Pelagic Reserves for Marine Top Predators: How Big and How Many?

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Introduction

Marine protected areas (MPAs) are increasingly being used as tools for protecting valuable and sensitive ecological, cultural and fishery resources throughout the world. In recent years, there has been mounting interest in the development of pelagic reserves designed to protect oceanic species and their dynamic habitats. In particular, marine ecologists have advocated reserves to protect highly-mobile marine mammals, birds, turtles and sharks. Mounting evidence that these top marine predators control populations of mid-level predators and structure marine food webs has highlighted the need to maintain the roles of these species in their ecosystems.

While the concept of pelagic reserves may seem unreasonable due to the vast movements of many of these oceanic species, recent conceptual and technological advances have provided managers with the necessary tools to design and manage MPAs in the open ocean. In particular, advances in satellite-derived information, such as animal tracking and remote sensing imagery, are allowing scientists to define the habitats of protected species, and to monitor oceanographic features and predator movements. Thus, it is becoming increasingly evident that pelagic reserves are not only feasible, but necessary to facilitate the long-term conservation of oceanic species and the management of pelagic ecosystems.

Herein, I focus on MPAs designed for conservation goals and discuss their use to protect pelagic species (i.e., living in the water column and not attached or associated with the sea floor). More specifically, I review the conceptual foundations of pelagic reserves and illustrate four critical design principles using marine mammal case studies. While this article focuses on cetaceans, these concepts are applicable to other highly-mobile species, including marine birds, turtles, and large predatory fishes like sharks and tunas.

Design Concepts: Life History Considerations

Because MPAs have many different goals, their designs and management plans vary widely. In particular, MPAs for protecting pelagic species and their oceanic habitats need to incorporate design concepts driven by the ecology and the oceanography. For example, managers need to understand critical life history aspects of the focal species: where and when they reproduce and feed; do different life stages and sexes use different habitats; whether they migrate seasonally between breeding and foraging grounds; and whether they repeatedly use specific migratory pathways. Equipped with this information, managers can determine whether important life history processes are associated with specific habitats that can be mapped in time and space. Even though a given species may rely on specific features during certain seasons or ages, they may use widely distributed resources at other times. Thus, MPAs may not be feasible or effective throughout the entire life cycle of the species, but may be a viable conservation option at those times and locations where the species concentrate in predictable features. These predictable aggregations provide, in principle, excellent opportunities for the creation of MPAs to protect these biological hotspots. While MPAs have long been used in coastal waters to protect benthic species and habitats like coral reefs and mangroves, they are

increasingly being used to protect highly-mobile species and oceanic habitats as managers learn where and when these far-ranging species concentrate to forage and to reproduce.
Depending on the life-history of the protected species, pelagic reserves can adopt four basic designs: hotspots, seascapes, reserve networks, and ecosystem reserves.

Hotspot Reserves

Reserves have long been used on land and at sea to protect relatively small areas of high biological value, because they harbor dense aggregations of protected species, sensitive or critical habitats, or areas of high biological diversity. For example, the eastern Pacific Gray Whale (*Eschrichtius robustus*) breeds off Baja California (Mexico) during the boreal winter, spends the summer foraging in the Bering and Chukchi Seas, and migrates along coastal waters from Baja California to Alaska every fall and spring. A small (approximately 3700 km ^{2}) MPA encompassing two lagoons (Laguna Ojo de Liebre and Laguna San Ignacio) and the surrounding land, was designated in 1971 to protect the Gray Whale calving grounds from development and associated pollution (e.g., oil and noise). Because Gray Whales have a fairly predictable oceanic migration, other marine reserves could be created to protect this species during other parts of its life cycle. In particular, whale concentrations in their Alaskan summer-time foraging grounds could be mapped and protected using MPAs. Potentially, other protective measures could also be used to mitigate human impacts along their migratory route between the breeding and foraging grounds (Figure 1A). Due to the shared responsibility for the conservation of this species between Canada, Mexico and the U.S., the Commission for Environmental Cooperation (CEC) selected the Gray Whale as a species of common conservation concern, which includes identifying ecological important areas for designating a network of MPAs within the framework of the Bering to Baja Conservation initiative (http://www.mcbi.org/what/b2bcd.htm).

Even though MPAs are more difficult to design and to implement in the open ocean, pelagic reserves can protect highly-mobile species, like the Fin Whale (*Balaenoptera physalus*). Fin Whales are found in all the world's oceans, but occasionally concentrate in dense aggregations. In principle, MPAs can be used to protect these predictable aggregations from human impacts. For instance, the Pelagos Sanctuary for Mediterranean Marine Mammals was established in the Ligurian Sea (Western Mediterranean) in 1999 to protect a large local population of Fin Whales from accidental entanglement in drift nets, ship strikes, and pollution.

The Pelagos Sanctuary covers an area of approximately 84,000 km², and comprises the waters of three nations (France, Italy, Monaco) and the high seas beyond national jurisdiction. This MPA encompasses a persistent oceanographic front overlaying the continental shelf-break and upper slope (200 – 2000 m depth). These productive waters are believed to be the main feeding ground for Fin Whales in the Mediterranean basin, with an estimated 3,500 individuals using the area in summer. For more information on the design and implementation of the Pelagos Sanctuary, refer to NCEP module 498 ("The Pelagos Sanctuary for Mediterranean Marine Mammals"), available online at http://ncep.amnh.org/index.php.

Reserve Networks

Because many cetaceans engage in large seasonal migrations (over 1000s of km), reserves capable of encompassing their entire range would have to be very large, in some cases spanning entire ocean basins. Alternatively, multiple linked reserves may be required to afford protection to these migratory species throughout their year-long cycle, by protecting their calving areas (winter), their foraging grounds (summer), and seasonal their migratory routes (Figure 1B). Such a system of reserves would require an integrated management plan involving multiple countries and protective measures in the high seas, beyond national jurisdiction.

The International Union for the Conservation of Nature (IUCN) has defined MPA networks as "collections of individual reserves operating cooperatively and synergistically, at various spatial scales and with a range of protection levels, that are designed to meet objectives that a single reserve cannot achieve". While reserve networks could be used to protect cetaceans throughout their migratory routes, their feasibility and design will ultimately depend on the predictability of foraging / breeding grounds and the migratory routes connecting them. Thorough assessments will be required to guide these networks, because different threats have characteristic footprints which influence the ability of MPAs to mitigate their impacts. In particular, the inability of MPAs to mitigate large-scale human impacts with basin-wide footprints, such as climate change and plastic pollution, emphasizes the need for a comprehensive approach to oceanic conservation, including the judicious use of MPAs with diverse designs and management plans.

Seascape Reserves

In addition to MPAs designed to protect cetacean hotspots from focused impacts, large reserves may be required to protect widely-distributed species from far-reaching threats (Figure 1C). For instance, vast expanses of the ocean beyond national jurisdiction have been set aside as international cetacean sanctuaries under the auspices of the International Whaling Commission (IWC), exclusively to protect large whale populations from commercial whaling. Currently, two such IWC sanctuaries exist: the 1979 Indian Ocean Sanctuary and the 1994 Southern Ocean Sanctuary.

The Indian Ocean Whale Sanctuary (IOS) was established by the IWC in 1979 to protect large whale populations from commercial whaling in the high-seas beyond waters under national jurisdiction. This sanctuary extends from the tropics south to the northern border of the Southern Ocean Whale Sanctuary (SOS) at 55°S latitude, with a western boundary of 20 ° E longitude by Africa and an eastern boundary of 130°E longitude by Australia. The creation of the Southern Ocean Sanctuary in 1994, extending over 50 million km ^{2} around the entire Antarctic continent, lead to the protection of Indian Ocean whale stocks from commercial whaling during their entire latitudinal seasonal movements. Together, these two sanctuaries cover the entire ranges of several Indian Ocean cetaceans that migrate seasonally from tropical breeding grounds to the Antarctic.) The IOS and SOS have been extended after scientific evaluations conducted every ten years, and are still in existence. While these sanctuaries do provide research and management benefits to large whale populations, their major limitation is the continued hunting of whales (largely Antarctic Minke Whales *Balaenoptera bonaerensis*) by Japanese scientific permit whaling. This harvesting remains a major unresolved issue in the management of large whale populations and the monitoring of the Antarctic marine ecosystem. For more information, visit http://www.iwcoffice.org/conservation/permits.htm.

Moreover, two proposals for the establishment of additional IWC sanctuaries in the South Pacific Ocean and the South Atlantic Ocean failed to gain the required three-quarters majorities at the 56th annual IWC meeting, held in 2004. Thus, large whale stocks in these two oceans are not currently protected from commercial whaling throughout their life cycle, since these populations exit the protected waters of the SOS to breed in the tropics. Despite the failure to implement these new IWC sanctuaries, recent assessments of the two existing sanctuaries have stressed the need for broader management goals aimed at establishing a comprehensive ecosystem-based management of cetaceans within sanctuary waters. To learn more about the IWC sanctuary program, visit http://www.iwcoffice.org/conservation/sanctuaries.htm.

Ecosystem Reserves

Even though reserve networks may be critical for protecting migrating species throughout their life cycle, they may not suffice to preserve the key ecological interactions and ecosystem processes supporting them. In recent years, scientists are calling for the establishment of large pelagic reserves to protect some of the last remaining stretches of ocean that have not been harmed by human

activities such as overfishing and pollution. While most existing MPAs have been created to protect endangered species and their habitats, these novel no-take reserves would be created preemptively to ensure that marine regions with high biodiversity or ecological value remain undisturbed. Basically, they would provide an insurance policy against future ecological degradation. Furthermore, these sites would facilitate long-term research opportunities, critical for monitoring changes in marine ecosystems.

Conclusions

MPAs are increasingly being used to protect cetaceans throughout the world, including pelagic species in oceanic habitats (http://www.cetaceanhabitat.org). As more pelagic reserves are established, a more comprehensive approach for their design and management is emerging, built upon four principles: (i) small-scale MPAs can be used to protect predictable breeding and foraging sites; (ii) reserve networks are needed to protect the entire life cycle of migratory species; (iii) large-scale reserves are required to address broader ecosystem-level management considerations, including the long-term management and monitoring of ocean ecosystems ; and (iv) all reserve designs must include clear goals and management plans that are periodically evaluated and revised.

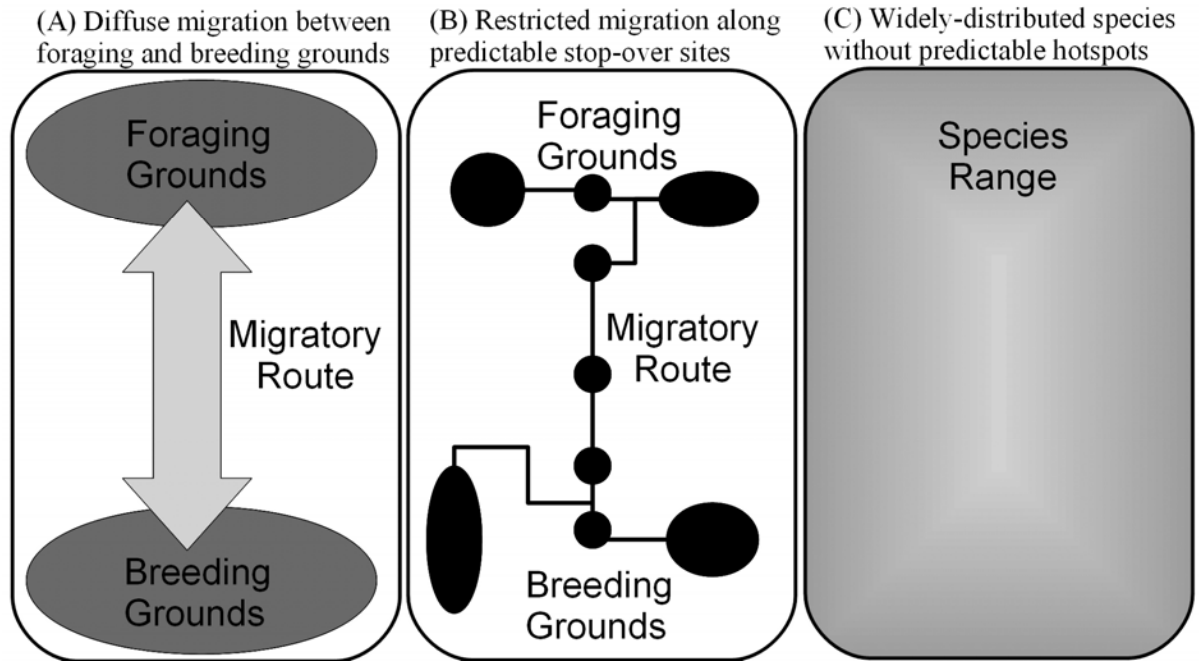
Ultimately, reserve designs are driven by the natural history of the species to be protected and by the threats affecting them. For instance, while hotspot reserves can protect species with small ranges from focused threats (e.g., incidental mortality from fisheries and ship strikes), large seascape reserves (often basin-wide) are needed to protect far-ranging species with seasonal migrations from widely distributed threats (e.g., commercial whaling). Nevertheless, reserves need not completely remove an anthropogenic impact from the entire range of a species to be effective conservation tools; small decreases in mortality rates from entanglement and ship strikes can help reverse the population declines of protected whale species. Thus, small-scale protective measures targeted at critical foraging and breeding sites can yield large conservation pay-offs, especially for species with small populations (e.g., the Pacific and Atlantic Northern Right Whale *Eubalaena glacialis*).

In those instances when cetaceans concentrate in predictable areas to breed (e.g., Gray Whales off Baja California) or to forage (e.g., Fin Whales in the Ligurian Sea), small reserves can protect these important habitats. These hotspot reserves can target productive habitat features associated with the sea floor (e.g., banks, seamounts, canyons, shelf-breaks) and with predictable locations where water flow causes high localized productivity (e.g., upwelling) or the concentration of weakly-swimming zooplankton prey (e.g., convergence zones). Because these bathymetric (static sea floor) and hydrographic (dynamic water movement) features vary in size and predictability, different MPA designs will be required to encompass top predator distributions in these habitats.

Existing cetacean MPAs (e.g., Pelagos and IWC Sanctuaries) and ongoing initiatives for ecologically-based MPA networks (e.g., Bering to Baja) underscore the potential use of international reserves in the conservation of pelagic species, including marine mammals, birds, turtles, and predatory fishes. The *Last Ocean* initiative for the creation of a basin-wide reserve to protect the diverse and productive Ross Sea, illustrates the advent of ecosystem-level MPAs. This reserve would protect marine top predators and the ecosystem processes they depend upon in perpetuity, by stopping the harvesting of marine resources - including scientific permit whaling - in this vast region of Antarctica.

The future of pelagic conservation will involve the implementation and evaluation of small-scale and basin-wide protections, including MPAs designed to protect biological hotspots, the migratory pathways of highly-mobile species, seascapes encompassing the entire life cycle of protected species, and entire marine ecosystems. A diverse array of reserves will be required, alongside other fisheries and conservation actions, to help protect and monitor far-ranging species and their oceanic habitats.

Figure 1. Diagram illustrating three different MPA scenarios: (A) two hotspot reserves protect key foraging and breeding grounds, connected by a diffuse migratory pathway; (B) a network of reserves protect stop-over sites along a fairly restricted migratory pathway connecting predictable foraging and breeding grounds; and (C) a large seascape reserve encompasses the entire range of a widely-distributed protected species. The shading indicates the abundance of the species, ranging from white (absence) to black (high density).



LINKS

- Case Study 1 – the Pelagos Sanctuary:
  http://www.cetaceanhabitat.org/pelagos.php

- Case Study 2 - International Whaling Commission Sanctuaries:
  http://www.iwcoffice.org/conservation/sanctuaries.htm

- Case Study 3 – The Bering to Baja Initiative:
  http://www.cec.org/files/PDF/BIODIVERSITY/IMpaper_en.pdf

- Case study 4 – Ecosystem-level MPAs:
  http://lastocean.com/story/overview/read/

FOOD FOR THOUGHT

- Visit the American Cetacean Society web-site (http://www.acsonline.org/factpack/) and compare the cetacean distribution maps. Read the species profiles and discuss possible marine reserve designs for the different species. Consider the following: do the species have large or small ranges, are their breeding and foraging grounds together or separated, do the species go on vast seasonal migrations. Hint: you may want to consider the following three species:

  Gray Whale: http://www.acsonline.org/factpack/graywhl.htm
  Fin Whale: http://www.acsonline.org/factpack/finwhl.htm
  Franciscana Dolphin: http://www.acsonline.org/factpack/Franciscana.htm

- The number and size of MPAs varies throughout the world. Look for existing MPAs in your region on the interactive map and the regional lists. What parts of the world have the highest / lowest concentrations of MPAs? Where are the world's largest MPAs?

  Interactive map: http://www.mpaglobal.org/index.php?action=aboutus
  Regional lists: http://www.mpaglobal.org/index.php?action=summary_by_country

- Effective MPAs need management plans devised by scientists together with local stakeholders. Management plans describe the specific conservation goals for the individual species and the entire ecosystem to be protected, the research and educational needs, the types of allowed and restricted uses, the management and enforcement regimes required, and the schedule for periodic monitoring and review of the MPA goals and performance. To learn more about the threats faced by cetaceans and the potential management actions to mitigate these threats, consult these MPA management plans: http://www.cetaceanhabitat.org/management_plans1.php

- Read about the scientific rationale for creating ecosystem-level MPAs, and their importance for long-term conservation, resource management and research: http://lastocean.com/