Paper Title: **A Biogeographic Assessment of Fauna in California Marine Sanctuaries**

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Abstract:
NOAA's Center for Coastal Monitoring and Assessment has recently collaborated with the National Marine Sanctuary Program to assess large-scale biogeographic patterns of marine fauna in three California sanctuaries. Using ArcGIS and ArcGIS Spatial Analyst and Geostatistical Analyst extensions, CCMA conducted a suite of quantitative spatial and statistical analyses based on the distribution and abundance of species found in the study area. The sanctuaries are conducting a joint review process to update sanctuary management plans. The management plans for these sanctuaries have not been updated for more than 10 years and the status of the natural resources and their management issues in and around the sanctuaries may have changed. In addition, significant accomplishments in research and resource assessments have been made with the region. Thus, it is important to incorporate new and expanding knowledge into the revised management plans for these sanctuaries.

Paper Body:

BACKGROUND

The mission of NOAA National Ocean Service's (NOS) National Marine Sanctuary Program (NMSP) is to serve as the trustee for a system of marine protected areas, to conserve, protect, and enhance their biodiversity, ecological integrity, and cultural legacy. To assist in accomplishing this mission, the NMSP has developed a partnership with NOAA's National Centers for Coastal Ocean Science (NCCOS) to conduct biogeographic assessments of living marine resources in all National Marine Sanctuaries to characterize and assess the distribution of marine resources that occur within and adjacent to the sanctuaries. The NMSP and NCCOS's Biogeography Program have developed a five-year plan to implement the assessments across the system of National Marine Sanctuaries. The biogeographic assessment process as defined in the plan is used to conduct studies that are designed to address research needs and support a wide array of sanctuary management decisions. In general, the priority to implement the biogeographic assessments is based on the need to update sanctuary management plans. Thus, the joint efforts are systematically proceeding to work with each sanctuary to provide assessments of species' distributions and their associated habitats in a region.

Since establishment, many of the sanctuaries have witnessed increased pressure on marine resources from natural and anthropogenic phenomena, including climatic variation and degradation of habitats. In order for the NMSP to increase management capabilities, it is imperative that the spatial and temporal distributions of biota and habitats within sanctuaries be delineated. Biogeography provides a framework to integrate species distributions and life history data with information on the habitats of the region to characterize marine resources in a sanctuary. When the biogeographic data are integrated into a Geographic Information System (GIS), it enables users to visualize species' spatial and temporal distributions and conduct ecological forecasts to assess potential changes in species distributions that may result from a variety of natural and anthropogenic perturbations. In addition, based on specific ecological metrics (e.g., diversity), biologically significant areas can be delineated. The final document provides the results of the GIS-based assessment conducted for the National Marine Sanctuaries off north/central California to initiate development of a biogeographic assessment capability for the sanctuaries.

BIOGEOGRAPHIC ASSESSMENT OFF NORTH/CENTRAL CALIFORNIA

The initial biogeographic assessment outlined in the five-year NCCOS/NMSP plan was implemented in the spring of 2001 to conduct a 24-month investigation to assess biogeographic patterns of selected marine species found within and adjacent to the boundaries of three contiguous West Coast National Marine Sanctuaries. These sanctuaries, Monterey Bay, Gulf of the Farallones, and Cordell Bank, are conducting a joint review to update sanctuary management

plans. To support the management plan review process, the Biogeography Program is leading a partnership effort to conduct a robust analytical assessment to define important biological areas and time periods within the region. The document represents the results of the first of two assessment phases. Phase I provides data, analytical results, and descriptions of ecosystems and their linkages; it also identifies data gaps, and suggests future activities to be addressed in Phase II.

Phase I of this effort was a biogeographic assessment of existing data on the distribution and abundance of marine fishes, marine birds, marine mammals and their associated habitats. The study did not attempt to define biogeographic patterns along the entire U.S. West Coast nor in very near-shore environments (e.g., estuaries). Rather, the study area was restricted to the marine area from Point Arena in Mendocino County (38˚54'32" N, the northern bound) to Point Sal in northern Santa Barbara County (34˚54'05" N, the southern bound). (Figure 1.)

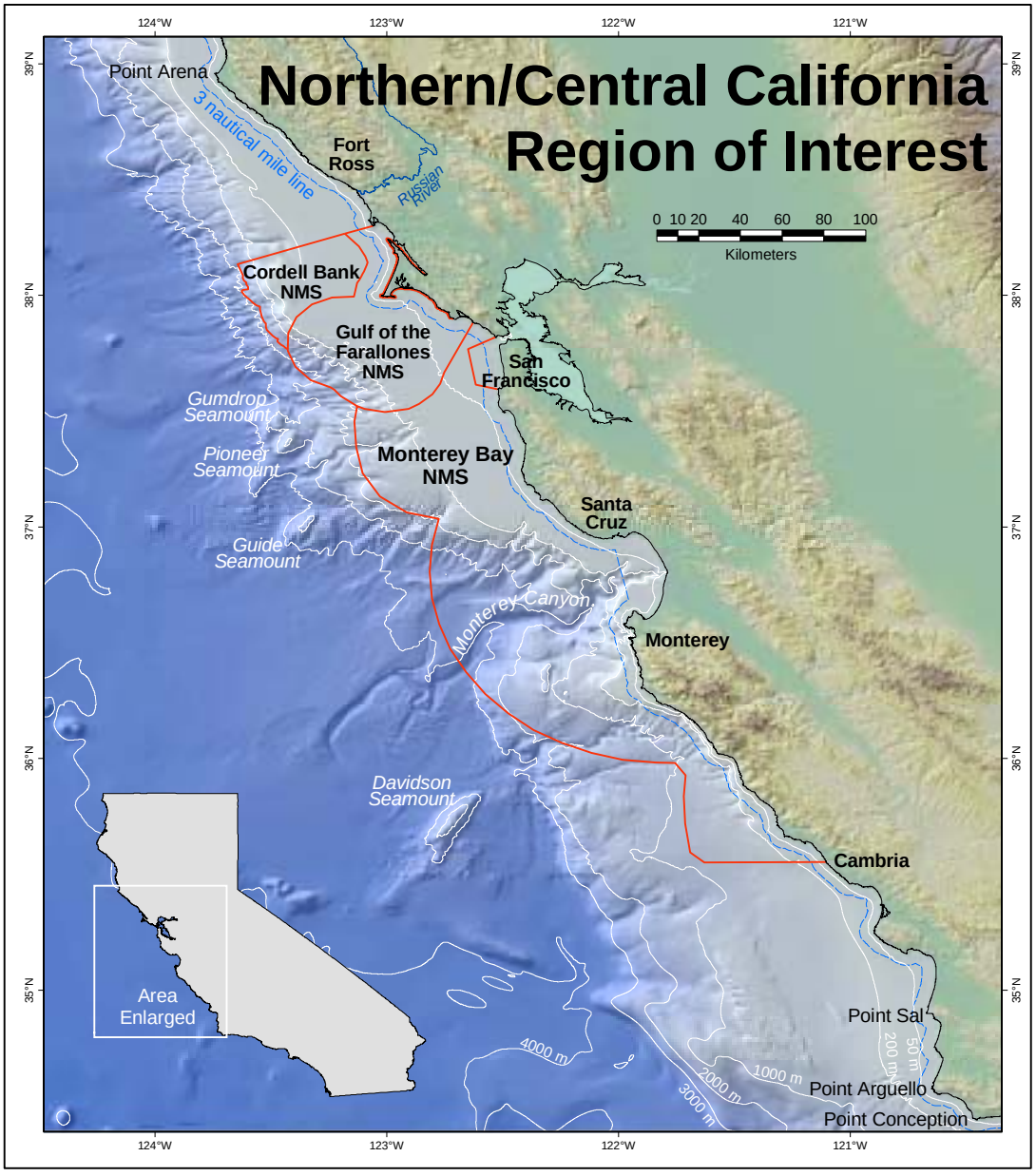

Figure 1. Study Area

This relatively large study area enabled the assessment to extend beyond the limits of current sanctuary boundaries to place study results in the context of north/cental California Coast biogeographic patterns. The biogeographic analyses are based on a synthesis of many data sources that were provided by project partners and contributors. Results of this assessment are being used to assist the NMSP in addressing issues such as evaluating potential modification of sanctuary boundaries and changes in management strategies or administration, based on the principles of biogeography.

The biogeographic assessment was formulated around three closely integrated study components: (1) an *Ecological Linkages Repor*t, (2) biogeographic analyses, and (3) development of GIS data for incorporation into NMSP's Marine Information System (MarIS). (Figure 2.) The majority of the results from the assessment are presented as a suite of GIS maps to visually display species' biogeographic patterns across the study area. The body of the document provides examples of the entire suite of digital map products found on the companion CD-ROM and located on the Web at http://biogeo.nos.noaa.gov/products/canms_cd/. The spatial data and additional information, such as digital species distribution maps and additional details on analytical methodologies, are also presented on the CD-ROM.

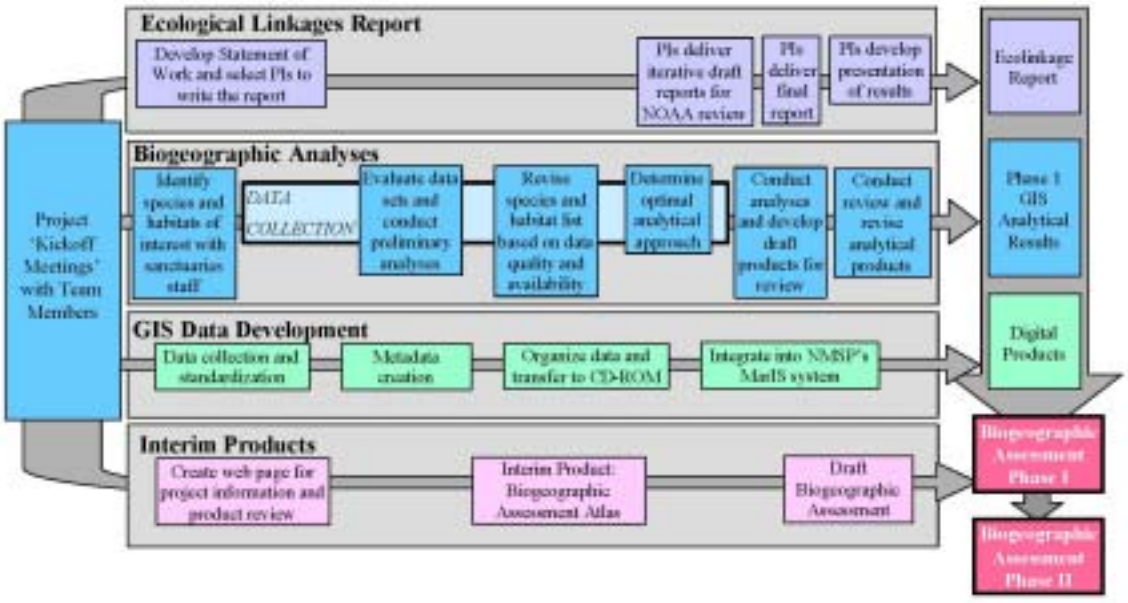

Figure 2. Project flow diagram of Phase I work

Ideally, biogeographic assessments utilize significant amounts of data that have been collected over the entire spatial extent of the study area over a long time period. However, such a wealth of data is rarely available. In many instances, little information exists to accurately characterize the study area or associated living marine resources. This paucity of comprehensive data can limit the efficacy of biogeographic assessments, but additional analytical methods can be employed to complement the assessment. In addition to analysis of databases, two additional tasks were used to conduct the assessment. First, a synthesis of existing information was compiled and presented in the *Ecological Linkages Report* to incorporate qualitative information about species, habitats and ecological characterization of marine ecosystems and linkages within the study area. Second, species habitat suitability modeling efforts were conducted for fishes to define potential species' distributions based on known habitat affinities and physiological limitations. The potential species distribution maps are displayed as a series of digital maps found on the CD-ROM.

In addition, a critical component of the assessment process was the extensive effort to have the data, analytical approaches, and results peer reviewed. Initial results from the suite of biogeographic analyses were presented to experts familiar with the marine ecosystem off north/central California, as well as to the originators of the data sources, in an attempt to improve the analyses. The role of expert review and input was considerable, and the contributions made by experts have significantly enhanced the assessment. In June 2002, project team members traveled to Seattle, WA and Santa Cruz, CA to discuss and present the results of the Interim Product to West Coast experts. Suggestions were incorporated and a Web site was created to further disseminate analytical products prior to an additional series of meetings. The final suite of review meetings was held in October 2002 in San Francisco and Monterey, CA and in Seattle, WA. At that time, NOS staff invited members of the scientific community to review the preliminary results of the biogeographic analyses. Comments from the October meetings were compiled and reviewed by project personnel, who either incorporated the experts' suggestions or provided explanations as to why they did not. Thus, the integration of the synthesis of ecological linkage information, statistical analyses of existing databases, species habitat suitability modeling, and peer review, resulted in the product “A Biogeographic Assessment off North/Central California: to Support the Joint Management Plan Review for Cordell Bank, Gulf of the Farallones, and Monterey Bay National Marine Sanctuaries: Phase I – Marine Fishes, Birds and Mammals”.

ECOLOGICAL LINKAGES REPORT

Section 1 of the document presents a synopsis of the *Ecological Linkages Report* and provides the context to understand overall biogeographic product results, relative to the ecosystems along the California Coast. The bulk of the report describes ecosystems in the region, key species associated with these ecosystems, and linkages between and among them. In addition, the report presents latitudinal range distributions of species groups, including algae, invertebrates, fish, marine birds and marine mammals. These maps provide an overview of marine species’ distributions and biogeographic transitions along the entire west coast of North America. The report also includes important information on ecosystems not easily studied at this large scale via GIS, particularly near-shore communities. The complete report is on the CD-ROM that accompanies the document.

Key West Coast Biogeographic Transitions

- Benthic algae exhibit three major biogeographic transitions at Point Conception, Puget Sound, and the Gulf of Alaska. At all latitudes, the average number of algal species increased with depth from high to low intertidal and subtidal zones.

- Five major transitions occur in distributions of marine invertebrates found in California waters: at Point Conception, Monterey Bay, Puget Sound, and off the coasts of British Columbia and southeastern Alaska. At all latitudes, greater numbers of gastropod species occur in the euphotic zone and on the continental shelf than on the continental slope.

- Pacific coast fishes exhibit two major biogeographic transitions. A biogeographic transition at the Bering Sea is relatively abrupt, corresponding to the northern limit of distributions of over 100 fish species. A broader biogeographic transition occurs along the southern coast of California between Baja California and Point Conception. A few minor shifts in fish species composition occur between Point Conception and the Bering Sea, particularly at Monterey Bay.

BIOGEOGRAPHIC ANALYSES

Section 2 introduces the methods used to conduct the assessment and the results of the biogeographic analyses of selected marine biota off the north/central California coast. This component of the assessment is the cornerstone of the overall biogeographic product to support the NMSP joint management plan review process. The data, analyses, and supporting information are linked using statistical and GIS tools to portray in space and time significant biological areas or “hot spots.” The term “hot spot” is defined based on specific criteria or metrics (e.g., species diversity, high species abundance). The vast majority of the analytical results are

displayed as a series of maps to identify biologically significant areas in the study area.

There are many different ways to analyze and organize biogeographic information; however, to efficiently support the management plan process, only a limited number of analytical options were invoked. These analyses were selected based on reviewers' comments on the Interim Product, feedback from technical review meetings, and peer review workshops. Thus, a very difficult step in the project was to select and rely on the most appropriate data and analyses to characterize the various components of the marine ecosystem that exist in the study area. The inclusion of the GIS-based products on the companion CD-ROM will enable NOAA staff, advisory councils, and research partners to query data and information relevant for questions and issues that are not specifically addressed in this product.

The first analyses focused on a suite of assemblages analyses to assess the biogeography of fishes and a few macro-invertebrates. Primary data included fisheries-independent data, such as those collected by researchers from the National Marine Fisheries Service (NMFS), and fisheries-dependent data, such as those collected by the California Department of Fish and Game (CDF&G) for recreational fisheries. These data sets, although not spatially or temporally comprehensive, are the most robust data sets that exist for the entire region, and provide considerable information on the distribution of several hundred fish and invertebrate species. (Figure 3.)

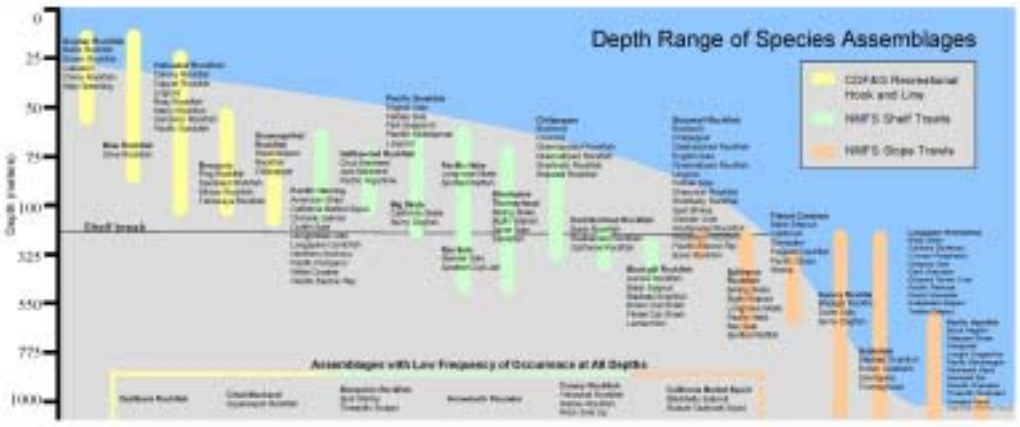

Figure 3. Overlap between three datasets that analyzed demersal fish

Key Assemblage Analysis Results for Fishes

- Species assemblages and site groups were distinguished through 1-Pearson correlation coefficients with average means clustering technique. Species assemblages from CDF&G recreational, NMFS shelf, and NMFS slope data sets were more resilient than assemblages from the NMFS midwater data set, emphasizing the ephemeral nature of the midwater environment and the smaller midwater data set. The site groups were displayed spatially in a GIS and the average frequency of occurrence of species assemblages was calculated to show the interaction between species assemblages and site groups (i.e., where species assemblages were caught).

- The interaction of the site groups with environmental parameters that were not used to create the groups can be informative about what conditions are affecting species distribution. Depth was highly significant between site groups in all data sets, emphasizing the importance of depth in structuring marine biological communities. Analyses comparing the site groups to other environmental parameters (latitude, sediment size, and bathymetric complexity) were inconclusive, as these parameters often had significant interactions with depth. Latitude was

found to have a significant effect only on the midwater assemblages in 1999; there were no discernible latitudinal breaks within the other four assemblages.

- Diversity and richness can be used to delineate fish hot spots. While little variation in diversity and richness were explained by depth (r^2 =0.04 between both richness and depth and diversity and depth), trawls with high diversity tended to be deeper than trawls with high richness. Trawls with high species richness of rockfish (*Sebastes* and *Sebastolobos*) followed the 200-meter contour, which approximates the break between the shelf and slope.

- Even though richness and diversity are correlated, the maps showed different results. Hot spots in either richness or diversity were identified in all three sanctuaries. In Cordell Bank NMS, there was a group of trawls with high richness near the center of the sanctuary, and another group of trawls with high diversity in the region around the northwest boundary. There was also a large collection of trawls with either high richness or diversity straddling the boundary between Gulf of the Farallones and Monterey Bay NMS. There were lines of high diversity along the 200-meter depth contour north of CBNMS boundary and from Lopez Point south to the southern edge of the study area.

- Rick Starr, a marine advisor for the University of California Sea Grant Extension Program, addressed the implementation of rockfish no-take areas with two important recommendations. First, in order to properly manage marine ecosystems, fish assemblages must be better understood. Starr stated that once these assemblages are delineated, steps can be taken to ensure that each assemblage receives proper management. This study defined assemblages of fishes for near-shore, shelf, slope and midwater ecosystems. The results of the community metrics and species assemblages are displayed in the document as a series of maps and tables.

- The second recommendation by Starr was to delineate rectangular no-take areas that cover 20-50 km of the coast and extend west to the edge of the continental shelf. From a biogeographic viewpoint, the results of the spatial analyses coincided with that recommendation, and also identified that deep-slope communities significantly contribute to ground fish biogeographic patterns. Because assemblages follow bathymetry at the scale of this analysis, setting aside an area from the coast through the continental slope could protect all demersal species assemblages identified in this study.

Key Species Habitat Suitability Model Results

Due to limitations in the spatial and temporal extent of data and to complement the assemblage analyses of fishes, species habitat suitability index (HSI) models were developed. This was done primarily to accommodate the paucity of empirical data in near-shore areas and to target species of special significance to the sanctuaries. An extensive literature review of the life history characteristics of individual species resulted in information on species' habitat affinities that were converted into quantifiable habitat suitability index values. The life history information and associated species habitat suitability index values are found on the CD-ROM. These derived values were input into an equation and used to predict potential species' distributions based on their affinity for the mosaic of bathymetry and bottom habitats found throughout the region. The species habitat suitability models were validated through statistical and spatial analyses, using fishery-independent survey data.

- Bottom substrate and water depth were statistically significant variables used to predict the potential distribution of species based on their habitat affinities. (Figure 4.)

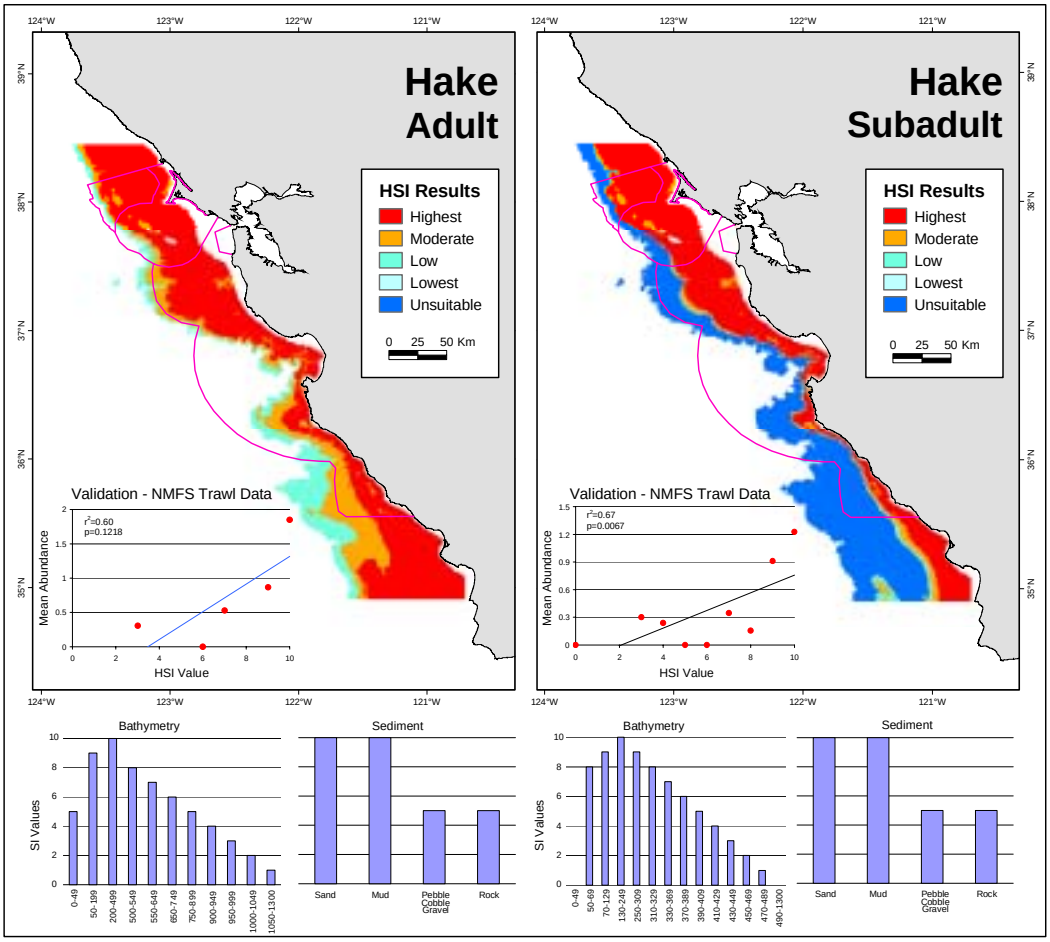

Figure 4. Potential distribution of habitat suitability for adult and subadult Hake.

- Habitat suitability models for an assemblage of rockfish were developed and results indicated that rocky habitats located on the shelf were identified as potential hot spots for adults; whereas mud and sand substrates on the shelf were delineated as potentially important habitats for subadult rockfish.

- Map overlays of all species' HSI models resulted in the delineation of a broad range of important areas that cover the majority of the continental shelf within and adjacent to the three sanctuary boundaries.

Key Marine Bird Analytical Results

The Biogeography Team contracted principal investigators David Ainley and Glenn Ford (of H.T. Harvey and Associates and R.G. Ford Consulting Co.) to work with the NOAA project team to define and assess biogeographic patterns and important areas for marine birds (and mammals) found within the study area. These experts used regression analysis, GIS and over eight spatial data sets to develop over 50 maps that display marine spatial and temporal patterns, and estimated densities and diversity for selected marine birds in the study area. The resulting maps and discussion summarize important locations, time periods, and life history information for marine birds in the study area. Phase II of the assessment may include a technical report on the methods and results summarized in the Phase I map and tabular products.

- In general, the marine birds of the three sanctuaries are dominated in number and biomass by seasonally resident, nonbreeding species, such as sooty shearwater, pink-footed shearwater, northern fulmar and black-legged kittiwake. The richness of the food web is the primary factor that attracts these species to the region.

- Seasonal, interannual and decadal variation of the regional biogeography of marine birds is influenced by the vagaries of marine climate, which is driven by the California Current System and local upwelling centers. Therefore, the biogeographic patterns of marine birds are not static and exhibit a dramatic spatial and temporal variation, both in species composition and species abundance. (Figure 5.)

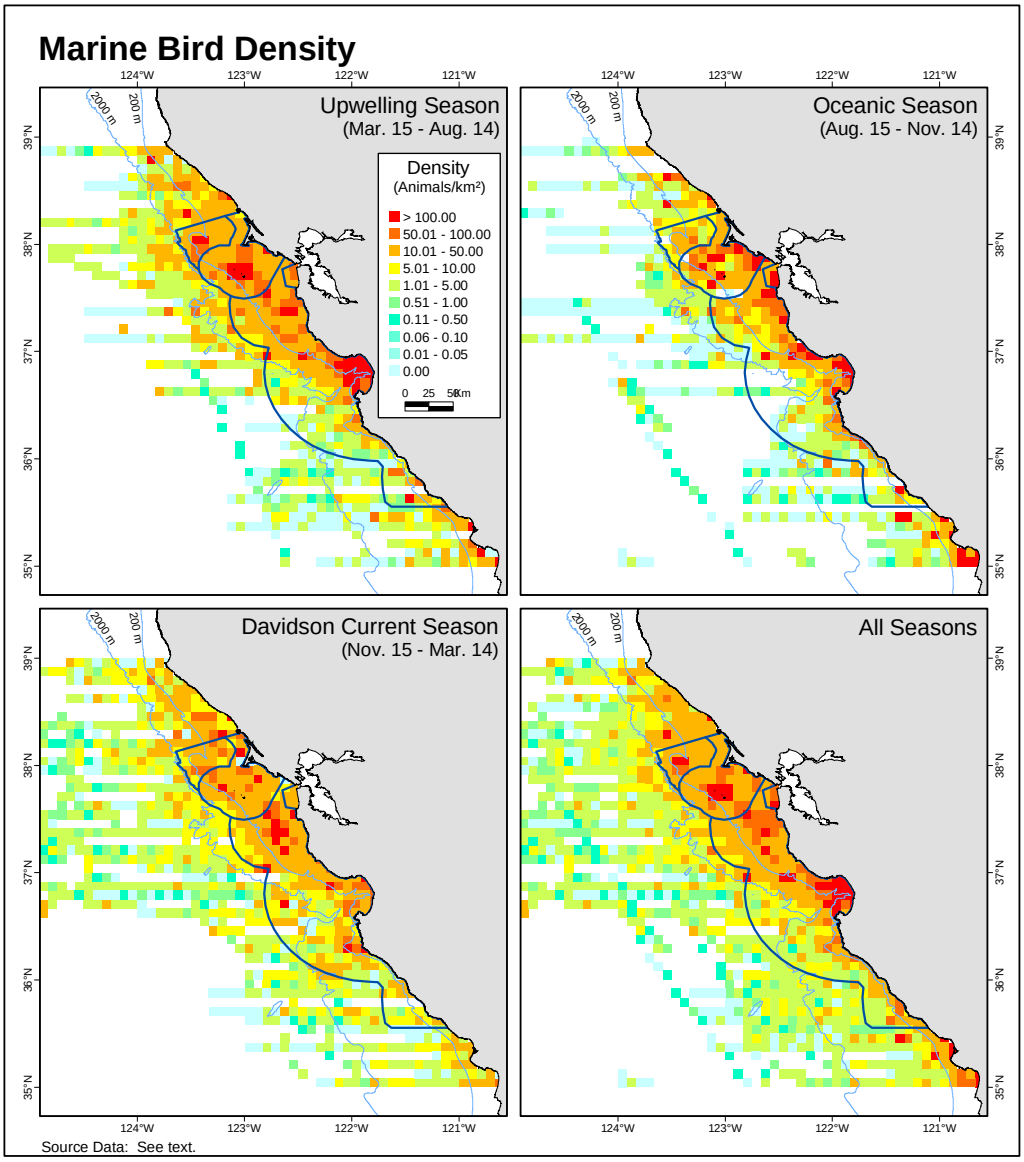

Figure 5. Marine bird density by season and for all seasons.

- The Gulf of the Farallones, the area lying inside a triangle defined by Point Reyes, the Farallon Islands and Año Nuevo Island, is the most important area for marine birds in California. The

reasons are: (1) large and taxonomically diverse, demographically related populations breed at the three afore-mentioned sites; and (2) an unparalleled diversity of habitat (e.g., San Francisco Bay tidal plume, shallow sandy shelf, rocky reefs, submarine peaks, and the upper continental slope) attracts a variety of migrant and seasonally resident species.

- A "halo" of individuals was apparent around important breeding sites, such as the Farallon Islands and Año Nuevo Island. This pattern is the result of breeding individuals searching for food, but going only as far as necessary to provide for their young. The Farallon "halo" for ashy storm-petrel, western gull, common murre, rhinoceros auklet and Cassin's auklet extends substantially west of the Gulf of the Farallones National Marine Sanctuary.

- The marine birds of the Gulf of the Farallones/Cordell Bank NMS (as defined above) and the birds of the Monterey Bay NMS are associated with different habitat features. The Gulf of the Farallones has islands and a relatively broad shelf, while Monterey Bay has a relatively narrow but sheltered shelf, cut by an immense, deep submarine canyon. The greater oceanic influence and lack of breeding islands in the Monterey Bay NMS drive the marine bird species groups there.

Preliminary Marine Mammal Analytical Results

The Biogeography Team contracted principal investigators David Ainley and Glenn Ford (of H.T. Harvey and Associates and R.G. Ford Consulting Co.) to work with the NOAA project team and local marine mammal experts to identify biogeographic patterns and important areas and time periods for marine mammals occurring in the study area. NOAA/NMFS scientists provided additional marine mammal sightings data along the entire West Coast to aid in analyzing marine mammal biogeographic patterns relative to the study area. The "bird and mammal team" used a GIS to develop a preliminary series of maps that show occurrence patterns and important areas and time periods for 13 marine mammals in the study area. Phase II of this assessment will: incorporate additional data, develop additional marine mammal species and species group maps, and attempt to develop selected community metrics analyses across species and time periods. A technical report on this work is also planned.

Spatial Patterns. The spatial occurrence of marine mammals relative to large bathymetric features (e.g., shelf, upper slope, lower slope) and discrete physiographic features (e.g., seamounts, banks, canyons, points and islands) varied by species and ocean condition. The occurrence patterns of most marine mammals are strongly linked to the highly variable ocean conditions of the study area, which significantly affect the distribution of prey availability. In Phase II of this work, when the data sets are more spatially and temporally robust, summary analyses will be conducted to identify important areas and time periods across marine mammal groups.

Large Cetaceans. Important areas for the large cetaceans varied by species: the coast and inner shelf were important for the gray whale; the outer shelf, slope, and deep ocean were important for the humpback and blue whales; and many important areas for large cetaceans were identified seaward of the sanctuary boundaries.

Small Cetaceans. Review of the maps indicated that important areas for the relatively abundant small cetaceans were the outer shelf and upper slope, Monterey Canyon, Sur and Lucia Canyons (west and south of the Monterey Bay NMS), Pioneer Canyon (west of the Monterey Bay NMS), Ascension, Cabrillo, Año and Carmel canyons, Cordell Bank (and to the north of the Cordell Bank NMS boundary), and the San Francisco Bay tidal plume area (e.g., harbor porpoise). Smaller cetaceans were also relatively abundant in areas that include canyons, and in locations beyond sanctuary boundaries, but within the study area.

Pinnipeds. Important areas for resident breeders (e.g., harbor seal, Steller sea lion) were inner and outer shelf habitats, and for northern elephant seal, pelagic deep ocean habitats seaward of sanctuary boundaries. Seasonal visitors (e.g., northern fur seals) occurred mostly in slope and deep ocean habitats, seaward of sanctuary boundaries.

Temporal Patterns. The patterns of seasonal occurrence for marine mammals varied by species. In Phase II of this work, when the data sets are more complete, summary spatial and temporal analyses across marine mammal groups will be conducted.

Large Cetaceans. The seasonal occurrence of the larger cetaceans in the study area reflected their migrations. The Davidson Current season was important for the gray whale, a period when this species is migrating either south or north. Several species of the large cetaceans migrate to forage seasonally in the study area, a pattern reflected in the relative abundance of the humpback and blue whales during the Upwelling and Oceanic seasons. (Figure 6.)

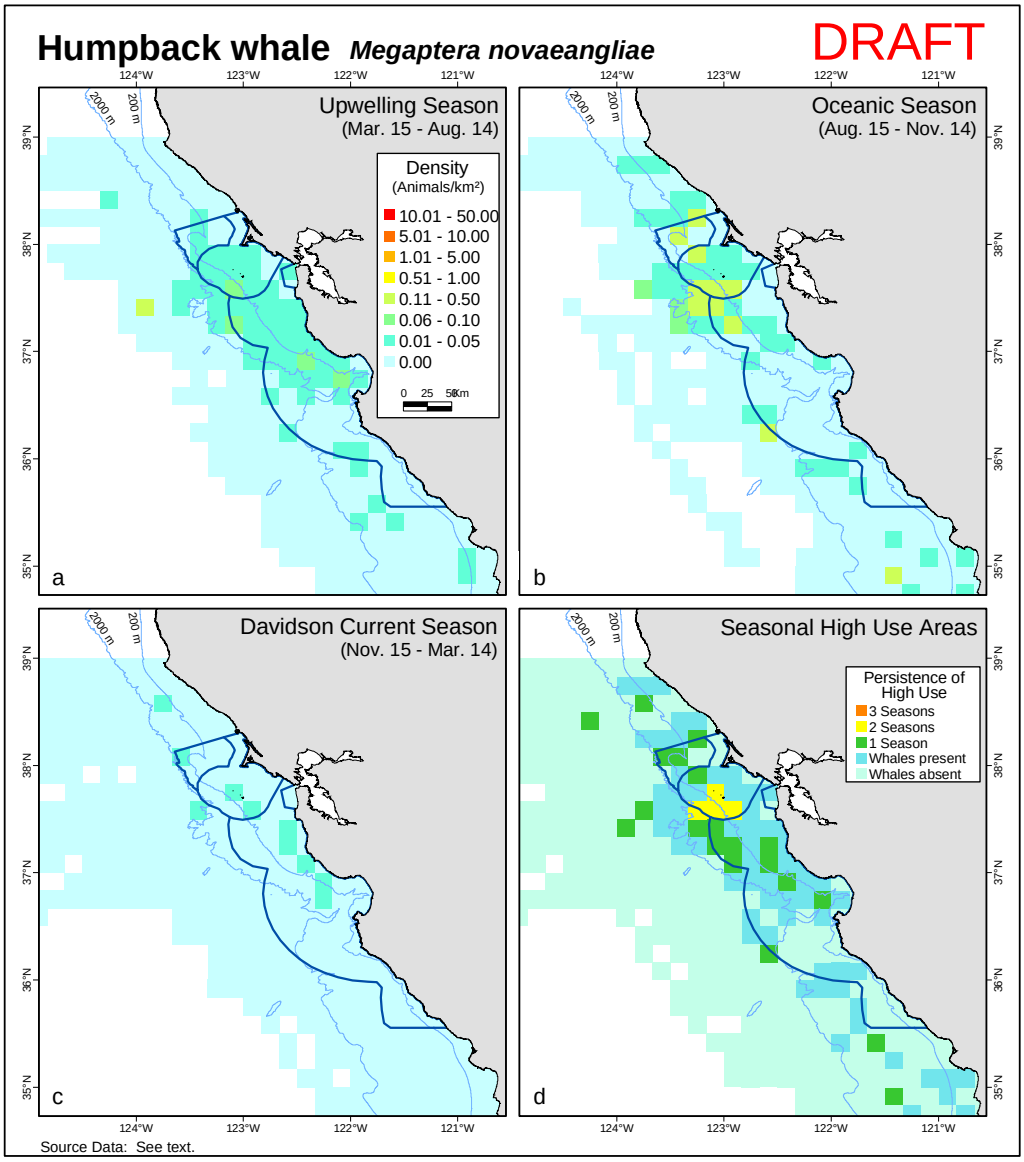

Figure 6. Humpback whale seasonal at-sea densities and high use areas.

Small Cetaceans. An important time period for the Pacific white-sided dolphin (the most abundant small cetacean in this study) was the Oceanic season. Important time periods for the other

relatively abundant smaller cetaceans (northern right-whale dolphin, Risso's dolphin, Dall's porpoise) could not be determined in this preliminary assessment.

Pinnipeds. The seasonal occurrence of pinnipeds was associated with the breeding cycles of the species. Important time periods for the relatively abundant northern fur seal were winter and early spring (Davidson Current and early Upwelling seasons), which reflected the pelagic offshore distribution along the West Coast during the nonbreeding season. The relatively abundant California sea lion was present year-round in the study area, with densities greater during the Oceanic season (just after breeding) and Davidson Current season (before the breeding season). Elephant seals, Steller sea lions, and harbor seals were present in sanctuary waters year-round in relatively low numbers; and important time periods for these infrequently sighted species were inconclusive due to differences in behavior and low abundance (e.g., at-sea sightings typically consist of single individuals or small groups of two or three, elephant seals are rarely at the surface, and Steller sea lions are a threatened species).

INTEGRATION OF ANALYSES

The integration of analyses across taxa occurs in Section 3. Many possible combinations of the data layers could be integrated for the biogeographic assessment. Because of differences in sampling design, it was not appropriate to combine data from different taxa (e.g. birds and fish) in order to calculate community metrics. Therefore, to minimize confounding results and to focus on the "protection of biodiversity" component of the NMSP mission, diversity and density were calculated separately for each taxon and the resulting patterns were overlaid to identify biologically important areas across species groups. Spatial interpolation methods were applied to survey data to provide a clearer picture of the distribution of diversity and density within the study area. Hot spots were defined as regions in which diversity or density was estimated to be in the top 20% for a particular taxon. These hot spots were mapped for fish and birds individually and then combined to show areas of overlap. These areas of significant biological importance contributed to defining and assessing biogeographic patterns within the study area and are discussed in the context of known oceanographic features and Sanctuary boundaries. All of the conclusions listed below should be considered with an understanding of the inherent limitations of the available data and the approaches used to analyze it. A detailed discussion of these concerns is presented in Section 3.

Key Findings of Integration of Analyses

Fish Diversity (Trawl data). Three major areas of relatively high fish diversity (i.e., hot spots) were delineated, as noted below.

- The northernmost hot spot is centered on Cordell Bank, within the northwestern corner of the Cordell Bank NMS, and extends northward along the continental slope to Point Arena.

- The central hot spot is centered at the boundary between the Gulf of the Farallones NMS and the Monterey Bay NMS. The area extends in a southeasterly direction past Point Año Nuevo and ends offshore, north of Monterey Bay.

- The southernmost hot spot is located between Point Sur and Lopez Point and covers the inshore portions of Sur and Lucia Canyons. Portions of this last hot spot, however, were poorly sampled. There is evidence of an additional hot spot straddling the southern boundary of the Monterey Bay NMS.

Marine Bird Diversity

- The interpolated maps of marine bird diversity show one continuous area of high diversity along the continental slope, and, to a lesser extent, along the shelf between Point Arena and Point Sur. Within this area, diversity appears to be highest on, and seaward of, the Farallon Escarpment, in the northwestern corner of the Monterey Bay NMS (Pioneer Canyon), and in the marine region between Point Lobos and Point Sur.

- The Farallon Escarpment in particular received a disproportionate amount of survey effort. The high estimated marine bird diversity for the Farallon Escarpment is, in part, due to high sampling effort.

- A marine bird diversity hot spot was found in the region between Point Lobos and Point Sur. The high residual diversity in this area supports the interpretation that this is a real hot spot and not an artifact of survey effort.

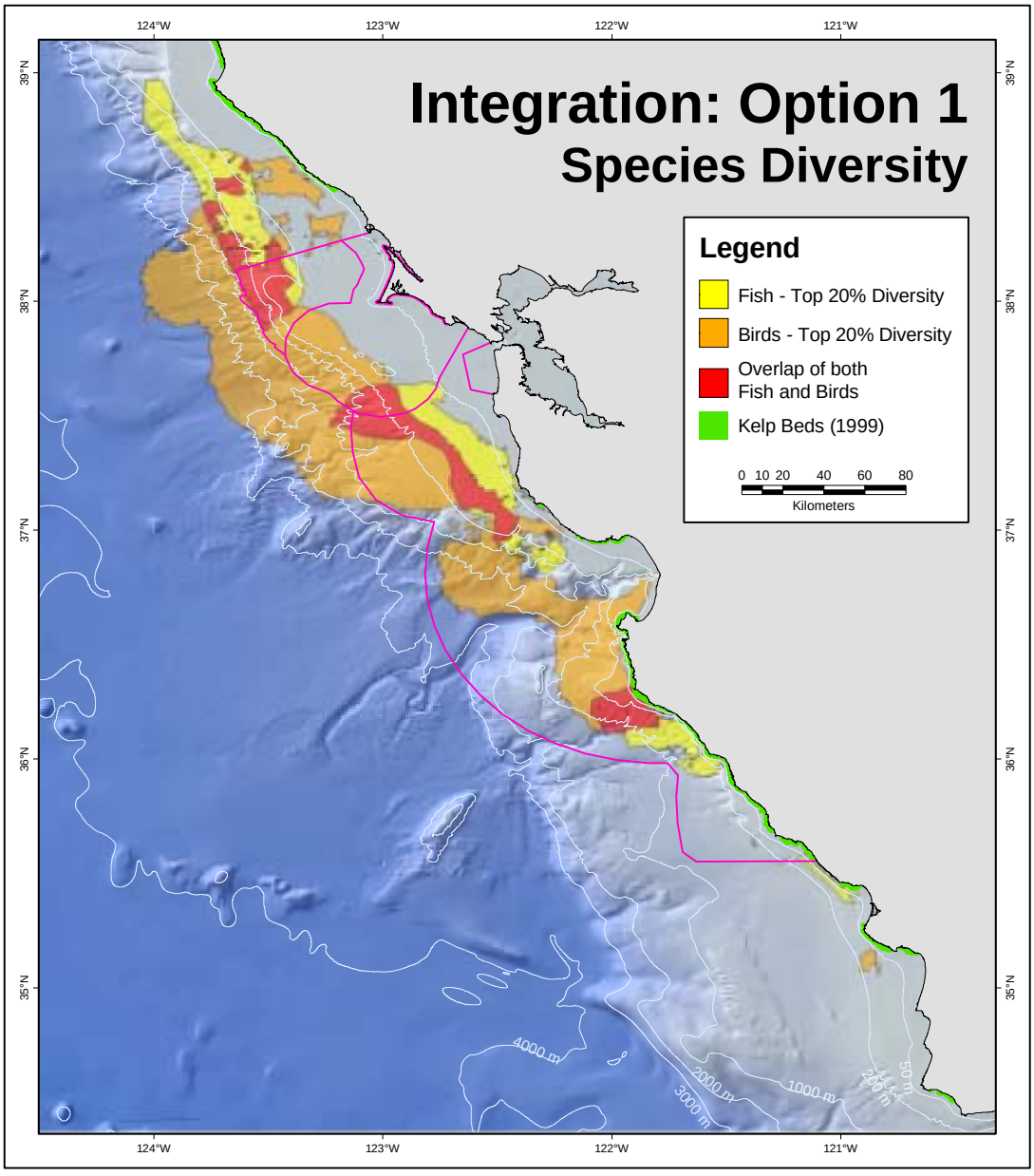

Figure 7. Diversity hot spots for fish and marine birds.

- Marine bird diversity was correlated with survey effort, so some of the “hot spot” diversity areas coinciding with areas of high survey effort may, in part, be influenced by high levels of effort. However, the general patterns of marine bird diversity are robust, and were largely unchanged by methods designed to correct for effort.

Overlap of Marine Bird and Fish (Trawl) Diversity

• Fish diversity shows overlap with the areas of high bird diversity. The northernmost fish hot spot overlaps the marine bird hot spot from Cordell Bank north to approximately midway between Bodega Head and Point Arena. The seaward half of the central fish hot spot overlaps with the area of high marine bird diversity within the Gulf of the Farallones NMS and the Monterey Bay NMS. The northern half of the southernmost fish hot spot overlaps the southern tip of the marine bird hot spot. (Figure 7.)

Fish Density (Trawl Data)

Four major hot spots of fish density were found:

- The northernmost hot spot is found on and to the southeast of Cordell Bank.
- A small hot spot is found off of Point Reyes.
- The largest fish density hot spot covers a large portion of the shelf to the north of Monterey Canyon, the entire area of Monterey Bay, and the near shore waters south to Point Sur. Although portions of this hot spot are found over Monterey Canyon, this fact should be interpreted with caution since the deep canyon waters themselves were not sampled.
- The fourth hot spot is found to the south of Monterey Bay NMS and covers a substantial area of the shelf from Point Estero to Point Sal. This final hot spot is the largest region of high fish density within the mapped area that falls outside of Sanctuary boundaries.

Marine Bird Density

- Marine bird density patterns should be interpreted with caution since they largely reflect the distribution of the two numerically dominant species.
- A large region of high (top 20th percentile) marine bird density exists adjacent to and shoreward of the marine bird diversity hot spot. This density hot spot covers most of the shelf waters of all three sanctuaries, from Point Sur in the south to midway between Bodega Head and Point Arena in the north. The density hot spot extends into Monterey Bay.
- An additional density hot spot exists off of Morro Bay to the south of the Monterey Bay NMS.

Overlap of Marine Bird and Fish (Trawl) Density

- Nearly all of the fish density hot spots are coincident with the two areas of high bird density.
- The hot spots for both metrics are generally confined to the shelf (<200m) with the notable exception of Monterey Canyon which appears as a density hot spot for both groups. The deep Canyon, however, was not sampled in the fish trawl surveys.
- Although the majority of the hot spots for fish and bird density fall within sanctuary boundaries, it is notable that overlapping hot spots for both groups exist to the south of Monterey Bay NMS. (Figure 8.)

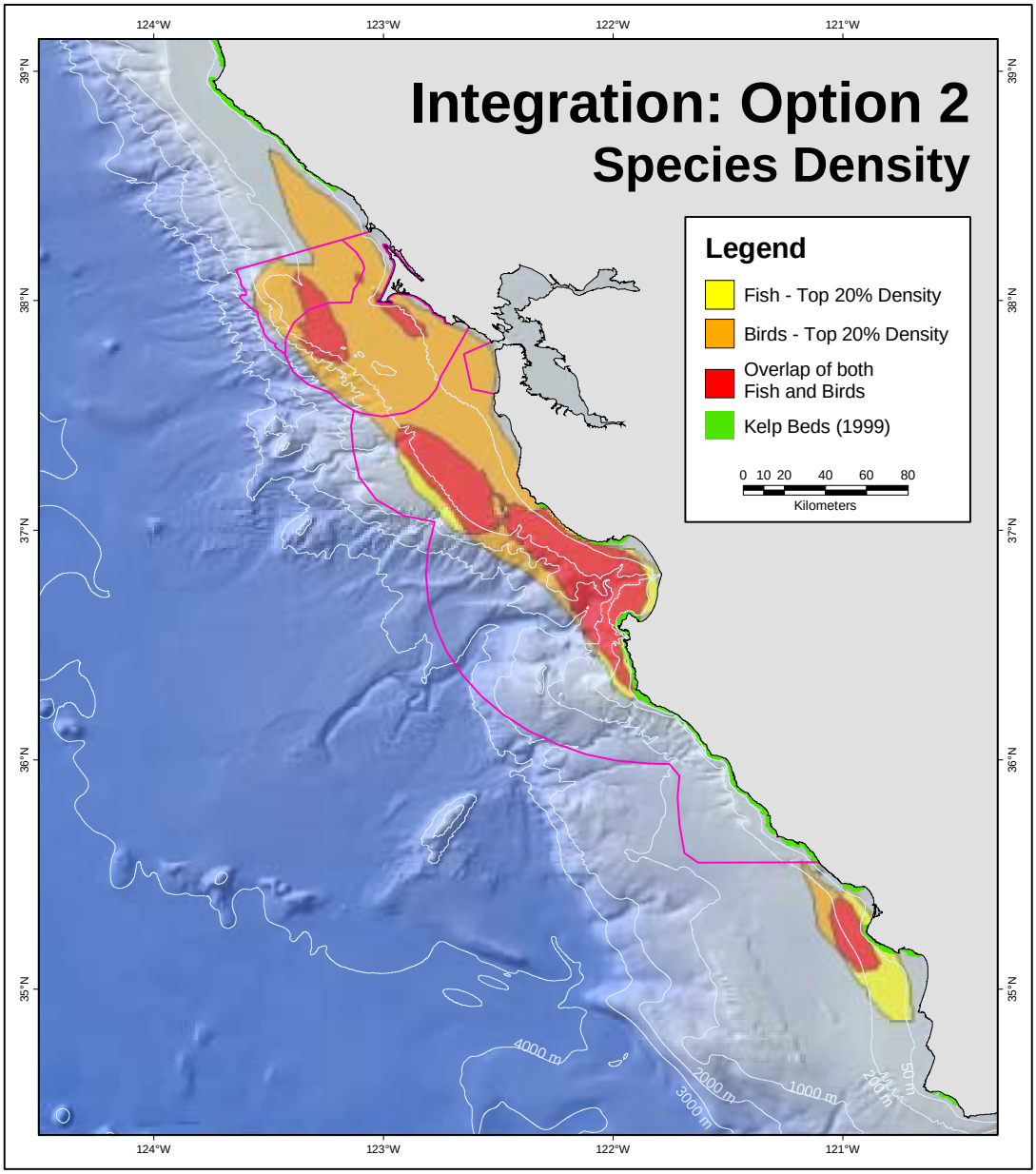

Figure 8. Density hot spots for marine birds and fish.

Overall Integration Summary

- The current Sanctuary boundaries incorporate much of the highest diversity and highest density areas within the region.

- Many of these biologically important regions coincide with known oceanographic and bathymetric features, such as upwelling regions, areas of high bathymetric variance, and the continental shelf break.

- Regions of high diversity and high density outside of the current sanctuary boundaries exist to the north, across much of the shelf and slope, and to the south, in near-shore waters.

- Uneven sampling effort across the study region and a lack of trawl samples to the west of the Sanctuary boundaries limit the scope of any integrated biogeographic assessment.

- Known limitations and biases of the two metrics (diversity and density) exist and are discussed in greater detail within Section 3.

DATA SOURCES AND GAPS

Recognizing that any analysis is only as good as the data upon which it is based, the project team undertook a qualitative evaluation of the data used in this project and identified relevant data gaps. This information is presented in Section 4: Data Content and Gaps. This section describes the process used to select key databases for analyses and briefly addresses strengths and limitations of each database. This information was used to aid in the interpretation of the biogeographic analyses to minimize confounding of results due to information gaps. Also provided are recommendations for future research activities that would enhance biogeographic assessment products.

PHASE II BIOGEOGRAPHIC ASSESSMENT

Section 6 suggests potential next steps to augment the Phase I analyses. Phase II, however, will not be completely designed until a review of Phase I products has occurred. The NMSP and NCCOS project team members will meet to define the additional suite of activities that will comprise Phase II. Nevertheless, a few priority activities are expected to occur in Phase II, including expanding the analytical products for fishes, marine birds, and marine mammals. Special emphasis will be placed on the biogeographic analyses of marine mammal data, as that component of the study was not completed in Phase I. The marine mammal analyses are one of the first efforts to assess biogeographic patterns of marine mammals in the study area; thus, additional analyses and peer review are required to complete this component of the study.

Phase II activities may include publishing technical reports and peer-reviewed articles that complement the results of the Phase I assessment, as well as additional analyses to further define biological areas and time periods important to marine fishes, birds, and mammals found throughout the study area.

CD-ROM

A digital version of the document, the *Ecological Linkages Report*, all GIS-compatible files used to conduct the biogeographic analyses, metadata for GIS files, and a complete suite of digital species maps, are found on the CD-ROM located on the back cover of the document.

All appropriate digital data and analytical products are found on the CD-ROM. The products come in several formats, including the document (in .pdf format), map products in a browsable web format (HTML), GIS shapefiles and grids for use with MarIS or ArcView (GIS) software, tables in Excel format (.xls), and descriptive text files. Metadata for each shapefile or grid accompanies each file and appears in .xml format.

To support the NMSP and others in making maximum use of the spatial data generated from this study, along with other products (e.g., economic assessments) that support the joint management plan review, the NMSP is developing a GIS tool, the Marine Resource Information System (MarIS). MarIS has been designed to facilitate the organization, analysis and display of spatial data to support analysis of NMSP management questions and issues within and across sanctuaries. All applicable spatial data will be integrated into MarIS to enable NMSP staff and partners to conduct additional biogeographic analyses in Phase II.

CONCLUDING COMMENTS

This spatially explicit assessment provides a robust set of analytical results and GIS data to strengthen the sustainable management of marine resources within and adjacent to the sanctuaries. A primary use of the biogeographic assessment will be to support the NMSP as it

continues to conduct the joint management plan review for the three sanctuaries. In addition, the Biogeography Program will assist the NMSP in further analyses and presentations of the data and analytical results to address specific research and management questions. This Phase I product provides the foundation to continue the development of a biogeographic assessment capability to support the Cordell Bank, Gulf of the Farallones, and Monterey Bay National Marine Sanctuaries.