PART III

Democratizing Data: Civil Society Groups' Usage of Marine GIS

Chapter 9

Continental-scale Conservation Planning

The Baja California to Bering Sea Region

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Abstract

The North American Commission for Environmental Cooperation (CEC) provides a facilitative body for Canada, Mexico, and the United States to address common environmental concerns and promote biodiversity conservation. The CEC is implementing a North American Marine Protected Areas Network (NAMPAN) with a wide array of partners in governmental and nongovernmental sectors in order to protect marine species throughout their ranges and across these three Exclusive Economic Zones. Identifying priority conservation areas for the Baja California to Bering Sea Region (B2B), is one initiative of this network. Marine Conservation Biology Institute (MCBI) worked jointly with the CEC in a multi-year process of consultation, data gathering, data analysis and GIS development culminating in an experts' workshop to define priority conservation areas. In this chapter we describe this effort, the workshop to identify priority conservation areas and briefly describe the final output of this process. A total of 28 sites were identified as priority conservation areas (PCAs), totaling 8% of the total Exclusive Economic Zone (EEZ) area of the three nations. PCAs vary by threat and protection status, but they represent a shared vision of critical places for North America's marine biological diversity. This portfolio

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of sites is a first step towards building a continental community to foster the development of cooperation and stewardship of the B2B region.

Introduction

In recent years, conservation strategies, noting past failures to stem the tide of extinctions, have focused to a greater degree on large-scale ecosystem approaches (e.g., Wildlands Strategy, World Wildlife Fund's Global 2000). Conservation efforts traditionally focused on individual populations, often protecting small areas that can safeguard only a small portion of the total population (Soulé et al., 2003). But outside small, isolated reserves, contamination, fragmentation, and the death of individuals occur daily. Thus, we must look to maintain ecological processes across an entire seascape.

Landscape ecology provides a new conceptual basis for continental conservation plans. (Soulé and Terborgh, 1999) Sherman's "Large Marine Ecosystems" (LME) (Sherman et al., 1990; Sherman and Duda, 1999) and the work on "Biogeochemical Provinces" (BGCP) by Longhurst and colleagues (Longhurst, 1998) have conceptually helped bring marine ecosystems into a management context. Several multinational planning exercises have been carried out in the marine realm in recent years, suggesting the importance of a broader ecosystem focus (e.g., Banks et al., 1999; Sullivan-Sealey and Bustamante, 1999). Marine conservation planning, similar to terrestrial conservation planning, should recognize four critical aspects necessary to conserve species and processes: (1) conserving species and processes that require the greatest area to persist; (2) conserving widespread species and continental phenomena; (3) quantifying patterns of beta diversity and endemism; and (4) predicting the location and intensity of threats to biodiversity (Olson et al., 2002). Conservation planning must also map important areas, such as biodiversity hotspots and other conservation priorities, in order to set priorities for action (e.g., Hixon et al., 2001; Roberts et al. 2002).

Although many conservation efforts and sustainable development initiatives exist at different scales along the Pacific Coast of North America, they generally work independently of each other. Unless these efforts are coordinated, species numbers will continue to decline and ecosystem integrity will continue to be at risk. For example, gray whales have rebounded, thanks to an international agreement to stop whaling, and local efforts to protect calving lagoons in Mexico. The successful conservation of the North American seascapes requires cooperative action from all three countries and from diverse sectors of society. The CEC was created by the governments of these three countries— Canada, Mexico, and the United States—to address common environmental concerns under the North American Agreement for Environmental Cooperation, a side agreement to the North American Free Trade

Agreement (NAFTA). The North American Marine Protected Areas Network (NAMPAN) represents one initiative to facilitate collaboration to safeguard ecological linkages, and conserve marine biodiversity and productivity throughout the exclusive economic zones (EEZs) of the three nations. This initiative also complements the conclusions of the World Summit for Sustainable Development, where participating governments, including the NAFTA signatories committed to implementing marine protected area networks by 2012.

This chapter describes the process of developing appropriate datasets and analyses for identifying priority conservation areas (PCAs) in the Baja California to Bering Sea Region (B2B). Iteratively over the course of this project, the definition of PCAs was refined to reflect the mandate of the CEC, the variable nature of data available in the three nations, and the spatial scale of the region. Other initiatives advance a common framework by mapping marine ecoregions **(Wilkinson et al., 2004b)**, identifying species of common conservation concern, and working to provide an understanding of the institutions in each country through which an integrated network of linked organizations can implement the NAMPAN. This PCA initiative seeks to detail where conservation action is immediately necessary, and charts a course for future conservation alliances and action in the B2B region.

Methods

The methodology for identifying PCAs relied on teaming experts' knowledge with the development of a geographic information system (GIS). GIS systems are ideally suited to conservation planning across large ecosystems because they can combine physical, biological, and social data into a single spatial frame of reference. GIS can scale spatially from the continental to the regional, and temporally from the annual to the daily. Recent advances in GIS technology allow visualization of the seafloor and water column in three dimensions, a critical aspect of conservation initiatives such as this one, with benthic and pelagic components.

The large geographic extent of the B2B region limits the viability of an entirely data-driven analysis at this scale. Comprehensive data and dependable proxies do not exist. It was independently concluded several times that the most likely approach for the entire B2B region is a site nomination Delphic approach that combined specific datasets and analyses, and captured the range of habitat diversity based on expert judgment related to biodiversity, threat and opportunity.

The GIS included appropriate spatial datasets of physical, biological, and social information. Analyses focused on translating several of these datasets to highlight regions where physical processes lead to unique features or high abundances of species. At the final PCA identification workshop, experts reviewed the aggregated datasets and analyses to inform their judgments of ecological value and conservation priority.

Priority was identified based on the ecological significance of the areas to North America, threats to the area, and opportunities to advance conservation.

This initiative spanned the course of three years, and tapped the knowledge of over 200 marine and social scientists from three different countries and 75 different organizations. The process can be described in the following manner: outline of work plan, data needs assessment, data needs ranking, data gathering and distribution, analysis, and Delphic selection of priority conservation areas. Here we present a detailed description of the process, in the hope that this effort may inspire cooperation and greater openness in conservation planning in other multinational waters.

Goal of the Priority Conservation Areas Project

In 2000, the CEC identified the Baja California to Bering Sea region as one of its Priority Regions for Biodiversity Conservation of North America[1] —this region is defined as the EEZ of Mexico, the United States, and Canada from 22°N latitude to 65°N latitude. The B2B region was advanced as the first test case for the CEC to implement its strategic plan in the marine environment[2] .

In May 2001, MCBI and the CEC convened a workshop in Monterey, California, in the United States, where scientific experts, resource users, and marine conservationists from the three countries addressed the goals and identified the types of baseline data that are required for conservation in the B2B region. They agreed on the need to identify PCAs as a step in a larger continental-scale conservation effort. They also reached consensus that the overarching goal of a PCA is to conserve biodiversity, and should also include benefits to fisheries, cultural values, recreation, and scientific research. These experts agreed on the development of a GIS, based on common physical data for the entire region, to serve as a framework for integrating other information. The GIS included biological, physical, and social data layers. Experts also addressed issues of size and spatial scale, incorporating previous priority setting efforts and anthropogenic threats (Morgan and Etnoyer, 2002).

What is a PCA?

The first and most challenging aspect of this project was the definition of a priority conservation area. The definition was iteratively defined and refined through out the scope of this project. Consensus was achieved in a statement that defined PCAs on the basis of significant biodiversity and continental uniqueness, and incorporating three factors: (1) ecological value; (2) anthropogenic threat; and (3) opportunity for conservation (government or local support, existing designations, and conservation initiatives). Since no comprehensive measure of biodiversity exists for the B2B region, experts were asked to assess biodiversity indirectly, relying on their accumulated knowledge of species, habitats and ecological processes. Several factors were to be considered in their assessment: (1) continental scale physiographic and oceanographic features (features on the order of 100–1,000 km^2); (2) high beta-level biological diversity (between-habitat diversity); (3) continental endemism; (4) key habitats—concentration areas such as breeding and feeding sites or migration routes—for marine species of common conservation concern (Appendix 9.1); (5) critical habitats of umbrella and charismatic species that require large areas to persist; (6) areas that provide whole region benefits, e.g., seasonally productive, migration corridors; and (7) areas of high biomass and/or productivity, e.g., coastal upwelling centers.

These criteria are consistent with other approaches that suggest capturing areas that contain regional representation of major habitats, diverse types of habitats, rare and threatened species and habitats, and endemic species, is a viable conservation strategy for defining priorities. At the same time, it is important to capture oceanographic processes and ecological linkages that interconnect these habitats. The geographic scope of the project (EEZ from 22°N latitude to 65°N latitude) included estuaries and islands, but not upland areas of freshwater environments. We also emphasize transboundary areas, owing to the international aspect of this project.

Data Compilation and Distribution

Conservation planning exercises include physical, biological, and social components, and the data that goes into GIS analyses must reflect each of these. The physical oceanography community has a long history of basin scale data collection efforts, but biological and social datasets are more limited in scope. Therefore, we generated relevant datasets through synthesis of country-level information such as EEZ boundaries, population, ports, national parks, and local priorities. Few of these datasets had ever been observed in the context of their partners, nor in the same software, or projection. All data were projected to a uniform Lambert Azimuthal equal area projection with a central longitude that bisects North America. This compromise permits easy comparison with forthcoming North Atlantic datasets.

Digital assets from the physical oceanography community range from ships of opportunity to moored buoy arrays to satellite-derived measurements for gravity, topography, surface temperature, surface height, and chlorophyll. The physical oceanography community also has a long history of data sharing and distribution, and these types of information are readily available on the internet from NASA's Jet Propulsion Laboratory (JPL) Physical Oceanography Distributed Active Archive Center (PODAAC).

Biological data were both the most difficult to obtain and the most revealing types of information. No single biological survey encompasses the entire B2B latitudinal extent. Satellite derived estimates of chlorophyll from the SeaWIFS project, which were converted to primary productivity using methods described by Behrenfeld and Falkowski (1997), come the closest. Neither the NOAA triennial trawl surveys, nor the Partnership for Interdisciplinary Studies of Coastal Oceans (PISCO) consortium, nor the bi-national California Cooperative Oceanic Fisheries Investigation (CalCOFI) survey programs encompass a uniform spatial and temporal extent over the entire Pacific Coast of North America out to 200 nautical miles. We compiled several datasets, including almost 2,700 records of habitat forming deep-sea coral occurrences from 10 different record-keeping institutions, to represent the benthic component of the region (Etnoyer and Morgan, 2003), and blue whale tracks from the Department of Fisheries and Wildlife of Oregon State University. Future data gathering efforts should focus on and support large-scale efforts and seek to integrate national fisheries statistics and survey programs.

All the datasets described in Table 9.1 are included on the B2B 1.1 CD-ROM as either attributed points (e.g., deep-sea corals and ports and harbors), lines (e.g., blue whale tracks), and polygon (e.g., EEZ) coverages, shapefiles (federal MPAs), or rasters (4 km-resolution altimetry, 9 km-resolution sea surface temperature). The oceanographic datasets are bi- weekly or monthly over a four-year El Niño Southern Oscillation (ENSO) cycle (1996-1999). Postscript maps and animations of sea surface temperature and sea surface height from the US Navy Layered Ocean model were included in an extras folder on the CD-ROM.

All datasets on the B2B CD-ROM include federally compliant metadata regarding the data's origin, and most are groundtruthed for data quality, as well as vertical and horizontal accuracy. This is an important step in the process of analysis to insure the legitimacy of results, and to anticipate criticism from federal or commercial interests opposed to conservation measures. Smith and Sandwell's (1997) global satellite altimetry-derived bathymetry was compared to multi-beam data for peak heights on 12 seamounts in the Gulf of Alaska, and found to vary within a remarkable range of 39 to 504 m (Etnoyer, 2004; Fig. 9.1; see page XXX). This quality control exercise indicates our continuing

Table 9.1. All of these datasets are uniformly projected and included on the B2B 1.1 CD-ROM with FGDC compliant metadata for use in a marine conservation GIS.

Physical	*Biological*	*Social*
Surface Currents	Chlorophyll	Local priorities
World Vector Shoreline	Mammals	Population
Sea Surface Temperature	Turtles	Ports and Harbors
ETOPO2 Bathymetry	Deep-Sea Corals	MPAs
Seamounts	EEZ	GTOPO30 topography

need for finer scale coastal bathymetry data. All bathymetry values were upgraded from the satellite-derived resolution of 4 km to a 100 m tri-national synthesis product that covered approximately 40% of the non-Alaska study area. Maps of deep-sea corals were found to reflect research effort, and to likely underestimate the abundance and distribution of deep-sea corals within their cosmopolitan range and their 20 m–4,000 m vertical extent. The Hawaiian Undersea Research Laboratory regularly groundtruths NASA's Advanced Very High Resolution Radar from Pathfinder, finding that data to vary in accuracy from day to night, falling generally within one tenth of a degree.

It is important to note that different countries have different data standards and different policies regarding the freedom of information. The United States passed the Freedom of Information Act in 1967, but Mexico passed its own in 2003. Before B2B, medium-resolution seafloor bathymetry in Canada was proprietary, and some government agencies had to pay for access to bathymetry data off British Columbia. In keeping with the spirit of transparency and cooperation, the Canadian Department of Fisheries and Oceans granted MCBI distribution rights to that information. Mexico also met the challenge of cooperation, with ready access to medium-resolution bathymetry from the Gulf of California. These datasets were not made available as part of the B2B 1.1 CD-ROM, but they were made available to researchers participating in the B2B analyses.

Spatial scale is a critical aspect of GIS analyses that range, for example, over three different countries with three different data standards and three different levels of investment in data development. One must "draw the line" somewhere to avoid an overabundance of spatially or temporally irrelevant data. We considered two spatial approaches: first, selecting datasets with a common resolution over the B2B extent, and second, building a "patchwork" of variable resolution datasets. We agreed that it was "unfair" to ultimately discern smaller PCAs from countries with higher-resolution datasets (e.g., bathymetry), so we settled on common resolution data derived largely from satellites. In the end, we incorporated medium-resolution (~100 m) bathymetry in our benthic complexity analysis (Ardron, 2002). For temporal consistency, we identified a contemporary four-year time frame (1996-1999) that captures the extremes of ENSO variability.

In June 2002, MCBI, in collaboration with the CEC, Ecotrust, and Surfrider Foundation, organized a "Data Potluck" workshop in Portland, Oregon. In this workshop, nearly 80 representatives from 30 organizations offered and exchanged datasets that appeared relevant to the spatial scale of the B2B region. This information and advice was incorporated into the B2B CD-ROM. The Data Potluck was the second in a series of technical meetings designed to build consensus on spatial methods of analysis for priority conservation areas.

Whereas experts at the first meeting held in Monterey placed emphasis on data types such as sea surface temperature and surface currents, the Data Potluck presentations revealed a new emphasis on socioeconomic information that was not evident in the previous Monterey Workshop. This difference in emphasis may be a result of the different backgrounds of the attendees at the two workshops, or may reflect the evolving nature of marine protected area (MPA) science. Socioeconomic data that were included on the B2B CD-ROM included locations of fishing ports and landings information, cities, population, MPAs, and previous efforts to identify conservation priorities for different regions within the B2B realm. The mandate given to the project was to use existing sources. Thus, no new data were collected, although significant efforts to digitize certain datasets did occur. In several cases, we included previous exercises to define priorities at regional scales. The spatial data generated by this effort are available on CD-ROM in GIS format (Etnoyer et al., 2002).

Workshop participants identified many "parallel projects" within the continental B2B region that have strong sub-regional potential, and identified common data needs for a more evenly distributed workload, and a potential for these disparate organizations to begin to speak with one voice, without sacrificing their individual institutional goals. The Data Potluck idea was very well received. Ed Backus of Ecotrust mentioned that the Potluck idea seemed awkward at first, but his staff eventually came to terms with the idea that a Potluck methodology provides an incentive to contribute, lowers expectations, and levels the playing field by providing all participants with the same information, which they then might use to address their own concerns.

MCBI staff also took advantage of the assembled expertise to conduct a survey of marine GIS users to understand their opinions on the data needed for successful identification of priority conservation areas. Twenty respondents from the three countries, all familiar with data-driven priority-setting exercises for conservation goals, completed a survey distributed by MCBI. Respondents ranked data types for their potential contribution to a priority habitat analysis at the continental scale, commented on methods, and future data needs.

Bathymetry, primary productivity, existing MPAs, and fishing pressure data were ranked highest (>4.5) for their ability to strengthen a GIS for a priority habitat analysis. All listed data (Table 9.2) save LIDAR and NGO Activity ranked above 3.5 on a scale of 5. Respondents generally valued their personal contributions ("Other") very highly, with substrate type, spawning aggregations, submarine cables, political climate, pollution and "community will" each receiving unsolicited votes from 20% of the respondents.

The general response to the qualitative question, "How would you like to see these data layers used in a GIS to generate a list of priority habitats for the B2B region?" suggested that most viewed "priorities" as a qualification of either the degree of threat or the opportunity for

Table 9.2. Responses to survey asking participants to rank the data types they believed had the greatest ability to strengthen a GIS priority areas analysis at the continental scale (1= will not add much to the analysis, 5 = will strengthen the analysis considerably).

Physical Data Type	*Rank*	*Biological Data Type*	*Rank*	*Social Data Type*	*Rank*
Bathymetry	4.67	Primary Productivity	4.67	Other	4.78
Other	4.66	Other	4.66	MPA	4.53
Seamounts	3.93	Mammal Tracks /Dist.	4.23	Fishing Pressure	4.49
Sea Surface Temperature	3.71	Submerged Aquatic Vegetation	4.19	Jurisdictions	4.00
Altimetry (Surface Currents)	3.59	Seabird Tracks/Dist.	4.10	Ports and Harbors	3.87
LIDAR	2.67	Turtle Tracks/Dist.	4.05	Previous Priorities	3.66
Deep-Sea Corals	3.93	NGO activity	2.87	NOAA Atlas	3.67

Other	*Count*	*Other*	*Count*	*Other*	*Count*
Substrate	4	Spawning Aggregations	4	Cables	4
Sediment Transport	3	Fish Sp. Distributions	3	Political climate	4
Lagoons	3	Nurseries	2	Community will	4
Upwelling	2	Feeding Aggregations	2	Pollution/ Dump sites	4
Recreational uses	3				

Other	*Count*
Consistent high resolution shoreline, upwelling, salinity, shelf, ocean features	2
Large Predators, Benthic Sp. Assemblages, historical abundance/ distribution, migration corridors, kelp/ mangrove	1
Pipelines, current litigation, shipwrecks, ongoing efforts, oil leases, population, enforcement, access, mega- development projects	1
Outfalls, shipping channels, economic impact, fishing grounds, indigenous use	2

Comments: Bathymetry and primary productivity were ranked highest for their ability to strengthen a priority area analysis. All data save LIDAR and NGO Activity ranked above 3.5 on a scale of 5. Respondents generally valued their contributions ("Other") highly, with substrate type, spawning aggregations, submarine cables, political climate, pollution and community will each receiving unsolicited votes from 20% of the respondents.

action. That is, most felt that the highest conservation priorities were those sites in great danger, or those sites where conservation actions were in progress, but incomplete. Individuals varied widely in their opinion of PCA goals, but the above model stands out as the most common view, with the most applicability. Comments by Mexican participants strongly suggested that some kind of "governance index" or measurement of "community will" was important. This was reinforced by some U.S. respondents, who had previously thought existing MPAs were the strongest candidates for enhanced protection. This reflects the general opinion that existing legislation rarely translates into effective management, and that boundaries are poor indicators of protection. Respondents also felt that submarine features and upwelling indices could benefit any PCA algorithm. Survey results indicated a large amount of variability and opinion regarding critical data.

In the 12 months anticipating the Priority Conservation Areas Workshop, MCBI distributed nearly 200 copies of the B2B CD-ROM to more than 50 different organizations and more than a dozen different countries. We charged a nominal fee to offset the costs of data packaging and distribution, and encouraged researchers to perform and submit their own priority setting exercises for consideration. Two submissions of outside analyses were received, benthic complexity by Jeff Ardron of the Living Oceans Society in British Columbia, and primary productivity analyses by Chuanmin Hu and Frank Muller-Karger at University of Southern Florida. The B2B 1.1 CD-ROM provides the foundation for half a dozen graduate theses to date, and background data for many regional investigations. The B2B CD-ROM provides a model for future "democratic" priority-setting exercises in marine conservation by providing information to all as an open data source.

Data Analyses

Several data analyses were conducted in order to highlight the significance of selected datasets to the conservation priority setting exercise. These analyses include: (1) benthic complexity—a measure similar to rugosity; (2) sea surface temperature fronts—areas known to aggregate a wide-variety of pelagic sea life, including fishes, sea turtles, birds and mammals; (3) primary productivity—chlorophyll measures modified by relative factors like day length and water temperature; and (4) sea-surface height—a measure that discerns currents and eddies, which transport nutrients and aggregate ocean life.

BENTHIC COMPLEXITY

Benthic complexity is a unique measure related to both slope and roughness. Generally speaking, it is a measure of the intricacy of the seafloor, that is, how much it changes in a given unit of area. This is, in many ways, similar to "rugosity." However, unlike rugosity, complexity is not greatly affected by large, unidirectional changes in depth, such as cliffs. The benthic complexity methodology, described by Ardron (2002)[3], is used to capture regions of high seafloor irregularity that previous methods, such as slope and relief, had not. It differs from slope and relief by differentiating between uniformly steep features, such as fjords, and those features that display more complexity, such as rocky reefs, seamounts, and archipelagos. The latter are especially known for their ecological significance.

For the purposes of our analysis, bathymetry with sufficiently high resolution (roughly 1:250,000) was not uniformly available throughout the B2B region. Bathymetry was available for three large regional areas: (1) British Columbia; (2) coastal California, Oregon, and Washington; and (3) Baja California. This analysis selected areas of highest benthic complexity such as the shelf slope, canyons, gullies, island archipelagos,and seamounts.

SEA SURFACE TEMPERATURE FRONTAL DENSITY

Oceanographic fronts can be some of the most persistent features in the pelagic realm, and they are known to perform vital habitat functions for fishes (Seki et al. 2002), sea turtles (Polovina et al., 2000), seabirds (Decker and Hunt, 1996), and marine mammals (Davis et al., 2002). Fronts are characterized by the interaction of two dissimilar water masses, such as cold water and warm water, fresh water and salt water, or nutrient-rich water with nutrient-poor water. This interaction can bring deep-water nutrients to the surface, where sunlight and warm water stimulate a phytoplankton bloom, often followed by a zooplankton bloom, producing a pulse of resources to species at higher levels.

The multi-channel sea surface temperature (MCSST) data are derived from the five-channel advanced very-high-resolution radiometers (AVHRR) on board NOAA polar-orbiting satellites. Clouds hinder frontal detection by radiometry. Cloud-free, interpolated sea surface temperature (SST) data are available at coarse scales. We tested satellite-derived SST data at three different resolutions to examine the effect of scale upon edge-detection algorithms. We found that the coarse-scale, cloud-free MCSST interpolated data underestimated the total linelength of frontal features from finer scale raw AVHRR at nine-kilometer resolution, and Coastwatch data at two-kilometer resolution. However, MCSST data can reliably detect the strongest, most persistent temperature fronts within the B2B extent. We examined monthly MCSST data over a four-year period, from 1996–1999. This “cloudless” temporal window captured a strong El Niño, a La Niña and two “normal” years.

Using new analysis methods to detect temporal variation in SST frontal concentrations (Etnoyer et al., 2004), we found less than 1% of the Northeast Pacific is active for temperature fronts across seasons and between years. We identified three of these large features—offshore

Los Cabos (Mexico), Point Conception (United States), and the southern California Channel Islands (United States). The frontal density signature off northern Baja California (Ensenda Front) appeared weaker and closer to shore in an El Niño year, and stronger and more offshore during a normal year. Satellite telemetry data and fisheries statistics demonstrate these pelagic habitats are important to migrating blue whales (*Balaenoptera musculus*) (Fig. 9.2; see page XXX), swordfish (*Xiphias gladius*), and striped marlin (*Tetrapturus audax*). B2B is the first marine conservation initiative to identify and quantify "persistence" for pelagic marine habitat.

SEA SURFACE HEIGHT: CURRENTS, GYRES AND EDDIES

At the scale of an ocean basin, the sea surface is not flat. Warm water expands, producing higher than average surface heights (hills), while cool water contracts, registering lower than average surface heights (valleys). Orbital satellites such as TOPEX/Poseidon use pulses of radar to measure minute differences in sea surface height. This is known as "altimetry." In an altimetry map, wind and waves are averaged, and sea surface height is expressed as an "anomaly"—a negative or a positive difference from the mean sea surface height.

These small differences in water height translate into current movement. Warm-core eddies, areas with higher than average sea surface heights, spin clockwise or anti-cyclonically. Lower than average sea surface heights, or cold-core eddies, spin counterclockwise or cyclonically. Furthermore, cold-core eddies create upwelling conditions that bring nutrients to the surface, and may result in trophic cascades and plankton blooms. Eddies can form when large freshwater flows from terrestrial rivers spill into the saline waters of the sea. The Haida Eddy (Pacific Canada) is a three-dimensional "swirling freshwater tornado," about the size of Lake Michigan, that transports coastal nutrients (such as iron) to nutrient-poor offshore waters, fertilizing the environment and creating a plankton bloom (Crawford and Whitney, 1999). The Haida Eddy appears most strongly in El Niño winters off British Columbia. The footprint of the Haida Eddy varies within El \h \r 1Niño Southern Oscillation cycles, and appears weakest in La Niña years.

For this analysis, we used altimetry to study surface current patterns in the Gulf of Alaska. The Colorado Center for Atmospheric Research provided four years of bi-weekly averaged surface current magnitude and velocity, derived from a blended product of TOPEX/Poseidon, and ERS-1 and ERS-2 satellites. We masked all but the highest waters or the greatest slope and sequenced the data to reveal the location and trajectory of warm core rings in the Gulf of Alaska.

We identified the 1998 Haida Eddy and tracked it from Gwaii Haanas (Queen Charlotte Islands) in a southwesterly direction to beyond the Canadian EEZ. The feature persisted for more than a year, originally

100 kilometers in diameter, then dissipating down to 75 km for much of the year. We identified an equally impressive anti-cyclonic feature that seemed to originate in Shelikof Strait and to propagate westward along the Aleutian Archipelago, gaining strength as it passed. This feature traveled more than 400 km in the course of six months. Several Sitka eddies came and went in the Gulf of Alaska throughout the four-year investigation period. These eddies represent a trans-boundary export of nutrients and larvae between British Columbia, Canada, and Alaska, United States. It is equally possible that these retentive eddies could concentrate and transport inorganic pollutants and contaminants to rare and delicate seamount ecosystems.

PRIMARY PRODUCTIVITY

Obtaining synoptic chlorophyll distribution in the global ocean is only possible with satellite ocean color sensors. Sea-viewing wide field-of-view sensor (SeaWiFS) and moderate-resolution imaging spectroradiometer (MODIS) satellites provide one- to two-day coverage of the entire Earth, allowing study of regional and global ocean color patterns. The primary data product from the sensors is the surface chlorophyll concentration (in mg/m^3). Combined with the SST data obtained from satellites with an AVHRR, primary production can also be estimated from empirical models.

Net primary productivity (NPP) can be estimated from three parameters: chlorophyll, photosynthetically available radiation (PAR), and SST. We estimate the NPP in g C m^{-2} $month^{-1}$ (Behrenfeld and Falkowski, 1997). Monthly chlorophyll data for the region bounded by 12°N–72°N and 180°W–100°W between September 1997 and June 2002 were obtained from the US National Aeronautics and Space Administration (NASA) Distributed Active Archive Center[4], PAR data from SeaWiFS[5], and monthly SST data from NASA's Jet Propulsion Laboratory[6].

Briefly, atmospheric effects were removed and chlorophyll concentration was estimated. To estimate primary production, the model takes into account the depth-dependent chlorophyll and light profile, and estimates the primary production per unit chlorophyll from SST, using an empirical relationship. Based on the NPP monthly results for each location, we estimated the number of occurrences (frequency) in a year when NPP exceeded a pre-defined number (10 g C m^{-2} $month^{-1}$). The number was chosen according to visual examination of the difference between oligotrophic and productive waters, but is somewhat arbitrary. The results serve as an index to describe how long enhanced productivity exists.

PCA Workshop

This process culminated in April of 2003 with an experts' workshop, held at Simon Fraser University in Burnaby, British Columbia, Canada, to map North American PCAs, summarized herein. The methodology selected for identifying PCAs relied on teaming experts' knowledge with the development of a geographic information system. The use of expert knowledge in such an interactive team approach to decision-making is referred to as a Delphic approach or poll. It is characterized by experts informed of current consensus but not harassed by arguments, with both majority and minority opinions maintained. Subsequent review and refinement based on these opinions results in consensus.

The GIS included appropriate spatial datasets and selected analyses available for the B2B region at a common resolution, as well as smaller subsets of regional information. Analyses focused on translating several of these datasets in order to highlight regions where physical processes lead to unique features or concentrations of species. At the final PCA identification workshop, experts reviewed the aggregated datasets and analyses to inform their judgments of ecological value and conservation priority.

Throughout all consultations, this process attempted to interact with the appropriate federal agencies in each of the CEC countries, rather than directly involving state, provincial, or regional governing bodies (though these offices were involved to differing degrees). This led to a number of significant restrictions on this project. For example, the use of local ecological knowledge was discussed and considered. During our consultative process it was agreed that this type of information was clearly an important component of local conservation efforts, but at the continental scale, it should be left to additional regional and local efforts. This constraint of top-down efforts highlights the necessity of eventually matching this project with a community-based action plan involving members of the communities within the PCA regions.

IDENTIFYING PRIORITY CONSERVATION AREAS WORKSHOP/CONSENSUS MAPPER

The final aspect of this work was an experts' workshop to select priority conservation areas. This workshop involved a series of interactive mapping exercises (detailed later in this chapter). In April 2003, MCBI and the CEC led a three-day workshop at Simon Fraser University, British Columbia, where marine experts from government agencies, nongovernmental organizations, academia, and regional organizations in Canada, Mexico, and the United States met to identify PCAs in the B2B region. These experts represented interests from resource use, science, management, and conservation. The experts were supported by a team of GIS experts from MCBI and the geography departments of Simon Fraser University and McGill University, Montreal, Canada, to provide technical support for the mapping workshop.

At the identification workshop, we reviewed for the experts the appropriate rationale for continental scale PCAs in accordance with the goals of the project and the consultations at previous meetings. Experts were asked to identify those regions that offered high diversity of all criteria ("the most bang for your buck"). We briefed experts on the history of the B2B initiative, goals of the workshop, definitions of key terms, and criteria for selecting priority conservation areas. The organizers also informed the participants that the end product of this workshop would guide the three nations' governments in their joint conservation collaborations, as well as provide a framework for regional conservation efforts and programs.

Workshop organizers presented the assembled data and analyses, and individual experts made presentations on a range of species and areas of concern. These presentations were on topics such as the natural history of seamounts, benthic complexity, sea surface temperature frontal regions, species hotspots, fisheries, threats from human activities, and ongoing conservation activities in each of the three nations.

Next, experts participated in a round-table mapping exercise. Consensus Mapper is a software program and methodology that allows exploration of spatial data, discussion of decision priorities and mapping of selected regions. Individual maps are overlaid to show areas of overlap, or consensus, between different working groups. The round table permits experts from different fields of expertise to uncover their commonalities, while those with divergent interests can clarify their points of disagreement and work towards compromise. This system was developed by Community-Based Environmental Decision Support at McGill University (Faber, 1996; Balram and Dragicevic, 2002). The advantages of collaborative mapping include the following (Balram et al., 2003; Balram et al., 2004):

- facilitating collaboration and consensus building within a dynamic social setting;
- providing structure and documenting the stakeholder participation process;
- incorporating inputs and policies at various levels of spatial aggregation;
- encouraging spatial thinking and exploration of environmental issues;
- providing feedback into the decision-making process;
- integrating data from expert sources;
- managing the technical and social network of the participation process; and
- facilitating collaborative monitoring of decision actions.

Following an overview of the available data and instructions from the workshop facilitators, experts learned how to use Consensus Mapper software, a simplified version of ArcView software. Finally, participants were assembled into expert working groups. The workshop was conducted as a series of break-out sessions for mapping and plenary discussions to review progress.

During the workshop, experts engaged in several exercises to identify PCAs. In order to do so, the experts first identified ecologically significant regions (ESRs) in the B2B extent. The experts were asked to base ecological significance on the data available, and on their personal knowledge of species, habitats, and physical and oceanographic features in the B2B region. Experts reached consensus on ESRs by overlaying individual team maps to show areas of agreement between expert working groups. In subsequent exercises, experts were asked to review the specific criteria for each ESR and rate it according to their knowledge of regional threats (e.g., resource extraction, pollution, coastal development) and opportunities for collaboration (e.g., previous designation as a priority or site of conservation interest, existing protected status, sustainable practices, local support) relative to the other ecologically significant regions. The resulting map of ESRs served to highlight places of high ecological significance. PCAs are a subset of ecologically significant regions that become priorities based on significant threats and/or opportunities.

MAPPING EXERCISES

Exercise One: Thematically Identify Ecologically Significant Regions. The participants were divided into six groups according to their expertise: one benthic environment group, two pelagic environment groups, and three planning and management groups. Within each group, there were six to ten participants and at least one representative from each of the four B2B subregions: (1) Mexico, (2) California, Oregon, and Washington, USA, (3) Canada, and (4) Alaska, USA. Each group identified areas that they knew to be ecologically significant, and discussed and debated these with others in their group. These areas were drawn on a digital map using the Consensus Mapper program. For each place identified, they noted the rationales in a spreadsheet, stating the physiographic, oceanographic, and biological features, species diversity, endemism, or other criteria they believed relevant to the site's ecological significance. Pelagic groups were also asked to focus on migratory species (including the CEC's list of marine species of common conservation concern, Appendix 9.1). In this exercise, each group was allowed to select up to 40% of each nation's EEZ within the B2B extent. They were also asked to refrain from selecting areas smaller than 1° square. At the end of this exercise, all the groups' selections were superimposed onto one consensus map, with areas shaded in accordance with the degree of overlap among the six groups. In a plenary session workshop, participants were able to review and comment on the overlaid map of ESRs.

Exercise Two: Review and Refine Ecologically Significant Regions. We divided experts into four groups by region: Mexico; California, Oregon, and Washington, USA; Canada; and Alaska, USA. Within each group, members had differing expertise. They reviewed the results of the previous exercise, seeking to refine the coarser-scale analysis. They either modified the boundaries of those high-consensus regions from Exercise One, adopted them as ESRs, or added new selections. In this exercise, the groups also documented the rationales for each ESR they identified. Each group was allowed to identify up to 40% of its respective EEZ as ecologically significant. At the end of this exercise, all the groups' selections were combined and shown on a map in a plenary session. The participants saw the final ESRs from Baja California to the Bering Sea. Each group had an opportunity to explain their selections to the other groups

Exercise Three: Identify Threats and Opportunities. In addition to ecological significance, threats and opportunities are crucial factors in assigning priority. In this exercise, the participants were again divided into regional groups to rate the relative level of threats and opportunities in each of the ESRs previously identified. The workshop organizers categorized threats into the following types: (1) non-renewable resource extraction; (2) exploitation of renewable resources; (3) coastal land use change; (4) pollution; (5) damaging recreational use; and (6) physical alteration of coastlines. Opportunities were categorized as: (1) existing legal protection; (2) available management; (3) local and/or regional support; (4) funding available for information management and/or conservation; and (5) sustainable business practices. Each group of experts received a list of these categories. Group members discussed the relative significance of the types of threats and opportunities existing in their ESRs. Where applicable, experts provided additional details pertaining to the threats, ranked their relative intensity (high, medium, or low), and assessed the current trend (getting better, the same, or getting worse). The description, intensity, and trend were all recorded in a spreadsheet.

Exercise Four: Identify Priority Conservation Areas. The final step in the workshop was to identify PCAs. The participants were divided into six tri-national teams with at least one expert from each of the four B2B geographic regions. In this exercise, the goal was to select not more than 20% of the area within the ESRs from Baja California to the Bering Sea as PCAs. The group members used Consensus Mapper to digitally map their selections, and specified their rationales for every PCA. At the end of this exercise, the six sets of PCAs selected by the six groups were overlaid and shown to all workshop participants in a plenary session. The selected areas were colored according to the degree of overlay. The participants saw the level of consistency across the

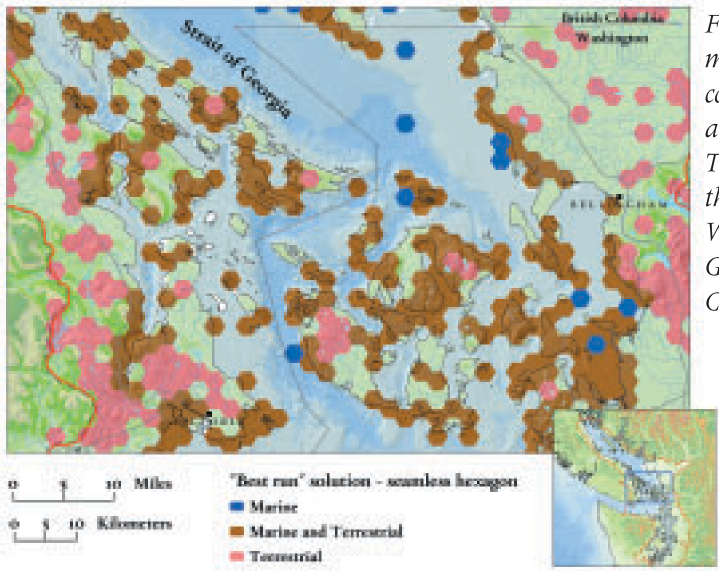

Figure 8.3. The analysis of marine and terrestrial conservation targets run within a single spatial planning unit. Transboundary region between the San Juan Islands in Washington and the Southern Gulf Islands in British Columbia

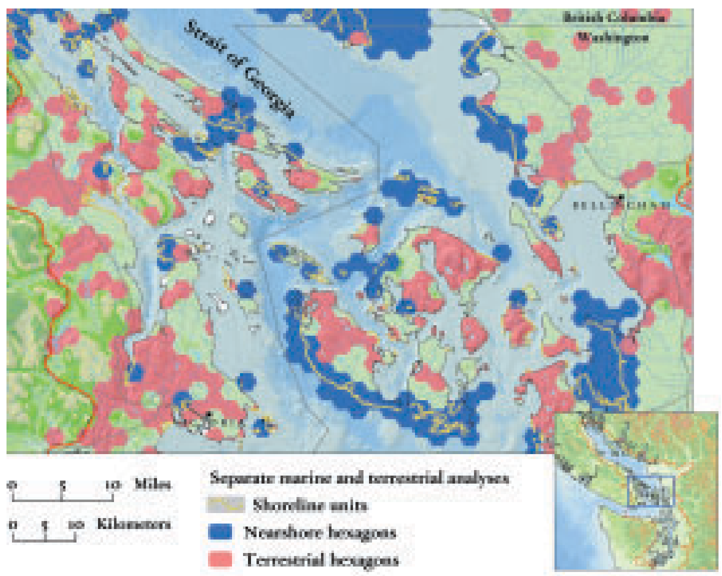

Figure 8.4. Marine and terrestrial conservation targets analyzed within three separate spatial planning units. Transboundary waters between Washington and British Columbia

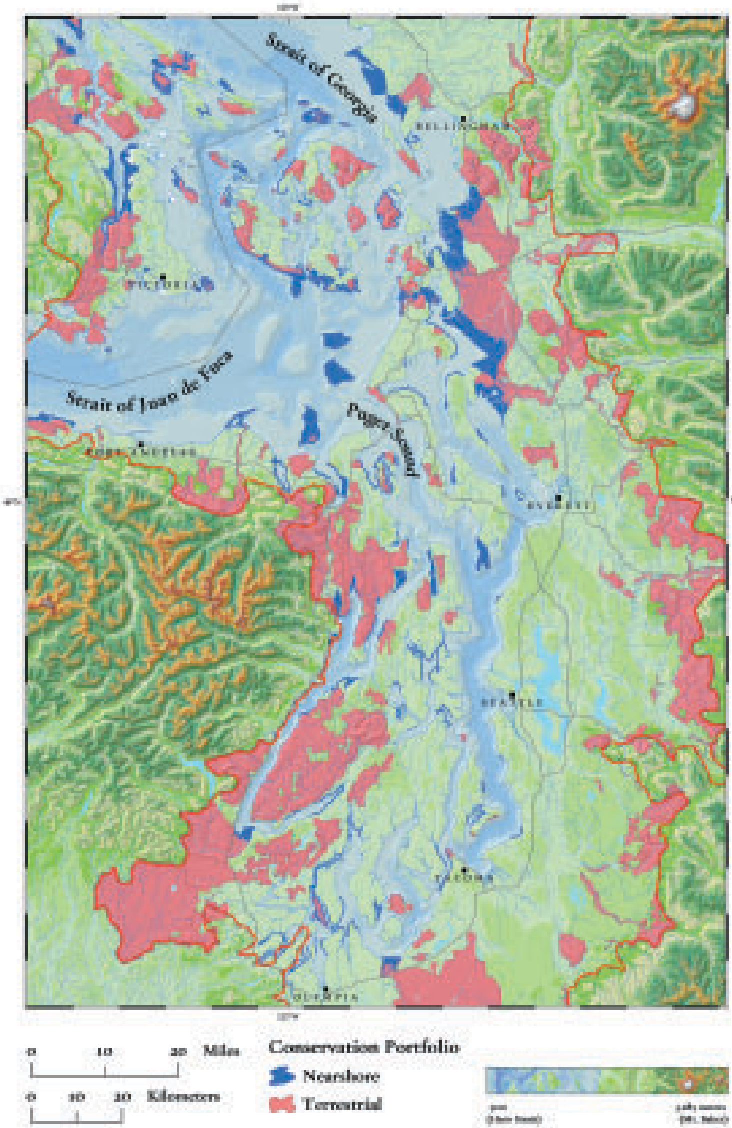

Figure 8.5. Final analysis and site delineation of nearshore marine and terrestrial high priority conservation areas. Puget Sound, Washington

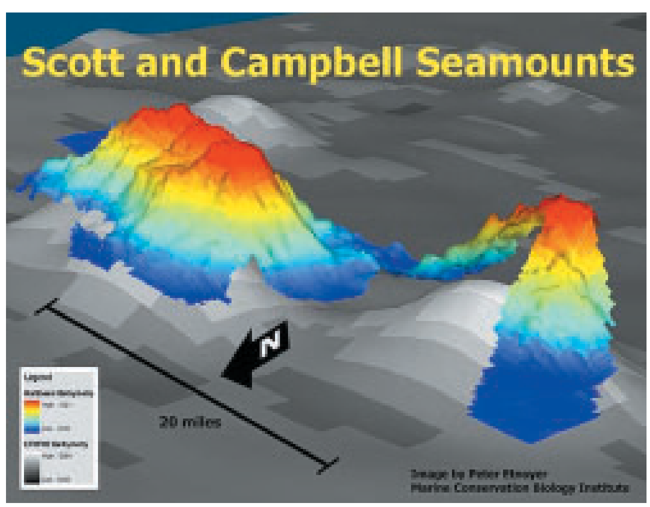

Figure 9.1.Overlay of multibeam bathymetry (color, NOAA GOASEX) and ETOPO2 bathymetry (gray scale, Smith and Sandwell, 1997), demonstrating offset between the two data sources.

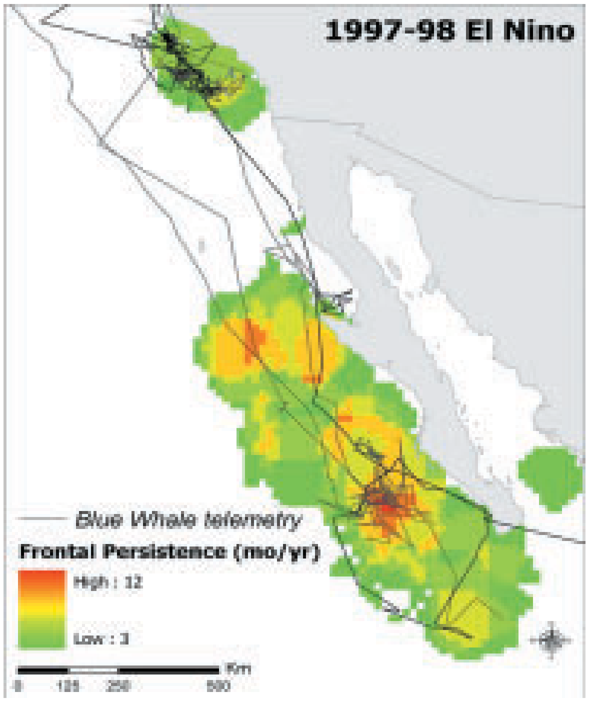

Figure 9.2. Results of frontal density analysis (1998) overlaid with blue whale tracks. Whales congregate in areas of high persistence of sharp SST discontinuities.

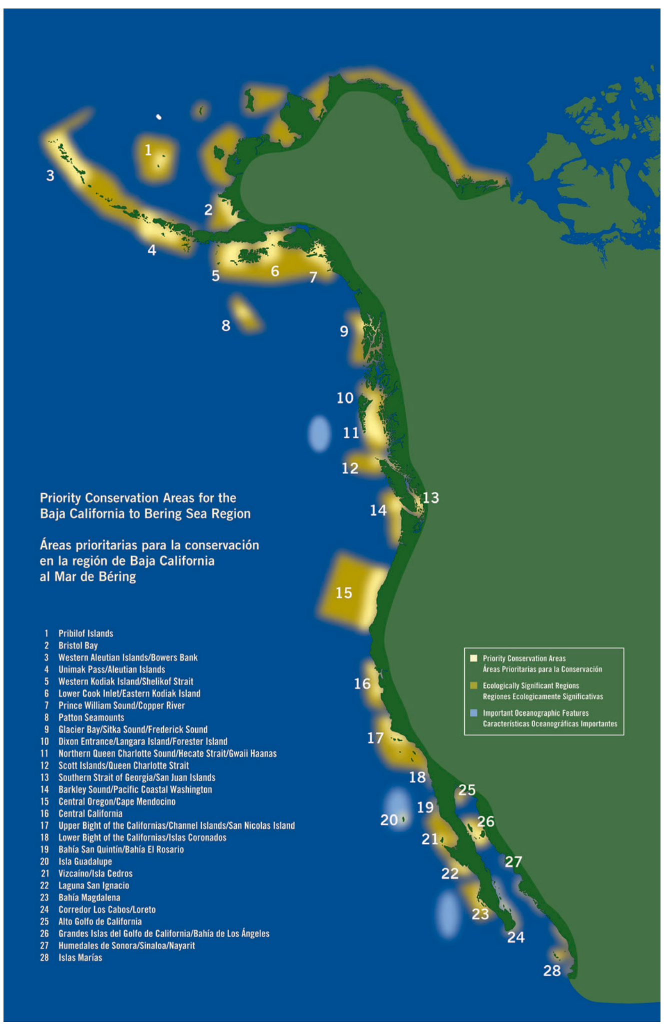

Figure 9.3. Priority Conservation Areas (gold), Ecologically Significant Regions (yellow) and Important Oceanographic Features (light blue) for the Baja California to Bering Sea Region.

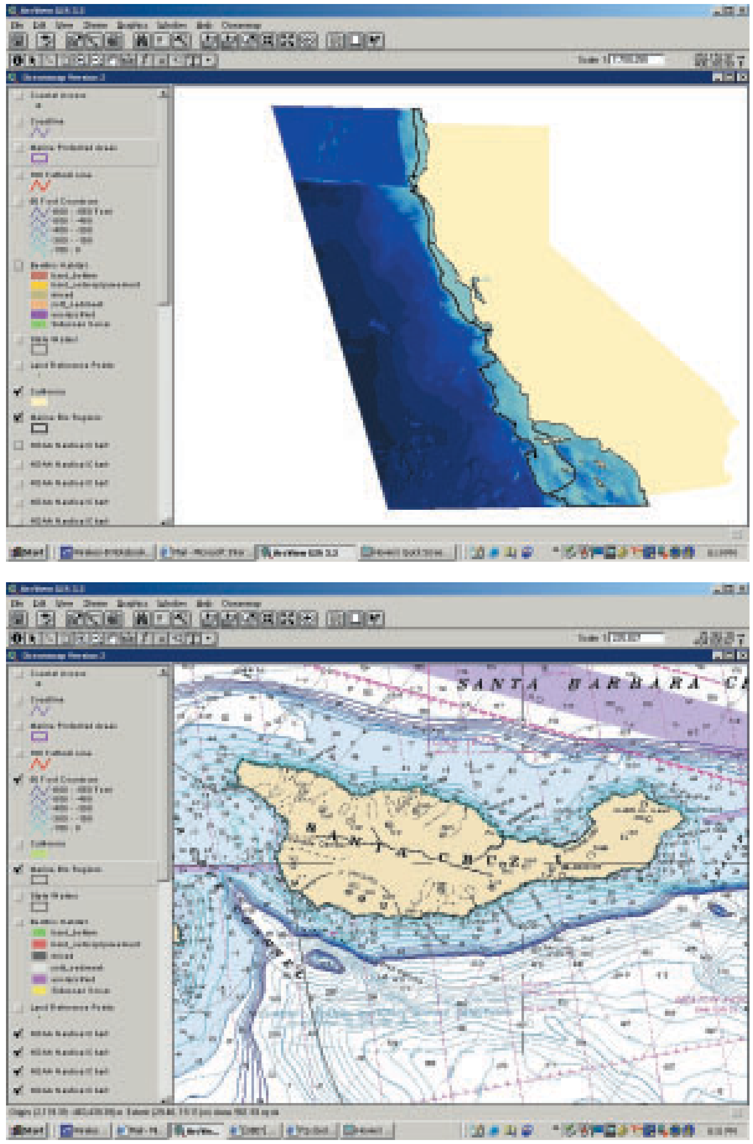

Figure 10.1. (a) GIS-based OceanMap full view. (b) GIS-based OceanMap enlarged view.

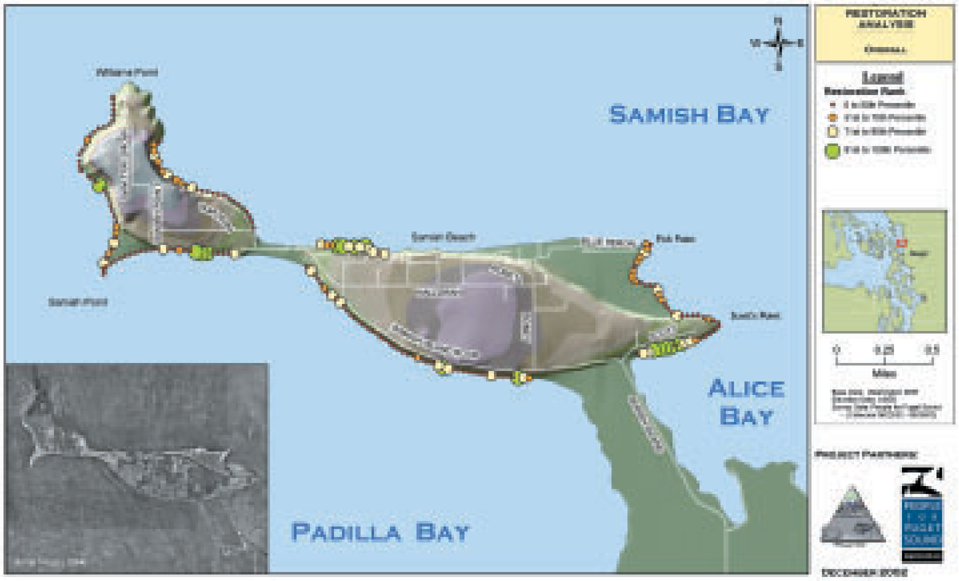

Figure 11.3. Example output for overall Restoration score, combined for all five models. Restoration ranks are relative.

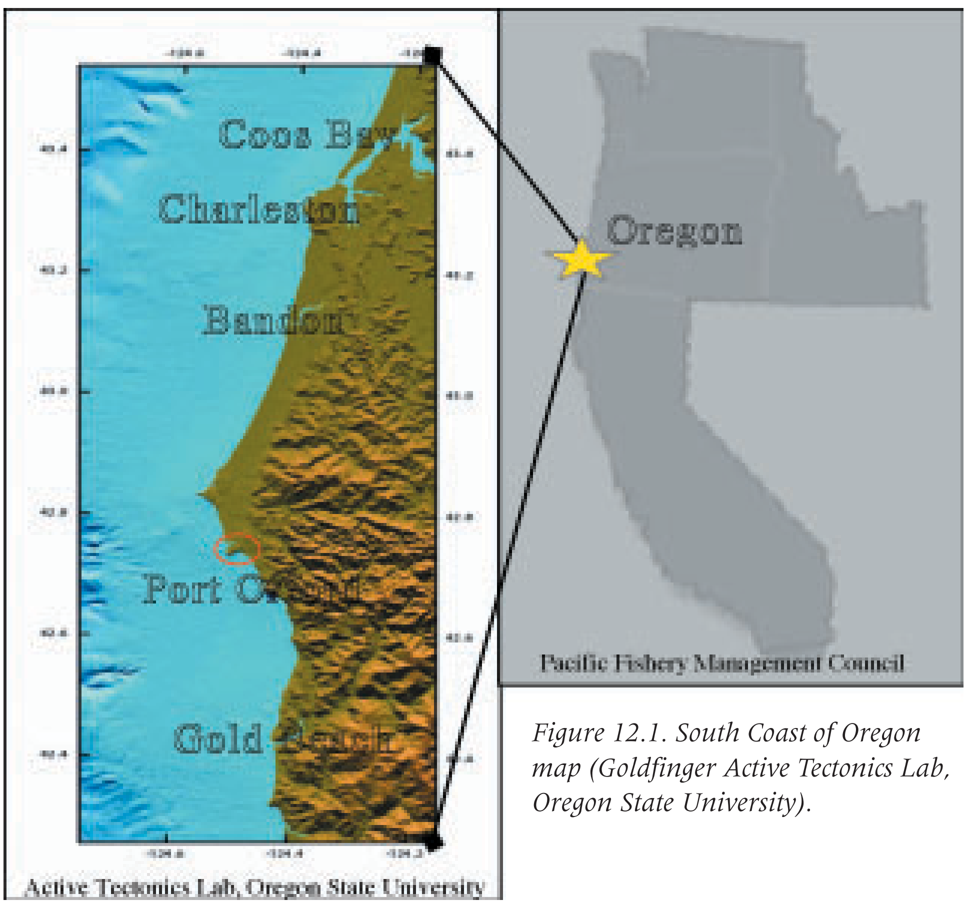

Figure 12.1. South Coast of Oregon map (Goldfinger Active Tectonics Lab, Oregon State University).

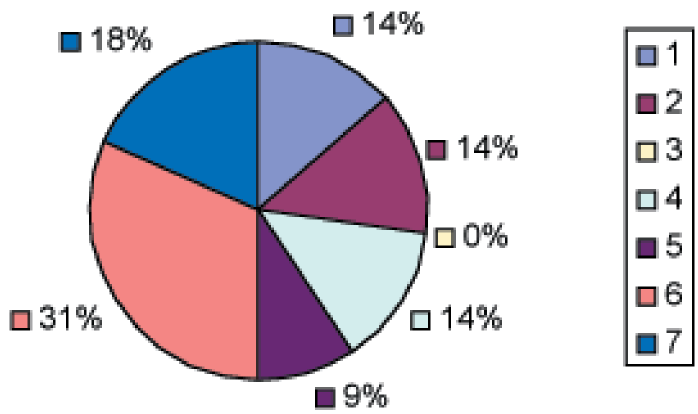

Figure 12.3. Percent of LKI participants and the number of target fisheries in their portfolio.

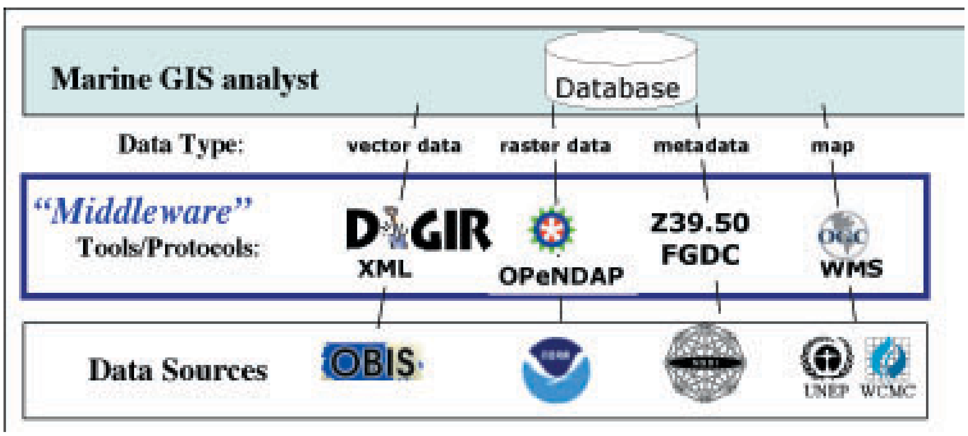

Figure 13.4. Common data discovery, data transport and Internet mapping tools, protocols and standards common to marine GIS operations (from Halpin, 2004).

groups. Each group had the opportunity to explain the reasoning behind their selection and to point out unique features they had taken into consideration.

Results and Discussion

Defining priority conservation areas (PCAs) is the fulfillment of a workplan by the three nations to identify opportunities to work collaboratively, at the North American level, on marine conservation. A total of 28 sites were identified as PCAs, totaling 8% of the total EEZ area of the 3 nations (Fig. 9.3; see page XXX). By country, these areas represent approximately 7% of the B2B region within Mexico, 10% of the area in Canada's Pacific EEZ, and 8% of the US EEZ (within the B2B defined region). The full discussion of the expert criteria and descriptions of the PCAs are included in the final report (Morgan et al. **2005**). Boundaries of these PCAs were purposely left fuzzy to reflect the inappropriateness of human delineation to ecological phenomenon.

The CEC, through convening and coordinating NAMPAN, is developing capacity for a network of MPAs to span the jurisdictions of the three CEC member countries. The aim of NAMPAN is to enhance and strengthen the conservation of biodiversity in critical marine habitats throughout North America by creating a functional system of ecologically based MPA networks that cross political borders and depend on broad cooperation. The identification of these PCAs is not intended as the MPA network design, but is rather a portfolio of continentally significant sites that can serve as nodes around which a network of reserves can be built. Networks of reserves are an important tool for conserving biological diversity (Lubchenco et al., 2003) and these PCAs should be viewed as places to begin building a more comprehensive, effective MPA network for North America. Although these PCAs are science-based and anchored in a continental perspective, they are not intended to be a marine reserve network design as envisioned by others (Margules and Pressey, 2000; Possingham et al., 2000). Rather, the workshop organizers and participants clearly intend this report to be a first step towards a continental conservation strategy for B2B species and ecosystems. We hope that these priority areas for conservation will be used in formulating MPA networks based on broad input from all interested sectors.

Participants' attitudes towards the concept of a priority conservation area designation at the North America continental scale ranged from enthusiastic to confused, to doubtful, concerning the challenges of data integration, international cooperation, and synthesis. Despite this, the final workshop to identify PCAs was successful, though subject to the bias of available data and experts involved. The most prevalent concern was how to incorporate existing MPA designations, previous priority designations, and local projects. This concern is mostly alleviated by noting the consistency of these PCAs with past works on identifying important biodiversity sites (Ford and Bonnell, 1996; Banks et al., 1999; Ardron et al., 2001; Sala et al., 2002). In part, the process was designed to address this issue by asking various groups to come forward with their data, priorities, and projects in a sense of greater community. In general, participants benefited from exposure to relevant projects and avenues for collaboration throughout the B2B region and the success of the process itself may ultimately rest with initiating such exchanges.

An alternative approach to a vision of "the map" that represents a unified, multi-institutional perspective on priority areas for conservation over this 6,000-mi extent, is a process that allows individuals open access to baseline data and analyses. To this end, North Americans should view the identified PCAs as expert advice; information to include in their own regional or local planning efforts. It is our hope that the identification of these areas will generate discussion, catalyze action, inform opinion, and foster future cooperation. MCBI, the CEC, and Ecotrust distribute the available information on a CD-ROM (B2B 1.1). Hopefully, this dataset will serve as a foundation for future regional analyses. Although it is tempting to incorporate all relevant data in order to produce a high-quality dataset with simple baseline information, the first release, B2B 1.0, delimits the data at the highest common denominator resolution across the entire B2B extent, e.g., ~4 km Smith and Sandwell (1997) bathymetry, 9 km AVHRR SST, 7 km surface currents. It is likely that finer-scale resolution will be necessary for regional analyses.

While biodiversity protection is the ultimate goal of this priority conservation area assessment, no such datasets are available. Comprehensive biogeographic datasets of species diversity will need to be researched and built if they are to be incorporated into future analyses. Continental scale biodiversity could be captured by protection of representative areas and endemic species at the regional scale.

Conclusion

From the Gulf of California, with its deep canyons, nutrient-rich upwellings, and high levels of endemism, to the 20,000 km of bays, inlets and inland drainage systems of the Pacific Northwest, to the high productivity of the Bering Sea, the west coast of North America is home to unique and important shared marine environments. It is also home to a great number of shared marine species—such as Pacific gray and blue whales, leatherback sea turtles, bluefin tunas, black brant geese and Heermann's gulls—that migrate thousands of kilometers, moving across national borders without hesitation. Hence, be it through shared species or ecosystems, the marine environments of Canada, Mexico, and the United States are intimately linked. Accordingly, action or inaction on one side of a border will have consequences for the shared living organisms occupying ecosystems with no such definite boundaries. The process of identifying PCAs attempted to provide individuals throughout the B2B region with the same information as well as incorporate processes already finished or underway. Future efforts in the B2B region have a place to start.

Notes

1 <http://cec.org/trio/stories/index.cfm?ed=2&ID=18&varlan=english>
2 <http://cec.org/pubs_docs/documents/index.cfm?varlan=english&ID=1088>
3 See also http://srmwww.gov.bc.ca/risc for further information on complexity.
4 <http://daac.gsfc.nasa.gov>
5 Frouin, R., B. Franz, and M. Wang. Algorithm to estimate PAR from SeaWiFS data <http://daac.gsfc.nasa.gov/CAMPAIGN_DOCS/OCDST/PDFs/seawifs_par_algorithm.pdf>
6 <http://podaac.jpl.nasa.gov/sst>
7 Later expanded to include species that were affected by actions of two or more countries, and were not necessarily migratory or transboundary, such as the endemic vaquita.

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Appendix 9.1.

Marine Species of Common Conservation Concern

In an activity parallel to the identification of PCAs, the CEC convened an advisory group to identify the first list of marine species of common conservation concern, (Wilkinson et al. 2004a). The goal of the present project was to focus on key conservation actions and protected areas needed to support these populations. These umbrella species captured a different conservation perspective by shifting the focus to processes that affect species as well as the places they inhabit. Compulsory criteria focused the initiative towards species that were: (1) transboundary or migratory[9]; and (2) at high risk of extinction, given their current status or trends, their inherent natural vulnerability and their susceptibility to anthropogenic threats. Using secondary or recommended criteria, priority was then given to species: (1) deemed ecologically significant, e.g., umbrella, keystone, or indicator taxa; (2) officially listed as being of conservation concern by one of the three North American countries, by the World Conservation Union (IUCN), or by the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES); (3) whose recovery or management was feasible, including re-establishment potential, as well as the opportunity to strengthen management and learn from successes; and (4) which had a high potential for public engagement (flagship species). To this end, key habitats for these species, as identified in this report (Wilkinson et al., 2004a), were included as criteria for PCAs.