BIOGEOGRAPHIC ASSESSMENTS: INTEGRATION OF ECOLOGY AND GIS TO DEFINE AND EVALUATE MARINE PROTECTED AREA BOUNDARIES

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Introduction

The world's marine resources face multiple stresses from both human activities and natural environmental perturbations. As pressures on marine resources continue to increase, it has become evident that data required to make informed management decisions, bounded by policy aspects, are either lacking or not easily accessed (Battista and Monaco 2004). Information technologies provide a suite of capabilities that can be used to organize, visualize, analyze, and conduct integrated assessments of geographic data in support of the world's estuarine, coastal, and marine habitats and associated living marine resources (Parker 1988; Haddad and Michener 1991). However, to make maximum use of geographic information system (GIS), remote sensing, and database management technologies, a clear process must be implemented to consistently and efficiently collect, ingest, and analyze spatial and temporal ecological data sets.

The purpose of this chapter is to demonstrate how the implementation of a biogeographic assessment process can be utilized to define and evaluate marine protected area (MPA) boundaries, including "no take" marine reserves. The designation and implementation of marine reserves is a tool available to marine resource managers to effectively protect and maintain the complexity of quality fish habitat as well as mitigate the effects of fishing (Bohnsack and Ault 1996). The biogeographic assessment process facilitates the integration of ecology and GIS technology to define and address issues of place based management, such as defining MPA boundaries (Battista and Monaco 2004).

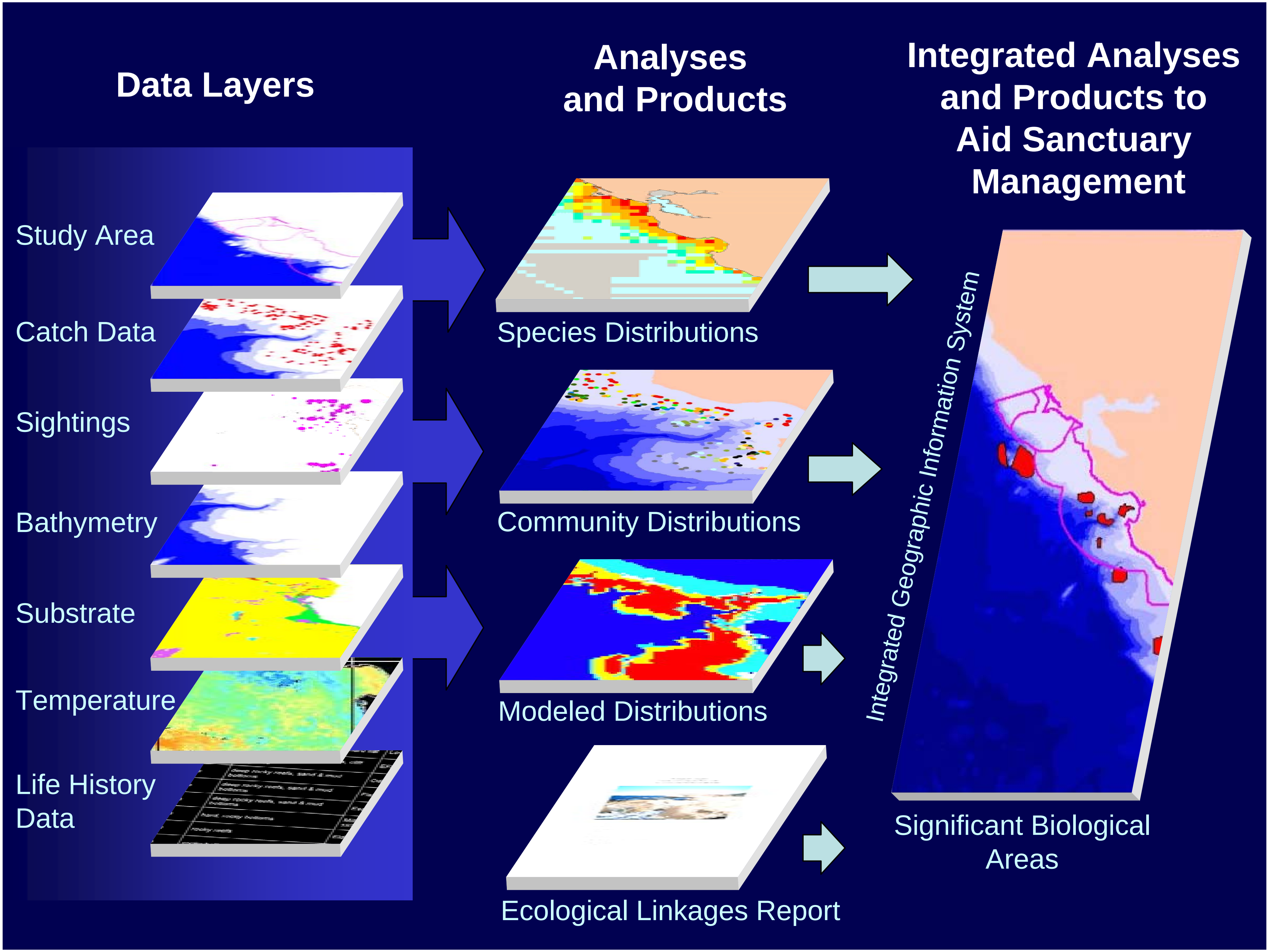
Biogeography is the study of spatial and temporal distributions of organisms, habitats, and the historical and biological factors produced them (Cox and Moore 1993). The principles of biogeography can be used to visualize and integrate biological and physical data through GIS to support development of management tools such as, MPAs (Kendall and Monaco 2003). Implementation of the process begins with the development of individual biogeographic data layers (e.g., bottom substrates and species distributions), integrated biogeographic analyses (e.g., areas of high species diversity), and concludes with products to support marine resource management (Figure 1).

This chapter provides three case examples that utilize the biogeographic assessment process to: 1) define biologically relevant boundaries for MPAs, 2) evaluate current MPA boundaries relative to the distribution of marine resources, and 3) evaluate alternative MPA boundaries. The three case studies address MPA science and management issues in the US Caribbean and four National Oceanic and Atmospheric Administration (NOAA) national marine sanctuaries along the California coastline.

CASE STUDIES

Defining Caribbean Reef Fish Marine Protected Areas

Background
NOAA's National Centers for Coastal Ocean Science (NCCOS) Biogeography Team conducts mapping, research, and monitoring in tropical coral reef ecosystems to support coastal marine resource management (Monaco et al. 2001). Defining the strength of coupling between species and habitat is facilitated by integrating spatial statistics and indices that are visualized in GIS and result in spatially articulated ecological models (Monaco et al. 1998, Gill et al. 2001). The biogeographic approach enables defining of biologically significant areas that can be used to identify and evaluate MPA boundaries (NCCOS 2003, Monaco et al. In press). Specific areas


Data Layers
Analyses and Products
Integrated Analyses and Products to Aid Sanctuary Management
Study Area
Catch Data
Sightings
Bathymetry
Substrate
Temperature
Life History Data
Species Distributions
Community Distributions
Modeled Distributions
Ecological Linkages Report
Integrated Geographic Information System
Significant Biological Areas

where Caribbean reef fish ecology studies are underway include Buck Island Reef National Monument, just north of St. Croix, US Virgin Islands (USVI), around the island of St. John, USVI, and in southwestern Puerto Rico (Kendall et al. 2004). The reef fish ecology studies are based on NOAA's integrative mapping and monitoring activities of coral reef ecosystems (Monaco et al. 2001).

Approach

Benthic Habitat Mapping

In 1999, NOAA's NCCOS acquired and visually interpreted orthorectified aerial photography for the near-shore waters (nominally 25 meters water depth) off Puerto Rico and the US Virgin Islands. Features visible in the Caribbean imagery were mapped directly into a GIS. Visual interpretation of the imagery was guided by a hierarchical classification scheme that defines and delineates benthic polygon types based on insular-shelf zones and habitat structures of the benthic community. Zones describe the insular-shelf location (e.g., back reef or fore reef), whereas habitat structure includes the cover type (reef, mangrove, submerged aquatic vegetation (SAV), unconsolidated sediments, etc.) of the benthic community (Kendall et al. 2001). This process resulted in digital maps classified to 27 levels of habitats (e.g., seagrass, patch reef) and these habitats are located in cross-shelf zones (e.g., back reef).

Reef Fish Surveys

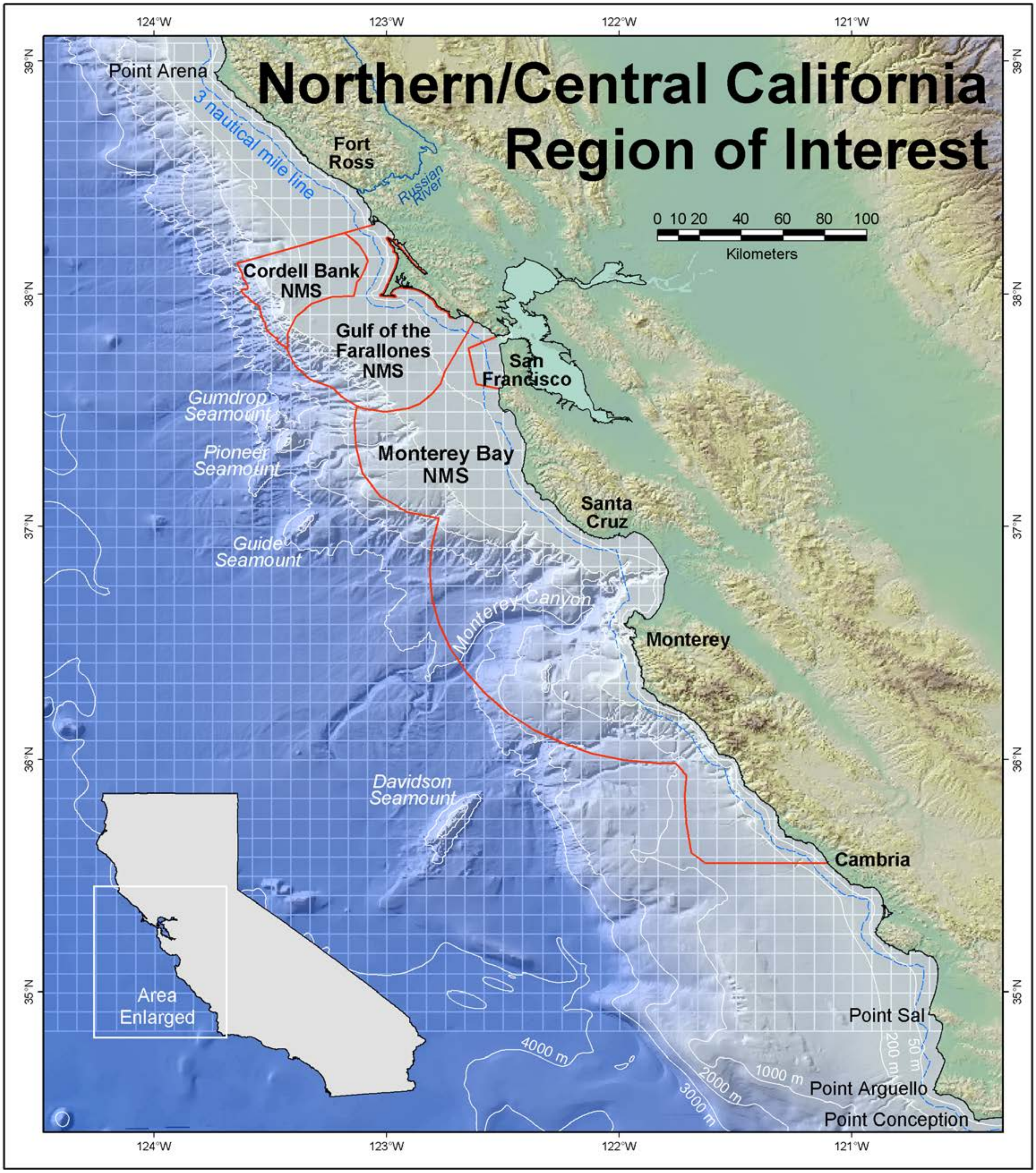
The digital habitat maps were used to stratify study areas into distinct zone-structure combinations, or strata. Random stratified sampling sites were selected based on the distribution of habitats contained within the digital habitat maps (Christensen et al. 2003). Scuba divers estimated fish abundance and size at each sample location, and conducted micro-scale measurements of benthic habitat variables, such as percent cover of abiotic and biotic substrates, depth, and rugosity along each 25 X 4 m visual belt transect. The belt-transect diver swam a random compass heading at a constant speed for 15 minutes. The diver identified to the lowest possible taxon, counts, and estimated the size of all fishes observed within 2 m on either side of a centerline (100 m2 total area).

Results and Discussion

Christensen et al. (2003) demonstrated the use of the biogeographic assessment process to define species habitat utilization patterns in southwestern Puerto Rico to aid in determining biologically relevant boundaries for potential MPAs. Analyses included determining the size and number of fish and the calculation of mean species density, sighting frequency, richness, and diversity within each zone, structure, and stratum (zone-structure combination).

Hierarchical clustering (classification) of species presence resulted in persistent similarities in the composition of fish assemblages among Puerto Rico habitat strata. There was a distinct grouping of sites by habitat, indicating that species composition is more similar among sites within the same structure (e.g., seagrass, hardbottom, mangroves) than among zones (e.g., fore reef, lagoon). Species richness and diversity was greatest among reef sites, followed by mangrove sites, and SAV sites (Figure 2). Species richness at reef sites was significantly higher than in SAV sites, but no difference was observed among sites in reef and mangrove structures. The lower diversity in mangroves and SAV was accounted for by the dominance of a few species in each habitat.

Many forces act in concert to shape the assemblage structure of a reef fish community. At the scale of a single patch-reef, a multitude of ecological forces such as localized predation and competition may be the primary factors in shaping reef fish communities. By increasing study scale to tens of kilometers, the relative effects of habitat zone and structure on community assemblages become apparent. Habitat structure is the overriding factor shaping southwestern Puerto Rico reef fish assemblages (Christensen et al. 2003). Furthermore, the abundance and distribution of single families, species, and even life stages, showed strong spatial correlations



Northern/Central California
Region of Interest
124°W
123°W
122°W
121°W
39°N
38°N
37°N
36°N
35°N
Point Arena
3 nautical mile line
Fort Ross
Russian River
0 10 20 40 60 80 100
Kilometers
Cordell Bank NMS
Gulf of the Farallones NMS
San Francisco
Gumdrop Seamount
Pioneer Seamount
Monterey Bay NMS
Santa Cruz
Guide Seamount
Monterey Canyon
Monterey
Davidson Seamount
Cambria
Area Enlarged
4000 m
3000 m
2000 m
1000 m
200 m
50 m
Point Sal
Point Arguello
Point Conception

with habitat types that enables modeling of the potential distribution of species across the seascape. The biogeographic modeling efforts suggested that a mosaic of habitats must be protected to support reef fish populations across all life history stages. Exclusion of any habitat type could impose a “bottleneck” at which population maintenance and growth potential might be significantly reduced (Christensen et al. 2003, Kendall et al. 2004)).

To enable integration of community metrics (e.g., species richness), habitat, and bathymetry variables, canonical correlation analyses were conducted to define the statistical relationships between the physical and biological parameters across multiple spatial units. An analysis matrix comprised of information on habitat type, the variance in the spatial extent of each habitat type, depth, and the variance in depth were correlated to the biological parameters of species richness, diversity, and abundance. Figure 3 represents the canonical solution between the seascape physiography and reef fish community structure data. The predicted “super” diversity comprised of the biological parameters resulted in a prediction surface with and overall map accuracy (kappa) of 77% ($p<.0001$) when validated with independent data. Areas within the prediction map that displayed relatively high diversity (warmer colors) are under exploration with the University of Puerto Rico to further determine if they are biologically relevant boundaries for potential MPAs. The results indicate that when defining an MPA boundary the overall seascape should be considered to enable protection of all species life stages across the spatial extent of the study area.

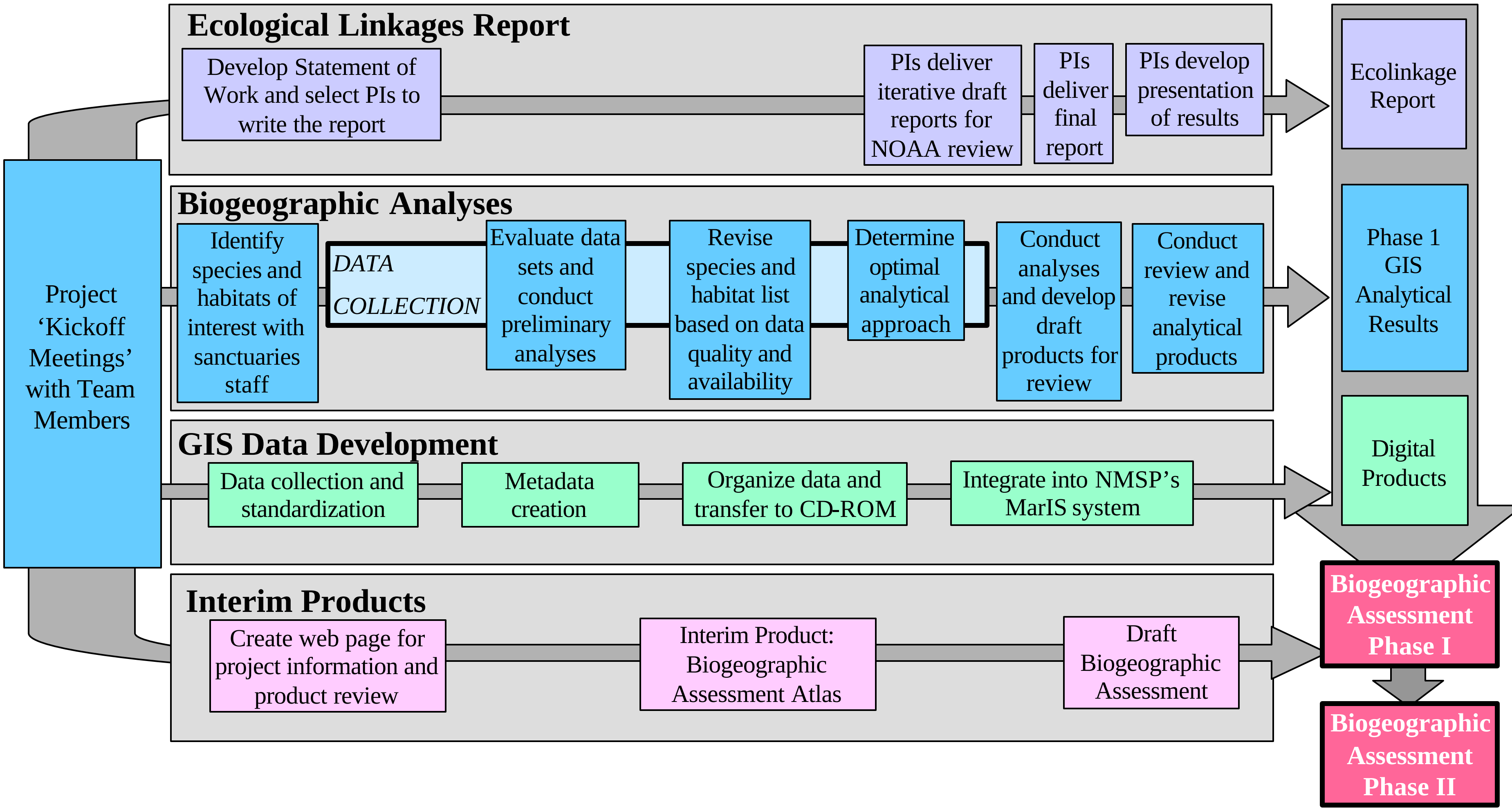
In summary, a biogeographic approach enables the coupling of digital benthic habitat maps and species habitat utilization patterns to define biologically relevant MPA boundaries, define the strength of species habitat affinities, and evaluate MPA effectiveness. Biogeographic assessment products include species distribution maps depicting the probability of encountering a species or groups of species based on their habitat affinities, maps of community metrics (e.g., species richness), and a suite of other spatially-articulated models. These products have been used by the US Caribbean Fisheries Management Council to define essential fish habitats, the National Park Service to characterize benthic habitats and associated species found around US Virgin Islands National Parks and Monuments, and the University of Puerto Rico to define biologically relevant MPA boundaries (NOAA 1998, Christensen et al. 2003, Monaco et al. in review, Kendall et al. 2004).

Biogeographic Assessment off North/Central California

Background

NCCOS and the National Marine Sanctuary Program (NMSP) conducted 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 (NCCOS 2003). 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 Team is leading a partnership effort to conduct a robust analytical assessment to define important biological areas and time periods within the region. Phase I of this project provided data, analytical results, and descriptions of ecosystems and their linkages; it also identified data gaps, and suggested future activities now underway in Phase II (NCCOS 2003, Monaco et al. In press).

Phase I of this effort was a biogeographic assessment using 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 US 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 (the northern bound) to Point Sal in northern Santa Barbara County (the southern bound). This relatively large study area enabled the assessment to


Ecological Linkages Report
Develop Statement of Work and select PIs to write the report
PIs deliver iterative draft reports for NOAA review
PIs deliver final report
PIs develop presentation of results
Ecolinkage Report
Project 'Kickoff Meetings' with Team Members
Biogeographic Analyses
Identify species and habitats of interest with sanctuaries staff
DATA COLLECTION
Evaluate data sets and conduct preliminary analyses
Revise species and habitat list based on data quality and availability
Determine optimal analytical approach
Conduct analyses and develop draft products for review
Conduct review and revise analytical products
Phase 1 GIS Analytical Results
GIS Data Development
Data collection and standardization
Metadata creation
Organize data and transfer to CD-ROM
Integrate into NMSP's MarIS system
Digital Products
Interim Products
Create web page for project information and product review
Interim Product: Biogeographic Assessment Atlas
Draft Biogeographic Assessment
Biogeographic Assessment Phase I
Biogeographic Assessment Phase II

extend beyond the limits of individual sanctuary boundaries and to place study results in the context of west coast biogeographic patterns. 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.

Approach

The integrated biogeographic assessment consisted of three complementary study components: (1) an Ecological Linkages Report, (2) biogeographic analyses, and (3) development of GIS data for incorporation into NMSP's Marine Information System. The majority of the results from the assessment were presented as a suite of GIS maps to visually display species' biogeographic patterns across the study area. NCCOS (2003) provided examples of the entire suite of digital map products, data, and analyses found on a companion CD-ROM. The spatial data and additional information, such as digital species distribution maps and details on analytical methodologies are also included on the companion CD-ROM and on the internet at: http://biogeo.nos.noaa.gov/products/canms_cd/.

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 adequately 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 existing databases, two additional techniques were used to conduct the assessment. First a synthesis of existing information was compiled and presented in the Ecological Linkages Report to provide qualitative information on marine ecosystems and linkages within the study area. Second, species' habitat suitability models were constructed for fishes to define potential species' distributions based on known habitat affinities and physiological limitations (Brown et al. 2000, NCCOS 2003).

A critical component of the biogeographic assessment process for central/northern California 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 significantly enhanced the assessment. 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 biogeographic assessment product (NCCOS 2003).

Ecological Linkages Report

The Ecological Linkages Report provided the context to understand overall biogeographic results, relative to the biogeography of the US West Coast (Airamé et al. 2003). The bulk of the report described ecosystems in the region, key species associated with these ecosystems, ecosystem status, and linkages among them. The report presented the latitudinal range distributions of species groups, such as invertebrates, fish, marine birds and marine mammals. This analysis provided an overview of marine species' distributions along the entire west coast of North America by documenting the reported northern and southern range endpoints of species that occur in all or part of this region. In addition, the report identified gaps in current knowledge about regional ecosystems.

Biogeographic Analyses

This component of the assessment was the cornerstone of the overall biogeographic product to support the NMSP joint management plan review process. Primary data included fisheries-independent data, such as those collected by the National Marine Fisheries Service (NMFS), and fisheries-dependent data, such as those collected by the California Department of Fish and Game for recreational fisheries. The data, analyses, and supporting information were linked using statistical and GIS tools to portray in space and time significant biological areas or "hot spots."

The term “hot spot” was defined based on specific criteria or metrics (e.g., species diversity, high species abundance) (Figure 4). The vast majority of the results were displayed as a series of maps to visualize where the analyses identified biologically significant areas (NCCOS 2003, Monaco et al. In press).

There are many different ways to analyze and organize biogeographic information; however, to effectively support the management plan process, only a limited number of analytical options were invoked. These analyses were selected based on reviewers' comments on the Project’s Interim Atlas Product, feedback from technical review meetings, and peer review workshops.

Results and Discussion

Many possible combinations of the data layers could be integrated for the biogeographic assessment. In most instances, however, it was not appropriate to integrate all results across taxa. Therefore, to minimize confounding of results and to focus on the "protection of biodiversity" component of the NMSP mission, the integration of patterns in diversity was utilized to define biologically significant areas across species groups. In addition, results of individual species habitat suitability models were integrated across species. Thus, an approach was developed to integrate individual species habitat suitability models into a single cumulative suitability metric indicating areas of high potential groundfish abundance (Brown et al. 2000, NCCOS 2003). These results complemented the community metrics derived for fish and marine bird populations to define areas of integrated biological hot spots.

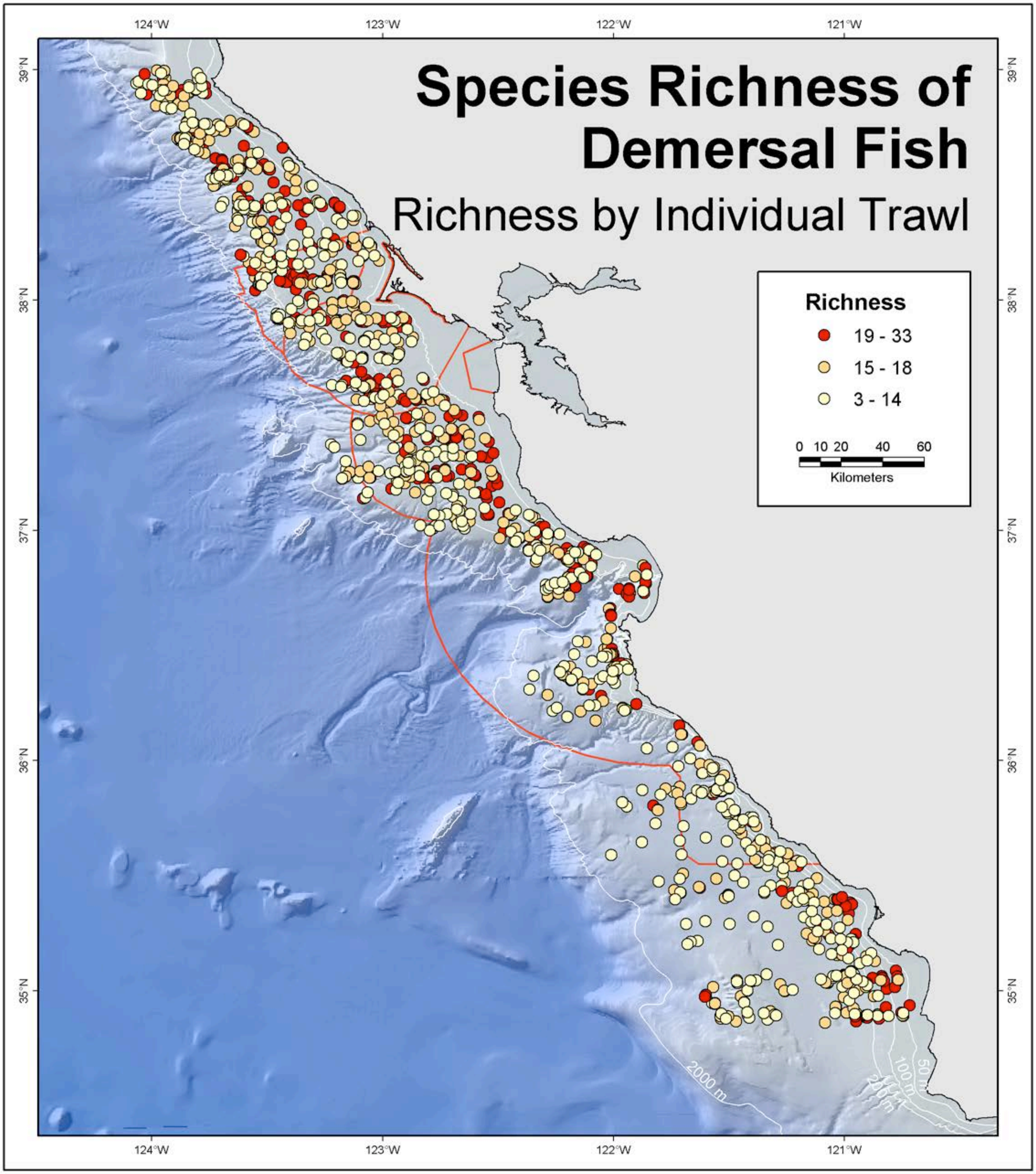
In an attempt to achieve the most explanatory information describing community metrics, analyses were conducted to detect recurring spatial patterns that were present among the multiple species groups. Thus, areas that showed significant biological concentrations, high species diversity, or usage by multiple species groups were delineated. These areas of significant biological importance contributed to defining and assessing biogeographic patterns within the study area. Figure 5 portrays overlays of the top 20% of fish diversity and density cells along with the top 20% of marine bird diversity and density cells. These analyses indicated that the majority (71%) of the fish biological hot spots were coincident with the much larger marine bird hot spots. Although the majority of the area that was identified as hot spots for fish and marine birds occur within National Marine Sanctuary waters, there are hot spots beyond sanctuary boundaries to the north and south. This type of biogeographic assessment has been used to aid in assessing the biological relevancy of existing boundaries and stimulate discussions on potential modification of existing sanctuary boundaries (NCCOS 2003).

Biogeographic Assessment of Channel Islands National Marine Sanctuaries

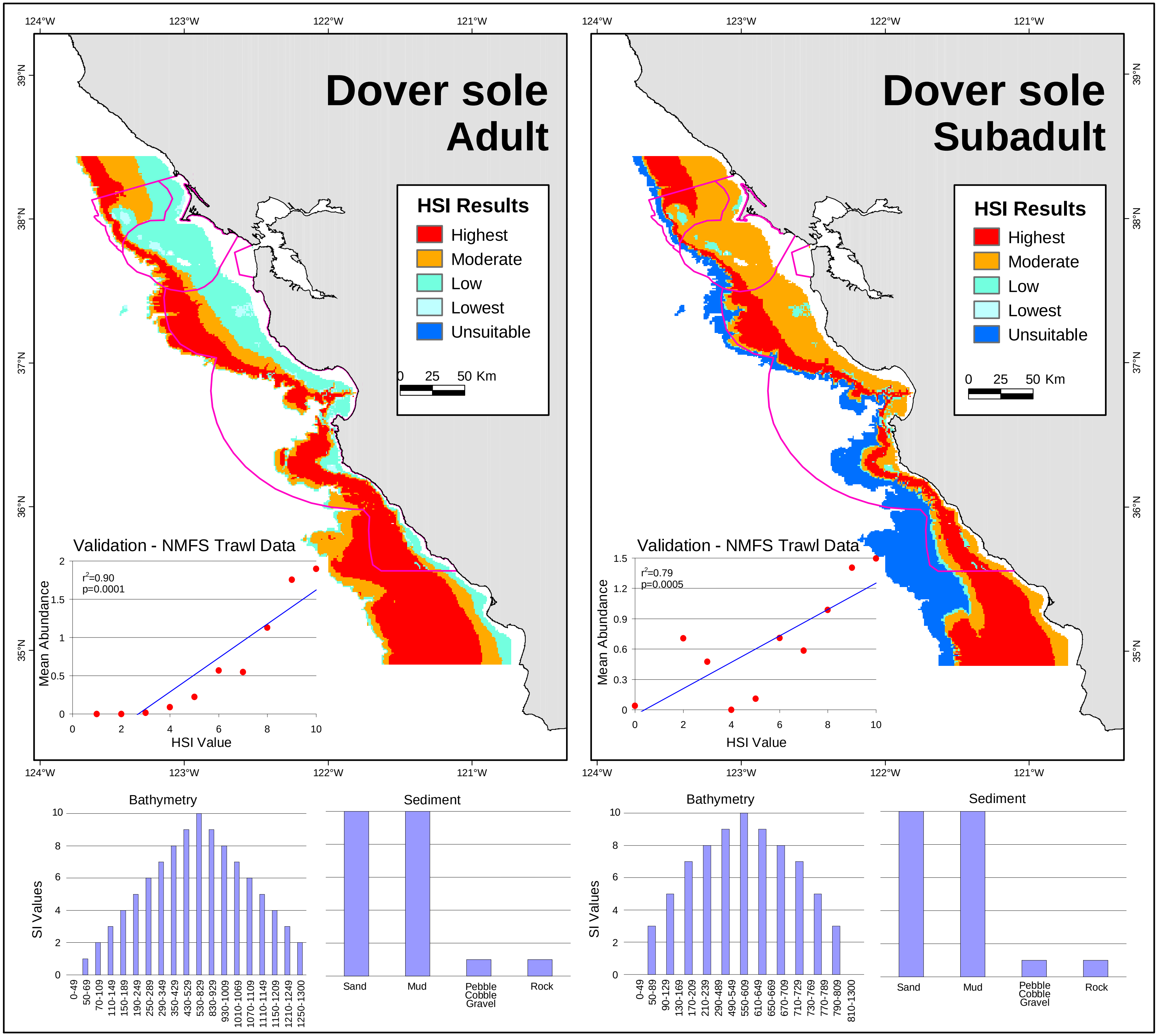
Background

NCCOS and NSMP are jointly conducting a biogeographic assessment of the marine region surrounding the Channel Islands National Marine Sanctuary (CINMS). The assessment supports revision of the CINMS management plan. The primary objective of the study is to assimilate and analyze comprehensive spatial data on the distribution of habitats and species to evaluate potential implications of six different boundary expansion alternatives. The six sanctuary boundary expansion alternatives that are under investigation have not been rigorously assessed from a biogeographic perspective (Figure 6). Defining how these boundary alternatives correspond to the distribution of critical biotic and habitat resources is a necessary component of assessing the potential implications of changes in the boundaries or management of the CINMS.

The study area to conduct the spatially articulated characterization of the Channel Islands ecosystem and surrounding areas extends from Morro Bay, California to 30 km south of Santa Catalina Island. Within this study area an initial suite of biogeographic data layers are being compiled and include information of the distribution of habitats, marine fishes, marine birds, and marine mammals. Using this suite of data a series of assessment activities are underway for each

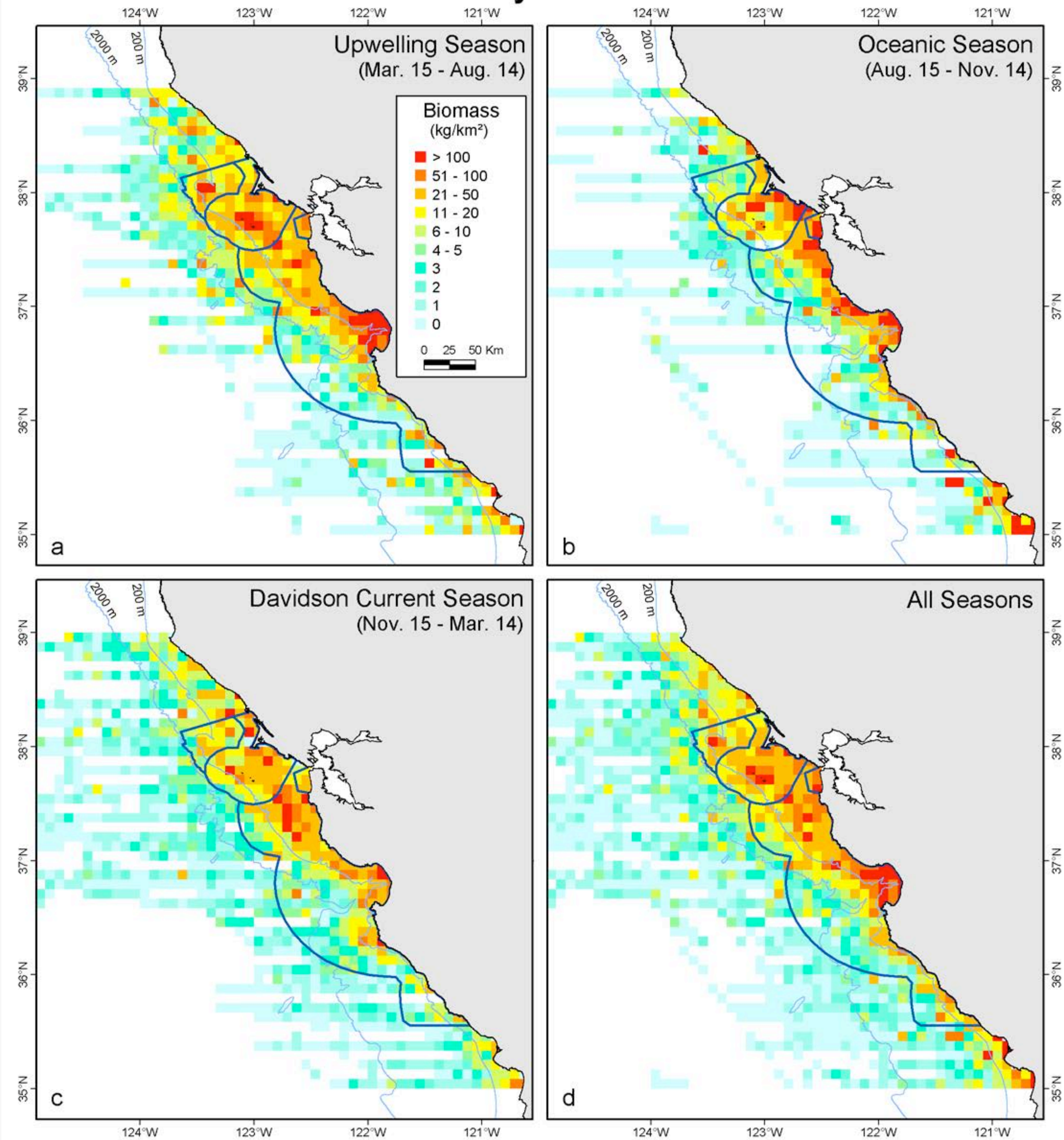


Species Richness of Demersal Fish
Richness by Individual Trawl
Richness
19 - 33
15 - 18
3 - 14
0 10 20 40 60
Kilometers
124°W
123°W
122°W
121°W
39°N
38°N
37°N
36°N
35°N
2000 m
100 m
50 m



Dover sole
Adult
HSI Results
Highest
Moderate
Low
Lowest
Unsuitable
0 25 50 Km
124°W
123°W
122°W
121°W
39°N
38°N
37°N
36°N
35°N
Validation - NMFS Trawl Data
r²=0.90
p=0.0001
Mean Abundance
HSI Value
Dover sole
Subadult
HSI Results
Highest
Moderate
Low
Lowest
Unsuitable
0 25 50 Km
Validation - NMFS Trawl Data
r²=0.79
p=0.0005
Mean Abundance
HSI Value
Bathymetry
SI Values
0-49
50-69
70-109
110-149
150-189
190-249
250-289
290-349
350-429
430-529
530-829
830-929
930-1009
1010-1069
1070-1109
1110-1149
1150-1209
1210-1249
1250-1300
Sediment
Sand
Mud
Pebble
Cobble
Gravel
Rock
Bathymetry
SI Values
0-49
50-89
90-129
130-169
170-209
210-239
290-489
490-549
550-609
610-649
650-669
670-709
710-729
730-769
770-789
790-809
810-1300
Sediment
Sand
Mud
Pebble
Cobble
Gravel
Rock

Marine Bird Biomass Density



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proposed boundary alternative. The results will enable visualization and quantification of the spatial extent of biologically significant areas defined in each boundary alternative.

The information provided below addresses the preliminary analyses for marine birds as an example of how the assessment will be conducted across all species groups. Ultimately, analysis of marine fishes, invertebrates, birds, and mammals will result in a series of integrated map products to evaluate biological relevancy of the various boundary alternatives.

<u>Approach</u>

Metrics

The choice of appropriate metrics for comparison of boundary alternatives is a difficult one, and involves implicit value judgments. Since such judgments are often policy decisions, and inherently beyond the scope of a biogeographic assessment, three separate metrics along with a discussion of their biases and implied values are presented.

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 alternative 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 per square kilometer recorded in boundary alternative 5 or the average bird density within the current CINMS boundaries.

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 alternatives are also generally subsets of the larger alternatives, with all options encompassing the current boundary. To the extent that each species or community metric matches the hypothetical situation, absolute metrics will be biased toward the larger boundary alternatives and relative metrics will favor the smaller options.

Because of the inherent biases of absolute and relative metrics, an index was used to provide a more balanced gauge of the relative merits of different boundary alternatives. This third metric, the Biological Area Index (BAI) represents the relative increase in biological "value" divided by the relative increase in area compared to the current boundaries. The BAI is calculated using the formula:

$$BAI = \frac{\left(B_1 - B_0 / B_0\right)}{\left(A_1 - A_0 / A_0\right)}$$

where B_1 and B_0 refer to the value of the biological estimate (e.g. sightings, diversity, richness, etc.) within the boundary alternative and the current boundaries, respectively, and A_1 and A_0 are the respective areas. This provides some balance against the previously discussed biases, but may not eliminate them entirely.

Marine Bird Diversity

The marine bird diversity data were 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) v.2.1 (MMS 2001). Although CDAS contains survey data from the entire US west coast, the analyses were limited to sightings data south of Point Arena. A total of 95 bird species were observed in the combined surveys.

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). The diversity 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 diversity index is highest when there is an equal number of individuals of each species.

Since the CDAS data includes summaries for 5-minute of latitude by 5-minute of longitude grid cells, we calculated total observed diversity for each 5-minute cell. The diversity 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 (5 minute grid), and N is the total number of individuals in the sample (Magurran 1988). To aid analysis and visual interpretation of the diversity map, estimated diversity was then interpolated using kriging to provide a statistically smoothed 1km raster surface (Figure 7).

Results and Discussion

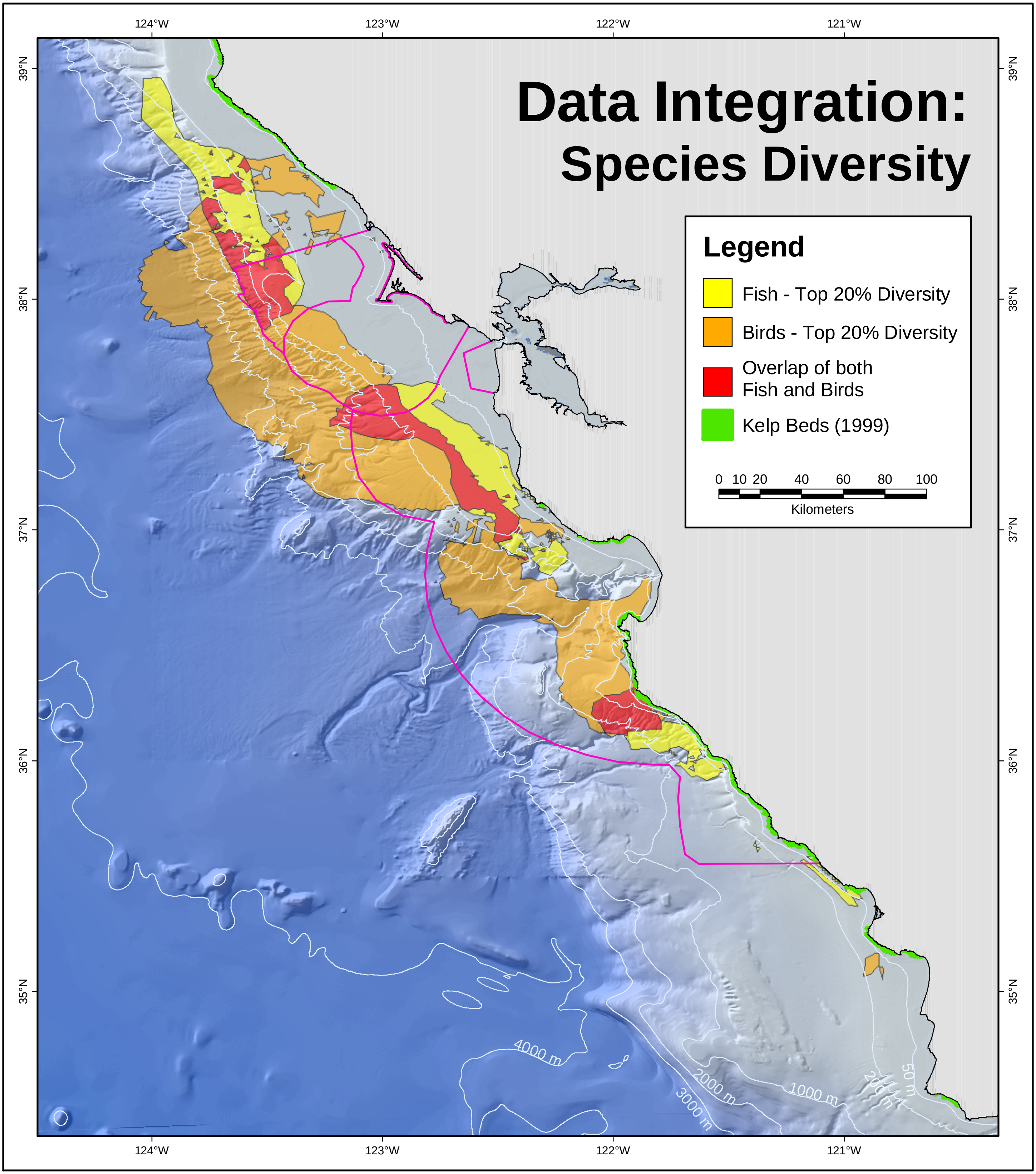
Marine Bird Diversity

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 US-Mexico border in the south. Regions of high estimated diversity (warmer colors) 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 7). A second conspicuous area of high estimated diversity appears approximately 140 kilometers 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 Banks. This small patch appears to be a seaward extension of the most prominent extent of high diversity, which ranges from Morro Bay in the north along the shelf down to Point Conception. This significant feature then spreads throughout the entire Southern California Bight, with concentrations around the Channel Islands (San Miguel, Santa Rosa, Santa Cruz, and Anacapa, Santa Catalina, and San Clemente Islands), the Santa Barbara Channel, and shelf areas throughout the southern portion of the Bight.

In general, model results indicate that the current configuration of National Marine Sanctuaries (NMS) along the California coastline captures substantial areas of high estimated diversity. In this analysis (ranging from 39o to 32o north latitude), the total area represented by the top 25% of the estimate was 33,881 km2. Roughly 5,770 km2 (17%) of this overall area is contained within the four California Sanctuaries, with 6% falling inside the boundaries of the CINMS. A total of 61% of the area contained within current CINMS boundaries was classified as having high marine bird diversity. This is the largest area proportion of any California NMS.

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 correlation between diversity and sampling effort (He et al., 1994). 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.

Analysis of Boundary Alternatives


Data Integration:
Species Diversity
Legend
Fish - Top 20% Diversity
Birds - Top 20% Diversity
Overlap of both Fish and Birds
Kelp Beds (1999)
0 10 20 40 60 80 100
Kilometers
124°W
123°W
122°W
121°W
39°N
38°N
37°N
36°N
35°N
4000 m
3000 m
2000 m
1000 m
200 m
50 m

The preceding discussion identified a large region of high bird diversity centered on the Channel Islands, ranging from Morro Bay in the north along the shelf down to Point Conception, where it then spreads throughout the entire Southern California Bight. A total of 61% of the area contained within current CINMS boundaries was classified as having high (top 25%) marine bird diversity. Thus, it is important to recognize that the no action alternative (NAA, current boundary) is well configured to capture areas of high marine bird diversity; however, a review of the remaining alternatives suggests that an expansion could provide further benefit in terms of preserving areas of high bird diversity.

Mean estimated diversity for the NAA was calculated to be 1.49 with a coefficient of variation (CV) of 8.8%. Mean diversity and CV values for the remaining alternatives, ranging from smallest in size to largest are as follows: Alternative 5 – 1.49, 8.7%; Alternative 4 – 1.52, 9.9%; Alternative 3 – 1.53, 9.8%; Alternative 2 – 1.50, 10%; Alternative 1a – 1.37, 20.3%; Alternative 1 – 1.38, 20.4% (Figures 6, 7). These results are generally predictable, with a trend of boundary alternatives of larger areas exhibiting lower mean diversity values than smaller boundary alternatives. It should be noted; however, that this trend is largely driven by alternatives 1 and 1a, and that while the trend is predictable, alternatives 2, 3, and 4 are higher than expected. This indicates that the boundary configuration for these alternatives disproportionately captures areas of high bird diversity, and that any of these alternatives would be a suitable choice for expansion. Alternatives 1 and 1a would be a less suitable choice based on mean diversity alone.

The more balanced BAI was used to assess the relative value of bird diversity as it provides the ratio of the relative change in mean diversity to the proportional gain in area. While the index decouples the predictable relationships between alternative area and biological value to some extent, results are still dependent upon the input data – absolute vs. relative measures. Results indicate that alternatives 3 and 4 provide the largest biological value per area gained. The results of the preliminary biogeographic analyses to define biologically significant areas for marine birds under various boundary alternatives can be summarized by reviewing the three analytical metrics. Patterns of marine bird diversity appear to reflect the distribution of known upwelling regions and areas of high productivity. The current boundaries of the CINMS encompass a region of high bird diversity. Finally, of the five boundary alternatives being considered in addition to the NAA, options 3 and 4 provide relatively large increases in mean bird diversity within sanctuary boundaries (Figure 6).

CONCLUDING COMMENTS

The use of GIS in coastal and marine environments can provide scientists, managers, and the public with a powerful tool to address complex spatial issues for natural resource management (Battista and Monaco 2004). The biogeographic assessment process enables integration of ecology and GIS technologies to define and evaluate the spatial and temporal distributions of marine resources. Spatially explicit biogeographic assessments provide information necessary to strengthen the sustainable management of marine resources within and adjacent to MPAs. The three case studies presented in this chapter demonstrates the power of the biogeographic assessment approach to define MPA boundaries, evaluate biological relevancy of existing boundaries, and assess MPA boundary alternative scenarios.

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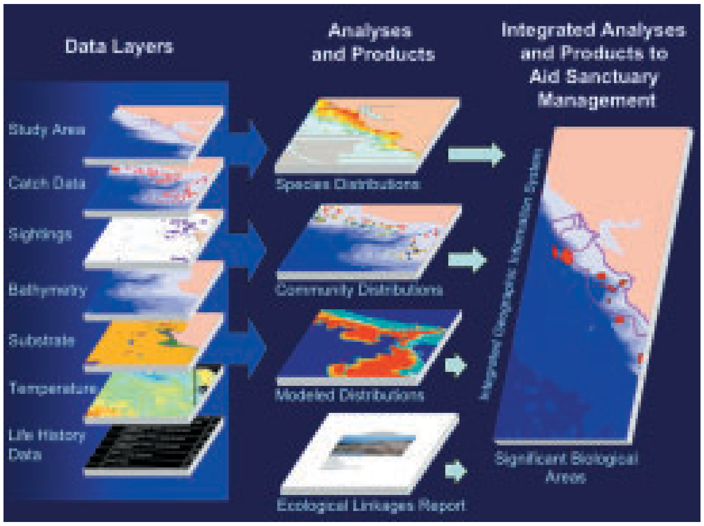


Figure 1.1. Generalized biogeographic approach to study NOAA national marine sanctuaries.

Figure 1.2. Locator map of entire study area from Point Arena to Point Sal. National marine sanctuary boundaries shown in red.

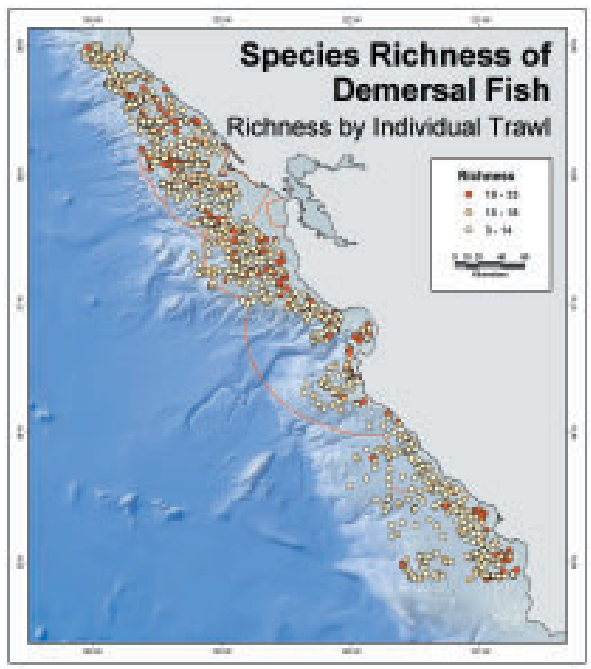


Figure 1.4. Species richness of rockfish from individual NMFS shelf and slope trawls.

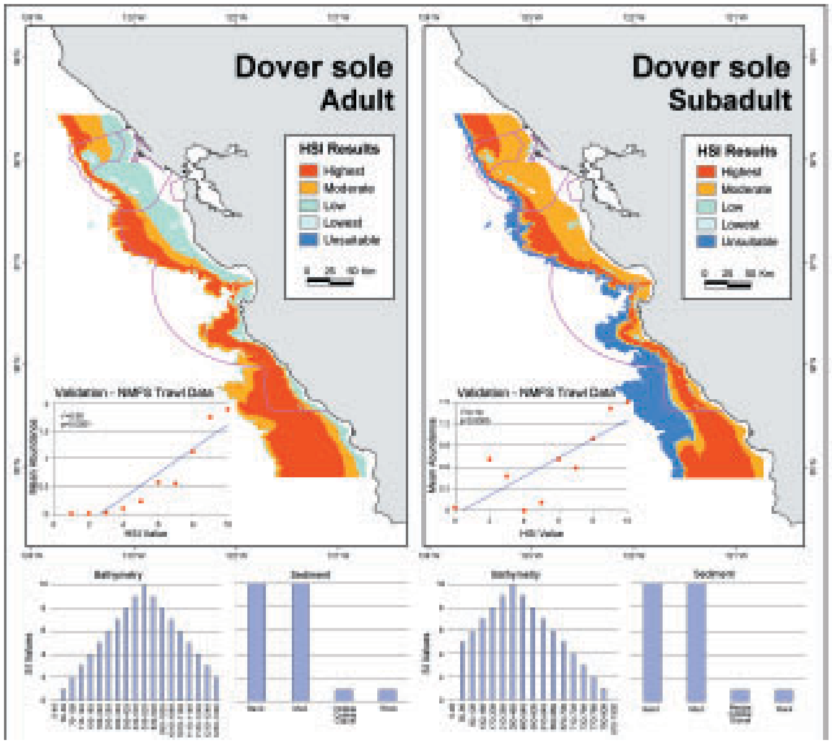


Figure 1.5. Potential distribution of habitat suitability for adult and juvenile Dover sole. Map inset contains validation statistics, and Suitability Index values for bathymetry and substrate are displayed below the maps.

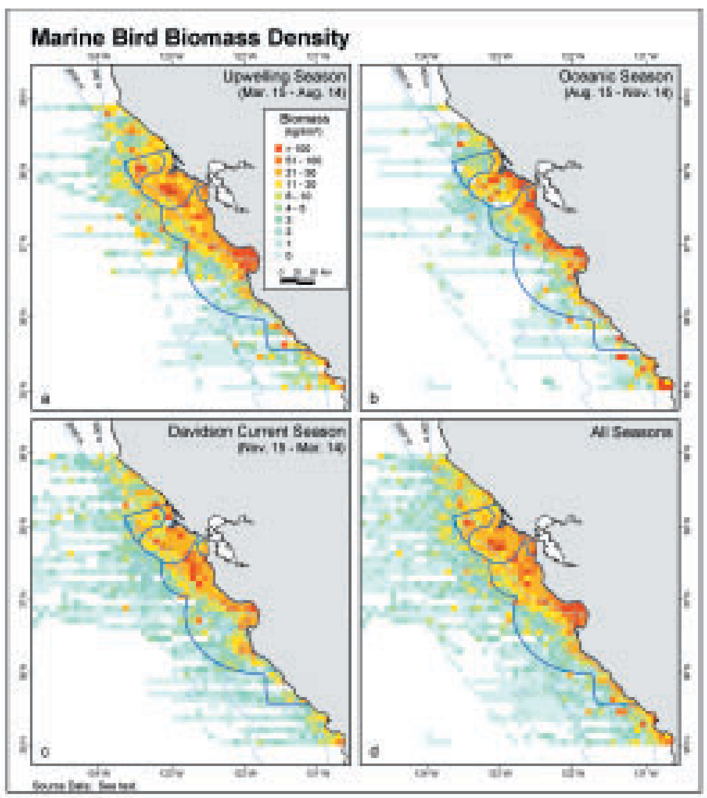


Figure 1.6. Marine bird biomass, by season and for all seasons in study area.

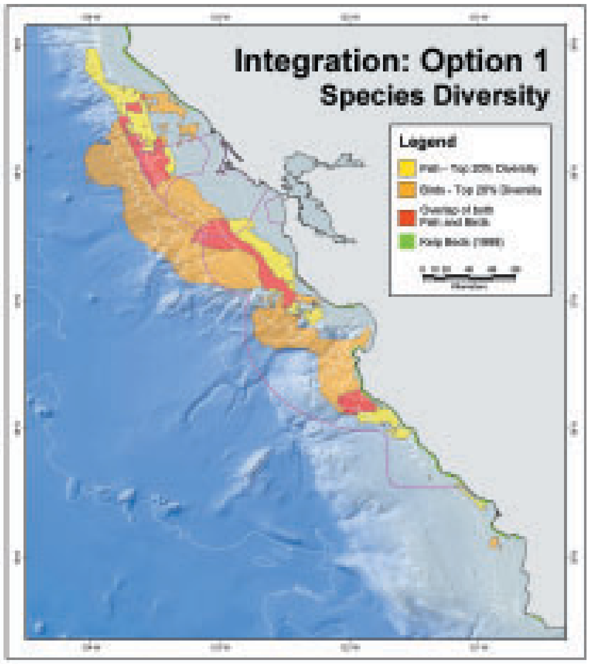
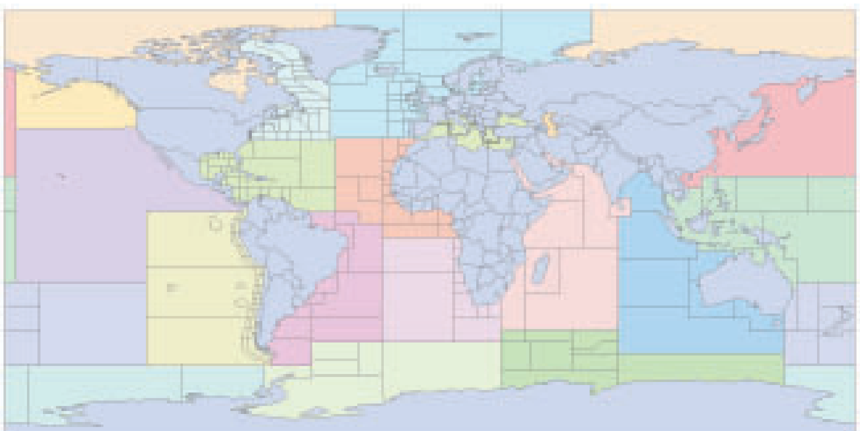


Figure 1.7. Data Integration: diversity hot spots (top 20%) for fish and marine birds. Coastal kelp bed areas are also shown.

Figure 2.1. Reporting areas used for fisheries statistics by Food and Agriculture Organization (FAO) and its regional bodies, the International Council for the Exploration of the Sea (ICES), and the Northwest Atlantic from the Northwest Atlantic Fisheries Organization (NAFO), currently used



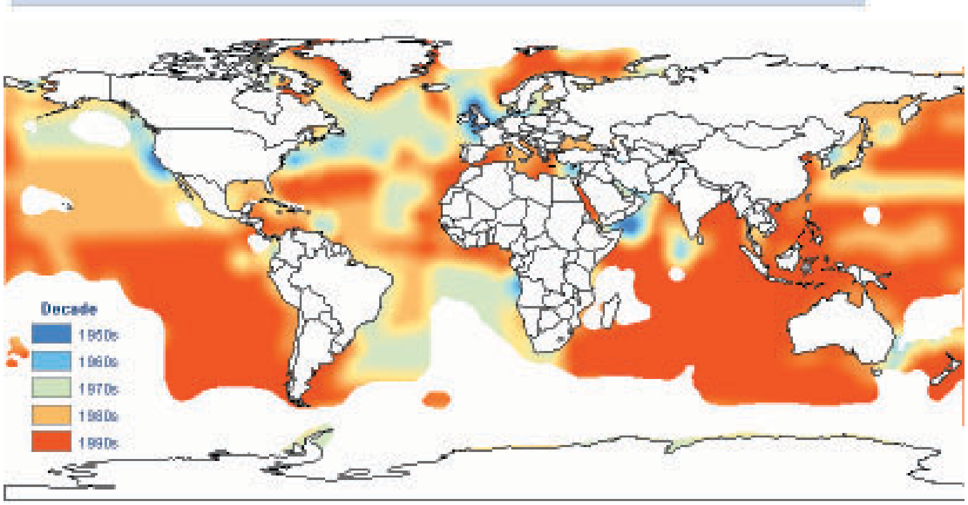


Figure 2.2. Decade of maximum commercial landings.