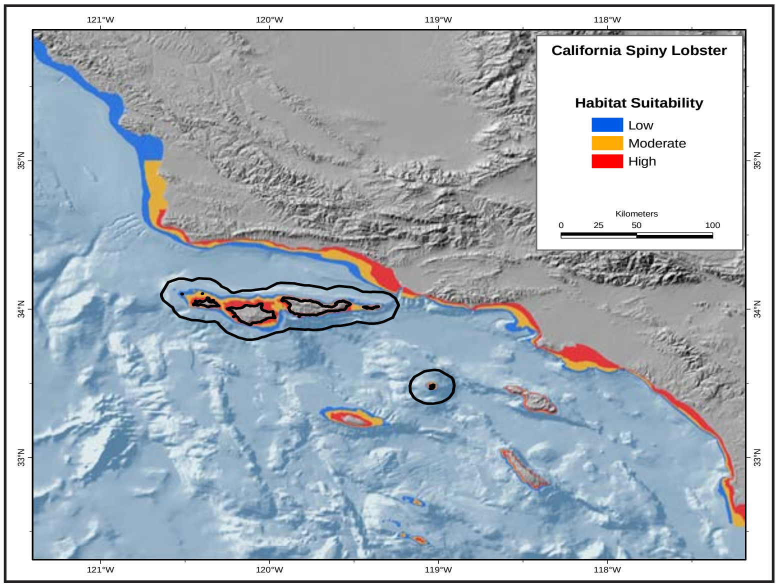

Figure 3.1.33. California spiny lobster habitat suitability off southern California.

California sea cucumber *(Parastichopus californicus)*

California sea cucumbers inhabit low intertidal and subtidal waters to depths of 120 m from Alaska to central Baja California and occur mainly on soft-bottom habitats (Morris *et al*., 1980; Leet *et al.,* 2001). Although relatively sedentary, they may move up to 4 m per day (Lambert, 1997). The diet of California sea cucumbers consist of detritus and small organisms, which they ingest with bottom sediments. This species may live up to12 years. (Morris *et al*.,1980; Leet *et al.,* 2001).

No sport fishery for this species exists. A commercial fishery for California sea cucumbers started in California in 1978 (Leet *et al.,* 2001). In 1982, the center of the fishery shifted to southern California where they are harvested from the Santa Barbara channel by trawling. Other sources of mortality include predation by sea stars, fishes, and crabs.

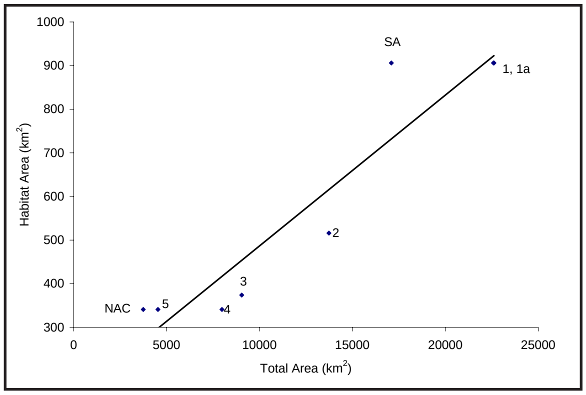

Figure 3.1.34. Regression of highly suitable habitat area for California spiny lobster and total area for the current and proposed boundary alternatives. Numbers indicate concepts and NAC=No Action Concept, SA=Study Area.

Table 3.1.10. Analysis of California spiny lobster habitat suitability within boundary concepts. Numbers in bold indicate an increase in the estimate when compared to the No Action Concept (NAC). OAI estimates shaded in gray represent maximum observed benefit. Delta (D) indicates a rate of change calculation, and is always expressed as a percent change from the NAC.

Concept	Area (km^2)	High Suitability Area (km^2)	Δ Area (%)	Δ High Suitability Area(%)	OAI (absolute)
NAC	3475	341	-	-	-
5	4538	341	21.12	0.00	0.00
4	7981	341	113.11	0.00	0.00
3	9044	**374**	141.50	9.68	0.07
2	13736	**516**	266.78	51.32	0.19
1	22613	**906**	503.82	165.69	0.33
1a	22591	**906**	503.23	165.69	0.33
SA	*17093*	***906***	*356.42*	*165.69*	*0.46*

Broad-scale Patterns

Highly suitable habitat was considered to occur over hard and soft habitats between 40-90 m; moderate suitability extends from the intertidal zone to 40 m and between 90-110 m. Low suitability was determined to occur between 110-120 m. As such, highly suitable habitat is extensive comprising vast areas of the continental shelf throughout offshore California waters, including all national marine sanctuaries, and the southern islands (Figure 3.1.35).

Trawl data from SCCWRP surveys (1994 and 1998) were used to test model performance. Catches appeared to occur primarily close to the mainland of southern California (Figure 3.1.36) and around Santa Catalina Island. Chi-square results indicated a statistically significant relationship (X^2<0.0001, r^2=0.09), with mean abundance increasing as habitat suitability increased.

Analysis of Boundary Concepts

Highly suitable habitat comprises approximately 40% of the current CINMS boundary (Figure 3.1.37). Slight gains were observed within Concepts 3, 4, and 5, while significant gains of highly suitable habitat were observed within Concepts 1, 1a, 2, and the Study Area (Figure 3.1.38). Maximum benefit, in terms of the OAI, was observed for Concept 2, which yielded the best proportional change of highly suitable habitat/total area relative to the NAC (Table 3.1.11). The Study Area had the highest OAI value, but this concept is not under consideration.

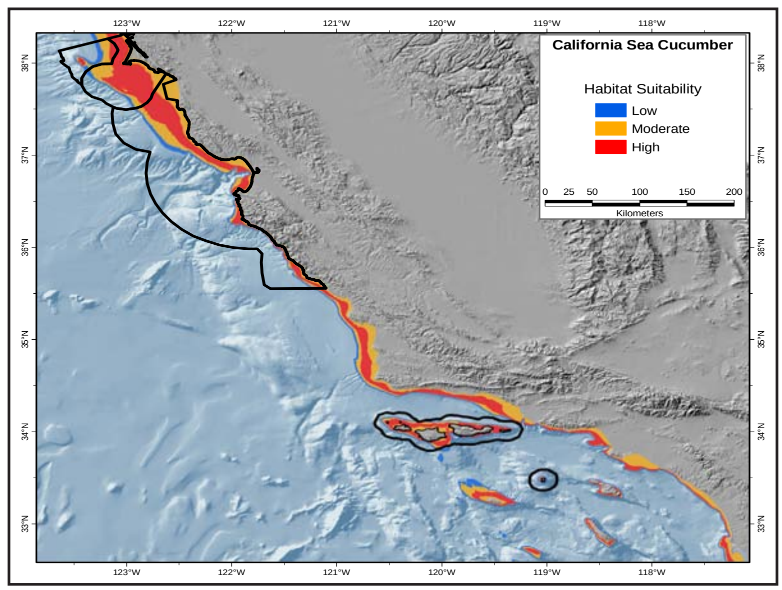

Figure 3.1.35. California sea cucumber habitat suitability off central and southern California.

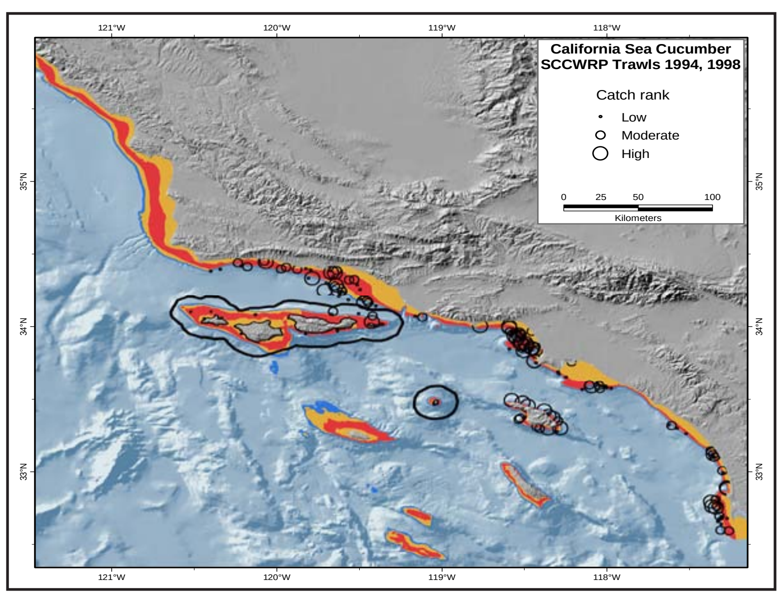

Figure 3.1.36. Location of SCCWRP trawls (1994, 1998) and California sea cucumber mean abundance superimposed over predicted habitat suitability.

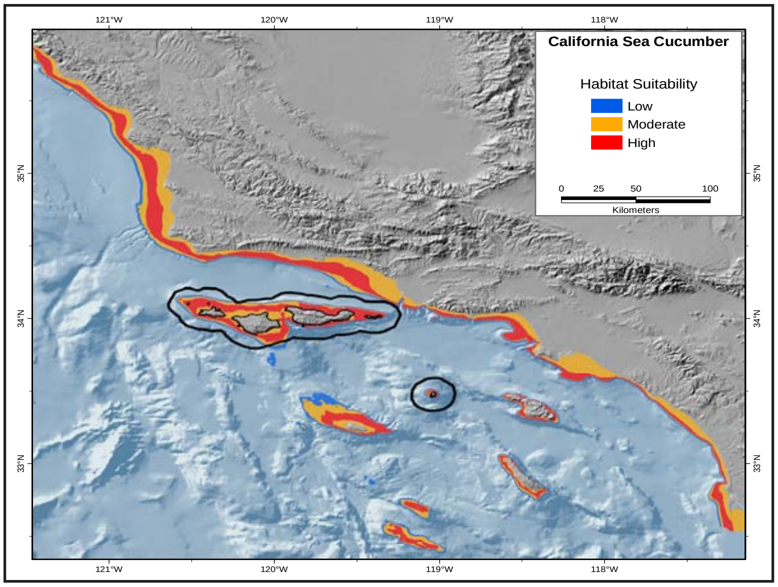

Figure 3.1.37. California sea cucumber habitat suitability off southern California.

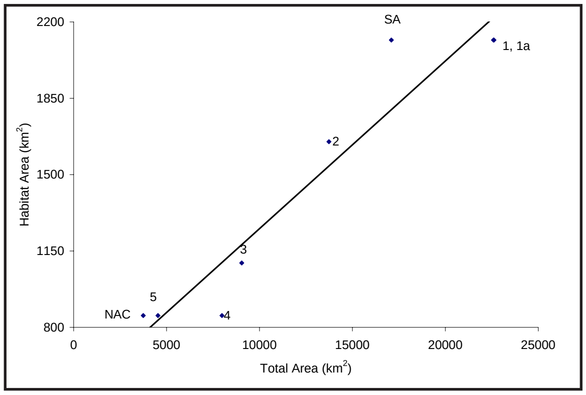

Figure 3.1.38. Regression of highly suitable habitat area for California sea cucumber and total area for the current and proposed boundary concepts. Numbers indicate concepts and NAC=No Action Concept, SA=Study Area.

Summary

• Highly suitable habitat for California sea cucumbers occurs over all substrates between 40-90 m.

• A significant commercial fishery has recently developed in southern California.

• Of the five boundary concepts being considered, Concept 2 provided the best proportional change of highly suitable habitat for California sea cucumbers/total area relative to the NAC.

Table 3.1.11. Analysis of California sea cucumber habitat suitability within boundary concepts. Numbers in bold indicate an increase in the estimate when compared to the No Action Concept (NAC). OAI estimates shaded in gray represent maximum observed benefit. Delta (D) indicates a rate of change calculation, and is always expressed as a percent change from the NAC.

Concept	Area (km²)	High Suitability Area (km²)	Δ Area (%)	Δ High Suitability Area (%)	OAI (absolute)
NAC	3475	854	-	-	-
5	4538	854	21.12	0.00	0.00
4	7981	854	113.11	0.00	0.00
3	9044	**1095**	141.50	28.22	0.20
2	13736	**1651**	266.78	93.33	0.35
1	22613	**2117**	503.82	147.89	0.29
1a	22591	**2117**	503.23	147.89	0.29
SA	*17093*	*2117*	*356.42*	*147.89*	*0.41*

Warty sea cucumber *(Parastichopus parvimensis)*

Warty sea cucumbers habitat overlaps slightly with California sea cucumbers. Warty sea cucumbers occur predominantly in low intertidal waters to depths of 27 m from Monterey Bay to central Baja California and may range to 40 m (Morris *et al*.,1980; Leet *et al*., 2001). These warmer-water sea cucumbers are common on both soft substrates and rocky reefs. Warty sea cucumbers are common in the study area, though natural populations are poorly studied (Gotshall and Laurent, 1979; Morris *et al*., 1980). This slow-moving sea cucumber feeds on detritus and small organisms, which it ingests with bottom sediments. It may live about 12 years (Morris *et al*.1980; Leet *et al.,* 2001).

No sport fishery for this species exists. A commercial fishery by hookah divers using rakes started in California in 1978 (Leet *et al*., 1992). Other sources of mortality include predation by sea stars, fishes, crabs, sea otters, and bacterial diseases which may significantly reduce population sizes (Engle, 1994; Eckert *et al.,* 2000).

Broad-scale Patterns

Highly suitable habitat for warty sea cucumbers was considered to occur over hard and soft substrates between the intertidal zone and 20 m. Moderately suitable habitats extended from 20-30 m, while habitats between 30 -40 m were considered low suitability. Warty cucumbers are less abundant north of Point Conception (Leet *et al*., 2001), thus habitat suitability is moderate from the intertidal to 60 m north of 34.5°N to Monterey Bay (Figure 3.1.39). Highly suitable habitat is located nearshore from Point Conception through southern California to San Diego. Also, highly suitable habitat encompasses most of the Channel Islands.

No data were available for testing model performance.

Analysis of Boundary Concepts

Less than 10% of the area (341 km^2) within the current CINMS boundary was considered highly suitable for warty sea cucumbers (Figure 3.1.40). No additional gains of highly suitable habitat were contained within Concepts 4 and 5. Considerable gains of suitable habitat occurred within concepts that included area along the mainland (Figure 3.1.41). The OAI was used to assess the relative abundance of highly suitable habitat within boundary concepts compared to the NAC (Table 3.1.12). Although the Study Area ranked highest for the OAI, it is not a concept under consideration. Therefore, Concepts 1 and 1a are the most preferable for warty sea cucumber.

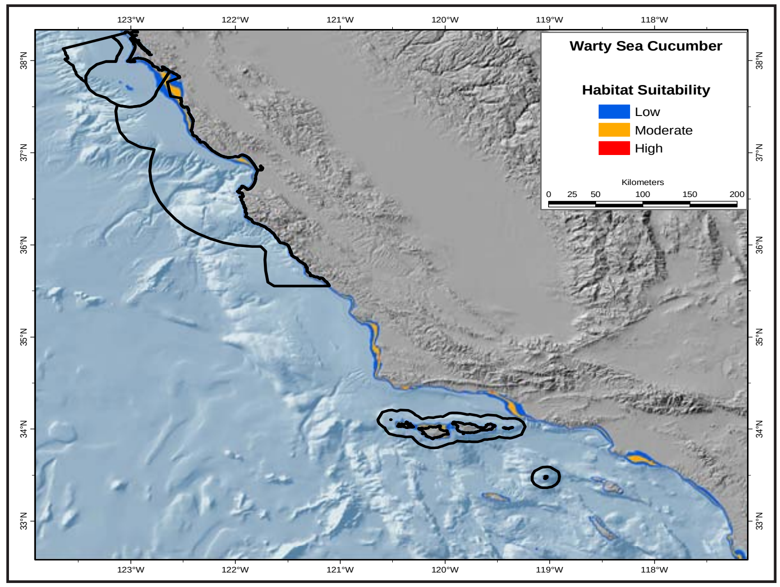

Figure 3.1.39. Warty sea cucumber habitat suitability off central and southern California.

Summary

• Suitable habitat for warty sea cucumbers consists of hard and soft substrates between 0-30 m south of 35°N.

• Of the six boundary concepts being considered, Concept 1a provided the best proportional change of highly suitable habitat for warty sea cucumbers/total concept area relative to the NAC.

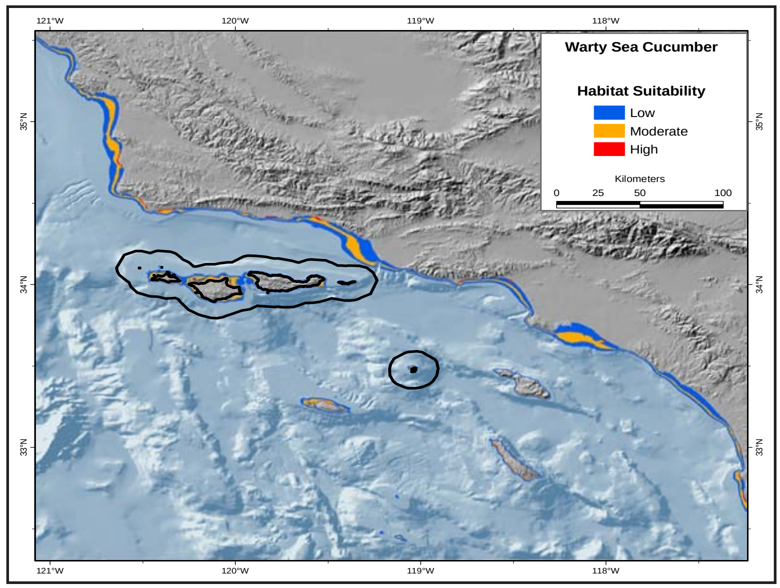

Figure 3.1.40. Warty sea cucumber habitat suitability off southern California.

Red sea urchin *(Strongylocentrotus franciscanus)*

Red urchins inhabit intertidal and subtidal rocky substrates to depths of 130 m from Alaska to central Baja California, but are most abundant from 10-30 m (Bernard and Miller, 1973; Russo, 1979; Durhan *et al*., 1980; Barr and Barr, 1983). Red urchins are identified by their red, maroon, or black color and large size (Morris *et al*., 1980; Leet *et al.,* 2001). When food is abundant, red urchins are relatively sedentary. However, when food is scarce, red urchin motility increases (to 1 m/day) (Harrold and Reed, 1985). Red urchin spines are refuges for a variety of small invertebrates (including juvenile red urchins) and fishes (Tegner and Dayton, 1977). The diet of red urchins consists of a variety of red and brown algae, but the kelp M*acrocystis* is preferred. Red urchins compete with abalone for food and space. This species may live 20 years or more. (Morris *et al*.,1980).

A significant commercial fishery for red urchin began during the 1970s in the study area (Leet *et al.,* 1992). Commercial hookah divers harvest red urchins using rakes at depths of up to 33 m. Landings of red urchins increased from the beginning of the fishery until 1989, after which the statewide fishery declined steadily through 1996. Landings from the Channel Islands began to decline in the late 1970s. The relative abundance of red urchins in southern California has also declined (Carroll *et al*., 2000). Other sources of mortality include predation by sea stars, fishes, lobsters, and sea otters (Tegner and Dayton, 1981; Tegner and Levin, 1983; Rogers-Bennett, 1998; Leet *et al*., 2001).

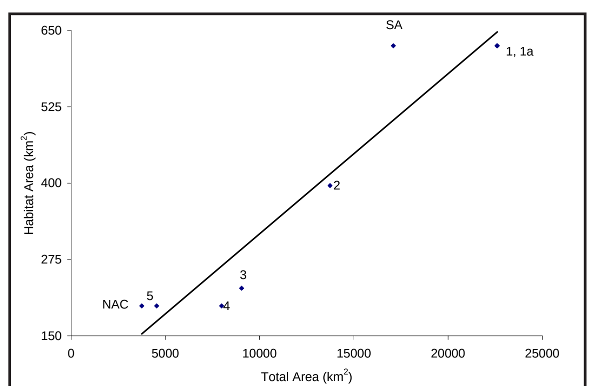

Figure 3.1.41. Regression of highly suitable habitat area for warty sea cucumber and total area for the current and proposed boundary concepts. Numbers indicate concepts and NAC=No Action Concept, SA=Study Area.

Broad-scale Patterns

Highly suitable habitat for red sea urchins was considered to occur over hard and soft substrates between the depths of 10-30 m. Moderate suitability was assigned to depths from the intertidal zone to 10 m and 30-90 m. Habitat suitability was considered low at depths between 90-130 m. As such, highly suitable habitat extends narrowly off the California mainland with broader areas located in southern California. Small bands of highly suitable habitat are also observed around the Channel Islands (Figure 3.1.42).

No commercial data were available for testing model performance.

Analysis of Boundary Concepts

Approximately 7% (257 km^2) of the total area within the current CINMS boundary is considered high suitability habitat for red sea urchins (Figure 3.1.43). These areas are located close to shore along the Channel Islands, with the greatest areas located on the northern shores of San Miguel and Santa Rosa Islands. No additional highly suitable habitat was gained with the increases of boundary size for Concepts 4 and 5. Suitable habitat increased by 33% within Concept 3, which included areas near Point Conception. Highly suitable habitat was significantly greater within Concepts 1, 1a, 2 and the Study Area (Figure 3.1.44), which can be attributed to increases in habitat near Point Conception and other nearshore areas along the mainland. Although the Study Area ranked highest for the OAI (Table 3.1.13), Concepts 1 and 1a yielded the highest OAI ranking among the six concepts under consideration.

Summary

• Highly suitable habitat for red sea urchins was determined to occur between 10-30 m on hard and soft substrates.

• The commercial fishery for red sea urchins occurs primarily in southern California.

• Of the six boundary concepts being considered, Concepts 1 and 1a displayed the highest OAI ranking.

Table 3.1.12. Analysis of warty sea cucumber habitat suitability within boundary concepts. Numbers in bold indicate an increase in the estimate when compared to the No Action Concept (NAC). OAI estimates shaded in gray represent maximum observed benefit. Delta (D) indicates a rate of change calculation, and is always expressed as a percent change from the NAC.

Concept	Area (km^2)	High Suitability Area (km^2)	Δ Area (%)	Δ High Suitability Area (%)	OAI (absolute)
NAC	3475	199	-	-	-
5	4538	199	21.12	0.00	0.00
4	7981	199	113.11	0.00	0.00
3	9044	**228**	141.50	14.57	0.10
2	13736	**396**	266.78	98.99	0.37
1	22613	**625**	503.82	214.07	0.42
1a	22591	**625**	503.23	214.07	0.43
SA	*17093*	***625***	*356.42*	*214.07*	*0.60*

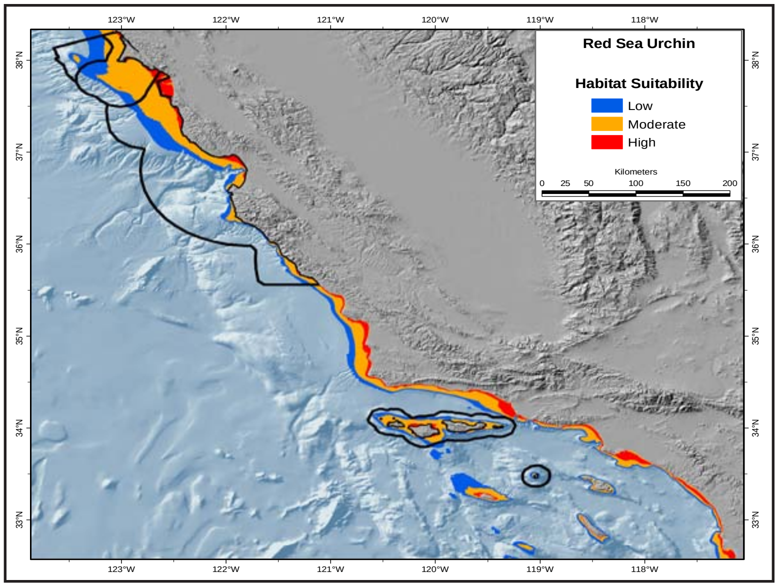

Figure 3.1.42. Red sea urchin habitat suitability off central and southern California.

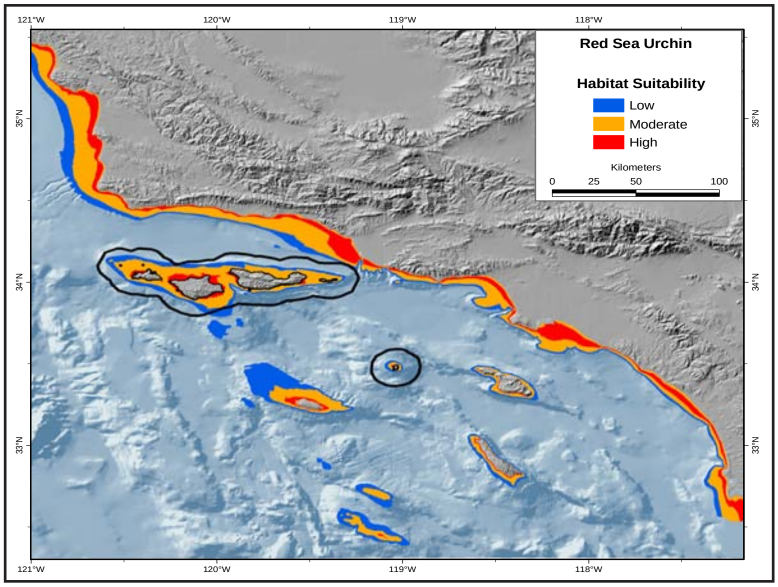

Figure 3.1.43. Red sea urchin habitat suitability off southern California.

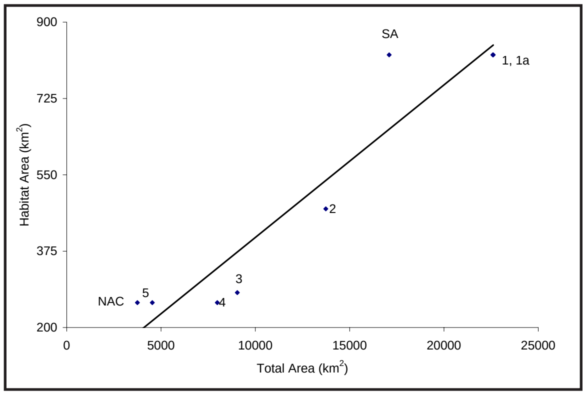

Figure 3.1.44. Regression of highly suitable habitat area for redsea urchin and total area for the current and proposed boundary concepts. Numbers indicate concepts and NAC=No Action Concept, SA=Study Area.

Table 3.1.13. Analysis of red sea urchin habitat suitability within boundary concepts. Numbers in bold indicate an increase in the estimate when compared to the No Action Concept (NAC). OAI estimates shaded in gray represent maximum observed benefit. Delta (D) indicates a rate of change calculation, and is always expressed as a percent change from the NAC.

Concept	Area (km^2)	High Suitability Area (km^2)	Δ Area (%)	Δ High Suitability Area (%)	OAI (absolute)
NAC	3475	257	-	-	-
5	4538	257	21.12	0.00	0.00
4	7981	257	113.11	0.00	0.00
3	9044	**280**	141.50	8.95	0.06
2	13736	**472**	266.78	83.66	0.31
1	22613	**825**	503.82	221.01	0.44
1a	22591	**825**	503.23	221.01	0.44
SA	*17093*	*825*	*356.42*	*221.01*	*0.62*

Purple sea urchin (*Strongylocentrotus purpuratus)*
Purple urchins inhabit low intertidal and subtidal depths (to 160 m) from southern British Columbia (Canada) to central Baja California. They prefer intertidal and subtidal (to 30 m) rocky habitats with moderate to strong wave action, where they normally inhabit crevices or depressions (Kalvass, 1992). Purple urchins are identified by their purple color and relatively small size. The diet of purple urchins consists of a variety of red and brown algae, but the kelp *Macrocystis* is preferred. They are relatively sedentary when food is abundant, with motility increasing as food availability decreases (to 1 m/day) (Harrold and Reed, 1985). This species may live up to 30 years (Morris *et al*., 1980).

A minor fishery for purple urchins exists, but the small size and variable development of roe has precluded expansion of the fishery at this time. Other sources of mortality include predation by sea stars, fishes, lobsters, and sea otters (Tegner and Dayton, 1981; Tegner and Levin, 1983; Leet *et al*., 2001). Coincident with the decline of competing red urchins described above, purple urchin populations have increased markedly at many island sites, creating vast areas denuded of macroalgae (Harold and Reed, 1985; Ambrose *et al*., 1993; Engle, 1994; Richards *et al*., 1997; Carroll *et al*., 2000; Lafferty and Kushner, 2000).

Broad-scale Patterns
Highly suitable habitat for purple sea urchin overlaps that defined for red sea urchins (0-30 m) while moderate suitability extends to deeper waters (30-90 m). Suitability was considered low at depths between 90-160 m (Figure 3.1.45). As such, greater amounts of highly suitable habitat are available for purple sea urchins than for red urchins and the same pattern of distribution is observed with the exception of highly suitable habitat extending up to the intertidal zone for purple sea urchins.

No commercial data were available for testing model performance.

Analysis of Boundary Concepts
Approximately 341 km^2 of suitable habitat was determined to occur within the current CINMS boundary (Figure 3.1.46). No additional gains of highly suitable habitat were observed within Concepts 4 and 5. Highly suitable habitat increased by 12% within Concept 3, while considerably larger gains were observed within the larger concepts (Figure 3.1.47). These gains were attributed to the inclusion of nearshore habitat along the mainland. Although the Study Area ranked

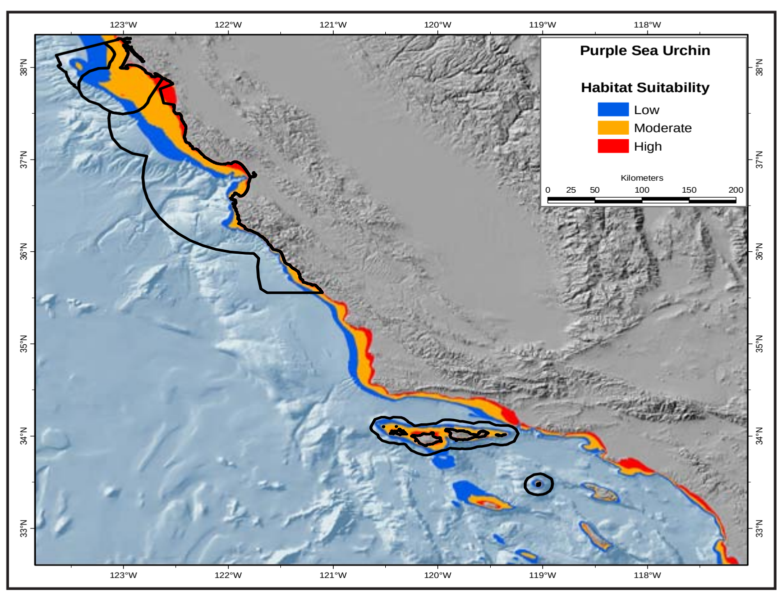

Figure 3.1.45. Purple sea urchin habitat suitability off central and southern California.

highest for the OAI, Concepts 1 and 1a provided the most beneficial proportional change of suitable habitat/total concept area gained relative to the NAC (Table 3.1.14).

Summary

• Highly suitable habitat for purple urchins consists of hard and soft substrates within 0-30 m.

• Of the six boundary concepts being considered, Concepts 1 and 1a provided the optimal proportional change of suitable habitat/total concept area relative to the NAC.

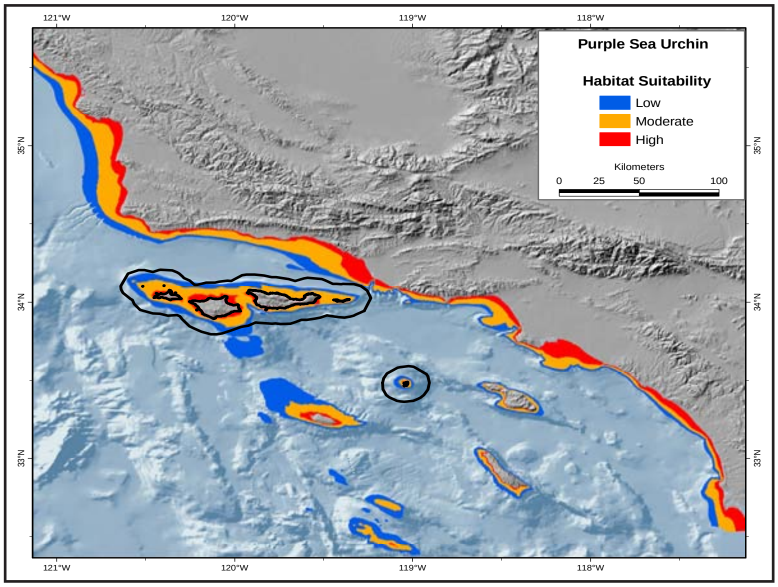

Figure 3.1.46. Purple sea urchin habitat suitability off southern California.

Table 3.1.14. Analysis of purple sea urchin habitat suitability within boundary concepts. Numbers in bold indicate an increase in the estimate when compared to the No Action Concept (NAC). OAI estimates shaded in gray represent maximum observed benefit. Delta (D) indicates a rate of change calculation, and is always expressed as a percent change from the NAC.

Concept	Area (km^2)	High Suitability Area (km^2)	Δ Area (%)	Δ High Suitability Area (%)	OAI (absolute)
NAC	3475	341	-	-	-
5	4538	341	21.12	0.00	0.00
4	7981	341	113.11	0.00	0.00
3	9044	**374**	141.50	9.68	0.07
2	13736	**626**	266.78	83.58	0.31
1	22613	**1052**	503.82	208.50	0.41
1a	22591	**1052**	503.23	208.50	0.41
SA	*17093*	*1052*	*356.42*	*208.50*	*0.58*

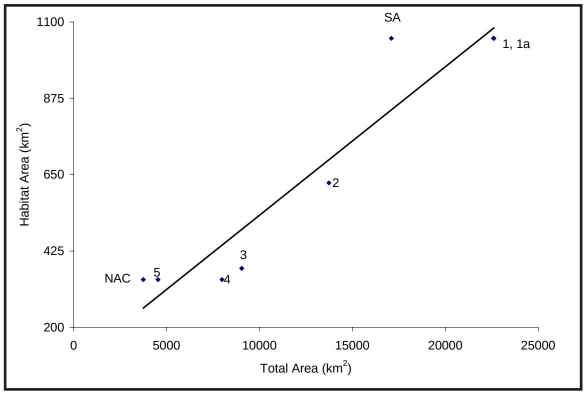

Figure 3.1.47. Regression of highly suitable habitat area for purple sea urchin and total area for the current and proposed boundary concepts. Numbers indicate concepts and NAC=No Action Concept, SA=Study Area.

3.2 MACROINVERTEBRATE ASSEMBLAGE STRUCTURE

The primary objective of this chapter is to define biogeographic patterns of invertebrates and to provide an understanding of invertebrate multi-species community structure in a spatial context. Community metrics and multivariate statistics were used to analyze marine invertebrate species assemblages off southern California. Analyses were completed using data provided by the Southern California Coastal Water Research Project (SCCWRP) for 41 species of demersal invertebrates. Five objectives were defined to:

- Calculate Shannon index of diversity for all invertebrates identified to species level in all trawls;
- Determine which species tend to co-occur (i.e., species assemblages);
- Map locations that contained similar catches (i.e., site groups);
- Resolve where species assemblages were being caught by combining results from objectives 1 and 2; and,
- Investigate boundary concepts using objectives listed above.

Data and Methods

Southern California Bight Regional Survey data obtained from SCCWRP consisted of 426 fisheries-independent trawl samples collected June to September in 1994 and 1998. Samples were collected with a 7.6 m headrope semiballoon otter trawl with 1.25 cm codend mesh towed for 5 minutes (in bays) to 10 minutes (on coast) along isobaths at each station, ranging in depth from from 2-215 m (Allen *et al.,* 1998, 2002). In 1994, the survey targeted the mainland shelf at 10-200 m, whereas the 1998 survey added trawls near islands and within bay and harbor areas, sampling from 2-200 m (Allen *et al.,* 1998, 2002). The data set contained information for 288 invertebrate species in 426 trawls, but removal of rare species (see below) resulted in 41 species in 401 trawls analyzed for assemblage structure.

Invertebrate diversity (H') was calculated with the Shannon index of diversity (Shannon and Weaver, 1949):

$$H' = -S[(n_i/N)\ ln(n_i/N)]$$

where n_i is the number of individuals belonging to the i^{th} species (s) in the sample, and N is the total number of individuals in the sample. Individual results are presented to show the distribution of effort and site diversity. Spatially summarized results also are provided to determine if larger spatial patterns were present that may have been masked by the high variability present in the individual trawl results. Using ArcGIS, 5 x 5 minute grids were created and mean diversity was calculated for each grid cell containing data. Results were sorted by diversity and divided into quintiles (i.e., each quintile contains 20% of the sites) for display.

It is important to analyze not just the diversity of species present, but to also investigate which species are commonly found together. Clustering is "a technique for optimal grouping of entities according to the resemblance of their attributes as expressed by given criteria" (Boesch, 1977), or in short, a method that puts variables (sites, species, etc) into groups. Cluster analyses began with either a site by species, or species by site matrix of invertebrate abundances which resulted in species assemblages or site groups depending on which matrix was utilized. Invertebrates that were not present in at least 5% of the trawls were removed from this analysis. Rare species were removed because their occurrence is often due to chance, and can therefore negatively impact results (Boesch, 1977; Gauch, 1982). The 5% cutoff was implemented because it reduced the number of zeros present in the matrices, while keeping an adequate number of species for analysis. Abundance estimates were transformed because the raw data did not conform to assumptions of a normal distribution and homogeneity of variances. A fourth root transformation was utilized as it is invariant to scale changes (Field *et al*., 1982). Data were standardized by species abundances (i.e., the abundances for each species were adjusted such that the mean is zero and the standard deviation is one). This places all species on the same scale regardless of overall abundance, and ensures that abundant species did not overly influence the results. A series of exploratory analyses were performed on a variety of clustering methods to determine which consistently provided interpretable results without excessive chaining. When chaining occurs, entities fuse to a few nuclear groups one at a time rather than forming new groups, and make it impossible to divide the data into meaningful smaller groups (Boesch, 1977). Two dissimilarity methods, Bray-Curtis and Jaccard (both paired with average means clustering) met these criteria. As such, the Bray-Curtis technique was chosen to allow for comparisons with previous analyses of the SCCWRP data (Allen *et al*., 1998, 2002). The Bray-Curtis dissimilarity coefficient (b_{jk}) is calculated as:

$$b_{jk} = \frac{\sum_{i=1}^{n} | X_{ij} - X_{ik} |}{\sum_{i=1}^{n} (X_{ij} + X_{ik})}$$

where X_{ij} is the ith attribute (column) measured on the j^{th} object (row), and X_{ik} is the ith attribute on the k^{th} object (Romesburg, 1984). The Bray-Curtis dissimilarity metric often produces meaningful results with species abundance data, and is therefore one of the most widely used clustering methods in ecology (Boesch, 1977). Scree plots were used to determine where breaks in the similarity level occurred (McGarigal *et al*., 2000). Subsequently, group composition was analyzed to determine the best ecological groupings (*i.e*., if smaller or larger groups would provide a better ecological explanation; Boesch, 1977).

To resolve where the invertebrate assemblages were being caught (i.e., interaction between species assemblages and site groups), the average frequency of occurrence for each species was calculated for each site group. This analysis is a modified nodal analysis (Boesch, 1977). By analyzing average frequencies for species by site groups, it was possible to determine which species assemblages were influential in forming the site groups. Spatial distribution was visualized by mapping the site groups in a GIS. A step-wise discriminant analysis was performed to determine if parameters such as depth, latitude, or effort were significantly different between site groups.

Broad-scale Patterns

The SCCWRP trawls were concentrated in the Southern California Bight, and provided information on benthic species found in water less than 215 m depth. Invertebrate diversity ranged from 0-2.38 with a mean of 1.0 ± 0.6, and a median of 0.95. Patches of high diversity exist northwest of San Miguel and Santa Cruz Islands, and southeast of Point Conception (Figure 3.2.1). Low diversity patches can be found on the southeast corner of Santa Catalina Island and within the Santa Barbara Channel near Carpinteria. There were no statistically significant relationships between diversity and any of the following: latitude (r^2=0.0, P=0.36), longitude (r^2=0.0, P=0.24), depth (r^2=0.01, P=0.11), or effort (r^2=0.0, P=0.47).

Clustering resulted in 41 invertebrate species being combined into eight species assemblages (Table 3.2.1), and sites classified into eight distinct groups (Figure 3.2.2; Table 3.2.2). There was a clear relationship between species assemblages and depth. This relationship can be visualized in Table 3.2.2, where site groups have been ordered from shallow to deep. The tuberculate pear crab assemblage consists of shallow species, the California sand star assemblage mid-shelf species, and the fragile sea urchin assemblage deeper, offshore species. Three assemblages contain species that were not collected around the islands: tuberculate pear crab assemblage, short-spined sea star assemblage, and sandflat elbow

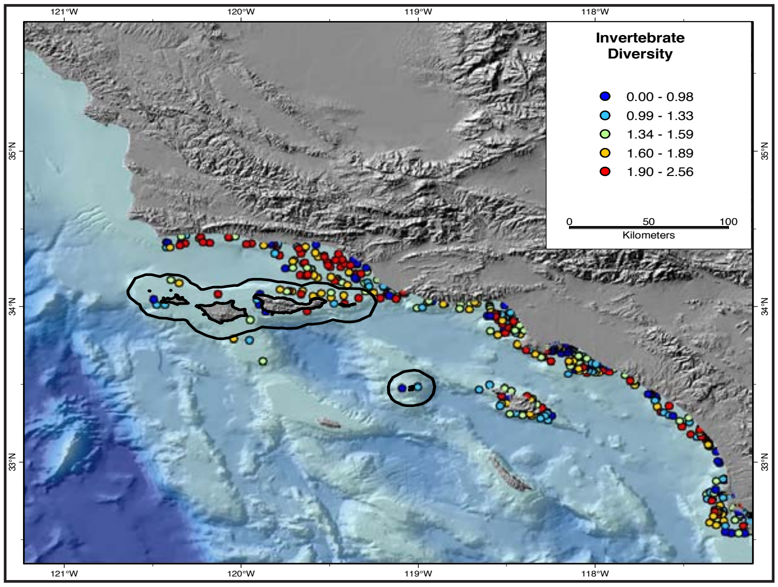

Figure 3.2.1. Invertebrate diversity for individual SCCWRP trawls during 1994 and 1998.

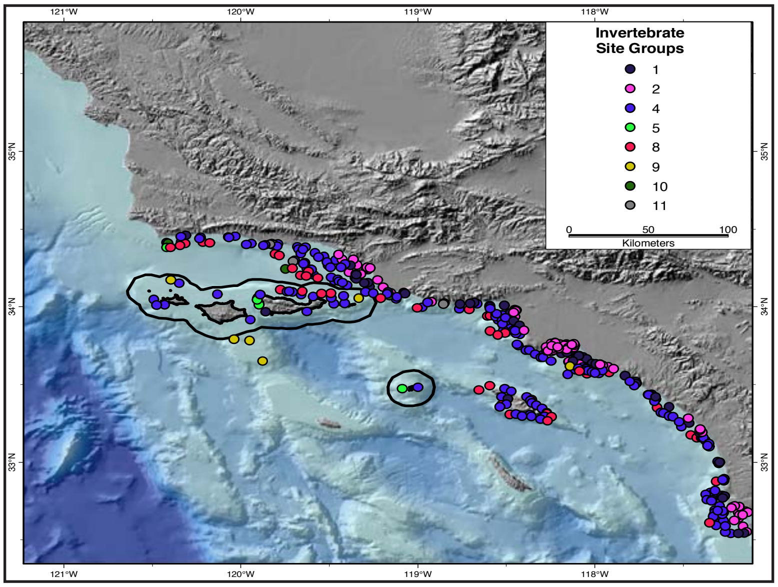

Figure 3.2.2. Location of site groups for SCCWRP survey data (1994, 1998).

crab. Site groups also form clear bands along a depth gradient off the coast (Figure 3.2.2). Site Groups 1 and 2 tend to be shallow and coastal, while Groups 4 and 8 are deeper and common around the islands. Groups 5, 9, 10, and 11 only contain a few sites each. The reasons these sites were isolated and grouped separately are not clear. Because the numbers of stations involved were so few, clustering could be a result of random conditions. Therefore, the clustering results for these groups are provided, but no discussion of these site groups was included. After using discriminate analysis (N=398) there were significant differences observed between site groups in all three parameters investigated: depth (r^2=0.79; F=213; P<0.0001), effort (r^2=0.23; F=16; P<0.0001), and latitude (r^2=0.03; F=2; P<0.06). Changes in areas targeted for trawling and large-scale weather/temperature patterns may have affected observed species assemblages. In 1994, the survey targeted the mainland shelf at 10-200 m, whereas the 1998 survey added trawls near islands and within bay and harbor areas sampling from 2-200 m. In addition, 1998 was a strong El Niño year, with water temperatures much warmer than normal. The cluster results presented here, while based on both years (1994 and 1998), align closely with previous results from 1998 alone (Allen *et al*., 1998, 2002).

Table 3.2.1. Species assemblage results for SCCWRP survey data (1994, 1998) using the Bray-Curtis dissimilarity metric with average means clustering. Assemblages are named for the most influential species in each group.

Group	Common Name	Scientific name
tuberculate pear crab assemblage	tuberculate pear crab spiny sand star blackspotted bay shrimp navanax sea slug yellowleg shrimp	*Pyromaia tuberculata* *Astropecten armatus* *Crangon nigromaculata* *Navanax inermis* *Penaeus californiensis*
shortspined sea star assemblage	shortspined sea star spotwrist hermit	*Pisaster brevispinus* *Pagurus spilocarpus*
sandflat elbow crab assemblage	sandflat elbow crab	*Heterocrypta occidentalis*
California sand star assemblage	California sand star trailtip sea pen California blade barnacle mosaic sand star fringed sand star gray sand star white sea urchin red octopus Pacific spiny brittlestar brokenspine brittlestar California sea cucumber New Zealand paperbubble California sea slug ridgeback rock shrimp slender sea pen yellow sea twig California market squid eastern Pacific bobtail	*Astropecten verrilli* *Acanthoptilum* spp. *Hamatoscalpellum californicum* *Luidia armata* *Luidia asthenosoma* *Luidia foliolata* *Lytechinus pictus* *Octopus rubescens* *Ophiothrix spiculata* *Ophiura luetkenii* *Parastichopus californicus* *Philine auriformis* *Pleurobranchaea californica* *Sicyonia ingentis* *Stylatula elongata* *Thesea* spp. *Loligo opalescens* *Rossia pacifica*
tower snail assemblage	tower snail Alaska bay shrimp thinbeak neck crab rosy tritonia	*Megasurcula carpenteriana* *Crangon alaskensis* *Podochela lobifrons* *Tritonia diomedea*
red sea star assemblage	red sea star orange sand star slenderclaw hermit crab	*Mediaster aequalis* *Astropecten ornatissimus* *Paguristes turgidus*
fragile sea urchin assemblage	fragile sea urchin northern heart urchin Pacific heart urchin flagnose bay shrimp moustache bay shrimp California heart urchin	*Allocentrotus fragilis* *Brisaster latifrons* *Brissopsis pacifica* *Neocrangon resima* *Neocrangon zacae* *Spatangus californicus*
sheep crab assemblage	sheep crab armed box crab	*Loxorhynchus grandis* *Platymera gaudichaudii*

The Channel Islands are divided into two main biogeographical provinces: the warm-temperate San Diegan and the cold-temperate Oregonian. San Miguel, Santa Rosa, and San Nicolas largely have Oregonian biota, while Santa Cruz (eastern part) Anacapa, Santa Barbara, Santa Catalina and San Clemente Islands contain San Diegan biota. Research on intertidal areas and kelp forests further separated the San Diegan province into two smaller groups (Murray *et al*., 1980; Murray and Littler, 1981; Littler *et al*., 1991; Pondella *et al*., 2005). All of these studies placed Santa Catalina and San Clemente into one group and Santa Barbara and Santa Cruz into a second group. It is important to note that most of these studies analyzed rocky intertidal flora and fauna, and are greatly influenced by local temperatures and conditions. The invertebrate site groups from this analysis do not segregate according to these provinces. However, because the SCCWRP trawls targeted benthic species up to 215 m, the species may be less influenced by surface currents and temperature and less likely to show the segregations detailed above.

Analysis of Boundary Concepts

Areas of high invertebrate diversity were observed within the NAC and near the mainland which would be included within Concepts 3, 2, 1, 1a, and the Study Area. However, quantitative comparison of the boundary concepts was not possible due to the distribuiton of survey effort. Few samples were conducted in the deeper portions of the Southern California Bight and no surveys were conducted north of Point Conception. Given the available data highest mean invertebrate diversity was observed within Concept 2 (Figure 3.2.3).

Table 3.2.2. Mean frequency of occurrence for each SCCWRP site group. N=trawl effort. Bold common names indicate principle species for each site group. Gray and blue shaded cells represent species presence in half or a quarter of the groups in that site, respectively.

	Site Groups							
	2 N=87	1 N=73	5 N=4	11 N=4	4 N=182	10 N=3	9 N=7	8 N=41
tuberculate pear crab	57	34	0	0	7	0	0	0
spiny sand star	21	32	0	0	1	0	0	0
blackspotted bay shrimp	54	14	0	25	1	0	0	0
navanax sea slug	18	1	0	0	2	0	0	0
yellowleg shrimp	46	4	0	0	1	0	0	0
shortspined sea star	8	15	0	0	2	0	0	0
spotwrist hermit crab	6	10	0	0	5	0	14	0
sandflat elbow crab	3	29	0	0	6	0	0	0
California sand star	5	79	0	50	85	0	0	17
trailtip sea pen	1	1	0	0	39	0	14	22
California blade barnacle	0	7	0	0	25	0	0	10
California market squid	2	5	0	25	25	0	0	29
mosaic sand star	1	7	0	0	27	0	0	2
fringed sand star	0	3	0	0	12	0	0	0
gray sand star	1	10	0	0	46	0	14	61
white sea urchin	2	10	100	0	74	33	0	22
red octopus	0	3	25	100	29	0	0	17
Pacific spiny brittlestar	2	4	50	0	39	0	0	5
brokenspine brittlestar	0	0	0	0	20	0	14	0
California sea cucumber	5	3	0	0	63	33	0	41
New Zealand paperbubble	20	8	0	0	35	0	14	7
California sea slug	1	3	0	25	37	100	0	44
eastern Pacific bobtail	1	0	0	0	17	0	0	29
ridgeback rock shrimp	6	8	0	75	79	0	0	78
slender sea pen	3	7	0	0	20	0	0	5
yellow sea twig	0	0	0	0	28	0	43	5
tower snail	0	3	0	0	18	0	0	10
Alaska bay shrimp	1	0	0	0	12	33	0	0
thinbeak neck crab	0	1	0	0	9	33	0	5
rosy tritonia	0	1	0	0	10	0	0	7
red sea star	0	0	0	0	15	0	57	12
orange sand star	0	0	0	0	10	0	0	17
slenderclaw hermit crab	1	1	0	0	7	0	43	12
fragile sea urchin	0	0	0	0	14	0	29	95
northern heart urchin	0	0	0	0	4	0	0	59
Pacific heart urchin	0	0	0	0	1	0	0	44
flagnose bay shrimp	0	0	0	25	4	0	0	46
moustache bay shrimp	0	0	0	25	8	0	0	63
California heart urchin	0	0	0	0	9	0	0	34
sheep crab	10	1	0	0	4	0	0	2
armed box crab	0	1	0	0	9	0	0	2

Quantitative evaluation of species assemblages were not conducted but general trends can be described. Four site groups were located within the existing sanctuary boundary. Site groups 4 and 8 occurred most frequently within the current sanctuary boundary and were more numerous in the larger concepts that reached the mainland. The majority of the trawls were located east and south of the sanctuary and were not included in any of the concepts. Site groups 2, 10, and 11 were not present in the current sanctuary boundaries, however, they were included within the larger concepts. Site Group 2 occurred frequently along the mainland and was most prevalent south of

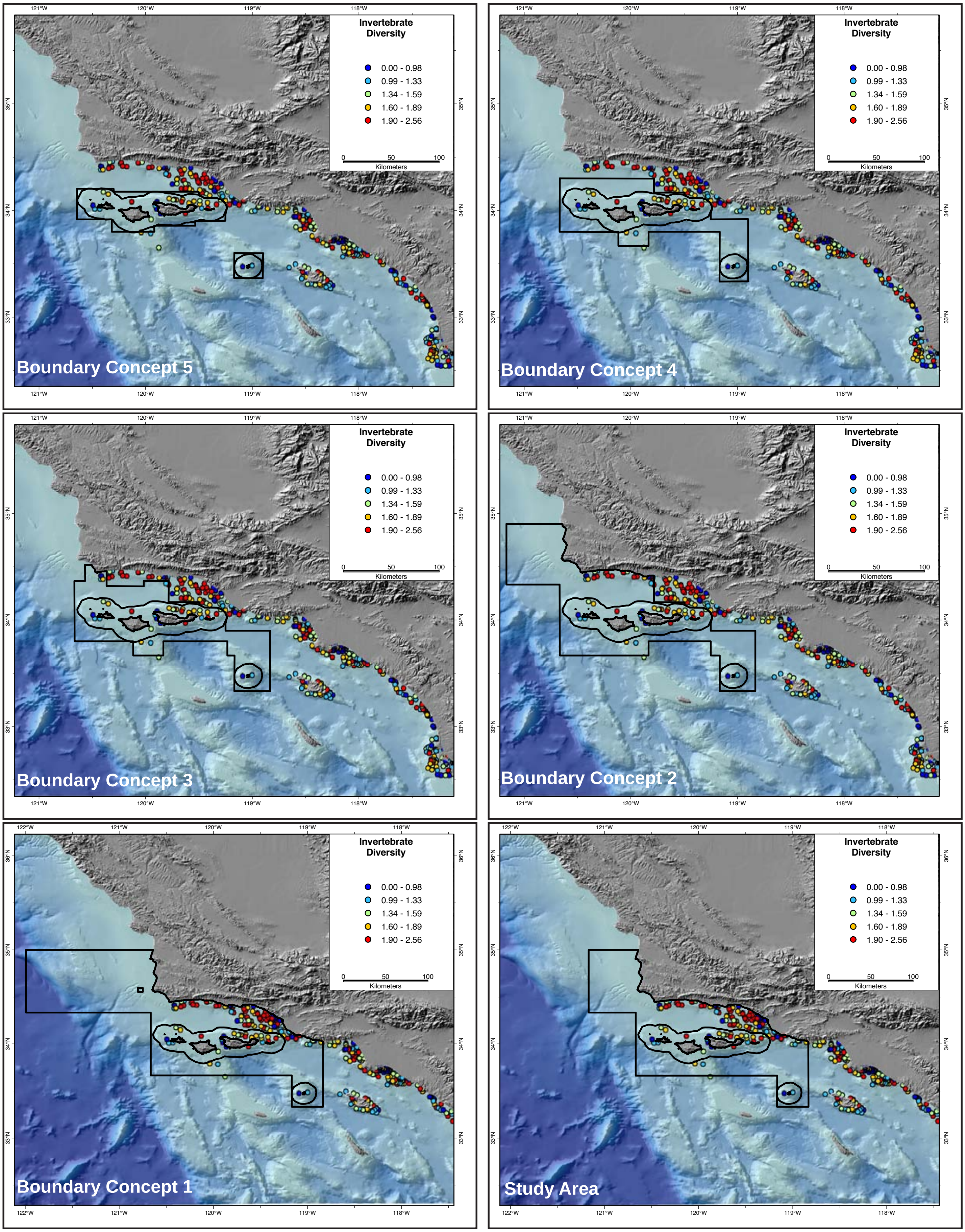

Figure 3.2.3. Overlay of invertebrate diversity and CINMS boundary concepts.

Palos Verdes Point. This group was defined by 87 shallow water trawls and these species may occur within the sanctuary, but shallow water trawls were limited within the sanctuary. It is recommended that additional surveys are needed to conduct an accurate spatial analysis for invertebrates.

Summary

• Invertebrate diversity ranged from 0 to 2.38, with a mean of 1.0. No spatial patterns within the diversity results were identified.

• Eight site groups and eight species assemblages were identified. There was a significant relationship between site groups and depth.

• In general, results indicate that invertebrate diversity and community structure may increase with the inclusion of coastal habitat that would be gained within the larger boundary concepts.

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CHAPTER 4 – BIOGEOGRAPHY OF MARINE FISHES

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The Southern California Bight is a dynamic region of mixing water masses which leads to a wide diversity of organisms, including fishes. The southern range terminus of many high-latitude fishes, as well as the northern range terminus of equatorial species occurs around Point Conception [see Chapter 1.3] (Eschmeyer *et al*., 1983). While this chapter does not address all species that inhabit southern California waters, it does examine habitat suitability for 10 species of commercial, recreational, or ecological importance. Community structure analyses are also included, which examine data collected from groundfish trawls, recreational fishing surveys, and scuba surveys in kelp habitats. Finally, an assessment of larval fish abundance in southern California is described.

4.1 SINGLE SPECIES HABITAT SUITABILITY MODELS (HSM)

As described in Section 3.1, habitat suitability modeling (HSM) is a tool for predicting the adequacy of habitat for a given species or assemblage of species. Models are constructed as a mathematical expression to provide an index of habitat quality as a function of one or more environmental variables. Model development can range from qualitative to quantitative, and is wholly dependent on the type of data being used to model the species in question (Brown *et al*., 2000; Wright *et al*., 2000; Clark *et al*., 2004). These mathematical expressions can then be mapped in a geographic information system (GIS) to portray areas of potential distribution for a given species.

Currently, the National Marine Fisheries Service (NMFS) is developing an Environmental Impact Statement (EIS) to consider the designation of Essential Fish Habitat (EFH) for Pacific coast groundfish. Habitat suitability models expressed as habitat suitability probabilities (HSP), ranging from 0 (unsuitable) to 1 (most suitable), were developed by NMFS for federally managed groundfish based on a combination of fishery-independent trawl data and scientific literature (NMFS, 2004). Suitability values for species and life stages in the Groundfish Fisheries Management Plan (FMP) were based on three variables: benthic habitat, depth, and latitude. Model results are expressed as the probability that the composite of depth, substrate, and latitude at a given location is suitable for a given species. While many species of fish occur in southern California, the 12 species listed in Table 4.1.1 were determined to be representative of species that have significant commercial, ecological, and/or recreational importance within the southern California region. Five of these species (bocaccio, cowcod, lingcod, leopard shark, and tope [soupfin shark]) are federally managed so HSP values developed by NMFS for adults and juveniles were used in this chapter. Qualitative habitat suitability models (HSM) as described in Chapter 3.1, were developed for four species of non-federally managed fish and three federally managed pelagic/highly migratory species.

Table 4.1.1. Fish species of interest for the CINMS biogeographic assessment. Common and scientific names are from Nelson *et al*., 2004.

Common Name	Scientific Name	Management
thresher shark	*Alopias vulpinus*	Federal
tope (soupfin shark)	*Galeorhinus galeus*	Federal
leopard shark	*Triakis semifasciata*	Federal
Pacific angel shark	*Squatina californica*	State
Pacific sardine	*Sardinops sagax*	Federal
northern anchovy	*Engraulis mordax*	Federal
bocaccio	*Sebastes paucispinis*	Federal
cowcod	*Sebastes levis*	Federal
lingcod	*Ophiodon elongatus*	Federal
giant seabass	*Stereolepis gigas*	State
California sheephead	*Semicossyphus pulcher*	State
California halibut	*Paralichthys californica*	State

Data and Methods

The framework GIS data (bathymetry, substrate type) were the same as those used by NMFS for groundfish HSP modeling (NMFS, 2004). Bathymetry was mapped at 10 m intervals and extended from the shoreline to 4,000 m. Although there were 35 classifications of habitat type associated with the benthic substrate data (Chapter 2.9), information gathered from scientific literature was less resolved, and thus habitat preferences could only be confidently attributed to hard or soft substrate type (Chapter 2.10). The unaltered substrate map developed by NMFS was used to map their HSP model results while the substrate map combining NMFS and MMS data was used to map HSM results.

NMFS HSP's for federally managed groundfish were developed using trawl surveys (1977-2002) and a Habitat Use Database (HUD), which is a compendium of life history information collected from scientific literature.

Where information was adequate, NMFS trawl surveys were used to develop suitability values for bathymetry and latitude. Depth and latitude information from the HUD were used to develop suitability values for species that were poorly represented in NMFS trawl surveys and for developing suitability values for benthic habitat type and latitude for all species (NMFS, 2004). Adult bocaccio, cowcod, and lingcod suitability values for bathymetry and latitude were developed from NMFS survey data, while suitability values for adult leopard sharks and tope as well as all juvenile stages were developed from the HUD. HSP model results range from 0.01 (low habitat probability) to 0.999 (high habitat probability). Boundary analysis consited of taking a subset of the habitat information for the selected federally managed species and classifiying probability values by quintile (20%). The top quintile was determined to possess the highest habitat suitability and patterns were analyzed in the context of boundary concepts using the Optimal Area Index (OAI) described in Chapter 1.4.

Suitability values for the remaining non-federally managed species (California halibut, California sheephead, giant seabass, and Pacific angel shark) were developed primarily from habitat associations described in scientific literature. Life history information from the Coastal Pelagic Species and Highly Migratory Species FMP's were used to model northern anchovy, Pacific sardine, and thresher shark habitat suitability values. Habitat suitability for these species was modeled and mapped using a qualitative measure of suitability-high, medium, or low. For example, the distribution of California halibut (*Paralichthys californicus*) was reported to occur over soft substrates at depths between 0-200 m, with greater abundances occurring at 0-100 m. Based on this information, high suitability was assigned to soft substrates between 0-100 m, and moderate suitability on soft substrates between 100-200 m. Hard substrate between 0-200 m and all substrates >200 m were considered low suitability. OAI calculations compared the ratio of highly suitable habitat area and total area for all boundary concepts relative to that of the current Channel Islands sanctuary.

Typically, fisheries independent monitoring data are used to validate model results (Rubec *et al*.,1999; Clark *et al*., 2004). The models developed by NMFS for federally managed groundfish are currently being reviewed and, as a result, model performance was not conducted herein. Commercial Passenger Fishing Vessel data (CPFV) provided by California Department of Fish and Game (CDFG) were mapped and superimposed over suitability maps to assess model performance for California halibut and California sheephead. These data consist of abundance and location data collected by commercial party boats within CDFG's fishing block system (a block represents 100 square miles). Additionally, trawl data collected by SCCWRP were used to assess California halibut model performance.

Thresher shark (*Alopias vulpinus)*

The thresher shark is a large pelagic shark which is federally managed by the Highly Migratory Species Fisheries Management Plan (PFMC, 2003). Species managed by this FMP exhibit high variability in their distribution as they are most responsive to dynamic patterns of sea surface temperature, current patterns, and food availability. While information regarding thresher shark life history information is scarce, data are available from the drift gill net and the NMFS fishery observer program.

The thresher shark exhibits a circumglobal distribution, and is found from Goose Bay, British Columbia, to Baja California (Leet *et al*., 2001). Data from the management plan provide general descriptions of juvenile and adult distribution. Juveniles (<102 cm fork length) occur in oceanic waters off beaches and in shallow bays within the U.S.-Mexico EEZ border north to 37°N. They occur over bottom depths between 10-750 m, most commonly between 10-180 m. Adults (>66 cm fork length) also occupy oceanic waters off beaches and open coastal bays from the U.S.-Mexico Exclusive Economic Zone north to Cape Flattery, Washington. South of the Mendocino Escarpment, adult thresher sharks are most abundant in waters ranging in depth between 70-3,480 m (PFMC, 2003). The thresher shark is the leading commercial shark in California, with landings averaging 1.1 million pounds during 1977-1989. However, catches declined to 0.4 million pounds during 1990-1998 (Leet *et al*., 2001).

Broad-scale Patterns

Adult thresher shark habitat suitability was determined to be high at depths between 70-3,480 m, moderate at depths between 30-70 m and greater than 3,480 m, and low at depths less than 30 m. This relates to a vast area of high suitability along the west coast of the U.S. (Figure 4.1.1) with considerable amounts found within the central coast and Channel Islands sanctuaries.

Juvenile habitat suitability was less extensive and shallower than that for adults; highly suitable habitat extends from the U.S.-Mexico border north to 37°N at depths between 10-180 m. Moderately suitable habitat was determined to occur in depths between 180-550 m, while depths >550 m were considered low suitability. Highly suitable habitat comprises a large portion of the continental shelf in southern California through the Monterey Bay NMS in central California (Figure 4.1.2).

Analysis of Boundary Concepts

Approximately 75% of the total area of the current CINMS was considered highly suitable for adult thresher sharks (Figure 4.1.3). Highly suitable habitat comprised over 80% of the total area for all the boundary concepts. Although Concepts 1 and 1a contained the most highly suitable habitat area (Figure 4.1.4), OAI results indicate that Concept 4 was the most favorable of the six concepts under consideration (Table 4.1.2).

Approximately 50% of the total area within the current CINMS boundary was considered highly suitable for juvenile thresher sharks. These areas form a wide band encompassing the northern Channel Islands (Figure 4.1.5). Slight increases in the amount of highly suitable habitat were observed within Concepts 3, 4 and 5 and more significant gains were contained within the larger boundary concepts (Figure 4.1.6). OAI results comparing the relative gains of highly suitable habit/total concept area indicate that Concept 2 was optimal for juvenile thresher shark habitat (Table 4.1.3).

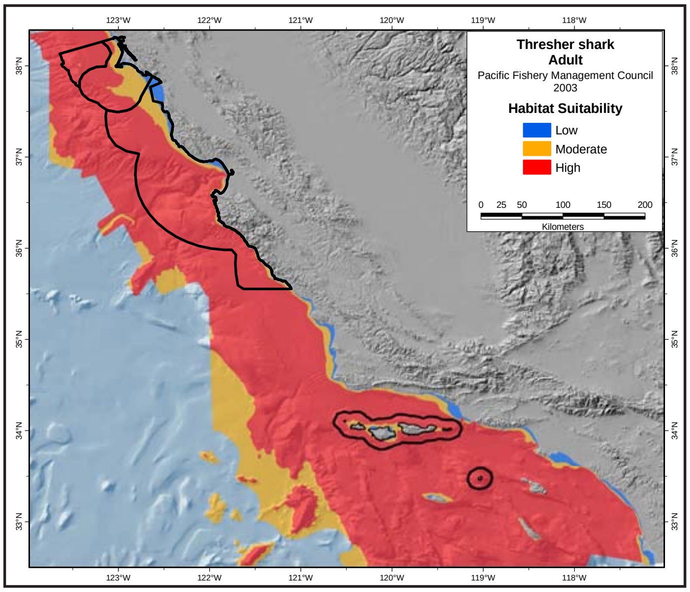

Figure 4.1.1. Adult thresher shark habitat suitability off central and southern California.

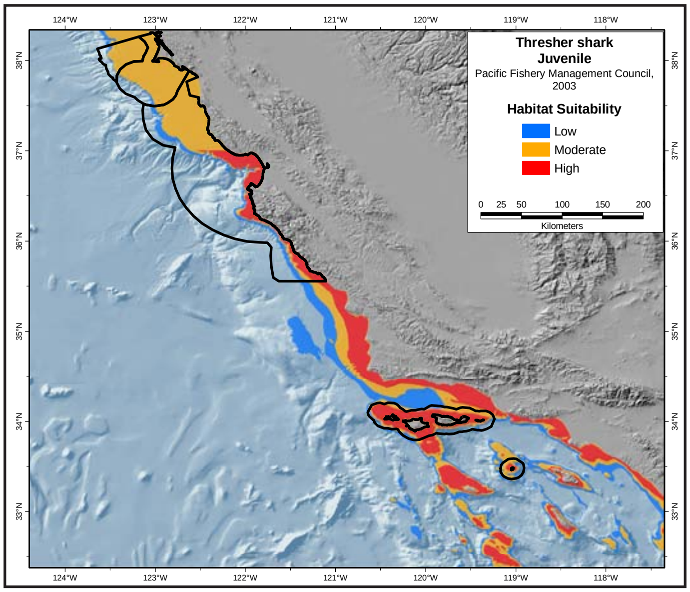

Figure 4.1.2. Juvenile thresher shark habitat suitability off central and southern California.

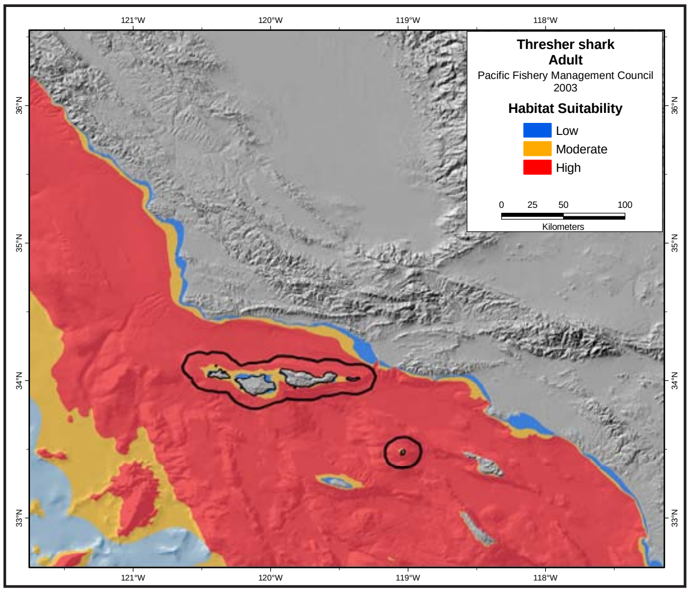

Figure 4.1.3. Adult thresher shark habitat suitability off southern California.

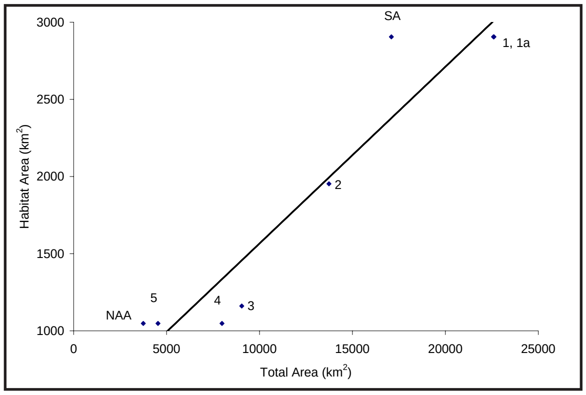

Figure 4.1.4. Regression of total habitat area for adult thresher shark and total area within the current and proposed boundary concepts. Numbers indicate concepts and NAC=No Action Concept, SA=Study Area.

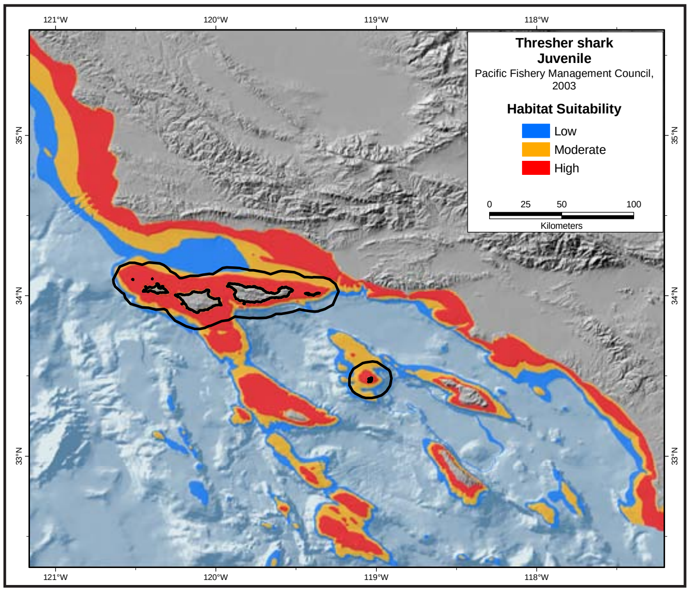

Figure 4.1.5. Juvenile thresher shark habitat suitability off southern California.

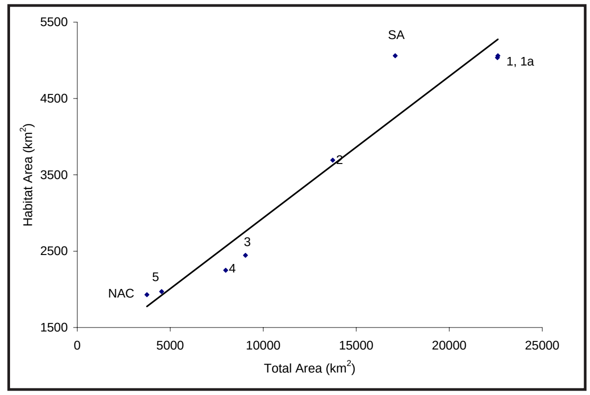

Figure 4.1.6. Regression of total habitat area for juvenile thresher shark and total area within the current and proposed boundary concepts. Numbers indicate concepts and NAC=No Action Concept, SA=Study Area.

Summary

• The thresher shark has the highest commercial landings of all shark species in California.

• Highly suitable habitat for adult thresher sharks consists of waters with depths between 70-3,480 m. Highly suitable habitat for juveniles occurs in depths between 10-180 m.

• Concept 4 provides the most optimal gain of highly suitable habit for adult thresher sharks/total concept area gained relative to the NAC; Concept 2 was the most favorable for juveniles.

Table 4.1.2. Analysis of adult thresher shark habitat suitability within boundary concepts. Numbers in bold indicate an increase in the estimate when compared to the No Action Concept (NAC). OAI estimates shaded in gray represent maximum observed benefit. Delta (D) indicates a rate of change calculation, and is always expressed as a percent change from the NAC.

Concept	Area (km²)	High Suitability Area (km²)	Δ Area (%)	Δ High Suitability Area(%)	OAI (absolute)
NAC	3475	2860	-	-	-
5	4538	**3648**	21.12	27.55	1.30
4	7981	**7089**	113.11	147.87	1.31
3	9044	**8061**	141.50	181.85	1.29
2	13736	**12083**	266.78	322.48	1.21
1	22613	**18576**	503.82	549.51	1.09
1a	22591	**18598**	503.23	550.28	1.09
SA	*17093*	*14554*	*356.42*	*408.88*	*1.15*

Tope *(Galeorhinus galeus)*

Tope distribution ranges from northern British Columbia to central Baja California and the Gulf of California and in temperate waters of the South Pacific, eastern North Atlantic, South Atlantic, and southwestern Indian Ocean (Ebert, 2003). Tope are a coastal-pelagic species, often associated with benthic habitats at depths between 2-471 m. Males and females segregate by sex. Males generally favor deeper waters, whereas females occur closer to shore (Compagno, 1984; Leet *et al*., 2001). Males are also more abundant in the northern part of their range through northern California whereas females are more abundant in southern California (McCain, 2003).

The tope has been one of the most economically important shark fisheries on the Pacific coast of the U.S. Historically, high demand for shark liver oil and fins for soup stock placed heavy pressure on the fishery, which collapsed during the 1940s. Currently, commercial and recreational fisheries target the shark

Table 4.1.3. Analysis of juvenile thresher shark habitat suitability within boundary concepts. Numbers in bold indicate an increase in the estimate when compared to the No Action Concept (NAC). OAI estimates shaded in gray represent maximum observed benefit. Delta (D) indicates a rate of change calculation, and is always expressed as a percent change from the NAC.

Concept	Area (km²)	High Suitability Area (km²)	Δ Area (%)	Δ High Suitability Area(%)	OAI (absolute)
NAC	3475	1930	-	-	-
5	4538	**1971**	21.12	2.12	0.10
4	7981	**2250**	113.11	16.58	0.15
3	9044	**2446**	141.50	26.74	0.19
2	13736	**3692**	266.78	91.30	0.34
1	22613	**5060**	503.82	162.18	0.32
1a	22591	**5035**	503.23	160.88	0.32
SA	*17093*	*5060*	*356.42*	*162.18*	*0.46*

for food and commercial landings have averaged about 75,000 pounds annually since 1990. Little information exists for the recreational fishery (Leet *et al*., 2001).

Broad-scale Patterns

NMFS model results indicate that suitable habitat for adult tope occurs over all substrate types at depths between 0-480 m. In southern California suitable habitat shifted to deeper water (60-480 m). Habitat suitability for adults was, on average, highest off the coast of Washington, Oregon and northern California, moderate in central California, and low throughout southern California. In northern California, highly suitable habitats exist offshore at depths between 140-370 m north of Cape Mendocino and decline to moderate suitability closer to shore (Figure 4.1.7). In central California, moderately suitable habitat occurs at depths of 180-330 m, which extends southward through Cordell Bank, Gulf of the Farallones, and northern Monterey Bay sanctuaries. Low suitability extends deeper to 480 m and shoreward. Habitat suitability was low in southern California at depths between 60-480 m.

Model results for juvenile tope exhibit similar distributions of habitat suitability in regards to bathymetry; however, highly suitable habitat extends further south (to Morro Bay) and high to moderate suitability habitats extend throughout southern California (Figure 4.1.8). Highest suitability values were observed at depths of 100-380 m, and declined to moderate between 60-100 m. Low suitability extends from 0-60 m and 380-480 m.

Analysis of Boundary Concepts

Highest HSP values for adult tope in southern California consisted of a long band of area situated parallel to the mainland and around the Channel Islands. These habitats comprised approximately 541 km^2 of the NAC (Figure 4.1.9). Habitat area increased with increasing boundary concept area, with Concepts 1 and 1a containing the largest amount of high probability habitat (Figure 4.1.10). Mean probability was highest within the NAC and declined as boundary concept size increased (Table 4.1.4). As such, relative OAI results indicated that none of the concepts surpassed mean suitability values for the NAC; however, absolute OAI results, which are based on habitat area, suggest that Concept 5 was the most favorable (Table 4.1.4).

Nearly 90% of the total area of the NAC was considered suitable for juvenile tope; however, only 25% was considered high probability (Figure 4.1.11). While high probability habitat area increased within the larger concepts (Figure 4.1.12), relative to the NAC, mean probability declined (Table 4.1.5). Although each concept contained significant amounts of habitat, mean suitability for each concept did not exceed that of the NAC. Absolute OAI

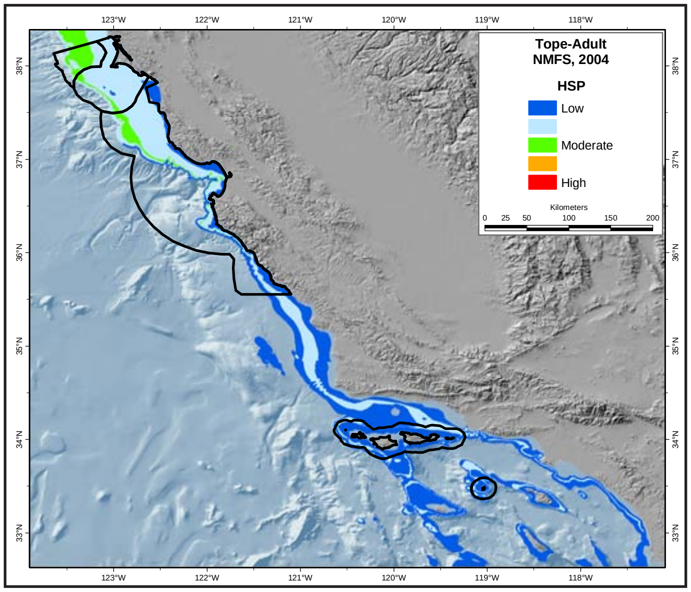

Figure 4.1.7. Adult tope habitat suitability probability (HSP) off central and southern California.

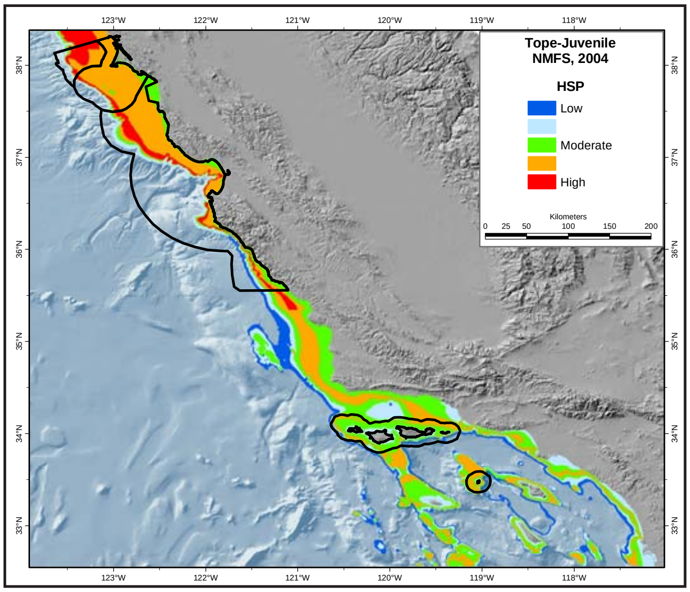

Figure 4.1.8. Juvenile tope habitat suitability probability (HSP) off central and southern California.

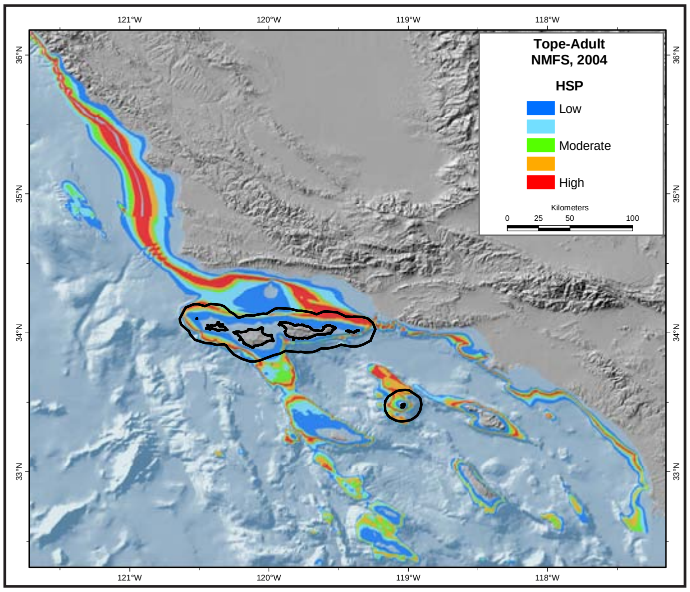

Figure 4.1.9. Adult tope habitat suitability probability (HSP) off southern California.

results indicated that Concept 2 provides the optimal relative proportion of suitable habitat for juvenile tope (Table 4.1.5).

Summary

• Suitable habitat for adult and juvenile tope occurs over all substrates at depths ranging from 0-480 m. Suitability is low in California and increases with increasing latitude.

• Mean habitat suitability decreases with increasing boundary concept size. Of the six boundary concepts being considered, Concept 5 provides the most favorable gain of adult tope habitat/total concept area relative to the NAC. Concept 2 was most favorable for juveniles.

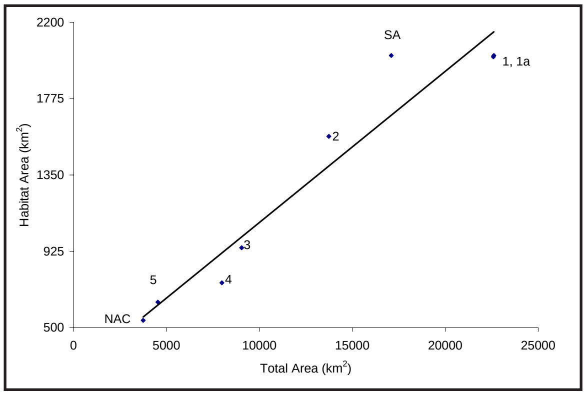

Figure 4.1.10. Regression of high probability habitat area for adult tope and total area within the current and proposed boundary concepts. Numbers indicate concepts and NAC=No Action Concept, SA=Study Area.

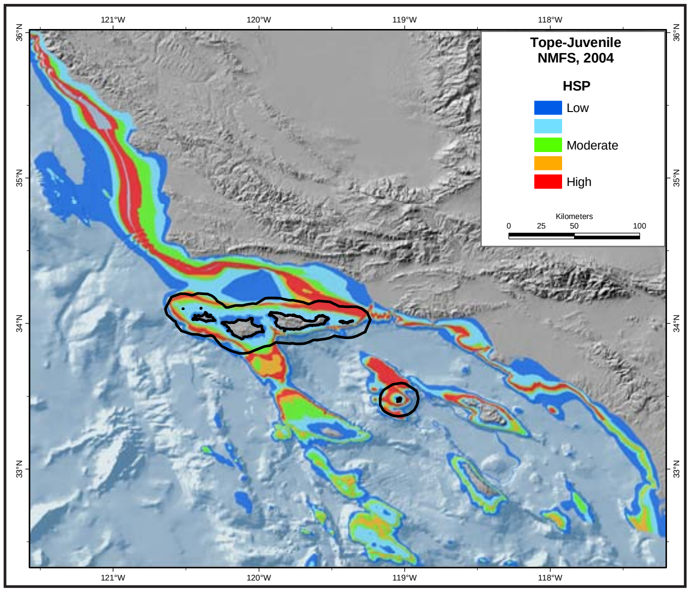

Figure 4.1.11. Juvenile tope habitat suitability probability (HSP) off southern California.

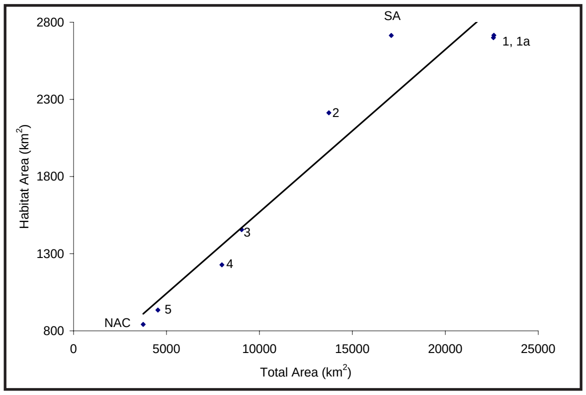

Figure 4.1.12. Regression of high probability habitat area for juvenile tope and total area within the current and proposed boundary concepts. Numbers indicate concepts and NAC=No Action Concept, SA=Study Area.

Table 4.1.4. Analysis of adult tope habitat suitability within boundary concepts. Numbers in bold indicate an increase in the estimate when compared to the No Action Concept (NAC). OAI estimates shaded in gray represent maximum observed benefit. Delta (D) indicates a rate of change calculation, and is always expressed as a percent change from the NAC.

Concept	Area (km^2)	High Probability Area (km^2)	Mean Probability	Δ Area (%)	Δ High Probability Area (%)	OAI (absolute)	OAI (relative)
NAC	3475	541	0.086	-	-	-	-
5	4538	**642**	0.083	21.12	2.12	0.88	-0.17
4	7981	**750**	0.068	113.11	16.58	0.34	-0.19
3	9044	**945**	0.071	141.50	26.74	0.53	-0.12
2	13736	**1565**	0.068	266.78	91.30	0.71	-0.08
1	22613	**2015**	0.052	503.82	162.18	0.54	-0.08
1a	22591	**2008**	0.051	503.23	160.88	0.54	-0.08
SA	*17093*	*2015*	*0.067*	*356.42*	*162.18*	*0.76*	*-0.06*

Table 4.1.5. Analysis of juvenile tope habitat suitability within boundary concepts. Numbers in bold indicate an increase in the estimate when compared to the No Action Concept (NAC). OAI estimates shaded in gray represent maximum observed benefit. Delta (D) indicates a rate of change calculation, and is always expressed as a percent change from the NAC.

Concept	Area (km^2)	High Probability Area (km^2)	Mean Probability	Δ Area (%)	Δ High Probability Area (%)	OAI (absolute)	OAI (relative)
NAC	3475	842	0.490	-	-	-	-
5	4538	**935**	0.500	21.12	11.10	0.53	0.10
4	7981	**1228**	0.400	113.11	45.85	0.41	-0.16
3	9044	**1456**	0.360	141.50	72.88	0.52	-0.19
2	13736	**2213**	0.340	266.78	162.74	0.61	-0.11
1	22613	**2715**	0.270	503.82	222.38	0.44	-0.09
1a	22591	**2700**	0.270	503.23	220.54	0.44	-0.09
SA	*17093*	*2714*	*0.350*	*356.42*	*222.24*	*0.62*	*-0.08*

Leopard shark *(Triakis semifasciata)*

Leopard sharks are found from southern Oregon to Baja California, Mexico, including the Gulf of California (Roedel and Ripley, 1950; Miller and Lea, 1972; Russo, 1975; Talent, 1976; Castro, 1983; Eschmeyer *et al*., 1983; Compagno, 1984; Lineaweaver and Backus, 1984; Adams, 1986; Smith and Abramson, 1990; Emmett *et al*., 1991; Kusher *et al*., 1992; Love, 1996). The leopard shark is most abundant in California bays and estuaries and along the shoreline (Leet *et al*., 2001). Preferred habitats for adults include: sand and mud flats, sand and mud bottoms with scattered rocks near rocky reefs, and shallow kelp beds (Eschmeyer *et al*., 1983; Compagno, 1984; Ferguson and Cailliet, 1990; Emmett *et al*., 1991; Love, 1996). Juvenile habitat is located in sand and mud habitats within coastal bays and estuaries.

The leopard shark is taken as both a food and game fish in California. Since 1991, commercial landings have averaged about 31,000 pounds per year, with the majority of landings occurring south of Point Piedras Blancas. Recreational landings are greater than the commercial catch with an estimated average of 45,000 sharks taken by anglers since 1993 (Leet *et al*., 2001).

Broad-scale Patterns

Along the west coast of the U.S., suitable habitat for adult leopard sharks extends from the shoreline out to depths of 80 m. Suitability was low at depths greater than 40 m while higher values were found nearshore and in coastal bays and estuaries. Suitability of habitats associated with kelp beds located around offshore islands in central California were considered moderate, but decreased to low around the Channel Islands (Figure 4.1.13). Juvenile habitats predominantly occur in bays and estuaries and are not considered in these analyses.

Analysis of Boundary Concepts

In southern California, highest habitat probabilities were found in shallow habitats (<10 m) along the mainland from Pt. Conception through San Diego. Less suitable habitat extends out to 80 m (Figure 4.1.14). Less than 1% of the total area of the NAC contained high probability habitat for adult leopard sharks and approximately 30% was considered low or moderate. No additional habitat with high probability was gained within Concepts 4 and 5. Modest gains were observed as boundaries expand northward and include habitats closer to the mainland. Concepts 1, 1a, and the Study Area contained the greatest amount of high probability habitat. (Table 4.1.6, Figure 4.1.15).

Mean suitability was highest within the NAC and decreased with increasing boundary concept area. OAI

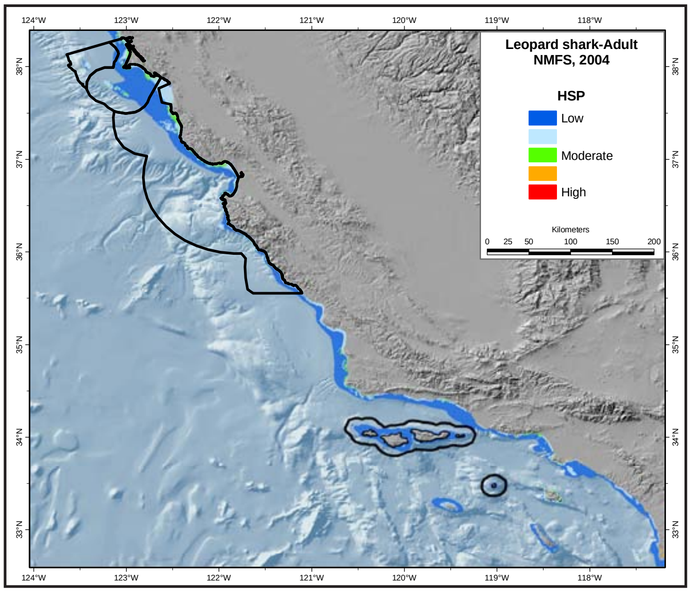

Figure 4.1.13. Adult leopard shark habitat suitability probability (HSP) off central and southern California.

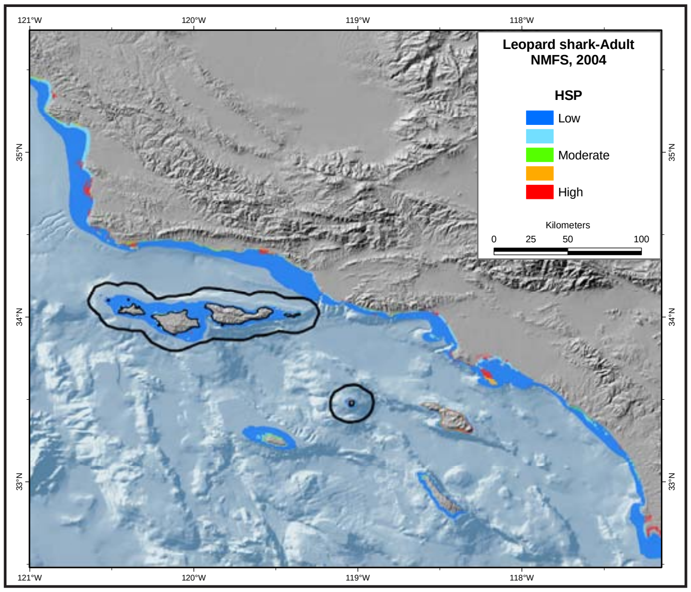

Figure 4.1.14. Adult leopard shark habitat suitability probability (HSP) off southern California.

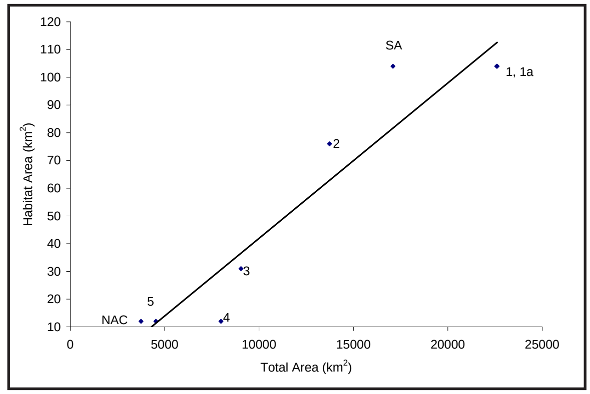

Figure 4.1.15. Regression of high probability habitat area for adult leopard shark and total area within the current and proposed boundary alternatives. Numbers indicate alternatives and NAC=No Action Alternative, SA=Study Area.

results indicated that the Study Area provides the optimal increase of leopard shark habitat/total area gained relative to the NAC; however, this boundary is not under consideration. Therefore, Concept 2 yielded the highest OAI when comparing total habitat area among the boundary concepts with the NAC (Table 4.1.6).

Table 4.1.6. Analysis of adult leopard shark habitat suitability within boundary concepts. Numbers in bold indicate an increase in the estimate when compared to the No Action Concept (NAC). OAI estimates shaded in gray represent maximum observed benefit. Delta (D) indicates a rate of change calculation, and is always expressed as a percent change from the NAC.

Concept	Area (km^2)	High Probability Area (km^2)	Mean Probability	Δ Area (%)	Δ High Probability Area (%)	OAI (absolute)	OAI (relative)
NAC	3475	12	0.017	-	-	-	-
5	4538	12	0.014	21.12	0.00	0.00	-0.84
4	7981	12	0.008	113.11	0.00	0.00	-0.47
3	9044	**31**	0.010	141.50	148.28	1.05	-0.29
2	13736	**76**	0.009	266.78	495.31	1.86	-0.18
1	22613	**104**	0.006	503.82	715.39	1.42	-0.13
1a	22591	**104**	0.006	503.23	715.39	1.42	-0.13
SA	*17093*	*104*	*0.008*	*356.42*	*715.39*	*2.01*	*-0.15*

Summary

- The recreational fishery for leopard sharks is centered in southern California.

- Suitable habitat for adult leopard sharks occurs in waters less than 80 m over sand and mud habitats and areas containing kelp beds. High suitability occurs in coastal areas at depths less than 10 m.

- Mean habitat suitability decreases with increasing boundary concept size. Of the six boundary concepts being considered, Concept 2 provided the most favorable gain of adult leopard shark habitat/total area relative to the NAC.

Pacific angel shark *(Squatina californica)*

Pacific angel sharks are reported to only occur in the eastern Pacific Ocean from southeastern Alaska to the Gulf of California. They are a benthic species usually found on flat sandy bottoms and in sand channels between reefs at depths ranging from 1-200 m (Leet *et al*., 2001). Pacific angel sharks became one of the more highly sought after commercial shark species in the Santa Barbara Channel during the 1980s. Angel sharks were targeted by gill net fishermen where landings exceeded one million pounds during 1985-1986. A minimum size limit and fishing area closures have contributed to a significant reduction in landings since 1986. The demand for angel shark products are now almost wholly provided by Mexican imports. No significant recreational fishery exists for angel sharks (Leet *et al*., 2001).

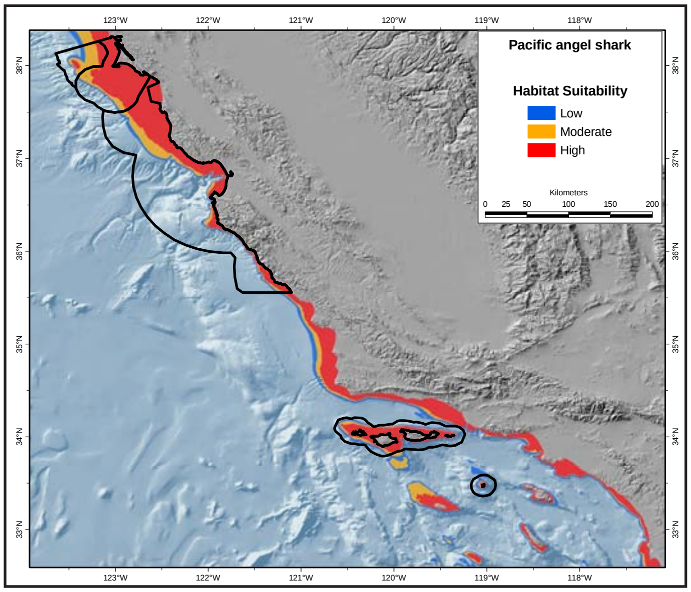

Figure 4.1.16. Pacific angel shark habitat suitability off central and southern California.

Broad-scale Patterns

The model developed for Pacific angel shark determined that highly suitable habitat occurs over soft substrates at depths >100 m, moderate suitability occurs over soft substrates between 100-150 m, and low suitability between 150-200 m. Along the coast of California, highly suitable habitat for Pacific angel sharks occurs on most of the continental shelf, comprising significant areas of the Gulf of the Farallones and Monterey Bay national marine sanctuaries and throughout southern California and the CINMS (Figure 4.1.16).

No fisheries data were available for testing model performance.

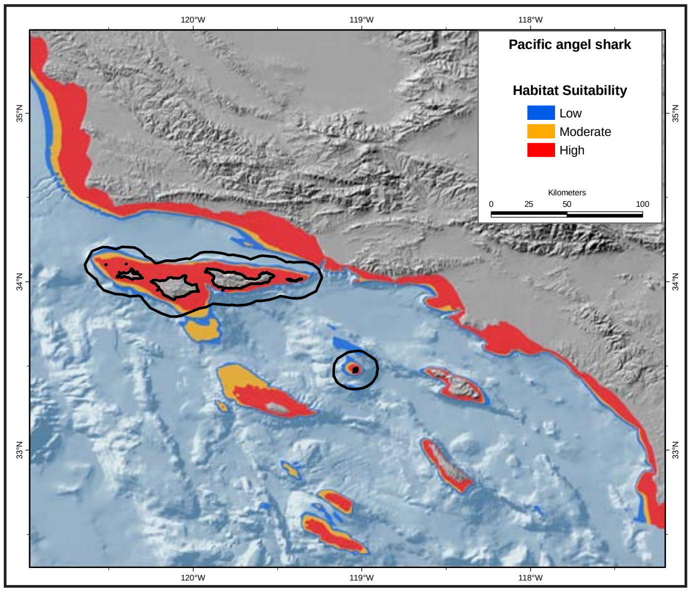

Figure 4.1.17. Pacific angel shark habitat suitability off southern California.

Analysis of Boundary Concepts

Approximately 32% of the total area within the current CINMS was considered highly suitable for Pacific angel sharks; 14% was moderately suitable (Figure 4.1.17). Small gains (>1%) of highly suitable habitat were observed within Concepts 4 and 5, and an increase of 200 km^2 occurred in Concept 3. Significant gains were also observed within the larger boundary concepts (Figure 4.1.18).

OAI values for the six concepts indicated that the Study Area provided the most favorable gain of highly suitable habitat for angel sharks per total area gained relative to the NAC (Table 4.1.7); however this boundary is not under consideration. Therefore, Concepts 1 and 1a were determined to be the most favorable boundary concepts with regard to angel shark habitat.

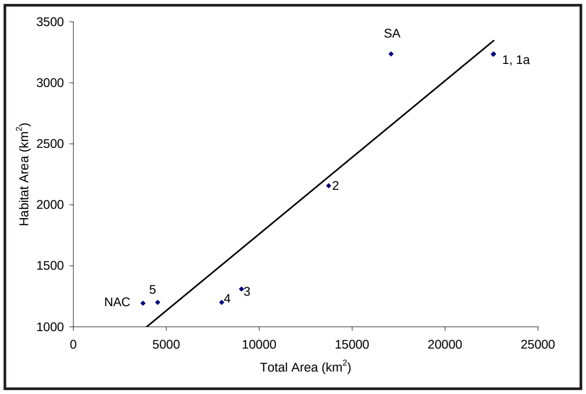

Figure 4.1.18. Regression of total habitat area for Pacific angel shark and total area within the current and proposed boundary concepts. Numbers indicate concepts and NAC=No Action Concept, SA=Study Area.

Summary

- Commercial and recreational fisheries for Pacific angel shark are insignificant in California waters.

- Highly suitable habitat was considered to occur over soft substrates at depths ranging from 0-100 m.

• Of the six boundary concepts being considered, Concepts 1 and 1a provide the greatest proportional change of suitable habitat for Pacific angel shark/total area in relation to the NAC.

Table 4.1.7. Analysis of Pacific angel shark habitat suitability within boundary concepts. Numbers in bold indicate an increase in the estimate when compared to the No Action Concept (NAC). OAI estimates shaded in gray represent maximum observed benefit. Delta (D) indicates a rate of change calculation, and is always expressed as a percent change from the NAC.

Concept	Area (km^2)	High Suitability Area (km^2)	Δ Area (%)	Δ High Suitability Area (%)	OAI (absolute)
NAC	3475	1194	-	-	-
5	4538	**1201**	21.12	0.59	0.06
4	7981	**1201**	113.11	0.59	0.01
3	9044	**1310**	141.50	9.72	0.16
2	13736	**2157**	266.78	80.65	0.69
1	22613	**3237**	503.82	171.11	0.77
1a	22591	**3234**	503.23	170.85	0.77
SA	*17093*	*3237*	*356.42*	*171.11*	*1.09*

Pacific Sardine *(Sardinops sagax)*

Pacific sardines are a small pelagic, schooling fish that inhabit coastal subtropical and temperate waters. They also occur in estuaries, but are most common in the nearshore/offshore environment. Pacific sardine are highly mobile and move seasonally along the coast. The overall population has three distinct stocks: northern (northern Baja California to Alaska), southern (off Baja California), and Gulf of California. The northern stock is federally managed by the Coastal Pelagic Species Fishery Management Plan (PFMC, 1998). Spawning grounds have been identified to occur in southern California and northern Baja California and an adult feeding ground has been determined to occur in central and northern California. Eggs and larvae occur nearly everywhere adults are found and are most abundant between 14°C and 15°C (see Chapter 4.4 for a more detailed discussion about larval distribution). Habitat suitability is difficult to determine due to their lack of affinity to substrate and bathymetry and their spatial and seasonal distribution is highly influenced by sea surface temperature (PFMC, 1998). As such, we present no maps of suitability.

Similar to the northern anchovy, Pacific sardines are important components of the trophic web of the California Current system. Eggs and larvae are consumed by invertebrate and vertebrate planktivores, and adults and juveniles are consumed by a variety of predators, including: fish (yellowtail, barracuda, tuna, mackerel, sharks), seabirds (pelicans, gulls, and cormorants), and marine mammals (sea lions, seals, porpoises, and whales).

Northern anchovy *(Engraulis mordax)*

Northern anchovy are a pelagic, schooling species that are typically found at the top of the water column. Northern anchovy are distributed from Queen Charlotte Island, British Columbia, to Magdalena Bay, Baja California. The overall population is divided into northern, central, and southern stocks. The southern stock is found entirely within Mexican waters, while the northern and central stocks are managed by the Coastal Pelagic Species Fishery Management Plan (PFMC, 1998). The central stock supports significant commercial fisheries in the U.S. and Mexico, and ranges from San Francisco, to Punta Baja, Baja California. The majority of this stock is located in the Southern California Bight. Since northern anchovy are pelagic, habitat suitability is difficult to determine because they display little or no preference to substrate and bathymetry. Instead, northern anchovy distribution is regulated more by sea surface temperature and currents which are highly variable. As such, we do not present maps of habitat suitability for this species.

The central stock is typically found in waters that range from 12°-21°C. There is high regional variation in age composition and size, with older and larger individuals further offshore and to the north. These patterns are accentuated during El Nino years (Methot, 1989). Juveniles are typically found near shore (at depths <90 m), which support at least 70% of the juvenile population (Methot, 1981; Smith, 1985). All life stages are found in the surface waters of the EZZ. See Chapter 4.4 for a further description of northern anchovy larval distribution.

Northern anchovy are an important component of the southern California trophic structure. Eggs and larvae are prey for a wide variety of invertebrate and vertebrate planktivores. Juveniles and adults are important food sources for a wide variety of predators, including: fish, birds (California brown pelican and least tern), and mammals. Furthermore, explicit links between brown pelican breeding success and anchovy abundance have been documented (PFMC, 1998).

Bocaccio *(Sebastes paucispinis)*

Bocaccio range from central Baja California to Kodiak Island, Alaska (Miller and Lea, 1972; Hart, 1973) and are most abundant between Oregon and northern Baja California (Love *et al*., 2002). Bocaccio are considered a middle shelf species occurring at depths between 50-300 m (Allen and Smith, 1988). Adults are generally found in schools over rocky areas or as solitary individuals among rocky substrates (Yoklavich *et al*., 2000). Juvenile bocaccio typically occur in shallower waters than adults (Wilkins, 1980; Yoklavich *et al*., 2000) and settle over rocky substrates with algae cover or sandy areas with eelgrass (Love *et al*., 2002). Larvae are commonly found in the Southern California Bight and areas offshore of Monterey Bay (Leet *et al*., 2001; Love *et al*., 2002). Analysis of bocaccio larval data can be seen in Chapter 4.4.

Historically, bocaccio was the dominant rockfish in California's longline and bottom trawl fisheries. Prior to 1970, six million pounds were landed annually by California fisheries. Landings peaked in 1983 (15 million pounds) and have since declined steadily (0.5 million pounds in 1998). Recreational catches have shown similar declines (Leet *et al*., 2001).

Broad-scale Patterns

NMFS HSP model results indicate that suitable habitat for adult bocaccio occurs between 30-380 m with suitability being higher over hard substrates. Moderate suitability values were widely dispersed throughout California's offshore hard bottom habitats, with considerable amounts located within the central California sanctuaries (Cordell Bank, Gulf of the Farallones, and Monterey Bay) and the Channel Islands NMS (Figure 4.1.19). Soft substrates at depths between 30-380 m were predicted as low suitability.

Similarly, habitat suitability for juvenile bocaccio were highest over hard substrates but at shallower depths (0-200 m). The majority of highly suitable habitat was located nearshore from northern California to Point Conception. Hard substrates south of Point Conception were lower than those to the north (Figure 4.1.20). Suitability values for soft substrates were low in California waters, while suitability was higher over shallow soft substrates in Oregon and Washington.

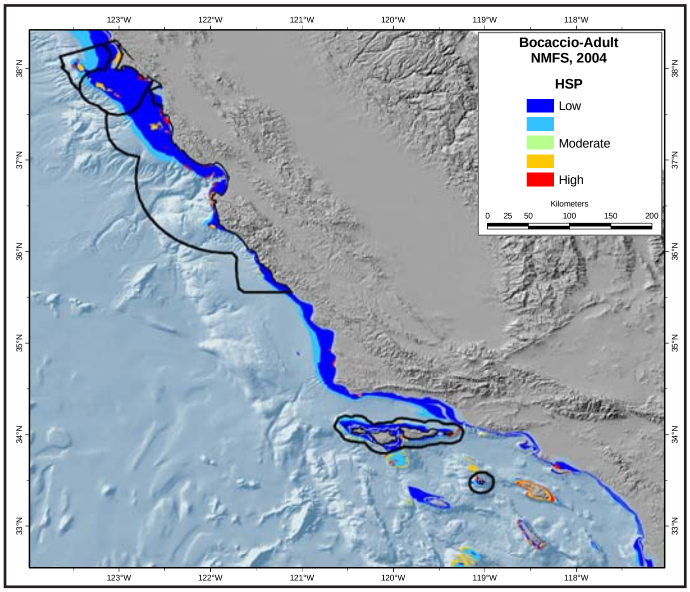

Figure 4.1.19. Adult bocaccio habitat suitability probability (HSP) off central and southern California.

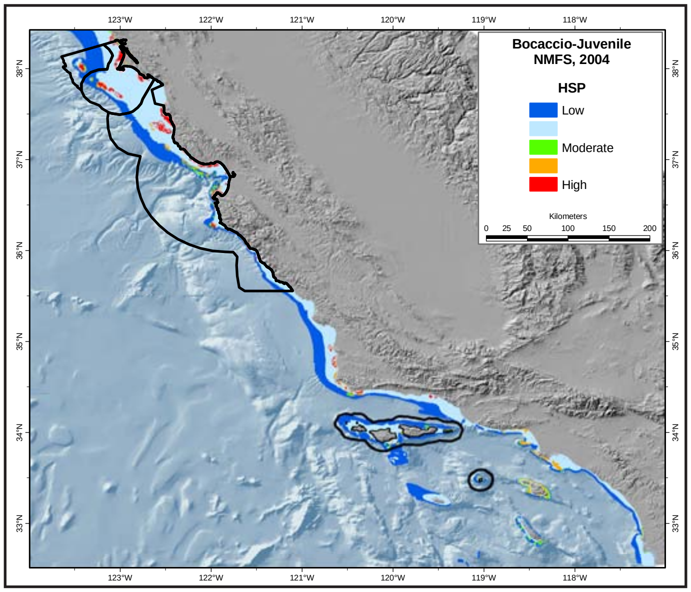

Figure 4.1.20. Juvenile bocaccio habitat suitability probability (HSP) off central and southern California.

Analysis of Boundary Concepts

Approximately 1,700 km^2 of habitat was modeled as suitable for adult bocaccio within the current CINMS (NAC) boundary (Figure 4.1.21); however, only 225 km^2 were classified as high probability habitat and were located in the southern portion of the sanctuary and around Anacapa Island. Additional habitat located south of Santa Rosa Island was included in Concepts 4 and 5, most of which was low probability. Modest gains of high probability habitat were observed in the larger concepts (Figure 4.1.22). Mean habitat probability was highest for the NAC (Table 4.1.8); however, on average, suitability was low throughout southern California.

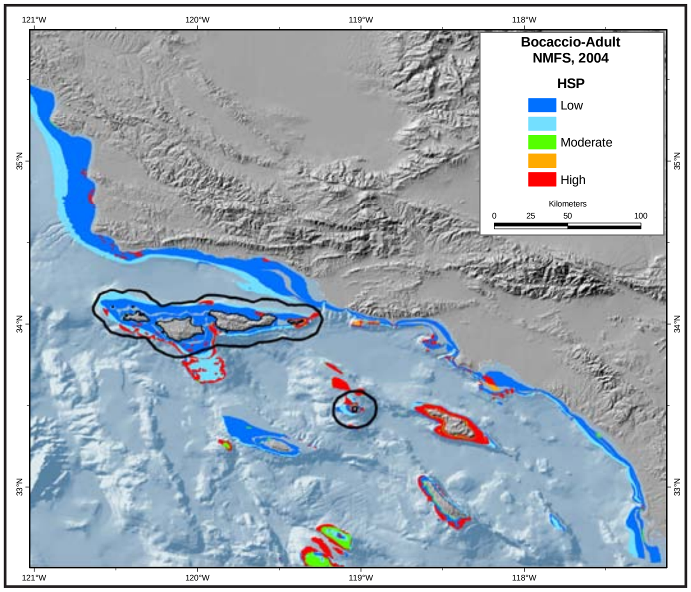

Figure 4.1.21. Adult bocaccio habitat suitability probability (HSP) off southern California.

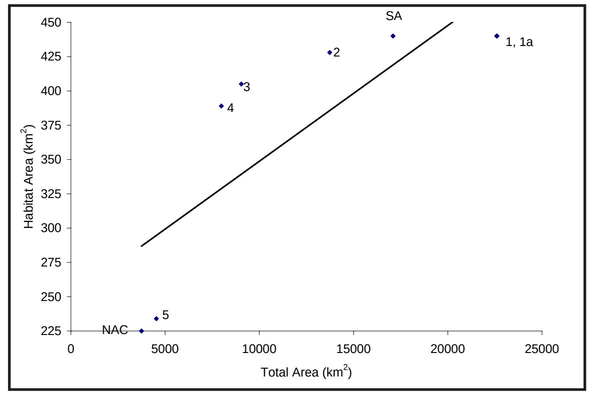

Figure 4.1.22. Regression of high probability habitat area for adult bocaccio and total area within the current and proposed boundary concepts. Numbers indicate concepts and NAC=No Action Concept, SA=Study Area.

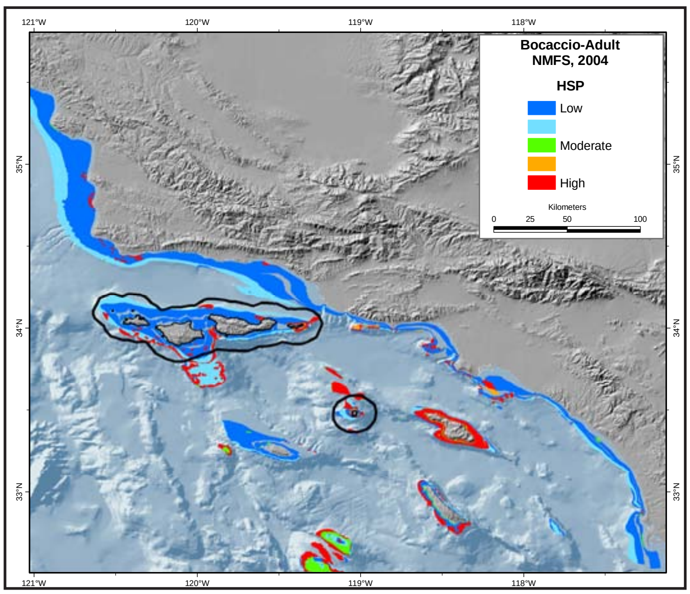

Figure 4.1.23. Juvenile bocaccio habitat suitability probability (HSP) off southern California.

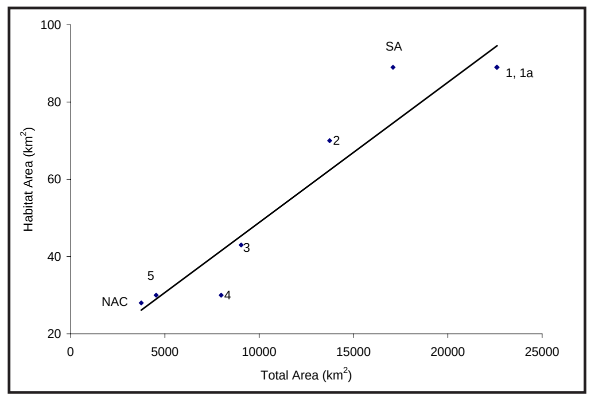

Figure 4.1.24. Regression of high probability habitat area for juvenile bocaccio and total area within the current and proposed boundary concepts. Numbers indicate concepts and NAC=No Action Concept, SA=Study Area.

Similar patterns of habitat distribution were observed for juvenile bocaccio; however, high probability habitats were significantly reduced (Figure 4.1.23). Only 28 km^2 of area was classifed as high quality habitat. Concepts 2, 1, 1a, and the Study Area contained greater amounts of high probability habitat (Figure 4.1.24) than the NAC; however, in comparison, mean probability was highest for the NAC (Table 4.1.9). These habitats were located south of Santa Rosa Island and around Anacapa Island. Additional areas of high probability habitat were located close to the mainland and around San Clemente and Santa Catalina Islands.

OAI calculations for both adult and juvenile bocaccio indicate that Concept 2 provides the optimal proportional gain of total habitat/total area gained relative to that for the NAC. OAI results for juvenile bocaccio indicated that Concept 4 demonstrated the most optimal gain of habitat/total area relative to the NAC. Mean habitat probability was highest for the NAC for both adults and juveniles.

Summary

• Commercial and recreational landings of bocaccio have declined over the past twenty years.

• The most suitable habitat for bocaccio in southern California occurs over hard substrates at depths ranging from 0-200 m, for juveniles and 30-380 m for adults.

• Of the six boundary concepts being considered, Concept 2 provides the most favorable gain of habitat for adult and juvenile bocaccio/total area relative to the NAC.

• Mean habitat probability was highest within the NAC.

Table 4.1.8. Analysis of adult bocaccio habitat suitability within boundary concepts. Numbers in bold indicate an increase in the estimate when compared to the No Action Concept (NAC). OAI estimates shaded in gray represent maximum observed benefit. Delta (D) indicates a rate of change calculation, and is always expressed as a percent change from the NAC.

Concept	Area (km²)	High Probability Area (km²)	Mean Probability	∆ Area (%)	∆ High Probability Area (%)	OAI (absolute)	OAI (relative)
NAC	3475	225	0.030	-	-	-	-
5	4538	**234**	0.028	21.12	4.10	0.19	-0.32
4	7981	**389**	0.023	113.11	72.52	0.64	-0.21
3	9044	**405**	0.021	141.50	79.84	0.56	-0.21
2	13736	**428**	0.017	266.78	89.85	0.34	-0.16
1	22613	**440**	0.012	503.82	95.44	0.19	-0.12
1a	22591	**440**	0.012	503.23	95.44	0.19	-0.12
SA	*17093*	*440*	*0.016*	*356.42*	*95.44*	*0.27*	*-0.13*

Table 4.1.9. Analysis of juvenile bocaccio habitat suitability within boundary concepts. Numbers in bold indicate an increase in the estimate when compared to the No Action Concept (NAC). OAI estimates shaded in gray represent maximum observed benefit. Delta (D) indicates a rate of change calculation, and is always expressed as a percent change from the NAC.

Concept	Area (km²)	High Probability Area (km²)	Mean Probability	∆ Area (%)	∆ High Probability Area (%)	OAI (absolute)	OAI (relative)
NAC	3475	28	0.096	-	-	-	-
5	4538	**30**	0.081	21.12	4.10	0.24	-0.74
4	7981	**30**	0.048	113.11	72.52	0.04	-0.44
3	9044	**43**	0.048	141.50	79.84	0.36	-0.35
2	13736	**70**	0.051	266.78	89.85	0.55	-0.18
1	22613	**89**	0.043	503.82	95.44	0.42	-0.11
1a	22591	**89**	0.043	503.23	95.44	0.42	-0.11
SA	*17093*	*89*	*0.057*	*356.42*	*95.44*	*0.59*	*-0.11*

Cowcod *(Sebastes levis)*

Cowcod range from Ranger Bank and Guadalupe Island, Baja California north to central Oregon. The majority of the preferred habitat for cowcod occurs in the Southern California Bight (Leet *et al*., 2001). Cowcod occur at depths from 21 to 366 m (Butler *et al*., 2003; Miller and Lea, 1972); adults generally favor depths of 180-275 m and juveniles are common at 20-100 m (Allen, 1982; Butler *et al*., 1999; Love *et al*., 2002; Butler *et al*., 2003). Adults are usually found over high-relief rocky habitats (Allen, 1982) and are generally solitary, but may aggregate (Love *et al*., 1990). Subadults have been found in association with ledges in submarine canyons and in crevices of isolated rock outcrops surrounded by mud (Yoklavich *et al*., 2000). Juveniles occur over sandy and clay bottoms (Love *et al*., 2002; Butler *et al*., 2003). Larval cowcod are almost exclusive to southern California in waters over the continental shelf adjacent to the northern Channel Islands at depths <2000 m (MacGregor, 1986; Moser *et al*., 2000).

Cowcod are important to the commercial and recreational fisheries. Combined, these fisheries amassed landings of 213 tons in 1976, which had declined to 14 tons by 1999. Exploitation of fishing grounds near major ports has been high and productive fishing grounds in the Southern California Bight are found far offshore (Leet *et al*., 2001).

Broad-scale Patterns

Suitable habitats for adult cowcod occur over hard substrates between 70-360 m and are intermittently dispersed along the continental shelf between 45°-32.5°N latitude (Figure 4.1.25). Large concentrations of adult habitat are found near Monterey Bay and the Channel Islands. Suitable habitat for juveniles was predicted to occur over both hard and soft substrates at depths between 0-90 m. Suitable habitat for juveniles extends from Pt. Arena (40°N) through southern California and is highest over hard substrates along the mainland from the northern sanctuaries through Point Conception (Figure 4.1.26).

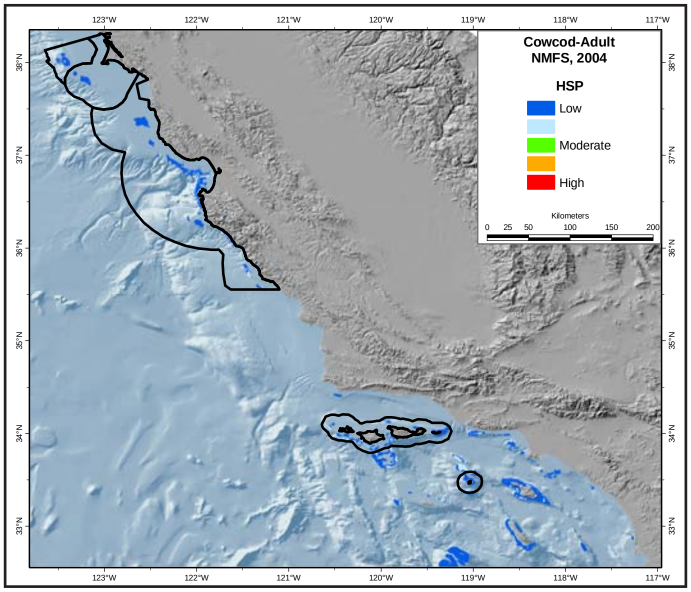

Figure 4.1.25. Adult cowcod habitat suitability probability (HSP) off central and southern California.

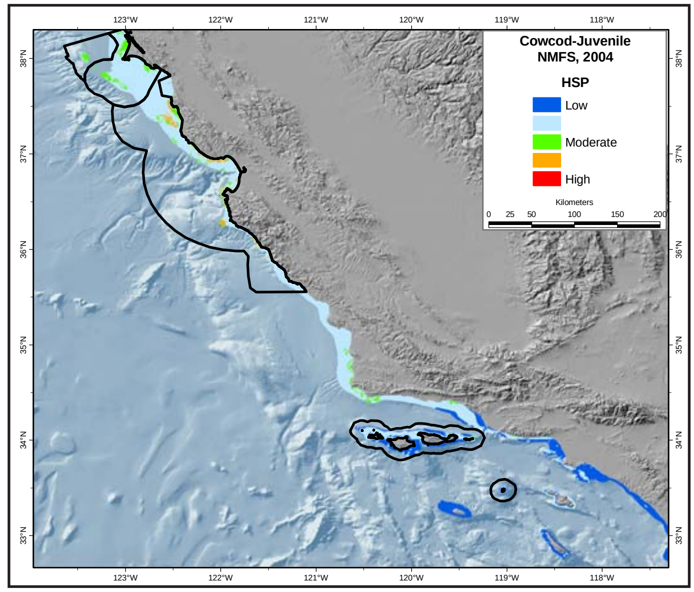

Figure 4.1.26. Juvenile cowcod habitat suitability probability (HSP) off central and southern California.

Analysis of Boundary Concepts

Approximately 1% (126 km^2) of the total area within the NAC was considered high probability habitat for adult cowcod (Figure 4.1.27). Similar to bocaccio, adult cowcod habitats were primarily located south of the northern Channel Islands. Additional areas were located around San Clemente and Santa Catalina Islands and near Cortes Bank. The amount of high probability habitat increased significantly within Concepts 3 and 4; small gains

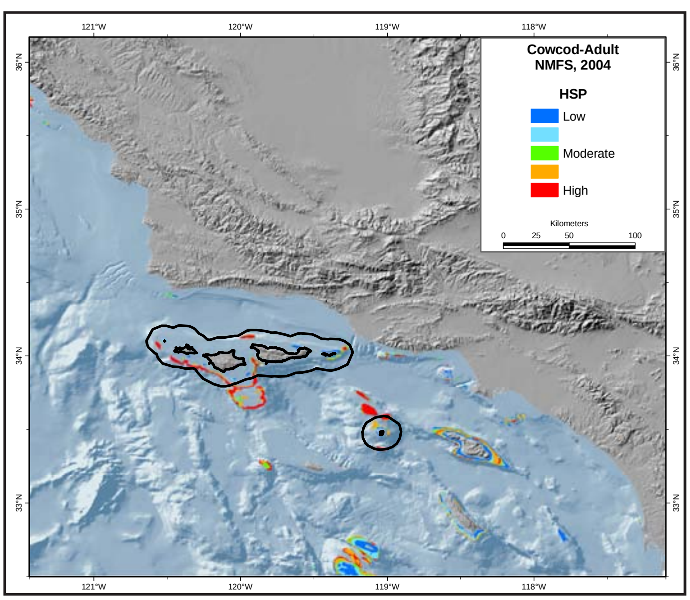

Figure 4.1.27. Adult cowcod habitat suitability probability (HSP) off southern California.

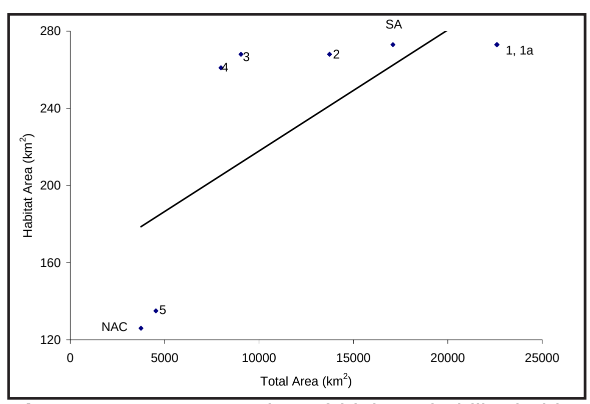

Figure 4.1.28. Regression of high probability habitat area for adult cowcod and total area within the current and proposed boundary concepts. Numbers indicate concepts and NAC=No Action Concept, SA=Study Area.

Table 4.1.10. Analysis of adult cowcod habitat suitability within boundary concepts. Numbers in bold indicate an increase in the estimate when compared to the No Action Concept (NAC). OAI estimates shaded in gray represent maximum observed benefit. Delta (D) indicates a rate of change calculation, and is always expressed as a percent change from the NAC.

Concept	Area (km²)	High Probability Area (km²)	Mean Probability	Δ Area (%)	Δ High Probability Area (%)	OAI (absolute)	OAI (relative)
NAC	3475	126	0.007	-	-	-	-
5	4538	**135**	0.006	21.12	7.32	0.35	-0.68
4	7981	**261**	0.007	113.11	107.23	0.95	0.00
3	9044	**268**	0.006	141.50	112.33	0.79	-0.10
2	13736	**268**	0.004	266.78	112.86	0.42	-0.16
1	22613	**273**	0.002	503.82	116.38	0.23	-0.14
1a	22591	**273**	0.002	503.23	116.38	0.23	-0.14
SA	*17093*	***273***	*0.002*	*356.42*	*116.38*	*0.33*	*-0.16*

were observed for concepts 1, 1a, 2, and the Study Area relative to Concepts 3 and 4 (Figure 4.1.28). As such, Concept 4 provided the most favorable gain of habitat for adult cowcod and total area gained relative to the NAC (Table 4.1.10).

High probability habitat for juvenile cowcod were limited within southern California. A considerable amount of area within the NAC was considered suitable; however, only 28 km² was determined to be high probaility (Figure 4.1.29). Other areas of high probability were observed in small patches adjacent to the mainland and around Santa Catalina Island. No additional gains were included within Concepts 4 and 5; a modest gain was observed within Concept 3 and considerable gains were noted within the larger concepts (4.1.30). Mean probability was greatest within the NAC (Table 4.1.11) and decreased with increasing concept size. Concept 2 yielded the highest OAI and was considered the optimal boundary concept for juvenile cowcod habitat.

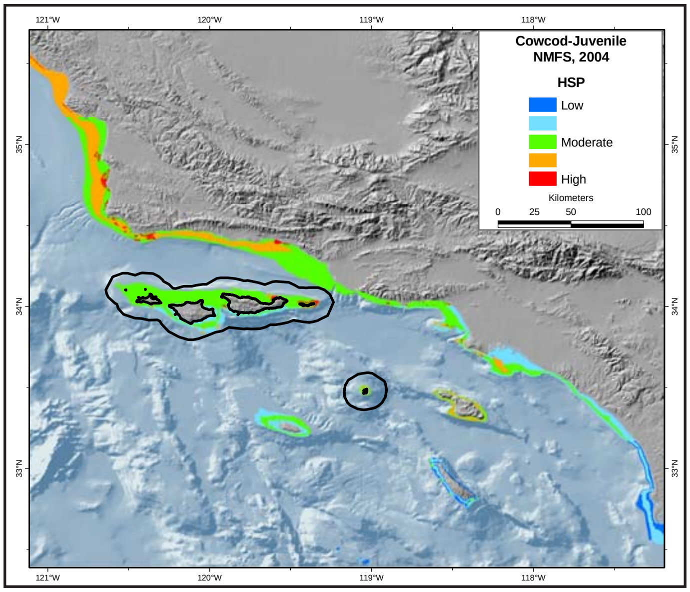

Figure 4.1.29. Juvenile cowcod habitat suitability probability (HSP) off southern California.

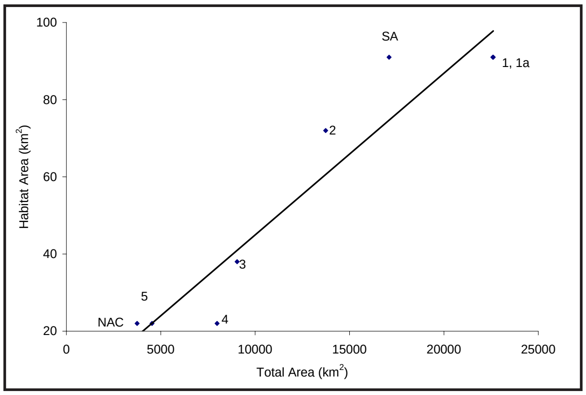

Figure 4.1.30. Regression of high probability habitat area for juvenile cowcod and total area within the current and proposed boundary concepts. Numbers indicate concepts and NAC=No Action Alternative, SA=Study Area.

Summary

• Commercial and recreational landings of cowcod have declined steadily since 1976.

• Suitable habitat for adult cowcod was determined to occur over hard substrates between 70-360 m; juvenile habitat occurred over hard and soft substrates between 0-90 m.

• Mean habitat probability decreases with increasing boundary concept size; however, Concept 4 provides the most favorable gain for adult cowcod habitat area relative to the NAC, while Concept 2 was the optimal for juvenile cowcod.

Table 4.1.11. Analysis of juvenile cowcod habitat suitability within boundary concepts. Numbers in bold indicate an increase in the estimate when compared to the No Action Concept (NAC). OAI estimates shaded in gray represent maximum observed benefit. Delta (D) indicates a rate of change calculation, and is always expressed as a percent change from the NAC.

Concept	Area (km^2)	High Probability Area (km^2)	Mean Probability	Δ Area (%)	Δ High Probability Area (%)	OAI (absolute)	OAI (relative)
NAC	3475	22	0.066	-	-	-	-
5	4538	22	0.055	21.12	0.00	0.00	-0.79
4	7981	22	0.031	113.11	0.00	0.00	-0.47
3	9044	**38**	0.031	141.50	67.64	0.48	-0.37
2	13736	**72**	0.036	266.78	217.56	0.82	-0.17
1	22613	**91**	0.032	503.82	299.91	0.60	-0.10
1a	22591	**91**	0.032	503.23	299.91	0.60	-0.10
SA	*17093*	***91***	*0.042*	*356.42*	*299.91*	*0.84*	*-0.10*

Lingcod *(Ophiodon elongatus)*
Lingcod range from Baja California to Kodiak Island in the Gulf of Alaska with a center of abundance located near British Columbia. Lingcod becomes less common toward the southern end of their range (Leet *et al*., 2001). Lingcod are generally found from the intertidal zone to depths of 475 m, but are most common on slopes of submerged banks with kelp and eelgrass beds, or habitats of ridges and boulders at depths <100 m (Giorgi and Congleton, 1984; Allen and Smith, 1988; Shaw and Hassler, 1989; NOAA, 1990; Emmett *et al*., 1991). Juveniles are usually found at shallower depths over sandy and rocky substrates, and are frequently found in estuaries (Hart, 1973; Fitch and Schulz, 1978; Shaw and Hassler, 1989; Emmett *et al*., 1991). Eggs and larvae occur in nearshore areas and small juveniles settle in estuaries and shallow waters along the coast (Emmett *et al*., 1991).

Lingcod support an important commercial and recreational fishery throughout their range. Lingcod are caught commercially by bottom trawls, handlines, set nets, and set lines and landings of this species averaged nearly three million pounds in California from 1972-1982. Landings oscillated between 1982-1989 and had declined to 313,000 pounds by 1999. Recently there has been a shift away from the commercial fishery towards recreational catches. Approximately 890,000 pounds are landed annually by the recreational fishery in California. Landings from both the commercial and recreational fisheries occur predominantly in central and northern California (Leet *et al*., 2001).

Broad-scale Patterns
Hard substrates at depths between 0-430 m were suitable bottom types for adult lingcod. Shallower depths (<120 m) provided greater predicted habitat probabilities. In California waters, these habitats are found on the shallow portions of the continental shelf, offshore banks, and around the Farallon and Channel Islands (Figure 4.1.31). Suitable habitats for juveniles were predicted to occur on all substrate types over the majority of the west coast continental shelf to depths of 180 m. Latitude strongly influenced juvenile lingcod habitat suitability; suitability was higher in northern latitudes. Suitability was low throughout the continental shelf of California (Figure 4.1.32).

Analysis of Boundary Concepts
Habitat probabilities were highest on hard substrates at depths <200 m and low at depths >200 m. The majority of suitable habitat for adult lingcod occurred in shallow waters among rocky bottoms or soft substrates with eelgrass and/or kelp beds along the mainland and around the northern Channel Islands (Figure 4.1.33). Approximately 73 km^2 of the Channel Islands Sanctuary was considered high probability habitat; areas of moderate probability occurred among the southern islands. No additional habitat was gained within Concept 5, while an additional 7 km^2 was gained within Concept 4. The remaining concepts gained habitat along the mainland, nearly

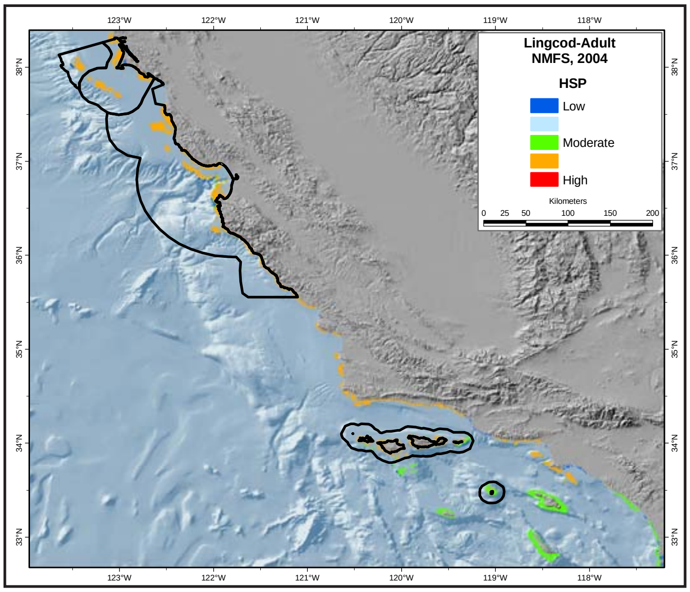

Figure 4.1.31. Adult lingcod habitat suitability probability (HSP) off central and southern California.

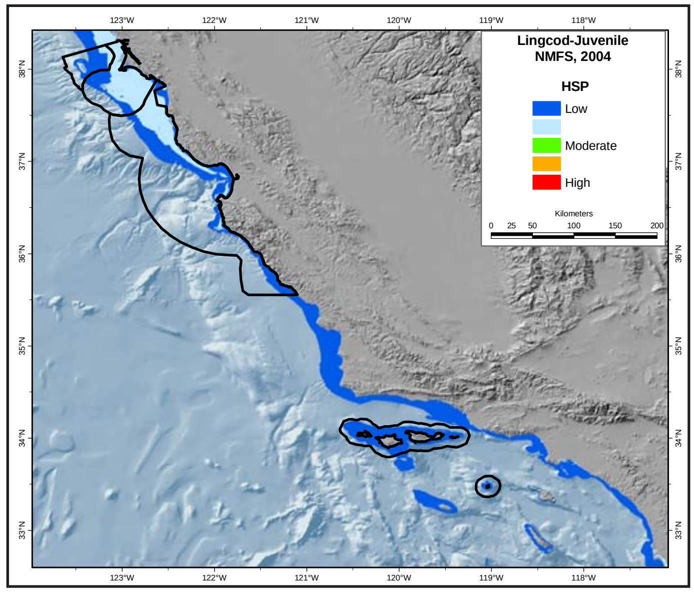

Figure 4.1.32. Juvenile lingcod habitat suitability probability (HSP) off central and southern California.

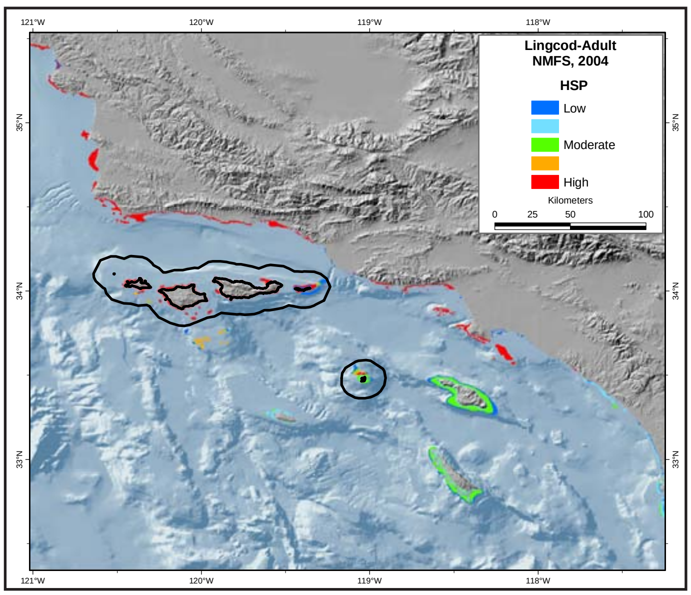

Figure 4.1.33. Adult lingcod habitat suitability probability (HSP) off southern California.

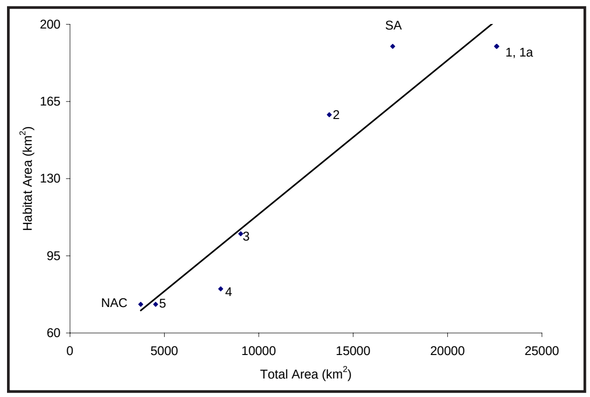

Figure 4.1.34. Regression of high probability habitat area for adult lingcod and total area within the current and proposed boundary concepts. Numbers indicate concepts and NAC=No Action Concept, SA=Study Area.

tripling that of the NAC within Concepts 1, 1a, and the Study Area (Figure 4.1.34). Mean habitat suitability was low for all the concepts and none were higher than the NAC (Table 4.1.12).

Overall, significantly more habitat was considered suitable for juvenile lingcod than adults. As such, almost half of the total area within the CINMS is considered suitable for juvenile lingcod (Figure 4.1.35) and 500 km^2 were considered as high probability. Significant increases of high probability habitat were observed in the larger concepts (Figure 4.1.36, Table 4.1.13). Mean habitat probability was highest for the NAC and declined with increasing boundary concept size.

OAI results for mean habitat suitability indicate that none of the concepts contain higher quality habitat for adults and juveniles, on average, than the NAC. When comparing the total amount of high probability habitat available for adults and juveniles, Concept 2 provides the optimal increase of habitat/total area gained relative to the NAC (Tables 4.1.12 and 4.1.13).

Summary

• Fisheries for lingcod are prevalent in central and northern California, and catches have declined over the past 30 years.

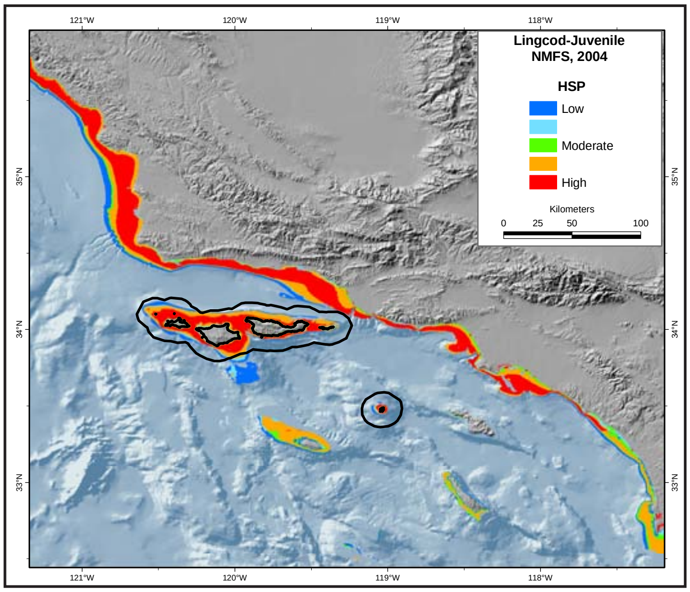

Figure 4.1.35. Juvenile lingcod habitat suitability probability (HSP) off southern California.

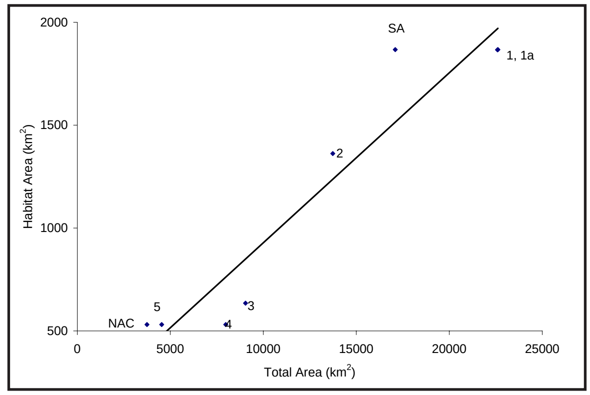

Figure 4.1.36. Regression of high probability habitat area for juvenile lingcod and total area within the current and proposed boundary concepts. Numbers indicate concepts and NAC=No Action Concept, SA=Study Area.

Table 4.1.12. Analysis of adult lingcod habitat suitability within boundary concepts. Numbers in bold indicate an increase in the estimate when compared to the No Action Concept (NAC). OAI estimates shaded in gray represent maximum observed benefit. Delta (D) indicates a rate of change calculation, and is always expressed as a percent change from the NAC.

Concept	Area (km^2)	High Probability Area (km^2)	Mean Probability	Δ Area (%)	Δ High Probability Area (%)	OAI (absolute)	OAI (relative)
NAC	3475	73	0.017	-	-	-	-
5	4538	73	0.014	21.12	0.00	0.00	-0.84
4	7981	**80**	0.009	113.11	9.49	0.08	-0.42
3	9044	**105**	0.010	141.50	44.49	0.31	-0.29
2	13736	**159**	0.009	266.78	118.53	0.44	-0.18
1	22613	**190**	0.006	503.82	160.49	0.32	-0.13
1a	22591	**190**	0.006	503.23	160.49	0.32	-0.13
SA	*17093*	*190*	*0.008*	*356.42*	*160.49*	*0.45*	*-0.15*

Table 4.1.13. Analysis of juvenile lingcod habitat suitability within boundary concepts. Numbers in bold indicate an increase in the estimate when compared to the No Action Concept (NAC). OAI estimates shaded in gray represent maximum observed benefit. Delta (D) indicates a rate of change calculation, and is always expressed as a percent change from the NAC.

Concept	Area (km^2)	High Probability Area (km^2)	Mean Probability	Δ Area (%)	Δ High Probability Area (%)	OAI (absolute)	OAI (relative)
NAC	3475	531	0.066	-	-	-	-
5	4538	531	0.056	21.12	0.00	0.00	-0.72
4	7981	**531**	0.033	113.11	0.00	0.00	-0.44
3	9044	**635**	0.032	141.50	19.59	0.14	-0.36
2	13736	**1362**	0.035	266.78	156.28	0.59	-0.18
1	22613	**1867**	0.029	503.82	251.20	0.50	-0.11
1a	22591	**1866**	0.029	503.23	250.98	0.50	-0.11
SA	*17093*	*1867*	*0.039*	*356.42*	*251.20*	*0.70*	*-0.11*

• Suitable habitat for adult lingcod occurs over hard and vegetated soft substrates at depths between 0-430 m; higher probability occurs at depths between 0-120 m. Juvenile lingcod habitat consists of both hard and soft substrates at depths <180 m. Habitat probability for both adults and juveniles is higher in the northwest and decreases towards the south.

• Mean habitat probability decreases with increasing boundary concept size. Of the six boundary concepts being considered, Concept 2 provides the most favorable gain of adult and juvenile lingcod habitat/total concept area relative to the NAC.

Giant seabass *(Stereolipis gigas)*

The giant seabass ranges from Humboldt Bay, California to the tip of Baja California, Mexico, and occurs in the northern region of the Gulf of California. Within California it is rare north of Point Conception. Adults prefer nearshore rocky reefs, especially those with kelp beds, at depths ranging from 0-80 m. Adults may also be found foraging over sandy substrates. Juveniles are typically found among drifting kelp or over soft muddy or sandy bottoms (Leet *et al*., 2001).

Giant seabass grow slowly, mature at a relatively old age, and are thus susceptible to overfishing. Historically, commercial and recreational fisheries were most active in Mexico; however, since 1970 landings have declined significantly in both Mexican and California waters. This is due, in part, to a 1981 law that prohibits the take of giant seabass with the exception that commercial fishermen can keep two fish as incidental catch in gillnet and trammel net fisheries (Leet *et al*., 2001).

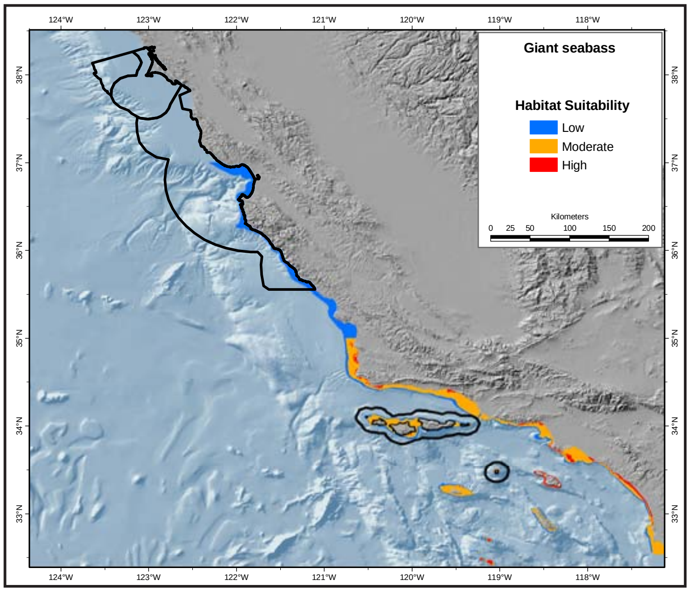

Figure 4.1.37. Giant seabass habitat suitability off central and southern California.

Broad-scale Patterns

Habitat suitability was modeled as high for rocky substrates and kelp bed habitats at depths ranging from 0-50 m, moderate between 50-70 m, and low at depths between 70-80 m. Soft substrates at depths ranging from 0-70 m were considered moderate and low from 70-80 m. Suitability was ranked low from 35°N through Monterey Bay. Highly suitable habitats for giant seabass are widely dispersed along the mainland from Morro Bay to San Diego, around the Channel Islands, and southern offshore banks (Figure 4.1.37). A much larger area of moderate suitability follows a similar spatial trend.

No fisheries data were available to test model performance.

Analysis of Boundary Concepts

Approximately 5% of the total area of the current CINMS boundary was considered highly suitable, while 50% was considered moderately suitable (Figure 4.1.38). The areas of high suitability are located close to shore among the northern islands, particulary in areas that have had kelp habitat. No high or moderately suitable habitats were included within Concepts 4 and 5. High and moderately suitable habitats located along

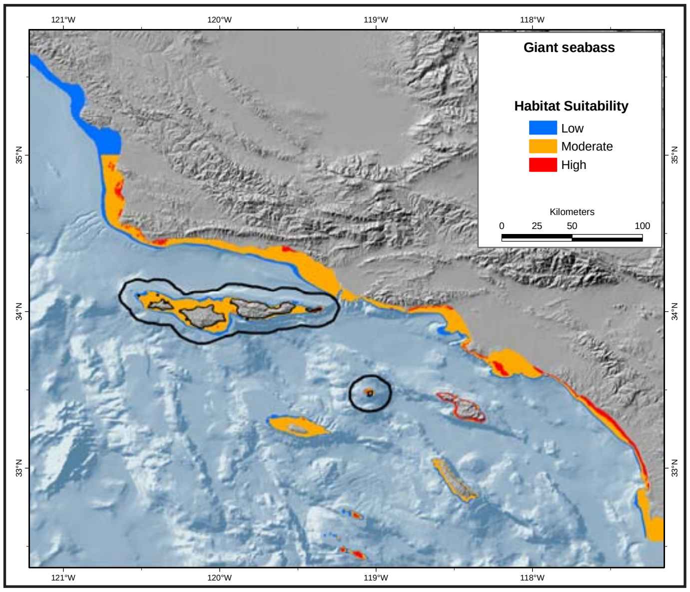

Figure 4.1.38. Giant seabass habitat suitability off southern California.

the mainland were included within the larger concepts where Concepts 1, 1a, and the Study Area contained the highest amount of highly suitable habitat (Figure 4.1.39). The Study Area yielded the highest OAI value; however this boundary is not under consideration. As such, Concept 2 displayed the optimal increase of highly suitable habitat/total area gained relative to the NAC (Table 4.1.14).

Summary

• Giant seabass are protected by law prohibiting recreational catch and allowing 1-2 fish/day as incidental catch in commercial fisheries.

• Highly suitable habitat was determined to occur over rocky substrates and kelp beds at depths between 0-50 m.

• Of the six boundary concepts being considered, Concept 2 provides the greatest proportional change of suitable habitat for giant seabass/total area in relation to the NAC.

Table 4.1.14. Analysis of giant seabass habitat suitability within boundary concepts. Numbers in bold indicate an increase in the estimate when compared to the No Action Concept (NAC). OAI estimates shaded in gray represent maximum observed benefit. Delta (D) indicates a rate of change calculation, and is always expressed as a percent change from the NAC.

Concept	Area (km^2)	High Suitability Area (km^2)	Δ Area (%)	Δ High Suitability Area (%)	OAI (absolute)
NAC	3475	198	-	-	-
5	4538	198	21.12	0.00	0.00
4	7981	198	113.11	0.00	0.00
3	9044	**229**	141.50	15.66	0.12
2	13736	**324**	266.78	63.64	0.25
1	22613	**375**	503.82	89.39	0.19
1a	22591	**375**	503.23	89.39	0.19
SA	*17093*	*375*	*356.42*	*89.39*	*0.27*

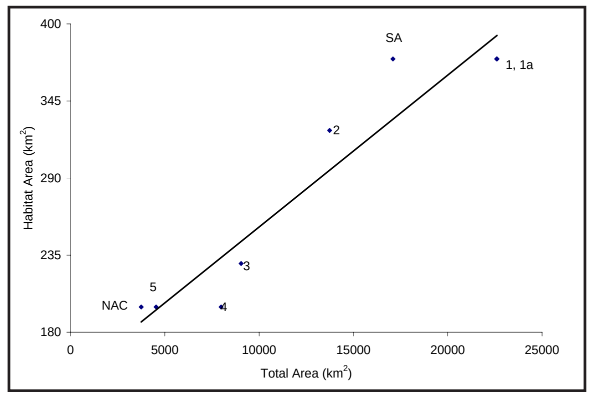

Figure 4.1.39. Regression of high habitat suitability for giant seabass and total area within the current and proposed boundary concepts. Numbers indicate concepts and NAC=No Action Concept, SA=Study Area.

California sheephead *(Semicossyphus pulcher)*

California sheephead range from Monterey Bay to the Gulf of California; however, they are not common north of Point Conception. Preferred habitat for sheephead occurs over rocky reefs and within kelp beds to depths of 90 m (Leet *et al*., 2001). Juveniles are most abundant between 3-30 m, while adults are most commonly distributed between 3-60 m (Love, 1996). Commercial landings of sheephead have recently increased due to the recent development of a live-fish fishery. During the 1990s, total landings of sheephead in California waters averaged approximately 91,000 kg/year. During 1994-1999, the live fish fishery accounted for 73-87% of the total sheephead landings (Leet *et al*., 2001); most of these are captured by hook-and-line (Love, 1996). Recreational landings of sheephead, as reported by party boats, have averaged approximately 25,000 fish per year during 1990-1999. There is no evidence that the sheephead population is threatened by existing fishery practices (Leet *et al*., 2001).

Broad-scale Patterns

The model developed for California sheephead indicated that highly suitable habitat occurs over hard substrate and among kelp beds between 0-60 m. Moderate suitability was determined to occur over hard substrate and kelp beds between 60-70 m, while low suitability was assigned to all substrates at depths between 70-80 m. Low suitability was also assigned to all habitats north of 35.5°N. As such, the majority of highly suitable habitat is distributed nearshore along the California mainland from Point Conception to Palos Verdes Point (Figure 4.1.40). Highly suitable habitat is also located among the rocky habitats around the Channel Islands and some of the southern offshore banks. Distribution of moderately suitable habitat follows the same pattern.

Commercial Passenger Fishing Vessel (CPFV) data provided by CDFG were used to assess model performance (Figure 4.1.41). A non-parametric chi-square test was used to compare ranked mean catch data by fishing block with the maximum habitat suitability value each block overlapped; results were statistically significant ($X^2<0.0001$, $r^2=0.26$).

Analysis of Boundary Concepts

Only 5% (218 km^2) of the area within the current boundary of CINMS was considered highly suitable habitat for sheephead; 68 km^2 was considered moderately suitable (Figure 4.1.42). No additional high or moderately suitable habitat was gained as boundary sizes increased for Concepts 4 and 5. Small gains of highly suitable habitat were observed within Concept 3 with the inclusion of nearshore habitat around Point Conception. Significantly more of these habitats along the mainland were contained within Concepts 1, 1a, 2, and the Study Area (Figure 4.1.43).

Although the Study Area and Concepts 1 and 1a contained the highest amount of highly suitable habitat, the amount of habitat/total area contained within Concept 2 relative to the NAC yielded the highest OAI for the six concepts under consideration (Table 4.1.15).

Summary

- The center for California sheephead distribution occurs in southern California.
- Highly suitable habitat was determined to occur over hard substrates and among kelp habitats at depths between 0-60 m.
- Sheephead landings from CPFV data exhibited statistically significant correlation with model results.
- Of the six boundary concepts being considered, Concept 2 provides the greatest proportional change of suitable habitat for halibut/total area relative to the NAC.

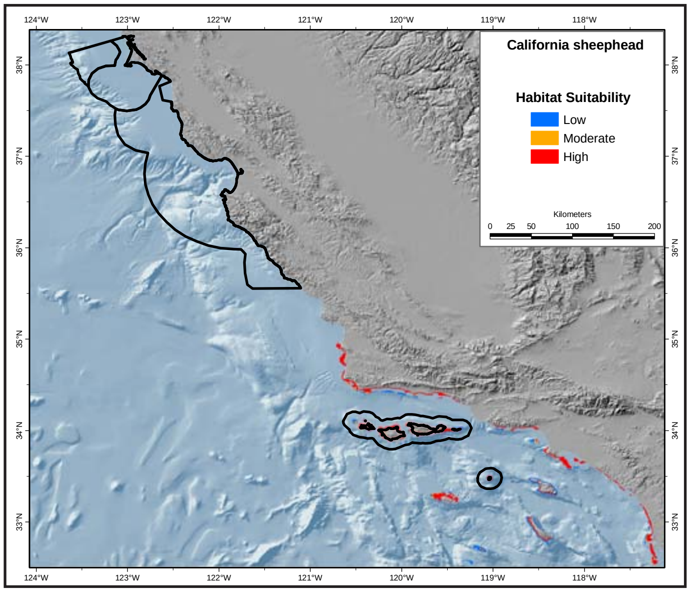

Figure 4.1.40. California sheephead habitat suitability off central and southern California.

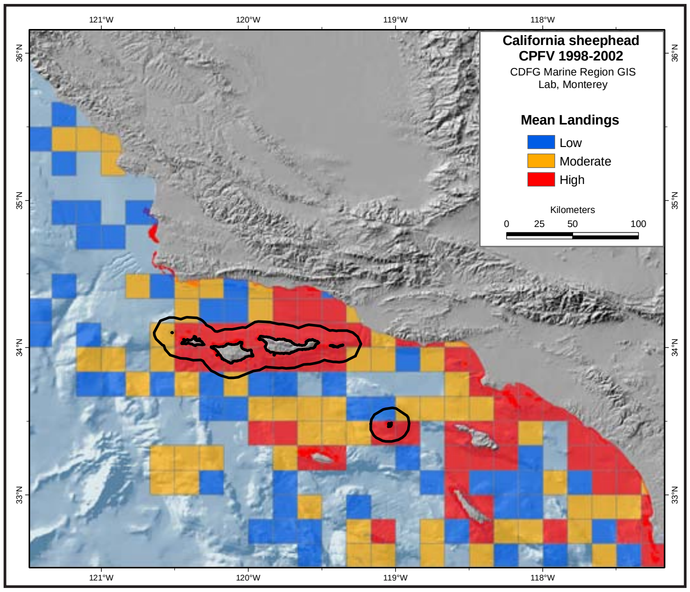

Figure 4.1.41. California sheephead landings data from CDFG's Commercial Passenger Fishing Vessel (CPFV) database, 1998-2002, superimposed over predicted habitat suitability

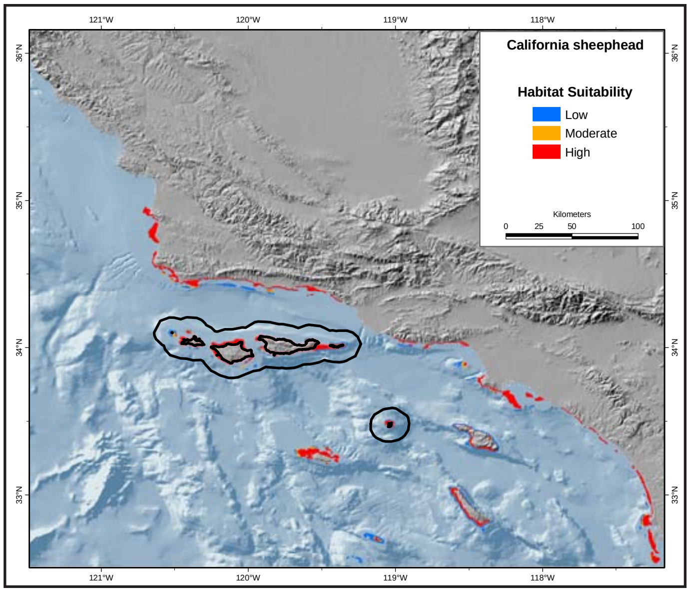

Figure 4.1.42. California sheephead habitat suitability off southern California.

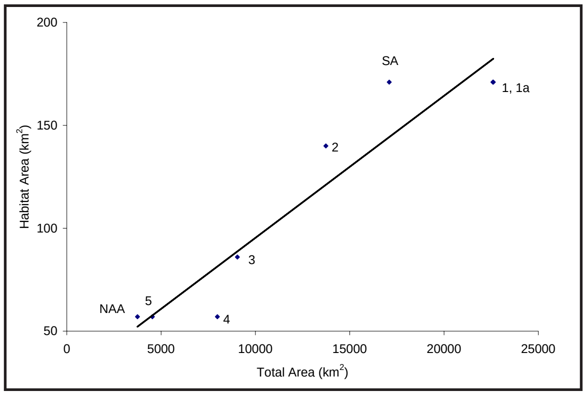

Figure 4.1.43. Regression of total habitat area for California sheephead and total area within the current and proposed boundary concepts. Numbers indicate concepts and NAC=No Action Concept, SA=Study Area.

Table 4.1.15. Analysis of California sheephead habitat suitability within boundary Concepts. Numbers in bold indicate an increase in the estimate when compared to the No Action Concept (NAC). OAI estimates shaded in gray represent maximum observed benefit. Delta (D) indicates a rate of change calculation, and is always expressed as a percent change from the NAC.

Concept	Area (km^2)	High Suitability Area (km^2)	Δ Area (%)	Δ High Suitability Area (%)	OAI (absolute)
NAC	3475	218	-	-	-
5	4538	218	21.12	0.00	0.00
4	7981	218	113.11	0.00	0.00
3	9044	**253**	141.50	16.06	0.29
2	13736	**353**	266.78	61.93	0.60
1	22613	**403**	503.82	84.86	0.43
1a	22591	**403**	503.23	84.86	0.43
SA	*17093*	*403*	*356.42*	*84.86*	*0.61*

California halibut *(Paralichthys californicus)*
California halibut are distributed from Quillayute River, Washington to southern Baja California, and are most common from Bodega Bay southward (Love, 1996). Adult and juvenile California halibut inhabit soft bottom habitats most commonly at depths less than 100 m, but some adults have been reported to 200 m. Juveniles are most commonly found in shallow embayments (Leet *et al*., 2001). California halibut are an important species in both the commercial and recreational fisheries of central and southern California. Since 1932, average annual commercial catch has been 412,000 kg, with a recent peak in 1997 of 567,000 kg. Historically, halibut have been commercially harvested by three gear types: otter trawl, set gill and trammel nets, and hook-and-line. Set nets are the gear of choice, primarily in San Francisco Bay and southern California, due to trawl restrictions in state waters. The commercial fishery is centered from Bodega Bay southward into Mexico waters (Leet *et al*., 2001). Halibut are most commonly taken in recreational fisheries using hook-and-line and spear fishing.

Broad-scale Patterns
Highly suitable habitat was determined to occur on soft substrate between 0-100 m, moderate suitability occurs on soft substrates between 100-150 m, and low suitability occurs at depths between 150-200 m (Figure 4.1.44). High and moderately suitable habitat comprises a large portion of the continental shelf including considerable area within Cordell Bank, Gulf of the Farallones, Monterey Bay, and Channel Islands national marine sanctuaries.

Halibut captured in SCCWRP trawl samples (Figure 4.1.45) and Commercial Passenger Fishing Vessel (CPFV) data (Figure 4.1.46) were used to assess model performance. Halibut data from these sources were compared with model results using a non-parametric chi-square test. Chi-square results from SCCWRP trawls indicated a significant correspondence between halibut catch and predicted habitat suitability (X^2<0.0001, r^2=0.11). Similarly, results using CPFV data showed a significant correlation (X^2<0.0001, r^2=0.17).

Analysis of Boundary Concepts

Approximately 30% of the area within the current CINMS was predicted highly suitable habitat for California halibut. An additional 521 km^2 was considered moderately suitable (Figure 4.1.47). Slight gains of highly suitable habitat were included as boundary size increased within Concepts 3, 4, and 5. Significant gains were included along the mainland within Concepts 1, 1a, 2, and the Study Area (Figure 4.1.48). The absolute OAI takes into account the proportional change (%) in highly suitable habitat and total area moving from the NAC to each of the concepts under consideration. While the Study Area includes the largest relative proportion of highly suitable habitat, this boundary is not under consideration as a boundary concept. OAI results for the remaining concepts (Table 4.1.16) indicate that Concepts 1 and 1a provide the greatest increase of highly suitable habitat relative to the increase in total boundary area from the NAC.

Summary

• The commercial and recreational fisheries for California halibut extend over a wide range from Bodega Bay through southern California.

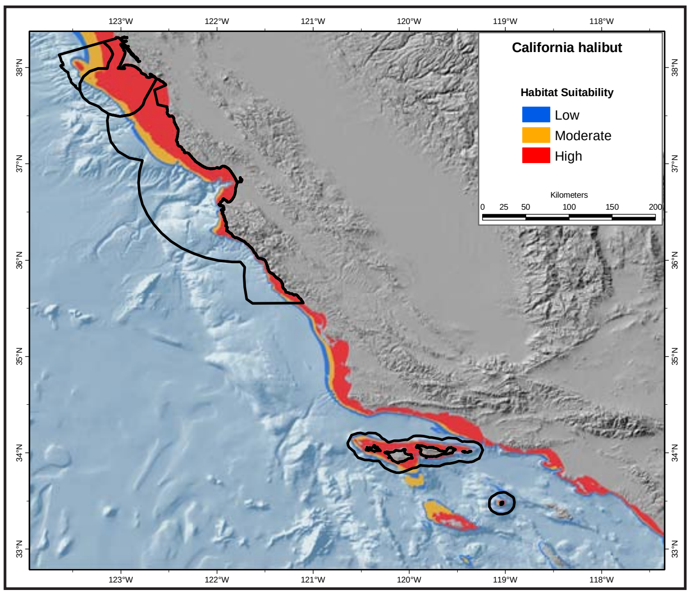

Figure 4.1.44. California halibut habitat suitability off central and southern California.

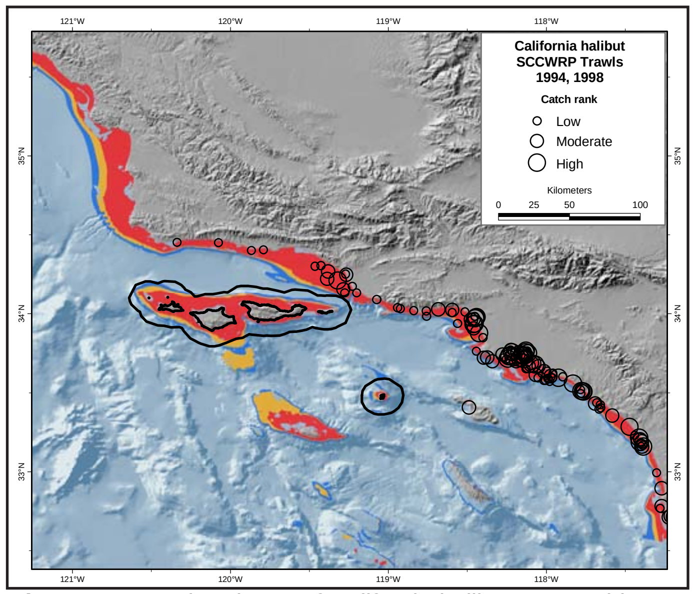

Figure 4.1.45. Abundance of California halibut captured in SC-CWRP trawls superimposed over predicted habitat suitability.

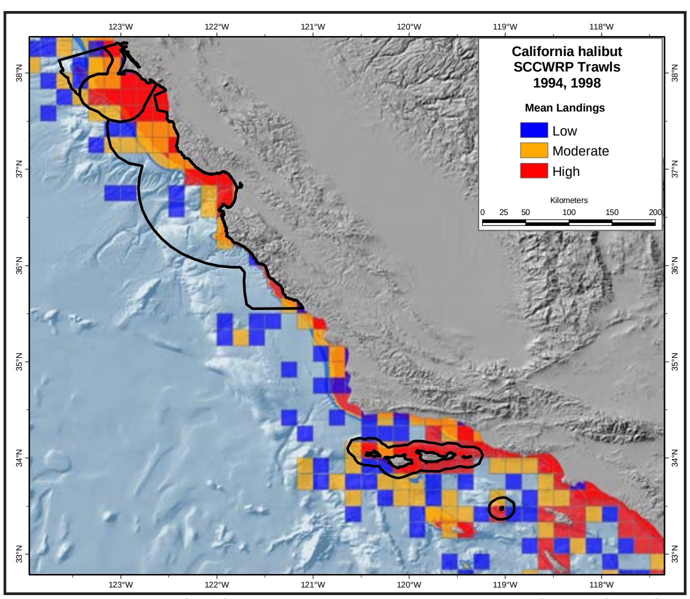

Figure 4.1.46. California halibut landings data from CDFG's Commercial Passenger Fishing Vessel (CPFV) database, 1998-2000, superimposed over predicted habitat suitability.

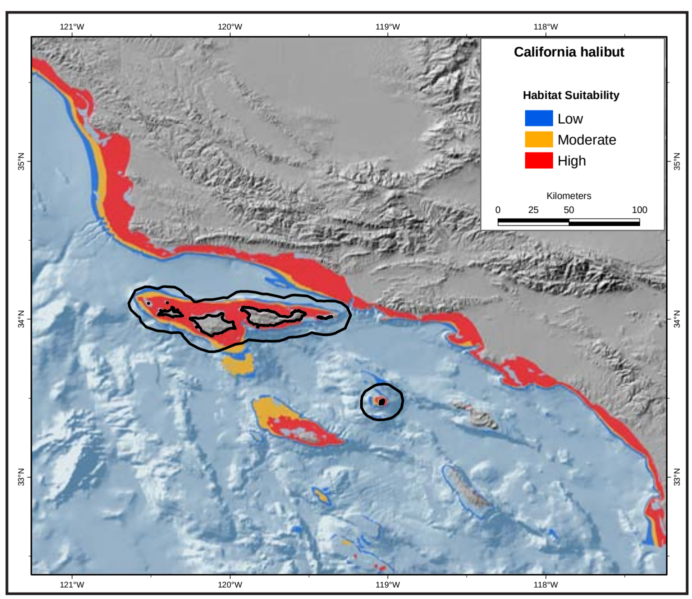

Figure 4.1.47. California halibut habitat suitability off southern California.

Table 4.1.16. Analysis of California halibut habitat suitability within boundary concepts. Numbers in bold indicate an increase in the estimate when compared to the No Action Concept (NAC). OAI estimates shaded in gray represent maximum observed benefit. Delta (D) indicates a rate of change calculation, and is always expressed as a percent change from the NAC.

Concept	Area (km^2)	High Suitability Area (km^2)	Δ Area (%)	Δ High Suitability Area (%)	OAI (absolute)
NAC	3475	1194	-	-	-
5	4538	1201	21.12	0.59	0.06
4	7981	1201	113.11	0.59	0.01
3	9044	**1310**	141.50	9.72	0.16
2	13736	**2157**	266.78	80.65	0.69
1	22613	**3237**	503.82	171.11	0.77
1a	22591	**3234**	503.23	170.85	0.77
SA	*17093*	*3237*	*356.42*	*171.11*	*1.09*

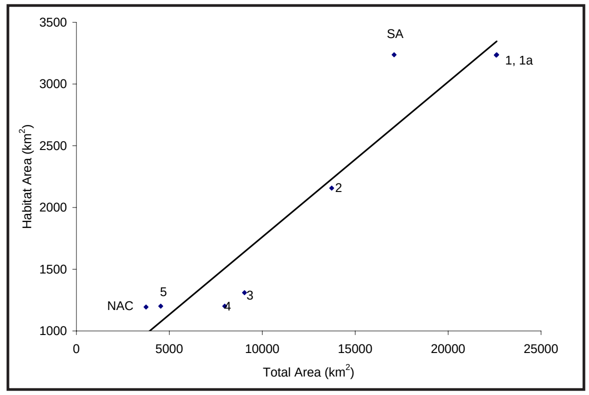

Figure 4.1.48. Regression of high habitat suitability for California halibut and total area within the current and proposed boundary concepts. Numbers indicate concepts and NAC=No Action Concept, SA=Study Area.

• Highly suitable habitat for California halibut was determined to occur over soft substrates at depths <100 m.

• Halibut catch data from SCCWRP trawls and CPFV data exhibited statistically significant correlation with model results.

• Of the six boundary concepts being considered, Concepts 1 and 1a provide the greatest proportional change of suitable habitat for halibut/total area in relation to the NAC.

4.2 FISH ASSEMBLAGE STRUCTURE

Community metrics and multivariate statistics were used to analyze marine fish species assemblages off southern California. Analyses were completed using four data sets (see Table 4.2.1) which contained fish abundance information for 364 species. Although none of the data sets were spatially and temporally comprehensive, results were combined to provide a region-wide assessment for fish community structure. Objectives for fish community analyses are as follows:

• Calculate Shannon index of diversity for each dataset;
• Determine which species co-occur (i.e., species assemblages);
• Analyze trawl data to determine which locations contained similar catches/sightings and utilize a GIS to map the results (i.e., site groups);
• Resolve where species assemblages were being caught/identified by combining results from objectives 1 and 2; and
• Calculate OAI and assess boundary concepts with repsect to the analyses conducted for the objectives listed above.

Data and Methods

Recreational Fishery Information Network (RecFIN) Commercial Passenger Fishing Vessel (CPFV): RecFIN is a database that integrates state and federal marine recreational fishery sampling efforts. This dataset is a subset containing GPS coordinates for 680 CPFV trips during 1999 and 2001 at depths ranging from 0-2,200 m. Fishermen targeted species and visited between 1 and 22 locations during each trip. Each trip/location combination was considered a unique site and was used as a sample unit in analyses. RecFIN provided information on four hook and line fishing methods: free drift, stationary drift, anchor, and troll. The trolling trips were removed before analysis because they targeted pelagic species and therefore provide limited information about species assemblages or diversity. Shannon's Diversity Index was calculated using 4,085 trip/location combinations which

Table 4.2.1. Summary of the datasets used to assess fish diversity and species assemblages.

Dataset	Gear	Geographic Area	Habitat Type/ Depth	Months	Years	# Sampling Sites	# Species (diversity)	# Species (assemblage)
RecFIN	Hook-and-line	California	NA/ 1-2200 m	All	1999, 2001	4085	130	18
SCCWRP	Trawl	Southern California	soft substrate/ 2-215 m	June-Aug	1994, 1998	425	150	48
NMFS GSP	Trawl	Southern California	soft substrate/ 55-1200 m	June-Nov	1977, 1989, 1992, 1995, 1997-2002	477	189	59
PISCO/ Vantuna	Scuba Diver visual survey	Southern California	Kelp bed/ NA	June, July	1999-2002	44	84	45

captured 130 fish species. In order to evaluate species assemblages, species that were infrequently captured (less than 5% of the total trip/locations) were omitted. As a result, the dataset was reduced to 2,697 trip/locations which captured 18 fish species.

Southern California Coastal Water Research Project (SCCWRP): Southern California Bight Regional Survey data obtained from SCCWRP consisted of 426 fisheries-independent trawl samples collected between June and September in 1994 and 1998. Samples were collected with a 7.6 m headrope semiballoon otter trawl with 1.25 cm codend mesh towed for 5 minutes (in bays) to 10 minutes (on coast) along isobaths at each station, and ranged in depth from 2-215 m (Allen *et al*. 1998, 2002). In 1994, the survey targeted the mainland shelf between 10-200 m, whereas the 1998 survey added trawls near islands and within bay and harbor areas, sampling from 2-200 m (Allen *et al*. 1998, 2002). Catch information for 150 species was used for Shannon Diversity calculations and (after omission of those species present in >5% of trawls) 48 species for assemblage analysis. For more information on sampling methodology, refer to Allen *et al*. (1998) and Allen *et al*. (2002).

National Marine Fisheries Service Groundfish Survey Program (NMFS GSP): Data from 477 fishery independent trawls ranging from 55-1,200 m in depth were collected June-November in 1977, 1989, 1992, 1995, and 1997-2002. Gear included a nor'eastern trawl (127 mm stretched-mesh body; 89 mm stretched-mesh codend; and 32 mm stretched-mesh codend liner) with a rubber bobbin roller which was trawled for 15-30 minutes on the bottom. Zimmerman's (2003) analysis of benthic species biomass was used to cull out the trawls that did not fish the bottom. The final data set used for the diversity analysis contained 189 fish species. After removal of rare species, the dataset contained information on 59 fish species. See Shaw *et al*.(2000), Turk *et al*. (2001), Wilkins *et al*. (1998) and Zimmermann *et al*. (2001) for detailed information on trawl and survey methods.

Kelp Visual Census: The Partnership for Interdisciplinary Studies of Coastal Oceans (PISCO) provided diver visual census data collected at 15 sites, while the Vantuna Research Group (VRG) provided data for 29 sites. Visual transect surveys, recording fish abundance and size, were completed by scuba divers along the bottom of the kelp forest. Each dataset used similar methods, yet transect distance differed, thus catch was standardized to a 2x60 m transect. Diversity analysis included 84 species of fish, while the assemblage analysis contained 45 species.

Fish diversity (H' Shannon index of diversity) (Shannon and Weaver, 1949) was calculated independently for each of the four datasets, which included abundance information for 364 species. The formula is expressed as:

$$H' = -\sum_{i=1}^{s} \left[\left(\frac{n_i}{N} \right) \ln \left(\frac{n_i}{N} \right) \right]$$

where n_i is the number of individuals belonging to the i^{th} species (s) in the sample, and N is the total number of individuals in the sample. Individual results for each survey method are presented to show the distribution of effort and site diversity. Gridded results were also provided to determine if larger spatial patterns were present that may have been masked by the high variability present between individual sites. Using ArcGIS, 5 x 5 minute grids were created and mean diversity was calculated for each grid cell containing data. The results were sorted by diversity and divided into quintiles (i.e. each quintile contains 20% of the sites).

Diversity results form the four datasets were combined to provide an overall map of fish diversity. To standardize, gridded results from each dataset were classified by quintiles with 5 denoting the greatest diversity and 1 the least diversity. Standardized diversity was then averaged where more than one diversity estimate was available for a cell. This technique removes differences that result from variable collection methods; however, it can minimize differences between habitats. For example, Allen (1985) analyzed multiple datasets and characterized fish habitats into three levels of diversity: high (kelp forests, deep rocky reefs and offshore soft bottom), medium (open coast sandy beaches, shallow rocky reefs, and harbor/nearshore soft bottom), and low (nearshore midwater, bay/estuary, and rocky intertidal). Thus selective habitat sampling may have been homogenized. To accurately compare areas, the same sampling method should be employed at all locations. However, lacking a comprehensive data set, standardization was considered a reasonable proxy.

It is important when analyzing fish community structure not just to analyze the diversity of species present, but also to investigate which species tend to co-occur. Clustering is a technique for optimal grouping of entities according to the resemblance of their attributes as expressed by given criteria (Boesch, 1977) or, in short, a method that puts variables (sites, species, etc) into groups. Cluster analyses was used to distinguish species assemblages and site groups. Data sets were initially filtered to remove incomplete or incorrect data (i.e., sites with coordinates that place them on land, stationed fishing trips that move greater than 0.01 degree latitude or longitude, etc). Fish that were not identified to species were removed (diversity analyses), as well as those present in less than 5% of the trawls (assemblage analyses). Rare species were removed from assemblage analyses because their occurrence is often due to chance and not biological response, and can therefore negatively impact results (Gauch, 1982; Boesch, 1977). The 5% cutoff was chosen because it reduced the number of zeros present, while keeping an adequate number of species for analysis. Because the raw abundance data did not conform to assumptions of a normal distribution and homogeneity of variances, fourth root transformations were utilized. This transformation was applied because it is invariant to scale changes (Field *et al*., 1982). Data were standardized by species abundance (i.e., abundance for each species was adjusted such that the mean is zero and the standard deviation is one). Exploratory analyses were conducted to investigate multiple resemblance metrics and clustering methods to determine which metric consistently provided interpretable results without excessive chaining. When chaining occurs, entities fuse to a few nuclear groups one at a time rather than forming new groups, and make it impossible to divide the data into meaningful smaller groups (Boesch, 1977). Two dissimilarity methods, Bray-Curtis and Jaccard (both paired with average means clustering), met these criteria. The Bray-Curtis dissimilarity coefficient (b_{jk}) is calculated as:

$$b_{jk} = \frac{\sum_{i=1}^{n} X_{ij} - X_{ik}}{\sum_{i-1}^{n} (X_{ij} + X_{ik})}$$

where X_{ij} is the ith attribute (column) measured on the j^{th} object (row), and X_{ik} is the ith attribute on the k^{th} object (Romesburg, 1984). The Bray Curtis dissimilarity metric often produces meaningful results with species abundance data, and is therefore one of the most widely used cluster methods in ecology (Boesch, 1977). Scree plots were used to determine where breaks in the similarity level occurred (McGarigal *et al*., 2000). Subsequently, group composition was analyzed to determine the best ecological groupings (i.e. if smaller or larger groups would provide a better ecological explanation) (Boesch, 1977). Results from the Bray-Curtis dissimilarity metric were used to allow for comparisons with previously completed analyses of the SCCWRP data (Allen *et al*., 1998, 2002).

To determine interaction between species assemblages and site groups, the average frequency of occurrence for each species was calculated for each site group. This analysis is a modified nodal analysis (Boesch, 1977). By analyzing average frequencies for species in site groups it was possible to determine which species assemblages were influential in forming the site groups. Spatial distribution of the site groups was visualized by mapping the site groups in a GIS. A step-wise discriminant analysis was completed on each dataset to determine if parameters such as depth, latitude, or effort were significantly different between site groups.

Broad-scale Patterns

Diversity

Kelp diver surveys exhibited the highest mean diversity (1.8 ± 0.5), followed by both SCCWRP and NMFS trawl datasets (1.4 ± 0.5 and 1.4 ± 0.4, respectively). The recreational data had the lowest diversity (0.6 ± 0.6). These differences likely reflect the variety of methods used as well as true differences in diversity among habitats. Due to this convolution, diversity results for each of the four datasets will be discussed independently. The composite diversity map displays many of the characteristics found in the individual datasets, and is therefore discussed last.

The recreational hook and line data was the only dataset containing information for the entire coast of California (Figure 4.2.1); however, the distribution of effort was concentrated in central California (San Francisco to Monterey Bay) and southern California (south of Santa Barbara). Overall, there were statistically significant ($P<0.05$) correlations between diversity and effort, depth, latitude, and longitude. However, using individual linear regressions, these variables explained very little of the variance (r^2=0.01, 0.03, 0.03, and 0.06, respectively). The most striking pattern from the recreational data was the large number of trips with very low diversity that occurred in southern California offshore environments (Figure 4.2.1). These low diversity trips targeted pelagic species and recorded either no catch or only a few species, such as albacore or yellowtail, thus biasing diversity results. Unfortunately, all trips targeting pelagic species could not be removed without implementing an in-depth analysis

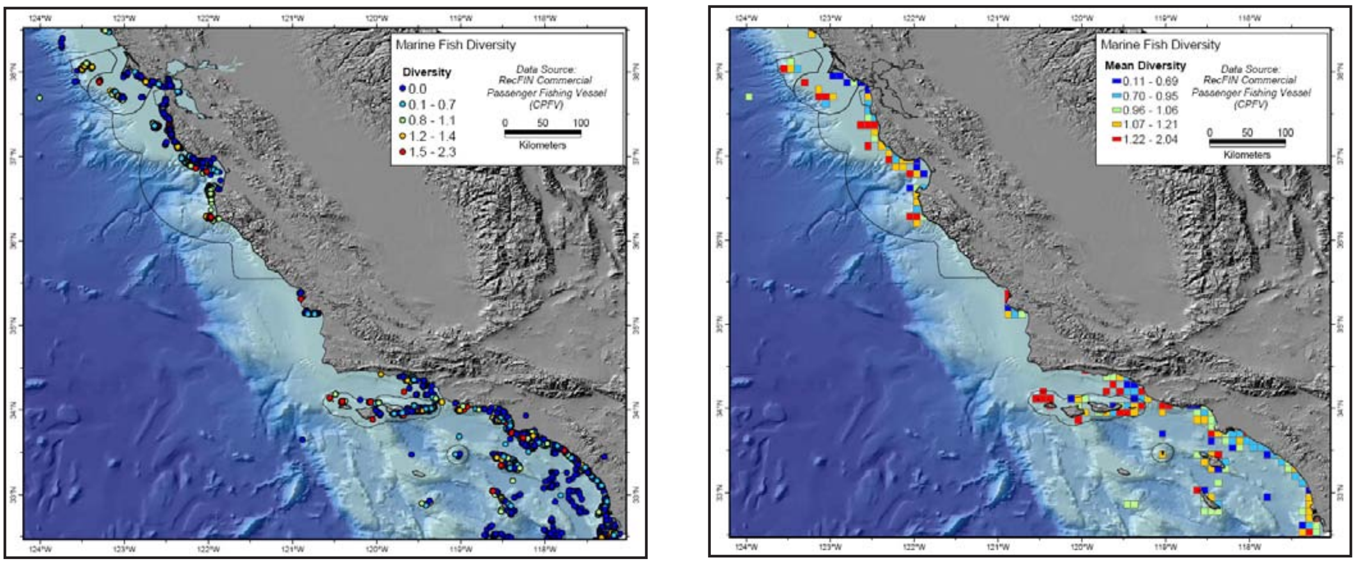

Figure 4.2.1. Fish diverisity calculated for individual RecFIN hook and line trips (left) and mean diversity for trips within 5x5 minute grids (right).

of species captured. Instead, all trip/location combinations with species diversity of zero (44%) were removed before calculating mean diversity within the five minute grid cells because they can substantially lower mean diversity. In this analysis, sites with zero diversity do not represent marine areas that lack fish species, but rather they depict areas where the targeted fish was not collected. Other low diversity areas were found within and just offshore of San Francisco Bay. Cells with high mean diversity that were based on at least 3 data points are found: west of San Francisco around the Gulf of the Farallones and Cordell Bank; northwest of Monterey Bay, in approximately 300 m depth; and directly south of Monterey Bay. In addition, cells east of Anacapa Island and along the coast of southern California also exhibited consistent measurements of high diversity.

High fish diversity observed in the SCCWRP trawls appear to be randomly dispersed throughout the study area. The Santa Barbara Channel has a large area of high diversity south of Carpinteria (Figure 4.2.2). Low diversity areas can be found west of San Miguel and Santa Cruz Islands, and south of Santa Catalina Island. There was a significant positive relationship between diversity and latitude, and a negative relationship between diversity and depth, but variance explained was minimal (r^2=0.01 and 0.08, respectively). The relationship between catch and depth could be attributed to gear avoidance. Fish species may be able to respond visually and escape from trawls in shallow water where the light is brighter, but not in deep water. The majority of mean diversity calculations were based on less than 3 sampling points, thus confidence in the accuracy of mean diversity is uncertain due to limited samples.

The majority (85%) of the NMFS GSP trawls were found north of Point Conception, allowing for only minor comparisons within the study area (Figure 4.2.3). Between Cape San Martin and Point Sal, a line of high diversity trawls were observed at approximately 200 m depth. High diversity trawls were infrequent south of Point Conception; 21 trawls (13%) were categorized into the top quintile.

Fish diversity within kelp habitats was calculated using PISCO scuba transect data from 44 sampling stations (Figure 4.2.4). Four of the nine sites representing the top 20% (quintile) were located on the coast north of Santa Barbara, two on San Nicolas, two on Santa Catalina, and one near San Clemente Island. Santa Cruz, Santa Catalina and San Clemente appear to have lower diversity sites south and east of the islands, while San Nicolas exhibited the opposite trend. Pondella *et al*. (2005) found lower overall diversity on warm water islands (Santa Catalina and San Clemente) when compared to colder islands to the north (Santa Cruz, San Nicolas and Santa Barbara). This overall pattern is supported by the results of this study.

Patterns of mean standardized diversity for the composite of all datasets are displayed in Figure 4.2.5. There was only one cell that contained information from all four datasets, and 13 that contained information from three of the four. Seventy-five percent of the cells contained information from only one dataset. The composite dataset provides an overall diversity map for fishes in southern California; much of the coastal and marine habitats are covered by one of the four datasets.

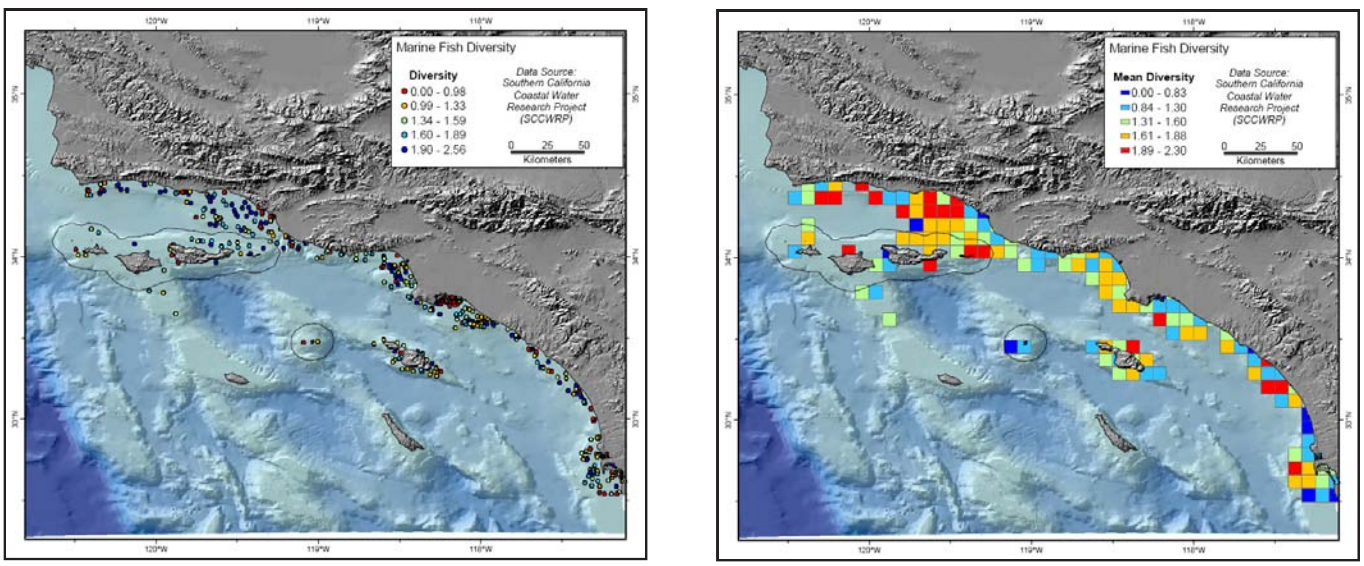

Figure 4.2.2. Fish diveirisity for individual SCCWRP trawls (left) and mean diversity of trawls within 5x5 minute grids (right).

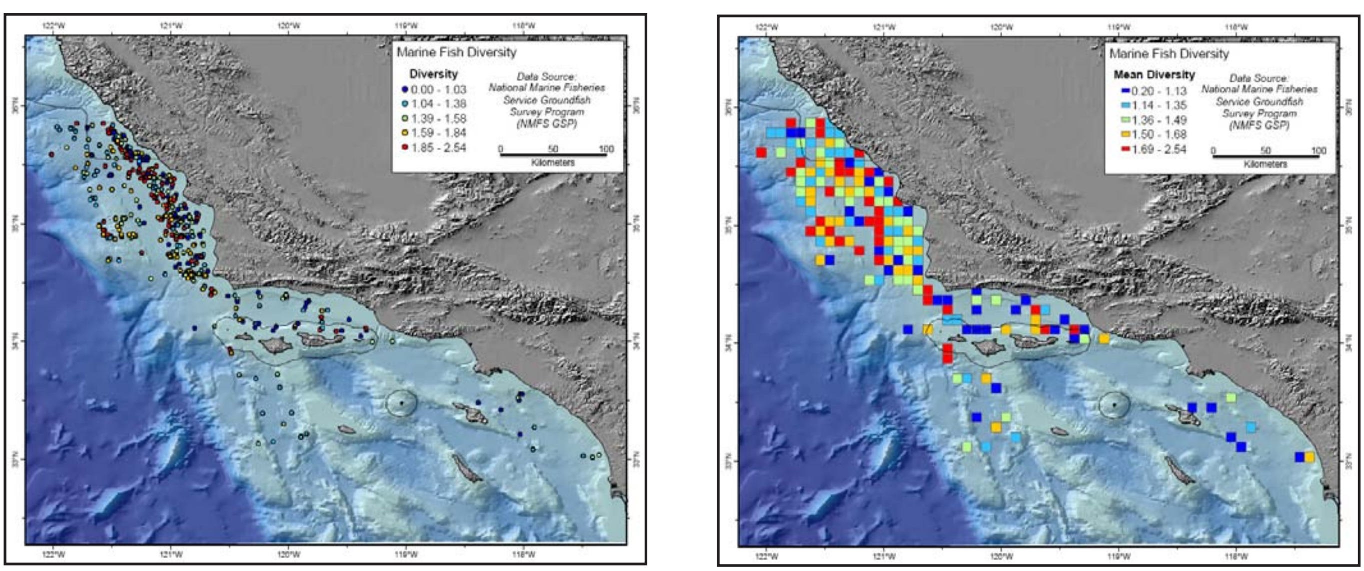

Figure 4.2.3. Fish diveirisity for individual NMFS GSP trawls (left) and mean diversity of trawls within 5x5 minute grids (right).

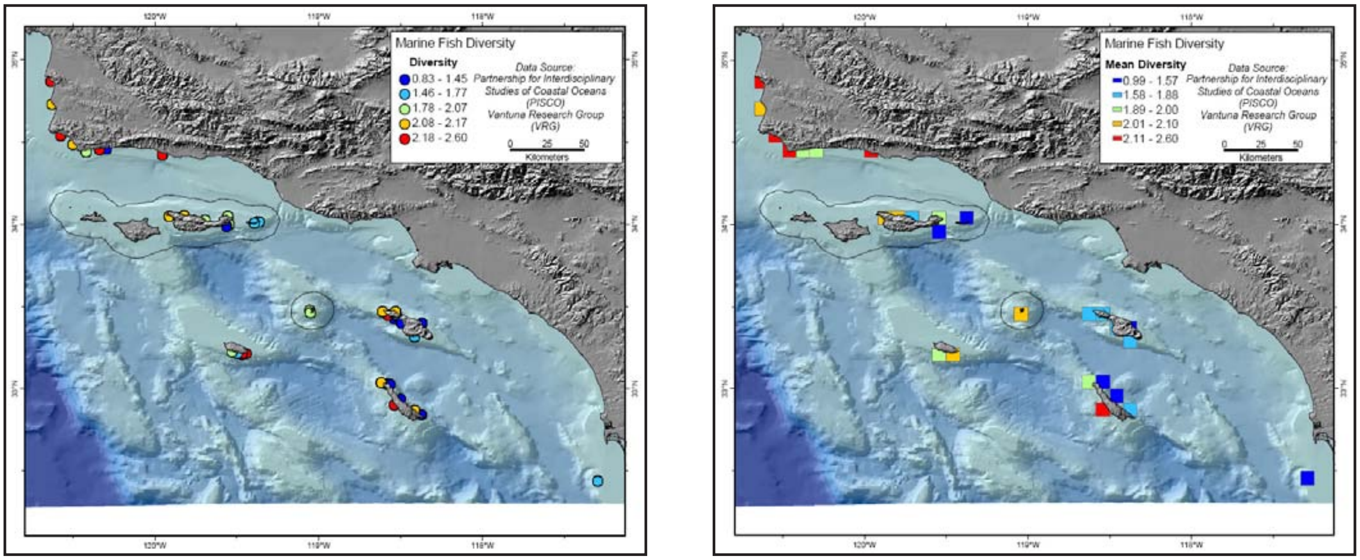

Figure 4.2.4. Fish diversity for individual kelp visual census surveys (left) and mean diversity of surveys within 5x5 minute grids (right).

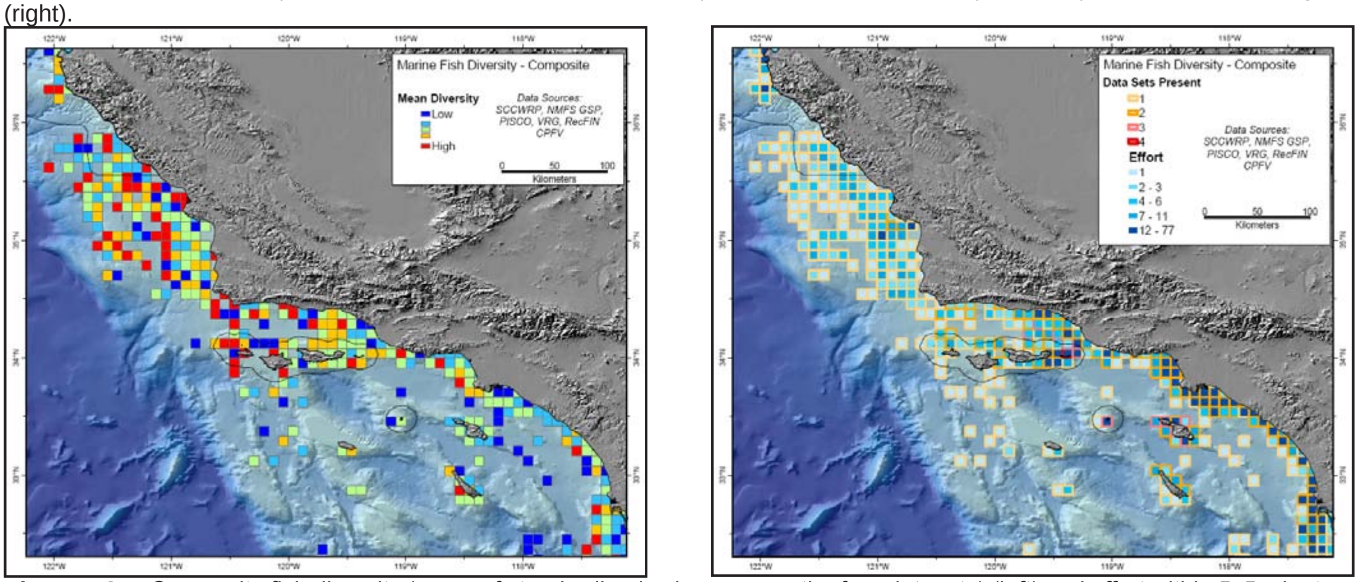

Figure 4.2.5. Composite fish diversity (mean of standardized values across the four datasets) (left) and effort within 5x5 minute grids (right).

Assemblages

Eighteen species of recreational fish from the RecFIN data were divided into six species assemblages (Table 4.2.2), and eighteen site groups (Figures 4.2.6-7). There was an attempt to reduce the number of site groups, but the degree of agreement between Bray-Curtis and Jaccard results decreased substantially. The strong agreement between methods highlights the importance of individual species in this data set. Each site group was based almost entirely on the presence or absence of one species (Table 4.2.3). Six of the eighteen (33%) site groups were only located south of Santa Barbara, while one site group was only located north of Monterey Bay. Fifteen (83%) site groups were found around Anacapa Island, highlighting the diversity of fishes found in this area.

A clear division was apparent between southern and northern species' assemblages. Two of the

Table 4.2.2. Species assemblage results for the RecFIN CPFV data using the Bray-Curtis dissimilarity metric with average means clustering. Assemblages are named for the most influential species in each group.

Group	Common Name	Scientific Name
vermilion rockfish assemblage	vermilion rockfish copper rockfish starry rockfish rosy rockfish	*Sebastes miniatus* *Sebastes caurinus* *Sebastes constellatus* *Sebastes rosaceus*
greenspotted rockfish assemblage	greenspotted rockfish bocaccio	*Sebastes chlorostictus* *Sebastes paucispinis*
yellowtail rockfish assemblage	yellowtail rockfish lingcod blue rockfish	*Sebastes flavidus* *Ophiodon elongatus* *Sebastes mystinus*
ocean whitefish assemblage	ocean whitefish California scorpionfish honeycomb rockfish	*Caulolatilus princeps* *Scopaena guttata* *Sebastes umbrosus*
barred sandbass assemblage	barred sandbass kelp bass California halibut Pacific chub mackerel Pacific barracuda	*Paralabrax nebulifer* *Paralabrax clathratus* *Paralichthys californicus* *Scomber japonicus* *Sphyraena argentea*
gopher rockfish assemblage	gopher rockfish	*Sebastes carnatus*

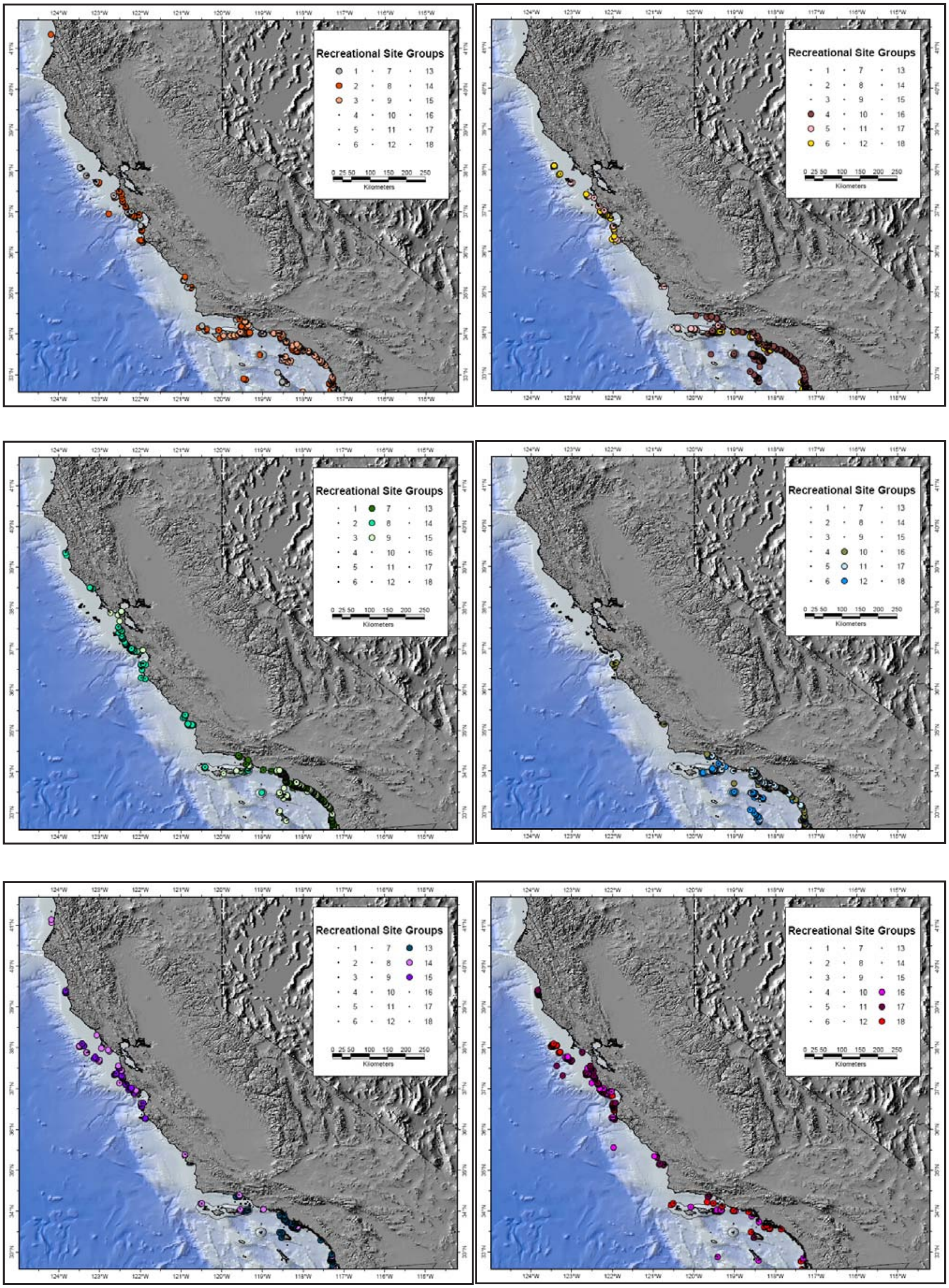

Figure 4.2.6. Location of site groups, RecFIN CPFV data.

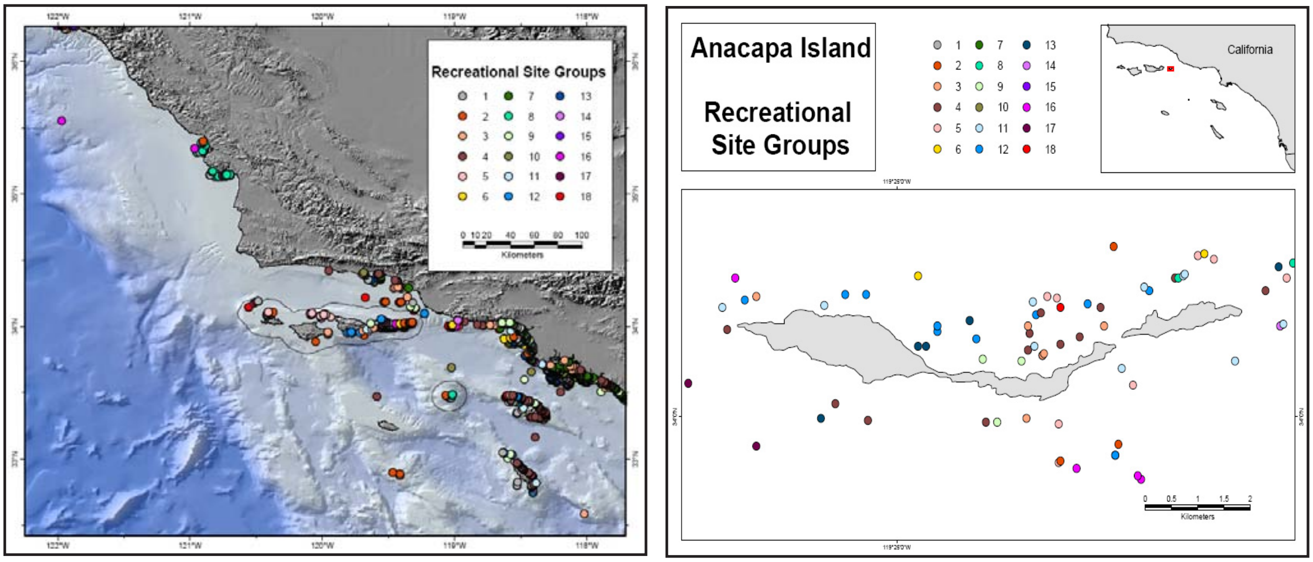

Figure 4.2.7. Location of site groups for the RecFIN CPFV data within southern California (left) and around Anacapa Island.

Table 4.2.3. Mean frequency of occurrence for each recreational site group. Shaded cells represent species present in over half of the groups in that site.

Species	Site Groups																	
	2 N=179	5 N=94	1 N=145	16 N=168	6 N=99	18 N=135	15 N=64	14 N=89	17 N=111	12 N=154	11 N=226	13 N=160	7 N=299	4 N=316	9 N=237	10 N=193	3 N=165	8 N=183
vermilion rockfish	100	39	35	25	3	4	17	2	17	25	11	31	6	0	2	4	1	30
copper rockfish	7	100	20	26	6	3	6	2	2	8	3	11	0	0	0	2	0	5
starry rockfish	22	6	100	52	10	13	2	0	5	12	4	34	0	1	0	1	0	3
rosy rockfish	19	13	32	98	25	15	2	6	22	7	3	18	0	0	0	0	0	14
greenspotted rockfish	25	5	28	6	100	59	0	11	0	10	2	9	0	2	0	3	0	0
bocaccio	43	16	30	25	2	100	0	0	1	11	7	9	1	0	0	2	1	2
yellowtail rockfish	4	14	7	55	15	50	98	11	24	1	0	0	0	0	0	1	0	7
lingcod	25	39	28	36	3	33	0	100	39	5	15	9	4	0	2	4	2	39
blue rockfish	2	19	10	31	0	2	48	0	100	3	1	1	0	0	0	1	0	41
ocean whitefish	4	1	10	4	1	0	0	0	1	100	33	46	4	17	1	5	1	3
California scorpionfish	2	4	32	2	3	0	0	1	0	8	100	31	37	16	21	18	7	0
honeycomb rockfish	0	1	9	1	0	0	0	0	1	7	20	99	2	1	0	11	1	0
barred sandbass	1	0	0	0	0	0	0	0	0	5	5	8	100	21	40	2	0	0
kelp bass	0	0	0	0	0	1	0	7	0	5	4	4	19	100	8	1	1	0
California halibut	0	0	0	0	0	0	0	0	0	2	0	1	7	4	100	0	5	2
Pacific chub mackerel	6	0	4	1	2	0	0	0	0	19	3	10	33	28	20	74	5	1
Pacific barracuda	1	0	0	0	0	0	0	2	0	1	4	1	26	27	1	0	100	0
gopher rockfish	1	16	1	5	0	0	31	0	4	5	11	4	1	5	0	1	1	100

species assemblages were comprised of predominantly Southern California Bight species: ocean whitefish and barred sand bass assemblages. The other assemblages contain species that are more common north of Point Conception.

Step-wise discriminant analysis (N=3,002) revealed significant differences among site groups for: latitude (r^2=0.59, F=234, P<0.0001), depth (r^2=0.40, F=110, P<0.0001), fishing type (anchored vs. drift: r^2=0.20, F=42, P<0.0001), and effort (r^2=0.09, F=16, P<0.0001). These results suggest that species' distributions are influenced by habitat variables such as depth and latitude, but could be based on either passive or active behaviors. The higher coefficients of determination associated with the habitat parameters compared to fishing effects suggests that habitat characteristics have a stronger influence on the site groups.

SCCWRP trawls were conducted in 1994 and 1998, and were combined for this analysis. Trawls were concentrated in the southern California bight at depths to 215 m, and provided information on 62 fish species. These fish species were combined into 15 species assemblages (Table 4.2.4) and sites were divided into six distinctive groups (Figure 4.2.8; Table 4.2.5).

Table 4.2.4. Species assemblage results for the SSCWRD trawl data using the Bray-Curtis dissimilarity metric with average means clustering. Assemblages are named for the most influential species in each group.

Group	Common Name	Species Name
white croaker assemblage	white croaker northern anchovy Pacific sardine queenfish	*Genyonemus lineatus* *Engraulis mordax* *Sardinops sagax* *Seriphus politus*
California halibut assemblage	California halibut barred sandbass spotted turbot diamond turbot thornback	*Paralichthys californicus* *Paralabrax nebulifer* *Pleuronichthys ritteri* *Plueronichthys guttulata* *Patyrhinoidis trisenata*
specklefin midshipman	specklefin midshipman	*Porichthys myriaster*
white seaperch assemblage	white seaperch shiner perch	*Phanerodon furcatus* *Cymatogaster aggregata*
hornyhead turbot a ssemblage	hornyhead turbot speckled sanddab California lizardfish California scorpionfish California tonguefish fantail sole	*Pleuronichthys verticalis* *Citharichthys stigmaeus* *Synodus lucioceps* *Scorpaena guttata* *Symphurus atricauda* *Xystreurys liolepis*
longfin sanddab assemblage	longfin sanddab bigmouth sole yellowchin sculpin	*Citharichthys xanthostigma* *Hippoglossina stomata* *Icelinus quadriseriatus*
Pacific argentine assemblage	Pacific argentine bay goby	*Aregentina sialis* *Lepidogobius lepidus*
longspine combfish assemblage	longspine combfish English sole pink seaperch	*Zaniolepis latipinnis* *Parophrys vetulus* *Zalembius rosaceus*
Pacific sanddab assemblage	Pacific sanddab stripetail rockfish slender sole Dover sole plainfin midshipman shortspine combfish	*Citharichthys sordidus* *Sebastes saxicola* *Lyopsetta exilis* *Microstomus pacificus* *Porichthys notatus* *Zaniolepis frenata*
California skate	Californa skate	*Raja inornata*
pygmy poacher assemblage	pygmy poacher roughback sculpin	*Odontopyxis trispinosa* *Chitonotus pugetensis*
rex sole assemblage	rex sole blackbelly eelpout Pacific hake splitnose rockfish blacktip poacher	*Glyptocephalus zachirus* *Lycodes pacifica* *Merluccius productus* *Sebastes diploproa* *Xeneretmus latifrons*
greenstriped rockfish assemblage	greenstriped rockfish pink rockfish greenblotched rockfish	*Sebastes elongatus* *Sebastes eos* *Sebastes rosenblatti*
spotted cusk-eel assemblage	spotted cusk-eel spotfin sculpin greenspotted rockfish halfbanded rockfish	*Chilara taylori* *Icelinus tenuis* *Sebastes chlorostictus* *Sebastes semicinctus*
Gulf sanddab	Gulf sanddab	*Citharichthys fragilis*

Discriminate analysis (N=413) revealed significant differences between site groups in all four parameters investigated: depth (r^2=0.88, F=597, P<0.0001), effort (r^2=0.37, F=48, P<0.0001), year (r^2=0.10, F=9, P<0.0001), and latitude (r^2=0.07, F=6, P<0.0001). Also, a clear relationship between species assemblages and depth was observed.

This relationship can be visualized in Table 4.2.5, where site groups have been ordered from shallow to deep. Both the northern anchovy and the California halibut assemblages consist of shallow species, but the northern anchovy assemblage includes schooling species often present inside bays, and the California halibut assemblage contains species more characteristic of the inner shelf and the outer limits of the bays. Similarly, two assemblages contain mid-shelf species (the hornyhead turbot and longfin sanddab), but the latter has species with a more southern distribution. The longspine combfish and stripetail rockfish assemblages consist of a combination of middle and outer-shelf species, while the rex sole, greenstriped rockfish and spotted cusk-eel assemblages contain deeper water species. Effort varied between offshore and bay habitats, which could explain the significant relationship between site groups and effort. Changes in areas targeted for trawling and large-scale weather/temperature patterns may have affected observed species assemblages. In 1994, nearshore ecosystems were targeted, while trawl effort focused on islands and bay areas during 1998. In addition, 1998 was a strong El Niño year, with water temperatures much warmer than normal. The cluster results presented here, while based on both years (1994 and 1998) align closely with previous results from 1998 alone (Allen *et al*., 1998, 2002).

Seven species assemblages (Table 4.2.6) and four site groups (Figure 4.2.9) were identified from the NMFS benthic trawls. Most of the trawls were located north of Point Conception, so limited information was available for the southern bight area. Frequency of occurrence for fish species in each site group provides information on the interaction between species assemblages and site groups (Table 4.2.7).

Only two of the parameters investigated with the discriminant analysis (N=466) were found to be significant: depth (r^2=0.87, F=1035, P<0.0001) and effort (r^2=0.09, F=16, P<0.0001). Latitude did not have a significant effect (r^2<0.01, F=1.4, P=0.24), and longitude was excluded from the analysis because it was confounded with latitude (r^2=0.83). Corrections were made for effort, but effort still accounted for 9% of the variance. Depth explained 87% of the variation, which can be visualized in Figure 4.2.9; the four groups partition themselves into obvious depth contours. Again, the break-out of species from this data-set fell into known species-depth associations. The Pacific sanddab,

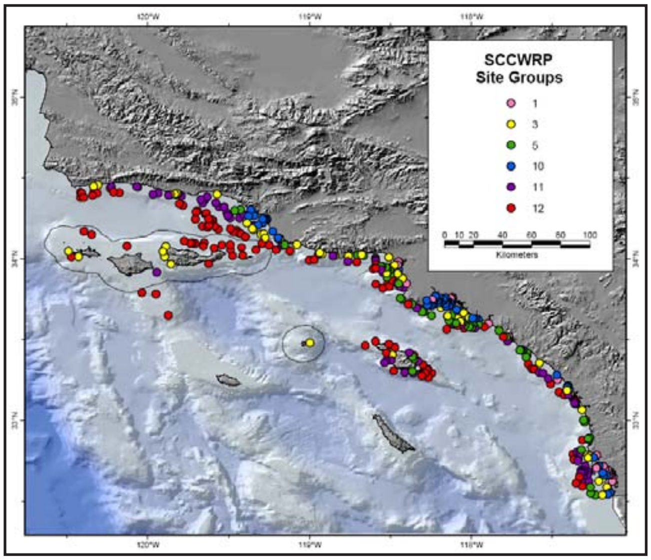

Figure 4.2.8. Location of site groups, SCCWRP.

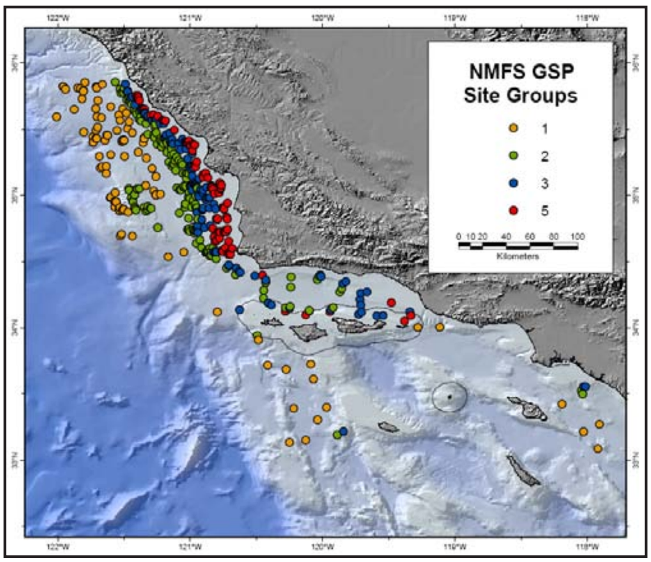

Figure 4.2.9. Location of site groups, NMFS GSP.

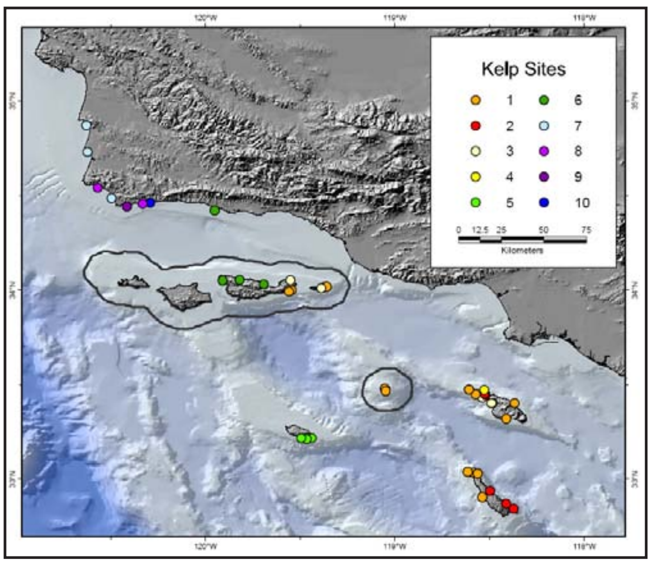

Figure 4.2.10. Location of site groups, kelp visual census surveys.

Table 4.2.5. Mean frequency of occurrence for SCCWRP site groups. Shaded cells represent species present in more than 50% of the groups in that site.

	Site Groups					
	10 N=73	1 N=33	3 N=64	5 N=63	11 N=75	12 N=106
northern anchovy	42	3	2	3	1	5
white croaker	90	24	9	11	11	1
Pacific sardine	22	0	0	3	0	2
queenfish	75	3	5	5	0	2
California halibut	63	73	56	41	11	1
barred sand bass	33	94	16	8	1	0
spotted turbot	30	39	30	2	0	0
diamond turbot	10	45	2	0	0	0
thornback	15	3	13	0	0	0
specklefin midshipman	32	9	8	22	23	0
white seaperch	44	0	9	0	3	0
shiner perch	33	6	3	3	0	0
hornyhead turbot	19	0	63	75	64	15
speckled turbot	19	6	100	40	25	1
California lizardfish	47	15	73	92	77	18
California scorpionfish	3	3	13	52	27	10
California tonguefish	49	12	39	86	81	7
fantail sole	21	12	42	37	17	1
longfin sanddab	3	0	36	97	80	13
bigmouth sole	0	0	17	92	84	35
yellowchin sculpin	0	0	13	60	91	17
Pacific argentine	0	0	0	0	25	26
bay goby	5	0	3	6	63	9
longspine combfish	0	0	0	10	77	39
English sole	5	0	30	19	55	47
pink seaperch	0	0	2	21	81	45
stripetail rockfish	0	0	0	2	57	70
Pacific sanddab	0	0	14	37	87	93
slender sole	0	0	0	0	12	75
Dover sole	0	0	0	2	52	95
plainfin midshipman	1	0	5	6	75	74
shortspine combfish	0	0	2	0	7	79
California skate	5	0	11	29	28	7
pygmy poacher	0	0	0	3	25	4
roughback sculpin	0	0	9	16	23	6
rex sole	0	0	0	0	0	35
blackbelly eelpout	0	0	0	0	5	33
Pacific hake	0	0	0	0	0	27
splitnose rockfish	0	0	0	0	1	22
blacktip poacher	0	0	0	0	0	36
greenstriped rockfish	0	0	0	0	5	25
pink rockfish	0	0	0	0	8	16
greenblotched rockfish	0	0	0	0	9	29
spotted cusk-eel	0	0	0	2	7	34
spotfin sculpin	0	0	0	0	5	21
greenspotted rockfish	0	0	0	0	5	18
halfbanded rockfish	0	0	0	0	3	28
gulf sanddab	0	0	0	0	17	19

Table 4.2.6. Species assemblage results for the NMFS GSP data using Bray-Curtis dissimilarity metric with average means clustering. Assemblages are named for the most influential species in each group.

Group	Common Name	Species Name
greenspotted rockfish assemblage	greenspotted rockfish greenstriped rockfis widow rockfish	*Sebastes chlorostictus* *Sebastes elongatus* *Sebastes entomelas*
blackbelly eelpout assemblage	blackbelly eelpout spotted cusk-eel	*Lycodes pacificus* *Chilara taylori*
Pacific sanddab assemblage	Pacific sanddab petrale sole white croaker lingcod English sole Pacific pompano curlfin sole plainfin midshipman halfbanded rockfish pink seaperch longspine combfish	*Citharichthys sordidus* *Eopsetta jordani* *Genyonemus lineatus* *Ophiodon elongatus* *Parophrys vetulus* *Peprilus simillimus* *Pleuronichthys decurrens* *Porichthys notatus* *Sebastes semicinctus* *Zalembius roaceus* *Zaniolepis latipinnis*
bocaccio assemblage	bocaccio Pacific argentine slender sole chilipepper rockfish shortbelly rockfish stripetail rockfish Pacific electric ray northern anchovy spiny dogfish	*Sebastes paucispinis* *Argentina sialis* *Lyopsetta exilis* *Sebastes goodei* *Sebastes jordani* *Sebastes saxicola* *Torpedo californica* *Engraulis mordax* *Squalus acanthias*
Dover sole assemblage	Dover sole sablefish sandpaper skate rex sole spotted ratfish bigfin eelpout black eelpout Pacific hake filetalk cat shark longnose skate aurora rockfish splitnose rockfish blackgill rockfish bank rockfish brown cat shark blacktail snailfish California grenadier shortspine thornyhead darkblotched rockfish	*Microstomus pacificus* *Anoplopoma fimbria* *Bathyraja interrupta* *Glyptocephalus zachirus* *Hydrolagus colliei* *Lycodes cortezianus* *Lycodes diapterus* *Merluccius productus* *Parmaturus xaniurus* *Raja rhina* *Sebastes aurora* *Sebastes diploproa* *Sebastes melanostomus* *Sebastes rufus* *Apristurus brunneus* *Careproctus melanurus* *Nezumia stelgidolepis* *Sebastolobus alascanus* *Sebastes crameri*
longspine thornyhead assemblage	longspine thornyhead giant grenadier California slickhead Pacific flatnose black skate twoline eelpout Pacific viperfish Pacific grenadier deepsea sole snakehead eelpout black hagfish longnose cat shark	*Sebastolobus altivelis* *Albatrossia pectoralis* *Alepocephalus tenebrosus* *Antimora microlepis* *Bathyraja trachura* *Bothrocara brunneum* *Chauliodus macouni* *Coryphaenoides acrolepis* *Embassichthys bathybius* *Embryx crotalinus* *Eptatretus deani* *Apristurus kampae*
threadfin slickhead	threadfin slickhead	*Talismania bifurcata*

bocaccio, Dover sole, and longspine thornyhead assemblages contain mid-shelf, outer-shelf, mesopelagic, and deep bathypelagic species respectively.

Diver surveys were only available at 44 sites, which were clustered into ten site groups. Discriminant analysis found significant differences among site groups in latitude (N=39, r^2=0.67, F=11, P<0.0001) and depth (N=39, r^2=0.43, F=4, P=0.005). Eight species assemblages were identified, and are arranged from northwest to southeast in Table 4.2.8. There was an obvious partitioning of the site groups between islands (Figure 4.2.10; Table 4.2.9). The assemblages segregate into three large groups: cold water sites around Point Conception (Groups 7-10), intermediate sites on Santa Cruz (western side) and San Nicolas Islands (Groups 5-6), and warm water sites on San Clemente, Santa Catalina, Santa Barbara, Anacapa, and Santa Cruz (eastern side) Islands (Groups 1-4). Within the warm water sites, Group 1 was the most wide-spread with sites on all of the islands. Group 2 is only located on Santa Catalina and San Clemente, which were characterized by warm water species. San Clemente Island shows a definite partitioning between the northwest and southeastern sections of the island. Within the intermediate sites, there is a definite separation of the sites found on San Nicolas Island. These sites have a lower occurrence of the northern fish species (i.e. lingcod assemblage) than the other intermediate sites in Group 6. The cold water site groups are located around Point Conception. Groups 9 and 10 contain only one site each, at Alegria and Cojo. Alegria was distinct from all other site groups, and only contains six fish species. The kelp species assemblages also divide into meaningful groups. The kelp bass assemblage is composed of many fish species common to kelp habitats. These species were more common at intermediate and southern site groups than northern site groups. There were two species assemblages with a northern distribution: lingcod and walleye surfperch.

Fish species diversity varied with each dataset due to the methods used and habitats sampled. The kelp visual surveys yielded

Table 4.2.7. Mean frequency of occurrence for NMFS GSP site groups. Shaded cells represent species present in more than %50 of the groups in that site.

	Site Groups			
	5 N=89	3 N=109	2 N=159	1 N=109
greensplotched rockfish	7	21	1	0
greenspotted rockfish	13	17	1	0
widow rockfish	13	12	1	0
blackbelly eelpout	15	19	4	0
spotted cusk-eel	11	23	2	0
Pacific sanddab	96	27	0	0
petrale sole	75	32	7	0
white croaker	63	1	0	0
lingcod	63	30	2	0
English sole	82	38	1	0
Pacific pompano	52	3	0	0
curlfin sole	47	3	0	0
plainfin midshipman	91	19	1	0
halfbanded rockfish	56	6	1	0
pink seaperch	84	4	0	0
longspine combfish	34	3	1	0
bocaccio	38	54	3	0
Pacific argentine	29	27	2	2
slender sole	36	83	25	0
chilipepper rockfish	63	76	9	0
shortbelly rockfish	53	58	4	0
stripetail rockfish	52	94	9	0
Pacific electric ray	37	38	8	2
northern anchovy	29	4	1	0
spiny dogfish	75	55	35	1
Dover sole	61	95	100	79
sablefish	38	78	97	92
sandpaper skate	0	31	49	5
rex sole	62	92	91	3
spotted ratfish	61	74	58	2
bigfin eelpout	13	52	72	6
black eelpout	1	12	58	13
Pacific hake	47	94	99	34
filetail cat shark	3	10	60	25
longnose skate	15	40	57	20
aurora rockfish	0	4	78	8
splitnose rockfish	6	86	74	1
blackgill rockfish	0	3	52	1
bank rockfish	6	16	25	0
brown cat shark	6	12	42	73
blacktail snailfish	0	17	22	50
California grenadier	0	0	12	15
shortspine thornyhead	3	30	87	99
darkblotched rockfish	2	15	11	0
longspine thornyhead	0	0	31	100
giant grenadier	0	0	1	69
California slickhead	0	1	0	90
Pacific flatnose	0	0	0	70
black skate	0	0	1	37
twoline eelpout	0	0	1	68
Pacific viperfish	1	0	4	21
Pacific grenadier	0	0	2	55
deepsea sole	0	0	2	68
snakehead eelpout	0	0	0	32
black hagfish	0	0	3	24
longnose cat shark	0	0	13	5
threadfin slickhead	0	1	0	49

Table 4.2.8. Species assemblage results for kelp visual census surveys using Bray-Curtis dissimilarity metric with average means clustering. Assemblages are named for the most influential species in each group.

Group	Common Name	Species Name
lingcod assemblage	lingcod	*Ophiodon elongatus*
	tubesnout	*Aulo rhynchus flavidus*
	spotfin surfperch	*Hyperprosopon anale*
	kelp greenling	*Hexagrammos decagrammus*
	rainbow seaperch	*Hypsurus caryi*
	cabezon	*Scopaenichthys marmoratus*
	brown rockfish	*Sebastes auriculatus*
	gopher rockfish	*Sebastes carnatus*
	copper rockfish	*Sebastes caurinus*
	black-and-yellow rockfish	*Sebastes chrysomelas*
	yellowtail rockfish	*Sebastes flavidus*
	blue rockfish	*Sebastes mystinus*
	grass rockfish	*Sebastes rastrelliger*
	olive rockfish	*Sebastes serraniodes*
walleye surfperch assemblage	walleye surfperch	*Hyperprosopon argenteum*
	white seaperch	*Phanerodon furcatus*
	jacksmelt	*Atherinopsis californiensis*
bocaccio assemblage	bocaccio	*Sebastes paucispinis*
	striped seaperch	*Embiotoca lateralis*
shiner surfperch	shiner surfperch	*Cymatogaster aggregata*
sargo assemblage	sargo	*Anisotremus davidsonii*
	barred sandbass	*Paralabrax nebulifer*
	horn shark	*Heterodontus francisci*
spotted kelpfish	spotted kelpfish	*Gibbonsia elegans*
jack mackerel assemblage	jack mackerel	*Trachurus symmetricus*
	Pacific barracuda	*Sphyraena argentea*
kelp bass assemblage	kelp bass	*Paralabrax clathratus*
	island kelpfish	*Alloclinus holderi*
	kelp perch	*Brachyistius frenatus*
	ocean whitefish	*Caulolatilus princeps*
	blacksmith	*Chromis punctipinnis*
	pile perch	*Rhacochilus vacca*
	black perch	*Embiotoca jacksoni*
	opaleye	*Girella nigricans*
	giant kelpfish	*Heterostichus rostratus*
	garibaldi	*Hypsypops rubicundus*
	rock wrasse	*Halichoeres semicinctus*
	halfmoon	*Medialuna californiensis*
	bat ray	*Myliobatis californica*
	senorita	*Oxyjulis californica*
	rubberlip seaperch	*Rhacochilus toxotes*
	California sheephead	*Semicossyphus pulcher*
	treefish	*Sebastes serriceps*
	kelp rockfish	*Sebastes atrovirens*

Table 4.2.9. Mean frequency of occurrence for kelp visual census site groups. Shaded cells represent species present in more than 50% of the groups in that site.

	SIte Groups									
	7 N=3	8 N=2	9 N=1	10 N=1	6 N=4	5 N=5	3 N=5	4 N=1	1 N=16	2 N=5
lingcod	100	50	100	0	50	40	0	0	0	0
olive rockfish	33	50	100	0	100	60	20	0	13	20
black-and-yellow rockfish	100	50	0	0	50	40	0	0	6	0
blue rockfish	100	50	0	0	100	20	0	0	13	0
brown rockfish	67	50	0	0	50	40	0	0	0	0
cabezon	100	100	0	0	50	40	20	0	13	0
copper rockfish	67	100	0	0	75	0	0	0	0	0
gopher rockfish	67	0	0	0	50	20	0	0	0	0
grass rockfish	67	100	0	0	0	0	0	0	6	0
kelp greenling	100	50	100	0	0	0	0	0	0	0
rainbow seaperch	100	100	100	0	75	100	0	0	25	40
spotfin surfperch	100	100	0	0	0	0	0	0	0	0
tubesnout	100	0	0	0	0	40	0	0	0	0
yellowtail rockfish	100	50	0	0	25	0	20	0	0	0
walleye surfperch	33	100	0	100	25	0	20	0	19	20
jacksmelt	0	100	0	0	0	0	0	0	6	60
white seaperch	100	100	100	100	50	0	40	100	13	20
bocaccio	33	0	100	100	25	100	20	0	6	0
striped seaperch	100	0	100	0	75	100	0	0	19	0
shiner surfperch	67	0	0	0	0	0	0	0	13	20
sargo	0	0	0	0	0	0	40	0	44	20
barred sandbass	0	0	0	0	25	0	20	0	25	20
horn shark	0	0	0	0	25	20	60	0	0	20
spotted kelpfish	0	0	0	0	0	0	40	100	25	0
jack mackerel	0	0	0	0	0	0	60	0	6	60
Pacific barracuda	0	0	0	0	0	20	20	0	6	40
kelp bass	100	100	100	100	100	100	100	100	100	100
bat ray	0	0	0	0	50	40	80	0	38	80
black perch	100	100	100	0	100	100	100	100	100	60
blacksmith	0	0	0	0	100	100	100	0	100	100
California sheephead	33	0	0	0	100	100	100	100	100	100
garibaldi	0	0	0	0	75	80	100	100	100	100
giant kelpfish	67	100	100	0	50	0	0	0	88	100
halfmoon	0	0	0	0	75	100	100	0	100	100
island kelpfish	0	0	0	0	0	20	100	0	56	20
kelp rockfish	100	50	100	0	100	100	40	0	63	0
kelp perch	67	100	100	100	75	80	60	100	100	100
ocean whitefish	0	0	0	0	75	40	100	0	38	100
opaleye	0	0	0	0	100	100	100	100	100	100
pile perch	100	100	100	0	100	100	100	0	75	40
rock wrasse	0	100	0	0	100	60	100	100	100	100
rubberlip seaperch	67	100	0	0	100	80	60	0	56	0
senorita	100	100	100	100	100	100	100	100	100	100
treefish	0	0	0	0	50	100	60	0	56	20

the highest diversity, followed by the benthic trawls, and then the recreational hook and line. The differences in methods could account for much of the variability.

Gridded mean diversity did not reveal obvious spatial patterns. In all datasets, there do not appear to be any trends between the islands and the coast, with all areas showing a mixture of high diversity and low diversity sites. The highest coefficient of determination was observed for the kelp dataset, where the sites located the farthest north and west contained slightly higher diversity than those located the farthest south and east. Depth was significantly different in the recreational and SCCWRP datasets, but in both cases, explained less than 10% of the variance in diversity.

There were similarities in the assemblage results from the four datasets. Depth was significantly different among site groups within all four datasets, and latitude was significant in the recreational, SCCWRP, and kelp datasets. These results agree with previous investigations (Horn and Allen, 1978; Gabriel and Tyler, 1980; Allen and Smith, 1988; Matthews and Richards, 1991; Sullivan, 1995; Allen *et al*. 1998, 2002; Williams and Ralston, 2002). Latitude and/or longitude were significantly different between site groups in all datasets, but explained little of the variance (r^2=0.01-0.22).

The Channel Islands are divided into two main biogeographical provinces: the warm-temperate San Diegan and the cold-temperate Oregonian. San Miguel, Santa Rosa, and San Nicolas Islands typically contain Oregonian biota, while Santa Cruz (eastern part) Anacapa, Santa Barbara, Santa Catalina and San Clemente Islands contain San Diegan biota. Research on intertidal areas and kelp forests further separated the San Diegan province into two smaller groups (Murray *et al*., 1980; Murray and Littler, 1981; Littler *et al*., 1991; Pondella *et al*., 2005). All of these studies placed Santa Catalina and San Clemente into one group and Santa Barbara and Santa Cruz into a second group.

Results from the kelp survey data presented here separate into the San Diegan and Oregonian provinces. The southern site groups (Groups 1-4) are San Diegan, while the intermediate and northern site groups (5-10) are Oregonian. These results show limited support for further division of the San Diegan province. Group 2 is only found on Santa Catalina and San Clemente Islands, but Group 1 is found on all of the islands in the San Diegan province.

There are six recreational groups that can be considered southern as they are located south of Point Conception and contain warm-water species: Groups 3, 4, 7, 11, 12, and 13. All seven site groups present on San Miguel and/or Santa Rosa Islands were also present on other islands, demonstrating that this region could be considered a transition zone between provinces. Overall, the recreational patterns are not easily discerned.

The NMFS and SCCWRP trawls did not differentiate site groups among islands. Because both of these data sets targeted benthic species, they may be less influenced by surface currents and temperature and less likely to show the segregations detailed above.

Analysis of Boundary Concepts

Evaluating the potential impacts of fish diversity and species assemblages in relation to boundary concepts was not attempted due to the disparate nature of the fish datasets (unequal effort, different sampling methods). However, results from these analyses provide some understanding of highly diverse fish habitats and species assemblages. Kelp forests have been well documented as supporting diverse communities of invertebrates and fish and our analyses are in agreement. Additionally, numerous soft bottom benthic habitats exhibited high diversity over the continental shelf and slope (Figure 4.2.11). Several ecologically important species assemblages were identified to occur within the region of interest, e.g. kelp species, shelf soft bottom species, and slope soft bottom species. In contrast, we were unable to provide comprehensive fish data captured over hard substrates, although this habitat type is critical for west coast rockfish species. In order to fully quantify diveristy and assemblage patterns, additional spatial and temporal data is recommended.

Summary

• Fish diversity was highest for the kelp dataset (1.8±0.5), followed by both SCCWRP and NMFS trawl datasets (1.4±0.5 and 1.4±0.4, respectively). The recreational data had the lowest diversity (0.6±0.6).

• Depth was significantly different between site groups in all four data sets, while latitude and effort were significantly different in three of the four data sets.

4.3 ICHTHYOPLANKTON

Data and Methods

The maps of regional ichthyoplankton (planktonic fish larvae) distribution presented here were derived from data provided by the California Cooperative Oceanic Fisheries Investigations (CalCOFI) consortium. CalCOFI represents a unique partnership of the California Department of Fish and Game (CDFG), the NOAA Fisher-

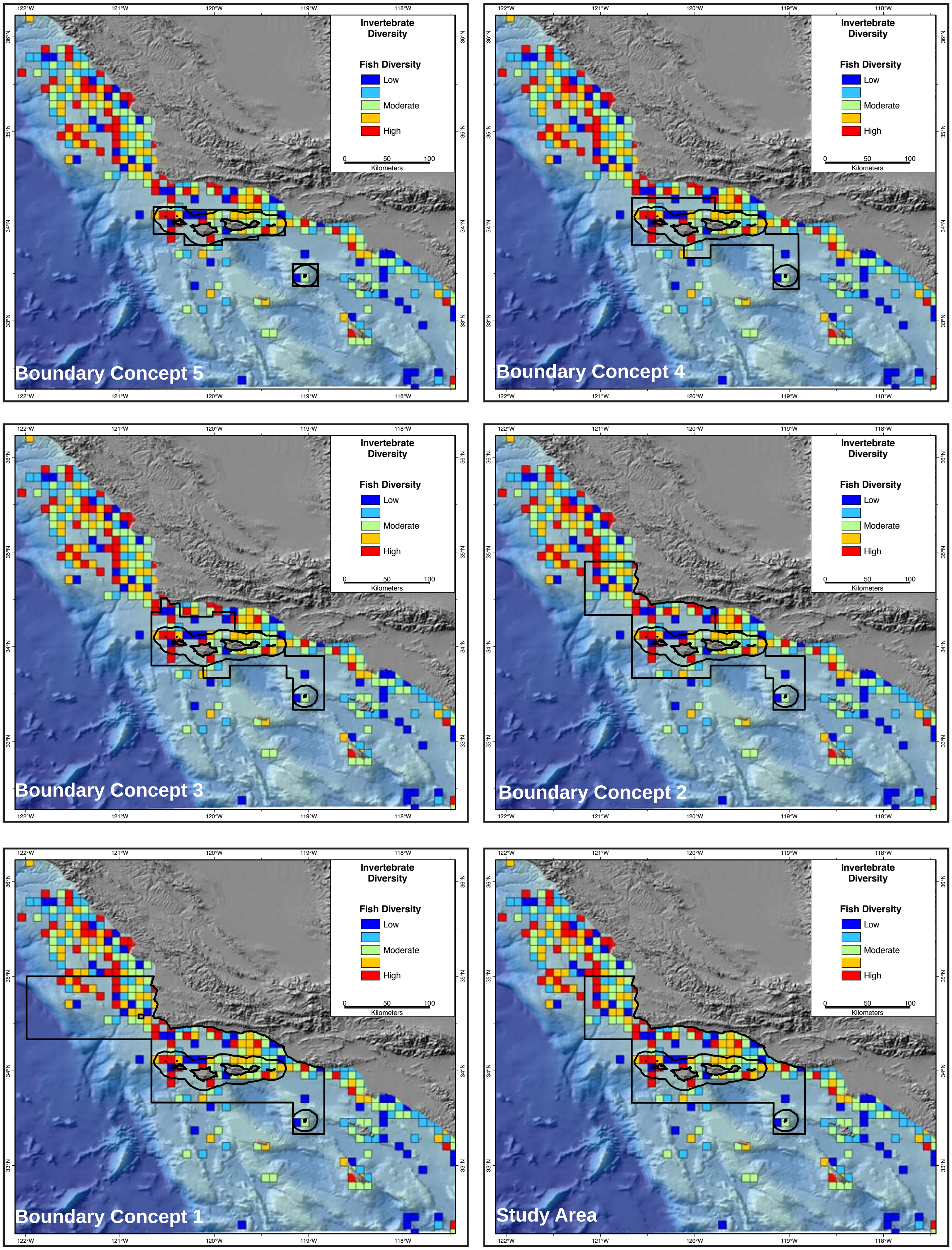

Figure 4.2.11. Composite fish diversity within boundary concepts.

ies Service (NMFS) and the Scripps Institution of Oceanography (University of California, San Diego). The CalCOFI partnership was formed in 1949 to study the ecological aspects of the collapse of the Pacific sardine (*Sardinops sagax*) populations off California; however, recently its focus has shifted to a more general study of the marine environment off the coast of California and to the management of its living resources. More information about CalCOFI and its member institutions can be found at: <http://www.calcofi.org>.

Since 1949, CalCOFI has organized cruises to measure the physical and chemical properties of the California Current System and to census living resource populations. Currently, 2-3 week cruises are conducted on a quarterly basis. Data presented here range from 20.2°-47.4° north latitude (~Baja California to Washington State), and from 107°-139° west longitude (Figure 4.3.1). Data were collected during a total of 46 years, ranging from 1951 through 2002 (missing years: 1970, 1971, 1973, 1976, 1979, and 1982). Over this time period, a total of 35,495 unique bongo net tows were performed on 276 cruises, resulting in the collection of 318 unique ichthyoplankton taxa. Figure 4.3.2 shows a summary distribution of collection effort between 1951 and 2002, and depicts the total number of bongo net tows taken. This map is not intended to be a proxy for a quantitative estimate of the cumulative number of kilometer-hours towed in a given region; rather it is designed to highlight areas of long-term scientific focus. The geographic extent and spatial framework (hexagons) shown in Figure 4.3.2 are used later in this chapter in analyzing abundance and distribution patterns. Specifics on the CalCOFI bongo net towing protocols can be found at <http://www.calcofi.org/newhome/cruises/equip/nets.htm>.

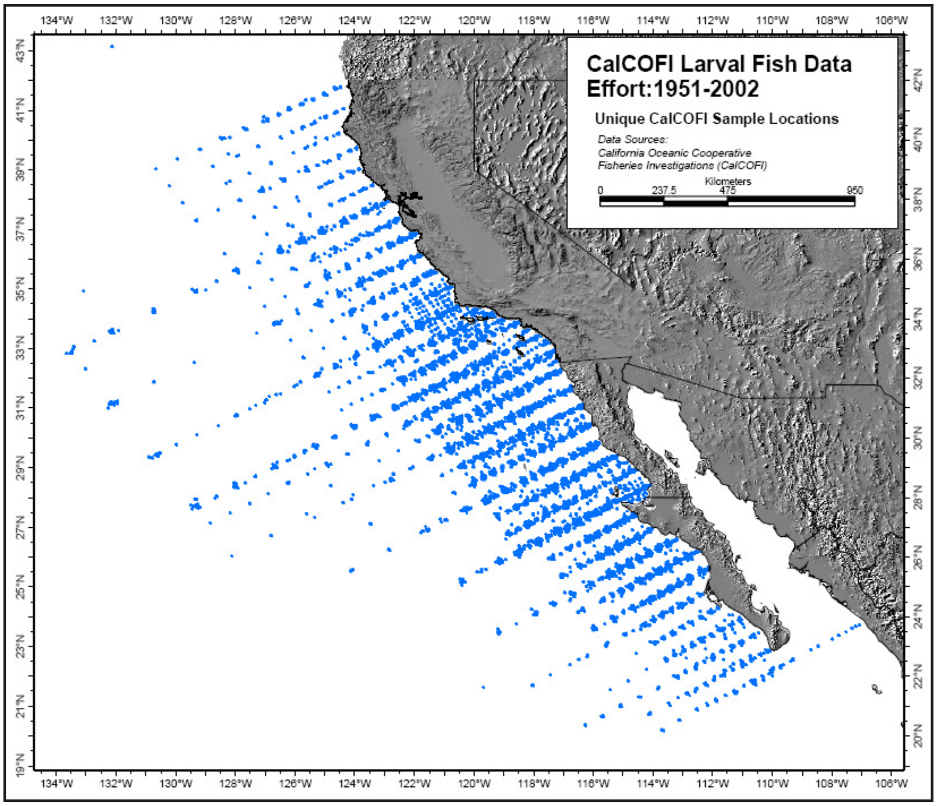

Figure 4.3.1. Geographic extent of CalCOFI bongo net data.

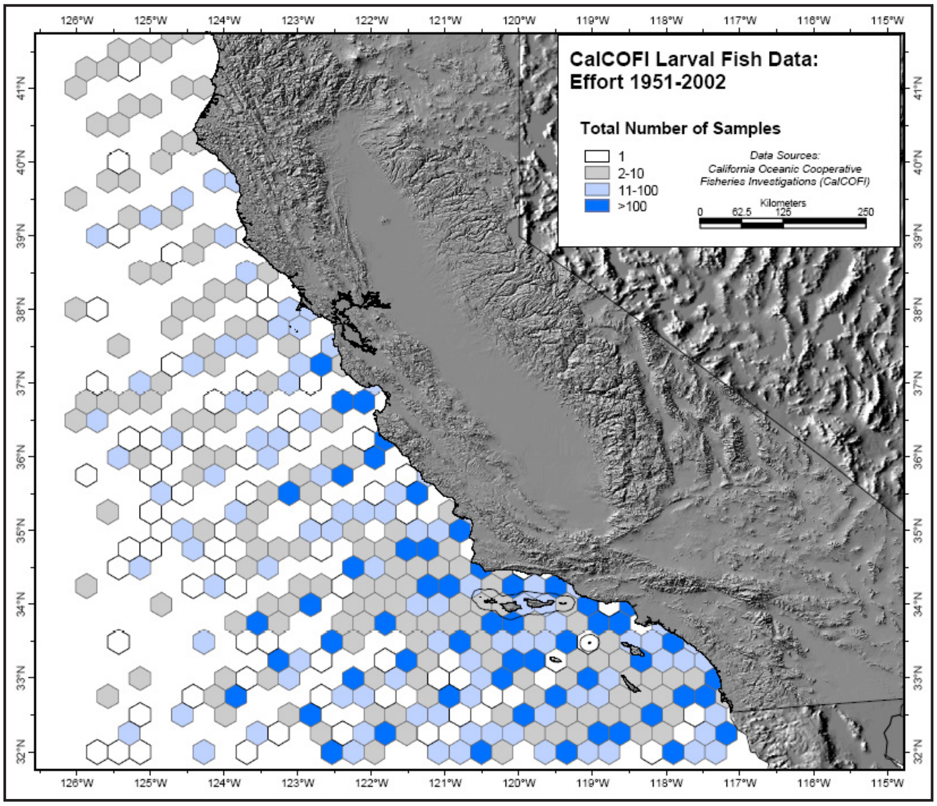

Figure 4.3.2. CalCOFI bongo net effort data.

Because these data span many years representative of both warm and cool water events in the El Niño-Southern Oscillation (ENSO) cycle, and 2-3 periods in the longer term ocean climatology of the Pacific Decadal Oscillation (PDO), a spatially-articulated analysis of total ichthyoplankton abundance trends is not presented. Many scientists have been studying the effects of ocean climate on larval distribution, and the results have necessarily varied based on the time period(s) and spatial domain of focus. Most agree that signals related to ocean climate can be seen in the abundance data (Loeb *et al*., 1983; Moser *et al*. 1993; Sakuma and Ralston, 1995); however, these effects are confounded by interaction, and are thus difficult to isolate and quantify. In analyzing the CalCOFI data, we found that because of the high degree of spatial and temporal variability, grouping all years and all species obscures distribution patterns. Although a species-level analysis of ichthyoplankton is beyond the scope of this report, we've chosen to focus our analyses on four individual species representative of both groundfishes (California halibut and bocaccio) and pelagic fishes (Pacific sardine and northern anchovy).

Distribution and abundance patterns for these four species were mapped by sampling all bongo tows into a hexagonal spatial framework. The total standardized number of individuals per tow was log-transformed (log10[Nstd+1]) and assigned to the hexagon in which it fell. Hexagons are 25 km wide (east-west) by 37 km long (north-south). Values in each hexagon represent the average log-transformed abundance of all tows in the hexagon, and were classified into 20th percentiles (quintiles). White hexagons indicate areas where bongo tows were performed, but resulted in no catch for that species. Because of the natural variability in larval abundance, estimated patterns of larval abundance must be interpreted with care, as they represent a composite of 46 years of sampling.

Broad-scale Patterns

California halibut (*Paralichthys californicus*)

Adult halibut are reported to prefer soft bottom habitats in coastal waters of 100 m or less, with greatest abundances occurring in waters shallower than 30 m. Spawning also generally occurs in shallow coastal waters, accordingly peak egg and larval densities are found in waters less than 100 m, and within 6.5 km from shore (Leet *et al*., 2001). Analysis of *P. californicus* larval data presented here corroborate these reports, with a clear nearshore trend in peak abundance (Figure 4.3.3). Incidences of halibut larvae in bongo nets beyond 6.5 km from shore are few, and where present, generally fall in the lowest 40% of estimated abundance values. All areas classified in the top 20% of halibut larval abundance are found in hexagons adjacent to the shore.

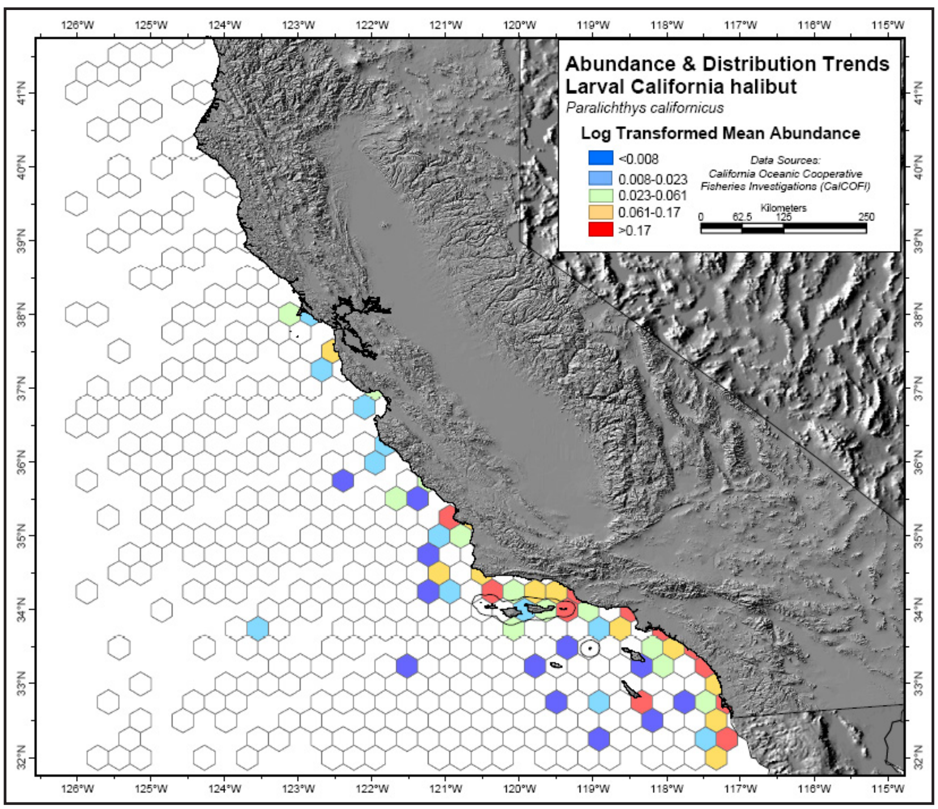

Figure 4.3.3. Estimated mean larval abundance for California halibut in CalCOFI bongo tows. Data are classified into quintiles (map range: 32° to 42°N).

Even though sampling effort north of Morro Bay is reduced compared to effort in the Southern California Bight, an analysis of variance suggested that mean larval abundance is significantly lower ($P<0.003$, $F=8.92$, $DF=376$) north of Pt. Conception (mean=0.005) than south of the promontory (mean=0.02). In general, the entire coastline along the Southern California Bight, including nearshore areas around San Miguel, Anacapa, and San Clemente Islands, is characterized by high halibut larval density. As such, the Santa Barbara Channel and the current sanctuary boundary capture large areas of high larval abundance for this species. Furthermore, any concept that captures areas nearshore to the mainland will likely include areas of high larval abundance (e.g., 1 and 1a). Monterey Bay, Gulf of the Farallones, and Cordell Bank national marine sanctuaries, while sampled less frequently, exhibited few cases of high halibut larval density.

Bocaccio (*Sebastes paucispinis*)

Bocaccio are live-bearing (viviparous) fish. Off central and northern California, brood release occurs from late winter through spring, with peaks in February. In southern California, the brood release is more protracted, ranging from October through July, peaking in January (Leet *et al*., 2001, Love *et al*., 2002). Female bocaccio in southern California have been reported to produce multiple broods in a season. This is more uncommon in the north (Leet *et al*., 2001). Larvae have been observed as far as 480 km from shore. Larval bocaccio grow rapidly, and young of the year juveniles recruit to rocky and/or eelgrass habitats in nearshore waters (Leet *et al*., 2001, Love *et al*., 2002).

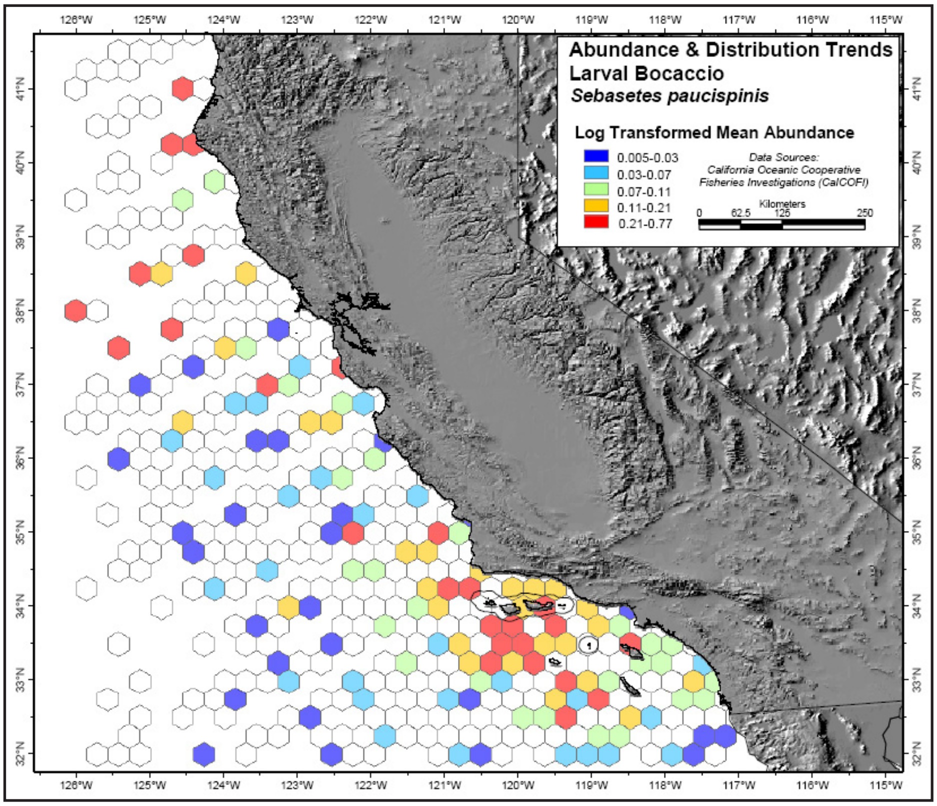

Figure 4.3.4. Estimated mean larval abundance for bocaccio in CalCOFI bongo tows. Data are classified into quintiles (map range: 32° to 42°N).

The analysis of larval bocaccio distribution presented here agrees with the reported literature. Two distinct areas of relatively high larval density can be seen – the first and largest area is centered just south of Santa Rosa Island in the Southern California Bight (Figure 4.3.4). As such, the current CINMS boundary (or No Action Concept, NAC) is well configured to capture a large area of high average bocaccio larval abundance. This is an expression of the high larval abundances that, on average, appear in the late winter months. A more diffuse area of high bocaccio larval abundance can be seen to the north of Monterey Bay, and farther offshore. These areas resulted from larval catches in early spring. Overall, an analysis of variance suggested that mean bocaccio larval abundances are no different (P<0.29, F=1.13, DF=376) north of Pt. Conception (mean=0.038) than south of the promontory (mean=0.049).

Pacific sardine (*Sardinops sagax*)

The Pacific sardine population is believed to be comprised of three subpopulations: 1) the Gulf of California, 2) a southern population off Baja California, and 3) a northern subpopulation. Most of the sardines occurring in the study area are part of the northern subpopulation which ranges from Baja California to Alaska (Leet *et al*., 2001). It is thought that the northern subpopulation's center of density is located off central and southern California. Spawning occurs year-round between Pt. Conception in the north to Magdalena Bay (Baja, California) in the south, with peaks from early spring through summer. Most of the spawning activity is believed to occur approximately 250 km from shore, with reports out to 560 km. Sardine spawning activity is influenced significantly by water temperature, and centers of spawning can vary widely based on ENSO driven ocean climate (Leet *et al*., 2001).

The analyses of larval Pacific sardines presented here suggest that distributions are highly variable, with maximum observed abundances ranging from coastal waters of the Southern California Bight out to 450 km southwest of Point Conception, and 300 km west of Monterey Bay in central California (Figure 4.3.5). An analysis of variance indicated that mean larval abundance is significantly lower (P<0.003, F=21.27, DF=376) north of Pt. Conception (mean=0.013) than south of the promontory (mean=0.063). This is likely due to the preponderance of optimum spawning temperatures south of the point, coupled with mesocale circulation patterns that dominate in the region during these months and entrain larval fishes (Figure 2.4.6, Chapter 2). Figure 2.5.1 (Chapter 2) indicates that mean spring and summer sea surface temperatures in areas of peak larval abundance range from 14°C (57.2°F) to 17°C (62.6°F), bounding the optimum spawning temperature which is reported by Leet *et al*. (2001) as ranging between 15°-16°C (59°-61°F).

Northern anchovy (*Engraulis mordax*)

Northern anchovy are widely distributed along the Pacific coast of North America, with a central subpopulation that ranges from San Francisco in the north to Punta Baja in the south. The center of this population is reported to occupy the Southern California Bight. Anchovy peak spawning occurs in late winter through spring (Leet *et al*., 2001). The analyses of larval northern anchovy presented here corroborate the results presented by Leet *et al*. (2001), with an expansive area of maximum observed abundance throughout the entire Southern California Bight (Figure 4.3.6). Results of an analysis of variance ($P<0.001$, $F=101.84$, $DF=376$) suggest that mean abundances of larval anchovy are an order of magnitude higher south of Point Conception (mean=1.0) than to the north (mean=0.18). As such, the current CINMS boundary captures large areas of high larval abundance for this species.

Analysis of Boundary Concepts

Due to the high degree of spatial and temporal variation in larval distributions as a whole, coupled with highly variable sampling efforts through the long history of the CalCOFI program, we have chosen not to sample the described broad-scale patterns into each of the Sanctuary boundary concepts in an effort to develop an Optimal Area Index (OAI). Data for each of the four species presented here suggest that the Southern California Bight, including the CINMS and all boundaries under consideration, capture areas important to larval fishes of the region. The data analyzed here are insufficient in spatial resolution (Figure 4.3.2) to develop a robust and confident estimate of potential "manageable" differences among boundary concepts.

Summary

• Larval abundance and distribution along the Pacific coast of North America can be highly variable, both spatially and temporally.

• Of the four species presented here, three exhibited higher larval abundance south of Point Conception than to the north (northern anchovy, Pacific sardine, and bocaccio).

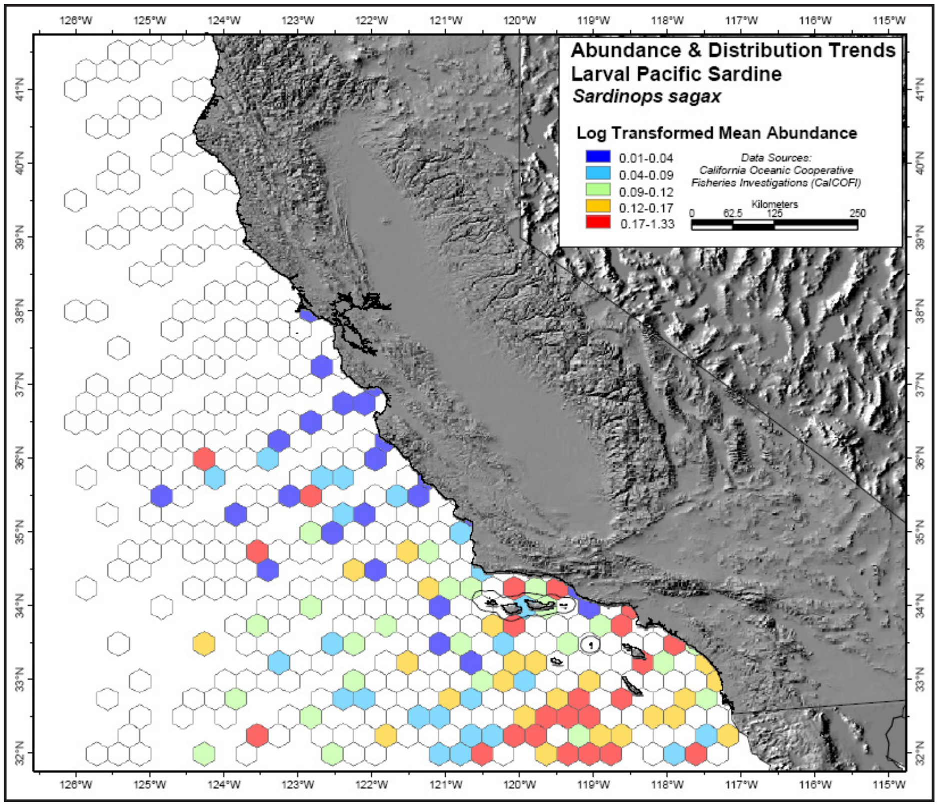

Figure 4.3.5. Estimated mean larval abundance for Pacific sardine in CalCOFI bongo tows. Data are classified into quintiles (map range: 32° to 42°N).

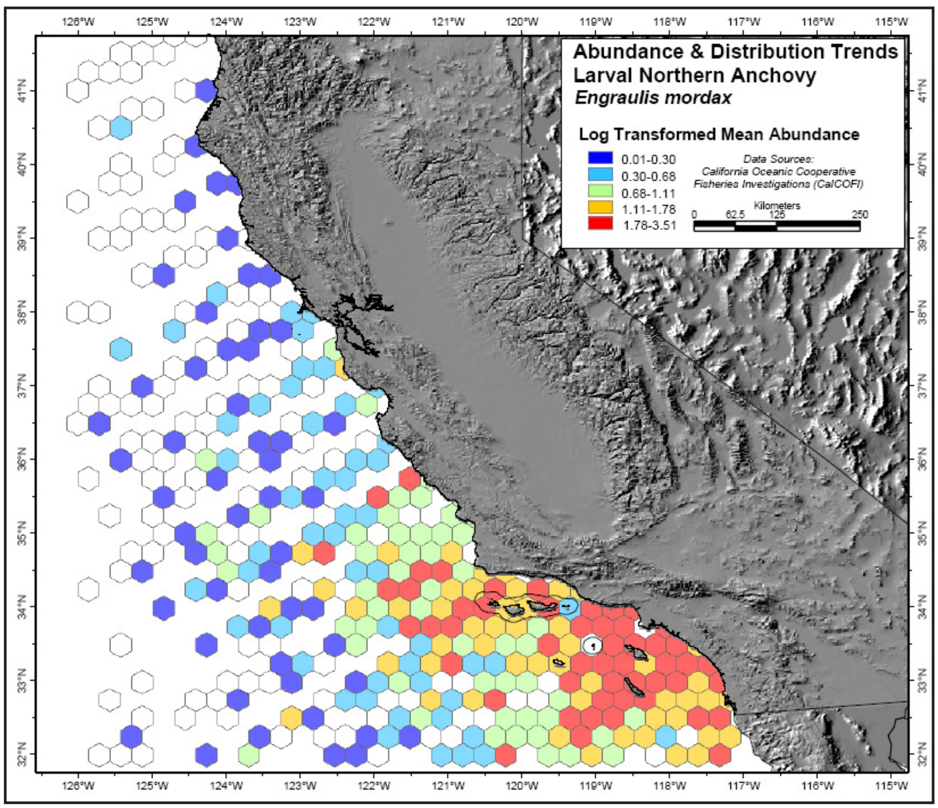

Figure 4.3.5. Estimated mean larval abundance for northern anchovy in CalCOFI bongo tows. Data are classified into quintiles (map range: 32° to 42°N).

• California halibut did not exhibit differences in mean larval abundance north vs. south of Point Conception.

• In general, the Southern California Bight, including the current and proposed CINMS boundary concepts, capture areas important to larval fishes of the region.

• Concepts which include more nearshore habitat are likely to include more halibut larvae.

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CHAPTER 5 – BIOGEOGRAPHY OF MARINE BIRDS

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Over 195 species of marine birds use open water, shore, or island habitats in the Southern California Bight south of Point Conception (Baird, 1993). As many as 10 additional species use the coast along Vandenberg Air Force Base. The region of interest is located along the Pacific Flyway, a major migratory route for birds, and acts as a stopover during both north (April through May) and south (September through December) migrations. The months of June and July are peak months for transient shorebirds (Lehman, 1994). The Channel Islands and the Southern California mainland coast provide breeding and nesting sites for many species of seabirds and shorebirds, including several listed as threatened or endangered. The status and distribution of the 11 requested bird species within the study area are summarized in Table 5.0.1. This chapter is divided into a single species analysis of the 11 requested species (Chapter 5.1), and a community analysis of all bird species sampled in at-sea surveys (Chapter 5.2).

5.1 MARINE BIRD SINGLE SPECIES ANALYSIS

Data and Methods

Data sources for this section are summarized in Table 5.1.1 and discussed in greater detail below. Three types of georeferenced survey data for marine birds (the term marine birds is used to encompass both seabirds and shorebirds) were available for this report: shipboard and aerial at-sea surveys, breeding colony surveys, and Xantus's murrelet telemetry data. Although no data were available in any of these surveys for snowy plover (*Charadrius alexandrinus*) or western snowy plover (*Charadrius alexandrinus nivosus*), the critical habitat delineations published in the Federal Register (USFWS, 1999) allow for some spatial analysis of the distribution of important snowy plover habitat. Scientific names and spellings of common names follow the Patuxent Bird Identification Infocenter (Gough *et al*., 1998). For display purposes, all maps were classified by quintile (five intervals, each of which contains approximately 20% of the data), except where fewer than five discrete values occurred. For discussion in this chapter, northern Channel Islands are: San Miguel, Santa Rosa, Santa Cruz, Anacapa, and Santa Barbara Islands.

A recent comprehensive survey of marine birds in the Southern California Bight was conducted in 1999-2002; however georeferenced data from these surveys were not available at the time of publication. From May 1999 to January 2002, aerial at-sea surveys were conducted by Humboldt State University (HSU) and the U.S. Geological Survey (USGS) for seabirds and marine mammals from Point Piedras Blancas to the U.S.-Mexico border, including the entire Southern California Bight (McChesney *et al*. 2000, 2001; Capitolo *et al*. 2003). Surveys were funded mainly by USGS, with additional support from the Minerals Management Service (MMS), U.S. Navy (USN) and California Department of Fish and Game (Office of Spill Prevention and Response; CDFG-OSPR). At-sea and shoreline roosting surveys were conducted: May and September 1999; January, May, and September 2000; January, May, and September 2001; and January 2002. These efforts used the same methods and essentially covered the same areas of the continental shelf examined by surveys during 1975-1977 below Point Conception and by surveys during 1980-1983 north of Point Conception (Briggs *et al*. 1987). Higher at-sea survey effort and greater coverage of coastline areas (on shore and at sea) occurred for each survey in 1999-2002, but they were conducted less frequently than in earlier surveys. Databases from 1999-2002 HSU/USGS surveys were not available for this report but will be available in the near future.

Computer Database Analysis System (CDAS)

At-Sea Surveys

Five at-sea surveys from the period 1975-1997 were compiled in CDAS v2.1 (MMS, 2001) and used to derive density maps for eight of the requested bird species:

Ashy storm-petrel (*Oceanodroma homochroa*)
California brown pelican (*Pelecanus occidentalis californicus*)
Double-crested cormorant (*Phalacrocorax auritus*)
Brandt's cormorant (*Phalacrocorax penicillatus*)
Pelagic cormorant (*Phalacrocorax pelagicus*)

Figure 5.0.1. Status, habitat locations, and seasonal use of the requested marine birds in the region of interest (Source: Working Draft Environmental Impact Statement for Channel Islands National Marine Sanctuary: Affected Environment Section, 2000).

	Common Name	Scientific Name	Status / Season	Federal / State Status	Habitat Type	Habitat Location within Study Area	Breeding (location)
Shorebirds	Western snowy plover	*Charadrius alexandrinus nivosus*	Fairly common/winter Fairly common to Uncommon /summer	Federally listed as Threatened	Beaches, sandy and rocky shores, Jetties	Vandenberg Air Force Base, Hollster Ranch, Ormond Beach, Point Mugu Lagoon, Coal Oil Point	Vandenberg Air Force Base, Hollster Ranch, Ormond Beach, Point Mugu Lagoon, Coal Oil Point, Channel Islands
	Black oystercatcher	*Haematopus bachmani*	Uncommon/year-round		Beaches, sandy and rocky shores, jetties	Vandenberg Air Force	Vandenberg Air Force Base, Channel Islands
Seabirds	Ashy storm-petrel	*Oceanodroma homochroa*	Common/spring, winter, fall Casual/winter	California Department of Fish and Game species of special concern	Open ocean	Channel Islands	San Miguel, Santa Cruz, Anacapa, Santa Barbara, San Clemente Islands
	California brown pelican	*Pelecanus occidentalis californicus*	Common/year-round	Federally listed as Endangered	Inshore ocean waters, bays and harbors	Most areas	Anacapa, Santa Barbara Islands
	Double-crested cormorant	*Phalacrocorax auritus*	Common/winter Uncommon/summer	California's Department of Fish and Game species of special concern	Open ocean, lakes, reservoirs, large streams, creeks and rivers	Santa Ynez River, Hollster Ranch, Devereux Slough, UCSB Lagoon, Goleta Slough, Ormond Beach	Anacapa, San Miguel, Santa Barbara, San Clemente Islands, San Diego Bay
	Brandt's cormorant	*Phalacrocorax penicillatus*	Uncommon to adundant/ winter		Fresh and/or salt water marshes, estuaries, mudflats, tidal lagoons, and brackish water, lakes, reservoirs, large streams, creeks and rivers, inshore ocean waters, bays and harbors	Vandenberg Air Force Base, Hollster Ranch, Channel Islands	Vandenberg Air Force Base,San Miguel, Santa Rosa, Santa Cruz, Santa Barbara, Anacapa, San Nicolas, San Clemente Islands
	Pelagic cormorant	*Phalacrocorax pelagicus*	Fairly common to common/winter Rare to fairly common/ summer		Open ocean, beaches, sand and rocky shores, jetties	Vandenberg Air Force Base, Hollster Ranch, Channel Islands	Vandenberg Air Force Base, San Miguel, Santa Rosa, Santa Cruz, Anacapa, Santa Barbara Islands
	California least tern	*Stena antillarum browni*	Rare to Common/year-round	Federally and State-listed as Endangered	Beaches, sandy and rocky shores, jetties, inshore ocean waters, bays and harbors	Vandenberg Air Force Base, Devereux Slough, UCSB Lagoon, Carpinteria Marsh, Ormond Beach, Point Mugu Lagoon	Vandenberg Air Force Base, Devereux Slough, Ormond Beach, Point Mugu Lagoon
	Pigeon guillemot	*Cepphus columba*	Common/summer		Beaches, sandy and rocky shores, jetties, inshore ocean waters, bays and harbors	Vandenberg Air Force Base, Hollster Ranch, Channel Islands	Vandenberg Air Force Base, San Miguel, Santa Rosa, Santa Cruz, Anacapa, Santa Barbara Islands
	Xantus's murrelet	*Synthliiboramphus hypoleucus*	Uncommon/spring, summer Rare/fall, winter		Open ocean	Channel Islands	San Miguel, Santa Cruz, Anacapa, Santa Barbara, San Clemente, Santa Catalina Islands
	Cassin's auklet	*Ptychoramphus aleuticus*	Fairly common/year-round		Open ocean	Channel Islands	San Miguel, Santa Cruz, Anacapa, Santa Barbara Islands

Pigeon guillemot (*Cepphus columba*)
Xantus's murrelet (*Synthliboramphus hypoleucus*)
Cassin's auklet (*Ptychoramphus aleuticus*)

Table 5.1.1. Data used for the analysis of marine bird distributions presented in this chapter.

Survey	Source	Dates	Platform	Months
CDAS- Minerals Management Service Aerial Surveys	R.G. Ford	1980-1983	airplane (low altitude)	Year-round
CDAS-California Department of Fish and Game, Office of Spill Prevention and Response	R.G. Ford	1994-1997	airplane (low altitude)	Year-round
CDA3-Southern California Bight Low Aerial Survey	R.G. Ford	1975-1978	airplane (low altitude)	Year-round
CDAS-Seabird Ecology Study	R.G. Ford	1985	ship and airplane	March and May
CDA3-Southern California Bight, Minerals Management Service Survey	R.G. Ford	1995-1997	airplane (low altitude)	Year-round
Breeding Colony Surveys-Humbolt State University and U.S. Fish and Wildlife Service	H.R. Carter	1989-1991	various	April-August
Xantus's Murrelet Breeding Colony Surveys-Humbolt State University	H.R. Carter	1991-2002	various	April-May
Xantus's Murrelet Telemetry Study-U.S. Geological Survey and Humbolt State University	H.R. Carter	1995-1997	Airplane and fixed station radio receivers	April-June
Snowy plover critical habitat-U.S. Fish and Wildlife Service	Federal Register	1999		
DRAFT California least tern breeding survey-California Department of Fish and Game	Lyann Comrack	2001-2003		

A sixth survey, the Southern California Bight ship survey, which is used in the calculation of bird diversity (Chapter 5.2) was not used in the calculation of individual species densities because of the difficulties of reconstructing survey effort for this survey. This was not problematic for the calculation of diversity for the reasons discussed in that chapter, but it precludes the calculation of density.

Bird densities were calculated for five minutes of latitude by five minutes of longitude cells. Densities were calculated as the number of individuals sighted divided by the area searched for each species in each five-minute cell. Areas searched were calculated as the total length of survey track in each cell multiplied by the effective strip width. Cells in which fewer than 5 km of survey track occurred were dropped from this analysis. For calculation of total individuals and density within the boundary concept, all grid cells which intersect the boundaries of a concept are included in calculations for that concept. This method is required because effort in the CDAS data set is summarized by cells. Consequently, any analysis involving effort is limited in spatial resolution by this five-minute cell size.

Breeding Colony Surveys

Surveys of marine bird breeding colonies were conducted in 1989-1991 by researchers from Humboldt State University (HSU) and the U.S. Fish and Wildlife Service (USFWS), and were funded by the Minerals Management Service (MMS) (Carter *et al*., 1992, 1995a). The survey counted birds, nests, and potential nesting sites for most breeding species. Additionally, the size of the breeding population at each site was estimated based on adjustments to the counts mentioned above or by capture-recapture methods. Details of the population estimates are given in Carter *et al*. (1992). All analysis of the breeding colony survey in this report is based on these site-specific population estimates. Breeding colony survey data were available for:

Ashy storm-petrel (*Oceanodroma homochroa*)
California brown pelican (*Pelecanus occidentalis californicus*)
Double-crested cormorant (*Phalacrocorax auritus*)
Brandt's cormorant (*Phalacrocorax penicillatus*)
Pelagic cormorant (*Phalacrocorax pelagicus*)

Black oystercatcher (*Haematopus bachmani*)
California least tern (*Sterna antillarum browni*)
Pigeon guillemot (*Cepphus columba*)
Xantus's murrelet (*Synthliboramphus hypoleucus*)
Cassin's auklet (*Ptychoramphus aleuticus*)

More recent surveys of California least tern nesting areas were provided by Lyann Comrack (CDFG, draft data). The maximum number of least tern breeding pairs observed at each site was complied from these CDFG surveys conducted in 2001, 2002, and 2003. Additionally, recent colony survey data for Xantus's murrelet were provided by H. Carter (HSU, unpubl. data). These data were compiled from surveys conducted from 1991-2002 and are summarized in Burkett *et al*., (2003). Because these data are available as summaries for individual shoreline segments rather than point counts they are presented for each island individually.

Xantus's Murrelet Telemetry Study
Data presented in this section represent the results of a radio telemetry survey of Xantus's murrelet in the Southern California Bight conducted by the U.S. Geological Survey (USGS) and HSU from 1995 to 1997 (Whitworth *et al*., 2000; Carter *et al*., 2000). Murrelets were captured at sea near Santa Barbara Island and 153 individuals were fitted with radio transmitters. Marked individuals were relocated mainly by aerial telemetry surveys conducted between April and June of 1995, 1996, and 1997. A receiving station on North Peak, Santa Barbara Island was also used to relocate marked individuals within a few km of the island. A raster density map of re-locations was created for visualization purposes using the kernel density function of ArcView Spatial Analyst (ESRI, 2003) with a radius of 15 km and a cell size of 2 km. Analysis of the boundary concepts was conducted on the re-location points not the density map.

Broad-scale Patterns and Analysis of Boundary Concepts

Ashy storm-petrel (*Oceanodroma homochroa*)
Ashy storm-petrel is a small procellariiform (Family Hydrobatidae) whose year round range extends from Cape Mendocino, California to northern Baja California, Mexico. CINMS is at the southern end of their core breeding and feeding distribution. This species nests mainly in cavities in rock piles and cliffs on offshore California islands with only one known nesting site outside of California on Islas Los Coronados, Mexico. Small numbers nest on small rocks near the coast at Point Reyes, south of Monterey, and possibly on the mainland at Vandenberg AFB (McChesney *et al*., 2000; Whitworth *et al*., 2002; Brown *et al*., 2003). Due to their widely dispersed and offshore foraging habits, ashy storm-petrels are likely to be underestimated by at-sea surveys, and their cryptic nests make it difficult to census colonies. Breeding colony surveys from 1989-1991 estimated a worldwide breeding population of 7,207 birds with 43% of the breeding population found in the northern Channel Islands (Carter *et al*., 1992). Although this estimate is greater than previous estimates, differences in survey sites and methods preclude any inference of a trend. Due to pollutant impacts and other factors, numbers may be declining in the northern Channel Islands (H. Carter, unpubl. data). Numbers have declined at the Farallon Islands due to high predation (Sydeman *et al*., 1998). Ashy storm-petrel is listed as a California "Species of Special Concern," but is not federally endangered or threatened.

At-sea sightings indicate that areas of high ashy storm-petrel density occur along the continental slope off Central California, with notable concentrations between Point Arena and Monterey Bay (including the deep waters of the Monterey Canyon), and in the Southern California Bight. Sightings also occur on the shelf between Point Buchon and Point Conception.

Analysis of the observed patterns of ashy storm-petrel sightings (Figure 5.1.1) and density relative to the proposed boundary concepts indicates that Concept 3 provides the greatest increase in both sightings (absolute metric) and mean density (relative metric) for its relative size compared to the current boundary (NAC; Table 5.1.2). Most of the additional sightings within the study area but outside of the current sanctuary boundaries occur in the Santa Barbara Channel. It should be noted that most of the increase in sightings and density observed in Concept 3 relative to the next smallest concept (Concept 4) is due to inclusion of one additional grid cell in which 55 ashy storm-petrels were observed.

In 1989-1991, breeding colonies of ashy storm-petrel (Figure 5.1.2) were found on San Miguel, Santa Cruz, and Santa Barbara Islands. More recent surveys (H. Carter, unpubl. data) have found greater numbers on Santa

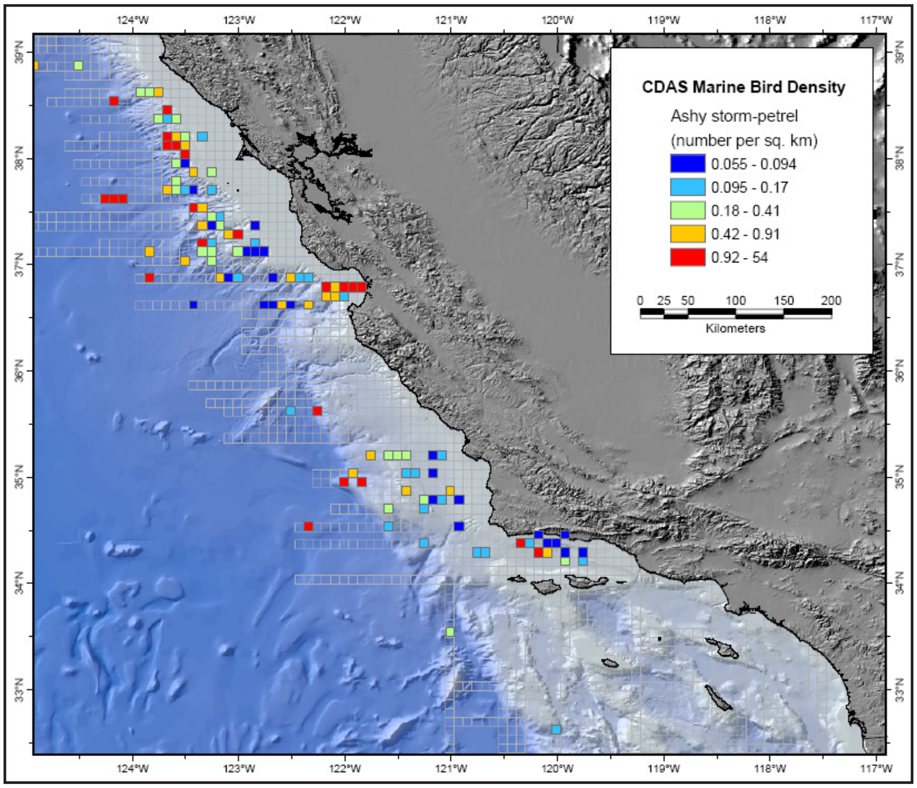

Figure 5.1.1. Ashy storm-petrel. At-sea densities (individuals/km^2) calculated for five minutes of latitude by five minutes of longitude grid cells from aerial and shipboard survey data collected from 1975-1997 and summarized in the Computer Database Analysis System v2.1 (MMS, 2001).

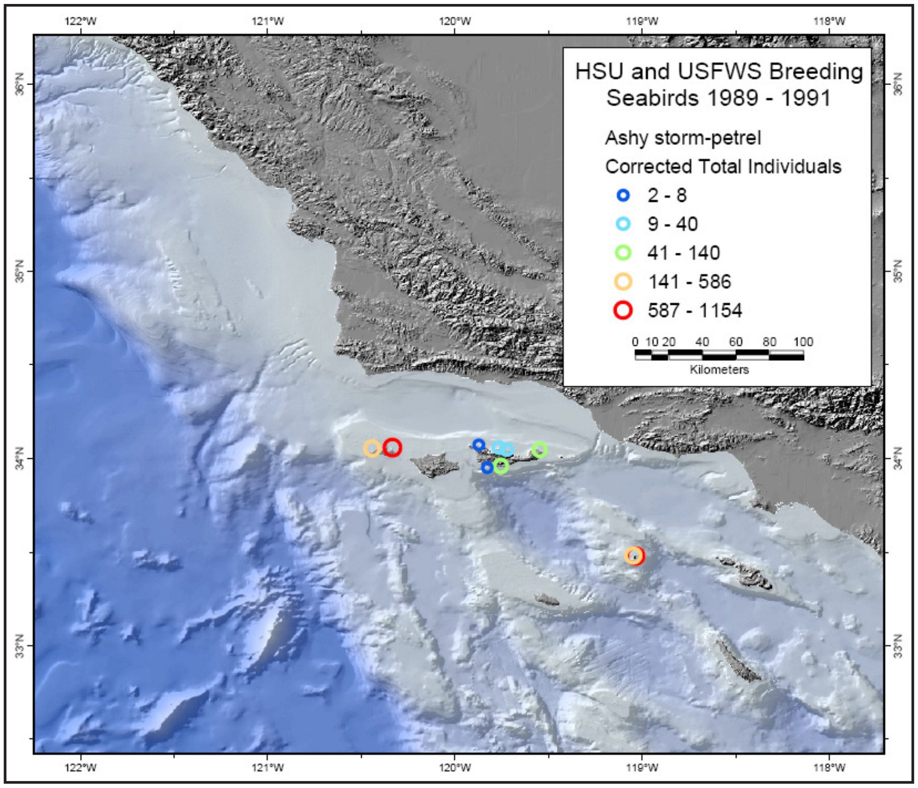

Figure 5.1.2. Ashy storm-petrel. Colony counts (corrected total individuals) 1989-1991 (Source: Carter *et al.*, 1992).

Cruz Island and colonies on Anacapa and San Clemente Island. Most colonies are within the current sanctuary boundaries as well as the boundaries of all of the concepts, and consequently no Optimal Area Index (OAI) analysis was done for the ashy storm-petrel colony data.

Table 5.1.2. Ashy storm-petrel. At-sea sightings, effort, density, and Optimal Area Index (OAI) for each boundary concept. Values in bold indicate an increase in the estimate when compared to the NAC. Shaded OAI estimates reflect the concept with the greatest positive value.

Concept	Total Individuals	Total Effort (Area swept km^2)	Density (Individuals per km^2)	Area (km^2)	Δ Individuals (%)	Δ Density (%)	Δ Area (%)	OAI Individuals (absolute metric)	OAI Density (relative metric)
NAC	2	448.2	0.004	3745	-	-	-	-	-
5	**3**	492.3	**0.006**	4538	50	36.56	21.12	2.37	1.73
4	**38**	748.3	**0.051**	7981	1800	1038.02	113.11	15.91	9.18
3	**95**	984.6	**0.096**	9044	4650	2062.25	141.50	32.86	14.57
2	**106**	1589.1	**0.067**	13736	5200	1394.85	266.78	19.49	5.23
1a	**128**	2460.3	**0.052**	22613	6300	1065.91	503.82	12.50	2.12
1	**128**	2460.3	**0.052**	22591	6300	1065.91	503.23	12.52	2.12
SA	*107*	*2115.2*	*0.051*	*17093*	*5250*	*1033.64*	*356.42*	*14.73*	*2.90*

California brown pelican (*Pelecanus occidentalis californicus*)
California brown pelicans (Family Pelecanidae) range from southern British Columbia to northern South America with the California subspecies breeding from California to the Pacific coast of southern Mexico. The CINMS is at the northern edge of this subspecies breeding range and feeding distribution. They nest in a variety of habitats on offshore islands. The 1991 breeding colony survey resulted in an estimate of 11,916 breeding birds in California with all of the breeding population of California occurring in the northern Channel Islands (Carter *et al*., 1992). This survey indicated a continued increase in abundance of pelicans since the low of 76 nests in 1977, reflecting partial recovery from pollutant impacts. Since 1991, pelicans have oscillated in numbers between years (F. Gress, pers. comm.). However, much larger numbers of pelicans occur in late summer and fall in the Santa Barbara Channel and the Southern California Bight when many disperse northward from large colonies in the Gulf of California (Jaques *et al*., 1996; Capitolo *et al*., 2003). The California brown pelican is a state and federally listed endangered species.

At-sea sightings indicate that areas of high brown pelican density can be found on the north side of Santa Cruz Island, and along the coast from Point Sal to Point Mugu. Much of the eastern half of the Santa Barbara Channel also exhibits high brown pelican density.

Analysis of the observed patterns of brown pelican sightings (Figure 5.1.3) and density relative to the proposed boundary concepts indicates that Concepts 1 and 1a provide the greatest increase in sightings (absolute metric) for its relative size compared to the NAC (Table 5.1.3). The density-based OAI, however, favors Concept 5, the smallest concept other than the NAC. The smaller concepts (3-5) fail to capture the region of high pelican density along the mainland coast and in the eastern Santa Barbara Channel, while the largest concepts (1 and 1a) include large areas of low pelican density along the shelf. Concept 2 exhibits both of these flaws in relation to brown pelican distributions.

Only two breeding colonies of brown pelican (Figure 5.1.4) were recorded in California in the 1989-1991 breeding colony survey. The larger colony (10,680 individuals) is found on West Anacapa Island, and a smaller colony (1,236 individuals) is found on Santa Barbara Island.

No analysis of boundary concepts was conducted for brown pelican breeding colonies since none of the concepts encompass any colonies not contained within the NAC.

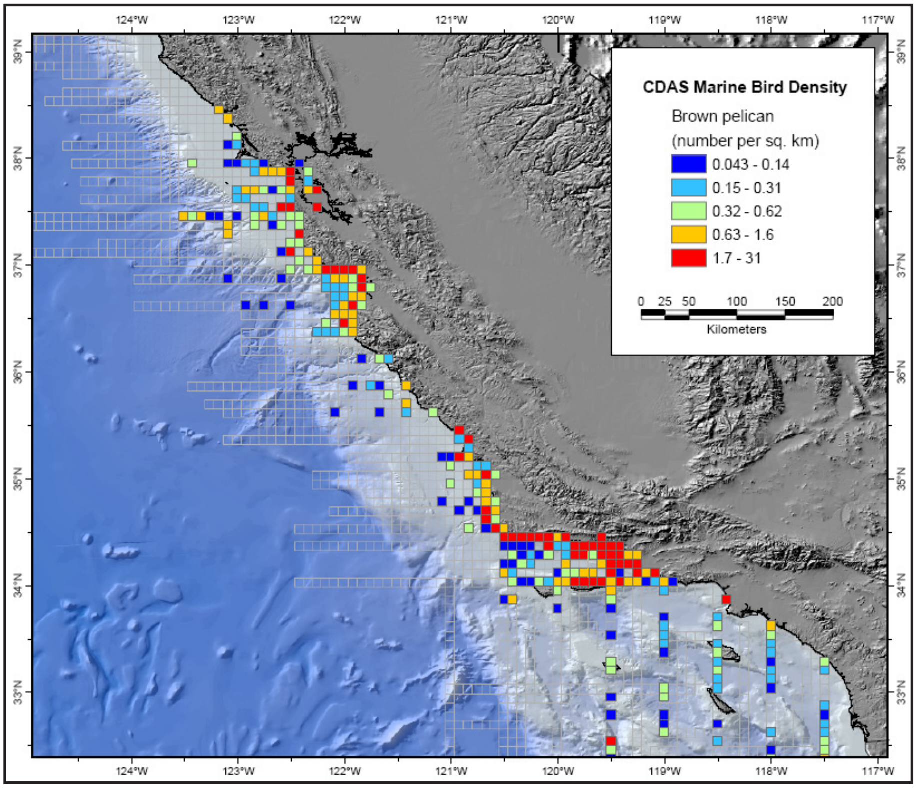

Figure 5.1.3. California brown pelican. At-sea densities (individuals/km^2) calculated for five minutes of latitude by five minutes of longitude grid cells from aerial and shipboard survey data collected from 1975-1997 and summarized in the Computer Database Analysis System v2.1 (MMS, 2001).

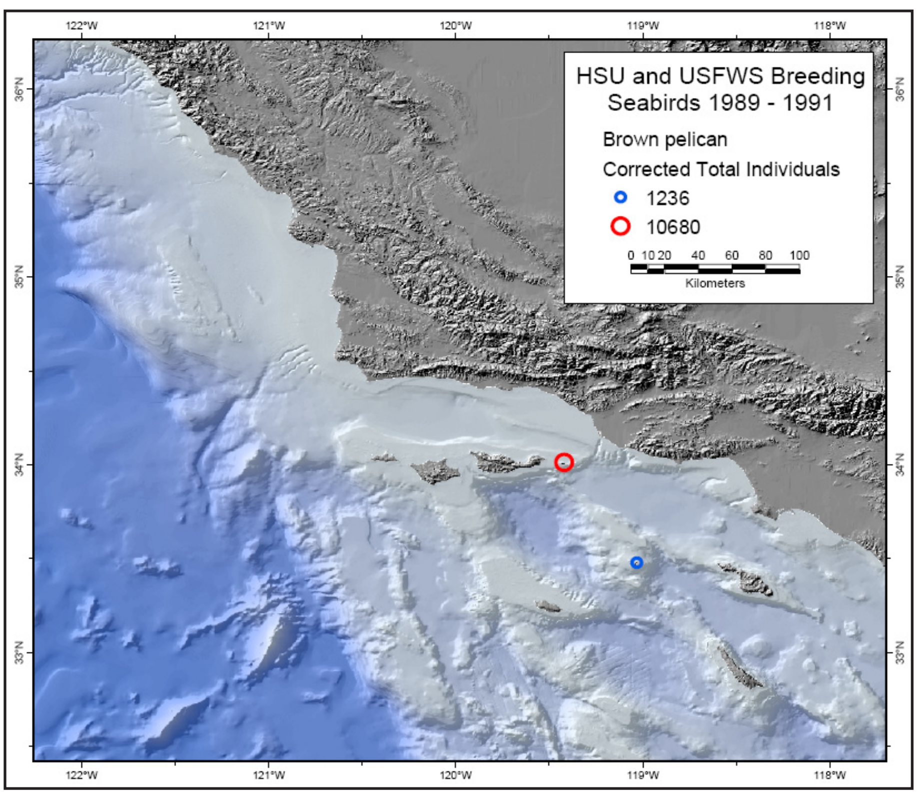

Figure 5.1.4. California brown pelican. Colony counts (corrected total individuals) 1989-1991 (Source: Carter *et al*., 1992).

Table 5.1.3. California brown pelican. At-sea sightings, effort, density, and Optimal Area Index (OAI) for each boundary concept. Values in bold indicate an increase in the estimate when compared to the NAC. Shaded OAI estimates reflect the concept with the greatest positive value.

Concept	Total Individuals	Total Effort (Area swept km^2)	Density (Individuals per km^2)	Area (km^2)	Δ Individuals (%)	Δ Density (%)	Δ Area (%)	OAI Individuals (absolute metric)	OAI Density (relative metric)
NAC	374	448.2	0.834	3745	-	-	-	-	-
5	**452**	492.3	**0.918**	4538	20.88	10.03	21.12	0.99	0.47
4	**540**	748.3	0.722	7981	44.39	-13.52	113.11	0.39	-0.12
3	**913**	984.6	**0.927**	9044	144.12	11.12	141.50	1.02	0.08
2	**1355**	1589.1	**0.853**	13736	262.30	2.19	266.78	0.98	0.01
1a	**2546**	2460.3	**1.035**	22591	580.75	24.01	503.23	1.15	0.05
1	**2546**	2460.3	**1.035**	22613	580.75	24.01	503.82	1.15	0.05
SA	*2546*	*2115.2*	*1.204*	*17093*	*580.75*	*44.25*	*356.42*	*1.63*	*0.12*

Double-crested cormorant (*Phalacrocorax auritus*)

Double-crested cormorant (Family Phalacrocoracidae) is found in marine, estuarine, and freshwater habitats throughout most of North America. CINMS is within the core breeding range of the *P. a. albociliatus* subspecies. In California, they nest in a variety of habitats including flat, sloping, and cliff areas of the mainland coast and offshore rocks and islands, as well as trees and artificial habitats. The 1989-1991 breeding colony survey resulted in an estimate of 10,037 breeding birds in marine and estuarine habitats of California with 25% of the breeding population of California occurring in the northern Channel Islands (Carter *et al*., 1992). The survey showed an increase in abundance of double-crested cormorant in the northern Channel Islands since earlier (1975-1980) surveys (Carter *et al*., 1995a, b). This increase reflected some recovery from pollutant impacts, but recent surveys have shown declines (Capitolo *et al*., 2004). The northern Channel Islands are one of the few areas in North America where double-crested cormorants are declining (Carter *et al*., 1995b). The double-crested cormorant is listed as a California "Species of Special Concern," but is not federally endangered or threatened.

At-sea sightings showed the highest densities of double-crested cormorant in San Francisco Bay, well to the north of the CINMS study area. However, an additional region of relatively high densities exists in nearshore waters along both sides of the Santa Barbara Channel. The highest densities in Southern California were found in nearshore waters from Point Conception to Point Hueneme.

Analysis of the observed patterns of double-crested cormorant sightings (Figure 5.1.5) and density relative to the proposed boundary concepts indicates that Concepts 1 and 1a provide the greatest increase in sightings (absolute metric) for its relative size compared to the NAC (Table 5.1.4). The density-based OAI favors Concept 3, which includes a region of high density around Point Conception. As with brown pelican, the smaller concepts (4 and 5) fail to capture the region of high double-crested cormorant density along the mainland coast, while the largest concepts (1 and 1a) include large areas of low density along the shelf. Again, Concept 2 exhibits both of these flaws.

Breeding colonies of double-crested cormorant (Figure 5.1.6) exist on San Miguel, West Anacapa, and Santa Barbara Islands, with the two largest colonies (720 and 768 individuals) in Southern California found on West Anacapa and Santa Barbara Islands respectively. A small colony was recently found at San Clemente Island (H. Carter, unpubl. data). Mainland colonies exist at Morro Bay and San Diego Bay.

No analysis of boundary concepts was conducted for double-crested cormorant breeding colonies since none of the concepts encompass any colonies not contained within the NAC.

Brandt's cormorant (*Phalacrocorax penicillatus*)

Brandt's cormorant (Family Phalocrocaracidae) is the most abundant cormorant in California, ranging along the Pacific coast from southern Vancouver Island, Canada to southern Baja California, Mexico. CINMS is within the core of their breeding range and feeding distribution. Nesting habitat for this species is variable and includes flat or sloping surfaces of offshore islands as well as mainland cliffs. Surveys of all known large (>100) breeding col-

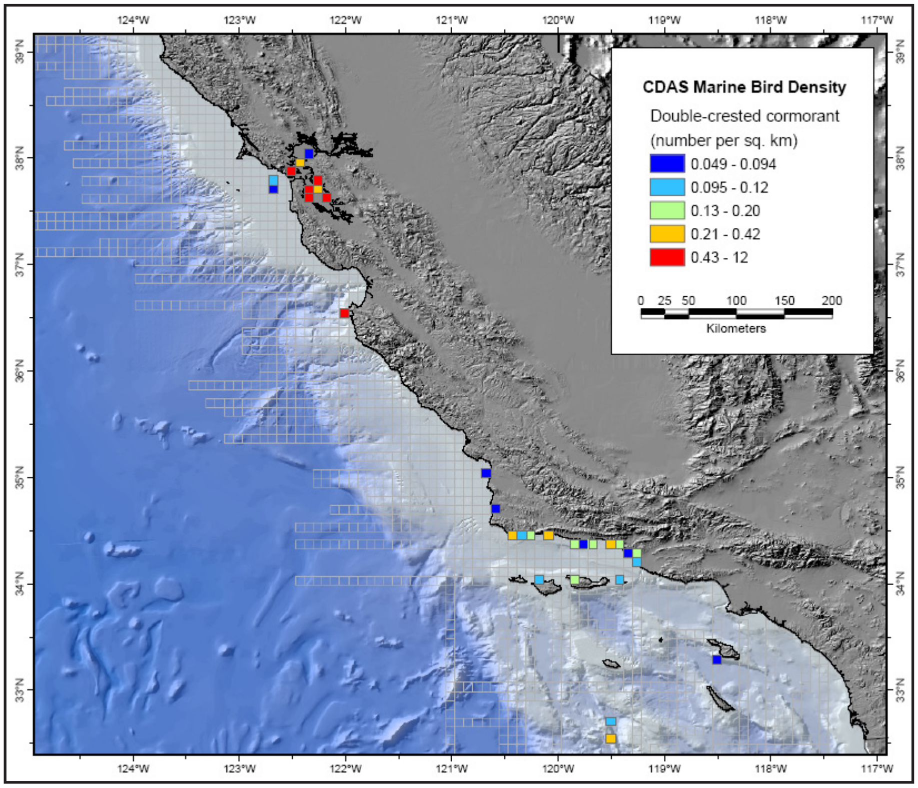

Figure 5.1.5. Double-crested cormorant. At-sea densities (individuals/km²) calculated for five minutes of latitude by five minutes of longitude grid cells from aerial and shipboard survey data collected from 1975-1997 and summarized in the Computer Database Analysis System v2.1 (MMS, 2001).

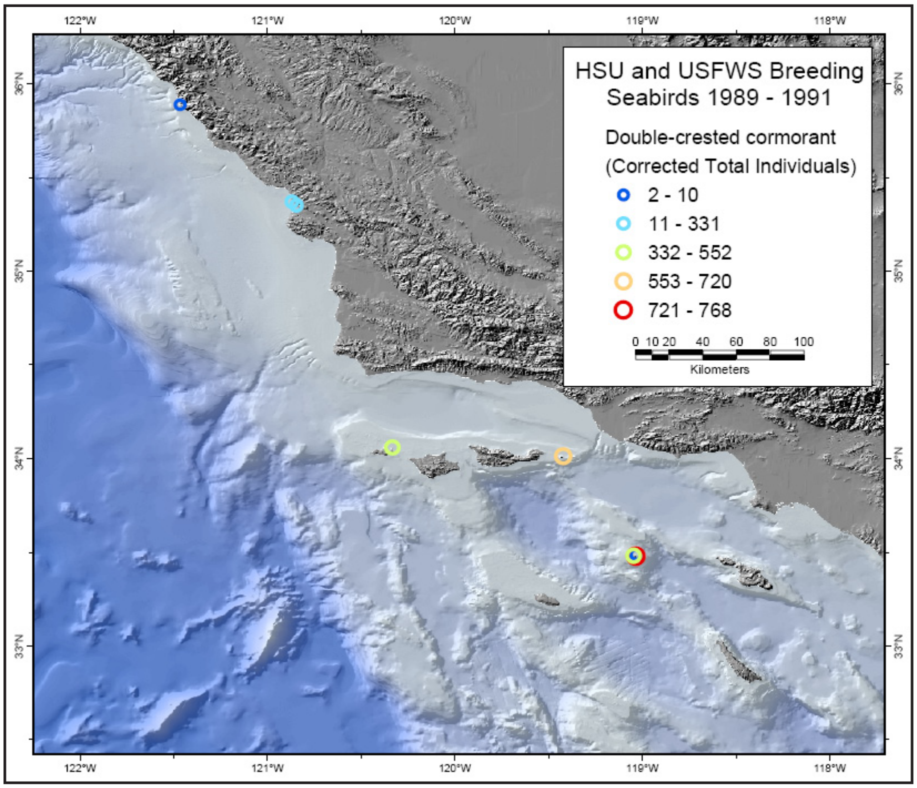

Figure 5.1.6. Double-crested cormorant. Colony counts (corrected total individuals) 1989-1991 (Source: Carter *et al*., 1992).

Table 5.1.4. Double-crested cormorant. At-sea sightings, effort, density, and Optimal Area Index (OAI) for each boundary concept. Values in bold indicate an increase in the estimate when compared to the NAC. Shaded OAI estimates reflect the concept with the greatest positive value.

Concept	Total Individuals	Total Effort (Area swept km²)	Density (Individuals per km²)	Area (km²)	∆ Individuals (%)	∆ Density (%)	∆ Area (%)	OAI Individuals (absolute metric)	OAI Density (relative metric)
NAC	3	448.2	0.007	3745	-	-	-	-	-
5	3	492.3	0.006	4536	0.00	-8.96	21.12	0.00	-0.42
4	3	748.3	0.004	7981	0.00	-40.10	113.11	0.00	-0.35
3	**11**	984.6	**0.011**	9044	266.67	66.91	141.50	1.88	0.47
2	**18**	1589.1	**0.011**	13736	500.00	69.23	266.78?	1.87	0.26
1a	**40**	2460.3	**0.016**	22591	1233.33	142.90	503.23	2.45	0.28
1	**40**	2460.3	**0.016**	22613	1233.33	142.90	503.82	2.45	0.28
SA	*40*	*2115.2*	*0.019*	*17093*	*1233.33*	*182.53*	*356.42*	*3.46*	*0.51*

onies in 1989-1991 resulted in an estimate of 83,394 breeding birds in California with 29% of this population occurring in the northern Channel Islands (Carter *et al*., 1992). This survey indicated a notable increase in abundance of Brandt's cormorants in the northern Channel Islands since surveys in 1975-1980. However, more recent surveys have shown a decline since 1991 (Capitolo *et al*., 2004). Brandt's cormorant is not a federal endangered or threatened species.

At-sea survey data suggest that Brandt's cormorant is widely distributed in nearshore waters of central and southern California with notable concentrations in the Gulf of the Farallones, near Point Sur, Morro Bay, Point Conception, and the northern Channel Islands (with the exception of Santa Barbara Island).

Analysis of the observed patterns of Brandt's cormorant sightings (Figure 5.1.7) and density relative to the proposed boundary concepts indicates that Concept 3 provides the greatest increase in sightings (absolute metric) for its relative size compared to the NAC (Table 5.1.5). Density (relative metric), however, was highest for Brandt's cormorant within the NAC and consequently the density-based OAI is negative for all of the concepts. Much of the increase in density for Concept 3 relative to the smaller concepts (4, 5, and the NAC) is due to the inclusion of two additional grid cells near Point Conception.

Breeding colonies of Brandt's cormorant (Figure 5.1.8) exist on seven Channel Islands (all except Santa Catalina), with major colonies (top quintile, 1,548-5,606 individuals) on San Miguel, Santa Rosa, Santa Cruz, and San Nicolas Islands. Mainland colonies in Southern California exist at Point Buchon, Morro Bay, Vandenberg AFB, Santa Barbara, La Jolla, and along the coast between Point Piedras Blancas and Cape San Martin.

No analysis of boundary concepts was conducted for Brandt's cormorant breeding colonies since none of the concepts encompass any colonies not contained within the NAC.

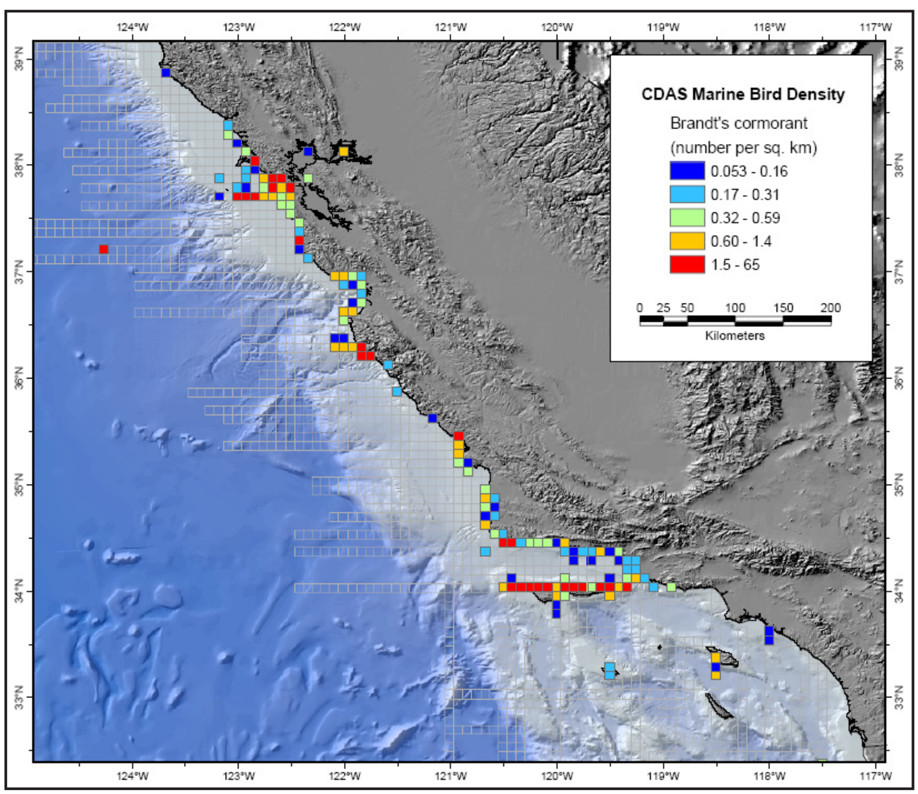

Figure 5.1.7. Brandt's cormorant. At-sea densities (individuals/km²) calculated for five minutes of latitude by five minutes of longitude grid cells from aerial and shipboard survey data collected from 1975-1997 and summarized in the Computer Database Analysis System v2.1 (MMS, 2001).

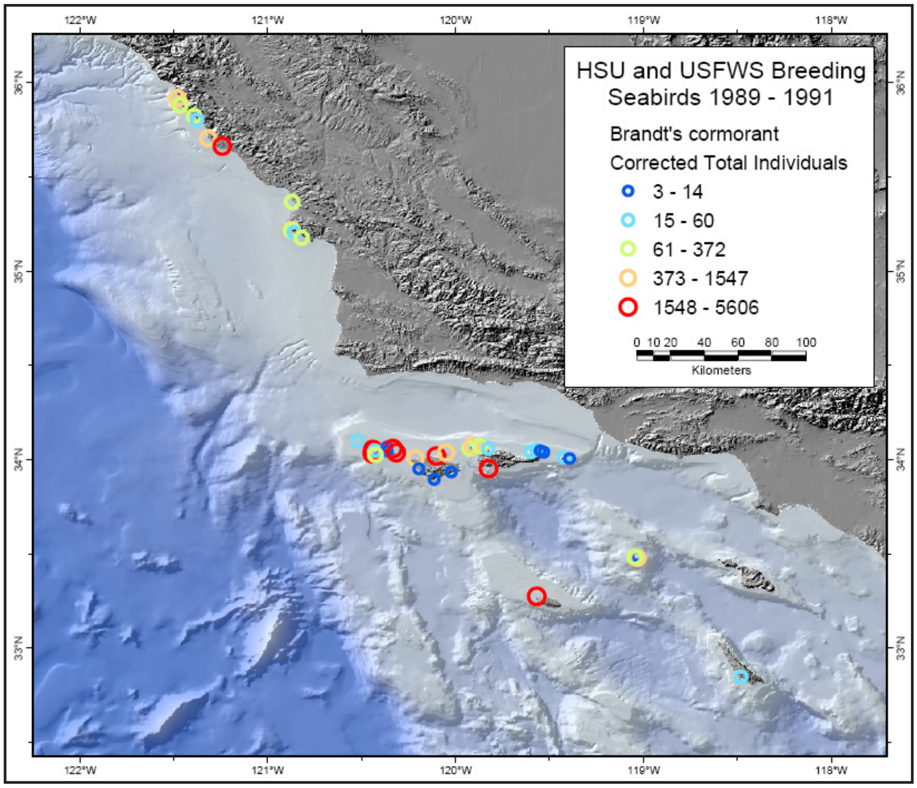

Figure 5.1.8. Brandt's cormorant. Colony counts (corrected total individuals) 1989-1991 (Source: Carter *et al*., 1992).

Table 5.1.5. Brandt's cormorant. At-sea sightings, effort, density, and Optimal Area Index (OAI) for each boundary concept. Values in bold indicate an increase in the estimate when compared to the NAC. Shaded OAI estimates reflect the concept with the greatest positive value.

Concept	Total Individuals	Total Effort (Area swept km²)	Density (Individuals per km²)	Area (km²)	∆ Individuals (%)	∆ Density (%)	∆ Area (%)	OAI Individuals (absolute metric)	OAI Density (relative metric)
NAC	377	448.2	0.841	3745	-	-	-	-	-
5	377	492.3	0.766	4538	0.00	-8.96	21.12	0.00	-0.42
4	**378**	748.3	0.505	7981	0.27	-39.95	113.11	0.00	-0.35
3	**477**	984.6	0.484	9044	26.53	-42.40	141.50	0.19	-0.30
2	**526**	1589.1	0.331	13736	39.52	-80.85	266.78	0.15	-0.23
1a	**589**	2460.3	0.239	22591	56.23	-71.54	503.23	0.11	-0.14
1	**589**	2460.3	0.239	22613	58.23	-71.54	503.82	0.11	-0.14
SA	*589*	*2115.2*	*0.278*	*17093*	*56.23*	*-66.89*	*356.42*	*0.16*	*-0.19*

Pelagic cormorant (*Phalacrocorax pelagicus*)
The pelagic cormorant (Family Phalacrocoracidae) ranges along the north Pacific coast with the southern end of their breeding range in North America occurring at Santa Barbara Island, with occasional nesting of a few individuals at Islas Los Coronados, Mexico. Nesting habitat includes cliffs on the coast and on islands. The 1989-1991 breeding colony survey resulted in an estimate of 14,345 breeding birds in California with 19% of the breeding population of California occurring in the northern Channel Islands (Carter *et al*., 1992). The survey showed a small decrease in abundance of pelagic cormorant since earlier (1975-1980) surveys (Carter *et al*., 1995b). Somewhat greater abundance was found in southern California. While this is likely due to greater survey effort, numbers at Anacapa Island have increased (F. Gress, pers. comm.). Pelagic cormorant is not a endangered or threatened species.

At-sea sightings indicate that pelagic cormorant are widely distributed in the nearshore waters of central and southern California, with high densities observed near many of the major points, including; Point Buchon, Point Sal, Point Arguello, and Point Conception. Additional high density areas exist near San Miguel, Santa Rosa, and Santa Cruz Islands.

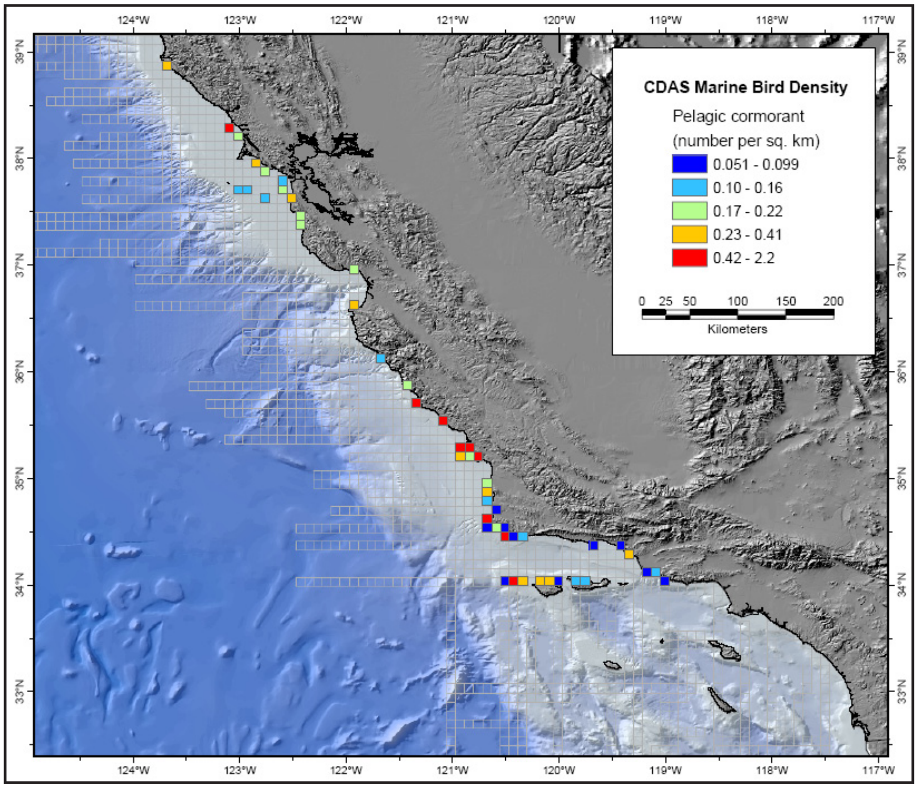

Figure 5.1.9. Pelagic cormorant. At-sea densities (individuals/km^2) calculated for five minutes of latitude by five minutes of longitude grid cells from aerial and shipboard survey data collected from 1975-1997 and summarized in the Computer Database Analysis System v2.1 (MMS, 2001).

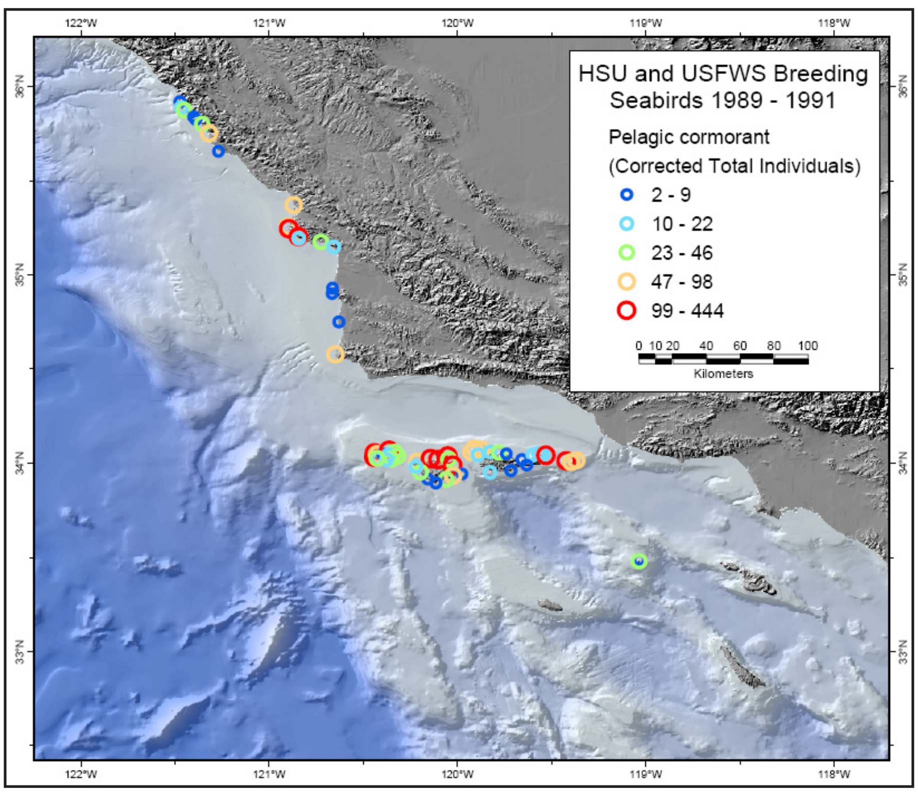

Figure 5.1.10. Pelagic cormorant. Colony counts (corrected total individuals) 1989-1991 (Source: Carter *et al*., 1992).

Analysis of the observed patterns of pelagic cormorant sightings (Figure 5.1.9) and density relative to the proposed boundary concepts indicates that Concept 3 provides the greatest increase in sightings (absolute metric) for its relative size compared to the NAC (Table 5.1.6). Density (relative metric), however, was highest for pelagic cormorant within the NAC and consequently the density-based OAI is negative for all of the concepts. Much of the increase in sightings for Concept 3 relative to the smaller concepts (4, 5, and the NAC) is due to the inclusion of one additional high density grid cell near Point Conception. Concepts 1, 1a, and 2 encompass additional high density grid cells off Point Sal and Point Arguello.

Breeding colonies of pelagic cormorant (Figure 5.1.10) exist on San Miguel, Santa Rosa, Santa Cruz, Anacapa (West, Middle, and East), and Santa Barbara Islands, with major colonies (top quintile, 99-444 individuals) found on San Miguel, Santa Rosa, and Santa Cruz Islands. Southern California mainland colonies exist from Point Arguello north to Cape San Martin.

Analysis of the distribution of pelagic cormorant breeding colonies within the proposed boundary concepts suggests that Concept 2 provides the greatest increase in breeding individuals for its relative size compared to the NAC (Table 5.1.7). The increase in breeding individuals for Concept 2 relative to the smaller concepts (3, 4, 5, and the NAC) is due to the inclusion of three additional colonies on Points Arguello, Purisima, and Sal. Concepts 1 and 1a also encompass these colonies and one additional colony of 4-5 pairs, but their larger areas result in lower values for the OAI.

Table 5.1.6. Pelagic cormorant. At-sea sightings, effort, density, and Optimal Area Index (OAI) for each boundary concept. Values in bold indicate an increase in the estimate when compared to the NAC. Shaded OAI estimates reflect the concept with the greatest positive value.

Concept	Total Individuals	Total Effort (Area swept km^2)	Density (Individuals per km^2)	Area (km^2)	Δ Individuals (%)	Δ Density (%)	Δ Area (%)	OAI Individuals (absolute metric)	OAI Density (relative metric)
NAC	20	448.2	0.045	3745	-	-	-	-	-
5	20	492.3	0.041	4536	0	-8.96	21.12	0.00	-0.42
4	20	748.3	0.027	7981	0	-40.10	113.11	0.00	-0.35
3	**33**	984.6	0.034	9044	65	-24.88	141.50	0.46	-0.18
2	**41**	1589.1	0.026	13736	105	-42.18	266.78	0.39	-0.16
1a	**57**	2460.3	0.023	22591	185	-48.08	503.23	0.37	-0.10
1	**57**	2460.3	0.023	22613	185	-48.08	503.82	0.37	-0.10
SA	*57*	*2115.2*	*0.027*	*17093*	*185*	*-39.61*	*356.42*	*0.52*	*-0.11*

Table 5.1.7. Pelagic cormorant. Colony counts (total individuals) and Optimal Area Index (OAI) for each boundary concept. Values in bold indicate an increase in the estimate when compared to the NAC. Shaded OAI estimates reflect the concept with the greatest positive value.

Concept	Total Individuals	Area (km^2)	Δ Individuals (%)	Δ Area (%)	OAI Individuals (absolute metric)
NAC	2687	3745	-	-	-
5	2687	4536	0.00	21.12	0.000
4	2687	7981	0.00	113.11	0.000
3	2687	9044	0.00	141.50	0.000
2	**2790**	13736	3.83	266.78	0.014
1a	**2799**	22591	4.17	503.23	0.008
1	**2799**	22613	4.17	503.82	0.008
SA	*2799*	*17093*	*4.17*	*356.42*	*0.012*

Western snowy plover

(*Charadrius alexandrinus nivosus*)

Western snowy plover is a shorebird (Family Charadriidae) which nests in sand, gravel, and salt pans on coastal beaches from southern Washington to southern Baja California, Mexico. CINMS is in the southern half of their core breeding range and feeding distribution. No information was available on population status or distribution within the study area; however, some individuals are known to nest on Santa Rosa, San Miguel, and San Nicolas Islands (P. Martin and G. Smith, pers. comm.).

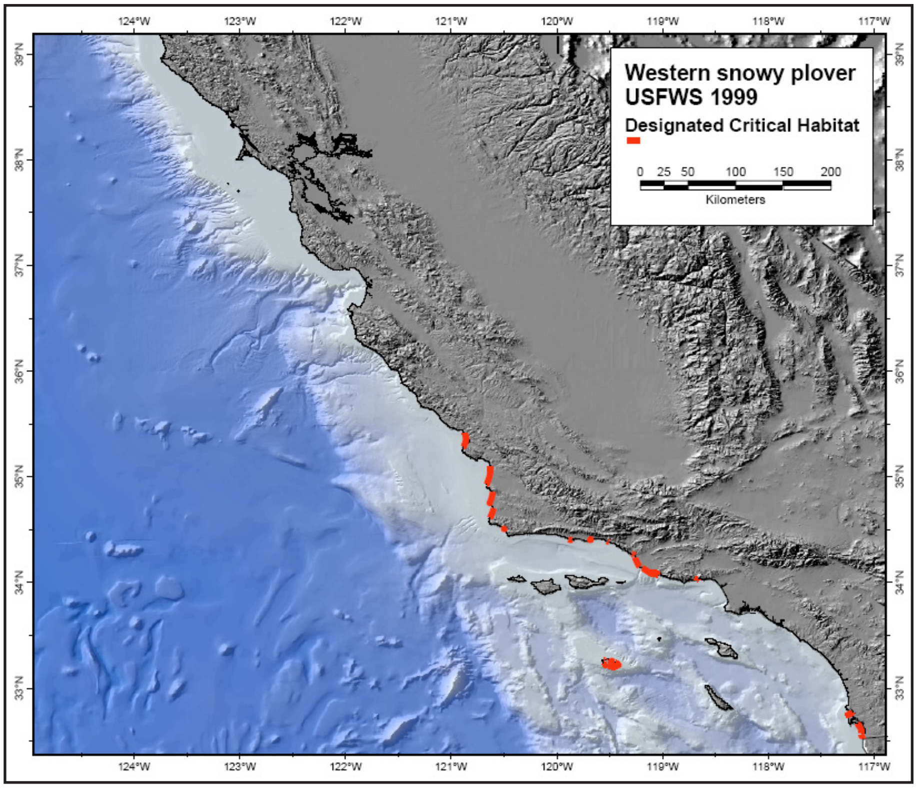

Figure 5.1.11. Western snowy plover. Designated critical habitat for the Pacific coast population of western snowy plover (Source: USFWS, 1999). Designated critical habitat is mapped for locales in the vicinity of CINMS; this map is not inclusive of all designated snowy plover critical habitat.

Along the U.S. Pacific coast of Washington, Oregon, and California, 290 km of coastline have been designated as critical habitat for the western snowy plover (USFWS, 1999). The current CINMS sanctuary boundary (NAC) and Concepts 4 and 5 do not include any designated critical habitat (Figure 5.1.11; Table 5.1.8). Concept 3 includes 2.3 km of critical habitat shoreline, less than 1% of the total designated habitat. Concept 2 encompasses 27.4 km (9.4%). The largest concepts (1 and1a) and the Study Area include 70 km (24%) of the designated western snowy plover critical habitat. Because there was no critical habitat designated within the NAC, it is not possible to calculate the OAI for western snowy plover critical habitat.

Table 5.1.8. Western snowy plover. Critical habitat for the Pacific coast population of western snowy plover.

Concept	Area (km^2)	Critical Habitat Length of Shoreline (km)
NAC	3745	0.00
5	4536	0.00
4	7981	0.00
3	9044	2.29
2	13736	27.35
1a	22591	69.85
1	22613	69.85
SA	*17093*	*69.85*

Black Oystercatcher (*Haematopus bachmani)*
Black oystercatcher is a large shorebird (Family Haemotopidae), ranging along the Pacific coast from the Aleutian Islands to central Baja California, Mexico. CINMS is at the southern end of their core breeding and feeding distribution. The black oystercatcher nests along rocky shorelines in mixed aggregations with other marine birds, and is known to hybridize with American oystercatcher in the Channel Islands. The 1989-1991 breeding colony surveys resulted in an estimate of 888 breeding birds in California, with 30% of the breeding population occurring in the northern Channel Islands (Carter *et al*., 1992). The cryptic, solitary nests make this a rough estimate, and population trends could not be determined from this survey. However, recent population declines are suspected in parts of Alaska. The black oystercatcher is not a endangered or threatened species. No at-sea sightings were available for this shorebird.

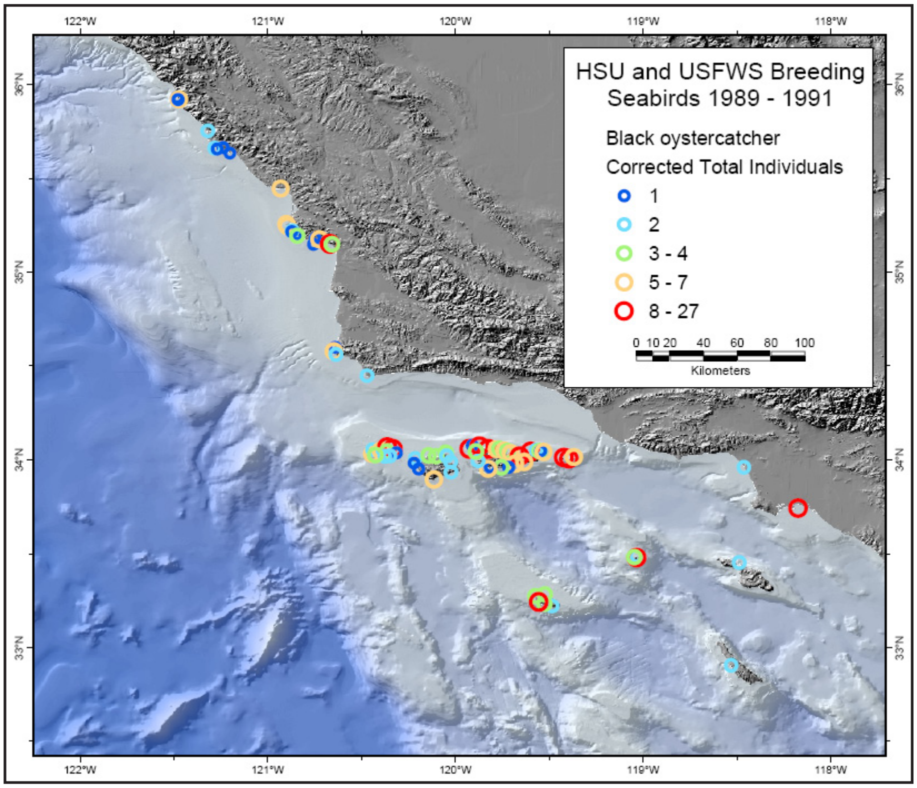

Figure 5.1.12. Black oystercatcher. Colony counts (corrected total individuals) 1989-1991 (Source: Carter *et al*., 1992).

Breeding colonies of black oystercatcher (Figure 5.1.12) exist on all eight of the Channel Islands with major colonies (top quintile, 8-27 individuals) occurring on San Miguel, Santa Cruz, Anacapa, Santa Barbara, and San Nicolas Islands. Numerous smaller colonies (less than 8 individuals each) exist on Santa Rosa Island.

Analysis of the distribution of black oystercatcher breeding colonies within the proposed boundary concepts suggests that Concept 2 provides the greatest increase in breeding individuals for its relative size compared to the NAC (Table 5.1.9). The increase in breeding individuals for Concept 2 relative to the smaller concepts (3, 4, 5, and the NAC) is due to

Table 5.1.9. Black oystercatcher. Colony counts (total individuals) and Optimal Area Index (OAI) for each boundary concept. Values in bold indicate an increase in the estimate when compared to the NAC. Shaded OAI estimates reflect the concept with the greatest positive value.

Concept	Total Individuals	Area (km^2)	Δ Individuals (%)	Δ Area (%)	OAI Individuals (absolute metric)
NAC	267	3745	-	-	-
5	267	4536	0.00	21.12	0.000
4	267	7981	0.00	113.11	0.000
3	**269**	9044	0.75	141.50	0.005
2	**278**	13736	4.12	266.78	0.015
1a	**278**	22591	4.12	503.23	0.008
1	**278**	22613	4.12	503.82	0.008
SA	*278*	*17093*	*4.12*	*356.42*	*0.012*

the inclusion of three additional colonies at Point Arguello. Concepts 1 and 1a also encompass these colonies, but their larger areas result in lower values for the OAI.

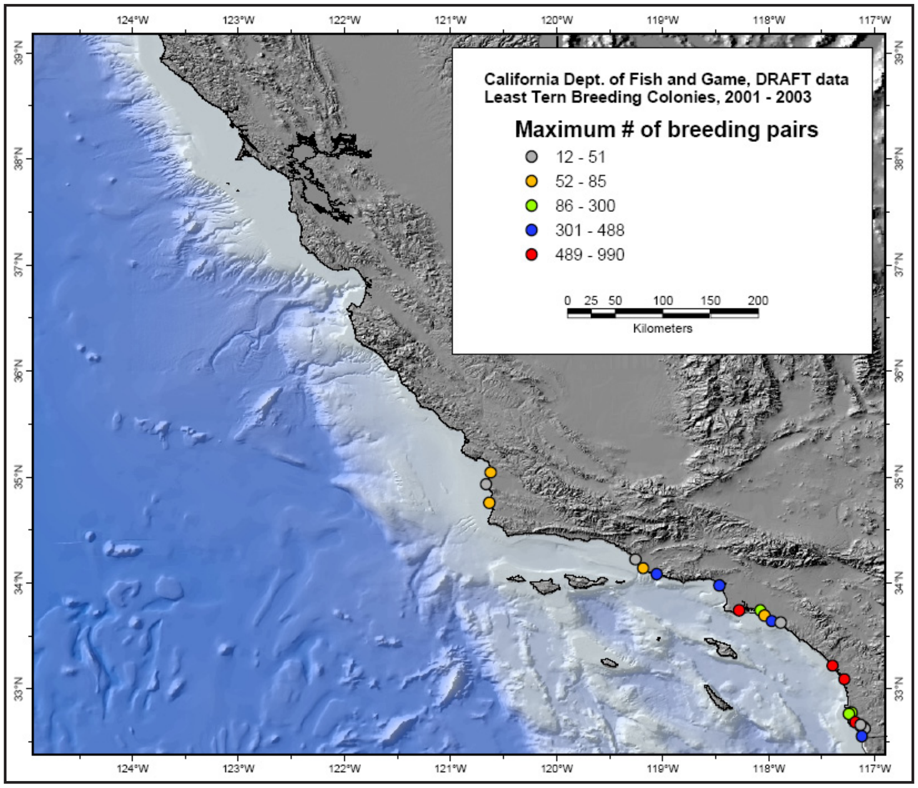

Figure 5.1.13. California least tern. Maximum number of breeding pairs 2001-2003 (Source: CDFG, draft data).

California least tern
(*Sterna antillarum browni*)
Five subspecies of least tern (Family Sternidae) are found in North America, with the California least tern nesting on beaches and sand dunes from the San Francisco Bay area south to Baja California, Mexico (Carter *et al*., 1992). CINMS is in the southern half of their core breeding distribution. A comprehensive survey of least terns in 1999 (Keane, 2001) estimated a California breeding population of 3,451 to 3,674 pairs at 36 colonies. The ten largest colonies (Mission Bay Mariner's Point, Santa Margarita River North Beach, NAB Ocean, NAS Alameda, Huntington Beach, Delta Beach North, L.A. Harbor Pier, NAWS Point Mugu, Batiquitos Lagoon and Tiuana River) represented 76.6% of the statewide breeding pairs. Numbers are declining in several areas in California (R. Jurek, pers. comm.). California least tern is listed as both a California and Federal endangered species.

There were no recorded breeding colonies of California least tern within the NAC or Concepts 3-5 between 2001-2003 (Figure 5.1.13; CDFG, draft data). Concept 2 encompasses one colony at Vandenberg AFB with a maximum of 79 breeding pairs (Table 5.1.10). Concepts 1 and 1a and the study area encompass an additional 4 colonies with a maximum of 676 breeding pairs. Because no colonies exist within the NAC, it is not possible to calculate the OAI for least tern colonies.

Table 5.1.10. California least tern. Maximum number of breeding pairs observed at each nesting site surveyed from 2001-2003 for each boundary concept (CDFG, draft data).

Concept	Maximum Breeding Pairs	Area (km^2)
NAC	0	3745
5	0	4536
4	0	7981
3	0	9044
2	**79**	13736
1a	**676**	22591
1	**676**	22613
SA	*676*	*17093*

Pigeon guillemot (*Cepphus columba*)
Pigeon guillemot range throughout the North Pacific coasts with the southern end of their breeding range and feeding distribution in North America occurring at Santa Barbara Island. They nest mainly in rock crevices on mainland and island cliffs. The 1989-1991 breeding colony survey resulted in an estimate of 15,470 breeding birds in California, with 21% of the breeding population occurring in the northern Channel Islands (Carter *et al*., 1992). The survey showed little change in the abundance of pigeon guillemot overall in California since earlier (1975-1980) surveys (Carter *et al*., 1995a). However, greater abundance was observed at colonies on San Miguel, Santa Cruz, Anacapa, and Santa Barbara Islands, likely due to greater survey effort and different survey techniques. Population trends are not known for Southern California. Pigeon guillemot is not an endangered or threatened species.

At-sea sightings indicate that within Central and Southern California, areas of high pigeon guillemot density are found in nearshore waters near Monterey Bay (off Santa Cruz and Carmel), near Point Reyes and the Farallon Islands, off Point Arguello, and, most notably, around the northern Channel Islands (San Miguel, Santa Rosa, and Santa Cruz Islands). Analysis of the observed patterns of pigeon guillemot sightings (Figure 5.1.14) and density relative to the proposed boundary concepts indicate that Concept 2 provides the greatest increase in sightings (absolute metric) for its relative size compared to the NAC (Table 5.1.11). Density (relative metric), however, was highest for pigeon guillemot within the NAC and consequently the density-based OAI is negative for all of the concepts. Much of the increase in density for Concept 2 relative to the smaller concepts (3, 4, 5, and the NAC) is due to the inclusion of two or three additional high density grid cells near Point Arguello.

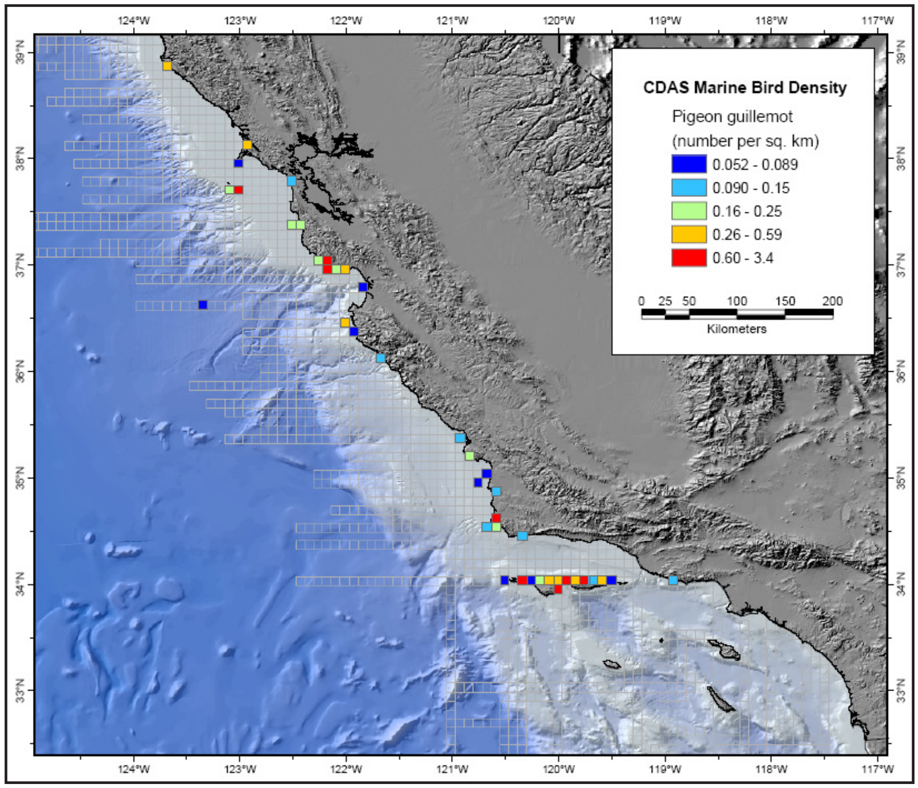

Figure 5.1.14. Pigeon guillemot. At-sea densities (individuals/km^2) calculated for five minutes of latitude by five minutes of longitude grid cells from aerial and shipboard survey data collected from 1975-1997 and summarized in the Computer Database Analysis System v2.1 (MMS, 2001).

Breeding colonies of pigeon guillemot (Figure 5.1.15) exist on San Miguel, Santa Rosa, Santa Cruz, Anacapa, and Santa Barbara Islands, with major colonies (top quintile, 130-953 individuals) found on San Miguel, Santa Rosa, and Santa Cruz Islands. Southern California mainland colonies exist from Point Conception north to Lopez Point.

Analysis of the distribution of pigeon guillemot breeding colonies within the proposed boundary concepts suggests that Concept 2 provides the greatest increase in breeding individuals for its relative size compared to the NAC (Table 5.1.12). The increase in breeding individuals for Concept 2 relative to the smaller concepts (3, 4, 5, and the NAC) is due to the inclusion of 11 additional colonies on and around Points Conception, Arguello, Purisima, and Sal. Concepts 1 and 1a also encompass these colonies and one additional colony of 5 individuals, but their larger areas result in lower values for the OAI.

Table 5.1.11. Pigeon guillemot. At-sea sightings, effort, density, and Optimal Area Index (OAI) for each boundary concept. Values in bold indicate an increase in the estimate when compared to the NAC. Shaded OAI estimates reflect the concept with the greatest positive value.

Concept	Total Individuals	Total Effort (Area swept km^2)	Density (Individuals per km^2)	Area (km^2)	Δ Individuals (%)	Δ Density (%)	Δ Area (%)	OAI Individuals (absolute metric)	OAI Density (relative metric)
NAC	61	448.2	0.136	3745	-	-	-	-	-
5	61	492.3	0.124	4536	0.00	-8.96	21.12	0.00	-0.42
4	61	748.3	0.082	7981	0.00	-40.10	113.11	0.00	-0.35
3	**67**	984.6	0.068	9044	9.84	-50.00	141.50	0.07	-0.35
2	**76**	1589.1	0.048	13736	24.59	-64.86	266.78	0.09	-0.24
1a	**79**	2460.3	0.032	22591	29.51	-76.41	503.23	0.06	-0.15
1	**79**	2460.3	0.032	22613	29.51	-76.41	503.82	0.06	-0.15
SA	*79*	*2115.2*	*0.037*	*17093*	*29.51*	*-72.56*	*356.42*	*0.08*	*-0.20*

Xantus's murrelet (*Synthliboramphus hypoleucus*)

Xantus's murrelet is a small alcid (Family Alcidae) that nests only in southern California and northwestern Baja California, Mexico. CINMS is at the northern edge of Xantus's murrelet breeding range, but not their feeding distribution. They nest in crevices and under bushes on offshore islands and rocks. The 1989-1991 breeding colony survey resulted in an estimate of 1719-1727 breeding birds in California. All of this breeding population occurs in the northern Channel Islands, with the vast majority nesting at Santa Barbara Island, and smaller numbers at San Miguel and Santa Cruz Islands (Carter *et al*., 1992). This survey estimate was substantially lower than that

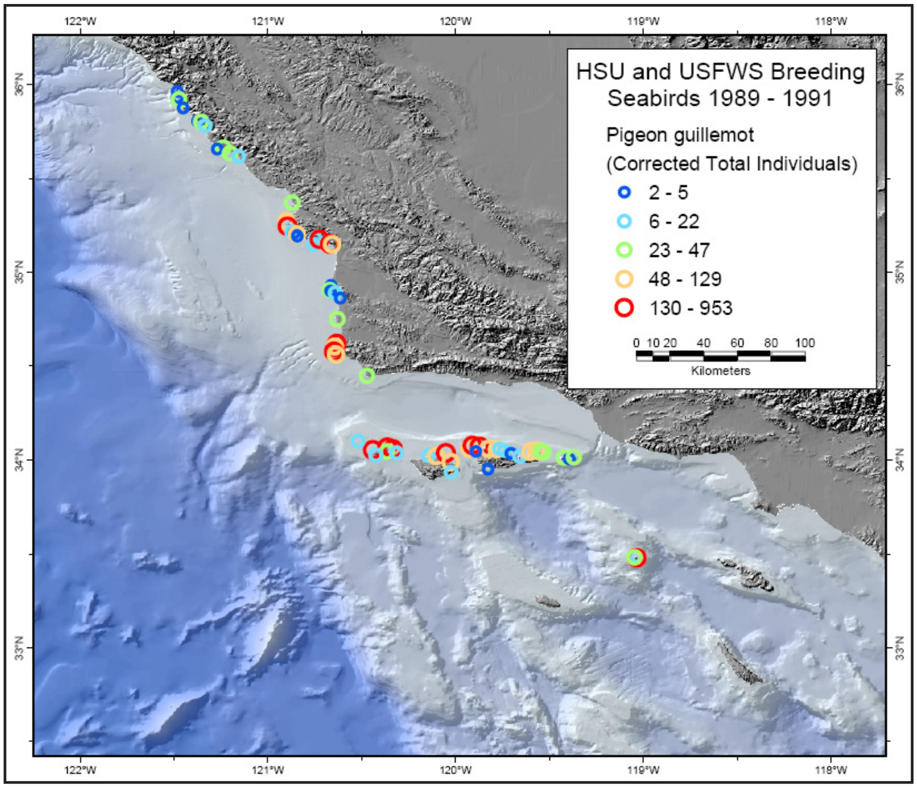

Figure 5.1.15. Pigeon guillemot. Colony counts (corrected total individuals) 1989-1991 (Source: Carter *et al.*, 1992).

Table 5.1.12. Pigeon guillemot. Colony counts (total individuals) and Optimal Area Index (OAI) for each boundary concept. Values in bold indicate an increase in the estimate when compared to the NAC. Shaded OAI estimates reflect the concept with the greatest positive value.

Concept	Total Individuals	Area (km²)	∆ Individuals (%)	∆ Area (%)	OAI Individuals (absolute metric)
NAC	3218	3745	-	-	-
5	3218	4536	0.00	21.12	0.000
4	3218	7981	0.00	113.11	0.000
3	**3247**	9044	0.90	141.50	0.006
2	**4777**	13736	48.45	266.78	0.182
1a	**4782**	22591	48.60	503.23	0.097
1	**4782**	22613	48.60	503.82	0.096
SA	*4782*	*17093*	*48.60*	*356.42*	*0.136*

from earlier (1975-1977) surveys due to an apparent decline at Santa Barbara Island, but differences in survey technique make it difficult to infer trends. More recent surveys (H. Carter, unpubl. data) have found new nesting areas at Anacapa, Santa Cruz and Santa Catalina Islands. More recent monitoring indicates that this species has continued to decline at Santa Barbara Island (Whitworth *et al*., 2003; Burkett *et al*., 2003; P. Martin, pers. comm.). Xantus's murrelet was recently recommended for listing as "Threatened" by the California Department of Fish and Game (California Regulatory Notice Register, March 5, 2004).

The at-sea pattern of Xantus's murrelet, as observed in the CDAS dataset, differs from that observed in the telemetry study. Both sources of information should be considered in order to fully understand the biogeography of this species in Southern California.

Although scattered observations of Xantus's murrelets occur in shelf waters off Central California in the fall and in the Santa Barbara Channel throughout the year, two cores of their distribution appear to occur in Southern California: (a) near the northern Channel Islands, and (b) near San Diego. The northern core reflects birds foraging from colonies in the northern Channel Islands, while the southern core reflects foraging from the large colony at Islas Los Coronados.

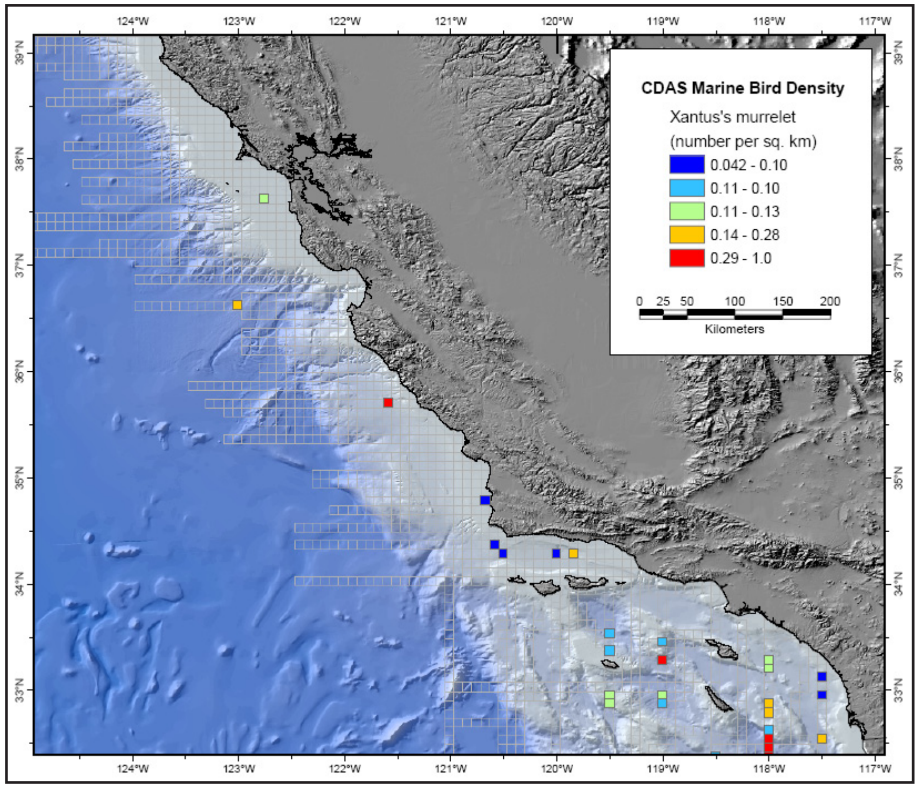

Figure 5.1.16. Xantus's murrelet. At-sea densities (individuals/km^2) calculated for five minute of latitude by five minute of longitude grid cells from aerial and shipboard survey data collected from 1975-1997 and summarized in the Computer Database Analysis System v2.1 (MMS, 2001).

Analysis of the observed patterns of Xantus's murrelet sightings (Figure 5.1.16) and density relative to the proposed boundary concepts indicates that Concept 3 provides the greatest increase in sightings (absolute metric) for its relative size compared to the NAC (Table 5.1.13). The density-based OAI favors Concept 4, which includes some of the sightings in the Santa Barbara Channel. None of the concepts encompass the apparent core of the distribution in the southern Channel Islands.

Breeding colonies of Xantus's murrelet (Figure 5.1.17) observed during the 1989-1991 survey on San Miguel (Prince Island), Santa Cruz, and Santa Barbara Islands, with the largest colony (1402 individuals) on Santa Barbara Island. More recent surveys of Xantus's murrelet (H. Carter, unpubl. data) also found colonies on Anacapa (East, Middle, and West, Figure 5.1.18), San Clemente (Figure 5.1.19), San Miguel (Mainland) (Figure 5.1.20), Santa Barbara (Figure 5.1.21), Santa Catalina (Figure 5.1.22), and Santa Cruz (Figure 5.1.23) Islands, with the largest colonies (two shoreline segments had 150-400 pairs each) found on Santa Barbara Island. No colonies were found on Santa Rosa or San Nicolas Islands.

Table 5.1.13. Xantus's murrelet. At-sea sightings, effort, density, and Optimal Area Index (OAI) for each boundary concept. Values in bold indicate an increase in the estimate when compared to the NAC. Shaded OAI estimates reflect the concept with the greatest positive value.

Concept	Total Individuals	Total Effort (Area swept km^2)	Density (Individuals per km^2)	Area (km^2)	Δ Individuals (%)	Δ Density (%)	Δ Area (%)	OAI Individuals (absolute metric)	OAI Density (relative metric)
NAC	1	448.2	0.0022	3745	-	-	-	-	-
5	1	492.3	0.0020	4536	0	-8.96	21.12	0.00	-0.42
4	**5**	748.3	**0.0067**	7981	400	199.48	113.11	3.54	1.76
3	**7**	984.6	**0.0071**	9044	600	218.65	141.50	4.24	1.55
2	**8**	1589.1	**0.0050**	13736	700	125.64	266.78	2.62	0.47
1a	**8**	2460.3	**0.0033**	22591	700	45.74	503.23	1.39	0.09
1	**8**	2460.3	**0.0033**	22613	700	45.74	503.82	1.39	0.09
SA	*8*	*2115.2*	*0.0038*	*17093*	*700*	*69.52*	*356.42*	*1.96*	*0.20*

No analysis of boundary concepts was conducted for Xantus's murrelet breeding colonies since none of the concepts encompass colonies not already contained within the NAC.

Relocation of radiomarked Xantus's murrelets from Santa Barbara Island occurs throughout the western Southern California Bight, with scattered observations occurring as far north as Monterey Bay (Whitworth *et al*., 2000; Figure 5.1.24). During the breeding season (April to June) the density of relocations were highest around the northern Channel Islands from west of San Miguel Island to Point Mugu, around Santa Barbara Island, and to the south of San Nicolas

Island. Modest densities of relocations was found west of the Santa Barbara Channel, between San Miguel Island and Point Sal, but these observations were from birds dispersing northward to central California in late summer (Whitworth *et al*., 2000).

Analysis of observed patterns of radio-marked Xantus's murrelet relocations relative to the proposed boundary concepts indicates that Concept 5 provides the greatest increase in sightings (absolute metric) for its relative size compared to the NAC (Table 5.1.14). As expected, however, more sightings are included in the larger concepts. Each successively larger concept appears to encompass new clusters of relocations, with the exception of Concept 1, which does not encompass any more relocations than Concept 1a.

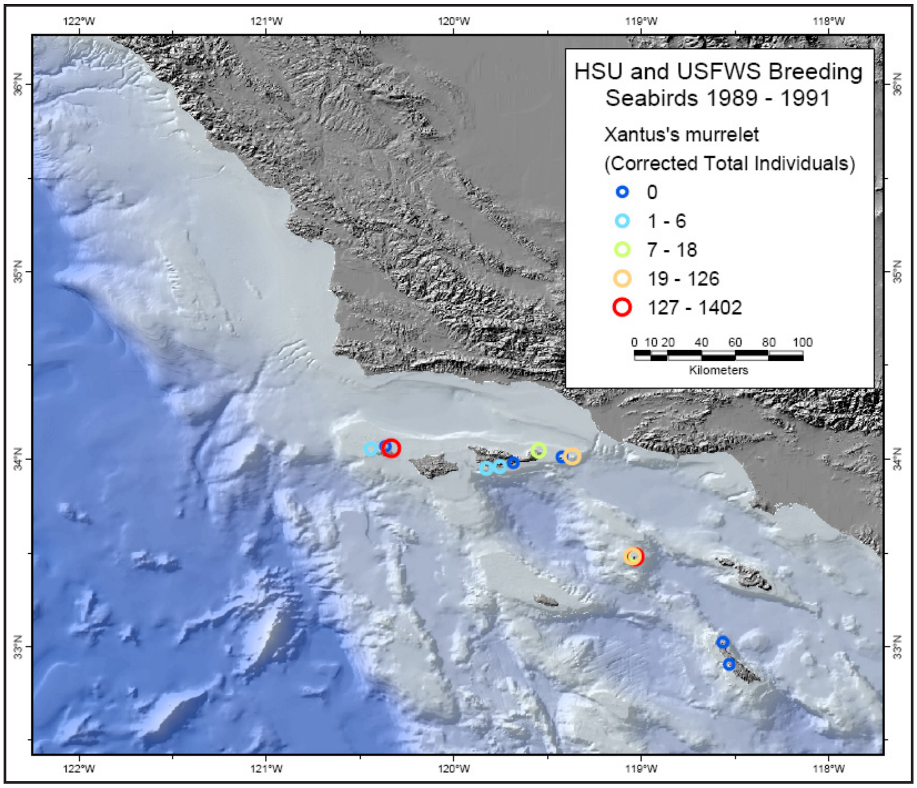

Figure 5.1.17. Xantus's murrelet. Colony counts (corrected total individuals) 1989-1991 (Source: Carter *et al*., 1992).

Table 5.1.14. Xantus's murrelet. Telemetry relocations and Optimal Area Index (OAI) for each boundary concept. Values in bold indicate an increase in the estimate when compared to the NAC. Shaded OAI estimates reflect the concept with the greatest positive value.

Concept	Total Relocations	Area (km²)	Δ Relocations (%)	Δ Area (%)	OAI Relocations (absolute metric)
NAC	127	3745	-	-	-
5	**223**	4536	75.59	21.12	3.579
4	**308**	7981	142.52	113.11	1.260
3	**313**	9044	146.46	141.50	1.035
2	**371**	13736	192.13	266.78	0.720
1a	**412**	22591	224.41	503.23	0.448
1	**412**	22613	224.41	503.82	0.445
SA	*411*	*17093*	*223.62*	*356.42*	*0.627*

Cassin's auklet
(*Ptychoramphus aleuticus*)

Cassin's auklet is a small alcid (Family Alcidae) that ranges from the Aleutian Islands to central western Baja California, Mexico. CINMS is south of their core breeding distribution. They nest in burrows and crevices on offshore islands. The 1989-1991 breeding colony survey resulted in an estimate of 56,572 breeding birds in California, with 22% of this population occurring in the northern Channel Islands (Carter *et al*., 1992). Although the survey showed an overall decline in abundance of Cassin's auklet since 1975-1980 surveys (Carter *et al*., 1995a), numbers of breeding birds at Santa Cruz Island were found to be greater than in the 1975-1977 surveys, but a trend could not be determined. Continued decline since 1991 is suspected (H. Carter, unpubl. data). Cassin's auklet is not an endangered or threatened species.

At-sea sightings indicate that Cassin's auklet densities appear to be greater to the north of the CINMS study area with the highest densities occurring north of Point Año Nuevo near the large Farallon Islands colony. Nevertheless, there are many sightings of Cassin's auklet within the study area and within the current CINMS boundaries. Areas of relatively high density exist within the western Santa Barbara Channel especially to the north of San Miguel and Santa Rosa Islands, adjacent to the large Prince Island colony.

Analysis of the observed patterns of Cassin's auklet sightings and density (Figure 5.1.25) relative to the proposed boundary concepts indicates that Concept 2 provides the greatest increase in both sightings (absolute metric) and density (relative metric) for its relative size compared to the NAC (Table 5.1.15). Concepts 1 and 1a also displayed high

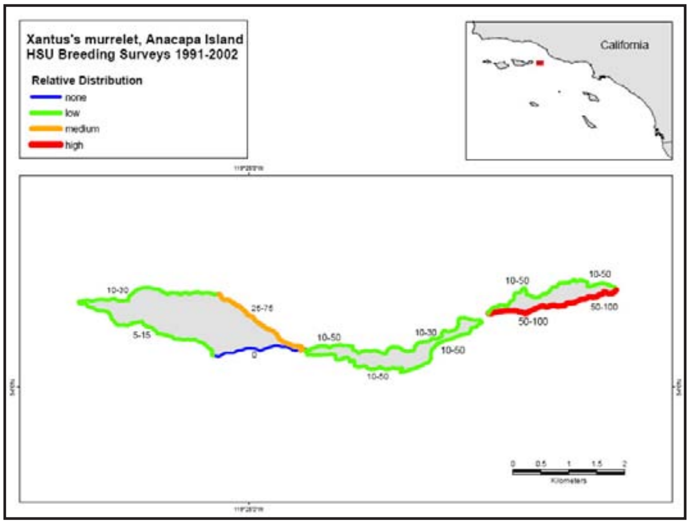

Figure 5.1.18. Xantus's murrelet. Anacapa Island colony counts (estimated total individuals per shoreline segment) 1991-2002 (Source: H. Carter, unpublished data).

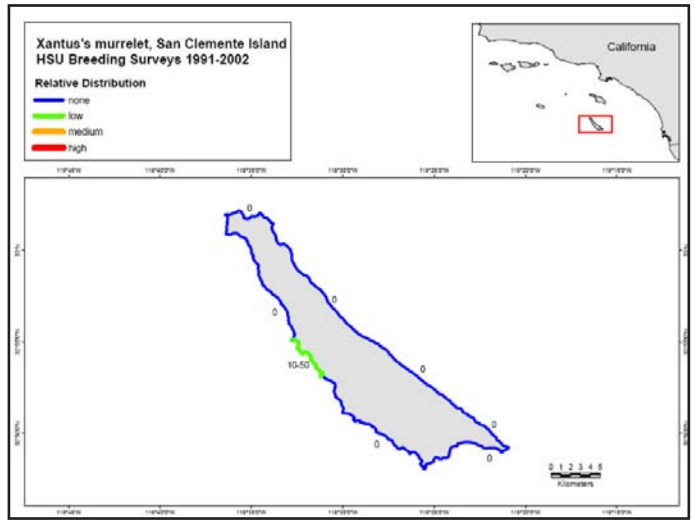

Figure 5.1.19. Xantus's murrelet. San Clemente Island colony counts (estimated total individuals per shoreline segment) 1991-2002 (Source: H. Carter, unpublished data).

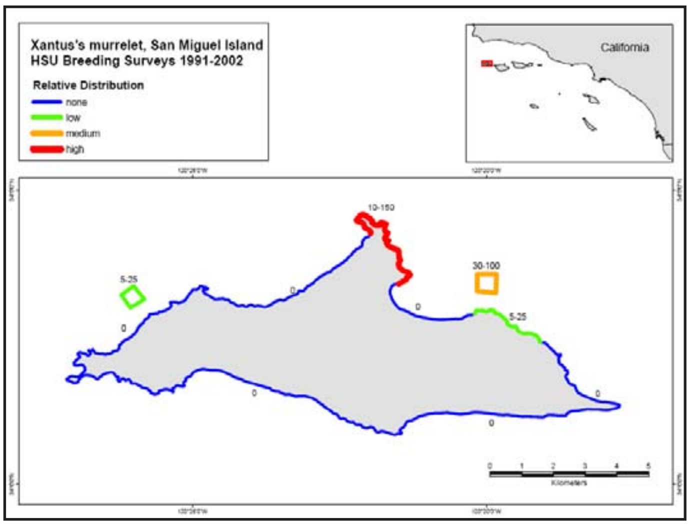

Figure 5.1.20. Xantus's murrelet. San Miguel Island colony counts (estimated total individuals per shoreline segment) 1991-2002 (Source: H. Carter, unpublished data).

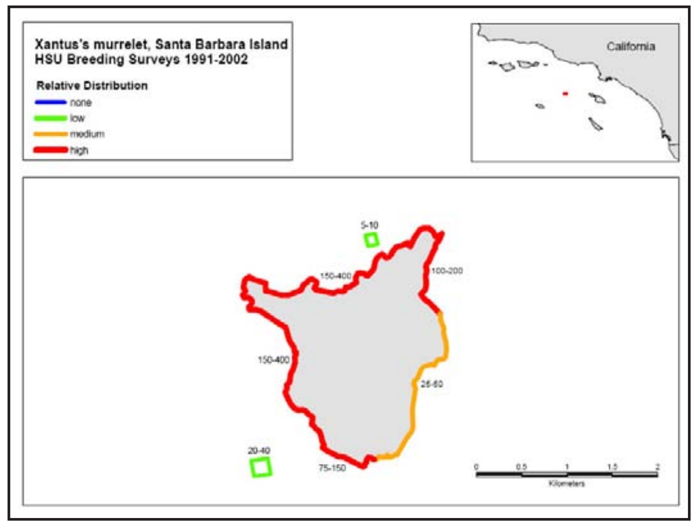

Figure 5.1.21. Xantus's murrelet. Santa Barbara Island colony counts (estimated total individuals per shoreline segment) 1991-2002 (Source: H. Carter, unpublished data).

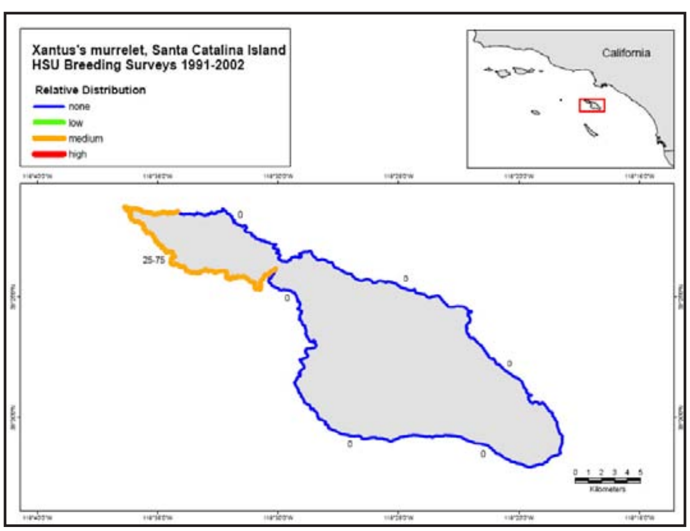

Figure 5.1.22. Xantus's murrelet. Santa Catalina Island colony counts (estimated total individuals per shoreline segment) 1991-2002 (Source: H. Carter, unpublished data).

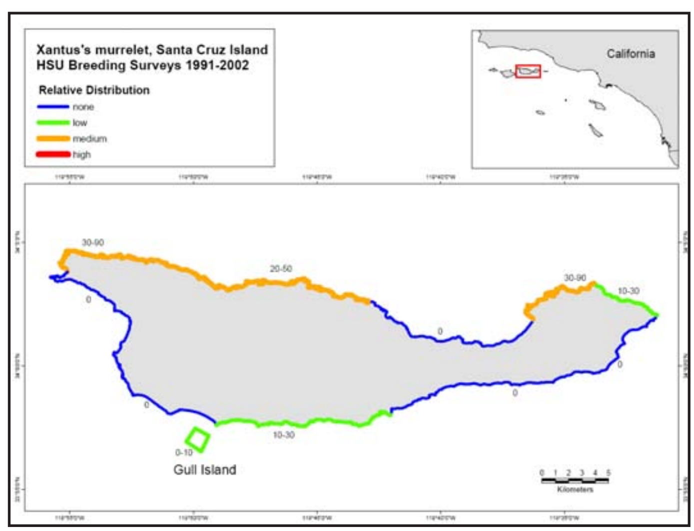

Figure 5.1.23. Xantus's murrelet. Santa Cruz Island colony counts (estimated total individuals per shoreline segment) 1991-2002 (Source: H. Carter, unpublished data).

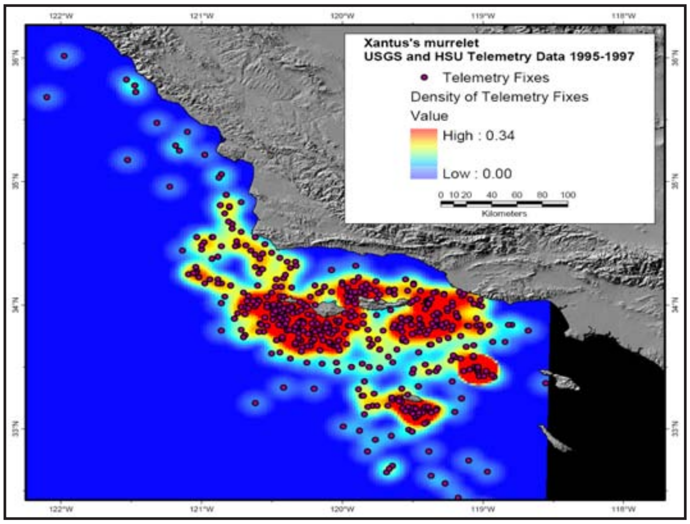

Figure 5.1.24. Xantus's murrelet. Telemetry relocations during 1995–1997 and kernel density surface based on the relocation points (cell size=2 km, radius=15 km). Black shading indicates no data available. (Source: USGS ands HSU; Whitworth *et al*., 2000; Carter *et al*. 2000).

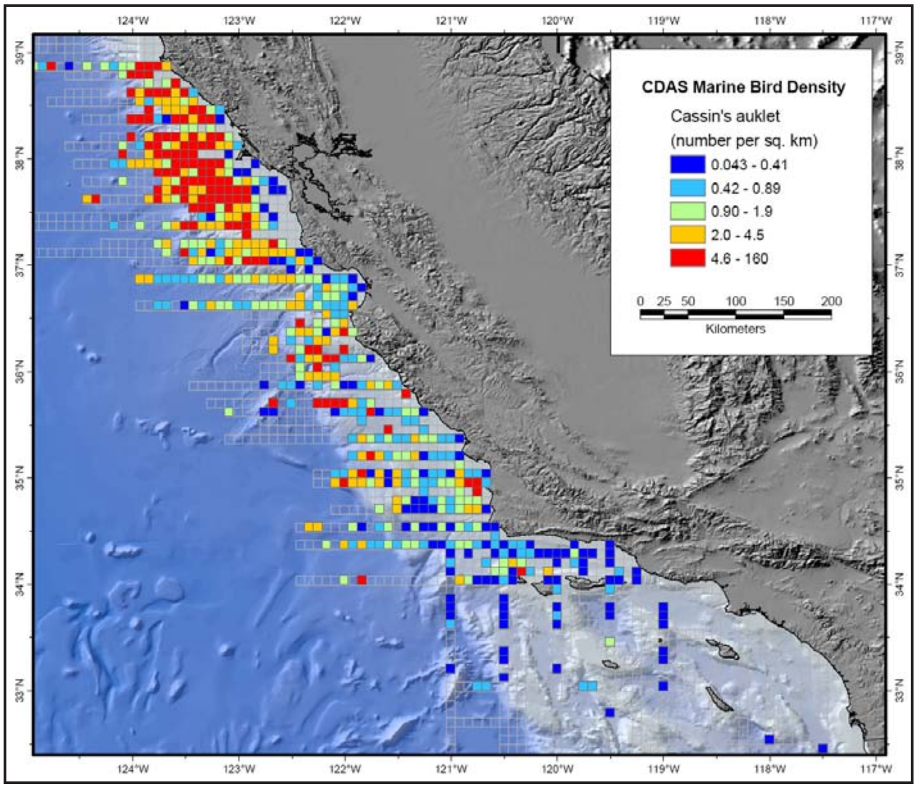

Figure 5.1.25. Cassin's auklet. At-sea densities (individuals/km^2) calculated for five minutes of latitude by five minutes of longitude grid cells from aerial and shipboard survey data collected from 1975-1997 and summarized in the Computer Database Analysis System v2.1 (MMS, 2001).

values for both OAI's, while the smaller concepts (3-5) showed only modest increases in sightings and lower densities compared to the NAC. Much of the improvement in sightings and densities observed for the larger concepts (1, 1a, and 2) is due to the inclusion of an area of high density off Point Sal.

Breeding colonies of Cassin's auklet (Figure 5.1.26) exist on San Miguel, Santa Cruz, and Santa Barbara Islands, with the two largest colonies (547 and 8922 individuals) in Southern California found on San Miguel Island (Prince Island and Castle Rock).

No analysis of boundary concepts was conducted for Cassin's auklet breeding colonies since none of the concepts encompass any colonies not contained within the NAC.

Other Marine Birds

In addition to the requested species, several other species of marine birds occur in the CINMS or possible concept areas in relatively large numbers at certain times of year or in certain years. Additional seabirds and shorebirds found in the study area may include the Pacific loon, western grebe, sooty shearwater, pink-footed shearwater, black-vented shearwater, Brant, surf scoter, red-necked phalarope, red phalarope, Heermann's gull, Bonaparte's gull, California gull, ring-billed gull, common murre, rhinoceros auklet, and the tufted puffin. While no quantitative analysis was conducted for these species, it is important to recognize that they may be impacted by changes to the boundaries of the CINMS and further investigation into these species may be warranted.

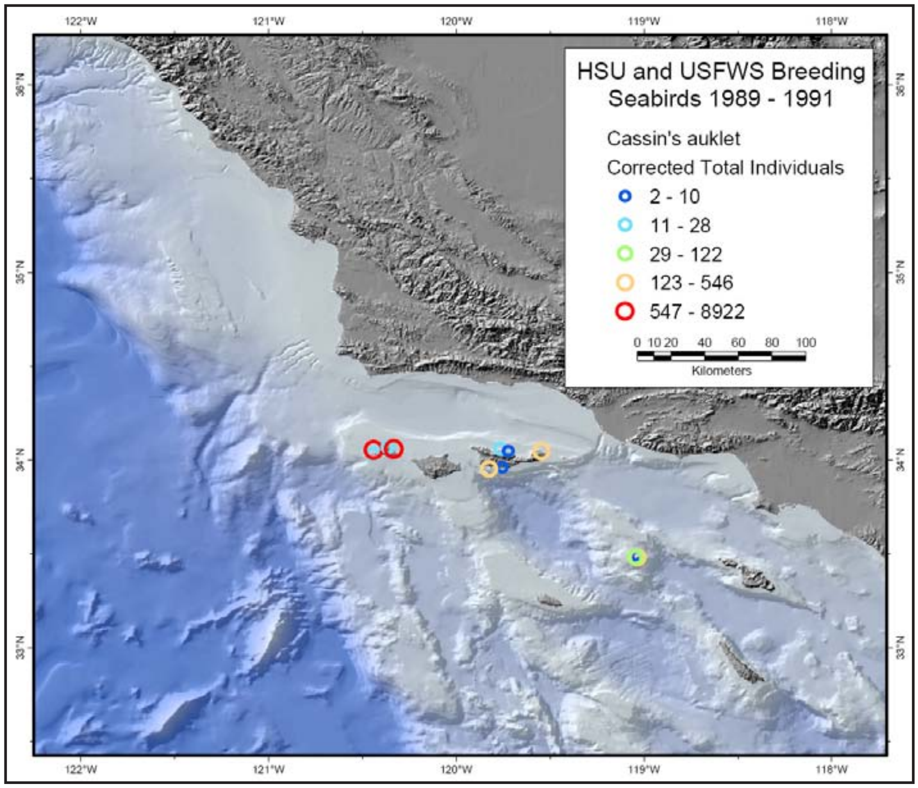

Figure 5.1.26. Cassin's auklet. Colony counts (corrected total individuals) 1989-1991 (Source: Carter *et al.*, 1992).

Table 5.1.15. Cassin's auklet. At-sea sightings, effort, density, and Optimal Area Index (OAI) for each boundary concept. Values in bold indicate an increase in the estimate when compared to the NAC. Shaded OAI estimates reflect the concept with the greatest positive value.

Concept	Total Individuals	Total Effort (Area swept km²)	Density (Individuals per km²)	Area (km²)	Δ Individuals (%)	Δ Density (%)	Δ Area (%)	OAI Individuals (absolute metric)	OAI Density (relative metric)
NAC	149	448.2	0.332	3745	-	-	-	-	-
5	**156**	492.3	0.317	4536	4.70	-4.68	21.12	0.22	-0.22
4	**229**	748.3	0.306	7981	53.69	-7.95	113.11	0.47	-0.07
3	**288**	984.6	0.293	9044	93.29	-12.01	141.50	0.66	-0.08
2	**1115**	1589.1	**0.702**	13736	648.32	111.06	266.78	2.43	0.42
1a	**1819**	2460.3	**0.739**	22591	1120.81	122.40	503.23	2.23	0.24
1	**1819**	2460.3	**0.739**	22613	1120.81	122.40	503.82	2.22	0.24
SA	*1481*	*2115.2*	*0.700*	*17093*	*893.96*	*110.61*	*356.42*	*2.51*	*0.31*

Summary

• Of the five boundary concepts being considered in addition to the NAC, the concept with the highest OAI value varies considerably depending on the particular species being considered.

• For many species, the NAC and the smaller Concepts 4 and 5 showed lower OAI values than the larger Concepts, 1, 2, and 3.

CHAPTER 5.2 MARINE BIRD DIVERSITY

Data and Methods

The marine bird diversity data presented in this section are derived from six at-sea surveys (including both marine and aerial platforms) of marine birds from the period 1975-1997. The results of these surveys are compiled in the Computer Database Analysis System (CDAS) v2.1 (MMS, 2001). The surveys used in this analysis are summarized in Table 5.2.1. Although CDAS contains survey data along the west coast of Washington, Oregon, and California, this analysis focused on those sightings south of Point Arena. The location of bird sightings and the distribution of survey effort are shown in Figure 5.2.1. A total of 95 bird species were observed in the combined surveys. Although some shorebirds are included in the list, these at-sea surveys were not designed to sample shorebirds or nesting colonies.

Table 5.2.1. Summary of the six surveys that were used in the analysis of marine bird diversity. The information in this table reflects the data used in this analysis, which in some cases may be a temporal and geographic subset of the entire survey.

Survey	Dates	Platform	Months	Total sightings	Total individuals
Minerals Management Service Aerial Surveys	1980-1983	airplane (low altitude)	Year-round	28525	91298
California Department of Fish and Game, Office of Spill Prevention and Response	1994-1997	airplane (low altitude)	Year-round	7751	71151
Southern California Bight Low Aerial Survey	1975-1978	airplane (low altitude)	Year-round	4250	17741
Seabird Ecology Study	1985	ship and airplane	March and May	2212	8641
Southern California Bight Ship Survey	1975-1978	ship	Year-round	17693	58719
Southern California Bight, Minerals Management Service Survey	1995-1997	airplane (low altitude)	Year-round	9780	46199

The Shannon index of diversity (Shannon and Weaver, 1949) was chosen for this analysis because it is one of the most commonly used diversity metrics in community ecology and has relatively small statistical bias when sample sizes are large (as is the case with this source data) (Magurran, 1988). The Shannon index attempts to balance species richness (*i.e.*, the total number of unique species) with species evenness (i.e. the distribution of individuals among the species). For a given number of individuals and species, the Shannon index is highest when there is an equal number of individuals of each species.

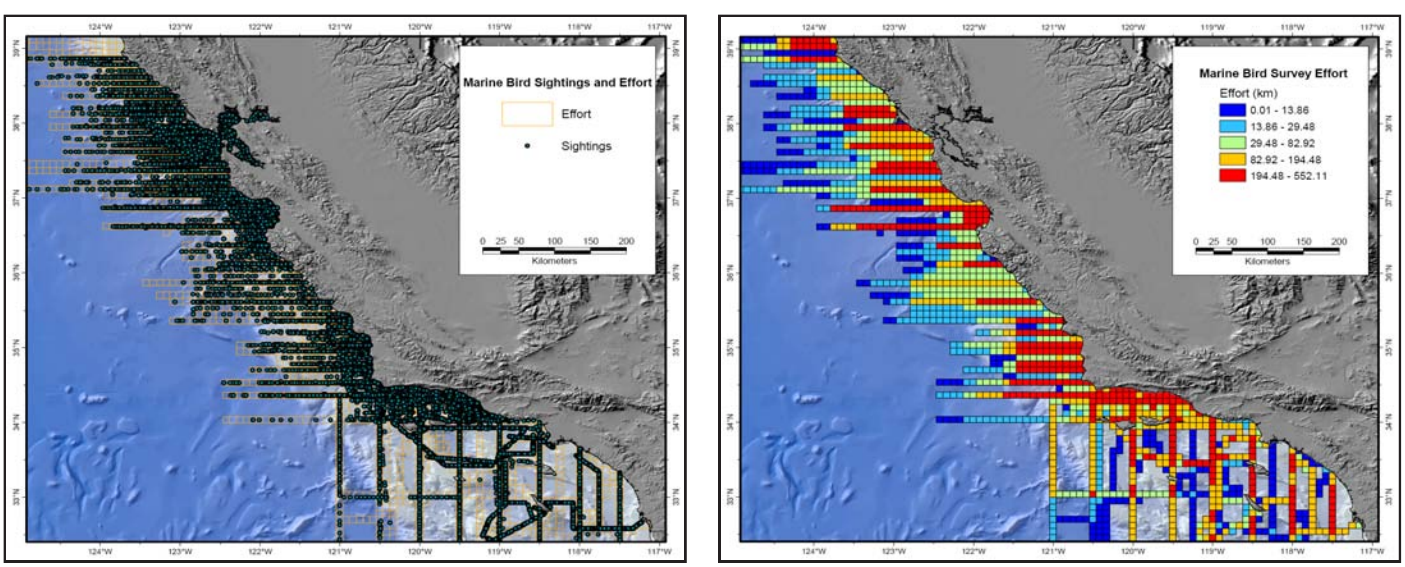

Figure 5.2.1. The distribution of CDAS marine bird survey effort and sightings (left) and the total amount of effort within 5 minutes of latitude by 5 minutes of longitude grid cells (right) within the region from Point Arena to the U.S.-Mexico border.

Since the CDAS data includes summaries for 5 minutes of latitude by five minutes of longitude grid cells, we calculated total observed diversity for each 5 minute cell. The Shannon index (H') was calculated using the formula:

$$H' = -\sum_{i=1}^{S} \left[\left(\frac{n_i}{N} \right) \ln \left(\frac{n_i}{N} \right) \right]$$

where n_i is the number of individuals belonging to the i^{th} species (S) in the sample (five minute grid), and N is the total number of individuals in the sample (Magurran, 1988).

To aid in the analysis and visual interpretation of the diversity map, the estimated diversity was then interpolated using kriging to provide a statistically smoothed one km raster surface. To accomplish this, the calculated diversity for each five minute cell was first assigned to a point at the center of the cell (i.e. the cell centroid). These point data were subsequently tested for significant spatial autocorrelation using the Moran's I and Geary's C statistics. A finding of significant autocorrelation indicates that points that are nearer to one another tend to have more similar values of diversity than points that are far away (Legendre, 1993), and is a prerequisite to accurate interpolation. Next, the spatial autocorrelation was described using a variogram, which summarizes the decrease in relatedness between pairs of points as the distance between them increases. The parameters of the variogram were used in a geostatistical interpolation technique known as kriging, which provides a surface of predicted values as well as a standard error surface indicating the regions in which we have higher or lower confidence in the accuracy of estimated diversity. To avoid displaying estimates of diversity in areas where we have little confidence in the prediction, the standard error map was used to clip the diversity surface. The resulting map (Figure 5.2.2) displays interpolated bird diversity for those regions where the standard error was in the lowest 25 percent.

The estimated patterns of bird diversity should be interpreted with care, as they represent a compilation of six surveys with different methods occurring over a period of nearly 25 years. The distribution and abundance of some species are known to have changed since 1975 (the earliest data used in this analysis). A drawback common to nearly all diversity metrics is the strong positive and non-linear (He *et al*., 1994) correlation between diversity and sampling effort. As sampling effort increases in a given region, the calculated diversity within that region increases as well. Consequently, when sampling effort varies over a given area (as it does within the project study area) some of the observed patterns in diversity may be related to patterns in the distribution of sampling effort. For this reason, we have included a map of sampling effort (Figure 5.2.1) to be considered alongside the map of diversity (Figure 5.2.2).

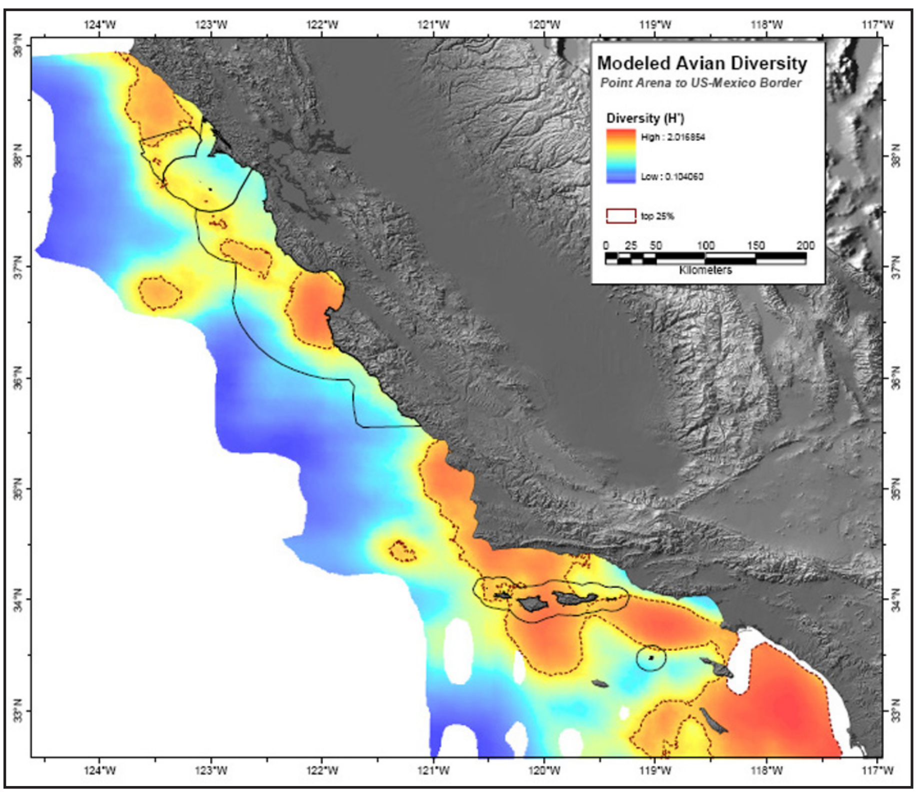

Figure 5.2.2. Estimated bird diversity from Point Arena, Calfiornia to the U.S.-Mexico border. Stippled areas delineate zones representing the 75th percentile of the estimate.

Broad-scale Patterns

The marine bird diversity model resulted in several meso-scale patches (tens to hundreds of kilometers in size) from Point Arena in the north to the U.S.-Mexico border in the south. Regions of high estimated diversity (warm tones) appear along the entire stretch, with a large patch extending from the shelf waters north of Cordell Bank National

Marine Sanctuary through the Gulf of the Farallones and Monterey Bay national marine sanctuaries along the shelf break terminating in the region of Monterey Bay and Point Sur (Figure 5.2.2). A second conspicuous area of high estimated diversity appears approximately 140 km west of Monterey Bay in the open waters over the Guide Seamount. Farther to the south another much smaller patch of high diversity appears in the vicinity of the Santa Lucia Bank. This small patch appears to be a seaward extension of the most prominent extent of high diversity, which ranges along the shelf from Morro Bay in the north down to Point Conception. This significant feature then spreads throughout the entire Southern California Bight, with concentrations around the Channel Islands, the Santa Barbara Channel, and southern shelf areas.

In general, model results indicate that the current arrangement of sanctuaries along the California coastline captures substantial areas of high estimated diversity. In this analysis (ranging from 39° to 32°N latitude), the total area represented by the top 25% of the diversity estimate (Figure 5.2.2, stippled area) was 33,881 km^2. Roughly 5,770 km^2 (17%) of this overall area is contained within the four California sanctuaries, with 6% falling inside the boundaries of the Channel Islands National Marine Sanctuary. A total of 61% of the area contained within current CINMS boundaries was classified as having high marine bird diversity. This is the largest proportion of any California sanctuary.

More than 195 species of birds occupy coastal and/or offshore aquatic habitats in the SCB (McGinnis, 2000). Although many of these species are widely distributed along the west coast, the area of upwelling off Point Arguello/Conception has long been discussed as a key attraction for many of the region's seabird species (Briggs *et al*., 1987). The convergence of two distinct water masses, coupled with elevated productivity associated with upwelling, attracts birds typical of both cool temperate and warm subtropical waters, and contributes to the diversity of the bird community (Baird, 1993).

Linkages between oceanographic character, marine biological productivity, and bird populations have been a topic of considerable study (Briggs *et al*., 1987; Ainley and Boekelheide, 1990; Ainley *et al*., 1995; Roemmich and McGowan, 1995; Sydeman *et al*., 1997; Schoenherr *et al*., 1999). Upwelling in the SCB has been correlated to relatively high concentrations of krill and secondary consumers off the northern Channel Islands. In turn, these pelagic invertebrates and forage fishes attract seabirds to the open ocean over the continental shelf around the Channel Islands. Sooty shearwaters (*Puffinis griseus*), which are among the most numerous seabirds in the region, forage on fish, squid, and euphausiids (Chu, 1984). Shortbelly rockfish, anchovy, and sardine are among the primary foods of common murres (*Uria aalge*), Brandt's cormorants (*Phalacrocorax penicillatus*), and rhinoceros auklet chicks (*Cerorhinca monocerata*). Murres and some other seabirds feed principally on euphausiids in the spring, before juvenile fish and anchovies are available (Ainley and Boekelheide, 1990; Ainley *et al*., 1995). California brown pelicans (*Pelecanus occidentalis californicus*) feed primarily on northern anchovy, Pacific sardine, and Pacific mackerel. Cassin's auklets (*Ptychoramphus aleuticus*) depend on euphausiids and mysids as their primary food supply (Sydeman *et al*., 1997). Rhinoceros auklets frequent waters of the continental slope, where they feed on euphausiids, oceanic squid, and fishes, including lanternfishes and Pacific saury. Adult rhinoceros auklets are also known to consume sablefish and juvenile lingcod found in deep waters far offshore (Airamé *et al*., 2003). The diet of the ashy storm-petrel is poorly known, but includes euphausids.

While these trophic linkages do not explain all of the diversity model results, they do corroborate many of the emerging patterns. Each of the high diversity areas identified in the results section occurs near well known upwelling centers (Breaker and Gilliland, 1981; Kelly, 1985; Breaker and Mooers, 1986; Huyer and Kosro, 1987; Tracy, 1990; Brink and Cowles, 1991; Schwing *et al*., 1991; Breaker and Broenkow, 1994; Rosenfeld *et al*., 1994), including the area near Point Arena, the area near Point Año Nuevo, the nearshore waters directly adjacent to Point Sur, and, as described above, the area of upwelling near Point Arguello/Conception.

Another likely contributing factor in the expression of patterns of bird diversity is proximity to nesting sites. The Farallon Islands are the highest density area for nesting seabirds along the California coast and offshore islands/rocks (Airamé *et al*., 2003). Over 300,000 adult birds nest on the islands in May, which represents the height of the breeding season, although two species (common murre and Cassin's auklet) comprise over half of all birds. Twelve species of marine birds, including common murre, Cassin's and rhinoceros auklets, pigeon guillemot, tufted puffin, western gull, cormorants (double-crested, Brandt's, and pelagic), ashy and Leach's storm-petrels, and black oystercatcher, breed on the Farallon Islands (Ainley and Boekelheide, 1990; Schoenherr *et al*., 1999). This concentration of individuals and species likely influences the broad band of relatively high diversity south and seaward of the Farallones. Most of the remainder of California breeding seabird populations nest on the northern Channel Islands, including: Leach's, ashy and black storm-petrels; California brown pelican; double-crested, Brandt's, and pelagic cormorants; western gull; pigeon guillemot; Xantus's murrelet; Cassin's and rhinoceros auklets; and tufted puffin. Over 200,000 adult birds nest on the islands in April-May, which represents the height of the breeding season. Although not condensed into such a small area as the Farallon Islands, the Channel Islands populations of breeding seabirds are of similar magnitude and diversity as the Farallon Islands. Additionally, the Channel Islands contain the entire U.S. populations of black storm-petrel, California brown pelican, and Xantus's murrelets, plus over 33% of the world populations of ashy storm-petrels and Xantus's murrelets. While the Farallon Islands also hosts over 33% of the world population of ashy storm-petrels, its populations of other species do not reach significant portions of world populations. Thus, in several ways, Channel Islands populations are more important than the Farralon Islands populations on a world scale. Breeding populations in the Channel Islands clearly influence diversity estimates in this area.

Analysis of Boundary Concepts

The preceding discussion identified a large region of high bird diversity centered on the Channel Islands, ranging along the shelf from Morro Bay in the north down to Point Conception, where it then spreads throughout the entire Southern California Bight. This region corresponds roughly with the general region of range termini between 36° and 26°N and the southern part of the California Current Upwelling System. A total of 61% of the area contained within current CINMS boundaries was classified as having high (top 25%) marine bird diversity – the largest proportion of any California Sanctuary. As such, it is important to note that the current sanctuary boundary captures areas of high marine bird diversity; however, a review of the remaining concepts clearly suggests that an expansion could provide further conservation benefit in terms of preserving areas of high bird diversity. In this section we will use the current boundary (NAC) as a reference point against which the remaining concepts and analyses will be compared.

Mean estimated diversity for the NAC was calculated to be 1.49 with a coefficient of variation (CV) of 8.8%. Mean diversity and CV values for the remaining concepts, ranging from smallest in size to largest, are as follows: Concept 5-1.49, 8.7%; Concept 4-1.52, 9.9%; Concept 3-1.53, 9.8%; Concept 2-1.50, 10%; Concept 1a-1.37, 20.3%; and Concept 1-1.38, 20.4%. Mean diversity for the Study Area boundary is estimated to be 1.49 with a CV of 9.9% (Figure 5.2.3, also see Table 5.2.2.) As discussed in Chapter 1.4 which describes absolute versus relative metrics, results shown here are generally predictable, with a trend of larger areas exhibiting lower mean diversity values than smaller ones. This trend is graphically represented in Figure 5.2.4 as a linear regression function between area (km^2) and mean diversity (r^2=0.60, P=0.02). It should be noted, however, that the trend shown in this figure is largely driven by concepts 1 and 1a, and that while the trend is predictable, concepts 2, 3, and 4 are higher than expected. This indicates that the boundary configuration for these concepts disproportionately captures areas of high bird diversity, and that any of these concepts would be a suitable choice for expansion. Clearly, concepts 1 and 1a would be a less suitable choice based on mean diversity alone. The relationship between the absolute areas of high diversity (Figure 5.2.2, stippled area) is even more predictable than mean diversity, with larger concepts containing ever larger areas of high diversity (Table 5.2.2). Figure 5.2.5 shows the linear regression function between the total area (km^2) and the area of high diversity contained within each concept (r^2=0.91, $P < 0.01$).

A more balanced metric to use in assessing the relative conservation value for bird diversity is the Optimal Area Index (OAI) (Table 5.2.2). While this metric decouples the predictable relationships between concept area and conservation value to some extent, results of the OAI are still dependent upon the input data – absolute vs. relative measures. As such, we've provided results of the OAI for both mean and absolute bird diversity. Again, the OAI takes into account the proportional (%) change in diversity as you step from the NAC to each of the concepts under consideration. It also incorporates the proportional change (%) in area from the NAC.

In both cases, the OAI indicate that concepts 3 and 4 provide the largest conservation value per area gained (Table 5.2.2). Because the mean OAI incorporated a negative value in the numerator for concepts 1 and 1a (decreased mean diversity), the calculated value is necessarily negative. Likewise, because the absolute count of high diversity area always increases with each concept, the OAI values are positive.

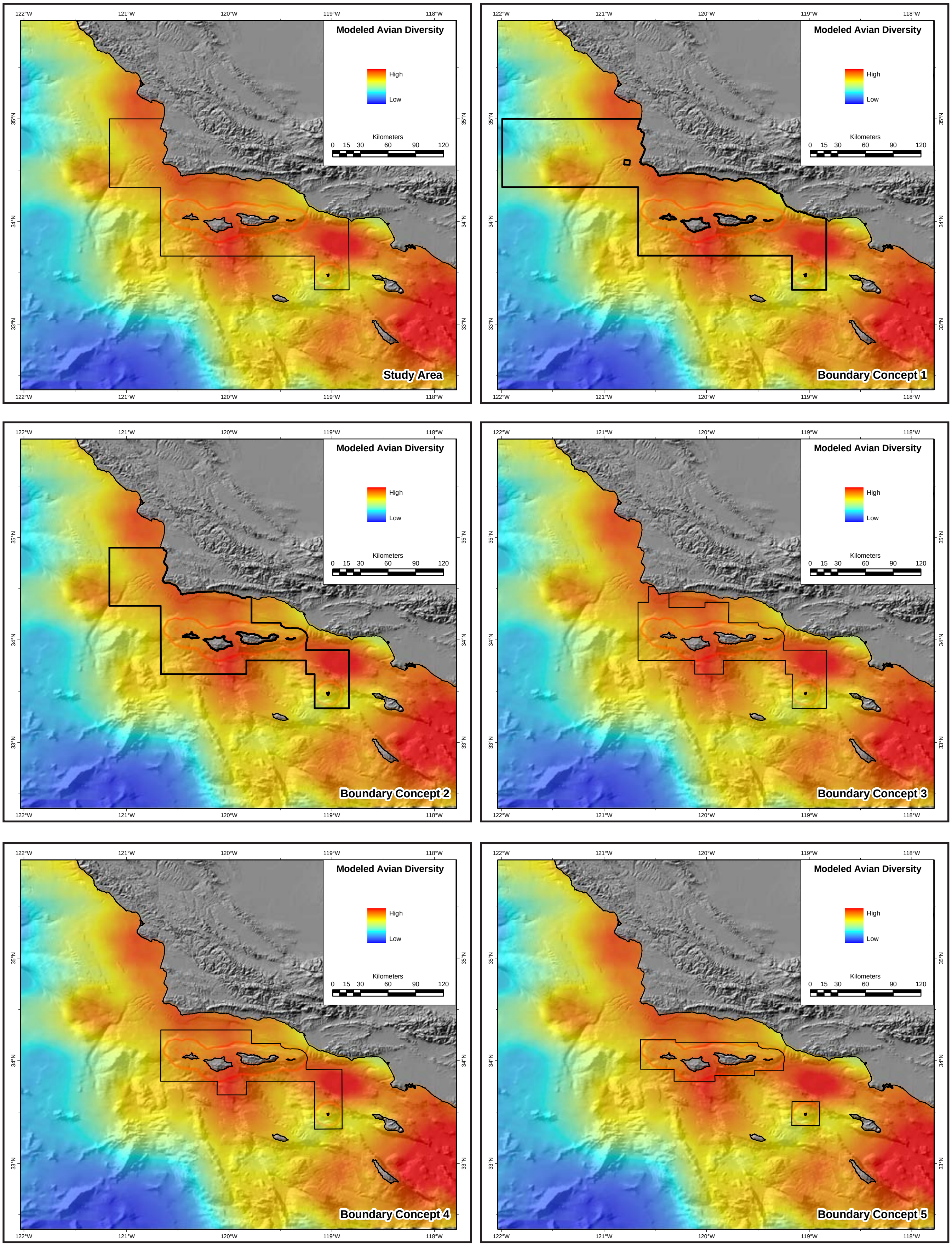

Figure 5.2.3. Overlay of estimated marine bird diversity and CINMS boundary concepts. The Study Area (upper left) is not a concept currently under consideration, but is analyzed to provide a point of comparison to the McGinnis report. Concept 1 is shown with the "cutout" and is to be used as a representative map for both Concepts 1 and 1a.

Table 5.2.2. Analysis of bird diversity within boundary concepts. Numbers in bold indicate an increase in the estimate when compared to the No Action Concept (NAC). Values in bold indicate an increase in the estimate when compared to the NAC. Shaded OAI estimates reflect the concept with the greatest positive value.

Concept	Area (km²)	Mean Bird Diversity	High Diversity Area (km²)	Δ Area (%)	Δ Mean Diversity (%)	Δ High Diversity Area (%)	Mean Bird Diversity OAI (relative)	High Diversity Area OAI (absolute)
NAC	3745	1.485	2284	-	-	-	-	-
5	4536	**1.487**	**2812**	21	0.13	23.12	0.00638	1.094
4	7981	**1.523**	**5507**	113	2.56	141.11	0.02262	1.248
3	9044	**1.53**	**6421**	141	3.03	181.13	0.02141	1.28
2	13736	**1.502**	**8791**	267	1.14	284.89	0.00428	1.068
1a	22591	1.372	**10391**	503	-7.61	354.95	-0.01512	0.705
1	22613	1.375	**10401**	504	-7.41	355.39	-0.0147	0.705
SA	*17093*	*1.489*	*9914*	*356*	*0.27*	*334.06*	*0.00076*	*0.937*

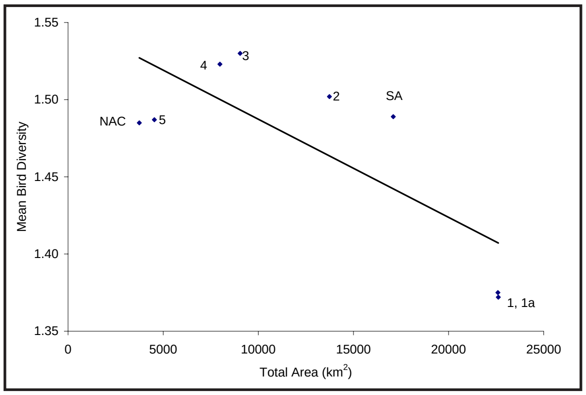

Figure 5.2.4. Regression of mean bird diversity and concept area. Numbers indicate concepts, and NAC=No Action Concept; SA=Study Area.

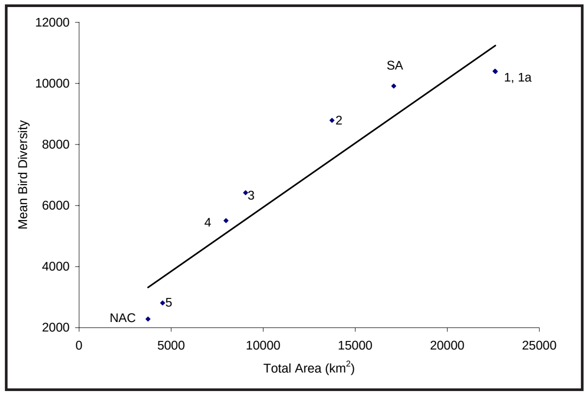

Figure 5.2.5. Regression of the area of highest mean bird diversity and concept area. Numbers indicate concepts, and NAC=No Action Concept; SA=Study Area.

Summary

• Patterns of marine bird diversity appear to reflect the distribution of known upwelling regions and areas of high productivity, as well as breeding areas.

• The current boundaries of the CINMS encompass a region of high bird diversity and a significant concentration of seabird breeding areas.

• Of the six boundary concepts being considered, Concepts 3 and 4 provide relatively large increases in mean bird diversity relative to the NAC; only a few small new breeding areas would be added in any concept being considered.

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CHAPTER 6 BIOGEOGRAPHY OF MARINE MAMMALS

Olaf Jensen, Karin Forney, Jay Barlow, Brian Hatfield, Mark Lowry

The waters around Point Conception and the northern Channel Islands are influenced by cool and warm water masses and strong nearshore upwelling which makes this area highly productive. Because of this productive environment, this region contains a rich fauna of marine mammals. The area around Point Conception is a significant biogeographic mixing zone for many species of marine mammals (Chapter 1.3).

6.1 Cetacean Single Species Analysis

This chapter presents a description of the distribution patterns of nine cetacean species off central and southern California, as well as an analysis of how these distribution patterns relate to the proposed CINMS boundary concepts. The nine cetacean species chosen by CINMS staff for individual analysis represent those species which are common in the region of interest and include:

Blue whale (*Balaenoptera musculus*)
Bottlenose dolphin (*Tursiops truncatus*)
Short-beaked common dolphin (*Delphinus delphis*)
Long-beaked common dolphin (*Delphinus capensis*)
Gray whale (*Eschrichtius robustus*)
Humpback whale (*Megaptera novaeangliae*)
Killer whale (*Orcinus orca*)
Pacific white-sided dolphin (*Lagenorhynchus obliquidens*)
Risso's dolphin (*Grampus griseus*)

In addition to these requested species, five additional cetaceans are briefly discussed at the end of this chapter. Spatial patterns for these species, though not selected for detailed analysis, are described within the sanctuary and the six proposed boundary concepts and include:

Dall's porpoise (*Phocoenoides dalli*)
Fin whale (*Balaenoptera physalus*)
Harbor porpoise (*Phocoena phocoena*)
Minke whale (*Balaenoptera acutorostrata*)
Northern right-whale dolphin (*Lissodelphis borealis*)

Spatial patterns of many cetaceans are not static. Cyclic movements exist on many time scales from seasonal migrations to distributional shifts related to interannual scale climate events, such as the El Niño/La Niña Southern Oscillation (ENSO). An analysis of seasonal distribution patterns is beyond the scope of this project, and in some cases, is not feasible given the available data. The analysis presented here describes general patterns, in many cases averaged over different seasons and years. Where seasonal movements are known, they are mentioned in the text. More detailed information about seasonal distribution patterns of cetaceans in California waters can be found in Forney and Barlow (1998). In addition to seasonal movements there are also trends in the abundance and spatial patterns of some cetaceans. Where known, these trends are also mentioned in the text.

Because of the patchy distribution of many marine organisms in time and space, the general patterns described here may not be a good predictor of abundance at a specific location and time. This is particularly true for species such as blue and humpback whales which track aggregations of seasonal prey (e.g., krill or small schooling fish), but is also likely to be the case for many other cetaceans that aggregate. For such species, the average abundances estimated in this report will most often be higher than the actual abundance at a particular time, but during high use periods, abundance may greatly surpass the average.

Data and Methods

Several types of geo-referenced survey data for cetaceans were used in this report, including: shipboard surveys from the NMFS Southwest Fisheries Science Center (SWFSC), shipboard and aerial surveys compiled for the Minerals Management Service (MMS) in the Computer Database Analysis System (CDAS), and an aerial survey of bottlenose dolphin (SWFSC). These surveys are summarized in Table 6.1.1 and discussed below. Only the SWFSC ship survey and the aerial bottlenose dolphin survey were used to develop densities or encounter rates

Table 6.1.1 Summary of marine mammal field surveys examined in this chapter.

Survey	Dates	Platform	Months	Marine Mammal Sightings	Marine Mammal Individuals
Southwest Fisheries Science Center Ship Surveys	1991, 1993, 1996, 2001	ship	July-December	2963	87402
Southwest Fisheries Science Center Aerial Southern California Bight Surveys	1992-1993 1998-2003	airplane	Year-round	37 (Gray whale)	-
Southwest Fisheries Science Center Coastal Bottlenose Dolphin Surveys	1990-2000	airplane	February-December (most effort in summer)	311	3190
Minerals Management Service Aerial Surveys-CDAS	1980-1983	airplane (high altitude)	Year-round	221	777988
Minerals Management Service Aerial Surveys-CDAS	1980-1983	airplane (low altitude)	Year-round	4089	40528
California Dept. of Fish and Game, Office of Spill Prevention and Response-CDAS	1994-1997	airplane (low altitude)	Year-round	351	1027
Southern California Bight High Aerial Survey-CDAS	1975-1978	airplane (high altitude)	Year-round	695	68557
Southern California Bight Low Aerial Survey-CDAS	1975-1978	airplane (low altitude)	Year-round	1319	15067
Southern California Bight Ship Survey-CDAS	1975-1978	ship	Year-round	3209	112136
Minerals Management Service Survey-CDAS	1995-1997	airplane (low altitude)	Year-round	898	3437

and abundance estimates for this report. This was only possible for certain species (listed below) for which there were sufficient numbers of sightings within the different boundary concepts. When properly corrected for survey effort, these sightings can be used to estimate density; however, without such corrections the sightings can only be plotted to confirm the presence of a given species at a given time and location. Such plots were developed for all of the requested species. Because of uneven distribution of effort, the absence of sightings does not necessarily indicate the absence of a species in a given area. Although only the requested species and five additional cetaceans commonly found in the Study Area were plotted, surveys generally recorded all marine mammals sighted. An analysis of the different boundary concepts was conducted for all species for which quantitative abundance estimates could be calculated. This analysis includes the Optimal Area Index (OAI), a metric for comparing boundary concepts that is discussed in greater detail in Chapter 1.4.

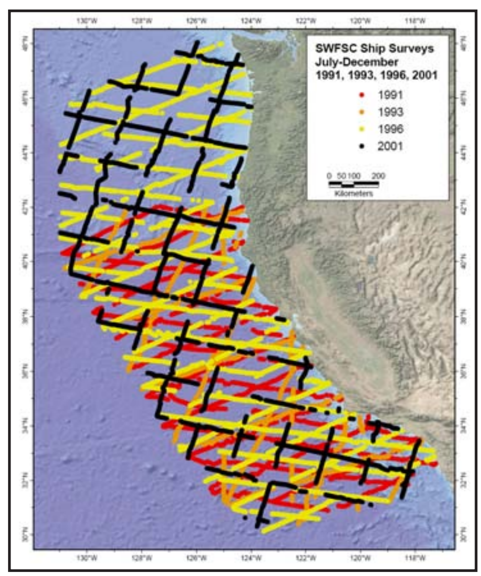

Figure 6.1.1. Survey tracks for the Southwest Fisheries Science Center (SWFSC) ship surveys 1991-2001.

SWFSC Shipboard Surveys

Line-transect surveys of marine mammals were conducted by the SWFSC from late July through early November in 1991, 1993, and 1996, and from late July through early December in 2001. The surveys were conducted off California in all years and additionally off Washington and Oregon in 1996 and 2001. Survey tracks are shown in Figures 6.1.1 and 6.1.2. Details of the survey methods are described fully by Barlow *et al*. (2001). Briefly, surveys were conducted aboard the *R/V David Starr Jordan* and the *R/V McArthur*. Three observers, two with 25x binoculars and one with the unaided eye, recorded marine mammal sightings, including species, group size, and perpendicular distance. Results of these surveys have been used by other researchers to estimate the abundance of cetaceans along the U.S. West Coast using line-transect methods (Barlow, 2003). Here, SWFSC shipboard survey data are used to calculate density estimates within the current CINMS boundary, No Action Concept (NAC), Study Area (McGinnis, 2000), and the six proposed boundary concepts for the following cetaceans:

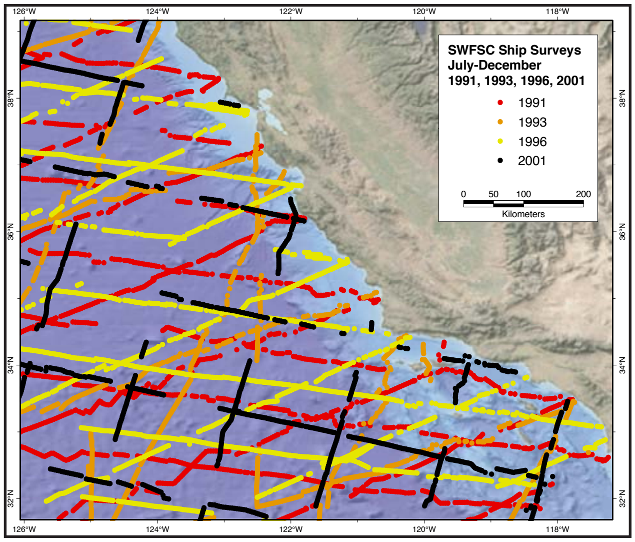

Figure 6.1.2. Survey tracks for the Southwest Fisheries Science Center (SWFSC) ship surveys 1991-2001 off central and southern California waters.

Blue whale (*Balaenoptera musculus*)
Short-beaked common dolphin (*Delphinus delphis*)
Long-beaked common dolphin (*Delphinus capensis*)
Unidentified common dolphin (*Delphinus* spp.)
Humpback whale (*Megaptera novaeangliae*)
Risso's dolphin (*Grampus griseus*)

Density and abundance of the above cetaceans were calculated using line-transect methods (Buckland *et al*., 1993), and ABUND4 (J. Barlow, pers.comm.), a Fortran program, was used to estimate abundance from this line-transect data using the equation:

$$N=A*n*S*f(0)/2*L*g(0)$$

where A equals the area of the region of interest, n equals the number of sightings, S is the mean group size, f(0) is the sighting probability density at zero perpendicular distance, L is the track length, and g(0) is the probability of seeing a group directly on the trackline. The parameters A, n, S, and L are intuitive and easily calculated from the data. The line transect parameters f(0) and g(0) require some explanation: The first parameter, f(0), is a component of the detection function which describes the decrease in sighting probability as the perpendicular distance from the transect line increases. The value of f(0) is the inverse of the Effective Strip Width (ESW), which determines the effective area searched, taking into account the detection function. The other major line-transect parameter, the detection probability on the transect line or g(0), is used to correct for animals that may have been missed on the transect line, either because they were diving and not available to be seen (availability bias) or because they were available to be seen but missed by the observer team (perception bias). Availability bias cannot be estimated empirically from the survey data and is generally determined from information on dive times and surface intervals of marine mammals. Availability bias during shipboard surveys is expected to be greatest for species that dive for prolonged periods, such as beaked whales and sperm whales, and low for most dolphins and other large whales. Perception bias, in contrast, is generally highest for small groups of inconspicuous cetaceans, and lowest for large whales and large, active dolphin schools. Values of g(0) used in this analysis were obtained from Barlow (2003) and include both sources of bias when possible.

Values of f(0) were determined empirically by fitting hazard rate detection functions to the sighting distances. Stratification and pooling of the data were used to obtain the simplest and best fitting models. Both group size and geographic strata were tested, and Akaike's Information Criterion (AIC) was used to select between competing models. To examine the value of geographic stratification, detection functions were fit to the entire pooled data sets (all four years) and a geographical subset of the data in Southern California (from 32.3° to 36°N and east of 122°W), which corresponds more closely to the region of the CINMS boundary concepts. AIC was compared between the pooled data and the sum of the two strata (southern California and all other west coast locations), and the geographic stratification that minimized AIC was selected. For all species except common dolphins and blue whale, the pooled data for the entire data set was selected.

The two common dolphin species and unidentified common dolphins were pooled for estimation of the detection function in order to increase the number of sightings and improve the precision of the f(0) estimate for this category. Estimates of f(0) were lower for the southern California subset than for the entire dataset. Lower f(0) indicates a greater effective strip width (ESW) and suggests that for some reason (*e.g.,* calmer conditions or behavioral differences) common dolphins were more visible within southern California than for the West Coast as a whole. Because of this difference, and a slight improvement in AIC (830.23 for the pooled data compared to 828.97 for the geographically stratified data), geographically specific f(0)'s were used for common dolphins.

Although Barlow (2003) used three group size strata (1-20, 20-60, and >60 individuals) when estimating f(0) coastwide for common dolphin, only two group size strata were used in this study because the f(0) values for groups of 20-60 and >60 were similar (0.464 and 0.451 respectively) in the southern California stratum, and pooling provided more robust sample sizes for variance estimation.

Density and abundance were estimated separately for the two common dolphin species and unidentified common dolphins, using the pooled estimates of f(0) and g(0). The unidentified common dolphin densities and abundances were then pro-rated to the two species according to the proportional abundances of the two species occurring in each concept. Unidentified common dolphins represented 3-10% of the estimated abundance of long-beak common dolphins and 4-7% of short-beak common dolphins within the boundary concepts. Confidence intervals for the combined (identified+unidentified) estimates of common dolphin abundance were approximated based on the coefficient of variation for each of the identified common dolphin abundance estimates. This was judged to be reasonable because the unidentified common dolphins represented only a small proportion of the combined abundance estimate and were expected to contribute little to the variance of the overall abundance estimate.

For blue whales, geographic stratification resulted in a lower f(0) and improved model fit, while group size stratification (1-2 and >2) did not.

Too few Risso's dolphin and humpback whale sightings were available for accurate f(0) estimation using only data from the southern California stratum; therefore coastwide values of f(0) were taken from Barlow (2003) for these species. A summary of input parameters for all species is provided in Table 6.1.2.

Table 6.1.2. Line transect parameters used to estimate the abundance of selected cetaceans within the six boundary concepts, the current CINMS boundary, and the Study Area. Numbers in bold are from Barlow, 2003.

	Overall	1-20	>20
Common dolphin			
f(0)		0.963	0.518
CV f(0)		0.289	0.212
g(0)		**0.77**	**1**
CV g(0)		**0.14**	**0**
Blue whale			
f(0)	0.349		
CV f(0)	0.13		
g(0)	**0.9**		
CV g(0)	**0.07**		
Humpback whale			
f(0)	**0.346**		
CV f(0)	**0.15**		
g(0)	**0.9**		
CV g(0)	**0.07**		
Risso's dolphin			
f(0)		**0.73**	**0.459**
CV f(0)		**0.16**	**0.2**
g(0)		**0.74**	**1**
CV g(0)		**0.39**	**0**

Because density and abundance are estimated independently for the individual boundary concepts, it is possible that a larger concept that completely contains a smaller one could have a lower estimated abundance. This counterintuitive result can occur when few or no sightings are recorded in the portion of the larger concept that does not overlap the smaller concept. Such a contradiction reflects the uncertainty associated with abundance estimation at the scales in this study. Such examples underscore the importance of considering the confidence interval of each estimate, not just the point estimates, when comparing boundary concepts.

For the remaining requested cetaceans, too few sightings were recorded within the region to accurately estimate density. Sightings from the SWFSC shipboard surveys are shown for the above species and for:

Bottlenose dolphin (*Tursiops truncatus*): Offshore Stock
Gray whale (*Eschrichtius robustus*)
Killer whale (*Orcinus orca*)
Pacific white-sided dolphin (*Lagenorhynchus obliquidens*)

SWFSC Aerial Surveys

Additional sightings from SWFSC aerial surveys are displayed for the gray whale, because they are winter/spring migrants through California waters, and no sightings were made during the summer/fall shipboard surveys. Unlike the ship surveys, these aerial surveys were restricted to small areas within the Southern California Bight (Southern California Bight) (Figure 6.1.3) and were conducted year-round, approximately every 1-2 months. Surveys in the area surrounding San Nicolas Island were conducted in 1992-1993, and a second set of surveys around San Clemente Island were conducted in 1998-2003. Details of the survey methods are found in Carretta *et al*. (1995 and 2000). Because of the geographically focused nature of these surveys, the distribution of sightings viewed at a broader scale (i.e. the entire Southern California Bight or southern California) largely reflects the distribution of survey effort. Nevertheless, this survey provides useful recent information about the location of gray whale sightings within surveyed areas of the Southern California Bight. As with all geographically focused surveys, the absence of sightings does not necessarily indicate the absence of a species in a given area.

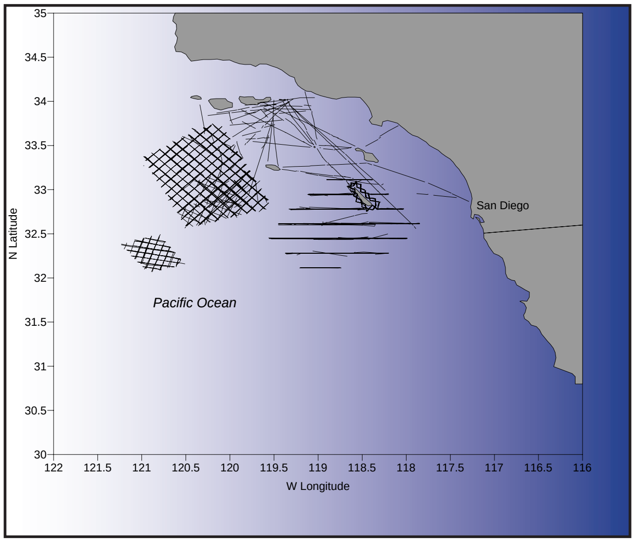

Figure 6.1.3. Survey tracks for the Southwest Fisheries Science Center (SWFSC) ship surveys 1991-2001 off southern California waters.

Computer Database Analysis System (CDAS)

Seven at-sea surveys from the period 1975-1997, compiled by R.G. Ford Consulting Co., in CDAS v2.1 (MMS, 2001) were used to display sightings and effort for the following cetaceans:

Blue whale (*Balaenoptera musculus*)
Bottlenose dolphin (*Tursiops truncatus*): Coastal and Offshore Stocks
Common dolphin (*Delphinus* spp.) (not identified to species)
Gray whale (*Eschrichtius robustus*)
Humpback whale (*Megaptera novaeangliae*)
Killer whale (*Orcinus orca*)
Pacific white-sided dolphin (*Lagenorhynchus obliquidens*)
Risso's dolphin (*Grampus griseus*)

This list represents all of the requested cetacean species. Effort is represented by the total length of survey track in each five minute of latitude by five minute of longitude grid cell (Figures 6.1.4 and 6.1.5). Although effort for the bird surveys in the CDAS data set was represented by area swept, this conversion was not used for displaying cetacean survey effort because different effective strip widths apply for different cetaceans and different surveys. The CDAS data, though comprehensive and thorough, were recorded over a period of more than 20 years, during which time the distributions of some species are known to have varied considerably (Forney and Barlow, 1998). Additionally, the quality of geographical position data and effort information varied during the study period. Consequently, no quantitative analysis was conducted on the CDAS data for this report.

SWFSC Bottlenose Dolphin Aerial Survey

Aerial surveys of California coastal bottlenose dolphins were conducted by SWFSC in May 1990; April, June, August, October, and December 1991; February, April, and July 1992; May-August 1993; July 1994; May 1999; and June 2000. The surveys covered the mainland coast from Point Montara to the U.S.-Mexico border and the Channel Islands. Coastal bottlenose dolphins are associated with nearshore habitat spending 99% of their time within about 500m of shore (Hanson and Defran, 1993). Aerial surveys were conducted at an altitude of 213 m within 300 to 500 m of shore by three observers: inshore (facing shoreward), offshore (facing seaward), and belly (facing down). Further details of the survey methods are reported by Carretta *et al*., (1998).

Encounter rates for bottlenose dolphin were calculated for 20 km shoreline segments by dividing the total number of sightings by the total length of survey track. Portions of survey track in which the sea state was rougher than Beaufort 4 were eliminated as were those portions for which the glare on the inshore observer window (from

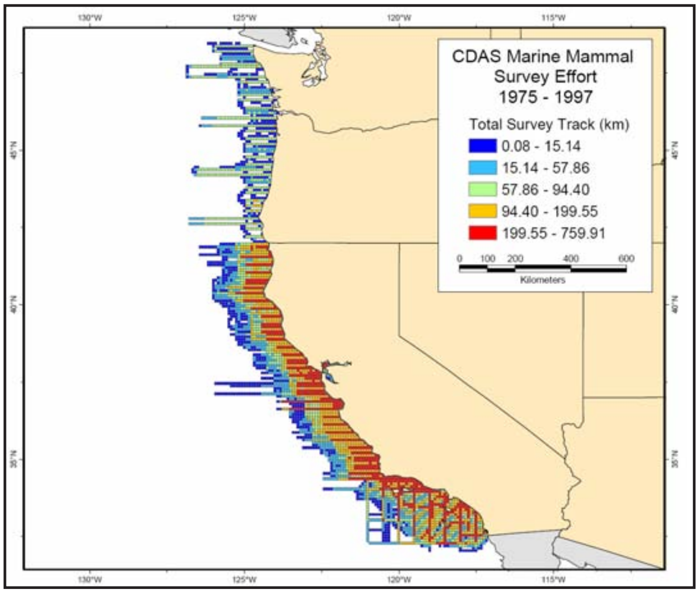

Figure 6.1.4. Survey effort (km of survey track) for the seven surveys of marine mammals compiled in the Computer Database Analysis System (CDAS) v2.1.

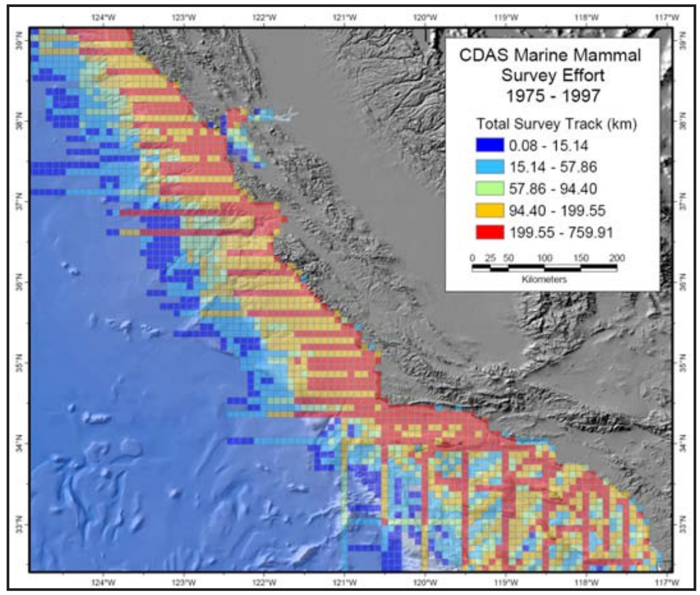

Figure 6.1.5. Survey effort (km of survey track) for the seven surveys of marine mammals compiled in the Computer Database Analysis System (CDAS) v2.1 off central and southern California waters.

which the majority of sightings were made) and the belly window obscured more than 75% of the viewing area. The shoreline segments adjacent to restricted air space near Point Mugu, Camp Pendleton, and Los Angeles International Airport were treated in the same manner as other segments; however, encounter rates in these areas may not accurately reflect bottlenose dolphin abundance because the survey aircraft was frequently required to change course or altitude for safety reasons. Shoreline segments with less than 5 km of effort were eliminated from the analysis. Although all of the Channel Islands were surveyed at least once, only two on-effort bottlenose dolphin sightings were recorded off Santa Catalina Island. Encounter rates were therefore estimated only for the mainland, and no OAI analysis was conducted for this species. Minimum abundance estimates were calculated for each of the concepts that include parts of the mainland coast. These estimates were calculated by multiplying the average encounter rate within each concept by the total length of mainland coast. Because this method does not account for individuals that were present but not sighted (Carretta *et al.,* 1998), it represents a minimum estimate. Because sightability was not considered, it was not possible to calculate the uncertainty associated with the abundance estimates.

Broad-scale Patterns and Analysis of Boundary Concepts

Blue whale (*Balaenoptera musculus*)

Although stock structure of blue whales in the North Pacific has been hypothesized to include one (Donovan, 1991) to five (Reeves *et al*., 1998) sub-stocks, the most recent U.S. stock assessments for this species (Carretta *et al*., 2002) includes an *Eastern North Pacific* stock in addition to the *Hawaiian* stock. The *Eastern North Pacific* stock, which feeds in California waters during the summer and fall and migrates to waters off Mexico and Central America during the winter (Calambokidis *et al*., 1990), is believed to be separate from the Gulf of Alaska population (Rice, 1992). The most recent abundance estimate for this stock, based on a weighted average of the estimates from the 1991-1996 SWFSC ship surveys (Barlow, 1997) and a 1993 mark-recapture survey (Calambokidis and Steiger, 1994) was 1,940 individuals (Carretta *et al*., 2002). Blue whale is a federally listed endangered species.

Sightings of blue whales from the SWFSC ship surveys and the CDAS surveys (Figure 6.1.6) occurred throughout the shelf, slope, and offshore waters of southern California. A notable cluster of sightings was found to the west of San Miguel Island in shelf waters. Because of the uneven distribution of survey effort, the pattern of sightings should be used only as confirmation that blue whales do exist in a given area; the absence of sightings for this widely ranging species may reflect insufficient survey effort rather than real absence from the area.

Estimates of the summer and fall abundance of blue whales within the NAC, the six boundary concepts, and the Study Area were derived from the 1991-2001 SWFSC ship surveys described above and are summarized in Table 6.1.3. Because of the relatively small number of on-effort sightings (4-14) and the uncertainty in the line transect input parameters, confidence intervals for the abundance estimates are wide and overlap substantially among different concepts. The wide intervals show that abundance cannot be estimated precisely, and the overlap indicates that the differences in estimated abundance among concepts are not likely to be statistically significant. Nevertheless, large differences in estimated blue whale density and abundance exist among the concepts. Blue whale sightings were numerous within the NAC and exhibited higher estimated density than any of the concepts or the Study Area. Sharp increases in estimated blue whale abundance relative to that of the NAC are apparent in Concepts 1, 1a, and 2. The OAI shows that, although none of the concepts provide higher density than the NAC, Concepts 1 and 1a provide the greatest relative increase in blue whale abundance for the smallest relative increase in area. It is important to remember, however, that blue whales aggregate in areas where their prey (krill) are concentrated. Any boundary concept might, therefore, contain a larger number of blue whales during times when krill densities are high.

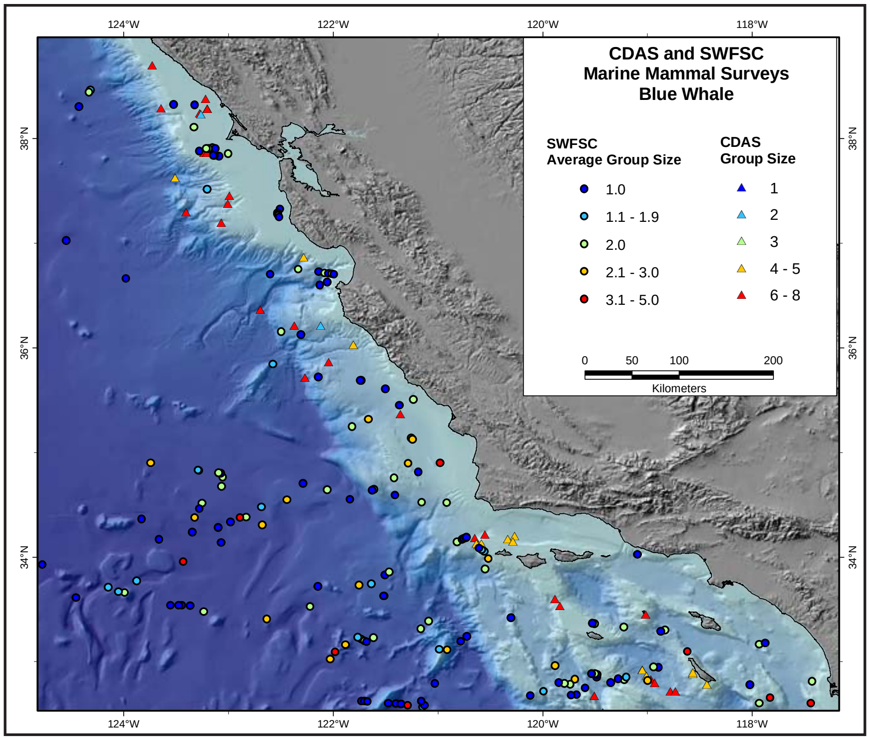

Figure 6.1.6. Blue whale. Sightings and group size (where available) from the Southwest Fisheries Science Center (SWFSC) ship surveys 1991-2001 and the seven surveys of marine mammals compiled in the Computer Database Analysis System (CDAS) v2.1, 1975-1997.

Table 6.1.3. Blue whale. Sightings, estimated density and abundance, coefficient of variation (CV), and upper and lower 95% confidence limits for the abundance estimate, and the Optimal Area Index (OAI) for the six boundary concepts, the No Action Concept (NAC), and the Study Area (SA). Abundance and density values in bold reflect increases from the NAC and shaded OAI values represent maximum observed benefit.

Concept	Area (km^2)	Sightings	Estimated Density	Estimated Abundance	CV	Lower 95% CI	Upper 95% CI	Δ Area (%)	Δ Density (%)	Δ Abundance (%)	Density OAI (relative)	Abundance OAI (absolute)
NAC	3745	4	0.00807	30	0.93	6	141	-	-	-	-	-
5	4536	4	0.00712	**32**	0.78	8	124	21.12	-11.77	6.67	-0.557	0.316
4	7981	4	0.004	**32**	0.73	9	115	113.11	-50.43	6.67	-0.446	0.059
3	9044	4	0.00358	**32**	0.72	9	114	141.50	-55.64	6.67	-0.393	0.047
2	13736	**7**	0.006	**82**	1.34	11	598	266.78	-25.65	173.33	-0.096	0.65
1a	22591	**14**	0.00587	**133**	0.4	63	283	503.23	.27.26	343.33	-0.054	0.68
1	22613	**14**	0.00587	**133**	0.4	63	283	503.82	-27.26	343.33	-0.054	0.681
SA	*17093*	**8**	*0.0053*	*91*	*0.44*	*40*	*208*	*356.42*	*-33.95*	*203.33*	*-0.095*	*0.57*

Bottlenose dolphin (*Tursiops truncatus*)

Two populations of bottlenose dolphin are found in California waters: 1) an offshore population found at distances greater than 1 km from the mainland shore in the Southern California Bight and extending to the offshore limits (300 nmi) of the SWFSC ship surveys throughout much of California waters; and 2) a coastal population that is found primarily within 500 m of the mainland shore from San Francisco south into Baja California, Mexico (Carretta *et al*., 2002). The abundance of the offshore population in U.S. west coast waters during the 1991-1996 SWFSC ship surveys was estimated at 956 individuals (Barlow, 1997). The most recent average estimate for the coastal population, based on 1999-2000 tandem aerial surveys by the SWFSC (a subset of the data was used to map encounter rates in this report), is 206 individuals (Carretta *et al*., 2002). A multi-year average estimate of the number of individuals in the Study Area was presented by Carretta *et al*. (2002), because some individuals in this population spend part of the time off Mexico and farther north along the central California coast. Although the abundance of the coastal population in California overall appears to be stable (Dudzick, 1999), there is movement along the coast, some of which appears to be related to seasonal and interannual changes in water temperature (Hansen and Defran, 1990; Wells *et al*., 1990). Bottlenose dolphins are not federally listed as a threatened or endangered species.

Sightings of bottlenose dolphin from the SWFSC ship surveys and the CDAS surveys (Figure 6.1.7) occur mostly in shelf and nearshore waters of the Southern California Bight. Both populations, coastal and offshore, are apparent in the sightings. A string of sightings likely to be from the coastal population occurs along the coast from west of Santa Barbara to Ventura and another between Dana Point and San Diego. Sightings that can be attributed to the offshore population occur throughout the Southern California Bight with a cluster of sightings from the SWFSC surveys found in the Santa Cruz Basin. Because of the uneven distribution of survey effort, the pattern of sightings should be used only as confirmation that bottlenose dolphin do exist in a given area; the absence of sightings may reflect insufficient survey effort rather than real absence from the area. No abundance estimates were calculated for the offshore stock of bottlenose dolphin.

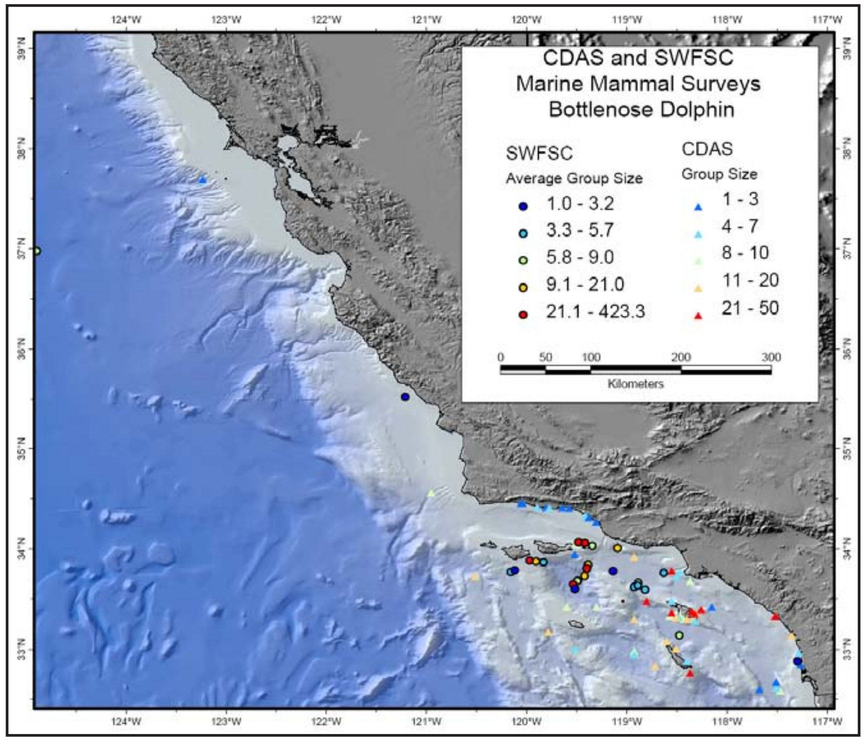

Figure 6.1.7. Bottlenose dolphin. Sightings and group size (where available) from the Southwest Fisheries Science Center (SWFSC) ship surveys 1991-2001 and the seven surveys of marine mammals compiled in the Computer Database Analysis System (CDAS) v2.1, 1975-1997.

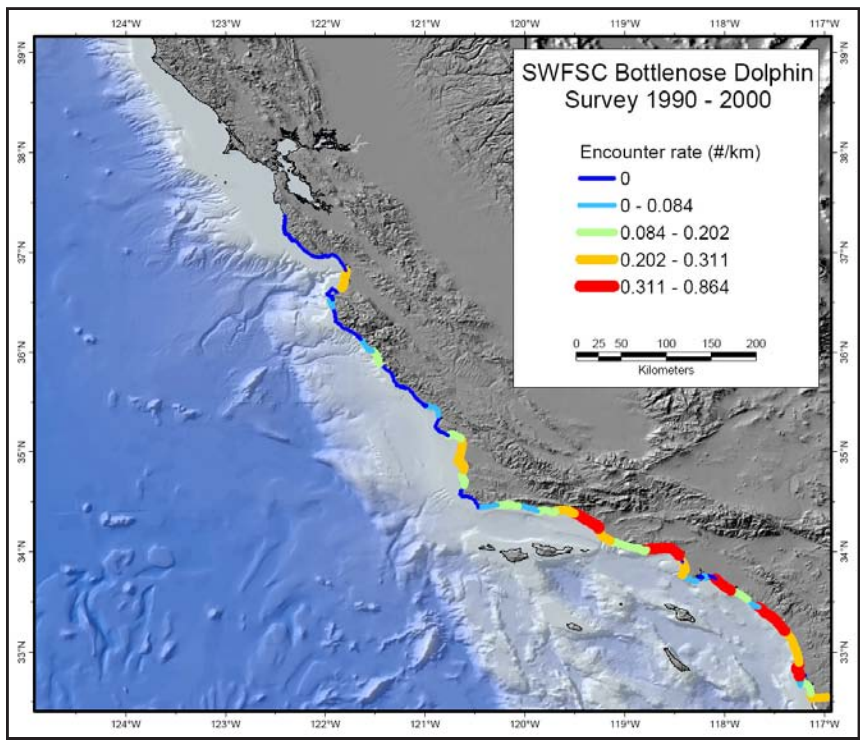

Figure 6.1.8. Bottlenose dolphin (coastal population). Encounter rates (#/km) based on Southwest Fisheries Science Center (SWFSC) aerial surveys, 1990-2000.

Encounter rates of coastal bottlenose dolphin derived from the 1990-2000 SWFSC aerial surveys designed specifically for this population (Figure 6.1.8) vary along the central and southern California coast, with the highest encounter rates observed to the south of Santa Barbara. Notable hotspots (encounter rates in the highest quintile or 0.311-0.864 individuals/km) for this species occur from Carpinteria to Ventura, Point Dume to Santa Monica, San Pedro Bay to Newport Beach, and near Oceanside to La Jolla. Many of these areas of high encounter rates contain long sandy beaches and/or river mouths.

Estimates for the mean encounter rates and abundance of the coastal stock of bottlenose dolphin within Concepts 1-3 and the Study Area were derived from the 1990-2000 SWFSC aerial coastal bottlenose dolphin surveys described above and are summarized in Table 6.1.4. Mean encounter rates and estimated abundance were greatest in Concepts 1 and 1a and the Study Area. Substantial increases in both the mean encounter rate and the estimated abundance were observed for each increase in shoreline length. Abundance of coastal bottlenose dolphin in those concepts which do not include portions of mainland shore, is assumed to be zero since coastal bottlenose dolphin are not known to occur away from the mainland shore.

Table 6.1.4. Coastal bottlenose dolphin. Sightings, mean encounter rate, and estimated abundance for four boundary concepts and the Study Area (SA). No analysis was done for the NAC or Concepts 4-5 since encounter rates were calculated for the mainland coast.

Concept	Area (km^2)	Mainland Shoreline (km)	Individuals Sighted	Mean Encounter Rate (#/km	Estimated Abundance
NAC	3745	0	-	-	-
5	4536	0	-	-	-
4	7981	0	-	-	-
3	9044	20.32	5	0.04	1
2	13736	140.02	199	0.11	15
1a	22591	277.64	1112	0.23	63
1	22613	277.64	1112	0.23	63
SA	*17093*	*277.64*	*1112*	*0.23*	*63*

Long-beaked and short-beaked common dolphins (*Delphinus* spp.)

Two distinct species of common dolphin, the long-beaked (*Delphinus capensis*) and the short-beaked (*Delphinus delphis*) common dolphin, have been recognized in the eastern North Pacific based on genetic and morphological differences (Heyning and Perrin, 1994; Rosel *et al*., 1994). Within California coastal waters, the distribution of the two species overlaps. Long-beaked common dolphins are found in nearshore (<50 nmi of the coast) waters from Baja California, Mexico to central California. Short-beaked common dolphins have a broader distribution along the west coast of North America, extending from approximately the California/Oregon border south into equatorial waters (Carretta *et al*., 2002). Short-beaked common dolphins may also be found farther from the coast, with many sightings in the SWFSC ship surveys occurring near the offshore limit (300 nmi) of the survey. Although common dolphins are frequently spotted during aerial surveys, the two species cannot be reliably distinguished from the air (Forney *et al*., 1995). The most recent abundance estimate for the California stock of long-beaked common dolphin based on data from the 1991-1996 SWFSC ship surveys (Barlow, 1997) is 32,239 individuals (Carretta *et al*., 2002). Estimated short-beaked common dolphin abundance throughout its U.S. West Coast range, based on the same data, is 373,573 individuals. Although these abundance estimates are for different geographic regions (stock assessments are for individual stocks which may have different geographic boundaries), analysis of the same data restricted to California shows that short-beaked common dolphin are the most abundant cetacean in California waters. The distributions of both species appear to vary seasonally and interannually with highest densities of long-beaks in California waters occurring during warm-water events (Heyning and Perrin, 1994). Neither species of common dolphin is considered a threatened or endangered species.

Sightings of common dolphins are divided into those that were not identified to species from the SWFSC ship surveys and the CDAS surveys (Figure 6.1.9) and those from the SWFSC ship surveys that could be identified as either long-beaked (Figure 6.1.10) or short-beaked (Figure 6.1.11). Common dolphins not identified to species were frequently sighted in the Southern California Bight in the CDAS surveys and were twice sighted in Monterey Bay. The SWFSC surveys include several sightings in shelf waters between Point Conception and Point Piedras Blancas as well as many

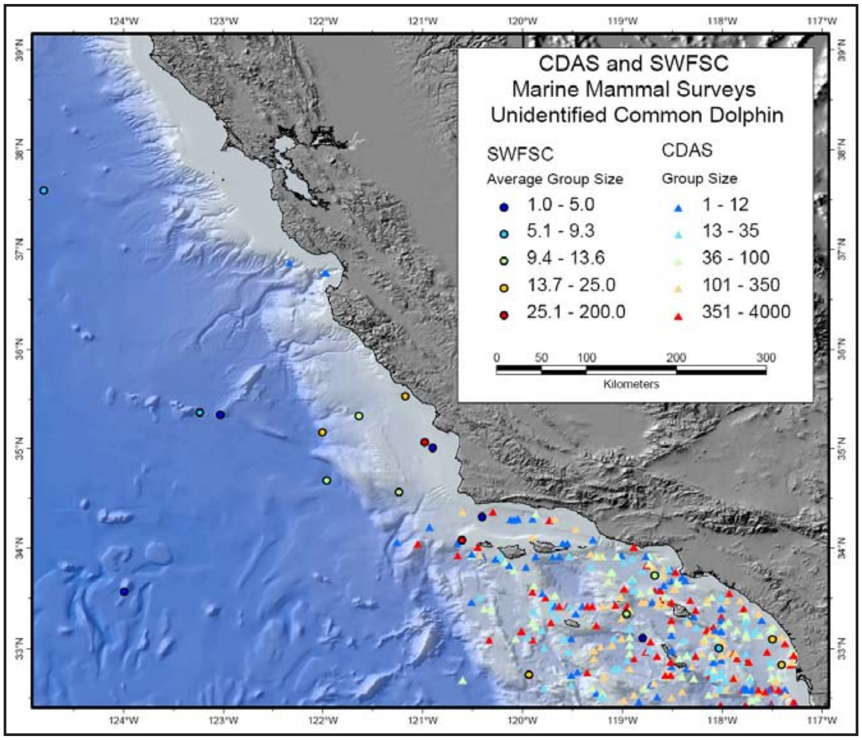

Figure 6.1.9. Common dolphin (*Delphinus* spp). Sightings and group size (where available) from the Southwest Fisheries Science Center (SWFSC) ship surveys 1991-2001 and the seven surveys of marine mammals compiled in the Computer Database Analysis System (CDAS) v2.1, 1975-1997.

throughout the Southern California Bight. Sightings of long-beaked common dolphins occurred predominantly in inshore shelf waters from Point Piedras Blancas south to Newport Beach. There were several sightings in the Santa Barbara Channel and near Anacapa Island. Sightings of short-beaked common dolphins were much more numerous and occurred throughout central and southern California shelf and offshore waters, although offshore sightings predominate north of Monterey Bay. Because of the coarse distribution of survey effort, the pattern of sightings should be used only as confirmation that common dolphins do exist in a broad geographic area. The absence of sightings within smaller geographic areas may reflect the distribution of survey effort rather than real absence from the area.

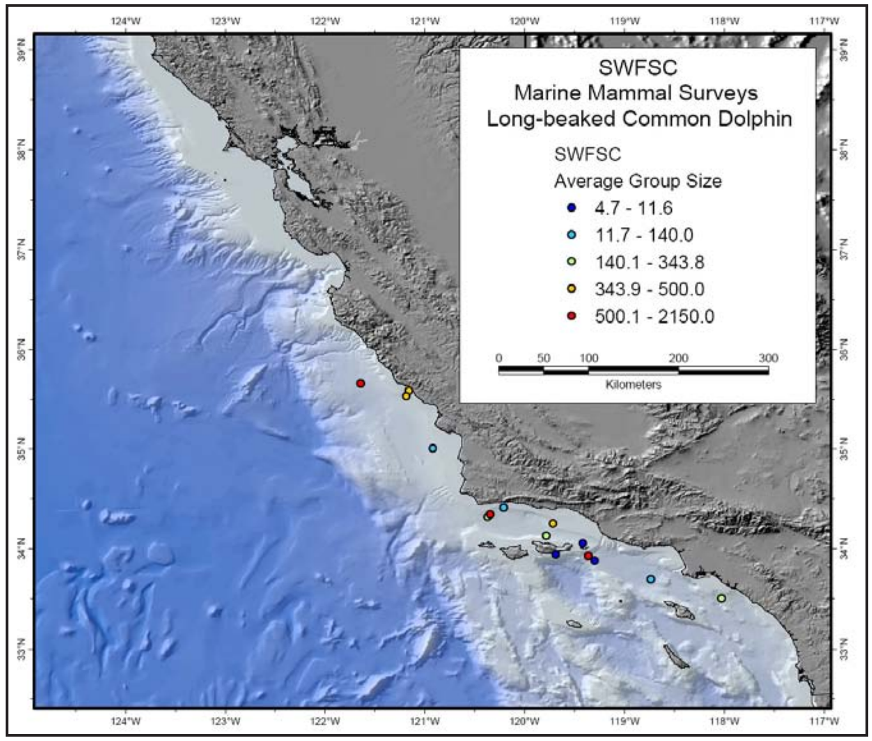

Figure 6.1.10. Long-beaked common dolphin. Sightings and average group size (where available) from the Southwest Fisheries Science Center (SWFSC) ship surveys 1991-2001.

Estimates of the summer and fall abundance of long-beaked and short-beaked common dolphins within the NAC, the six boundary concepts, and the Study Area, were derived from the 1991-2002 SWFSC ship surveys described above and are summarized in Tables 6.1.5 (long-beaks) and 6.1.6 (short-beaks). These results represent the combined estimates of species-specific abundance and, because many common dolphins could not be identified to species, an area-specific proportion of the estimated unidentified common dolphin abundance. Confidence intervals for the combined (identified + pro-rated unidentified) abundance estimates were approximated based on the coefficient of variation of the abundance estimates for identified sightings only. Because of the relatively small number of on-effort sightings (3-7 for long-beaks and 4-19 for short-beaks) and the uncertainty in the line transect input parameters, confidence intervals for the abundance estimates are wide and overlap substantially among different concepts. The overlapping confidence intervals indicate that the differences in estimated abundance among concepts are not statistically significant.

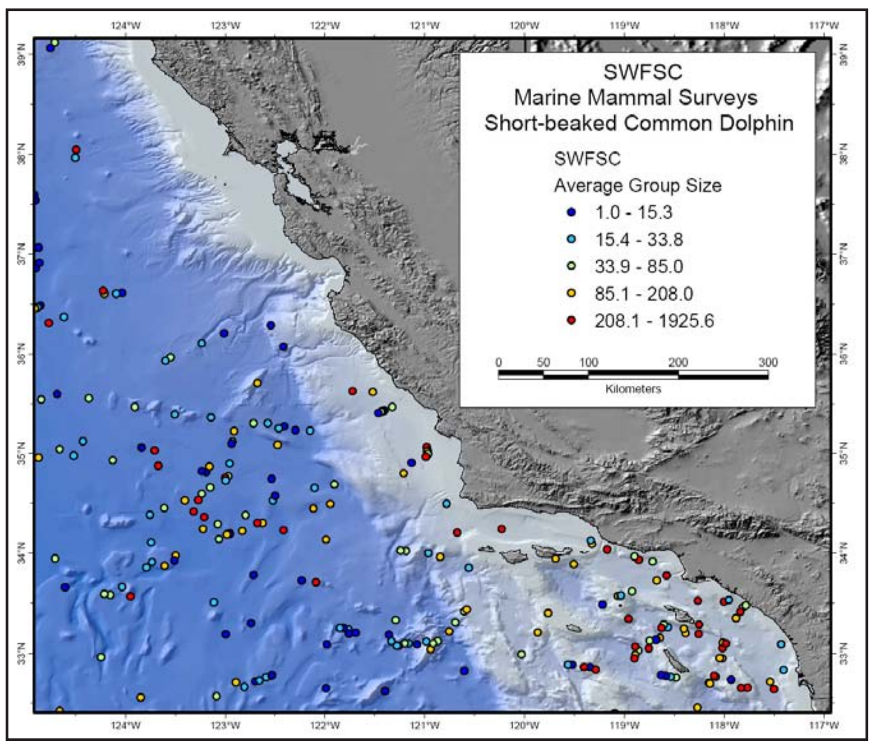

Figure 6.1.11. Short-beaked common dolphin. Sightings and average group size (where available) from the Southwest Fisheries Science Center (SWFSC) ship surveys 1991-2001.

Estimated long-beaked common dolphin density is highest in Concept 2 and estimated abundance is highest in Concepts 1, 1a, and the Study Area. Notable increases in estimated abundance relative to that of the NAC are apparent with each increase in concept size with the exception of Concept 5, which shows a 7% increase relative to the NAC. The OAI shows that, of the proposed boundary concepts, Concept 2 provides the greatest relative increase in both density and abundance for the smallest relative increase in area.

Table 6.1.5. Long-beaked common dolphin. Sightings, estimated density and abundance, coefficient of variation (CV) and upper and lower 95% confidence limits for the abundance estimate; and the Optimal Area Index (OAI) for the six boundary concepts, the No Action Concept (NAC), and the Study Area (SA). Abundance and density values in bold reflect increases from the NAC and shaded OAI values represent maximum observed benefit.

Concept	Area (km²)	Sightings (Long-beaked)	Sightings (*Delphinus* spp.)	Corrected Density	Corrected Abundance	CV	Lower 95% CI	Upper 95% CI	∆ Area (%)	∆ Density (%)	∆ Abundance (%)	Density OAI (relative)	AbundanceOAI (absolute)
NAC	3745	3	0	1.41	5262	-	-	-	-	-	-	-	-
5	4536	3	0	1.24	5620	-	-	-	21.12	-11.83	6.80	-0.560	0.322
4	7981	**4**	**2**	0.75	**5967**	1.06	1089	32693	113.11	-46.79	13.40	-0.414	0.118
3	9044	**4**	**2**	0.67	**6061**	1.01	1172	31355	141.50	-52.31	15.18	-0.370	0.107
2	13736	**6**	**2**	**1.72**	**23649**	0.74	6476	86362	266.78	22.52	349.42	0.084	1.310
1a	22591	**7**	**3**	1.16	**26115**	0.69	7686	88730	503.23	-17.73	396.29	-0.035	0.787
1	22613	**7**	**3**	1.16	**26141**	0.69	7694	88816	503.82	-17.73	396.78	-0.035	0.788
SA	*17093*	*7*	*2*	*1.59*	*27138*	*0.66*	*8351*	*88191*	*356.42*	*12.98*	*415.73*	*0.036*	*1.166*

Table 6.1.6. Short-beaked common dolphin. Sightings, estimated density and abundance, coefficient of variation (CV) and upper and lower 95% confidence limits for the abundance estimate; and the Optimal Area Index (OAI) for the six boundary concepts, the No Action Concept (NAC), and the Study Area (SA). Abundance and density values in bold reflect increases from the NAC and shaded OAI values represent maximum observed benefit.

Concept	Area (km²)	Sightings (Short-beaked)	Sightings (*Delphinus* spp.)	Corrected Density	Corrected Abundance	CV	Lower 95% CI	Upper 95% CI	∆ Area (%)	∆ Density (%)	∆ Abundance (%)	Density OAI (relative)	AbundanceOAI (absolute)
NAC	3745	4	0	0.62	2330	-	-	-	-	-	-	-	-
5	4536	4	0	0.55	**2489**	-	-	-	21.12	-11.83	6.82	-0.560	0.323
4	7981	**8**	**2**	**1.17**	**9356**	1	1830	47838	113.11	88.39	301.55	0.781	2.666
3	9044	**8**	**2**	**1.05**	**9503**	1	1859	48591	141.50	68.86	307.86	0.487	2.176
2	13736	**9**	**2**	**0.78**	**10756**	0.95	2234	51799	266.78	25.85	361.65	0.097	1.356
1a	22591	**19**	**3**	**0.92**	**20713**	0.57	7324	58579	503.23	47.35	788.97	0.094	1.568
1	22613	**19**	**3**	**0.92**	**20733**	0.57	7331	58636	503.82	47.35	789.85	0.094	1.568
SA	*17093*	*16*	*2*	*1.13*	*19321*	*0.6*	*6517*	*57286*	*356.42*	*81.66*	*729.25*	*0.229*	*2.046*

Estimated short-beaked common dolphin density is highest in Concept 4 and estimated abundance is highest in Concepts 1, 1a, and the Study Area. Estimated abundance for this species seems to fall into three relatively distinct groupings: the NAC and Concept 5, with approximately 2,500 individuals; Concepts 2-4, with around 10,000 individuals; and Concepts 1, 1a, and the Study Area, with around 20,000 individuals. The OAI shows that Concept 4 provides the greatest relative increase in both density and abundance for the smallest relative increase in area.

Abundance estimates of the two common dolphin species present two apparent contradictions. While there are more sightings of short-beaked common dolphin, and this species is the most abundant cetacean in California waters, estimated abundance is higher for long-beaked common dolphin within several of the boundary concepts. The higher estimated abundance for long-beaked common dolphin is in part due to the larger average group size of this species (*e.g.*, in Concept 1, the average group size for long-beaked common dolphin was 480 individuals while the average group size for short-beaked common dolphin was 140 individuals). Although short-beaked common dolphins are more abundant throughout California, this partly reflects their broader distribution into offshore waters. Within certain areas, including some of the boundary concepts, long-beaked common dolphins are more abundant because they have a more nearshore distribution.

Gray whale (*Eschrichtius robustus*)

Gray whales are currently found only in the North Pacific with two separate stocks recognized (Angliss and Lodge, 2002). The *Western North Pacific* stock is distributed throughout eastern Asia (Rice, 1981; Rice *et al*., 1984) while the *Eastern North Pacific* stock occurs from its summer feeding habitat in the northern Bering and Chukchi Seas (Rice and Wolman, 1971; Berzin, 1984; Nerini, 1984) to its winter calving habitat along the west coast of Baja California, Mexico (Rice *et al*,. 1984). The fall (southbound) migration begins in November-December (Rugh *et al*., 2001) and the spring (northbound) migration occurs from mid-February through May (Rice *et al*., 1981, 1984; Poole, 1984). The most recent estimate of the size of the *Eastern North Pacific* gray whale stock based on systematic counts of migrating (southbound) whales by shore-based observers at Granite Canyon, CA in 1997-98 is 26,635 individuals (Angliss and Lodge, 2002). There is evidence of a generally positive trend in gray whale abundance since 1992-1993. The gray whale was removed from the endangered species list in 1994.

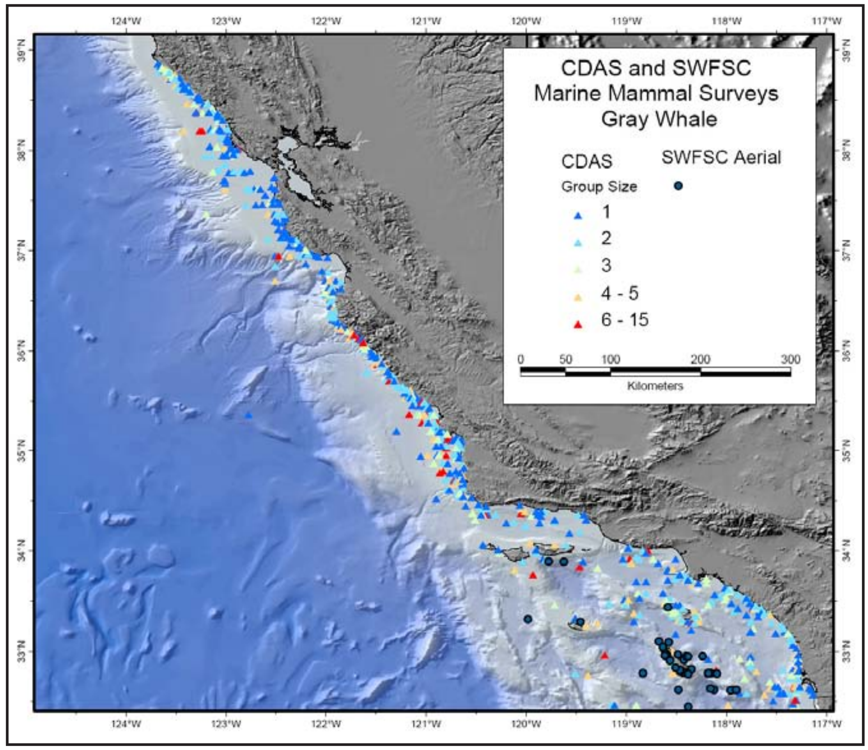

Figure 6.1.12. Gray whale. Sightings and group size (where available) from the Southwest Fisheries Science Center (SWFSC) aerial surveys conducted near San Nicolas (1992-1993) and San Clemente (1998-2003) islands and the seven surveys of marine mammals compiled in the Computer Database Analysis System (CDAS) v2.1, 1975-1997.

Sightings of gray whales from the SWFSC aerial surveys and the CDAS surveys (Figure 6.1.12) reflect the broad nearshore distribution of this species during its migration through California waters. Gray whale sightings occur in nearshore waters throughout the Southern California Bight, including the Santa Barbara Channel, and near the Channel Islands. The cluster of sightings around San Clemente Island is probably more reflective of survey effort than a particular preference for this location, although San Clemente Island lies along one of the gray whales' migratory routes through the Southern California Bight. Because of the uneven distribution of survey effort, the pattern of sightings should be used only as confirmation that gray whales do exist in a broad area; the absence of sightings may reflect insufficient survey effort rather than real absence from the area. Quantitative comparison of the different boundary concepts was not possible due to the lack of sightings during the SWFSC ship surveys, which do not take place during the gray whale migration season.

Humpback whale (*Megaptera novaeangliae*)

Evidence from survey data and genetic analyses supports the division of humpback whales into three populations within U.S. Pacific waters (Carretta *et al*., 2002), one of which migrates from coastal Central America and Mexico to the west coast of the U.S. and into British Columbia during the summer and fall (Steiger *et al*., 1991; Calambokidis *et al*., 1993). This population, referred to as the *Eastern North Pacific* stock, passes through the Study Area during its summer and fall migration. The most recent abundance estimate for this stock based on a 1998-2000 mark-recapture survey (Calambokidis *et al*., 2001) was 856 individuals and a modest upward trend in abundance since 1990 is apparent (Carretta *et al*., 2002). Humpback whale is a federally listed endangered species.

Sightings of humpback whales from the SWFSC ship surveys and the CDAS surveys (Figure 6.1.13) occur most frequently in shelf waters to the north of Point Conception. Scattered sightings also occur in the Southern California Bight (including several in the Santa Barbara Channel) and in offshore waters. Because of the uneven distribution of survey effort, the pattern of sightings should be used only as confirmation that humpback whales do exist in a given area; the absence of sightings may reflect insufficient survey effort rather than real absence from the area.

Estimates of the summer and fall abundance of humpback whales within the NAC, the six boundary concepts, and the Study Area were derived from the 1991-2001 SWFSC ship surveys described above and are summarized in Table 6.1.7. Because some of the sightings recorded as "Unidentified Large Whale" (including one that fell in Concepts 1 and 1a) were likely to be humpback whales (Carretta *et al*., 2002), abundance estimates in Concepts 1 and 1a may be negatively biased. Very small numbers of on-effort sightings (0-4) make the density and abundance estimates for this species extremely uncertain. This uncertainty is reflected in the wide and overlapping confidence intervals. The wide intervals show that abundance can not be estimated precisely, and the overlap indicates that the differences in estimated abundance among concepts are not likely to be statistically significant. No on-effort sightings were recorded within the NAC and only 1 on-effort sighting was recorded in Concepts 3-5, resulting in abundance estimates of approximately 10 individuals for these three concepts. Four on-effort sightings occurred in Concepts 1, 1a, 2, and the Study Area resulting in abundance estimates of approximately 50 individuals for these four areas. Because no on-effort sightings were recorded in the NAC, it was not possible to calculate the OAI for humpback whales. It is important to remember, however, that humpback whales aggregate in areas where their prey (krill and small schooling fish) are concentrated. Any boundary concept could, therefore, contain a larger number of humpback whales during times when prey densities are high.

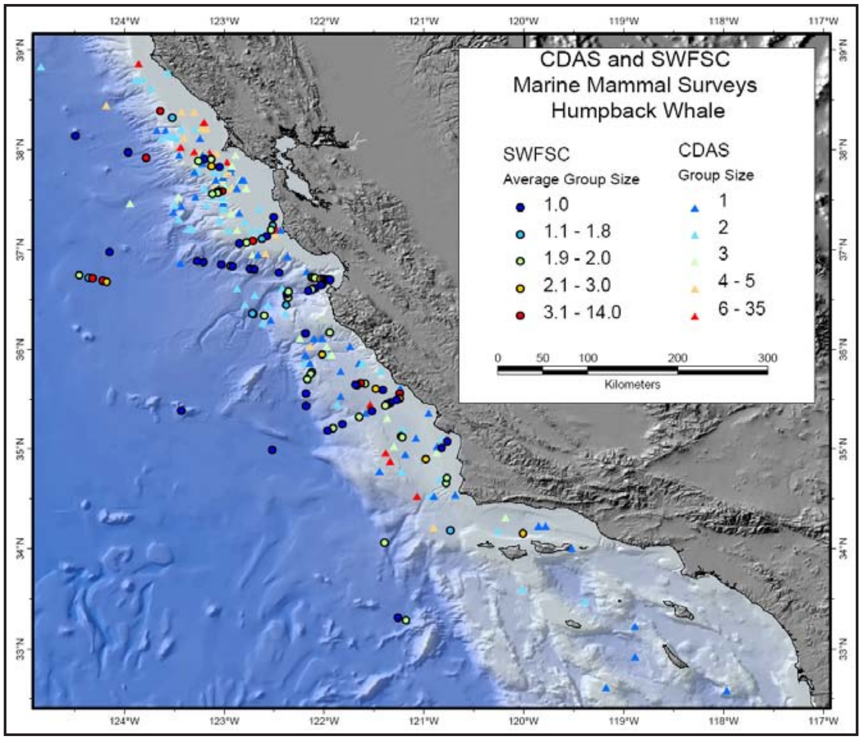

Figure 6.1.13. Humpback whale. Sightings and group size (where available) from the Southwest Fisheries Science Center (SWFSC) ship surveys 1991-2001 and the seven surveys of marine mammals compiled in the Computer Database Analysis System (CDAS) v2.1, 1975-1997.

Table 6.1.7. Humpback whale. Sightings, estimated density and abundance, coefficient of variation (CV) and upper and lower 95% confidence limits for the abundance estimate for the six boundary concepts, the No Action Concept (NAC), and the Study Area (SA). SIghtings and density values in bold reflect increases from the NAC.

Concept	Area (km²)	Sightings	Estimated Density	Estimated Abundance	CV	Lower 95% CI	Upper 95% CI
NAC	3745	0	0	0	-	-	-
5	4536	1	**0.00234**	11	1	2	56
4	7981	1	**0.00131**	10	1	2	51
3	9044	1	**0.00118**	11	1	2	56
2	13736	**4**	**0.00375**	52	2.33	4	754
1a	22591	**4**	**0.0023**	51	0.91	11	234
1	22613	**4**	**0.00226**	51	0.91	11	234
SA	*17093*	*4*	*0.0031*	*53*	*0.82*	*13*	*216*

Killer whale (*Orcinus orca*)

Relatively little is known about the killer whales found in California waters compared to the well-studied populations of Alaska and the Pacific Northwest. Nevertheless, four separate types of killer whales have been identified and regularly sighted in California. These groups differ in their behavior, genetics, distribution, coloration and preferred prey (Ford and Fisher, 1982; Baird and Stacey, 1988; Baird *et al*., 1992; Hoelzel *et al*. 1998). Three of the four types found in California waters (the so-called 'resident', 'transient', and 'offshore' types) were first identified and characterized in the eastern North Pacific. The fourth (the "LA pod") has only been recorded off southern and central California and off Baja California, Mexico. The killer whale is not federally listed as threatened or endangered; however, the Eastern North Pacific Southern Resident stock of killer whales, found primarily in the Pacific Northwest but occasionally seen off California, was listed as "depleted" under the Marine Mammal Protection Act in May 2003 and was designated as "endangered" by the State of Washington in April 2004. Furthermore, in November 2001, this stock of killer whale was listed as endangered by Canada's Committee on the Status of Endangered Wildlife in Canada (COSEWIC).

Resident-type killer whales have primarily been sighted from the Aleutian Islands south to Puget Sound, although there have been sightings of members of two resident pods as far south as Monterey Bay (N. Black, pers. comm.; Carretta *et al*., 2002). No sightings of this type have been recorded in southern California. The most recent estimate of the size of the resident killer whale population in southern British Columbia, Canada through central California based on direct counts of identified individuals is 82 individuals (Carretta *et al*., 2002).

Transient-type whales are unpredictable in their seasonal movements and travel throughout an extensive range with some individuals recorded in both central California and Southeast Alaska (Goley and Straley, 1994). Transients are the most frequently spotted type of killer whale off of central California (Black *et al*., 1997). They specialize on hunting marine mammals including seals and sea lions as well as large whales (such as gray whales) and their calves during seasonal whale migrations. The most recent estimate of the size of the Eastern North Pacific Transient stock of killer whales is a minimum of 346 individuals (Angliss and Lodge, 2002), of which 105 individuals have been identified in California (Black *et al*., 1997).

Offshore-type killer whales, first identified as a separate group off western Vancouver Island, Canada in the 1980's, are less well studied than residents and transients. The first offshore-type individuals in California were identified from photos taken in 1993 off of Point Conception, however, they may have been present in this area since the mid-1980s (Black *et al*., 1997). More recently, this type has been documented off Los Angeles and in Monterey Bay (Black *et al*., 1997). The offshore-type travels in larger groups, is more vocal than transient-types, and has not been observed feeding on marine mammals. The most recent estimate of the size of the offshore-type killer whale population in Washington, Oregon, and California based on the 1991-1996 SWFSC ship surveys is 285 individuals (Carretta *et al*., 2002). This is considered a conservative estimate.

The "LA Pod," named for the location where they were commonly observed during the 1980s, appears to be a distinct type that occurs primarily off Baja California, Mexico, but occasionally found off southern or central California. Members of this group were first photographed in 1982 and have been spotted from about San Francisco south to the Sea of Cortez, Mexico. They have never been observed feeding on marine mammals (Black *et al*., 1997).

Few sightings of killer whales were recorded in the SWFSC ship surveys and the CDAS surveys (Figure 6.1.14). Scattered sightings occur along the shelf and slope (with a few offshore sightings) north of Point Conception. Only two sightings exist in the Southern California Bight, one near Santa Barbara and one off San Diego. Because of the uneven distribution of survey effort, the pattern of sightings should be used only as confirmation that killer whales do exist in the broad area surveyed; the absence of sightings may reflect insufficient survey effort rather than real absence from the area.

Because so little distributional information or survey sightings exist for killer whales in the Study Area, it is difficult to evaluate the potential impacts of different boundary concepts. Concepts that have the potential to protect killer whales' prey species, including marine mammals such as gray whales and pinnipeds, as well as a variety of fish and cephalopod species, may provide indirect benefits to killer whales as well.

Pacific white-sided dolphin (*Lagenorhynchus obliquidens*)

Pacific white-sided dolphins are found throughout the temperate waters of the North Pacific, with most sightings in California waters occurring over the shelf and slope. Two forms of this species occur off California: a northern form ranging from the Southern California Bight north to Alaska, and a southern form found from Baja California, Mexico north to approximately 36°N (Carretta *et al*., 2002). Although both forms are found in the Southern California Bight, genetic (Lux *et al*., 1997) and morphological (Walker *et al*., 1986; Chivers *et al*., 1993) differences indicate little mixing. They are treated as one stock for management purposes, because the two forms are indistinguishable in the field. Seasonal and interannual movements along the U.S. West Coast have been documented, with greater numbers of Pacific white-sided dolphins found in California waters during cool-water periods, such as the winter months (Green *et al*., 1992; Forney, 1994). Within California, the abundance of Pacific white-sided dolphins can vary seasonally by an order of magnitude, and they are considerably more common in the Southern California Bight during winter (Forney and Barlow, 1998). The most recent stock assessment (Carretta *et al*., 2002) estimates a population size of 25,825 individuals along the U.S. west coast, based on the 1991-1996 SWFSC ship surveys. Pacific white-sided dolphin is not listed as a threatened or endangered species.

Pacific white-sided dolphins were frequently sighted during the CDAS surveys and occasionally recorded during the SWFSC ship surveys (Figure 6.1.15). Many sightings occurred along the shelf and slope (with a few offshore sightings) throughout central and southern California. Sightings were also scattered throughout the Southern California Bight. Relatively few sightings of this species were recorded during the SWFSC ship surveys because of the previously mentioned seasonal changes in abundance. Because of the uneven distribution of survey effort, the pattern of sightings should be used only as confirmation that Pacific white-sided dolphins do exist in a given area; the absence of sightings may reflect insufficient survey effort rather than real absence from the area. Quantitative comparison of the different boundary concepts was not possible for Pacific white-sided dolphins due to the lack of adequate numbers of sightings in the summer/fall SWFSC ship surveys.

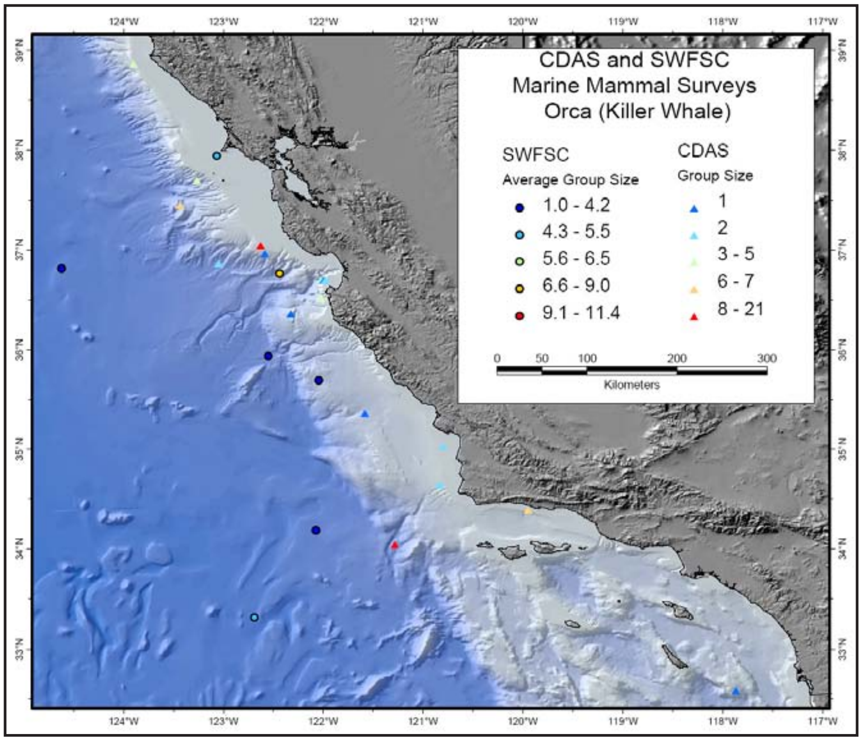

Figure 6.1.14. Killer whale. Sightings and group size (where available) from the Southwest Fisheries Science Center (SWFSC) ship surveys 1991-2001 and the seven surveys of marine mammals compiled in the Computer Database Analysis System (CDAS) v2.1, 1975-1997.

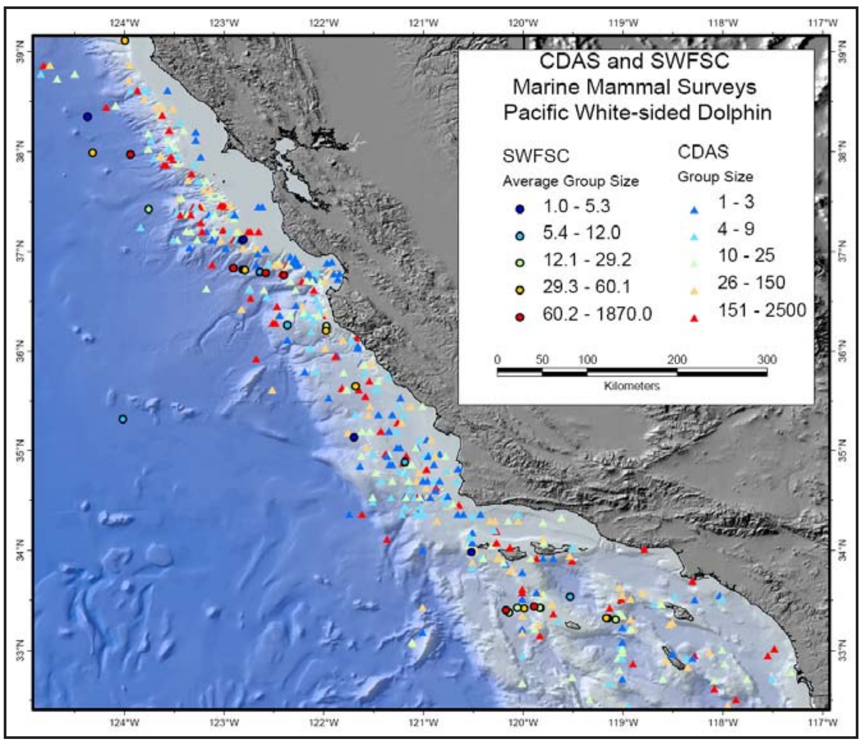

Figure 6.1.15. Pacific white-sided dolphin. Sightings and group size (where available) from the Southwest Fisheries Science Center (SWFSC) ship surveys 1991-2001 and the seven surveys of marine mammals compiled in the Computer Database Analysis System (CDAS) v2.1, 1975-1997.

Risso's dolphin (*Grampus griseus*)

Within U.S. Pacific waters, Risso's dolphin are divided into two stocks, a Hawaiian stock, and a California/Oregon/Washington stock. Green *et al*. (1992) suggest that Risso's dolphin in California move northward into Oregon and Washington in late spring and summer. The southern end of this stock's range appears to occur somewhere along the coast of Baja California, Mexico, with a large gap between this stock and Risso's dolphins found in equatorial waters. Although Risso's dolphin are generally found in slope and offshore waters in Washington, Oregon, and northern California, they are also found in large numbers in shelf waters off southern and central California (Carretta *et al*., 2002). The most recent abundance estimate for the California/Oregon/Washington stock, based on data from the 1991-1996 SWFSC ship surveys (Barlow, 1997), is 16,483 individuals (Carretta *et al*., 2002). The distribution of Risso's dolphin is highly variable, however, and seasonal and interannual shifts are common

(Forney and Barlow, 1998). Risso's dolphin is not considered a threatened or endangered species.

Risso's dolphins were frequently sighted during the SWFSC ship surveys and the CDAS surveys (Figure 6.1.16). Many sightings occur along the shelf and slope (with a few offshore sightings) throughout central and southern California. Sightings are also scattered throughout the Southern California Bight with clusters of sightings at both the western and eastern ends of the Santa Barbara Channel, but relatively few in the Santa Barbara Channel itself. Because of the uneven distribution of survey effort, the pattern of sightings should be used only as confirmation that Risso's dolphins do exist in a given area. The absence of sightings may reflect insufficient survey effort rather real absence from the area.

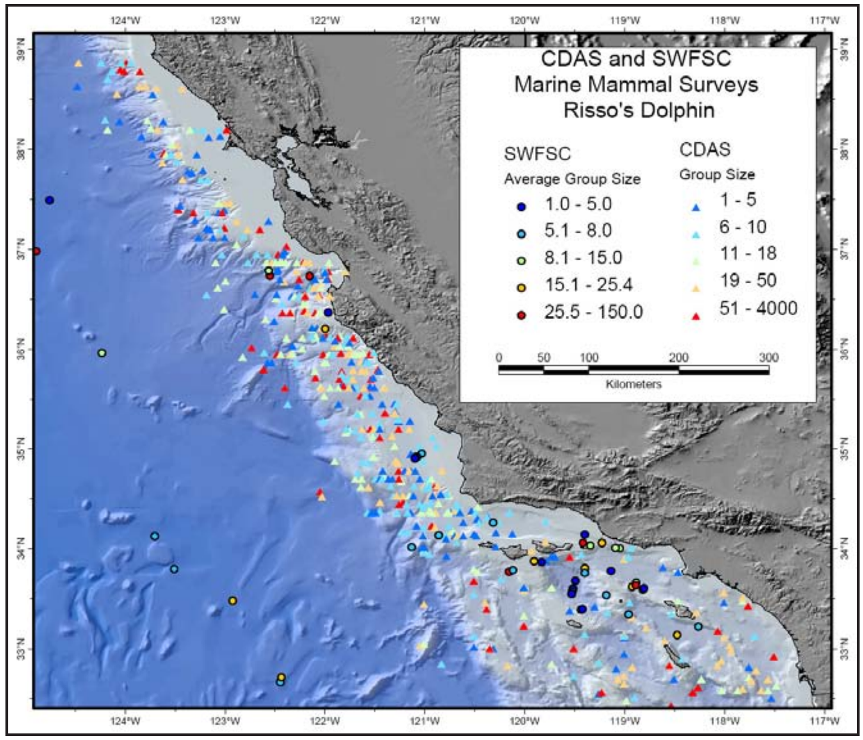

Figure 6.1.16. Risso's dolphin. Sightings and group size (where available) from the Southwest Fisheries Science Center (SWFSC) ship surveys 1991-2001 and the seven surveys of marine mammals compiled in the Computer Database Analysis System (CDAS) v2.1, 1975-1997.

Estimates of the summer and fall abundance of Risso's dolphin within the NAC, the five boundary concepts, and the Study Area were derived from the 1991-2001 SWFSC ship surveys described above and are summarized in Table 6.1.8. Because of the relatively small number of on-effort sightings (4-21) and the uncertainty in the line transect input parameters, confidence intervals for the abundance estimates are wide and overlap substantially among different concepts. The wide intervals show that abundance cannot be estimated precisely, and the overlap indicates that the differences in estimated abundance among concepts are not likely to be statistically significant. Estimated Risso's dolphin density is highest in Concept 3, and estimated abundance is highest in Concept 1 and the Study Area. Notable increases in estimated abundance relative to that of the NAC are apparent with each increase in concept size, with the exception of Concept 5, which shows only a 7% increase. Estimated abundance in Concept 4, for example, is more than twice as great as in the NAC, and the next largest boundary, Concept 3, has an estimated abundance approximately three times higher than the NAC. The OAI shows that, of the proposed boundary concepts, Concept 3 provides the greatest relative increase in both density and abundance for the smallest relative increase in area. Overall, the OAI is highest for the Study Area.

Table 6.1.8. Risso's dolphin. Sightings, estimated density and abundance, coefficient of variation (CV) and upper and lower 95% confidence limits for the abundance estimate; and the Optimal Area Index (OAI) for the six boundary concepts, the No Action Concept (NAC), and the Study Area (SA). Abundance and density values in bold reflect increases from the NAC and shaded OAI values represent maximum observed benefit.

Concept	Area (km^2)	Sightings	Estimated Density	Estimated Abundance	CV	Lower 95% CI	Upper 95% CI	Δ Area (%)	Δ Density (%)	Δ Abundance (%)	Density OAI (relative)	AbundanceOAI (absolute)
NAC	3745	4	0.12831	481	0.54	178	1296	-	-	-	-	-
5	4536	4	0.11313	**513**	0.54	190	1383	21.12	-11.83	6.65	-0.56	0.315
4	7981	**10**	**0.12535**	**1000**	0.46	424	2360	113.11	-2.31	107.90	-0.02	0.954
3	9044	**12**	**0.16215**	**1466**	0.46	621	3460	141.50	26.37	207.78	0.186	1.447
2	13736	**13**	**0.13464**	**1849**	0.44	811	4217	266.78	4.93	284.41	0.018	1.066
1a	22591	**21**	**0.12975**	**2931**	0.45	1263	6801	503.23	1.12	509.39	0.002	1.012
1	22613	**21**	**0.12975**	**2934**	0.45	1265	6808	503.82	1.12	509.98	0.002	1.012
SA	*17093*	*21*	*0.1788*	*3056*	*0.42*	*1387*	*6734*	*356.42*	*39.33*	*535.34*	*0.11*	*1.502*

Additional Cetaceans

In addition to the requested species, several other species of cetaceans are known to occur within the region, including Dall's porpoise, fin whale, harbor porpoise, minke whale, and northern right-whale dolphins. Although no quantitative analysis was conducted for these species, it is important to recognize that they may be impacted by changes to the boundaries of the CINMS and further investigation into these species may be warranted. While a complete analysis of the biogeography of these additional species is beyond the scope of this project, distribution maps and a brief discussion for each of these species is included here. Several species of beaked whales have also been recorded in the Study Area; however, little is known about the distribution of these poorly studied cetaceans.

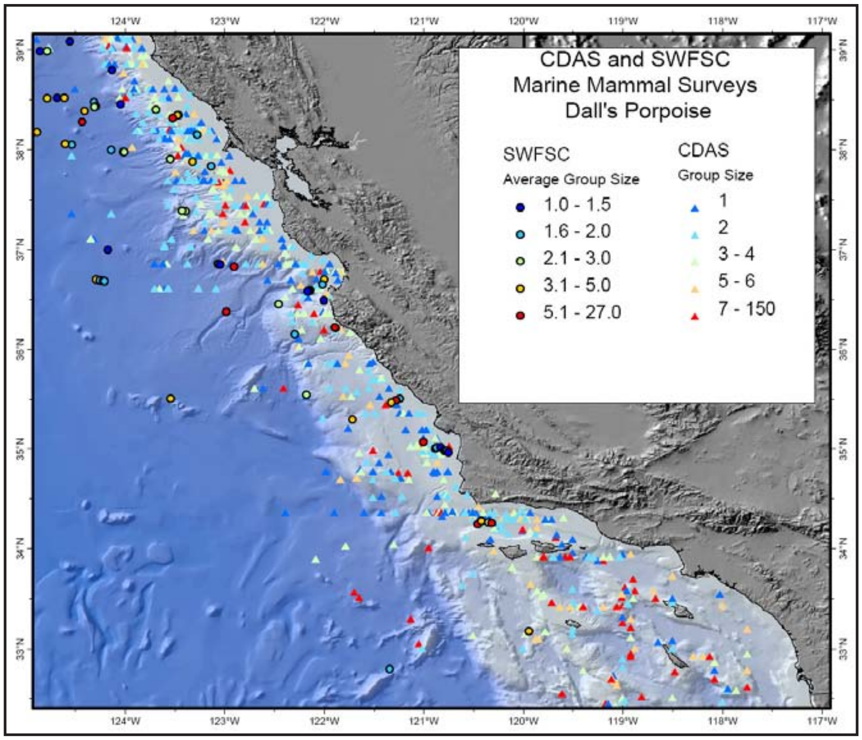

Figure 6.1.17. Dall's porpoise. Sightings and group size (where available) from the Southwest Fisheries Science Center (SWFSC) ship surveys 1991-2001 and the seven surveys of marine mammals compiled in the Computer Database Analysis System (CDAS) v2.1, 1975-1997.

Dall's porpoise (*Phocoenoides dalli*)

Dall's porpoise are found throughout the temperate shelf, slope, and offshore waters of the U.S. West Coast where they exhibit seasonal and interannual movements that appear to be related to changes in oceanographic conditions (Forney *et al*., 1995). They are most abundant off southern California in the winter. The California/Oregon/Washington stock size was estimated in the most recent stock assessment report (Carretta *et al*., 2002) at 116,016 individuals based on the 1991-1996 SWFSC ship surveys (Barlow 1997), with an estimated 1,500 additional individuals in Washington inland waters (Calambokidis *et al*., 1997). Dall's porpoise is not a federally listed endangered or threatened species.

Dall's porpoise were commonly sighted in shelf waters throughout central and southern California during the SWFSC ship surveys and the CDAS surveys (Figure 6.1.17). Many sightings were recorded in the Santa Barbara Channel, off Point Conception, and just south of Santa Cruz and Anacapa Islands. Because of the uneven distribution of survey effort, the pattern of sightings should be used only as confirmation that Dall's porpoise do exist in a given area; the absence of sightings may reflect insufficient survey effort rather than real absence from the area. Larger concepts are likely to encompass greater numbers of this widely distributed cetacean.

Fin whale (*Balaenoptera physalus*)

Although three fin whale stocks are recognized in U.S. North Pacific waters, little is known about the population structure of this species. Year round aggregations of fin whales have been recorded in central and southern California with lower abundance in California waters during the winter and spring (Dohl *et al*., 1983; Forney *et al*., 1995). The California/Oregon/Washington stock size was estimated in the most recent stock assessment report (Carretta *et al*., 2002) at 1,851 individuals based on the 1993 and1996 SWFSC ship surveys (Barlow and Taylor, 2001); however, this is thought to be a slight underestimate because not all fin whales could be identified to species in the field. Fin whale is a federally listed endangered species.

Fin whales have been sighted in shelf, slope, and offshore waters throughout central and southern California during the SWFSC ship surveys and the CDAS surveys (Figure 6.1.18). Within the Southern California Bight only one sighting was recorded in the Santa Barbara Channel and scattered sightings occurred to the south of the CINMS. Because of the uneven distribution of survey effort, the pattern of sightings should be used only as confirmation that fin whale do exist in a given area; the absence of sightings may reflect insufficient survey effort rather than real absence from the area. Concepts 1, 1a, and 2 encompass a cluster of sightings on the shelf waters to the northwest of the CINMS, with Concepts 1 and 1a encompassing several additional sightings in slope and offshore waters.

Harbor porpoise (*Phocoena phocoena*)
Along the west coast of the U.S., harbor porpoise are found in coastal waters from Alaska south to Point Conception. Harbor porpoise on the tend to form geographically and genetically distinct sub-populations with little mixing or movement among them (Chivers *et al*., 2002). A Morro Bay stock of harbor porpoise is one of four stocks identified in California waters by the most recent stock assessment report (Carretta *et al*., 2002). The Morro Bay stock ranges from about Point Sur to Point Conception, although the northern boundary which divides the Morro Bay stock from the Monterey Bay stock is uncertain because of a lack of genetic samples in this region. The most recent estimate of the size of the Morro Bay stock based on a 1997-1999 aerial survey is 932 individuals (Carretta *et al*., 2002). Harbor porpoise is not federally listed as threatened or endangered.

Harbor porpoise were commonly sighted in nearshore and shelf waters north of Point Conception during the SWFSC ship surveys and the CDAS surveys (Figure 6.1.19). Because of the uneven distribution of survey effort, the pattern of sightings should be used only as confirmation that harbor porpoise do exist in a given area; the absence of sightings may reflect insufficient survey effort rather than real absence from the area. Concepts 1, 1a, and 2 (and a small portion of Concept 3) as well as the Study Area, extend north of Point Conception and may include an unknown number of individuals from the Morro Bay stock.

Minke whale (*Balaenoptera acutorostrata*)
Two minke whale stocks are recognized in U.S. North Pacific waters, an Alaskan stock that is believed to be migratory, and a California/Oregon/Washington stock. In California, minke whales are present year-round (Dohl *et al*., 1983; Forney *et al*., 1995; Barlow, 1997) and some individuals are thought to establish home ranges (Dorsey *et al*., 1990). The California/Oregon/Washington stock size was estimated in the most recent stock assessment report (Carretta *et al*., 2002) at 631 individuals based on the 1991-1996 SWFSC ship surveys (Barlow 1997). Minke whale is not federally listed as threatened or endangered.

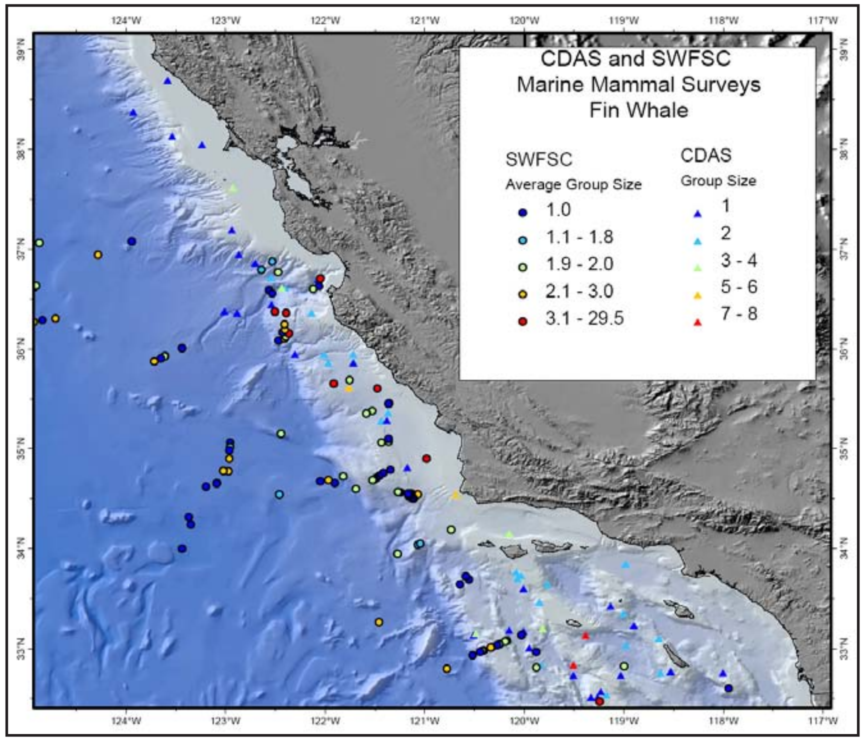

Figure 6.1.18. Fin whale. Sightings and group size (where available) from the Southwest Fisheries Science Center (SWFSC) ship surveys 1991-2001 and the seven surveys of marine mammals compiled in the Computer Database Analysis System (CDAS) v2.1, 1975-1997.

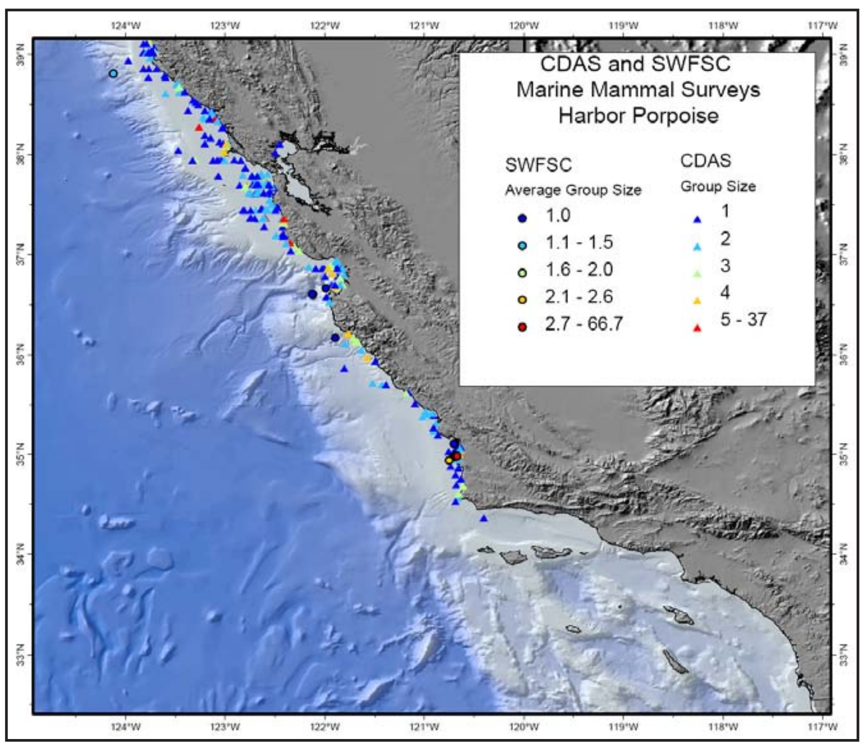

Figure 6.1.19. Harbor porpoise. Sightings and group size (where available) from the Southwest Fisheries Science Center (SWFSC) ship surveys 1991-2001 and the seven surveys of marine mammals compiled in the Computer Database Analysis System (CDAS) v2.1, 1975-1997.

Although scattered sightings of minke whales have been recorded in shelf, slope, and offshore waters off central California during the SWFSC ship surveys and the CDAS surveys (Figure 6.1.20), the bulk of sightings from the CDAS surveys occurred in the Southern California Bight, with a cluster of sightings around the northern Channel Islands. Because of the uneven distribution of survey effort, the pattern of sightings should be used only as confirmation that minke whales do exist in a given area; the absence of sightings may reflect insufficient survey effort rather than real absence from the area. The cluster of sightings around the northern Channel Islands is encompassed by all of the concepts including the NAC. Concepts that extend to the south and connect the northern Channel Islands to Santa Barbara Island appear likely to encompass more minke whales.

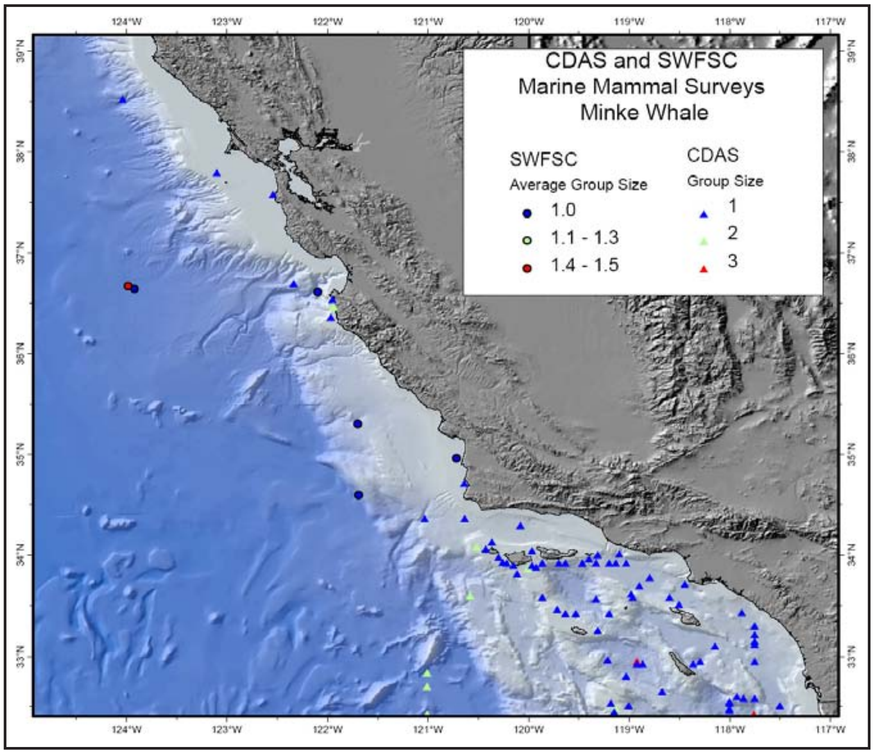

Figure 6.1.20. Minke whale. Sightings and group size (where available) from the Southwest Fisheries Science Center (SWFSC) ship surveys 1991-2001 and the seven surveys of marine mammals compiled in the Computer Database Analysis System (CDAS) v2.1, 1975-1997.

Northern right-whale dolphin (*Lissodelphis borealis*)

Along the west coast of the U.S., northern right-whale dolphins are found primarily in temperate shelf and slope waters. Abundance of this species in California waters is greatest during cold-water months (Forney *et al*., 1995), and they are thought to range south to Baja California, Mexico during cold periods. Northern right-whale dolphins in U.S. west coast waters are considered a single California/Oregon/Washington stock due to insufficient genetic evidence of subpopulations (Dizon *et al*., 1994). The size of this stock was estimated in the most recent stock assessment report (Carretta *et al*., 2002) at 13,705 individuals based on the 1991-1996 SWFSC ship surveys (Barlow 1997). Northern right whale dolphin is not considered threatened or endangered.

Northern right-whale dolphins were frequently sighted in shelf and slope waters throughout central and southern California during the SWFSC ship surveys and the CDAS surveys (Figure 6.1.21). Although sightings are recorded throughout the Southern California Bight, relatively few were recorded in the Santa Barbara Channel. Because of the uneven distribution of survey effort, the pattern of sightings should be used only as confirmation that northern right-whale dolphins do exist in a given area; the absence of sightings may reflect insufficient survey effort rather than real absence from the area. Concepts 1 and 1a, and, to a lesser extent Concept 2, encompass a cluster of sightings along the shelf and slope which are not encompassed by any of the smaller concepts.

Summary

• Marine mammal distributions within the region exhibit pronounced geographical heterogeneity with the consequence that the impact of extending the CINMS boundaries will vary depending on the specific areas added to the sanctuary. In general,

- Concepts that include the mainland will increase coastal bottlenose dolphin and both species of common dolphin sightings.
- Concepts that extend offshore will include a greater number of blue, fin, and humpback whales.
- Concepts that include waters between the northern Channel Islands and Santa Barbara Island added sightings for northern right-whale dolphins, offshore bottlenose dolphins, and Risso's dolphin.
- Concepts that extend north of Point Conception would add harbor porpoise and increase the abundance

of temperate cetacean species, such as Pacific white-sided dolphin and Dall's porpoise.

• Of those species for which abundance could be estimated (blue whale, bottlenose dolphin, long-beaked and short-beaked common dolphin, humpback whale, and Risso's dolphin), Concepts 1 and 1a provide the greatest estimated abundance within their boundaries, though density is often higher in the smaller concepts. This could be a sampling artifact, or indicate that the smaller areas contain a greater proportion of appropriate habitat for these species.

• Although their populations could not be estimated quantitatively, killer whales and gray whales are known to use the waters around and within the CINMS as feeding and migratory habitat, respectively.

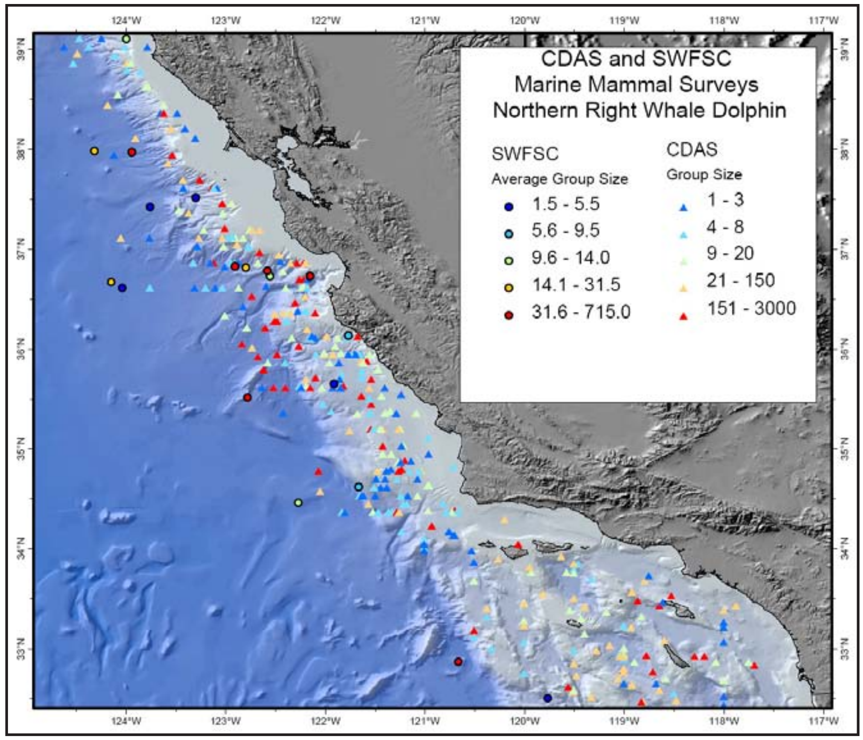

Figure 6.1.21. Northern right-whale dolphin. Sightings and group size (where available) from the Southwest Fisheries Science Center (SWFSC) ship surveys 1991-2001 and the seven surveys of marine mammals compiled in the Computer Database Analysis System (CDAS) v2.1, 1975-1997.

• The abundance estimates presented here are intended as approximate guidelines only, because the surveys on which they are based were designed for other purposes and, therefore, do not provide data at the most appropriate temporal and spatial scales for an examination of boundary concepts. Furthermore, while the abundances presented here may be considered estimates of the average number of animals that may be found, in fact, it is likely that considerably larger aggregations may occur at times, particularly for feeding blue and humpback whales. This is true as well for dolphins that occur in groups of hundreds or thousands, or are known to exhibit large seasonal and interannual changes in distribution.

6.2 PINNIPEDS AND SOUTHERN SEA OTTER

(Portions of this section are reprinted with permission from McGinnis (2000)).

Pinnipedia (seals, sea lions and fur seals)

Historically, six species of pinnipeds have occurred in the region of interest. These include four members of the family Otaridae and two representatives of the family Phocidae. In addition, a single sighting of one more phocid species has been reported in southern California. Two of the six species are listed as threatened under the Endangered Species Act (ESA).

Of the four otarid seals, the California sea lion (*Zalophus californianus c.*) is unquestionably the most abundant (Barlow *et al*., 1997). The Steller sea lion (*Eumetopias jubatus*) had two rookeries on San Miguel Island, but these rookeries have not been occupied since the 1982-1983 El Niño. The Steller sea lion is listed as threatened under the ESA. The northern fur seal (*Callorhinus ursinus*) has two rookeries on San Miguel Island. The Guadalupe fur seal (*Arctocephalus townsendi*) has been reported on San Nicolas and San Miguel Islands in very small numbers, usually from one to three individuals. A few strandings have occurred along the mainland coast (Hanni *et al*. 1997; Santa Barbara Marine Mammal Center, unpublished records). The Guadalupe fur seal is listed as threatened under the ESA.

Of the two species of phocid seals, the northern elephant seal (*Mirounga angustirostris*) is by far the most common, with rookeries at San Miguel, Santa Rosa, San Nicolas, and Santa Barbara Islands (Barlow *et al*., 1997). The Pacific harbor seal (*Phoca vitulina richardsi*) is common throughout the region, with numerous haulout and rookery sites throughout the Channel Islands and along the mainland coast (Barlow *et al*., 1997). The ribbon seal (*Histriophoca fasciata*), an Arctic species, is rare in California (Woodhouse, 2000).

Carnivora

The southern sea otter (*Enhydra lutris nereis*), a member of the mustelid family (which includes weasels), is the only marine representative of the order Carnivora. The southern sea otter is listed as threatened under the ESA. It has undergone drastic population changes, from an estimated pre-exploitation population of 16,000 individuals in California (Laidre *et al*., 2001), to near extinction in the early 1900s, to a current California population of around 2,300 individuals. The current population in the Channel Islands is considered an experimental population and investigations are currently underway to determine whether the translocation project at San Nicolas Island has been successful (USFWS, 2003).

Data and Methods

Surveys used in this chapter are summarized in Table 6.2.1. Counts of the four consistently sighted pinnipeds are presented for rookery and haulout sites in the Channel Islands and the Southern California mainland. At-sea distributions of pinnipeds and sea otter are difficult to estimate because they are not reliably sampled by the available at-sea visual surveys which mainly target either birds or cetaceans. At-sea distributions of pinnipeds have been estimated in previous biogeographic assessments, but at a scale (10 minutes of latitude by 10 minutes of longitude) that limits their usefulness for the current assessment of CINMS boundary concepts. The lack of at-sea distribution data means that conclusions in this section of the report reflect the distribution of haulout and rookery areas only. The waters nearest the high use rookery and haulout areas are clearly important, but pinnipeds also forage far from these sites. Sea otters are more closely associated with nearshore habitats, but are known to migrate considerable distances (Wendell *et al*., 1984).

California sea lion (*Zalophus californianus californianus*)

Sea lion data presented in this section are derived from aerial photo surveys conducted by the Southwest Fisheries Science Center (SWFSC) from 2001-2003. The surveys are conducted in July to coincide with the end of the pupping season and include all major rookeries and haulout sites. These survey results form the basis of SWFSC's stock assessment of California sea lion (Carretta *et al*., 2002). Counts at each location are total number of individuals (all sex and age categories) and total pups. Sightings should be considered minimum estimates of overall numbers since an unknown fraction of the population is at sea at any given time, and some pups may have already left the rookery. Data are georeferenced by beach codes which correspond to shoreline segments of varying length.

Pacific harbor seal (*Phoca vitulina richardsi*)

Harbor seal data presented in this section are comprised of a SWFSC aerial photo survey and an aerial photo and ground survey conducted by the California Department of Fish and Game (CDFG). Despite the fact that the two surveys occurred during the same time period, late May through mid-June 2002, counts for the Channel Islands differed by more than a factor of 2 between the two surveys, with 1,735 harbor seals counted at 61 sites

Table 6.2.1. Summary of pinniped and sea otter surveys used in this chapter.

Survey	Dates	Platform	Months	Location	Total Unique Survey Sites	Total Individuals
NOAA, Southwest Fisheries Science Center, California Sea Lion Survey	2001-2003	Aerial Photo	July	Channel Islands (8 islands)	127	230788
NOAA, Southwest Fisheries Science Center, Harbor Seal Survey	2002	Aerial Photo	May-June	California Coast (south of Pt. Sal and Channel Islands	160	5271
California Dept. of Fish and Game, Harbor Seal Survey	2002	Aerial Photo/ Grount	May-July	Californa Coast and Channel Islands	NA	18784
NOAA, Southwest Fisheries Science Center, Northern Elephant Seal Survey	1998, 2000-2001	Aerial Photo	January-February	Channel Islands (5 islands)	121	116548
Sea Otter Survey (Multi-agency	2001-2002	Aerial Photo/ Ground	November and May	California Coast (Pt. Montara to Santa Barbara)	Fall-1150 Spring-1061	Fall-2012 Spring-2139

in the CDFG survey and 3,878 counted at 144 sites in the SWFSC survey. Sweetnam and Read (2002) attribute the differences to the time of day and tidal state. Results from both surveys are presented to give an idea of intra-annual variability and population estimate uncertainty. Both surveys are georeferenced by a single latitude and longitude point for each site.

Northern elephant seal (*Mirounga angustirostris*)

Elephant seal survey data are extracted from an aerial photo survey (with the exception of San Clemente Island which was surveyed on the ground) of rookeries conducted by SWFSC in January and February 2001. Data are presented as the total number of individuals (all sex and age categories) and total number of pups (including live and dead pups). Stock assessments for elephant seals derive estimated population size by multiplying total pups counted at rookeries by the ratio of total individuals to pups because all age classes are not ashore at the same time (Carretta *et al*., 2002). Data are georeferenced by beach codes as for California sea lion (see above).

Northern fur seal (*Callorhinus ursinus*)

No georeferenced northern fur seal rookery data were available for this report. Two separate stocks of northern fur seal are recognized in U.S. waters: an Eastern Pacific stock and a San Miguel Island stock (Carretta *et al*., 2002). The San Miguel Island stock was established in the late 1950s or early 1960s (DeLong, 1982) and has generally increased since the first live pup counts in 1972. El Niño events are associated with both adult female and pup mortality and have had dramatic impacts on the population in 1982-1983 and 1997-1998. The most recent assessment of the San Miguel Island stock (2002 survey) estimates the population size at 7,784 individuals, and suggests continued rebuilding of the stock since the 1997-1998 El Niño event. Beginning in 1996, fur seals re-established a small breeding population on the South Farallon Islands, with fewer than 10 pups produced each year from 1997-2001 (Pyle *et al*. 2001).

Southern sea otter (*Enhydra lutris nereis*)

Sea otter data presented in this section are gathered from land-based surveys conducted by CDFG, USGS-Biological Resources Division, and the Monterey Bay Aquarium in November 2001 and May 2002. Sightings are georeferenced by 500 m shoreline segment, and were summarized by 20 km shoreline segment for clearer display.

Broad-scale Patterns and Analysis of Boundary Concepts

California sea lion

In order to account for interannual differences in survey effort (*i.e*., not all beach areas were surveyed in all years) and beach use, summary maps depict maximum recent usage calculated as the maximum number of individuals or pups counted at a beach area in the three most recent surveys. Although California sea lions do frequently haul out on man made objects such as barges and piers on the mainland, there are no known natural haulout areas or rookeries on the mainland (M. Lowry, pers. comm.).

Major haulout areas (top two quintiles, 620-12,760 individuals at maximum recent use) for California sea lions exist on East Anacapa, San Clemente, San Miguel, San Nicolas, and Santa Barbara Islands (Figure 6.2.1). Additional less populated haulout areas (less than 578 individuals at maximum recent use) exist on Santa Catalina and Santa Rosa Islands, and on Gull Island near Santa Cruz Island.

Major rookery areas (top two quintiles, 451-6,668 pups at maximum recent usage) exist on San Clemente, San Miguel, San Nicolas, and Santa Barbara Islands (Figure 6.2.2). Additional less-populated rookery areas (less than 373 pups at maximum recent usage) exist on East Anacapa and on Gull Island near Santa Cruz Island. No sea lion pups were counted on Santa Catalina or Santa Rosa Islands. There are no differences among the boundary concepts in terms of the number of sea lion haulout or rookery sites encompassed. However, this data cannot account for differences which may exist in the at-sea abundance of California sea lions within the different concepts.

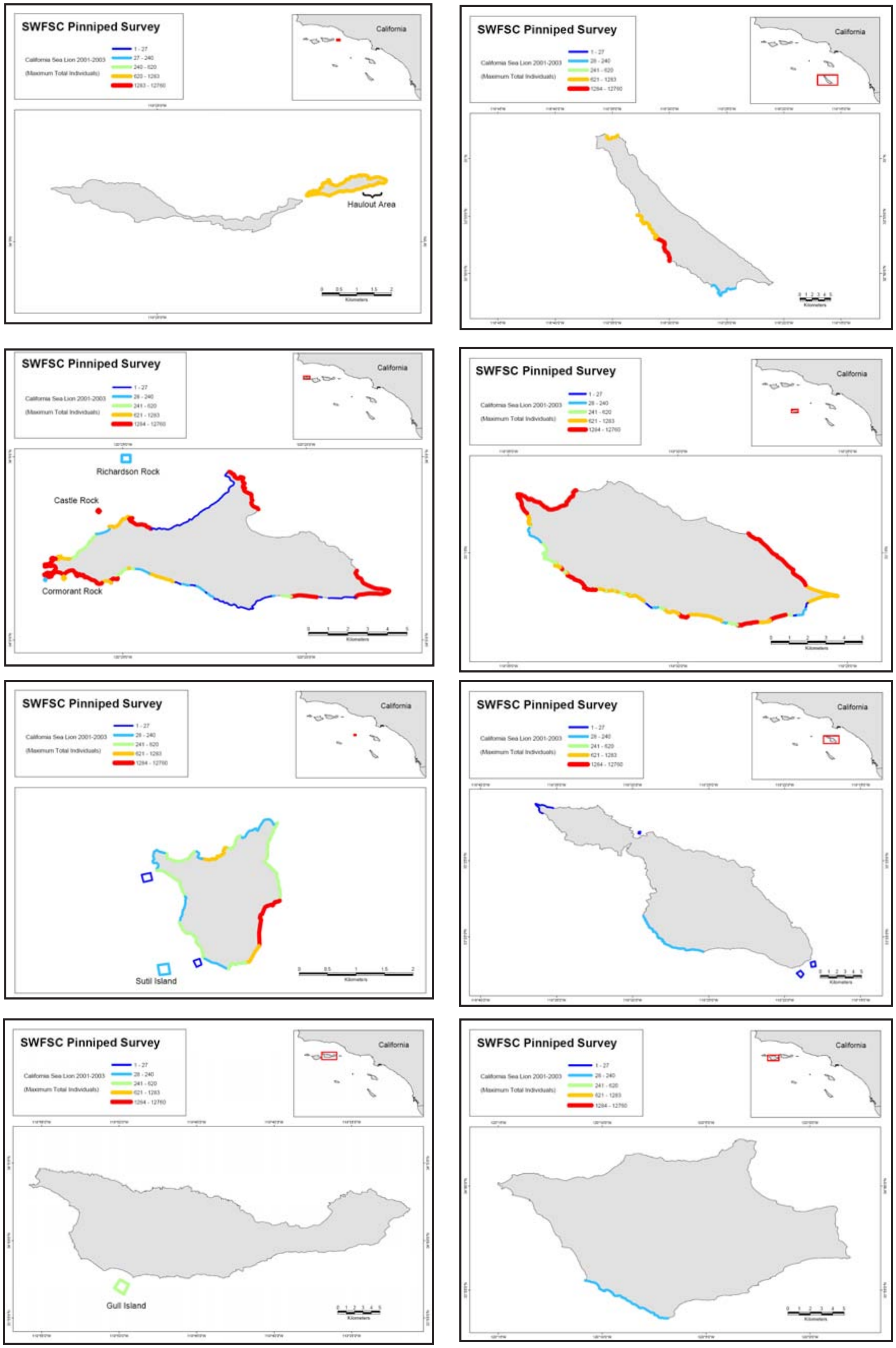

Figure 6.2.1. California sea lion. Maximum total individuals (greatest number of individuals of all sex and age classes counted for each beach area surveyed out of the three most recent SWFSC surveys 2001-2003) for (left to right) Anacapa, San Clemente, San Miguel, San Nicolas, Santa Barbara, Santa Catalina, Santa Cruz, and Santa Rosa Islands.

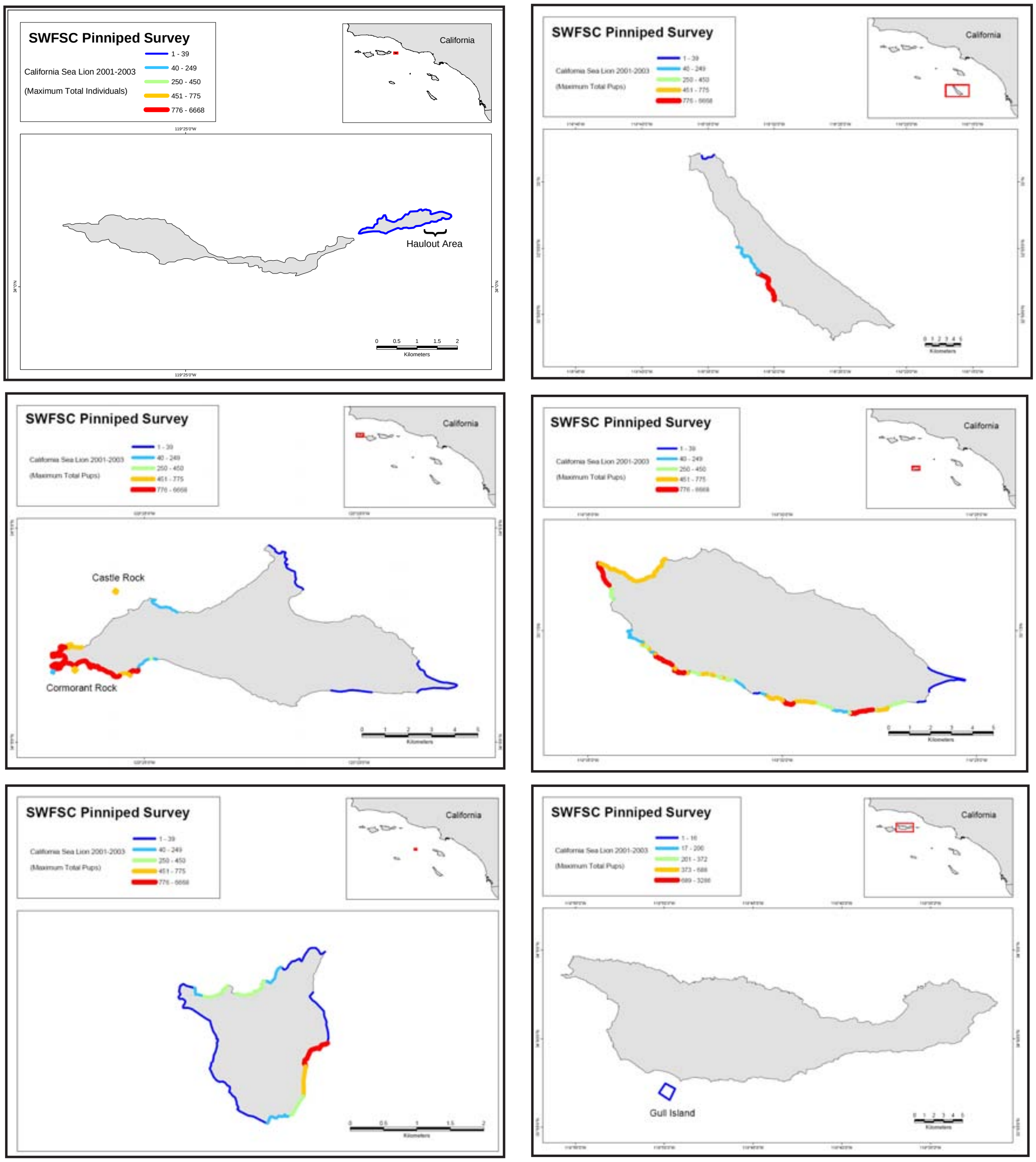

Figure 6.2.2. California sea lion. Maximum pups (greatest number of pups counted for each beach area surveyed out of the three most recent SWFSC surveys 2001-2003) for (left to right) Anacapa, San Clemente, San Miguel, San Nicolas, Santa Barbara, and Gull Islands.

Pacific harbor seal

Counts of Pacific harbor seals at haulout areas are shown for the SWFSC survey (Figure 6.2.3) and the CDFG survey (Figure 6.2.4). Overlap in coverage between flights in the CDFG survey resulted in some haulout areas being surveyed more than once. Therefore separate symbols are used to depict the different flights.

Major haulout areas (more than 20 individuals) for harbor seal exist on all of the Channel Islands other than Santa Barbara Island, which includes only one (CDFG survey) or two (SWFSC survey) haulout areas, each with fewer than 10 individuals. Other major haulout areas exist along the mainland coast near the Channel Islands, including notable sites at Point Conception, Point Arguello and Point Sal.

Many of the most populated harbor seal haulout areas are located on the northern Channel Islands within the current boundaries of the CINMS. A total of 56%, according to the SWFSC survey, or 33%, according to the CDFG survey of the harbor seal population south of Pt. Sal surveyed in 2002 is within the current CINMS boundaries. While Concepts 4 and 5 may offer greater potential protection for harbor seals at sea, these options do not include any additional haulout areas that are not currently within the sanctuary. Concept 3 encompasses the haulout area at Pt. Conception; Concept 2 further incorporates the haulout areas at Pts. Arguello, Purisima, and Sal, and one site just west of Santa Barbara; and Concept 1 includes all of these haulout areas, plus one additional site near Point Hueneme. The CDFG data shows an additional site located between Santa Barbara and Ventura that is included only in Concept 1. The OAI calculations (Table 6.2.2) convey that Concepts 2 (based on the SWFSC data) or 3 (based on CDFG data) offer the greatest relative increase in harbor seal abundance for the smallest relative increase in area.

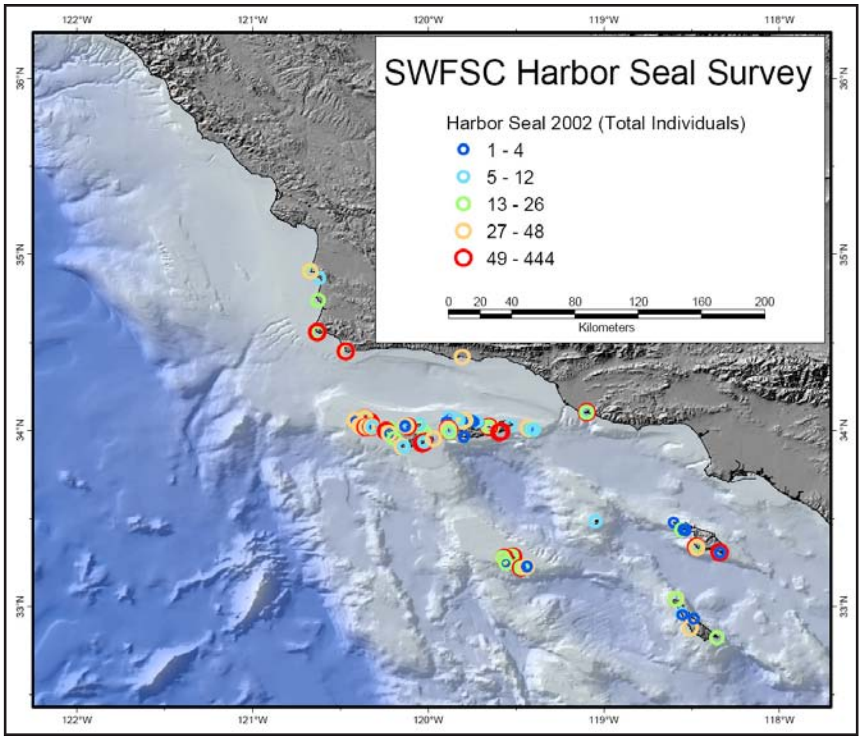

Figure 6.2.3. Pacific harbor seal. Total number of individuals counted (all sex and age classes) at each surveyed site for the 2002 SWFSC census.

Northern elephant seal

Northern elephant seal summary maps are presented in the same manner as those described for California sea lion, in that they depict maximum recent usage calculated as the maximum number of individuals or pups counted at a beach area out of the three most recent surveys. The haulout and rookery areas for northern elephant seal represent all known consistently used locations in southern California (M. Lowry, pers.comm.). The results of these surveys conducted since the early to mid 1980s (depending on the island) show that San Miguel Island is consistently the largest elephant seal rookery in the Southern California Bight (Lowry, 2002).

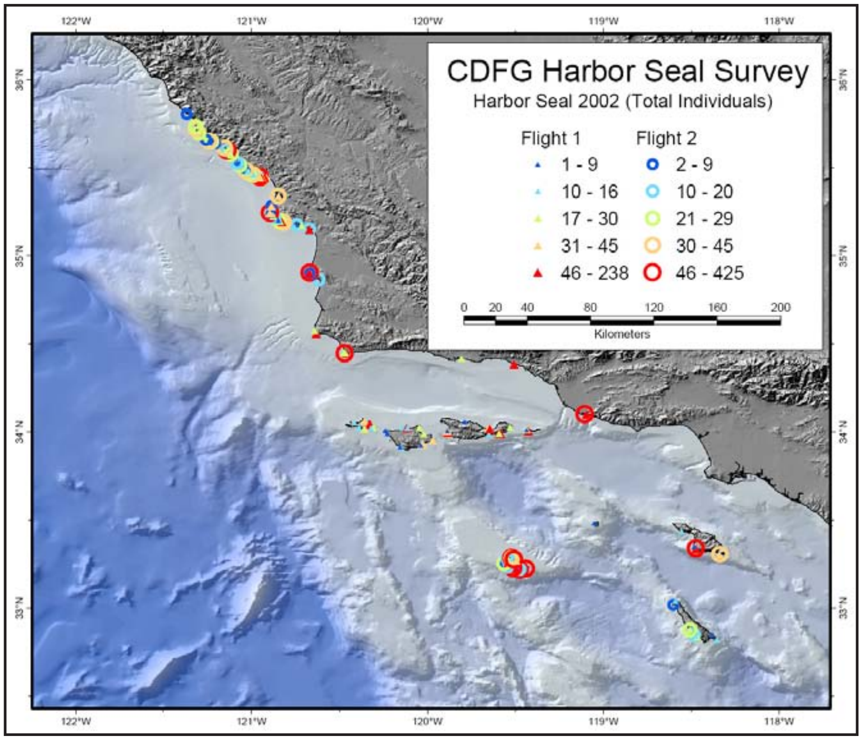

Figure 6.2.4. Pacific harbor seal. Total number of individuals counted (all sex and age classes) at each surveyed site for the 2002 CDFG census.

Major haulout areas (top two quintiles: 211-5,223 individuals at maximum recent use) for Northern elephant seal exist on San Miguel, San Nicolas, and Santa Rosa Islands (Figure 6.2.5). Additional less populated haulout areas (less than 211 individuals at maximum recent use) exist on Santa Barbara and San Clemente Islands.

Major rookery areas (top two quintiles: 148-2794 pups at maximum recent use) exist on San Miguel, San Nicolas, and Santa Rosa Islands (Figure 6.2.6). Additional less-populated rookery areas (less than 148 pups at maximum recent use) exist on Santa Barbara and San Clemente Islands.

There are no differences among the boundary concepts in terms of the number of elephant seal haulout or rookery sites encompassed. However, this data cannot account for differences which may exist in the at-sea abundance of northern elephant seal within the different concepts.

Table 6.2.2. Pacific harbor seal. Total number of individuals, total area, and Optimal Area Index (OAI) for each boundary concept for SWFSC and CDFG 2002 surveys. Abundance values in bold reflect increases from the NAC and shaded OAI values represent maximum observed benefit.

Concept	Area (km^2)	Total Individuals SWFSC	Total Individuals CDFG	Δ Individuals SWFSC (%)	Δ Individuals CDFG (%)	Δ Area (%)	OAI SWFSC	OAI CDFG
NAC	3745	2943	1361	-	-	-	-	
5	4536	2943	1361	0	0	21.12	0	0
4	7981	2943	1361	0	0	113.11	0	0
3	9044	**3431**	**1965**	16.58	44.38	141.50	0.12	0.31
2	13736	**3894**	**2263**	32.31	66.27	266.78	0.12	0.25
1a	22591	**4181**	**2897**	42.07	112.86	503.23	0.08	0.22
1	22613	**4181**	**2897**	42.07	112.86	503.82	0.08	0.22
SA	*17093*	*4181*	*2897*	*42.07*	*112.86*	356.42	*0.12*	*0.32*

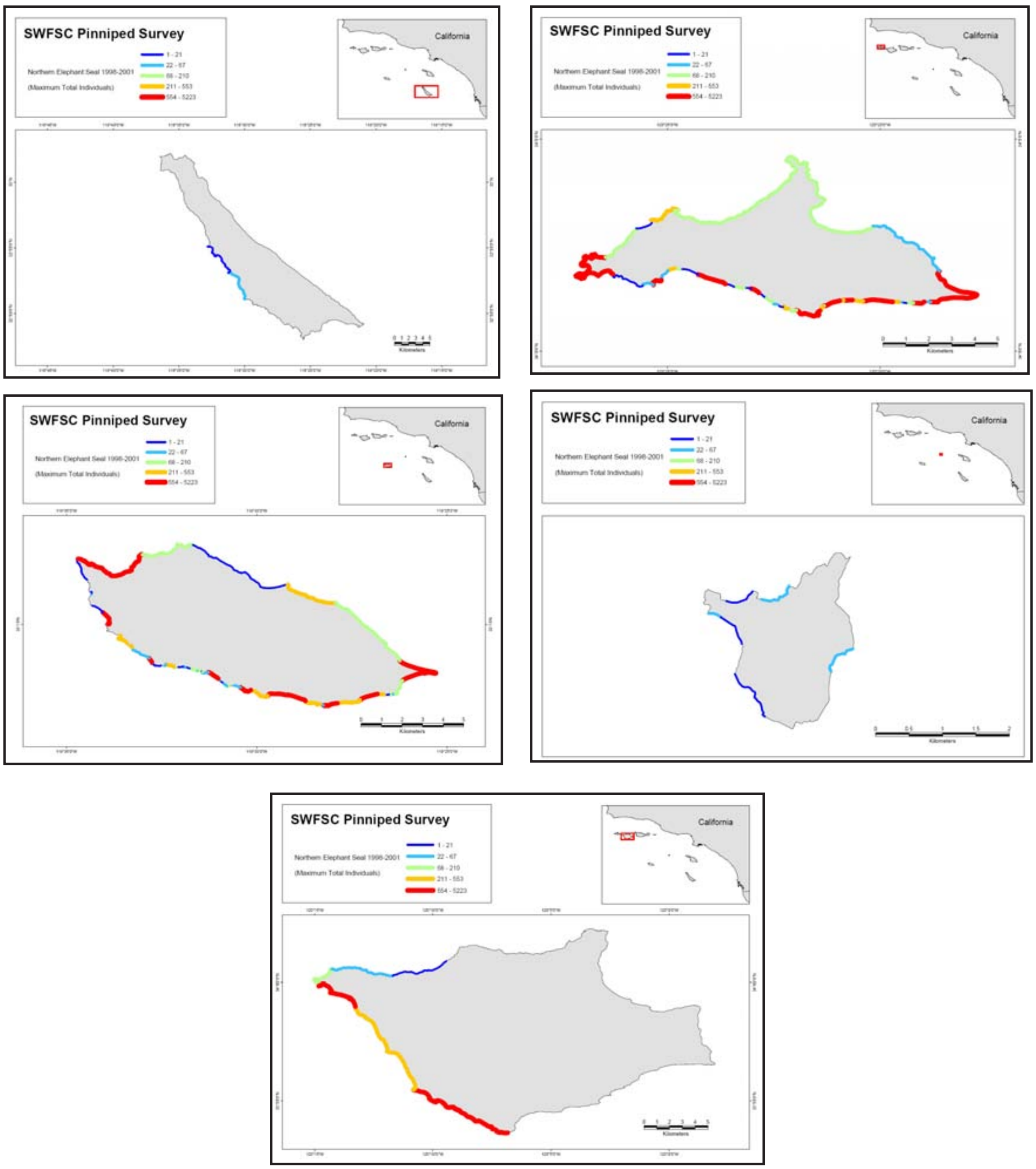

Figure 6.2.5. Northern elephant seal. Maximum total individuals (greatest number of individuals of all sex and age classes counted for each beach area surveyed out of the three most recent SWFSC surveys 2001-2003) for (left to right) San Clemente, San Miguel, San Nicolas, Santa Barbara, and Santa Rosa Islands.

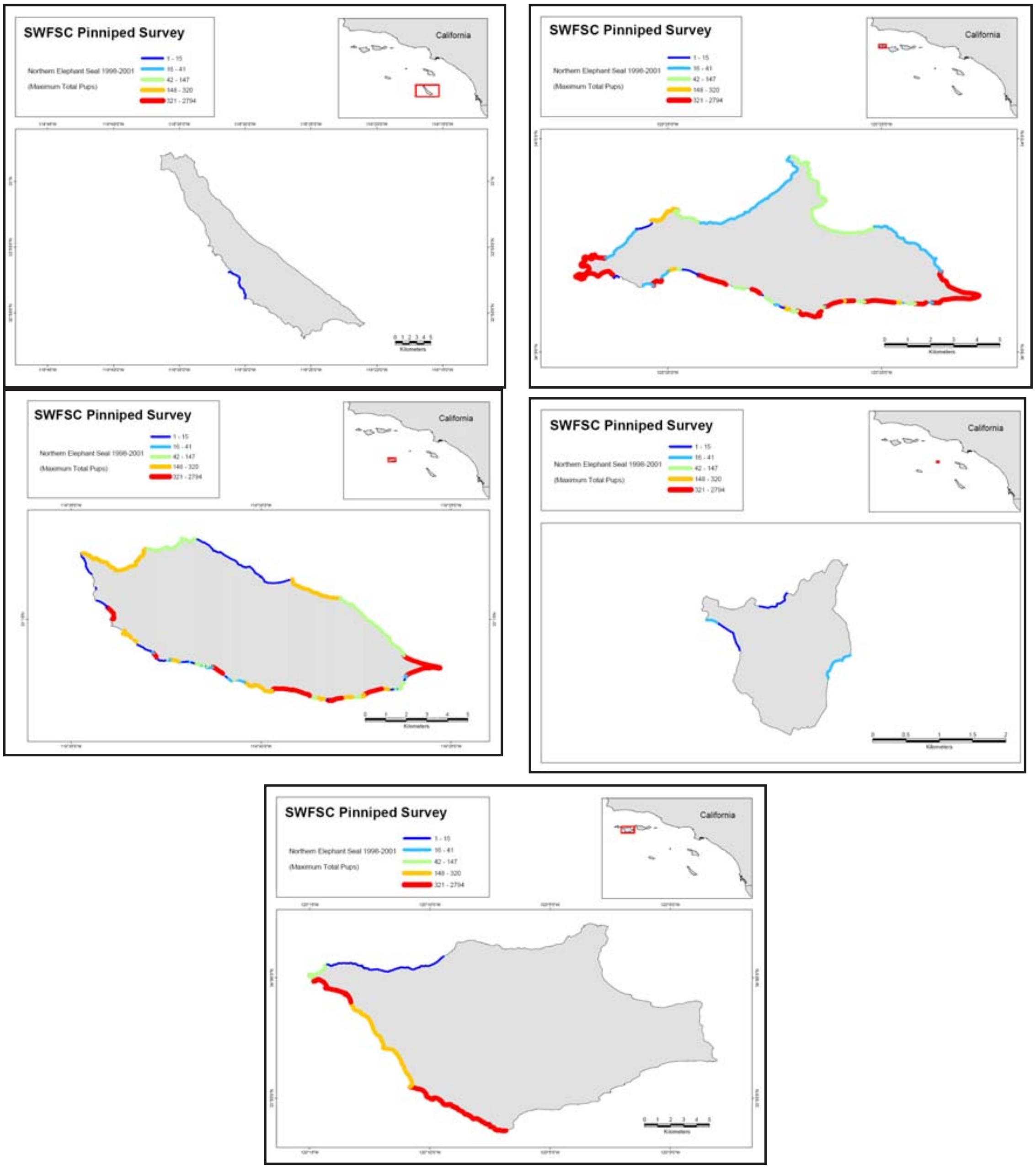

Figure 6.2.6. Northern elephant seal. Maximum pups (greatest number of pups counted for each beach area surveyed out of the three most recent SWFSC surveys 2001-2003) for (from left to right) San Clemente, San Miguel, San Nicolas, Santa Barbara, and Santa Rosa Islands.

Southern sea otter

Southern sea otter summary maps (Figure 6.2.7) show fall 2001 and spring 2002 distributions of sea otters along the California mainland. Georeferenced survey data within the Channel Islands were not available; however, the U.S. Fish and Wildlife Service does survey the San Nicolas Island experimental population approximately every two months (Carretta *et al*., 2002). The most recent recovery plan (USFWS, 2003) for this species estimates a population size of 27 individuals for the San Nicolas Island colony and states that more than 70 births have been recorded at this colony between 1987 and 2002. Sea otters have also been sighted irregularly near Point Bennett on San Miguel Island, with 14 individuals from this area captured and relocated between 1990 and 1993. More recently, 4 individuals were recorded in this area in a 1999 aerial survey, and no sightings were recorded during a September 2001 ground survey (USFWS, 2003). Historical expansion of the Southern sea otter's range (Figure 6.2.8) suggests that the mainland coast near the CINMS may provide increasingly important habitat for sea otter as the population grows; however, a three-year moving average (Figure 6.2.9) of the census results suggests that the population is not currently growing (USFWS, 2003).

Substantial differences exist among the six boundary concepts in terms of their potential impacts on sea otters. The current boundaries and Concepts 4 and 5 include only the small population at San Miguel Island. Reliable estimates of the size of this population are not available. For comparisons of boundary concepts, the higher 1999 aerial survey estimate of 4 individuals was used. To evaluate the sensitivity of the boundary concept analysis to this estimate, a high estimate of 25 individuals for the San Miguel Island population was also tested. While the absolute values of the OAI depend on the estimated population size within the current boundaries, the relative value of the OAI among concepts is not affected, therefore results (Table 6.2.3.) are shown only for calculations based on the estimate of 4 individuals within current boundaries.

Concepts 1, 1a, 2, and 3 all include portions of the mainland coast. To the extent that sea otter protection is a goal of the CINMS, Concepts 1, 1a, and 2 offer the greatest benefit. All of these options incorporate portions of the coast between Point Conception and Point Sal, which is in the primary range of the Southern sea otter. At this point in time, Concepts 1 and 1a appear to encompass little additional sea otter habitat than that encompassed by Concept 2. If the Southern sea otter's range continues to expand, however, the additional section of mainland coast to the south of Santa Barbara that is included in Concepts 1 and 1a may become important habitat. Although the coast south of Point Conception was designated as an otter management zone in 1986 (USFWS, 2003), and otters found in this zone were originally translocated out of the zone, this practice has been discontinued. Based on the most recent available surveys of sea otters, Concept 2 provides the greatest benefit in terms of sea otters encompassed by the boundaries for the smallest relative change in area. The OAI results support this conclusion for both the spring and fall survey data.

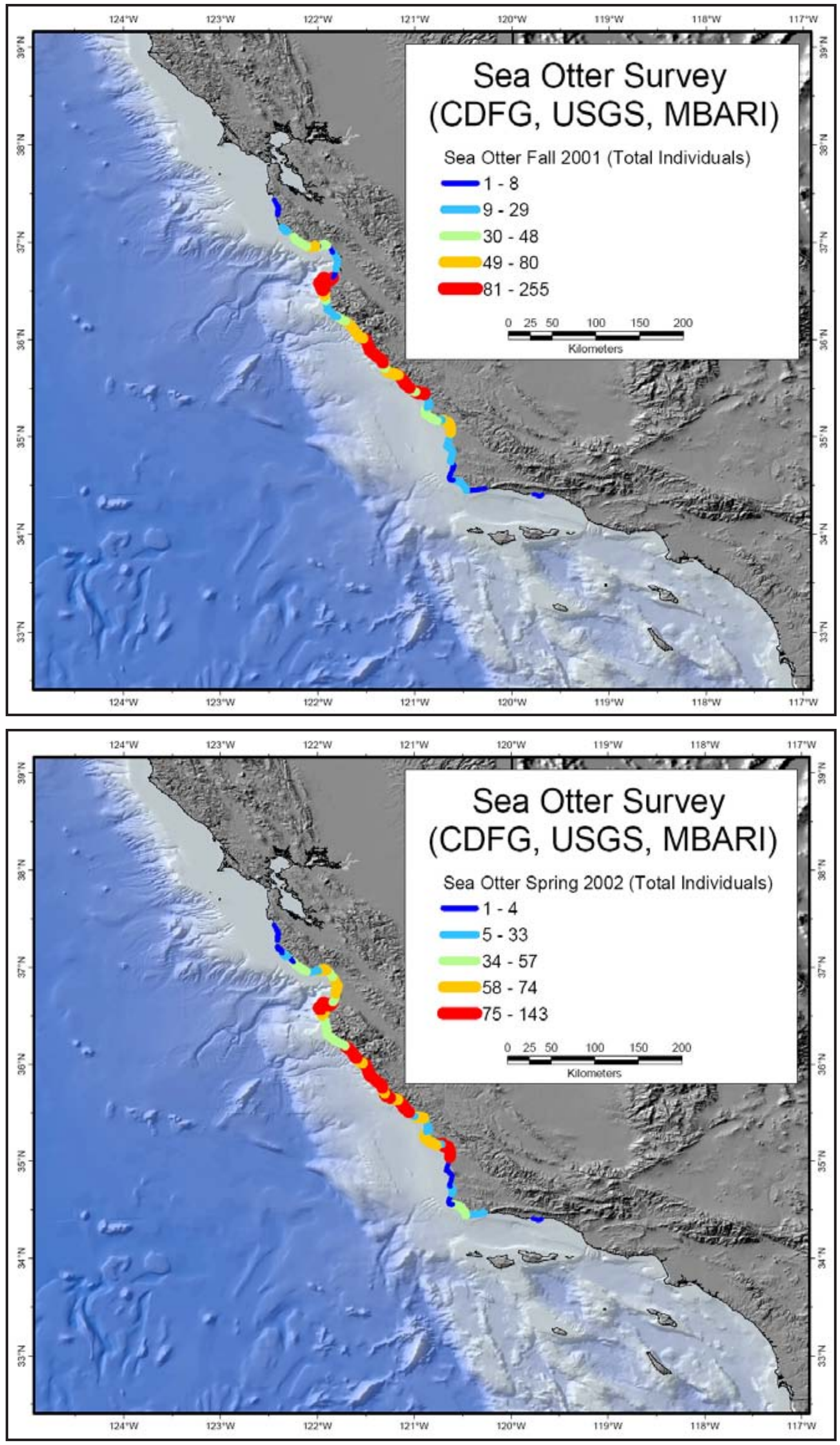

Figure 6.2.7. Southern sea otter. Counts summarized by 20 km shoreline segment for Fall 2001 (top) and Spring 2002 (bottom) surveys conducted by CDFG, USGS-Biological Resources Division, and the Monterey Bay Aquarium.

Summary

• The current boundaries of the CINMS encompass important haulout and rookery areas for California sea lion, harbor seal, northern elephant seal, and northern fur seal.

• San Miguel Island is used by all of these pinnipeds and has some of the most heavily used haulout and rookery areas in southern California for California sea lion, northern elephant seal, and northern fur seal.

• Although reliable estimates of at-sea distributions of pinnipeds at a scale useful for evaluating boundary concepts are not available, much of the waters surrounding the CINMS is likely to be important transit and foraging habitat for pinnipeds.

• Of the six boundary concepts being considered, Concepts 2 and 3 provide relatively large increases in harbor seal abundance within their boundaries relative to area.

• Expansion of the CINMS to include sections of mainland coast (Concepts 1, 1a, 2, and 3) would substantially increase the amount of occupied sea otter habitat within sanctuary boundaries. Of the six boundary concepts being considered, Concept 2 provides the greatest relative increase in sea otter abundance per area added.

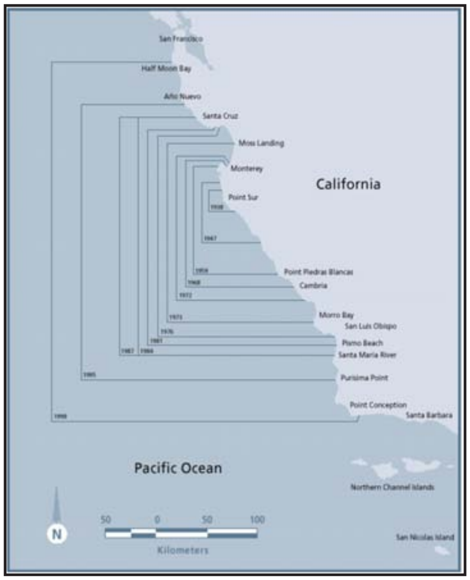

Figure 6.2.8. Southern sea otter. Expansion of sea otter range in California from 1938 to 1998. Reprinted with permission from The Otter Project Inc.

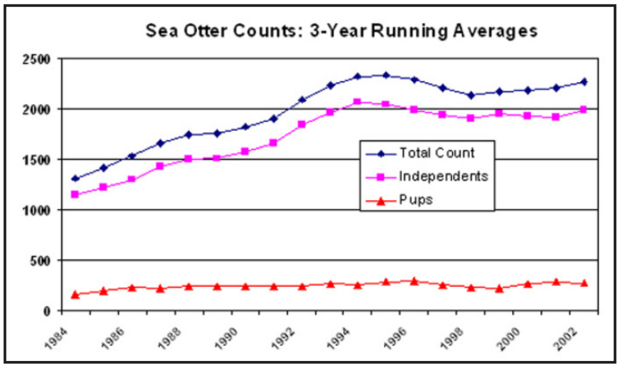

Figure 6.2.9. Southern sea otter. Three-year moving average of spring sea otter survey counts since 1984. Reprinted with permission from the USGS Western Ecological Research Center.

Table 6.2.3. Southern sea otter. Total number of individuals, mainland encounter rates, total area, and OAI for each boundary concept for Fall 2001 and Spring 2002 survey. Numbers in bold indicate an increase from the NAC and shaded OAI values represent maximum observed benefit.

Concept	Area (km^2)	Individuals (spring)	Spring Encounter Rate (#/km)	Individuals (fall)	Fall Encounter Rate (#/km)	Δ Area (%)	Δ Individuals (spring)	Δ Individuals (fall)	OAI Spring (absolute)	OAI Fall (absolute)
NAC	3745	4	NA	4	NA	-	-	-	-	-
5	4536	4	NA	4	NA	21.12	0	0	0	0
4	7981	4	NA	4	NA	113.11	0	0	0	0
3	9044	**11**	**1.6**	**6**	0.4	141.50	175	50	1.24	0.35
2	13736	**89**	**0.62**	**41**	0.46	266.78	2125	925	7.97	3.47
1a	22591	**92**	**0.55**	**58**	0.425	503.23	2200	1350	4.37	2.68
1	22613	**92**	**0.55**	**58**	0.425	503.82	2200	1350	4.37	2.68
SA	*17093*	*92*	*0.55*	*58*	*0.425*	*356.42*	*2200*	*1350*	*6.17*	*3.79*

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CHAPTER 7 INTEGRATION

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Previous chapters examined taxon-specific patterns of abundance, distribution, and community structure, as well as, physical/oceanographic data to evaluate boundary expansion concepts being considered by CINMS. For a review of the boundary concepts see Appendix A. The intent of this chapter is to provide, where possible, a synoptic overview of these patterns. The analyses conducted within this chapter will examine the degree to which the cumulative set of prior analyses favors one concept over another. They will also depict the extent to which areas deemed important for each taxonomic group (invertebrates, fishes, birds, mammals) co-occur across the study area and which boundary concepts capture these important regions. This visual depiction of these important regions can also be utilized to suggest further concepts that warrant future consideration. Finally, the last section highlights species within this assessment listed as threatened or endangered under the Endangered Species Act and how their distributions relate to the boundary concepts.

7.1 NUMERICAL INTEGRATION

Data and Methods

The OAI (Optimal Area Index), defined in Chapter 1.4, provides a standardized set of information to assess the physical and biological environment in the context of sanctuary boundary expansion. Absolute OAI results for 48 analyses were used to rank boundary concepts in terms of ecological benefit and area gained. Only absolute OAI values were included in this integration due to their commonality across datasets. Ranks were calculated for individual analyses within 5 analytical groups: physical setting (e.g. sea surface temperature, kelp distribution), invertebrates, fishes, birds, and mammals, and for the composite of all analyses (Table 7.1.1). The final composite rank for each concept was determined by calculating the mean rank for all analyses. A standard Kruskal-Wallis rank sums test (Sokal and Rohlf, 1969) was used to determine whether mean ranks were statistically different across boundary concepts for each analytical grouping, as well as for the composite of these ranks (Table 7.1.2).

Analysis of Boundary Concepts

The Study Area boundary received the highest ranking for 56% of the individual analyses, and highest for all the taxonomic and physical setting groups, and the composite analyses. Concept 2 ranked highest for 17% of the individual analyses and ranked second, behind the Study Area, for all groups, except invertebrates. The Study Area was overwhelmingly favored for all but one of the invertebrate analyses, while more variability was observed within the other groups. Statistically significant differences were found for each of the groupings with the exception of the physical setting group. The variables in this group are a combination of dynamic and static parameters and tended to rank on the opposite ends of the expansion spectrum. For example, ocean color ranked higher in larger concepts, while substrate type and physiographic complexity ranked high in smaller concepts. When compared as a group, no difference in mean rank was observed; however, the remaining group analyses suggest that the difference in ranks is real. No significant difference was observed between the Study Area and Concept 2 for fish, birds, and mammal group rankings, but they were significantly different than the other concepts. The Study Area was statistically different than all other concepts for invertebrates and for all the data in composite (Table 7.1.2).

High rankings were predominant for concepts whose northern boundary included portions of the nearshore habitats associated with the mainland. Concepts that included portions of the mainland benefitted from the gain of complex nearshore habitats (kelp, seagrasses, rocky areas) and areas of high primary productivity that are typically associated with high species richness and diversity. Rankings increased for these concepts as their total nearshore area increased; however, this pattern was not linear. Concepts 1, 1a, and the Study Area contained the same amount of mainland coastal area, but Concepts 1 and 1a ranked behind the Study Area and Concept 2, respectively. OAI rankings tended to be lower for Concepts 1 and 1a due to large areas of deep water habitat which were less significant for the composite of species analyzed. These areas extend offshore west of Point Conception, including a portion of the Santa Lucia Bank (Figure 1.1.2). This contributed negatively to the ratio of analytical results and the increase in boundary size relative to the current CINMS boundary.

It has been well documented that the convergence of warm and cold water masses and their associated biota create a unique and diverse ecosystem around Point Conception and the CINMS. Patterns of OAI results support this and provide a good example of the physical and biological linkages within this region.

Table 7.1.1. Absolute OAI rankings for individual groups and the composite for all analyses.

		Concept						
		5	**4**	**3**	**2**	**1A**	**1**	**SA**
Physical Setting	Physiographic Complexity	1	2	5	7	3.5	3.5	6
	Benthic Substrate	1	2	3	6	4.5	4.5	7
	Bathymetric Life-Zones	7	6	5	2.5	2.5	4	1
	Ocean Color/ChlA	4	7	3	2	6	5	1
	Seagrasses	6.5	6.5	4	1	4	4	2
	Kelp	6.5	6.5	3	2	4.5	4.5	1
	Mean	4.33	5.00	3.83	3.42	4.17	4.25	3.00
	Rank	**6**	**7**	**3**	**2**	**4**	**5**	**1**
Marine Invertebrates	Brown rock crab	6.5	6.5	5	4	2.5	2.5	1
	Red rock crab	6.5	6.5	5	4	2.5	2.5	1
	Yellow rock crab	6.5	6.5	5	4	2.5	2.5	1
	Black abalone	6.5	6.5	5	2	3.5	3.5	1
	Red abalone	6.5	6.5	5	1	3.5	3.5	1
	White abalone	5	5	5	5	2.5	2.5	1
	California market squid	7	6	5	2	3.5	3.5	1
	Sheep crab	6.5	6.5	5	4	2.5	2.5	1
	Spot shrimp	1	5	4	3	6.5	6.5	2
	Ridgeback rock shrimp	7	6	3	2	4.5	4.5	1
	California spiny lobster	6.5	6.5	5	4	2.5	2.5	1
	California sea cucumber	5	7	6	2	3.5	3.5	1
	Warty sea cucumber	6.5	6.5	5	4	2.5	2.5	1
	Red sea urchin	6.5	6.5	5	4	2.5	2.5	1
	Purple sea urchin	6.5	6.5	5	4	2.5	2.5	1
	Mean	6.00	6.27	4.87	3.27	3.17	3.17	1.13
	Rank	**6**	**7**	**5**	**4**	**2.5**	**2.5**	**1**
Marine Fishes	Pacific angel shark	6	7	5	4	2.5	2.5	1
	Thresher shark (adult/juvenile)	2.5	2.5	2.5	2.5	7	6	5
	Leopard shark (adult)	6.5	6.5	5	2	3.5	3.5	1
	Tope (adult/juvenile)	1	7	4	3	5.5	5.5	2
	Cowcod (adult/juvenile)	5	1	2	3	5	5	4
	Bocaccio (adult/juvenile)	5	1	2	3	6.5	6.5	4
	Lingcod (adult/juvenile)	7	6	5	2	3.5	3.5	1
	Giant seabass	6.5	6.5	5	2	3.5	3.5	1
	California sheephead	6.5	6.5	5	2	3.5	3.5	1
	California halibut	6	7	5	4	2.5	2.5	1
	Mean	5.20	5.10	4.05	2.75	4.30	4.20	2.10
	Rank	**7**	**6**	**5**	**2**	**4**	**3**	**1**
Marine Birds	Ashy storm-petrel	7	3	1	2	5	6	4
	Black oystercatcher	6.5	6.5	5	1	3.5	3.5	2
	Brandt's cormorant	6.5	6.5	1	3	4.5	4.5	2
	Brown Pelican	5	7	4	6	2.5	2.5	1
	Cassin's auklet	7	6	5	2	3	4	1
	Double-crested cormorant	6.5	6.5	4	5	2.5	2.5	1
	California least tern	6	6	6	3.5	1.5	1.5	3.5
	Pelagic cormorant	6.5	6.5	5	1	3.5	3.5	2
	Pigeon guillemot	7	6	5	1	3.5	3.5	2
	Xantus's Murrelet	1	2	3	4	6.5	6.5	5
	Comminity/Bird diversity	3	2	1	4	6.5	6.5	5
	Mean	5.64	5.27	3.64	2.95	3.86	4.05	2.59
	Rank	**7**	**6**	**3**	**2**	**4**	**5**	**1**

Table 7.1.1. (cont).

		Concept						
		5	4	3	2	1A	1	SA
Marine Mammals	Blue whale	5	6	7	3	2	1	4
	Long-beaked common dolphin	5	6	7	1	4	3	2
	Short-beaked common dolphin	7	1	2	6	4.5	4.5	3
	Risso's dolphin	7	6	2	3	4.5	4.5	1
	Pacific harbor seal	6.5	6.5	5	1	4	3	2
	Southern sea otter	6.5	6.5	5	1	3.5	3.5	2
	Mean	6.17	5.33	4.67	2.50	3.83	3.17	2.33
	Rank	**7**	**6**	**5**	**2**	**4**	**3**	**1**
Composite	**Composite Mean**	5.56	5.52	4.26	3.01	3.77	3.72	2.05
	Composite Rank	**7**	**6**	**5**	**2**	**4**	**3**	**1**

7.2 SPATIAL INTEGRATION

Data and Methods

In addition to the numerical integration of OAI values, spatial data for fish, invertebrates, marine birds, and mammals were overlaid to identify areas of potential ecological importance across taxa. This allows a visual examination of the spatial coincidence of these species which may reflect ecosystem "hotspots".

Integration of datasets is a difficult task due to varying sampling techniques and issues of scale. Often, there is a disparity between spatial and temporal scales of biological data (McGowan *et al*., 1998) where inadequate spatial coverage may create unwanted bias within specific areas. As such, only datasets with similar spatial ranges and sampling techniques were considered suitable for this integration and certain datasets that were analyzed in previous chapters were not included. Based on these criteria, the datasets utilized for this analysis were the fish and invertebrate habitat suitability models (HSM) and bird and mammal sightings data (MMS, 2001). For a more complete description of these datasets refer to Chapter 3 (invertebrates), Chapter 4 (fish), Chapter 5 (birds), and Chapter 6 (mammals).

Table 7.1.2. Results of Kruskal-Wallis ranks sums test. X^2 values with probabilities less than 0.05 were considered statiscally significant.

Group	X^2	Probability	Highest Concept Ranking
Physical Setting	4.27	0.64	Study Area
Invertebrates	80.52	<0.0001	Study Area
Fish	21.1	0.0018	Study Area/ Concept 2
Birds	27.57	0.0001	Study Area/ Concept 2
Mammals	25.88	0.0002	Study Area/ Concept 2
Composite	140.19	<0.0001	Study Area

Selecting an appropriate scale to display the integrated data was crucial in order to depict trends at the smallest scale possible without making the assessment so general that the entire region becomes homogeneous. Various scales of data exist within the datasets used in this assessment: HSM data were based on bathymetric and benthic substrate data ranging from tens to hundreds of meters and bird and mammal sightings data ranged from tens to hundreds of kilometers. In order to optimize the search for pattern and to maximize the number of samples in a grid cell for the bird and mammal data, a cell size of ~950 km^2 was chosen. HSM data were then sampled into the same sized grid cells used for bird and mammal sightings, which were the limiting factor between the two types of data (Figure 7.2.1). HSM models and bird and mammal sightings data were integrated separately since they were the most comparable. Then, to provide a synoptic overview, all four data sets were combined in the final composite integration.

The areas of highest habitat suitability for all 25 fish and invertebrate species listed in Table 7.1.1 were superimposed and linked to the larger grid cells. The number of species with highly suitable habitat within each grid cell was then categorized by quintile (20%).

Bird and mammal at-sea sightings data (MMS, 2001) were examined to determine spatial co-occurrence. Sightings data for eight of the ten bird species listed in Table 7.1.1 (excluding black oystercatcher and California least tern) and four of the six mammal species (excluded Pacific harbor seal and Southern sea otter). At-sea sightings data were also available for bottlenose dolphins, gray whales, humpback whales, Pacific white-sided dolphins, Dall's porpoise, and minke whales, but lacked sufficient data for OAI analysis in Chapter 6. Presence/absence data for these species were analyzed to determine areas of co-occurrence within each grid cell. Abundance and estimated density data were not used due to difficulties in standardizing effort and sampling techniques. The number of species within each grid cell were then categorized by quintile (20%).

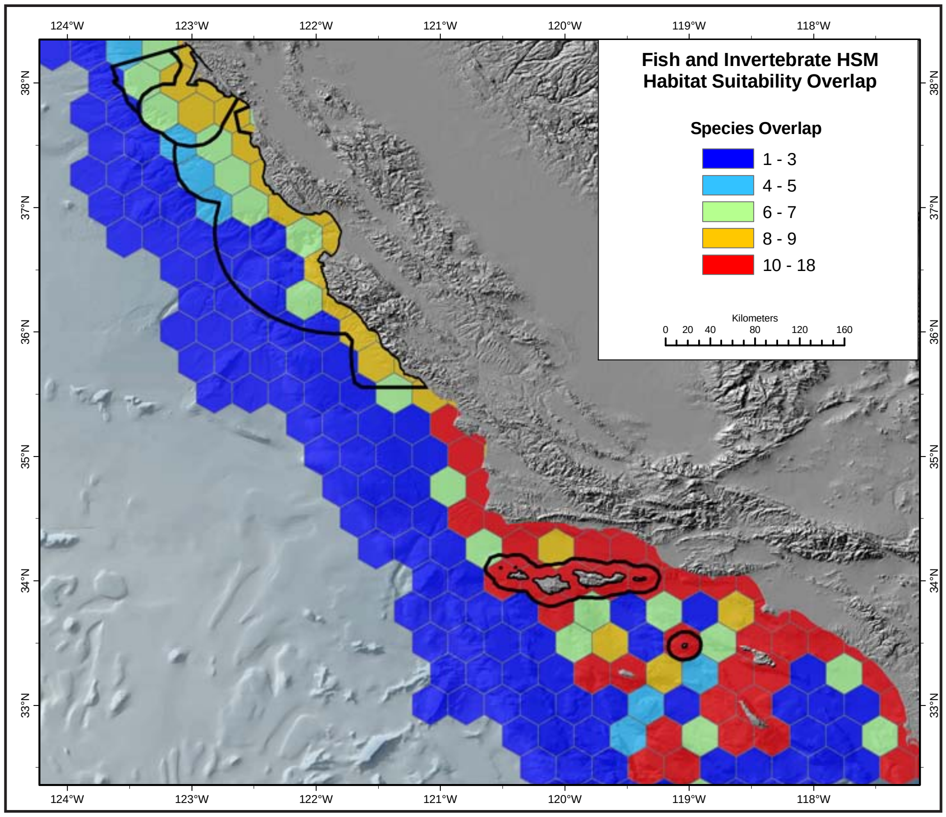

Figure 7.2.1. Broad-scale distriibution of the overlap of fish and invertebrate highly suitable habitat.

Finally, a composite integration was conducted to provide a comprehensive spatial analysis for all the datasets mentioned above. Grid cell values for fish and inveretebrate habitat suitability overlap and bird and mammal co-occurrence were summed and categorized by quintile (20%). Overall, 43 species were examined in this analysis.

Broad-scale Patterns and Analysis of Boundary Concepts

Areas of highest overlap for fish and invertebrate habitat suitability occur predominantly off southern California, from Morro Bay to San Diego (Figure 7.2.1). Overlap is lower north of Morro Bay as many of the species analyzed have southerly ranges, rarely extending north of Point Conception. Patterns of overlap were correlated with depth, where low values were observed in deep slope waters and increasing values over the continental shelf. Overlap was highest in waters near the mainland and islands off southern California.

Within southern California (Figure 7.2.2), areas of highest habitat suitability overlap occurred along the mainland from Morro Bay to San Diego, around the Channel Islands, and a large area over Cortes Bank. This pattern coincides with complex nearshore benthic habitat types, including kelp, submerged seagrass beds, rocky reefs or hardbottom, and soft substrate. This area of overlap also coincides with areas of high primary productivity (see Chapter 2.8) associated with nearshore upwelling near Point Conception and the Channel Islands (Dever, 2004).

While the patterns of overlap are broader than the original maps of suitability based on the smaller scale bathymetry and substrate maps, the analysis highlights the nearshore environment of southern California and the ecological linkages within the Santa Barbara Channel described by McGinnis (2000). Oceanographic processes in the region foster the transport of materials, such as nutrients and fish and invertebrate larvae, between the marine (islands) and coastal habitats and are primary food sources that support biological communities.

Broad-scale patterns of bird and mammal at-sea sightings data (Figure 7.2.3) identify three regions of high co-occurrence (upper 20%, 13-17 species): Point Reyes, Monterey Bay, and a large area encompassing the northern Channel Islands and extending northwest to Point Conception. Smaller areas of high co-occurrence were observed southeast of Santa Barbara Island and Cortes Bank. The regions in central California have been previously highlighted as areas supporting high bird biomass, density, and diversity (NCCOS, 2003). The highlighted areas around Point Reyes, Monterey Bay, and much of southern California have been identified as hotspots for bird diversity in this assessment (Chapter 5.2).

Within southern California, high co-occurrence was observed throughout most of the Santa Barbara Channel, including the area from Point Conception through the northern Channel Islands and smaller areas south of Santa Barbara Island and Cortes Bank. Many species of birds and mammals are widely distributed along the west coast and patterns of abundance are highly correlated with areas of high primary productivity and plankton density (Airamé *et al*., 2003; Croll *et al*., 2005). Known areas of pronounced upwelling, such as Point Conception, are generally linked with areas of high physiographic complexity and dynamic currents and eddies which tend to concentrate phytoplankton, zooplankton, and secondary consumers. (Baltz and Morejohn, 1977; Ainley and Sanger, 1979; Briggs *et al*., 1984; Briggs and Chu, 1987; Chu, 1984; Ainley *et al*., 1996; Forney and Barlow, 1998; NCCOS, 2003). The expression of the patterns observed in Figure 7.2.4 are not static and can be highly variable and difficult to predict (Mann and Lazier, 1996); however, the patterns of distribution are found near well known areas of high primary production (Huyer and Kosro, 1987; Brink and Cowles; 1991; Rosenfeld *et al*., 1994).

Based on these data, it is apparent that many bird and mammal species utilize the area between the northern Channel Islands and Point Conception. These results may be biased due to the fact that most of the bird species chosen have nesting grounds within the region.

The areas around Cordell Bank, the Farallon Escarpment, Monterey Bay, and Point Conception are well known for their productivity and diverse biological communities (NCCOS, 2003). Areas of high physiographic complexity (canyons, ridges, banks, and shelf breaks) and distinctive oceanographic features associated with seasonal upwelling

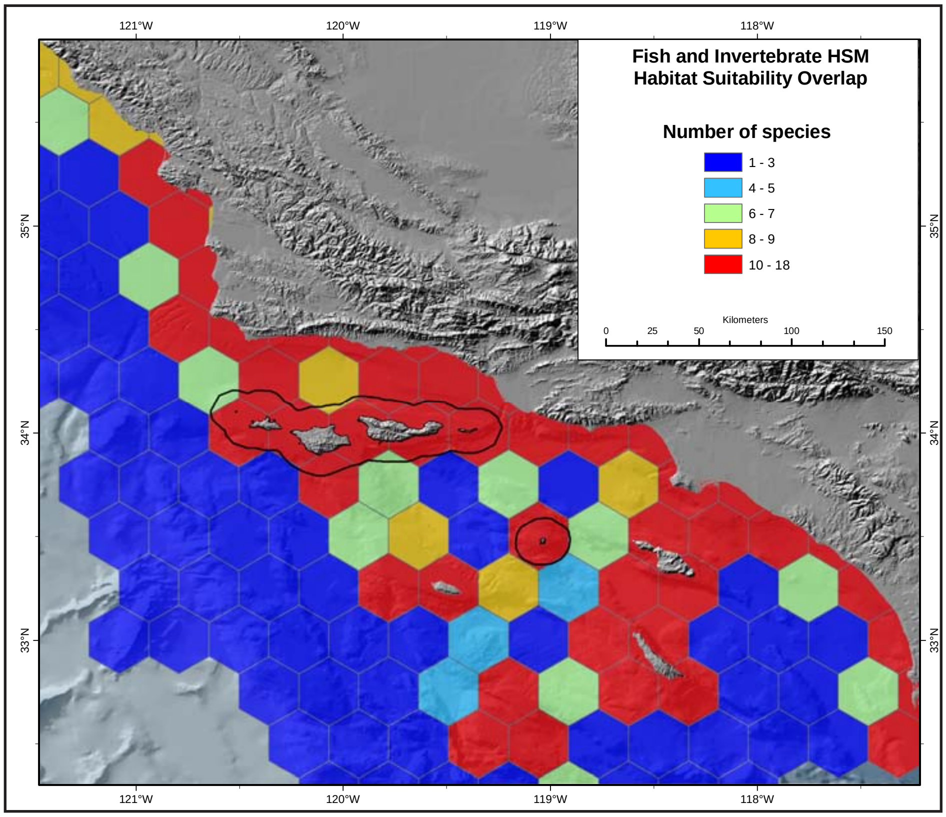

Figure 7.2.2. Overlap of fish and invertebrate highly suitable habitat off southern California.

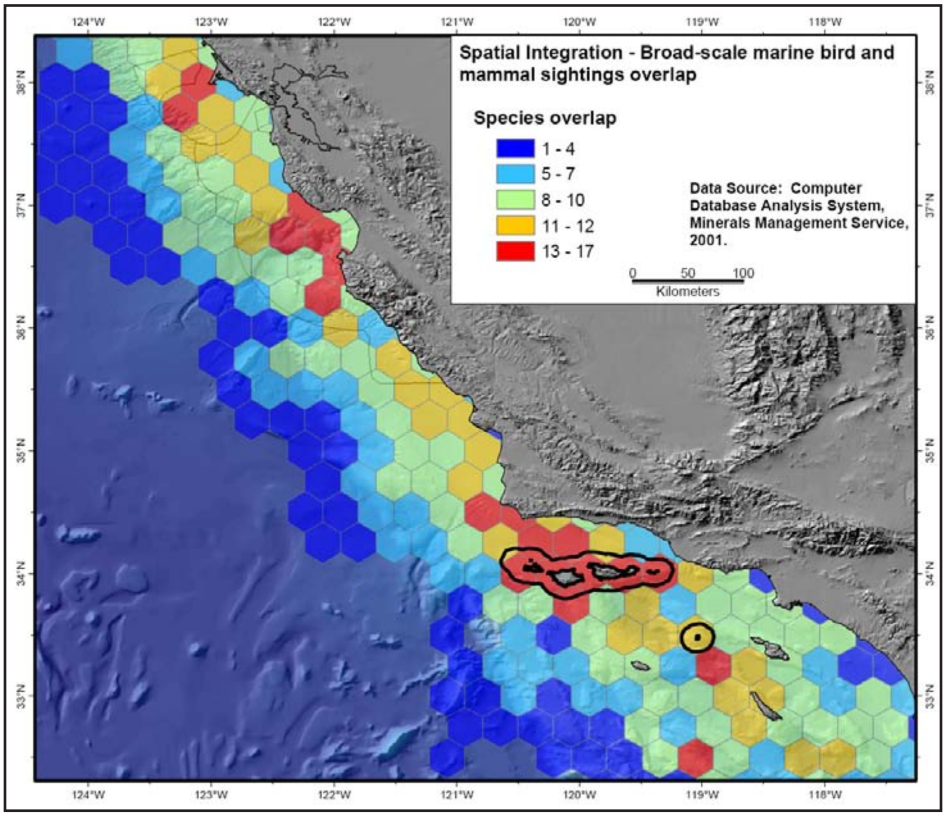

Figure 7.2.3. Broad-scale distribution of bird and mammal co-occurrence. Source: CDAS, MMS (2000).

(plumes, fronts, sea surface temperature variation, currents, and eddies) affect biological distributions patterns at many trophic levels. Broad-scale patterns for the composite of bird, fish, invertebrate, and mammal data highlight these areas of productivity. Species overlap was highest in many shelf regions with these characteristics and low in deeper habitats.

Within southern California, areas of high species overlap extend along the mainland from Morro Bay to Santa Monica Bay. A wide area encompasses the area from Point Conception to Point Dume, and south through the northern Channel Islands, including all of the Santa Barbara Channel. Another large area extends from Palos Verdes Point to San Clemente Island. Smaller areas of significance are observed around Santa Barbara Island, San Nicolas Island, and over Cortes Bank.

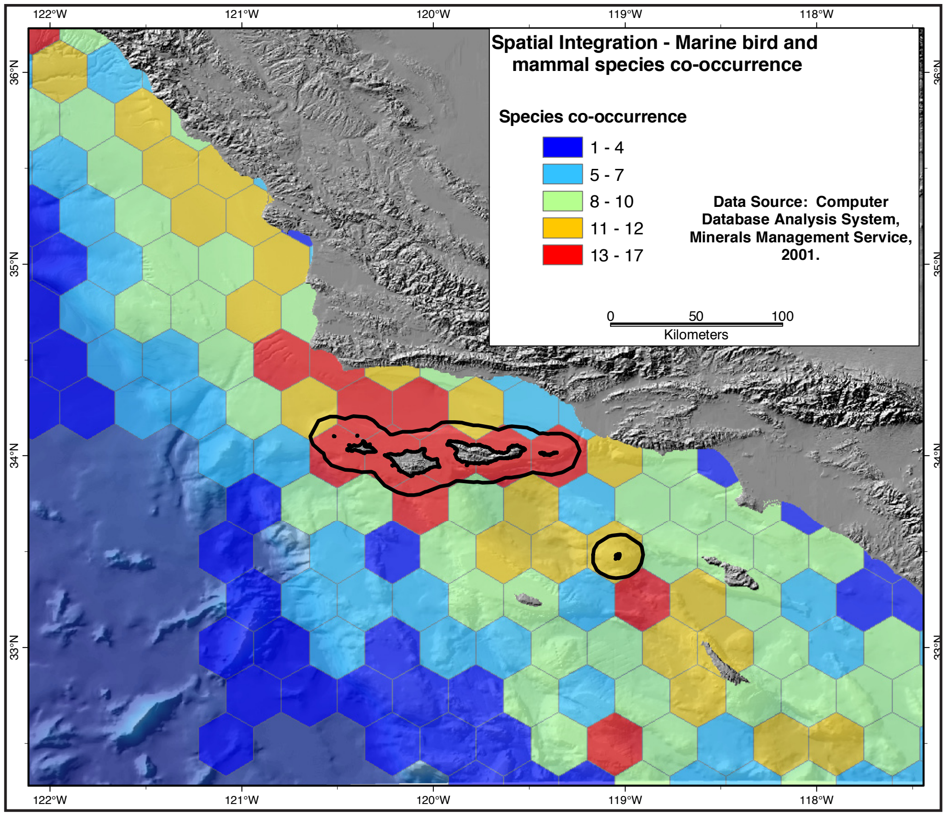

Figure 7.2.4. Bird and mammal co-occurrence off southern California. Source: CDAS, MMS (2000).

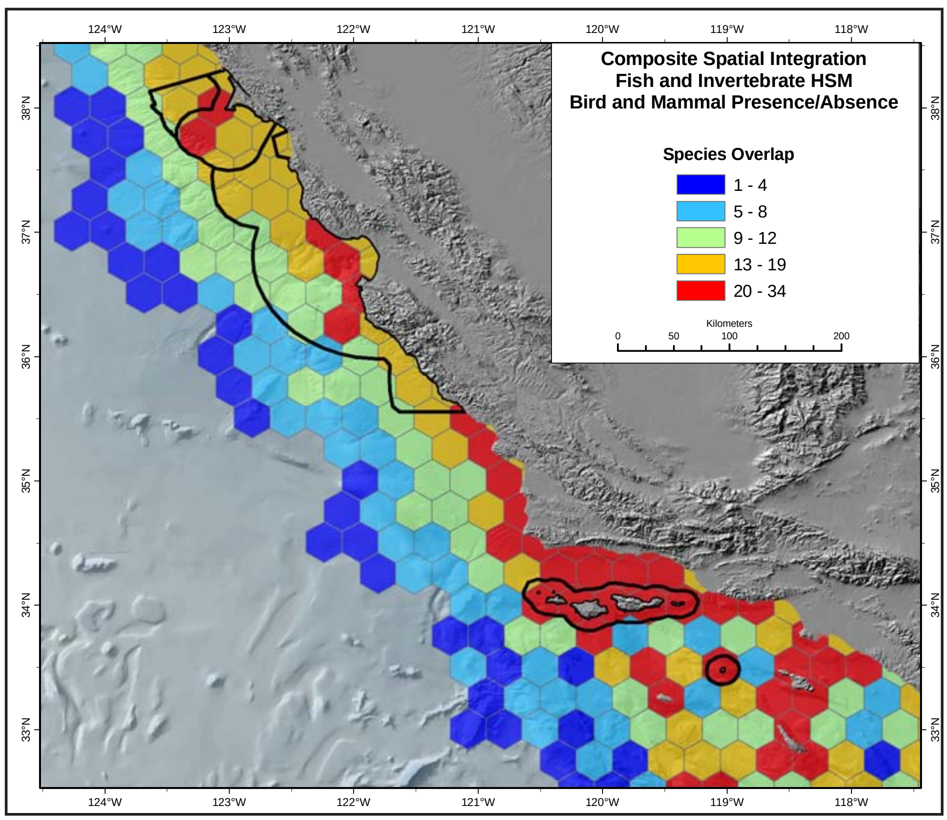

Figure 7.2.5. Broad-scale distribution of the composite spatial integration for bird, fish, invertebrate, and mammal data.

The area consisting of Point Conception and the CINMS is unique in that it is located in a transition zone between two biogeographical provinces: the warm Californian Province and the cooler Oregonian Province. Characteristics of this zone include a mix of shallow and deep water habitats, increased intensity of upwelling, dynamic eddies and surface currents, and persistent thermal fronts as a result of the meeting of the major currents (Southern California Countercurrent and California Current) from these provinces (Harms and Winant, 1998; McGinnis, 2000). This combined with important coastal habitats such as kelp, seagrass beds, and wetlands promote diverse assemblages of marine birds, fish, invertebrates, and mammals (Cross and Allen, 1993; U.S. Air Force, 1997; Schroeder, 1999; McGinnis, 2000; NCCOS, 2003). Although all species of marine birds, fish, invertebrates, and mammals were not represented in the spatial analyses, it is obvious that this transition zone is highlighted as an important ecological area for the species included in these analyses.

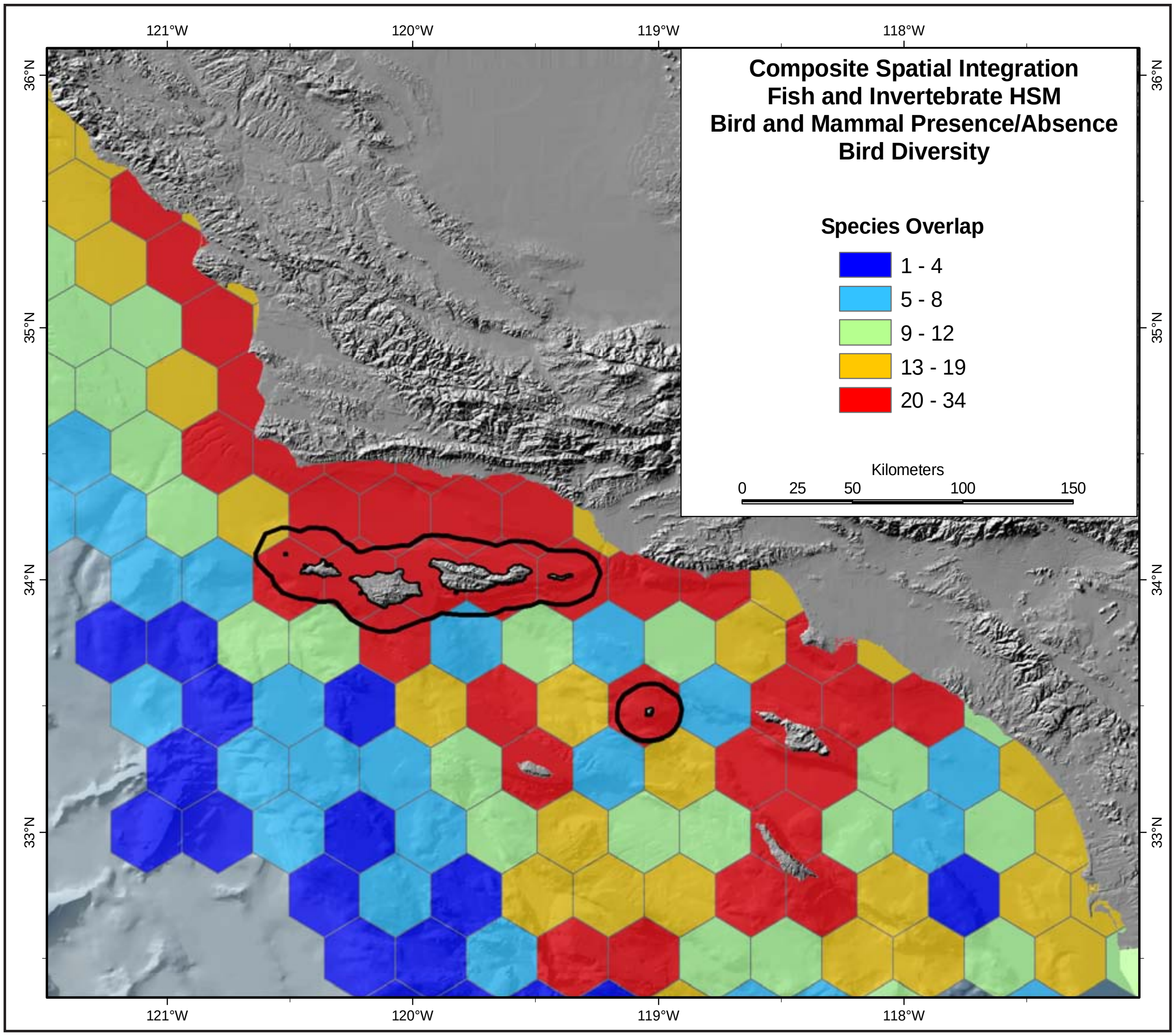

Figure 7.2.6. Composite spatial integration of bird, fish, invertebrate, and mammal data off southern California.

Summary

* The Study Area and Concept 2 ranked first and second, respectively, for most biological groups and physical processes and for the composite of all OAI analyses.

* The overlap of fish and invertebrate habitat suitability appears to be correlated with nearshore environments, predominantly kelp, seagrass beds, and rocky substrates.

* Marine bird and mammal co-occurrence appears to be associated with known centers of upwelling and primary production.

* Ecological hotspots occur in continental shelf and nearshore waters from Point Conception through the northern Channel Islands, where spatial patterns of bird, fish, invertebrate, and mammal habitat overlap.

7.3 THREATENED AND ENDANGERED SPECIES

Seven of the species considered in this bioassessment are listed as threatened or endangered under the Endangered Species Act of 1973:

White abalone	*Haliotis sorenseni*	Endangered
Western snowy plover	*Charadrius alexandrinus nivosus*	Threatened
California brown pelican	*Pelecanus occidentalis californicus*	Endangered
California least tern	*Sterna antillarum browni*	Endangered
Southern sea otter	*Enhydra lutris nereis*	Threatened
Blue whale	*Balaenoptera musculus*	Endangered
Humpback whale	*Megaptera novaeangliae*	Endangered

Biogeographic patterns of these species, with respect to the boundary concepts, are recapped for each of these species.

White abalone

Approximately 77 km^2 of habitat were considered suitable for white abalone within the current CINMS sanctuary boundary (NAC). This estimate remained the same for the smaller Concepts 2, 3, 4 and 5 (Table 7.3.1). The addition of nearshore waters along the mainland for the Study Area and Concepts 1 and 1a provide additional suitable habitat. The OAI analysis indicates that these larger concepts (SA, 1, and 1a) offer the greatest proportional change in habitat area/total area gained relative to the NAC.

Table 7.3.1. Analysis of white abalone habitat suitability within boundary concepts.

Concept	High Suitability Area (km^2)	D Area (%)	D High Suitability Area (%)	OAI (absolute)
NAC	77	-	-	-
5	77	21.12	0	0
4	77	113.11	0	0
3	77	141.50	0	0
2	77	266.78	0	0
1a	93	503.23	20.78	0.04
1	93	503.82	20.78	0.04
SA	*93*	*356.42*	*20.78*	*0.06*

Western snowy plover

290 km of coastline along the U.S. Pacific coast (Washington, Oregon and California) have been designated as critical habitat for the western snowy plover (USFWS 1999). The current CINMS sanctuary boundary (NAC) and Concepts 4 and 5 do not include any designated critical habitat (Table 7.3.2). Concept 3 includes 2.3 km of critical habitat shoreline, less than 1% of the total designated habitat. Concept 2 encompasses 27.4 km (9.4%). The larger Concepts 1, 1a and the Study Area include 24% (70 km) of the designated western snowy plover critical habitat. Because there was no critical habitat designated within the NAC, it is not possible to calculate the OAI for western snowy plover critical habitat.

Table 7.3.2. Critical habitat for the Pacific coast population of western snowy plover.

Concept	Critical Habitat: Length of Shoreline (km)
NAC	-
5	0
4	0
3	2.29
2	27.35
1a	69.85
1	69.85
SA	*69.85*

California brown pelican

Analysis of the observed patterns of pelican sightings and density relative to the proposed boundary concepts indicates that the Study Area and Concepts 1 and 1a provide the greatest increase in sightings (absolute metric) for its relative size compared to the NAC (Table 7.3.3). The density-based OAI, however, favors Concept 5, the smallest concept. The smaller concepts (3-5) fail to capture the region of high pelican density along the mainland coast and in the eastern Santa Barbara Channel, while the largest concepts (1 and 1a) include large areas of low pelican density along the shelf.

No analysis of boundary concepts was conducted for brown pelican breeding colonies since none of the concepts encompass any colonies not contained in the NAC.

Table 7.3.3. California brown pelican sightings and density OAI.

Concept	Total Individuals	Density (Individuals/km^2)	OAI (absolute)	OAI (relative)
NAC	374	0.834	-	-
5	452	0.918	0.99	0.47
4	540	0.722	0.39	-0.12
3	913	0.927	1.02	0.08
2	1355	0.853	0.98	0.01
1a	2546	1.035	1.15	0.05
1	2546	1.035	1.15	0.05
SA	*2546*	*1.204*	*1.63*	*0.12*

California least tern

There were no recorded breeding colonies of least tern within the NAC or Concepts 3-5 during 2001–2003 (Table 7.3.4). Concept 2 encompasses 1 colony at Vandenberg AFB for a maximum of 79 breeding pairs. Concepts 1 and 1a and the Study Area encompass an additional 4 colonies for a maximum of 676 breeding pairs. Because no colonies exist within the NAC, it is not possible to calculate the OAI for least tern colonies.

Table 7.3.4. California least tern breeding pairs observed within boundary concepts, 2001-2003. Source: CDFG, draft data.

Concept	Maximum Breeding Pairs
NAC	0
5	0
4	0
3	0
2	79
1a	676
1	676
SA	*676*

Southern sea otter

Substantial differences exist among the six boundary concepts in terms of their potential impacts on sea otters. The current boundary and Concepts 4 and 5 include only the small population at San Miguel Island. Reliable estimates of the size of this population are not available. Concepts 1, 1a, 2, and 3 all include portions of the mainland coast (Table 7.3.5). To the extent that sea otter protection is a goal of the CINMS, Concepts 1, 1a, and 2 offer the greatest benefit. All of these options incorporate portions of the coast between Point Conception and Point Sal, which is in the primary range of the Southern sea otter. At this point in time, Concepts 1 and 1a appear to encompass little additional sea otter habitat than encompassed by Concept 2. If the southern sea otter's range continues to expand, however, the additional section of mainland coast to the south of Santa Barbara that is included in Concepts 1 and 1a may become important habitat. Based on the most recent available surveys of sea otters, Concept 2 provides the greatest benefit in terms of sea otters encompassed by the boundaries for the smallest relative change in area. The OAI results support this conclusion for both the spring and fall survey data.

Table 7.3.5. Spring and fall abundance estimates and OAI for southern sea otter.

Concept	Spring/Fall Total Individuals	Spring/Fall Average Mainland Encounter Rate (#/km)	OAI Spring	OAI Fall
NAC	8	-	-	-
5	8	NA	0	0
4	8	NA	0	0
3	17	1.00	0	0
2	130	0.54	0	0
1a	140	0.47	20.78	0.04
1	140	0.47	20.78	0.04
SA	*140*	*0.47*	*20.78*	*0.06*

Blue whale

Because of the relatively small number of on-effort sightings (4-14) and the uncertainty in the line transect input parameters, confidence intervals for the abundance estimates are wide and overlap substantially among the concepts (Table 7.3.6). The NAC does seem to be well placed to capture regions of high blue whale density within the Southern California Bight as it exhibits higher estimated density than any of the other concepts. Sharp increases in estimated blue whale abundance relative to that of the NAC are apparent in Concepts 1, 1a, and 2. The OAI shows that, although none of the concepts provide higher density than the NAC, Concepts 1 and 1a provide the greatest relative increase in blue whale abundance for the relative increase in area.

Table 7.3.6. Sightings, estimated abundance and density, and OAI for blue whales.

Concept	Sightings	Density (individuals/km^2)	Estimated Abundance	OAI (absolute)	OAI (relative)
NAC	4	0.00807	30	-	-
5	4	0.00712	32	0.316	-0.557
4	4	0.00400	32	0.059	-0.446
3	4	0.00358	32	0.047	-0.393
2	7	0.00600	82	0.650	-0.096
1a	14	0.00587	133	0.680	-0.054
1	14	0.00587	133	0.681	-0.054
SA	*8*	*0.00530*	*91*	*0.570*	*-0.095*

Humpback whale

Because some of the sightings recorded as "Unidentified Large Whale" (including one that fell in Concepts 1 and 1a) were likely to be humpback whales (Carretta et al. 2002), abundance estimates in Concepts 1 and 1a may be negatively biased. Very small numbers of sightings (0-4) make the density and abundance estimates for this species extremely uncertain. No sightings were recorded within the NAC and only 1 sighting was recorded in Concepts 3-5 resulting in abundance estimates of approximately 10 individuals for these three concepts (Table 7.3.7). Four sightings occurred in Concepts 1, 1a, 2 and the study area, resulting in abundance estimates of approximately 50 individuals for these four areas. Because no sightings were recorded in the NAC, it was not possible to calculate the OAI for humpback whales.

Table 7.3.7. Sightings, estimated abundance and density for humpack whales.

Concept	Sightings	Density	Estimated Abundance
NAC	0	0	0
5	1	0.00234	11
4	1	0.00131	10
3	1	0.00118	11
2	4	0.00375	52
1a	4	0.00230	51
1	4	0.00226	51
SA	*4*	*0.00310*	*13*

Summary

Table 7.3.8 provides a summary of the boundary concept metrics for each of the Federally-listed species. Numerical values for each concept are ranked in ascending order (highest values receive the lowest rank); ranks for tied values are averaged. For species that do not have an OAI calculation for each concept (i.e. when the ecological metric was 0 inside the current sanctuary boundary), rankings were based upon a modified OAI, calculated as:

$$OAI_{modified} = B_1\text{-}B_0/A_1\text{-}A_0$$

where B_1-B_0 equals the difference of the metric (diversity, habitat area, etc) and A_1-A_0 equals the difference of total area between a given boundary concept and the NAC. This modified metric omits the relative weighting of the NAC to the difference in ecological value and the difference in area; however, it is suitable for ranking the concepts as it maintains the relative relationships between the gains in ecological value per gain in total area. As discussed in the Introduction, absolute metrics inherently favor the largest concept because each successively larger boundary encompasses the smaller concept. Accordingly, the Study Area and the larger concepts 1,1a and 2 are generally more favorable than the smaller concepts. This is generally upheld for metrics that are based on either absolute or OAI values.

Table 7.3.8. Ranked OAI for the 86 federally listed threatened or endangered species.

Concept	1	1a	2	3	4	5	SA
Area (km^2)	22613	22591	13736	9044	7981	4536	17093
White abalone High Suitability area	2.5	2.5	5.5	5.5	5.5	5.5	1
Western snowy plover critical habitat (km)	2.5	2.5	4	5	6.5	6.5	1
California brown pelican Total Individuals	2.5	2.5	6	4	7	5	1
California least tern Breeding Pairs	2.5	2.5	4	6	6	6	1
Southern sea otter Mean Individuals across Spring and Fall	3.5	3.5	1	5	6.5	6.5	2
Blue whale sightings	1.5	1.5	3	7	6	5	4
Humpback whale Estimated Abundance	3.5	3.5	2	6	5	1	7
Overall Ranking	**2.5**	**2.5**	**4**	**6**	**7**	**5**	**1**

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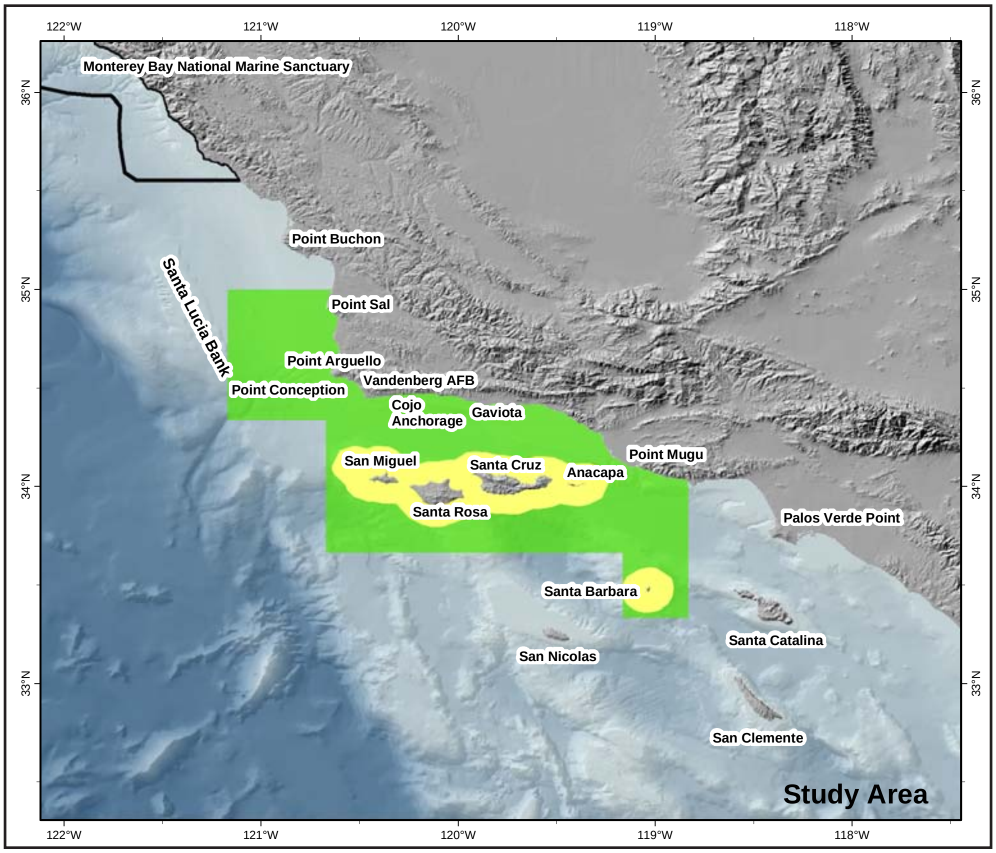
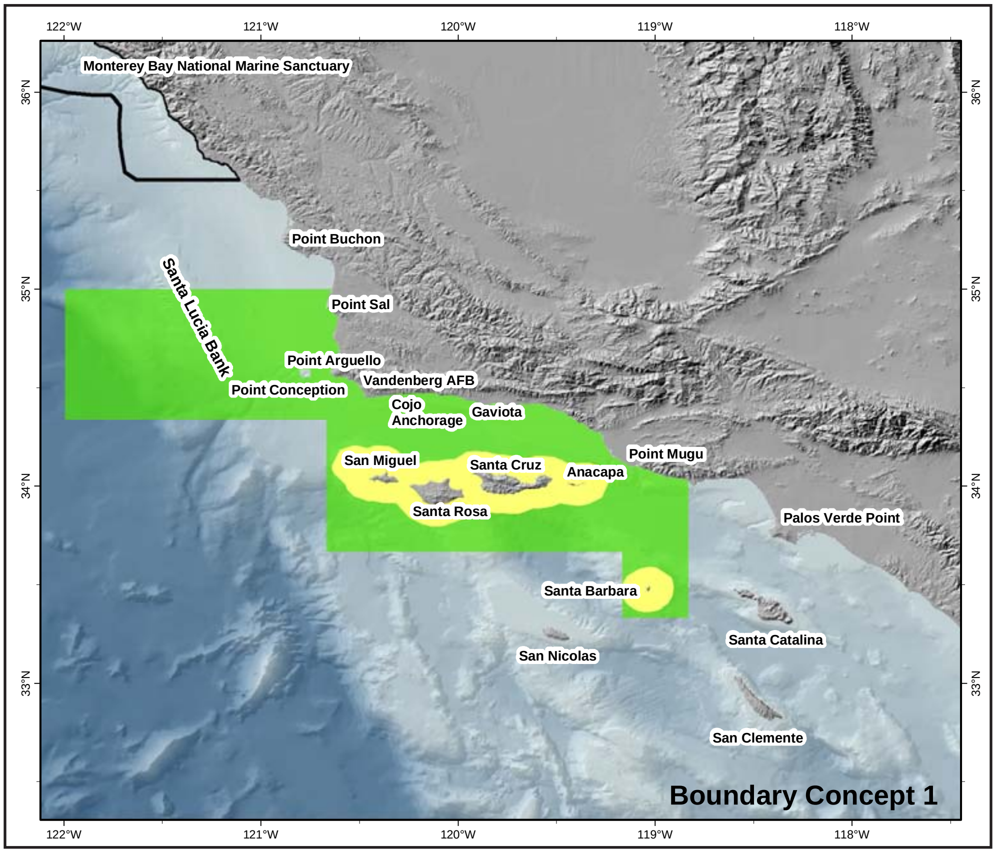
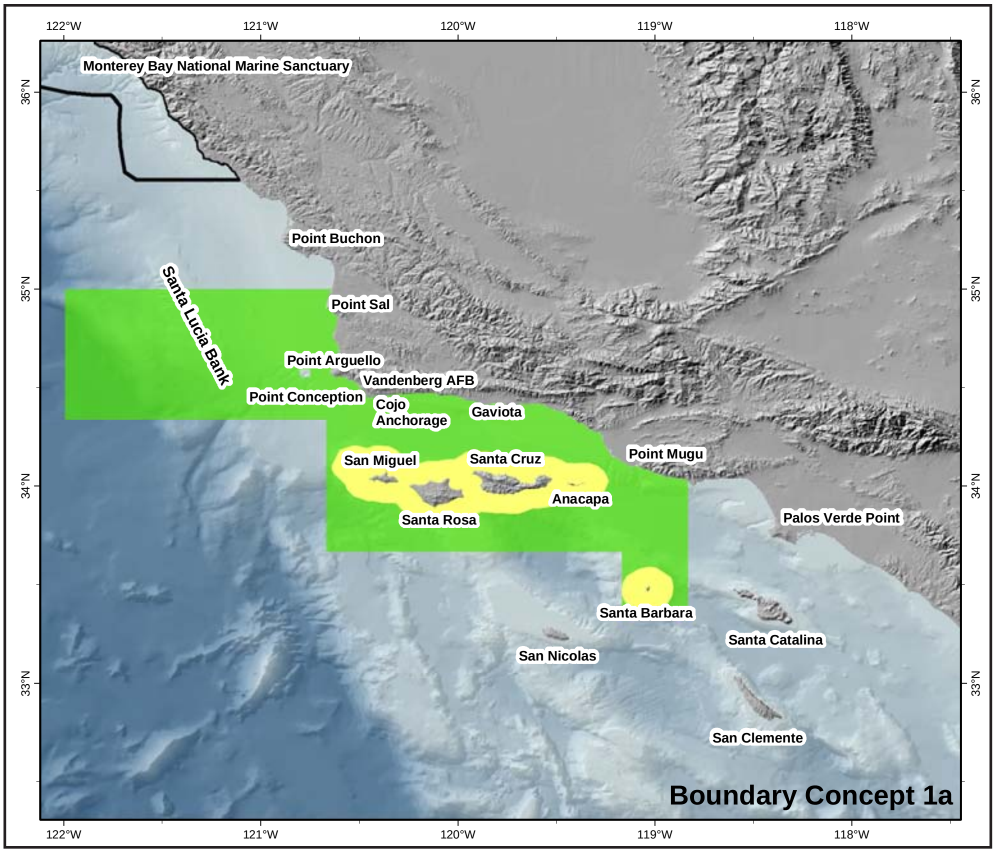
Appendix A. Spatial extent for the proposed boundary concepts**.**



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Point Sal
Point Arguello
Vandenberg AFB
Point Conception
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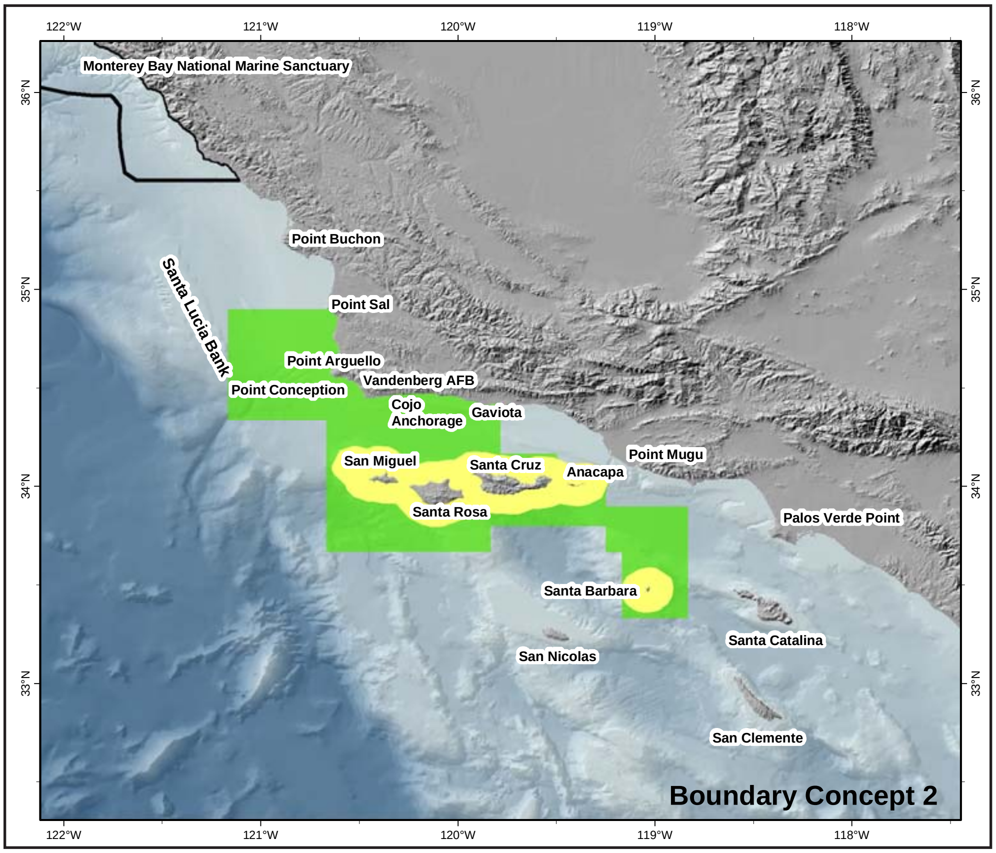
Boundary Concept 1a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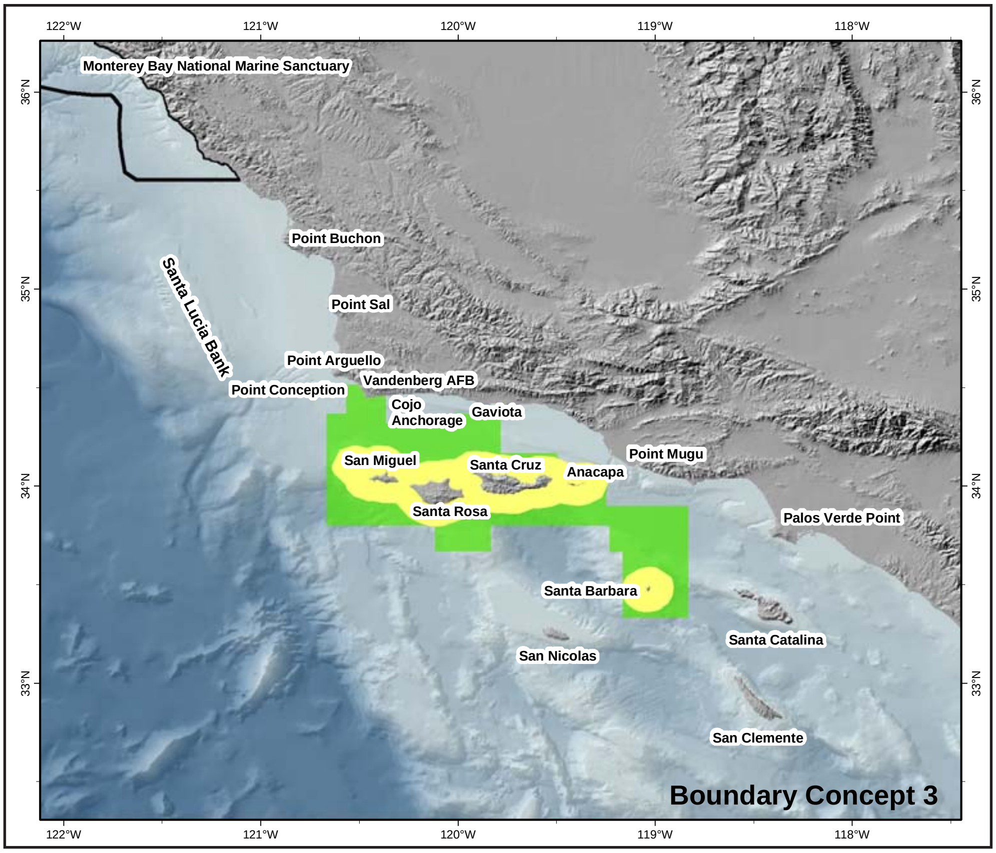
Boundary Concept 2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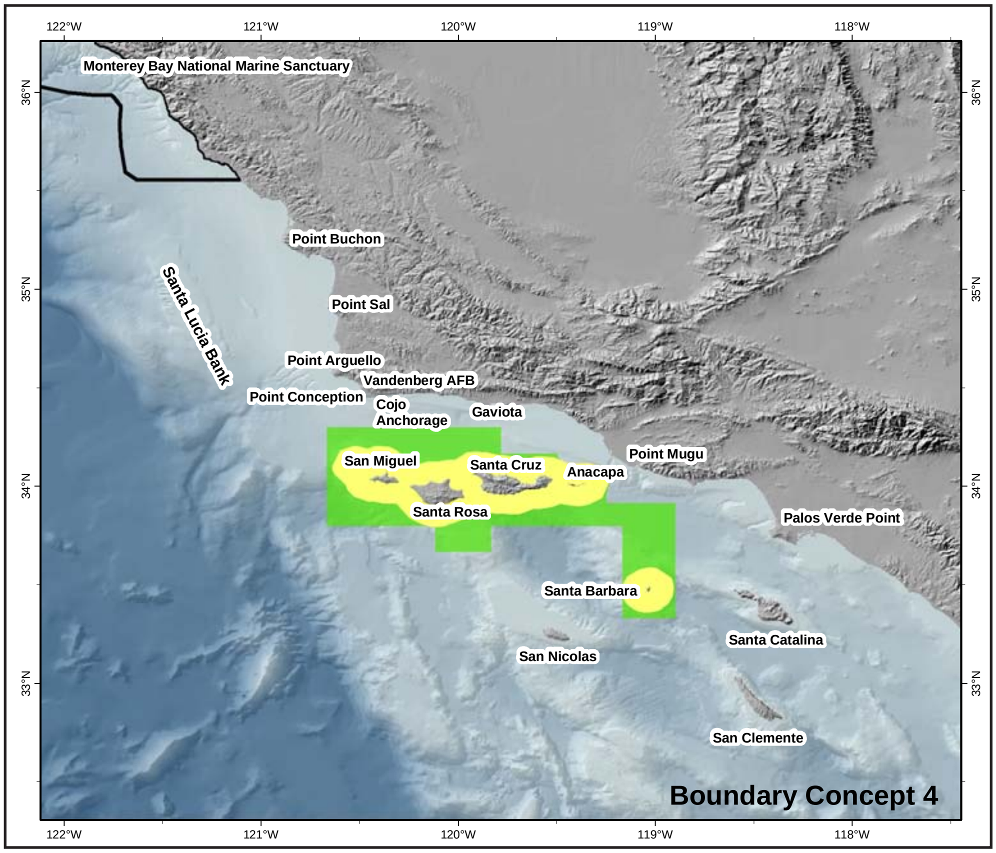
Boundary Concept 3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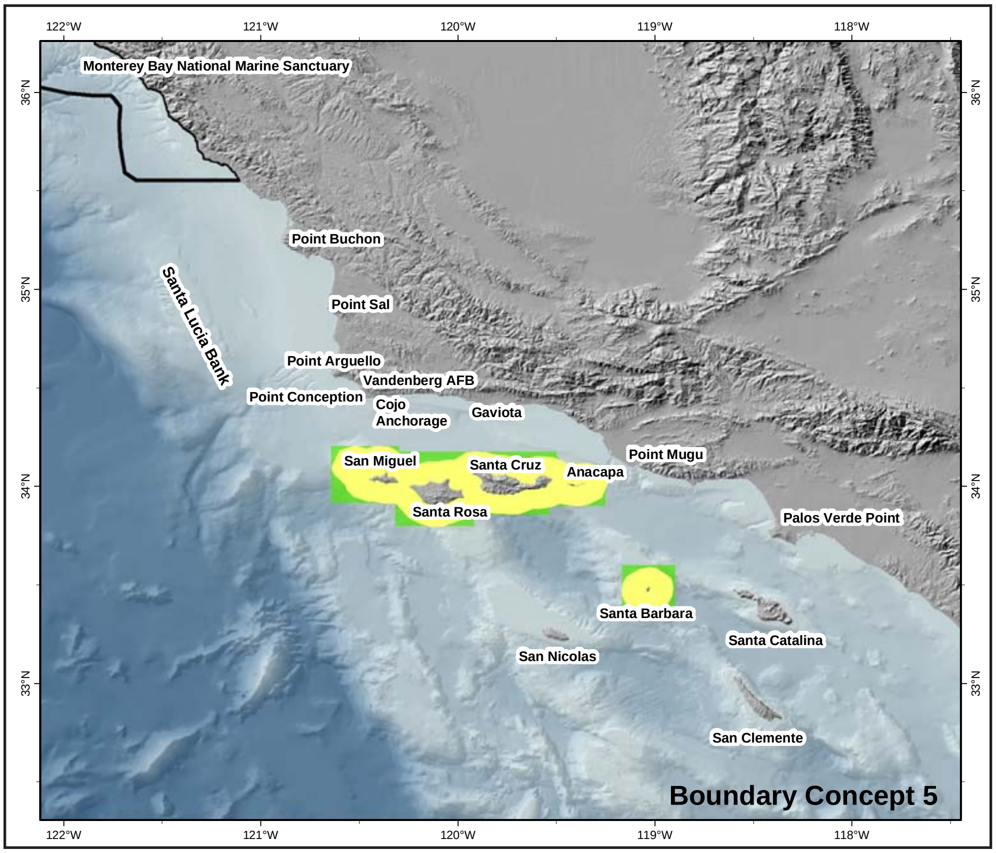
Boundary Concept 4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San Clemente
Boundary Concept 5

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