Pelagic Predators, Prey, and Processes:

Exploring the scientific basis for offshore marine reserves

January 17, 2002
Santa Cruz, California

Workshop Report

National Fish and Wildlife Foundation

PRBO Conservation Science

NOAA

Suggested Citation

Pelagic Working Group (2002). Pelagic Predators, Prey and Processes: Exploring the Scientific Basis for Offshore Marine Reserves. Proceedings of the First Pelagic Working Group Workshop. January 17, 2002. Santa Cruz, CA.

PRBO Conservation Science and the organizers of this workshop would like to extend thanks to all the workshop participants, and to all those who made this workshop and report possible, especially the National Fish and Wildlife Foundation, Institute for Marine Protected Area Science, Seymour Discovery Center, Starbucks Coffee, and photographers Phillip Colla, Randy Morse and Ron LeValley, whose work appears on the title page of this report. We also thank all those who have supported the development of this research and conservation initiative with their continued interest and dedication. This is PRBO Contribution No.1029.

Contents of Workshop Report

Background

The conservation of highly migratory vertebrates represents one of the major challenges facing marine conservation in the XXIst century. In particular, effective ecosystem-level marine conservation will require incorporating the needs of far ranging species and the protection of pelagic habitats into existing management plans, including the design of Marine Protected Area networks.

The "Pelagic Predators, Prey and Processes" (PPPP) initiative seeks to establish a collaborative scientific and management process, focused on the conservation opportunities facing pelagic predators and their prey of the California Current System (from southern British Columbia to Baja California). This initiative will complement and interface with other conservation efforts aiming to establish intertidal and coastal MPAs along the west coast of North America. As a first step in this process, we brought together key marine scientists and resource managers to discuss the scientific rationale for the implementation of offshore marine reserves in the California Current System. Thus, the Pelagic Working Group was born. We met on a sunny January day in Santa Cruz, and present the results of this first workshop in this report.

The Pelagic Working Group is healthy and growing, as we prepare for our second meeting scheduled for the fall of 2002. Eventually, we anticipate establishing a multi-disciplinary advisory board of scientists, funding sources, management agencies, conservation groups and resource users to promote specific pelagic conservation projects in concert with the priorities delineated by the Pelagic Working Group.

The Workshop

The Marine Science Division of PRBO, in collaboration with the National Fish and Wildlife Foundation (NFWF) and the National Oceanic and Atmospheric Administration – Institute for Marine Protected Area Science, has convened this workshop to assess the feasibility of pelagic (> 3 miles from shore) marine protected areas for the conservation of top predators and food webs off the west coast of North America. In particular, our objective is to enhance our understanding of the physical and biological processes responsible for temporal and spatial variability in pelagic predator-prey habitat associations in the California Current marine ecosystem.

We have invited oceanographers and ecologists to summarize their understanding of the ecology and the habitats of pelagic species, including marine birds, mammals, turtles, forage fish, krill and squid. Our operational hypothesis is that there exist habitat "hotspots", locations characterized by high and predictable ocean productivity and the aggregation of top predators and their prey, which can be delineated on the basis of physical (e.g., water temperature, bathymetry) and biological (e.g., chlorophyll concentration, prey abundance) characteristics. These "hotspots" are likely candidates for eventual designation as Marine Protected Areas (MPAs) or no-take Marine Reserves (MRVs).

Summary of presentations

Physical Oceanography

Oceanographic variability influences the structure of marine ecosystems and the dynamics of fisheries and predator populations. Thus, characterizing the dominant scales of temporal and spatial variability in the California Current System is a necessary first step to assess the scientific rationale for establishing offshore marine protected areas.

Cetaceans

Mysticete whales regularly occur at specific restricted localities off California (e.g., Monterey Bay, the Gulf of the Farallones, Point Conception, Cordell Bank, and Morro Bay), and Oregon-Washington (e.g., Heceta Bank). Yet, aggregations shift locations from year to year. Associations with specific bathymetric and hydrographic habitats have been documented for odontocete species. Nevertheless, because different species inhabit distinct habitats, it has been difficult to identify multi-species "hotspots." Instead, habitat protection will have to be prioritized on the basis of the status and ecology of specific "habitat guilds," the nature of anthropogenic threats, and the feasibility of implementing effective protective measures.

Sea Turtles

Because marine turtles require large quantities of prey, they likely forage in search of dense prey aggregations. The extent to which these predators aggregate at hydrographic and bathymetric features known to concentrate prey remains unknown. Moreover, little is known about sea turtle migration patterns across the Pacific Ocean. Thus, it is currently not possible to assess whether predictable foraging grounds and movement corridors could be protected using time-area closures or MPAs.

Marine Birds

Seabird abundance is highest along bathymetric (e.g., shelf-break) and hydrographic (e.g., temperature fronts) features, suggesting that these marine predators predictably aggregate at specific oceanic habitats. In principle, marine reserves could protect these highly mobile species by focusing on relatively small (100s - 1000s km^2) regions delineated by "static" (e.g., bathymetric) and "dynamic" (e.g., hydrographic) features. In particular, geographically restricted regions, where narrow continental shelves concentrate the species that migrate along the shelf and slope, might be ideal sites for marine reserve zoning. Conversely, marine reserves may not prove feasible for protecting broadly distributed species that do not aggregate at specific habitats.

Nekton of the Northern CCS

A substantial amount of effort has been expended to study the distribution and ecology of pelagic nekton in coastal waters off Washington and Oregon. A major goal of this research has been to assess how pelagic communities have changed over time (e.g., since the previous intense sampling period in the early 1980s) in response to oceanographic variability in the CCS. These long-term studies have revealed that nekton communities in the northern CCS respond to variability in ocean conditions at multiple scales of time (from seasons to decades), and space (from 10s to 1000s of km). However, little is known about how this variability in prey populations impacts marine top predators like seabirds and marine mammals. These results highlight the need to place local changes in species distribution and abundance within a broader ecosystem-level context. Large scale conservation measures for the CCS will have to accommodate the observed natural variability in nekton populations.

Forage Fish of the Southern CCS

Spatially explicit models of the sardine production index indicate that larvae production is an order of magnitude higher in cyclonic eddies than in inshore, slope, offshore and anti-cyclonic eddy habitats. These results suggest that eddies constitute intermittent but highly productive habitat features, where larvae are concentrated and retained. This research highlights the need to understand the ecological significance of dynamic and ephemeral habitats for populations of marine top predators and their prey.

Euphausiids (Krill) and Squid

A conceptual model has been formulated to link cetacean distributions with hydrographic variability via changes in euphausiid dispersion. Hydrographic variability (e.g., magnitude of coastal upwelling) influences euphausiid distributions off central California by advecting populations offshore. In turn, the seasonal and interannual variability in euphausiid dispersion influences the abundance and distribution of the large balaenopterid whales that target dense concentrations. These results highlight the importance of incorporating an understanding of how physical and biological variability influences the distribution and the patchiness of top predators and their prey into management plans. In particular, this research suggests that protective measures may be specifically effective during periods of low productivity, when highly aggregated marine predators are particularly susceptible to anthropogenic impacts. Time-area closures and Marine Protected Areas may be especially effective to restrict competition with fisheries and to mitigate bycatch during these “stressful” periods.

Discussion Summary

A broad discussion of the presentations ensued. This exchange, led by a professional facilitator, included the following topics:

- The utility of pelagic MPAs: what they can and cannot do;
- Targets for pelagic MPAs: threats, productivity, and aggregation;
- Physical-biological coupling and siting of pelagic MPAs;
- Pelagic MPAs as a tool to conserve highly migratory species;
- The need for international cooperation for effective pelagic conservation;
- Pelagic MPA design and implementation;
- Measuring the effectiveness of pelagic MPAs.

Draft Consensus Statement

Workshop participants broke out into four groups to develop a statement concerning the use, design and implementation of pelagic Marine Protected Areas and Marine Reserves, given the current state of scientific knowledge. Subsequently, the workshop conveners synthesized the breakout group statements, and drafted the consensus statement presented in this report. Salient points of consensus concerning no-take Marine Reserves (MRVs) are presented below.

- MRVs offer important tools for an integrated management of oceanic ecosystems. In principle, reserves can be used to help conserve endangered taxa, to keep common species common, to maintain marine biodiversity, and to protect productive areas where top predators aggregate. Additionally, MRVs can insure entire marine ecosystems against catastrophic events and mismanagement.

- MRVs cannot provide absolute protection for highly migratory species and cannot mitigate large-scale impacts such as non-point source pollution and climate change. Thus, MRVs should not be viewed as substitutes for single-species management. Instead, MRVs will complement other species-specific management approaches and conservation practices.

- MRVs can be used to set aside regions supported by strong physical-biological coupling including areas of high ocean productivity, prey concentration, and top predator foraging grounds. In particular, MRVs may be especially useful during “stressful” periods of low ocean productivity, when marine species are highly concentrated, thus becoming more susceptible to human impacts.

- Reserve networks will be needed to accommodate regional disparities in marine ecosystem structure and the far ranging habits of many pelagic species.

- A number of conceptual and logistical advances will be necessary to design, implement, and evaluate pelagic MRVs.

Next Steps

The Pelagic Working Group will continue to develop the concepts presented in this workshop report and to advance the understanding of the ecology and habitats of pelagic species. Future workshops are currently being planned. For more information or to contact the conveners of this workshop consult the Pelagic Working Group website at:

www.prbo.org/pelagicworkinggroup.htm

May, 2002

Dear Colleagues,

Every day, it seems, a new story hits the headlines about the declining condition of the world's oceans with ominous consequences for all marine life. Reports of collapsing fisheries, catastrophic oil spills, coral die offs, and coastal pollution have become commonplace.

Yet, public and political sentiment in favor of protecting the Earth's last great "frontier" has swelled. In particular, scientific, legislative and management initiatives to strengthen ocean protection and management off the west coast of North America are proliferating. A recent poll found that 8 out of 10 Californians are willing to give up access to certain ocean locales to ensure their full protection from human impacts.[1]

I believe that the information presented in this report is yet another hopeful sign that we can succeed in protecting our rich ocean resources.

The California Current System (CCS) is one of the five eastern boundary current systems worldwide, highly productive marine ecosystems supporting a great diversity and abundance of pelagic predators (seabirds, marine mammals and fish species). This vast oceanic domain spans over 25 degrees of latitude, from southern British Columbia, Canada to Baja California, Mexico.

A recent review of 80 marine reserves around the world reported gains in the abundance and productivity of local populations as a result of their protected status. [2] However, less than 1% of waters in the CCS are protected in reserves.

The workshop results presented here provide a novel perspective needed to ensure that ocean protection includes highly migratory species and entire marine ecosystems. Our goal is to recognize and protect the pelagic food webs and the habitats supporting the marine top predators that have become synonymous with ocean wilderness: whales, dolphins, seabirds, turtles, swordfish, tuna, and sharks.

As witnessed herein, the design of Marine Protected Areas (MPAs) and Reserves (MRVs) to protect highly migratory pelagic predators represents a major challenge because these species frequently exploit highly dynamic and ephemeral habitats. As detailed in this

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[1] From a SeaWeb poll of likely voters conducted by Edge Research in January 2002. Margin of error of +/- 3.1% at the 95% confidence level.

[2] University of California, Santa Barbara study to be published in the May, 2002 issue of the Journal Ecology Letters, as reported by the Associated Press, April 15, 2002.

report, however, predictable regions of elevated oceanic productivity and predator use *can* be identified off the west coast of North America.

Within this report, you will find:

- Background materials relevant to this workshop;
- Summaries of presentations addressing different facets of the ecology and habitats of marine top predators and the design of marine protected areas;
- Detailed notes from a synthesis discussion by workshop participants; and,
- A draft consensus statement concerning the scientific basis for the establishment of offshore marine reserves. This draft consensus statement addresses the value of pelagic reserves, provides design recommendations, and identifies needed conceptual and logistical advances required before such reserves can be implemented.

Welcome to the Pelagic Predators, Prey, and Processes (PPPP) Initiative!

I encourage you to contact us if you with to learn more about this ongoing process (Gregg Elliott at gelliott@prbo.org or 503-297-0353). Thank you for your interest.

Sincerely,

Ellie M. Cohen
Executive Director
PRBO Conservation Science

An Initiative to Protect Offshore Organisms and Habitats Along the West Coast of North America

Far ranging marine vertebrates, including seabirds, marine turtles, large predatory fishes, pinnipeds and cetaceans are essential ecological constituents of pelagic ecosystems. Many of these species are also economically, culturally and recreationally important, supporting ecotourism as well as commercial and artisanal fisheries. Moreover, the existence of these majestic pelagic species enriches the human experience. Yet, many of these populations have been impacted by over-exploitation, oil spills, bycatch, habitat degradation and climate change.

The movement to designate marine protected areas (MPAs) and no-take marine reserves (MRVs)[2] is proceeding rapidly along the Pacific Coast of North America, spurred on by such recent developments as the California Marine Life Protection Act (1999) and the U.S. President's Executive Order on MPAs (May 2000). MPAs are increasingly becoming a standard fisheries conservation and management tool, as evidenced by the Pacific Fisheries Management Council's efforts to replenish groundfish stocks; the inclusion of MPAs in the Nearshore Fishery Management Plan under development by the California Department of Fish & Game; and the ongoing initiative to designate marine reserves within the Channel Islands National Marine Sanctuary. Scientific support for the establishment of no-take reserves reached critical mass in February 2001, when an international research team from the National Center for Ecological Analysis and Synthesis (NCEAS) issued a broad-based consensus statement, signed by over 160 marine scientists and conservation biologists, declaring that "existing scientific information justifies the immediate application of fully protected marine reserves as a central management tool."

Current MPA initiatives have focused overwhelmingly on intertidal and benthic systems, which already constitute the vast majority of existing marine reserves worldwide. Indeed, research has shown nearshore reserves to be an effective conservation tool for sessile species with restricted ranges and their benthic habitats. Conversely, MPA initiatives have largely ignored far ranging marine predators and the dynamic pelagic systems upon which they depend. Thus, current protection efforts lack an essential component necessary for the effective ecosystem-level conservation of the California Current System.

The design of MPAs to protect far ranging pelagic predators represents a major challenge because these species frequently exploit highly dynamic and often ephemeral habitats. Yet many of these habitat features appear to be sufficiently persistent in time and space to consider the delineation of marine reserves and protected areas. In particular, many far ranging marine predators aggregate at predictable regions of elevated oceanic productivity along the west coast of North America. These high productivity "hotspots" are recognized as important foraging areas of elevated prey concentration. In addition to design of MPAs to protect the foraging grounds and migration routes of highly migratory predators, broader ecosystem-level effects must be considered. It is becoming increasingly apparent that oceanographic processes occurring offshore influence biological patterns in nearshore and coastal systems. For instance, dynamic oceanographic features

[2]*Marine Protected Area* (MPA) is a broad term referring to any site that has been afforded some level of protection (e.g. limiting oil and gas exploration) to preserve biological or cultural resources. The vast majority of MPAs (including national marine sanctuaries) allow fishing. *Marine reserves* (MRVs) are MPAs specifically designed to protect biological resources by excluding extractive activities such as fishing, and in some cases, deleterious recreational activities.

characterized by elevated ocean productivity and convergence (such as eddies, upwelling plumes and frontal systems) may represent important retention areas for juvenile fishes and invertebrate larvae. Therefore, it is essential that we address the design of offshore MPAs in tandem with efforts to designate nearshore reserves.

Incorporating the needs of far ranging marine vertebrates into ongoing MPA network designs represents a critical opportunity. The inclusion of this "pelagic perspective" in ongoing marine conservation efforts is crucial for the following reasons:

- Protection of far ranging marine vertebrate species and their pelagic habitats will provide a variety of important ecological services:
    - *Conservation of "Umbrella Species"*: Pelagic MPAs designed to protect threatened far ranging marine predators will afford protection to countless species with more restricted distributions. IN particular, MPAs designed to protect the foraging grounds and migration routes where pelagic vertebrates aggregate (e.g., eddies, coastal upwelling plumes and oceanic fronts) will also grant protection to the highly productive oceanic habitats that support other species not currently threatened, including the larval stages of many nearshore species.
    - *Ecosystem Conservation*: Large scale MPAs will buffer marine ecosystems against resource mismanagement and the associated indirect ecological consequences, including trophic cascades and the loss of ecological interactions. For instance, the protection of sub-surface predators will likely benefit surface-foraging species indirectly. Sub-surface predators (e.g., tunas, cetaceans, pinnipeds, alcids), enhance foraging opportunities for other surface foraging species (e.g. terns, pelicans, petrels) by driving and aggregating prey close to the surface.
    - *Management of Fish Stocks:* Because many commercially valuable species (e.g., tunas, salmonids) rely on the same food webs and highly productive oceanic regions exploited by seabirds, cetaceans, and turtles, pelagic MPAs will protect the essential habitats and prey resources of valuable fish stocks.
- The conservation of far ranging marine predator populations will ensure the preservation of important economic and cultural resources for future generations.

Our goal is to establish a collaborative scientific and management process that will focus on the threats and conservation opportunities facing pelagic predators of the California Current System (from southern British Columbia to Baja California). This initiative will complement and interface with other conservation efforts focused on establishing intertidal and coastal MPAs along the west coast of North America. The first step in this process will be to bring together key researchers, resource managers, and agency scientists to discuss a number of key issues:

- Can we identify (or characterize) persistent "hot spots" of ocean productivity and top predator aggregation?

- Are these "hotspots" associated with specific physiographic features? (e.g., upwelling plumes, fronts, seamounts, and shelf breaks)

- Would currently available scientific knowledge justify the establishment of a precautionary marine reserve network to protect krill, a major component of the California marine food chain?

- Are the linkages between offshore and nearshore processes / species important to habitat management programs?

- How can we promote a broader ecosystem-level management of pelagic systems?

- Should existing monitoring and research programs be modified to improve the collection and integration of physical and biological data?

- What monitoring programs would be needed to track the status of indicator species and habitats?

- We anticipate two phases in the development of this initiative:

    - Assembling a multidisciplinary "Pelagic Working Group" to review the current state of knowledge for pelagic species and habitats, and to develop a White Paper synthesizing the group's findings, highlighting threats and opportunities, and prioritizing research and management needs.

    - Establishing a management or advisory board of scientists, funding sources, management agencies, conservation groups and resource users to promote specific projects in concert with the priorities delineated by the Pelagic Working Group. This advisory board will implement (1) pilot projects to assess the efficacy of specific conservation recommendations and (2) broader research programs to assess the effectiveness of alternative MPA designs and management plans.

Current and potential partners
(list is not fully inclusive)

California Department of Fish and Game, Marine Region
Canadian Wildlife Service
COMPASS: Communication Partnership for Science and the Sea
Department of Fisheries and Oceans, Canada
Environmental Defense
National Fish and Wildlife Foundation
National Marine Fisheries Service
National Marine Sanctuaries
National Oceanic and Atmospheric Administration
National Park Service
Ocean Conservancy
Ocean Wilderness Network
Oregon Ocean Policy Advisory Council
Pacific Coast Federation of Fishermen's Associations
Packard Foundation
Point Reyes National Seashore
PRBO Conservation Science
The Nature Conservancy
U.S. Bureau of Land Management
U.S. Fish & Wildlife Service
United Anglers
World Wildlife Fund

Representatives of resource users, including fishers, shipping interests, and oil companies.

Key marine scientists from Canada, U.S. and Mexico (see list of participants, Appendix 1)

Pelagic Predators, Prey, and Processes: The Scientific Basis for Offshore Marine Reserves

January 17, 2001
Seymour Center at Long Marine Lab, Santa Cruz, CA
La Feliz Room

8:30 am Welcome / Introductions. *(Continental breakfast provided)*
Gregg Elliott & Kaya Pederson

8:45 am Facilitator Introduction / Overview of the day
Brock Bernstein & Bill Sydeman

- Background: Pelagic conservation and the motivation for pelagic MPAs.
- Meeting goals:

> To develop a consensus statement regarding the need and scientific support for the establishment of pelagic marine reserves in the California Current System.
>
> To use this meeting as a foundation to establish a pelagic scientific working group charged with integrating the needs of far-ranging marine predators into ongoing marine conservation and MPA initiatives throughout the California Current System.

9:00 am **Physical Oceanography of Offshore Habitats: Scales of Variability**
Presentation by Frank Schwing, Pacific Marine Environmental Laboratory

9:30 am **Cetaceans of the California Current System**
Presentation by Karin Forney, Southwest Fisheries Science Center

10:00 am **Marine Turtles of the California Current System**
Presentation by Scott Benson, Moss Landing Marine Lab & NMFS

10:15 am Break

10:30 am **Marine Birds of the California Current System**
Presentation by David Hyrenbach, Point Reyes Bird Observatory

11:00 am **Forage Fish of the Northern California Current System**
Presentation by Ric Brodeur & Robert Emmett, Northwest Fisheries Science Center

11:30 am **Forage Fish of the Southern California Current System**
Presentation by Elizabeth Logerwell, Alaska Fisheries Science Center

12:00 pm **Zooplankton and Squid of the California Current System**
Presentation by. Baldo Marinovic, U.C. Santa Cruz

12:30 pm Lunch *(provided)*

1:00 pm Review of morning presentations: Identify overlapping needs, habitat use, problems, threats, and solutions

1:30 pm Facilitated discussion to synthesize the group's knowledge

Suggested discussion questions:

- Can productivity "hot spots" be identified for protection? If so, how can spatial / temporal variation in "hot spots" be taken into account when managing human activity or designing marine reserves? Likewise, how can the effects of climate variability and change be taken into account?
- What anthropogenic activities that threaten species or act as stressors in the CCS can be managed or limited by establishment of MPAs?
- What monitoring systems / elements would be needed to assess MPA efficacy and to promote broader ecosystem-level management of pelagic systems (e.g. within National Marine Sanctuaries)?
- What are the data gaps / research needs for assessing the utility of establishing pelagic marine reserves?

2:45 pm Break

3:00 pm Breakout groups: Development of consensus statements concerning the need and scientific support for pelagic MPAs using maps of the California Current System

4:00 pm Reports from break-out groups; whole group consensus (if possible!)

4:45 pm Next steps and meeting feedback

5:00 pm Meeting adjourns

6:00 pm Reception at Costa Brava

An Introduction to the Pelagic Predators, Prey, and Processes (PPPP) Initiative: Geographical Orientation and Operational Hypotheses to Set the Stage

William J. Sydeman, K. David Hyrenbach, Gregg Elliott, and Kaya Pederson

PRBO, Marine Science Division, Stinson Beach, CA

The Marine Science Division of PRBO, in collaboration with the National Fish and Wildlife Foundation (NFWF) and the National Oceanic and Atmospheric Administration – Institute for Marine Protected Areas Science, has convened this workshop to enhance understanding of the ecology of top marine predators and their oceanic habitats off the west coast of North America. In particular, our objective is to promote discussion about the physical and biological processes responsible for temporal and spatial variability in pelagic (> 3 miles from shore) predator-prey habitat associations in the California Current marine ecosystem. We cordially welcome participants from the scientific community, resource management agencies and funding institutions.

Our principal goal is to discuss the scientific and managerial basis for pelagic marine protected areas (MPAs) and no take marine reserves (MRVs) designed to protect highly migratory marine species, such as seabirds, cetaceans, turtles, and predatory fish, and the habitats upon which they depend. The geographic area under consideration encompasses the Exclusive Economic Zones (EEZs) of the United States, Mexico and Canada and spans approximately 960,000 squared kilometers, from Triangle Island, British Columbia (50° 52' N, 129 ° 05' W) to the San Benito Islands, Baja California (28° 18' N, 115° 35' W), and from the coast out 200 miles. We have invited oceanographers and ecologists working in the California Current System to summarize their understanding of ocean habitats, marine birds, mammals, turtles, forage fish, krill and other zooplankton, and squid. We recognize that not all areas of expertise in physical and biological oceanography have been addressed in the initial workshop. However, these presentations have provided common currencies for discussion by highlighting similarities in the ecology of distinct taxa across entire food webs. We also have invited representatives from management agencies, conservation organizations, and funding sources to incorporate their concerns and insights into this inter-disciplinary initiative.

The ocean is a heterogeneous and dynamic landscape, where physically and biologically distinct habitats appear, change extent and location, and vanish. Nevertheless, some species distributions and predator-prey dynamics are associated with specific oceanic habitats. In principle, marine protected areas designed to maintain biodiversity, protect depleted or threatened species, and enhance ecosystem processes (such as production, aggregation, and energy transfer) could focus on these predictable wildlife-habitat associations. Our operational hypothesis is that habitat "hotspots", persistent locations of production and aggregation for multi-species groups, can be identified and delineated on the basis of physical (e.g., temperature, salinity) and biological (e.g., chlorophyll concentration, prey aggregation) characteristics. Building upon earlier work, we recognize at least 3 types of habitat "hotspots" in the California Current System:

(1) "bathymetric" habitats – waters associated with physiographic features of the ocean floor (e.g., seamounts and shelf breaks);

(2) "predictable hydrographic" habitats – specific currents and water masses that persist temporally but shift in extent and location (e.g., fronts associated with the edges of ocean currents); and

(3) "ephemeral hydrographic" habitats – waters associated with oceanographic features that appear, shift location, and vanish (e.g., upwelling plumes and filaments, eddies).

These habitat types represent progressively more difficult systems for the design of marine protected areas. Successful implementation of this novel management approach will require a major conceptual switch from an anthropocentric viewpoint to a broader ecosystem-level perspective capable of embracing the inherent natural variability of the system.

Important questions for the group to consider include:

- What spatial and temporal scales dominate the physical variability in the system for the species-groups of concern?

- Are there obvious habitat "hotspots" in the California Current System?

- Are these pelagic habitats sufficiently predictable and persistent to allow designation as marine protected areas?

- What species and processes could be protected through the designation of pelagic marine protected areas and reserves?

Physical Oceanography of Offshore Habitats: Scales of Variability Impacting Marine Resources

Franklin B. Schwing

NOAA, NMFS, Pacific Fisheries Environmental Laboratory, Pacific Grove, CA

A number of important considerations determine the role of the ocean environment in the context of pelagic MPAs:

- What are the dominant physical features and processes?
- What is the ecological importance of these features and processes?
- What are their key time and space scales?
- What are their persistence, variability, and extremes?
- Are they dynamical sources or sinks?
- Are they static (fixed) or dynamic?
- What are the links between offshore and coastal regions and features?

The west coast marine pelagic habitat, defined by the California Current System (32-48°N, coast to 200 nm offshore) is characterized by a large-scale equator-ward ocean flow, upon which is superimposed a field of strong, mesoscale (10-100 km) features. These include upwelling filaments, river plumes, eddies, and meanders at the interface between the California Current (CC) and recently upwelled water. They have strong thermal, salinity, and flow signatures. These features are generally persistent over time and fixed in space (i.e., their position and size). Their typical positions and dimensions are set by coastline morphology, with bottom bathymetry being less important in the creation and maintenance of most of these features. For example, coastal upwelling centers are associated with headlands. They are generated in response to atmospheric forcing (i.e., upwelling winds), interacting with coastal morphology and, in isolated locations, freshwater flow into the ocean. Episodic changes in forcing (e.g., relaxation of upwelling winds) occur infrequently; however, the response of ocean features to these changes is rapid. At these times, offshore features may disperse, or translate toward the coast where they interact with nearshore habitats. This may be an important mechanism for the recruitment of nearshore species, and for encounters between blue-water pelagic and nearshore species. However, these features generally return to their persistent state equally rapidly at the return of seasonal forcing conditions, making them reliable 'landmarks' for marine organisms. Dynamical ocean features can be characterized as potential biological sources (e.g. coastal upwelling centers and filaments) or sinks (e.g. upwelling fronts at the eastern edge of the CC).

Pelagic oceanic features and populations fluctuate on several time scales. The most obvious is the annual evolution of the CC's circulation and structure. Large-scale coastal upwelling begins in early spring and continues into autumn. During this upwelling season, the ocean's structure becomes more complex. This is reflected in the seasonality of primary production. In winter, near-surface waters are more isothermal and flow is pole-ward. This seasonal cycle is modulated by longer-term variability. For example, during El Niño years, the dominant source of interannual variability, upwelling may be reduced and the increasing seasonal complexity of the upwelling region retarded. These variations are also related to interannual changes in the size, distribution, health, and reproductive success of marine populations. The region is affected by planetary-scale climate change on decadal to centennial time periods as well. Because these time scales are similar to or longer than the lifespan of marine species, these climate fluctuations may have a very different effect on populations than intraseasonal to interannual variability.

Persistent environmental features and their variability are reflected in ecosystems and fisheries populations. However, the ecosystem response to these features appears to be complex. Characterizing the dominant physical oceanographic features and processes of the coastal habitats along the US west coast, and assessing their principal time and space scale of variability is the first step in developing a scientific rationale for establishing marine protected areas. Only when we can describe and understand these, can we link the region's ecosystem structure and processes to its physics, then implement scientifically based management strategies.

Cetaceans of the California Current System

Karin Forney [1], John Calambokidis [2], Scott Benson [3], Francisco P. Chavez [4], Don A. Croll [5], James T. Harvey [3], Baldo Marinovic [5], Bruce Mate [6]

[1] NOAA, NMFS, Southwest Fisheries Science Center, Santa Cruz, CA
[2] Cascadia Research Collective, Olympia, WA
[3] Moss Landing Marine Laboratories, Moss Landing, CA
[4] Monterey Bay Aquarium Research Institute, Moss Landing, CA
[5] University of California, Santa Cruz, CA
[6] Hatfield Marine Station, Oregon State University, Newport, OR

(Summary of the three presentations compiled by the conveners)

A diverse cetacean fauna characterizes the California Current system. Eight mysticete (baleen whale) and twenty-one odontocete (toothed whale) species regularly occur off the west coast of North America. Amidst the mysticetes, blue (*Balaenoptera musculus*) and humpback whales (*Megaptera novaeangliae*) have been the focus of intensive telemetry and photo-identification studies to characterize their movements and migrations. These species range over vast areas, and routinely travel thousands of kilometers from summer feeding areas in the California Current to distant wintering grounds at lower latitudes. However, there are no simple migratory patterns for humpback whales between the California Current and the three wintering areas. Similarly, blue whales migrate to the Costa Rica dome, Baja California and the Galapagos Islands. Moreover, researchers have identified distinct feeding aggregations along the west coast of North America, with little or no overlap between distinct regional groups. However, why certain individuals migrate to specific areas remains unknown.

In addition to these vast seasonal movements, large mysticete whales forage over large spatial scales while in the California Current. These species range over hundreds of kilometers, as they visit coastal upwelling centers off Baja, southern and central California. In spite of these far ranging movements, these predators often concentrate at specific localities. However, because these aggregations shift in space seasonally and from year to year, composite distributional maps do not reveal distinct high-density "hotspots". Nevertheless, when distribution data are analyzed on a per survey basis, large numbers of whales regularly occur within specific areas like Monterey Bay, the Gulf of the Farallones, Point Conception, Cordell Bank, and Morro Bay, CA and Heceta Bank, OR.

The more diverse odontocete fauna is composed of species with an affinity for diverse habitats: warm offshore waters (e.g., short-beaked common dolphin, *Delphinus delphis*), cooler within shelf-slope regions (white-sided dolphin, *Lagenorhynchus obliquidens*), upwelling-modified waters along shelf-slope regions (Dall's porpoise, *Phocoenoides dalli*), bathymetrically complex regions with warm water (Risso's dolphin, *Grampus griseus*), and nearshore shelf areas with cool ocean temperatures (Harbor porpoise, *Phocoena phocoena*). Because marine mammals have distinct habitat preferences and use a variety of habitats to feed, migrate and breed, there is little overlap between the distributions of many of these species. Thus, the selection of habitats for protection will have to be prioritized on the basis of the status, ecology (e.g., distribution, movements), threats, and the feasibility of implementing effective protective measures. Conceivably, multi-species initiatives may be designed to protect "habitat guilds" subject to similar threats.

(Summary of Croll et al. presentation by Forney)

An integrated ecosystem study, conducted by Don Croll, Baldo Marinovic, Scott Benson, Jim Harvey, and Francisco Chavez in Monterey Bay since 1996, illustrates some of the physical-biological coupling mechanisms for baleen whales. Random-systematic line-transect surveys of marine mammals were conducted monthly from August to November 1996, and May to November 1997-1999. Conductivity-Temperature-Depth (CTD) casts and zooplankton net tows were conducted opportunistically and at 10 predetermined locations, and sea-surface temperature was measured continuously while underway. Underway hydroacoustic backscatter was used to estimate abundance of zooplankton, with emphasis on euphausiids, a key trophic link between primary production and higher trophic level consumers. The study identified spatial and temporal concordance between baleen whales and krill aggregations. However, a proportionally greater number of whales were present during the 1998 El Niño compared to other years. It is hypothesized that a dramatic reduction in zooplankton biomass offshore during El Niño 1997/98 led to the concentration of rorquals in the remaining productive coastal upwelling areas, including Monterey Bay. Higher densities of other species, including warm-water zooplankton, fish and dolphins at this time, support this theory.

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(Forney presentation summary)

Marine mammals in the California Current System are diverse and adapted to their dynamic environment. At least 29 species of cetaceans have been documented in California waters, including whales that migrate annually between summer feeding and winter breeding areas, temperate odontocetes, tropical odontocetes, and species associated with offshore waters. Each species is uniquely adapted to different marine processes, feeding on a variety of fish and cephalopod prey and exhibiting large interannual and seasonal variation in distribution. Few generalities can be drawn to identify broadly applicable 'hotspots'. Examples of documented species-environment patterns include the temperate Dall's porpoise, which appears tightly linked to upwelling-modified waters < 17ºC along the California coast. Common dolphins exhibit the opposite pattern, with a widespread distribution in warmer waters as far north as about 42ºN. Pacific white-sided dolphins are largely restricted to cooler shelf and slope waters, and Risso's dolphins are common in shelf waters and well offshore, but are conspicuously absent from slope waters. The harbor porpoise is distributed nearshore and also appears linked to cooler waters.

Without broadly important "hotspots," an alternate approach to identifying appropriate pelagic marine reserves may be to focus on specific risks to each species or region. Species and areas could be prioritized based on (1) vulnerability (influenced by population size, distribution, movements & demography), (2) the nature of threats (e.g., fishing, vessel traffic, pollution or direct harvest), and (3) the feasibility of protective measures. Coastal species (harbor porpoise, bottlenose dolphin, gray whale), depleted populations (large whales), and naturally rare species (beaked whales, pilot whales) would be potential candidates for targeted measures. Habitat 'guilds' of taxonomically diverse species exposed to similar threats may alternately provide a means of prioritizing protective measures. One example would be coastal species, such as harbor porpoise, common murres, and sea otters, which are vulnerable to gillnets and coastal oil pollution. Highly migratory, offshore species face fewer threats throughout most of their range, but can nonetheless be exposed to large impacts, such as those created by pelagic long lines, high seas driftnet fisheries (1980s), and marine debris. Such species include albatross, shearwaters, pelagic dolphins, highly migratory fishes, and sea turtles. A multi-step decision process to identify human impacts and potential protective measures can aid in planning MPAs to complement other conservation and management efforts for vulnerable species. Implementation steps should include determining species priorities, identifying important regions, outlining required measures, establishing feasibility, building inter-agency and international cooperation and collaboration, and ensuring enforcement and feedback mechanisms.

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Leatherback Sea Turtles in the California Current System

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(Abstract compiled by the conveners)

Sea turtles are far ranging pelagic species vulnerable to anthropogenic impacts at three distinct localities along their vast oceanic ranges: (1) nesting beaches, (2) migration routes / corridors, and (3) foraging grounds. Leatherback (*Dermochelys coriacea*), loggerhead (*Caretta caretta*), green (*Chelonia mydas*), and olive ridley (*Lepidochelys olivacea*) turtles are taken by pelagic gillnet and longline fisheries operating throughout the Pacific Ocean. In particular, drastic declines in eastern Pacific leatherback turtle populations suggest that this species is in dire need of protection. Leatherbacks breed at low latitude nesting areas and migrate into high latitude foraging grounds, where they consume large quantities of gelatinous zooplankton. Because turtles require large quantities of prey, they likely forage in search of dense and predictable prey aggregations. Aerial surveys off central California have revealed that leatherbacks occur off the west coast in summer and fall (July – October), particularly during periods of upwelling relaxation. In spite of high interannual variability in distribution and abundance, leatherbacks are most numerous in the vicinity of upwelling centers, and appear to be associated with the 14 – 16 ^{o}C isotherm. Satellite telemetry has revealed that turtles tagged in Monterey Bay range through the fishing grounds of the Hawaiian pelagic longline fishery and the west coast pelagic gillnet fishery, as they migrate towards the western Pacific. Time-area closures were recently implemented to reduce marine turtle bycatch in the pelagic long-line and gillnet fisheries in the central and eastern North Pacific Ocean. Unfortunately, very little is known about sea turtle migration patterns across these vast pelagic ecosystems to delineate predictable movement corridors that could be protected using time-area closures or MPAs.

Seabirds and Marine Reserves in the CCS: Oceanographic and Natural History Implications

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The California Current System (CCS) supports a rich and diverse avifauna including 103 species and an estimated 2 – 8 million birds during winter and summer respectively. Conservation measures are needed to protect highly susceptible seabird populations and their marine habitats in the CCS. Moreover, seabirds are valuable focal species for the design of broader ecosystem-level pelagic reserves because they are numerous and conspicuous marine predators, known to respond to changing water mass distributions and ocean productivity patterns.

The CCS is a vast and heterogeneous marine ecosystem, characterized by latitudinal and longitudinal gradients in physical and biological properties. In particular, overall seabird abundance and species composition change with latitude, along onshore-offshore gradients, and with distance from breeding colonies. Moreover, the avifauna also shifts temporally in response to seasonal and interannual oceanographic variability. Marine reserve designs will have to account for this spatial and temporal variability in marine bird distributions, and for the disparate life history and habitat associations of the diverse CCS avifauna. Thus, distinct reserve concepts and designs will be required to accommodate regional disparities in oceanographic processes and food-web structure within the vast CCS. Furthermore, because non-breeding birds are numerically dominant during spring and summer, effective conservation measures will have to extend protective measures beyond the waters surrounding breeding colonies.

In principle, marine reserves could be designed to protect predictable foraging aggregations and migration corridors associated with specific oceanic habitats. In particular, seabird density is highest at certain bathymetric (e.g., shelf-break) and hydrographic (e.g., temperature fronts) features, suggesting that these marine predators predictably aggregate at specific oceanic habitats. Additionally, many seabird species including far ranging visitors (sooty shearwater *Puffinus griseus* and pink-footed shearwater *P. creatopus*), and local breeders (Cassin's auklet *Ptychoramphus aleuticus*, common murre *Uria aalge*) are most numerous along the shelf-break and the slope. These results suggest that marine reserves could focus on protecting relatively small (100s - 1000s km^2) regions delineated by “static” bathymetric features. In particular, geographically restricted regions, where narrow continental shelves concentrate the species that migrate along the shelf and slope, might be ideal sites for marine reserve zoning. Conversely, marine reserves may not prove feasible for protecting broadly distributed species that do not aggregate at specific oceanic habitats.

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Forage and Predatory Nekton of the Pacific Northwest

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Research on nekton in coastal waters of the Pacific Northwest first began almost 30 years ago and has continued somewhat sporadically since then. A large number of programs are actively sampling in coastal waters at the present time, and the coverage today is perhaps the most complete it has ever been. In this paper, we provide a brief overview of many of the studies that have been done and discuss some areas where we believe future efforts should be concentrated.

A substantial amount of effort has been expended to study the marine distribution and ecology of pelagic nekton in coastal waters off Washington and Oregon. Oregon State University (OSU) conducted one of the earliest and most extensive surveys. Multiple cruises were run from May through September of 1981 to 1985 for a total of 15 cruises. Fine-mesh purse seines were set from northern Washington (48^{o}N) to Cape Blanco (43^{o}N) in southern Oregon. In addition to purse seining, some environmental (temperature, salinity, and light) and biological (chlorophyll and zooplankton) sampling was done at each station. Details of sampling, environmental conditions, and catch of juvenile salmon and other nekton can be found in Brodeur and Pearcy (1992). Also examined were the diets of adult fishes to examine potential predation on juvenile salmon (Brodeur et al. 1987). A strength of this study was that sampling occurred under highly contrasting oceanographic conditions from strong upwelling to anomalous ENSO conditions and the effects of this variability on the ecosystem were examined (Pearcy et al. 1985; Brodeur and Pearcy 1992). Since 1998, researchers from NMFS and OSU have been sampling the coastal waters from northern Washington to central Oregon using large surface trawls. Multiple cruises were conducted each year generally during May, June, and September. Trawling was done from both chartered fishing boats and fishery research vessels, and was accompanied by extensive surface and depth-integrated plankton sampling, Conductivity-Temperature-Depth (CTD), and chlorophyll measurements, and some ancillary measurements including currents, light transmission, and acoustics. One of the goals of this research is to compare how the pelagic community has changed since the previous intense sampling period in the early 1980s (Emmett and Brodeur 2000). The nekton community has changed somewhat with large increases in sardines (*Sardinops sagax*) and a corresponding drop in northern anchovy (*Engraulis mordax*) and squids (Emmett and Brodeur 2000). These changes were seen also in the abundance trends in ichthyoplankton from surveys conducted off the Northwest coast from 1994 through 1998 (Bentley et al. 1996, Emmett et al. 1997, Brodeur et al. 2000). Process studies have examined the diel vertical distribution and catch rates of nekton (Emmett et al. MS). A parallel study has been underway to sample baitfish and predators from two transects near the mouth of the Columbia River (Emmett et al. 2001). Nighttime sampling again using surface trawls was conducted biweekly from April through August during 1998-2001. Substantial seasonal and interannual variation in the abundance of potential predators and forage fish was observed reflecting major changes in oceanographic conditions during the study period (Emmett and Brodeur 2000, Emmett et al. 2001).

Sampling for nekton off the U.S. west coast has been a component of the GLOBEC Northeast Pacific Program. This research extends from central Oregon to northern California and bridges a major oceanographic and zoogeographic break at Cape Blanco in southern Oregon. The first field sampling took place in June and August of 2000 involving coordinated activities of three vessels. The nekton sampling was done by surface trawling using the same gear as previously described in close proximity to the other sampling. In addition to analysis of nekton distributions in relation to the extensive biophysical sampling conducted, analyses of trophic interactions with predators and prey are underway (Brodeur et al. MS).

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Forage Fish of the Southern California Current System

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(Abstract compiled by the conveners)

Mapping forage fish larvae habitat with respect to mesoscale features provides insights into the physical processes responsible for local episodic population recruitment and the potential linkages with large-scale climatic variability. This presentation describes the spatial distribution and mesoscale habitat associations of northern anchovy (*Engraulis mordax*), Pacific sardine (*Sardinops sagax*), and Pacific hake (*Merluccius productus*) larvae with respect to sea-surface temperature structure (SST) within the California Cooperative of Oceanic Fisheries Investigations (CalCOFI) study area (1951-1998). The mapping of forage fish distributions revealed species-specific habitat characteristics at two spatial scales. Different species occupied distinct water masses: anchovies occurred in cold water (SST $< 17\ ^{o}$C) closer to shore; sardines inhabited warm water (SST $> 16\ ^{o}$C) farther offshore, and hake was found in cooler subsurface water (75 m temperature $< 13\ ^{o}$C). Moreover, larval distributions were also associated with smaller-scale habitats: anchovy and hake inhabited upwelling plumes, and sardine and hake occurred within mesoscale eddies.

In particular, a very strong habitat association was evident for sardine. The long-term (1951-1998) ichthyoplankton distributions revealed that sardine larvae were most numerous offshore, in a region characterized by low zooplankton volumes and chlorophyll concentrations. This apparent contradiction was resolved by relating sardine larvae distributions to the incidence of mesoscale eddies. High offshore larvae densities occurred during one quarter of the surveys and were associated with eddies. In particular, models of sardine production index, a measure of potential production resulting from individual growth rate and abundance, indicate that larvae production is an order of magnitude higher in cyclonic eddies than in inshore, slope, offshore and anti-cyclonic eddy habitats. These results suggest that eddies constitute intermittent but highly productive habitat features, where larvae are concentrated and retained. Analyses of atmospheric and eddy intensity time series (1987 – 1998), suggest that the Northern Extratropical Index (NOIx) influences the incidence of eddies in the California Current system, by changing the magnitude of the north-south wind speed and the volume of transport associated with the Sverdrup wind stress. Linking large-scale atmospheric processes with local ocean productivity and population dynamics is essential to place localized management strategies in perspective.

Euphausiids and Squid: Important Forage Species

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(Abstract compiled by the conveners)

The California Current is characterized by substantial spatial and temporal heterogeneity in sea-surface temperature and chlorophyll concentration. Off central California, this variability involves changes in the extent of plumes of cool and nutrient rich upwelled water associated with coastal promontories. Moreover, interannual variability in ocean circulation influences the patterns of ocean productivity and coastal upwelling in the California Current, causing shifts in the spatial extent of the near-shore band of high chlorophyll waters. These shifts were very apparent in the distributions of euphausiids and cetaceans off central California during the 1998 El Niño event and the subsequent 1999 La Niña period.

The euphausiids *Thysanoessa spinifera* and *Euphausia pacifica* constitute important prey species in the California Current. These large planktonic grazers link primary producers with higher trophic-level predators including squid, seabirds and cetaceans. Moreover, there is evidence that physical processes influence euphausiid population dynamics and dispersion. For instance, the complicated euphausiid life cycle appears to be impacted by physical (e.g., water temperature) and biological (e.g., ocean productivity) variability. Moreover, the availability of euphausiids to air-breathing predators is greatly influenced by their vertical distribution and patchiness.

Zooplankton surveys in Monterey Bay since July 1997 illustrate the high degree of seasonal and interannual variability in euphausiid abundance during periods of contrasting oceanographic conditions. Though euphausiids were recorded yearly from spring through fall (May – November), their annual peak in abundance occurred in late spring (May – June). Nevertheless, euphausiid abundance during late spring - summer was highly variable during the study period, ranging from approximately 2500 - 25000 individuals per 1000 cc^3.

In addition to changes in overall abundance, the springtime onshore-offshore distributions of larval and adult euphausiids off central California shift in response to hydrographic variability. In particular, the offshore extent of larval distributions is influenced by the magnitude of coastal upwelling. For instance, during years of high upwelling (e.g., 1999 La Niña), larvae are advected farther and occur in waters up to 250 km offshore. Conversely, during years of low upwelling (e.g., 1998 El Niño), larvae are largely

restricted to nearshore waters up to 25 km offshore. Finally, while there has been an apparent increase in zooplankton biovolume within Monterey Bay associated with the hypothesized regime shift in the winter of 1999, euphausiid abundance measured both hydroacoustically and via net sampling has not increased significantly. Preliminary analyses suggest that the observed increased in zooplankton biovolume is due largely to an increase in gelatinous zooplankton such as salps.

Based on these observations, we have formulated a conceptual model to link cetacean distributions with hydrographic variability via changes in euphausiid dispersion. Hydrographic variability (e.g., magnitudes of coastal upwelling) influences the offshore extent of euphausiid distributions by advecting these populations offshore. In turn, the seasonal and interannual variability in euphausiid dispersion influences the abundance and distribution of the large balaenopterid whales that target dense euphausiid concentrations.

The market squid (*Loligo opalescens*) is another important prey species in central California, taken by a variety of fish, seabird, and marine mammal predators. Time series of springtime (May – June) commercial catches during 1981 – 2000 reveal substantial interannual variability in squid abundance. In particular, catches are low during El Niño years (e.g., 82-83, 92-93, 97-98), and appear higher since the early 1990's (1994 - 2000). A closer inspection of squid commercial catches and euphausiid abundance in Monterey Bay between August 1996 and August 1999 reveals a coherent picture of interannual variability in these important prey resources, in conjunction with El Niño and La Niña events: abundance was low during the fall of 1997 and the spring of 1998, with marked increases during the fall of 1998 and the spring of 1999.

These results highlight the importance of incorporating an understanding of how physical and biological variability influences the distribution and the patchiness of top predators and their prey into management plans. In particular, protective measures may be specifically effective during periods when clumped marine predators are particularly susceptible to anthropogenic impacts. In particular, time-area closures and Marine Protected Areas may be vital to restrict fisheries catches and to mitigate bycatch during these "stressful" periods.

The information presented in this summary of the workshop's discussion uses language true to the thoughts originally expressed by workshop participants, with occasional paraphrasing to clarify some points. In no case are the thoughts of more than one speaker combined into one paragraph. The order in which information is presented has been changed to allow presentation of concepts in a logical sequence.

A professional facilitator led the discussion. In addition to the information they gained from the morning's presentations, workshop participants were asked to think about the following four issues in focusing their remarks.

- *Can productivity "hot spots" be identified for protection? If so, how can spatial / temporal variability in "hot spots" be taken into account when managing human activity or designing marine reserves? Likewise, how can the effects of climate variability and change be incorporated into marine reserve designs?*

- *What anthropogenic activities that threaten species or act as stressors in the California Current System can be managed or limited by establishing MPA's?*

- *What monitoring systems / elements would be needed to assess MPA efficacy and to promote broader ecosystem-level management of pelagic systems (e.g. within National Marine Sanctuaries)?*

- *What are the data gaps / research needs for assessing the ecological benefits of pelagic marine reserves?*

Please note that, although there was a discussion clarifying the meaning of "Marine Protected Area" (MPA) versus "marine reserve" (MRV), it did not occur until late in the day. Therefore, the term MPA is used loosely throughout the discussion, and sometimes refers to what would more accurately be termed a "no-take marine reserve".

A. The Utility of Pelagic Marine Protected Areas

When considering whether the establishment of pelagic Marine Protected Areas (MPAs) would benefit pelagic conservation, it is critical to assess the nature of the threats faced by top predators and their ecosystems. We address three general types of impacts:

- direct mortality, such as fisheries bycatch;
- indirect effects, such as depletion of prey resources;
- global effects, such as climate change, that may also affect prey availability.

The effectiveness and feasibility of marine zoning will vary depending on the nature of the threats these protective measures will have to mitigate. In particular, managers should assess how effective MPAs would be at protecting a given species or habitat from a variety of direct, indirect, and global impacts. Clearly, different management actions are better suited to address certain threats than others. For example, it may be more effective to address fisheries bycatch by regulating fishing effort directly, rather than by establishing a MPA network. On the other hand, large-scale MPAs may prove an effective way to address indirect effects, such as the fishing down of marine food webs and trophic cascades.

Marine Protected Areas cannot solve every marine conservation problem. Can we reach consensus on which objectives can be achieved using marine protected areas?

Pelagic MPAs cannot:

- Provide absolute protection for far ranging species;
- Be a substitute for single species protection measures;
- Protect from widespread non-point source threats, such as debris and ghost fishing.

Pelagic MPAs can:

- Set aside highly productive areas supporting marine food-web development;
- Protect important species-specific habitats, such as breeding colonies;
- Restrict localized anthropogenic impacts such as bottom trawling and ship strikes;
- Provide spatial refugia during “bad” or “stressful” conditions;
- Provide a baseline to study undisturbed ecological processes;
- Supplement fishery management and single-species conservation measures.

Pelagic reserves could reduce overall impacts to certain organisms and ecosystems over the long term. With the exception of specific breeding areas, most areas of interest for marine zoning involve the coupling of physical-biological processes supporting high productivity and the aggregation of prey. Such MPAs would be addressing the "direct" and the "indirect" threat categories.

Is there strong support to establish MPAs to provide baseline information on the status of undisturbed pelagic ecosystems? It would be difficult to justify pelagic MPA zoning using this rationale because far ranging pelagic organisms would spend considerable time exposed to anthropogenic threats outside of the MPAs. Thus, it may be difficult to claim that the MPA provides a "snapshot" of an undisturbed marine ecosystem.

Under certain circumstances, however, marine zoning may facilitate comparisons between ecologically similar areas under different management regimes. For instance, managers could compare the fish communities inhabiting nearby seamounts that were heavily fished and protected by MPAs.

Another example of a meaningful pelagic baseline relates to the indirect ecosystem-level consequences of fishery removals. For instance, what would happen if no salmon were removed from Monterey Bay? No one is suggesting we stop salmon fishing in Monterey Bay! However, we can still speculate about the response of this system, if fisheries did not remove these important predators. Frequently, we are unsure about the way large-scale removals of marine resources may be impacting oceanic food webs and ecosystem structure. If these extractions were halted in certain localities, we would be able to experimentally look for community-level changes. Similar experiments have documented strong direct and indirect effects in benthic systems (e.g. sea otters, invertebrates, kelp populations and fish communities in the Pacific Northwest).

B. Targets for Pelagic Marine Protected Areas: Threats, Productivity, and aggregation

Is there evidence that impacts on pelagic organisms and ecosystems could be ameliorated using marine reserves?

The answer is yes. The North Pacific high seas squid driftnet fishery on migratory species provides a good example. In approximately ten years, an estimated 11 million sooty shearwaters were taken in this fishery across the subarctic north Pacific. Similarly, large impacts are suspected for several species of pelagic dolphins, turtles, and tuna. When the United Nations shut down this fishery, it probably reduced the overall bycatch impacts to highly migratory species.

When animals move through an area there is a high potential for a large impact from a spatially small threat. It's important not to underestimate movement, that is, places where animals move through, especially bottlenecks or funnels. For example, drift gillnets are affecting leatherbacks as they are leaving concentration areas, and Alaska longlines take southern ocean shearwaters.

Is there evidence of threats to species in the California Current System?

If we eliminate nearshore gillnets—because they have been pushed into water deeper than 40 fathoms—this fishery will no longer threaten the harbor porpoise. However, oil spills in certain locations have been and could be devastating to some species, particularly those that aggregate in dense concentrations.

Other areas of high productivity that deserve protection include source locations, migratory corridors, and feeding areas. For some species these will be huge. This issue raises questions of political feasibility and logistics (e.g. which species should we focus on).

Protecting foraging areas near breeding aggregations will also be important. Some unanswered questions that remain for many organisms include:

- What habitats define these feeding grounds?
- How close are they feeding to breeding colonies?
- How predictable are these foraging grounds?

Targeting areas of high biomass is important and preferable to the use of "umbrella" species for defining MPAs. A single species conservation focus is often different from a focus on biodiversity. While the former target the centers of species distributions (where large and fecund organisms reside), the latter focus on the edges of species ranges (where many species co-exist).

We should be careful to recognize that some of the spatial specialization we see in pelagic organisms could be niche separation as opposed to something that is driven by physical processes. Nektonic species may be distributed independently from the physical structure because they are capable of regulating their location with respect to the water flow. It is thus essential to quantify the degree to which species distributions are correlated with physical variables, as well as the predictability, persistence and re-occurrence of important habitat hotspots where pelagic species occur.

In protecting feeding areas for seabird colonies, we would be protecting the food base that supports recruitment of chicks. However, we have seen that the important factor for many seabird populations is adult survival, so perhaps it would be more beneficial to protect wintering feeding areas.

Breeding seabird populations have less flexibility to change where they forage, so they are likely more vulnerable during the central-place foraging stage. Protecting foraging areas around colonies could thus provide greater benefit because of that constraint.

We need to determine what is the most effective place to protect. There is a need to protect the food for the chicks as well as the adults from sources of mortality both during the breeding and non-breeding seasons. If stressed for several years in a row, then a localized population may become extirpated.

Moreover, many species have "crunch" times, when things change and there are critical resource needs. During crunch times, there is a need to focus on key places. An example is that during the El Niño years, entire fish assemblages have shifted their distributions shorewards.

C. Physical-Biological Coupling and the Siting of Pelagic MPA's

One question with respect to protecting zones of physical-biological coupling is: how many times do humans impact that process? Before defining MPAs, we need to think about whether anthropogenic activities threaten these processes.

There is not a great deal of evidence that food limitation impacts these organisms we've been discussing; there are many El Niño-mediated effects. Would it be possible to adequately define an MPA to protect these areas? We could ask people to *not* do something they are currently not doing (such as maintain the krill fishing ban).

The answer is that we are not seeking to protect physical-biological coupling but to understand variability so that when we do address protection from direct effects, we will select those areas that will benefit the animals and will provide important ecosystem services (i.e. bio-physical coupling). We are not seeking to measure how humans are impacting the connection between phytoplankton and zooplankton. Rather, physical-biological coupling helps us focus on where to provide protection.

However, direct effects may impact important foraging grounds mediated by physical-biological coupling. We should define the places where this coupling occurs, and use this information to mitigate direct effects at those localities, which are often heavily targeted by fisheries.

There is not a lot we can do to change large-scale forcing processes affecting bottom-up food-web development. However, we want to use these biophysical processes as indicators to identify appropriate sites to protect. For example, in the case of ecotourism and whale watching: if someplace is of particular importance to whales for foraging, do we allow large vessel traffic in this area?

What is it that humans could be doing to negatively affect species in these localities of intense physical-biological coupling? There are potential impacts from:

- The krill fishery
- The squid fishery

- The baitfish fishery

- Any fishery affecting key species that connect primary production to apex species

- We could also add ship strikes and oil spills to this list.

In protecting these areas of biological relevance, do we even need to understand the processes explaining abundance, or do we simply need to know this is where species occur?

We focus on processes because we don't have data on pelagic species distributions everywhere, and because we want to anticipate variability in species distribution through time. In addition, it would be very difficult to defend an MPA solely on the basis of data of focal species abundance.

Here's an example of an MPA based on a dynamic management model: during El Niño events, no drift fishing is allowed in the southern California Bight to avoid green sea turtle bycatch. This raises the issue of who decides when we are experiencing El Niño conditions?

D. Pelagic MPA's and Migratory Species

The theory and the application of marine reserves are not well suited to pelagic species because they are far ranging organisms. It is not optimal if a species spends 90% of its time outside of the reserve. This makes it more difficult to define pelagic reserves that will be effective for highly migratory species.

We have been discussing ecosystem protection, where the benefits are ecosystem-wide management and the maintenance of systems in their natural state (or baseline). Species coming in and out of the reserve(s) will be more perturbed than species inhabiting the area; that's when metapopulation data are important. If species are coming and going from the reserve, it would not make sense as a means of protecting metapopulations. Biological hotspots attract pelagic predators at multiple trophic levels, but it's the trophic structure that is the target, not individual species. Another goal is to maintain systems in a natural state, for insurance against catastrophic events (e.g. oil spills). This is a precautionary insurance policy, which is an important element in thinking about ecosystem conservation. Protecting biophysical processes in the absence of any real or immediate threat is fine, even for fisheries.

By contrast, in the Channel Islands, reserves were proposed at least in part for fisheries benefits. Yet it is very difficult to make the argument that reserves will benefit fisheries and show evidence of tangible benefits. But if we say marine reserves focus on the conservation of biodiversity, that objective seems more appropriate.

Do we want to abandon the idea of pelagic MPAs for the protection of migratory species? For species with complex life cycles we could focus on one aspect of their life cycle tied to a specific area, and this could have substantial impact on the population as a whole. Enhancing fisheries, recovering imperiled species, and biodiversity/ecosystem conservation: keep all three of these goals in mind because some approaches apply some of the time and others apply at other times. The idea of protecting physical-biological coupling is viable scientifically, but how it flies politically is another question.

In the case of blue whales, a network of areas could be identified where the whales spend 90% of their time, and this series of MPAs wouldn't be huge. Would that be a benefit or not? There are certainly places where a network could address a larger percentage of species populations (for example, by covering 70% of foraging areas). We could use conspicuous indicators, such as seabirds, to define these areas.

However, the more time a species spends outside the MPA, the more time it will be susceptible to impacts we cannot mitigate. For example, to protect migratory hake we would need to set aside a huge area. If we were unable to cover a substantial amount of the habitat for a specific species, then the MPA wouldn't address that species.

The same thinking has affected the MPA process in Canada. Certain individuals within the Canadian Department of Fisheries and Oceans (DFO) have used the same argument concerning the benefits of MPAs to sessile versus mobile species. But MPAs should be considered just one tool in the management toolbox. We don't have to say that an MPA doesn't work just because it doesn't protect 100% of a population or species life cycle; it's simply one tool.

My original reaction to the proposal that MPAs be used for pelagic organisms like the highly migratory tunas and sharks was that it sounded silly. For example, we have no idea where such sharks as threshers go, but know they are off the west coast during summer. On the East coast they make 5000- to 6000-km movements. Therefore, the size and spatial scale of MPA's would be unlikely to protect many of the highly migratory pelagic sharks and other fishes. Relative to the issues affecting large pelagic fishes, such as bluefin tuna and swordfish in the Atlantic, the problem was not protection of areas but mismanagement by other nations. There is no protection in all spawning sites for these species. For highly migratory species, it seemed MPAs are not an answer. However, if we knew where the important foraging areas were, MPA's could help to protect these species.

In different years and different types of regimes, certain areas become more important to certain species. What happens when production is concentrated in a smaller area? There are more animals spending a greater percentage of their time in a smaller area because there is less flexibility to move and a greater cost of moving out of the productive areas. In these times of high aggregation, there may also be greater impact from fishing, since fishing may also focus in these areas if it is responding to the same process. These areas would make sense to protect for migratory species.

E. International Cooperation

International cooperation is essential because multiple nations invariably have jurisdiction over the ranges of highly migratory pelagic species. It would be counterproductive for one nation to close an important fishery area because fishermen will adapt. When they do, we must ask whether their displaced fishing effort will have a greater impact where fishing regulations are more lax? It depends on the species.

It is hard to argue the need for pelagic reserves in the United States. Problems are much worse in other parts of the world. It is hard to find egregious effects off the west coast of the United States. However, a pelagic MPA here would be important to demonstrate to the rest of the world that such MPA's are important ecosystem management tools.

Here is an example of why international cooperation is so important. Sharks and rays are livebearers. Until recently, we did not know where most species of sharks and rays pup. Now we have some information, however limited, on this but really only for the eastern seaboard. Much work on nursery grounds needs to be done on the west coast. To set aside an area to help those populations would be crucial.

U.S. scientists working in the Atlantic and the Gulf of Mexico invited their Mexican colleagues to a meeting, and they found that the Mexican scientists knew where the sharks' pupping grounds were! An international collaborative project is now underway to protect those areas in the Gulf. This is not an easy task, especially because of subsistence economies in these areas. There are probably predictable patterns to how some migratory species reproduce, including many baitfish and pelagic predatory fish, if we only had the information.

F. Defining "Marine Protected Area"

The idea of MPAs doesn't necessarily imply stopping all human use. For example, if the goal is to reduce bycatch of seabirds, then an MPA could require scaring devices, etc. It does not have to be a full closure (i.e. no fishing).

When fishing is prohibited in an area, it is called a "no-take" marine reserve. A reserve restricts all activities. This "silver bullet" is very appealing to many. However, we should distinguish marine reserves from a time / area closures, which are more specific regulations that prohibit fishing for certain species in certain areas at certain times.

Marine reserves could complement conservation management if we knew there was a life history stage of a target species that is spatially aggregated, and if we knew which life history stage had a disproportionate effect on population dynamics. Pelagic marine reserves could constructively reduce bycatch mortality.

Enforceability is a critical issue facing bycatch mitigation in the high seas, because it requires VMS (vessel monitoring system) devices or onboard observers, and coverage is low and by no means uniform across fisheries. Advances in acoustic monitoring and satellite technology might enhance the ability to enforce marine reserves in the near future.

The notion of network design is appealing, because it can fulfill multiple objectives; that is, different reserves achieve different goals. If dense enough, the network could potentially protect a significant part of the life history of pelagic species. Network design ought to be first and foremost. To protect a large amount of water in small chunks may be more politically acceptable than protecting a huge area.

Reserves cannot reduce bycatch if displaced fishing effort outside of the reserve has an impact. Thus, it is not convincing to say reserves would reduce bycatch if they result in equal or higher impacts from displaced effort. To achieve that goal, perhaps we would need proportional effort controls outside of reserves, since the effort restrictions often limit bycatch. It's the effort that is more closely linked to bycatch. However, this is not the case if the fisheries focus their effort on hotspots.

In the case of seabirds, the fear of closing the groundfish fishery provided the impetus to reduce bycatch. In Canada, the Pacific Halibut Advisory Board have recommended to the Department of Fisheries & Oceans that as a condition of licensing all boats above a certain size must use a bird-scaring or "tori line" device. However, there are other reasons than bycatch to establish MPAs.

Let's not restrict our discussions of MPAs to reserves! Thinking creatively could lead to some innovative ways of addressing thorny problems. Most of what we have been discussing is feasible in practical terms. We could create MPAs to protect refugia and to protect foraging hotspots. We could even implement temporal/spatial MPAs (this is not that different from fisheries management). The challenge is to decide where the priority areas are, what the threats are, and make decisions on what needs protecting. We can then tailor the protective measures to fit those priorities.

Normally, outside the boundaries of a protected area, there is no protective effect. In fact, in the National Marine Sanctuaries Act, there is authority to continue to protect sanctuary resources outside the boundaries of the protected area. That precedent exists in law. There are also regulatory prohibitions against activities outside the sanctuaries that will negatively affect the species protected within. Protections for key species can also be extended outside the boundaries of the sanctuaries.

G. Measuring the Effectiveness of Pelagic MPA's

In testing effectiveness of a pelagic MPA, what species would you use? Sea turtles, elasmobranches, marine mammals? Where are the critical life stages, and would MPA's work to protect them?

By defining whether you can measure effectiveness, it begs the question of which species the MPA is helping to conserve. An MPA could lead to reducing mortality rates or increasing fecundity. This may not be a solution for fish. If we identify the species that we can predict benefits for, then we could set something up experimentally and test it.

For sharks, time and area closures would probably be preferable because they are so threatened. It would be a moot point to set up pelagic MPA's to protect them because presumably all size classes pass by our coastline during the summer, but usually it is only the small, younger (2-3 year old) ones that are taken as bycatch by other fisheries, such as those for swordfish. Obviously, young and immature sharks do require some form of protection from fishing.

This is true only if the assumption is that the MPA will protect against the take of that species. But, ask if there is a region more biologically valuable to them. That is the indirect side of things.

For sharks, we don't know. There is bycatch of sharks in the swordfish fishery; perhaps MPAs could prove beneficial to mitigate this impact.

Think of each species as a matrix including life stage, human/species interactions, and stressful times. We can use this information to create an index of vulnerability. Where would it be most valuable to protect them? This could address the "10% encounter" issue discussed previously with respect to far ranging species. We are victims of our own coordinate system; animals don't have maps. Relative location is what matters to them, i.e. downstream of an upwelling plume, not 36 ^{o} N. We need more insight into species' coordinate systems. In designing MPAs to benefit certain taxa, we should probably pick a winner! Pick a 'slow and fat" species that is non-controversial and has no fishing pressure.

The big concern for long-lived species is the removal of mature individuals by direct catch and bycatch. A long time frame is needed to detect an effect from management (i.e. how different biological and harvest parameters would increase biomass for species). For a huge range of parameters, we see an effect in 10 years in less than 10% of species! In most cases, we only see an effect in 40 years. That's a problem for measuring the effectiveness or success of MPAs. We need to think about size. The NCEAS[3] slogan is "20% by 2020."

"Slow and fat" is not always good. We need additional simulation studies: how big of an area, how much of an effect. This would be possible for Common Murres because we have data on their distribution and breeding, and a fair amount of data on mortality. We could look at interannual variability in the Gulf of the Farallones and Monterey Bay.

Some of that work has been done. Tundi Agardy has looked at the use of MPAs for cetaceans and other marine mammals. We need to brainstorm relevant documents to be accessible to this group.[4]

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[3] The National Center for Ecological Analysis and Synthesis (NCEAS) commissioned studies over 2 ½ years of MPAs worldwide, and the findings led to a consensus statement by the NCEAS scientists (Feb. 17, 2001) in favor of "the immediate application of marine reserves as a central management tool."
[4] Randy Reeves wrote a summary for cetaceans and Elliott Norse has a new book coming out.

It is critical to understand what species would benefit from marine reserves! Or, we could look at it the other way around: which are the species falling through the cracks?

We have a lot of information on the life history of static reserves (not the open water column). A lot of the ideas we've been discussing are actually area closures if they restrict a specific fishery to prevent impacts; remember a marine reserve is absolutely no-take.

The ***Pelagic Predators, Prey, and Processes Initiative*** aims to promote the design of ecosystem-level, multi-species management plans to protect entire marine food webs and the habitats where marine top predators and their prey aggregate.

We acknowledge that wildlife managers can use a vast array of management measures to help conserve threatened populations and to manage marine resources. Marine Protected Areas (MPAs) should thus be viewed as one of several useful management tools.

We are also aware that MPAs can seek diverse goals. Therefore, a number of different design concepts will be required to meet these disparate objectives. The PPPP initiative highlights "No Take" Marine Reserves (MRVs) designed to mitigate a variety of human impacts ranging from fisheries bycatch to vessel strikes.

A review of the best available evidence leads us to conclude the following:

(1) ON THE VALUE OF PELAGIC RESERVES -

Effective management of oceanic ecosystems will require comprehensive approaches and innovative tools, including the judicious use of MPAs. In particular, MRVs, used in conjunction with other species-specific management practices, will enhance the effective management of marine ecosystems.

MRVs offer important tools for an integrated management of oceanic ecosystems. In principle, reserves can be used to help conserve endangered species, to keep common species common, to maintain marine biodiversity, and to protect productive areas where top predators aggregate.

Additionally, MRVs can also insure entire ecosystems by buffering populations against catastrophic events and mismanagement.

On the other hand, MRVs cannot provide absolute protection for highly migratory species and cannot mitigate large-scale impacts such as non-point source pollution and climate change.

Thus, MRVs should not be viewed as substitutes for single-species management. Instead, reserves will complement species-specific management and conservation practices.

(2) ON The Design of Pelagic Reserves -

As in terrestrial and near-shore systems, pelagic reserve designs will be guided by an understanding of natural history, habitat variability, and human resource use patterns, both historical and current.

Important differences in scale and predictability set aside the pelagic environment from terrestrial and near-shore ecosystems. Given the complexity of oceanic systems, novel reserve design concepts will be required to accommodate the inherent spatial and temporal variability in species distributions and food-web dynamics.

Physical-biological coupling is an important determinant of productivity and species distributions in pelagic systems. However, the strength of this coupling varies in time and space. Yet, predictable regions of high productivity and strong physical-biological coupling do exist.

Thus, MRVs could protect regions of high ocean productivity, prey concentration, and top predator foraging grounds supported by strong physical-biological coupling.

MRVs may be particularly useful during stressful periods when ocean productivity decreases and species distributions are highly concentrated, thus becoming more susceptible to human impacts.

Reserve networks will be needed to accommodate regional faunal disparities and the far ranging habits of many pelagic species. In particular, regional differences in physical variability and marine food web structure along the vast California Current ecosystem will require flexible approaches to reserve designation, regulation, monitoring, and management.

MRVs should seek tangible population-level objectives such as a reduction in mortality rates or an increase in fertility rates. Furthermore, reserves should be designed to facilitate evaluation of whether these goals are being met.

Modeling studies can help assess to what extent species and populations will benefit from the implementation of MRVs. Additionally, population models can be used to determine which population stages and demographic processes should be targeted for more effective conservation.

(3) ON Advances Required for Pelagic Reserve Implementation -

- Conceptual Needs

- **Natural History**: An improved knowledge of the natural history (e.g., the habits and habitats) and the threats faced by upper trophic marine predators.

- **Physical - Biological Coupling**: An enhanced understanding of the physical mechanisms that support ocean productivity and influence the formation and persistence of the foraging and migration habitats exploited by marine predators.

- **Socio-economic Implications**: Knowledge of the way resource users respond to regulations is needed to better gauge the ecological / socio-economic consequences of MRV implementation. For example, managers should anticipate the potential ecological / social impacts of fishing effort displaced by time-area closures / marine reserves.

- **Population-level MRV Benefits**: Modeling studies are needed to predict which species, age classes (e.g., juveniles, adults) and processes (e.g., survivorship, reproductive success) will yield the largest population-level conservation return (e.g., increase in population growth rate, decline in expected time to extinction) from protection.

- **MRV Evaluation Criteria**: Modeling studies and field research within newly established or trial MRVs will be required to establish their effectiveness. Field-based metrics (e.g., population size, foraging trip duration, diet composition, growth rate, energetics, and reproductive success) will be particularly useful to evaluate reserves established around breeding colonies. Conversely, MRV effectiveness will be more difficult to assess in pelagic habitats, where field data will be limited to distribution and abundance data.

- **Benefits to Exploited Populations**: Evidence that MRVs designed to protect endangered species and habitats also provide indirect benefits to commercially valuable stocks will enhance the political will behind pelagic reserve implementation.

- Logistical Needs

- **Research Programs**: Integrated, multi-disciplinary studies of ocean productivity, prey dispersion, and top predator distributions are needed to assess the location and size of potential pelagic reserves in the California Current System.

- **Enforcement Ability**: Technological advances are essential to implement and enforce large-scale conservation actions such as time-area closures and MPAs.

- **Measuring Effectiveness**: Research and monitoring programs are necessary to evaluate MRV effectiveness.

The Pelagic Working Group will continue working to further refine the concepts presented in this workshop report and to facilitate formation of a broadly representative board that will sponsor pelagic MPA research and pilot projects. Future workshops are currently being planned.

For more information, or to contact the conveners of this workshop, please consult the Pelagic Working Group website at:

www.prbo.org/pelagicworkinggroup.htm

Thank you for your interest in the Pelagic Working Group and the conservation of highly migratory species and offshore ecosystems.

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