Examination of Pelagic Marine Protected Area Management

With Recommendations for the Pacific Remote Islands Marine National Monument

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Scope of Work (from NOAA terms of reference):

Conduct a scientific review of large marine protected areas that have relevant lessons for PRIMNM, including MPAs designed to protect pelagic and highly migratory species as well as large marine ecosystems. This review will detail where other large pelagic MPAs exist, their management goals, how they are being managed, the challenges being dealt with, anticipated and observed benefits of protecting these areas, and indicators of effective management. We will draft recommendations for managing large pelagic ecosystems and evaluating management effectiveness, including dealing with major human and environmental threats.

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Executive Summary

The US Pacific Remote Islands Marine National Monument (**PRIMNM**) designated in 2009 by Presidential Proclamation, protects 225,038 km^2 in the Central Tropical Pacific Ocean. It includes the US territories of Wake Island, Johnston Atoll, Palmyra Atoll and Kingman Reef, Jarvis Island, and Howland and Baker Islands. President George W. Bush designated it because of its exceptional natural heritage to US citizens, and called for strong protection of the region, including the exclusion of commercial fishing.

Pelagic ecosystems face a number of threats including overfishing, pollution, climate change, ocean acidification, shipping, eutrophication and species introductions. At the same time there has been an increasing trend in recent years in the creation of large-scale, mostly pelagic marine protected areas. In addition to guarding against threats, Pelagic Marine Protected Areas (**PMPAs**) are likely to be large enough to incorporate large portions of far-ranging or migratory animal habitats and movements, but as yet there has been no comprehensive assessment of *how* to manage PMPAs, and scientific evidence for their success is limited.

Management of so vast a region such as the PRIMNM is without significant precedent. Management of large areas, dynamic processes and highly migratory species that can move thousands of kilometers adds significant challenges to 'traditional' MPAs focused on enhancement or protection of nearshore ecosystems having species with relatively restricted home ranges (movement on the order of hundreds of kilometers or less). Nonetheless, the extent and number of PMPAs are increasing across the globe, presenting new opportunities for managers and scientists.

Benefits from MPAs to pelagic species have been documented, although it is unlikely that pelagic MPAs will ever be big enough to cover the entire range of large, wide-ranging species such as tunas, some sea turtles or whales. There is much uncertainty about the scale of movement as it relates to the size and location of MPAs for most pelagic species. The key factors that will determine whether closures provide benefits to marine life relate to the scale of movement relative to the size of the MPA, the amount of time within the MPA, the vulnerability outside the MPA, and the particular species' life history. PMPAs targeting protection in places where species spend particularly vulnerable life history phases such as spawning areas, juvenile habitats or migration routes are likely to be the most effective. Advances in telemetry over the past several decades have made identifying the locations of key life history phases imminently possible for a number of species. Field work also supports protecting targeted areas.

Perhaps the most certain conservation benefit of a pelagic MPA is the reduction in direct impacts to species either from target fishing or from incidental bycatch. However this depends on whether or not increased fishing effort outside of the MPA offsets any loss of effort in the MPA. In cases where the overall mortality of a target species remains unchanged because effort increases outside the MPA, it will be difficult to assess whether or not an MPA provides a conservation benefit for a target species. In general the success of any MPA will be strongly influenced by the management of pelagic fishing effort surrounding MPAs. While MPAs can provide added protection, in many cases they are not substitutes for well-managed fisheries.

Protected areas also offer fishery benefits by providing spillover of adult fishes from the reserve into adjacent fishing grounds and/or increased reproductive potential that seeds surrounding fishing grounds. MPAs also serve as scientific reference areas that supply important information on population dynamics in the absence of fishing. Protecting pelagic ecosystems from fishing may also benefit trophic and indirect interactions such as seabird-tuna foraging interactions.

The remaining sections of the report review considerations for planning and management. We highlight an approach from the conservation planning literature (Pressey and Bottrill 2009) for structuring a management plan for large pelagic MPAs, highlighting relevant information for the PRIMNM, and review several large MPA case studies. We review relevant lessons from existing large MPAs: the three US West Coast National Marine Sanctuaries, Monterey Bay, Gulf of the Farallones and Cordell Bank NMS (United States), the Phoenix Islands Protected Area (Kiribati), the Chagos Island Marine Reserve (United Kingdom) and the Pelagos Marine Mammal Sanctuary (Mediterranean high seas).

Finally we conclude with recommendations for managing the Pacific Remote Islands Marine National Monument. These include:

1. **Management Plan Recommendations**
   Consider the Phoenix Islands Protected Area Management Plan as a template

Coordinate with other federal agencies
Explicitly include functional ecological units in management plan
Explicitly incorporate US military responsibilities in management plan

2. **Enforcement**
Designate anchorages and create moorings
Promote peer reporting
Increase cooperative agreements with other countries
Create both biological and enforcement priorities

3. **Monitoring and Performance Measurements**
Consider threats and ecological processes outside of PRIMNM
Coordinate monitoring and research activities with PIPA
Consider the National Marine Sanctuary Program plan for evaluating performance measures
Coordinate monitoring with outside partners
Apply monitoring tiers
Monitor pelagic species
Improve the scientific understanding of seabird-tuna interactions

Bumphead parrotfish (photo: NOAA CRED).

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Introduction

The oceans cover approximately 71% of the Earth's surface and in this vast area the majority of habitat space is in the water column or pelagic realm. Pelagic ecosystems encompass 99% of the biosphere's volume (Angel 1993, Norse 1994), provide over 80% of global fish production (Pauly et al 2002), are critical in the regulation of the Earth's climate (Field et al 1998) and support the majority of marine life during some part of their life history (Hays et al 2005). Pelagic ecosystems can be split into a variety of zones including the oceanic and neritic zones, each having slightly different characteristics. The neritic zone refers to the areas overlying continental shelves to a depth of 200m; while the oceanic zone refers to the far deeper and offshore areas that extend beyond the neritic zone and around oceanic islands such as those found in the Central Tropical Pacific Ocean.

Pelagic ecosystems face a number of threats including overfishing, pollution, climate change, ocean acidification, shipping, eutrophication, and species introductions (Game et al 2009, Halpern et al 2008). Protecting these ecosystems will be critical to meeting global marine conservation targets, such as the Convention on Biological Diversity's call to establish 10% of the worlds' oceans as MPAs by 2020 (CBD 2010). There has been an increasing trend in recent years in the creation of large-scale, mostly pelagic marine protected areas (PMPAs) (Table 1) (McCrea-Strub 2010). In addition to guarding against threats, PMPAs are likely to be large enough to incorporate large portions of far-ranging or migratory animal habitats and movements (Hyrenbach et al 2000, Norse et al 2005, Alpine and Hobday 2007, Ardron et al 2008, Game et al 2009). Still, a comprehensive assessment of *how* to manage PMPAs, as well as scientific evidence for their success is limited (Gaines et al 2010).

The Pacific Remote Islands Marine National Monument (PRIMNM) is one such PMPA that was designated in 2009 by Presidential Proclamation number 8336

Table 1. Marine protected areas with large pelagic ecosystem components.

Name	Size	Year	Administrative Body	Management measures
Chagos Protected Area	640,000 km^2 (247,000 mi^2)	2010	UK	No commercial fishing allowed.
Phoenix Islands Protected Area	408,250 km^2 (157,626 mi^2)	2006	Kiribati	Permits are required for science, cultural, management, or educational studies; specimen collection; tourism operators; tourist visits. All Kiribati fishing vessels larger than 7 m have to be licensed. All fishing restricted within 12 nm of the Phoenix Islands. Purse seining restricted within 60 nm of Kanton Island.
Papahānaumokuākea MNM	362,074 km^2 (139,797 mi^2)	2006	USA	Entering the monument requires permit. Exemptions for uninterrupted passage, law enforcement, armed forces activities, emergencies response. No commercial fishing is allowed. Fishing is allowed under Native Hawaiian Use permit for sustenance at Midway Atoll.
Great Barrier Reef Marine Park	345,400 km^2 (133,360 mi^2)	1975	Australia	Zoning plans define what activities can occur in which locations. More than 33% of the GBRMP is no-take.
Northeast Atlantic high seas areas	287,311 km^2 (110,931 mi^2) (total of six HS closures)	2010	Oslo Paris Commission (OSPAR)	No regulations as of yet; however most overlap with NEAFC bottom fishing closures
Marianas Trench MNM	246,608 km^2 (95,216 mi^2)	2009	USA	Management plan in development. No commercial fishing allowed in Islands Unit of MNM.
Pacific Remote Islands MNM	225,040 km^2 (86,888 mi^2)	2009	USA	No commercial fishing allowed. USFWS permits non-commercial sport fisheries at Palmyra Atoll. NOAA manages fishing activities in the U.S. Exclusive Economic Zone.
Prince Edward Islands Marine MPA	180,000 km^2 (69,498 mi^2)	2009	South Africa	Fishing ban within 22.2 km of the Islands. Limited fishing and other activities seaward of this 22.2 km zone. Some limited fishing to monitor fish populations may be allowed within a few restricted areas.
Macquarie Island Commonwealth Marine Reserve	162,000 km^2 (62,548 mi^2)	1999	Australia	Mining and recreational fishing are not allowed anywhere in the reserve, commercial activities including commercial fishing (other than demersal trawl) requires a permit in the management zone, scientific research requires a permit in both zones, commercial transit is allowed under general approval.
Motu Motiro Hiva Marine Park	150,000 km^2 (58,000 mi^2)	2010	Chile	Designated as a no-take area.
Galapagos Marine Reserve	133,000 km^2 (51,351 mi^2)	1998	Ecuador	The reserve is split into three main zones, a multi-use zone, a limited-use zone, and a port zone. These three main zones are split further into a number of subzones. Within the limited use zones are some areas designated as non-extractive areas.

(Federal Register, Vol. 74, No.7, January 12, 2009), protecting 225,038 km^2 in the Central Tropical Pacific Ocean. It includes the US territories of Wake Island, Johnston Atoll, Palmyra Atoll and Kingman Reef, Jarvis Island, and Howland and Baker Islands (Figure 1). President George W. Bush designated it because he deemed its preservation in the interests of the US citizens, and he called for strong protection of the region, including the exclusion of commercial fishing. The Proclamation states: "The Secretaries of Commerce and the Interior shall not allow or permit any appropriation, injury, destruction, or removal of any feature of this monument except as provided for by this proclamation and shall prohibit commercial fishing within boundaries of the monument." The intention of PRIMNM was clearly to protect the natural character of the region, including fish as they function in the overall ecosystem.

The demands on MPA managers to incorporate information from diverse scientific disciplines, including oceanography, marine ecology, marine biogeochemistry, marine fisheries and conservation planning into a novel management paradigm – pelagic ecosystems – is not without significant challenges. Despite growing bodies of literature in conservation planning, marine reserve design and MPA effectiveness monitoring, very little of it specifically references managing large pelagic systems as incorporated in the Pacific Remote Islands Marine National Monument. There is also the significant challenge of dealing with the naturally dynamic nature of ocean ecosystems against a background of uncertain impacts from climate change and other oceanographic phenomenon (i.e., El Niño Southern Oscillation). These changes will affect the distributions of species, habitats and human activities (Cheung et al 2009, Halpern et al 2008, Nye et al 2010; Smith et al 2011). Management will need to be flexible and adaptive, and will require ongoing monitoring and research.

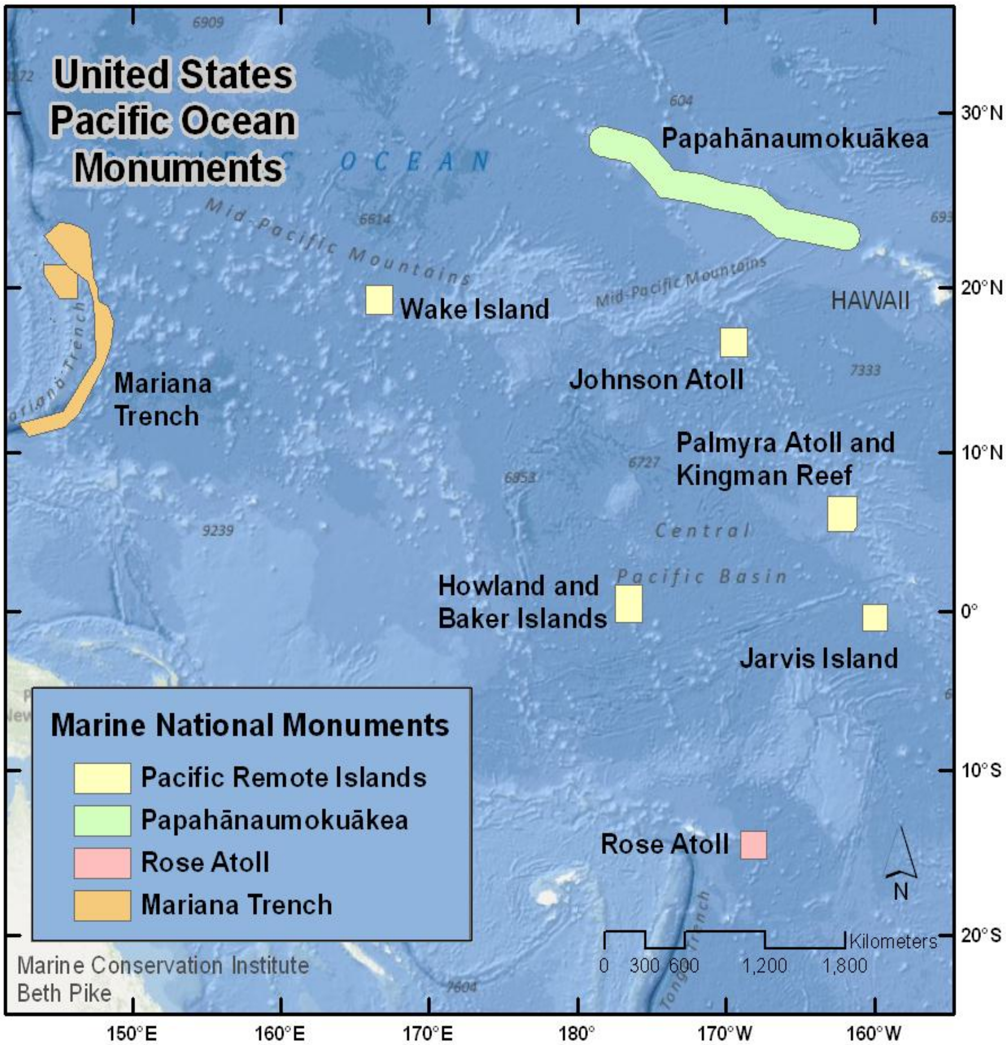


Figure 1. US Marine National Monuments in the central Pacific ocean.

Only within the last decade, following the designation of several extremely large MPAs, has it become necessary to consider how to manage protected areas in the oceanic realm. The first scientific papers on open ocean reserves date from the 1990s (Carlton and Mills 1998, Hyrenbach et al 2000).

This report is broken up into four sections. The first section examines and highlights science relevant to large, pelagic protected areas, drawing on recent reviews. Section two discusses a recent paper from the conservation planning literature (Pressey and Bottrill 2009) as a possible approach to structuring a management plan for a large pelagic MPA, highlighting relevant information about the Pacific Remote Islands Marine National Monument. In the third section we review relevant lessons from several existing large MPAs for guidance on managing MPAs, these areas include the three West Coast, US National Marine Sanctuaries (Monterey Bay, Gulf of the Farallones and Cordell Bank), the Phoenix Islands Protected Area (Kiribati), the Chagos Island Marine Reserve (United Kingdom) and the Pelagos Marine Mammal Sanctuary (Mediterranean high seas). Finally we conclude with recommendations for managing large, pelagic protected areas.

Management Context

The PRIMNM is co-managed by the Secretaries of the Interior (delegated to the USFWS) and Commerce, the National Oceanic and Atmospheric Administration (NOAA). Both executive branch agencies had existing authorities to manage natural resources in the area over which the PRIMNM was overlaid. Examples of existing authorities include the US National Wildlife Refuges that are managed by the USFWS and the NOAA jurisdiction over marine living resources and habitats in the marine environment, including those areas that overlapped with the Refuges. Due to the historical nexus of authority and jurisdiction, USFWS and NOAA have worked together for decades to manage natural resources now included in the PRIMNM.

NOAA is also responsible for the marine areas outside the PRIMNM, including managing US participation in international fishery regimes in the Pacific. Additionally, other authorities are embedded in the PRIMMN, namely the Department of Defense exercises authorities at Wake Island and Johnston Atoll, ownership and management of a portion of Palmyra Atoll is conducted in accordance with federal law by The Nature Conservancy, and the Department of

Homeland Security continues its enforcement of coastal and international interests via the US Coast Guard. In short, there is a myriad of existing authorities that were included in the PRIMNM that also contain a focus-driven set of directives within the context of the Presidential Proclamation.

Proposed Benefits of Pelagic Marine Protected Areas

A number of scientific reports over the past decades have described the benefits of marine protected areas. These reviews focus primarily on smaller, coastal MPAs rather than larger, pelagic areas, as this is historically where MPAs have been designated. Benefits from these coastal MPAs are now well documented and include increases in biomass, density, diversity, and size of individuals (Gell and Roberts 2003, Lester et al 2009), as well as seeding areas outside the MPA (Christie et al 2010). Even with this wealth of research, there has been resistance to the idea of pelagic or open ocean MPAs. This stems, in part, from conventional wisdom that suggests areas would need to be incredibly vast to achieve any similar benefits for pelagic ecosystems. Others have argued that MPA benefits can extend to pelagic areas (Game et al, 2009 is a good review), but very few pelagic areas have been designated, little research has been conducted, and most of these benefits have yet to be demonstrated (Gaines et al, 2010).

Benefits from MPAs to pelagic species have been documented. Two recent reviews have summarized some of the available literature related to the empirical and hypothetical benefits of marine reserves to highly mobile, pelagic species. Ceccarelli (2011) reviewed the literature as it applied to the Coral Sea in Australian waters and summarized the literature found in Table 2. A variety of proposed benefits exist based on modeling studies, but empirical evidence is scant to date. Likewise Davies and colleagues reviewed a number of studies and reached similar conclusions. Their report, conducted for the International Seafood Sustainability

Foundation, reviewed the conservation benefits of marine protected areas for pelagic species associated with fisheries (Davies et al 2012) concluding that,

> *"Targeted MPAs offer perhaps the greatest potential for area-based management of very highly mobile and large oceanic pelagic species. However the success of this type of closure is dependent on whether the gains are greater than the losses generated from effort displacement outside the closure and, with few evaluations of real-world examples, it is difficult to draw definitive conclusions on their effectiveness."*

Both of these reports focus on oceanic, pelagic areas without a direct link to coastal areas, and therefore did not examine the pelagic environment adjacent to the coast. This omits at least one important finding that found predator diversity hotpots consistently associated with prominent topographic features such as reef islands, shelf breaks, or seamounts (Worm et al 2003). Davies and co-authors' focus on offshore areas likely undervalues the significance of MPAs that surround oceanic islands and provide benefits to seabirds and other central place foragers (we will return to this point later). These authors highlight three possible conservation benefits from pelagic MPAs:

1) populations that spend a majority of their life history within a reserve,
2) populations whose key demographically-important periods (spawning, mating, nursing or feeding, etc.) occur within a reserve, and
3) populations that experience reduced incidental fishing impacts by removing this threat from some part of their life-history.

Conservation benefits likely decrease from the first (where fishing mortality might be totally eliminated) to the third (where only some fishing mortality will be eliminated), but all can be significant. It is relatively straight-forward to understand that if a reserve of sufficient size can include all or a substantial portion of a species' range in all or some of its life history, then even highly mobile and migratory species will benefit substantially. These areas will need to be vast to protect very large species that move long distances, but there may be benefits to individuals with smaller average home ranges, and to species with restricted ranges. Still, it is unlikely that pelagic MPAs will ever be big enough to cover the entire range of large, widely-ranging species such as tunas, some sea turtles or whales. The key factors that will determine whether closures provide benefits to marine life relates to the scale of movement relative to the size of the MPA, the amount of time within the MPA and the vulnerability outside the MPA.

Understanding the diversity of life histories in the pelagic realm will be important to understanding the potential benefits of MPAs (Claudet et al 2010). While we focus here on literature from the larger vertebrate species because these are the most often discussed with reference to MPAs that restrict fishing, there are a wide range of pelagic life histories. Many species have wide ranging larval periods, others are strong diel vertical migrators and others are long-distance commuters from nesting/breeding grounds to foraging areas. Still others target specific oceanographic features and move with currents. We do not cover the range of this diversity, but highlight studies that represent species of relevance to the PRIMNM. We do note that each of these classes of species poses a unique challenge to MPA managers, and more work needs to be done.

One example of a successful response to protection is the striped marlin, an ocean species with relatively limited dispersal. This species showed a significant and rapid increase in abundance following closure of the longline fishery in Mexico (Jensen et al 2010). This increase was thought to occur because the species spent the majority of its life history inside the closed area.

PMPAs targeting protection in places where species spend particularly vulnerable life history phases such as spawning areas, juvenile habitats or migration routes are also discussed by Davies et al (2012). For this to be an effective strategy, these areas must be clearly identified. Modeling work also supports the idea of protecting key life history phases such as juvenile stages and, to a lesser extent, spawning sites and key foraging areas (Pelletier and Magal 1996, Apostolaki et al 2002, West et al 2009).

Advances in telemetry over the past several decades have made identifying the locations of key life history phases imminently possible for a number of species (i.e., Block et al 2011) though the nature of particular habitat associations is not always clear (Jorgensen et al 2010). Many species, including tunas, are now known to be associated with seamounts and other features, and residency times can last from days to weeks (Itano and Holland 2000, Morato et al 2010). Satellite tracking of leatherback sea turtles has demonstrated not only long migrations, but also restricted migratory bottlenecks (Bailey et al 2012). A study looking at feeding grounds for blue whales and sea turtles identified these areas tied to productivity fronts (Etnoyer et al 2006). While a number of studies have demonstrated important habitats for seabirds (Louzao et al 2006, Louzao et al 2011), the nature of these aggregations and how much time animals spend in these areas is unclear, and only hints at strategies for effective PMPAs.

Field work also supports protecting targeted areas. Protection of a nesting area for leatherback sea turtles showed a positive result (Dutton et al 2005). Pichegru and colleagues (2010) demonstrated that restricting fishing for small pelagic fishes resulted in a 30% decrease in foraging effort for African penguins (a central place forager) in response to an increase in local prey density over a very short period of time (months). The authors demonstrated an immediate benefit of the MPA by reducing competition between purse-seine fisheries and penguins on their foraging grounds (i.e., a successful "forage" reserve).

Perhaps the most certain conservation benefit of a pelagic MPA is the reduction in direct impact to species either from target fishing or from incidental bycatch. However this depends on whether or not increased effort outside of the reserve makes up for any loss of effort in the reserve. In this case assuming the overall mortality of a target species remains unchanged because effort increases outside the reserve, it will be difficult to assess whether or not an MPA leads to a conservation value for a target species. If discrete areas of high bycatch can be closed, and several such areas have been identified in many areas of the world (Lewison et al 2004, Amande et al 2011), then stopping fishing in these areas can have significant conservation benefits. There is much uncertainty about the scale of movement and the size and location of MPAs for most pelagic species. In general the success of any MPA will be strongly influenced by management of pelagic fishing effort surrounding MPAs. While MPAs can provide added protection, in many cases they are not substitutes for well-managed fisheries.

Protected areas also offer fishery benefits by providing spillover of adult fishes from the reserve into adjacent fishing grounds (Roberts et al 2001, Goñi et al 2008), and/or increased reproductive potential that seeds surrounding fishing grounds (Christie et al 2010). MPAs are also scientific reference areas that supply important information on population dynamics in the absence of fishing. Protecting pelagic ecosystems from fishing may also benefit trophic and indirect interactions such as seabird-tuna foraging interactions. While these interactions are important to seabirds (Ashmole and Ashmole 1967, Harrison and Seki 1987, Spear et al 2007), they are not well understood in the central Pacific (Maxwell and Morgan in press).

Table 2. Summary of studies predicting marine reserve benefits for pelagic and migratory species, using a variety of methods (modified from Ceccarelli 2011).

Source (study description)	Location	Species	Summary of findings
Lauck et al (1998, modeling)	Hypothetical	Hypothetical	Marine reserves need to include up to 50% of a population or home range in order to protect a species from overfishing.
Roberts and Sargant (2002, modeling)	Hypothetical	Hypothetical migratory fish	Protecting important aggregation areas has a disproportionate effect on entire populations of highly mobile and migratory species.
Baum et al (2003, modeling)	Northwest Atlantic	Sharks	Priority areas for shark conservation are highlighted. Population benefits for sharks with fishing closures of different areas are modeled. Marine reserves coupled with reductions in fishing effort have positive effects on sharks and other large pelagic predators.
Gell and Roberts (2003, review)	Global	All species	Highlights reversal of notion that mobile species cannot be protected by marine reserves. Even for highly mobile species, a portion of the population may remain within a small home range. Protecting migration bottlenecks, nurseries, spawning or feeding aggregation sites can benefit even highly migratory species.
Worm et al (2003, modeling)	Northwest Atlantic	Pelagic species, primarily predators	Identify pelagic diversity hot spots associated with productivity and habitat features. Protecting hot spots from fishing has large benefits for pelagic populations.
Willis et al (2003, empirical, modeling)	Northern New Zealand	Snapper (*Pagrus auratus*)	Density and size of snapper increase inside marine reserves, despite its high mobility.
Hooker and Gerber (2004, discussion paper)	Global	Predators and megafauna	Marine reserves are beneficial for protecting predators and other megafauna (e.g., cetaceans, seabirds). Present tools and approaches for enhancing marine reserve effectiveness.
Micheli et al (2004, meta-analysis)	Global	All species	Highly mobile species benefit from marine reserve protection.
Palumbi (2004, review)	Global	All species	Is ambivalent about the value of marine reserves for migratory pelagic species but states that “If fishing effort is not displaced, then the impact of reserves on highly migratory species is similar to the effect of decreasing fishing effort by the same percentage as the percent area dedicated to reserves.”
Hyrenbach et al (2006, empirical)	Central California	Black-footed albatross (*Phoebastria nigripes*)	Advocates protecting albatross foraging grounds, even though these comprise only a part of their overall range.

Louzao et al (2006, empirical, modeling)	Balearic Islands	Balearic shearwater (*Puffinus mauretanicus)*	Marine zoning measures can benefit populations of far-ranging seabirds by extending protective measures beyond their breeding colonies.
Alpine and Hobday (2007, modeling)	Eastern Australia	Pelagic fisheries or species of conservation concern	Quantified the area requirements of protected area networks to protect pelagic species (target and non-target). Area requirements ranged from 7 to 26% of the region for adequate protection of pelagic species.
Pichegru et al (2009, empirical)	Benguela upwelling region	Cape gannets (*Morus capensis*) & African penguins (*Spheniscus demersus*)	Measured overlap between seabird feeding and commercial fishing grounds. Marine reserves in foraging hot spots may increase the birds' breeding success.
Beare et al (2010, empirical)	North Sea	North Sea gadoids	Large North Sea area unfished during World War II. Large benefits to exploited fish, including migratory species. Older fish benefit fastest and in greatest proportion
Claudet et al (2010, meta-analysis)	European marine reserves	Fish	Density and size of species targeted by fisheries increase inside marine reserves, even highly mobile species.
De Juan and Lleonart (2010, modeling)	Mediterranean	All pelagic species	Identifies habitats critical to pelagic species in the Mediterranean. Advocates for marine reserve protection of pelagic species.
Jensen et al (2010, empirical)	Baja California	Striped marlin (*Kajikia audax*)	Temporary closures of Mexico's EEZ to long-lining (1977–1980, 1984–1985) caused increase in striped marlin, despite its range extending outside the closed area.
Koldewey et al (2010, review)	Global	All species	Increasing evidence that even partial protection of highly mobile and migratory species is beneficial. "Highly migratory" species may be based on long-range movements of a few individuals, while most of the population remains within a home range.
Gormley et al (2012, empirical)	New Zealand	Hector's dolphin *Cephalorhynchus hectori*	Photo identification work over 21 years showed survival improved significantly in a closed area (the Banks Peninsula Marine Mammal Sanctuary) that banned gillnets.
Sibert et al (2012, modeling)	Western Central Pacific Ocean	Bigeye tuna *Thunnus obesus*	Zoning fishing effort and closing critical life history areas (spawning grounds) to longline fishing provided best long term population recovery.
Maxwell and Morgan (in press, review)	Global, but focused on Central Pacific Ocean	Seabirds	MPAs which restrict fishing around seabird colonies may indirectly benefit seabirds by improving the positive foraging interactions between seabirds and tunas.

Systematic Conservation Planning in the Pelagic Realm

Managing PMPAs involves the overseeing of large areas, dynamic processes (e.g., fronts or eddies) and highly migratory species that can move thousands of kilometers. This adds significant challenges to 'traditional' MPAs focused on enhancement or protection of nearshore ecosystems having species with relatively restricted home ranges (move on the order of hundreds of kilometers or less) and incorporate processes which operate on much smaller scales (Vandeperre et al 2011, Hargreaves-Allen et al 2011, Cote et al 2001, Claudet et al 2008). Despite this, there is no comprehensive knowledge of how the challenges and benefits of MPAs in pelagic systems differs from coastal ecosystems, or what are the most effective means of managing PMPAs. Nonetheless, the extent and number of PMPAs are increasing across the globe (Table 1). PMPAs are similar in some ways to traditional coastal MPAs, but the challenges to effectively manage these areas can be markedly different, particularly enforcement, monitoring and management. Despite the increasing prevalence of PMPAs, few have been in existence for more than a few years (Table 1). As a result, there is very little institutional knowledge about how to manage PMPAs on the ground.

A number of strategies for large-scale conservation planning may be applicable to PMPAs (Leslie 2005). Perhaps the most notable is the systematic conservation planning process defined by Margules and Pressey (2000) and refined and expanded by Pressey and Bottrill (2009). In this strategy they detail eleven steps to both effective planning ***and*** management in spatial conservation, including MPAs. The steps include: (1) scoping and costing the planning process; (2) identifying and involving stakeholders; (3) describing the context for conservation areas; (4) identifying conservation goals; (5) collecting data on socio-economic variables and threats; (6) collecting data on biodiversity and natural features; (7) setting conservation objectives; (8) reviewing current achievement of objectives; (9) selecting additional conservation areas; (10) applying conservation actions to selected areas; and, (11) maintaining and monitoring conservation areas (Pressey and Bottrill 2009) (see Figure 1 for detailed descriptions of each stage). The planning approach they outline contains the common threads found in other planning frameworks, and includes additional components to counter common bottlenecks and points of contention frequently encountered in planning processes. It has been successfully applied in a number of terrestrial and marine planning processes including the Great Barrier Reef (Pressey et al 2003), the South African Cape Floristic Region (Fernandes et al 2005) and the California Marine Life Protection Act (Airamé et al 2003).

Ban and colleagues (in preparation), are applying this framework to open ocean conservation areas to highlight the overarching challenges encountered there, and how the challenges differ between benthic and pelagic planning, and between High Seas and national jurisdiction planning processes. How the various components have been implemented in PMPAs or networks of PMPAs, however, has not been systematically studied. Reviewing the specific actions and strategies managers are employing in PMPA management and planning - from the initial implementation stages to enforcement - can provide important lessons and concrete recommendations for current and future PMPA managers.

Here we outline considerations for PMPAs for each of the relevant conservation planning steps, giving concrete examples of ways to manage these vast areas such as the PRIMNM efficiently and effectively, even in the face of limited resources. We focus specifically on post-designation management, assuming that the area under consideration is undergoing a planning process as the PRIMNM is; thus we focus our discussion on Steps 5-11 ("collecting data on socio-economic variables and threats" through "maintaining and monitoring conservation areas"). We outline several case studies of PMPAs, highlighting the successes and shortcomings of these areas and how these lessons can be applied to other PMPAs. This information was compiled through an extensive literature review of scientific and grey literature, management plans and interviews with managers of existing PMPAs and individuals with key roles in the implementation or management process. We hope that this will provide a framework for the PRIMNM and other PMPA managers that can be built on as more areas are designated.

Scoping and costing the planning process; Identifying and involving stakeholders; Describing the context for conservation areas; and, Identifying conservation goals (Steps 1-4; Pressey and Bottrill)

The focus of our discussion is on management plan development post-designation. Steps 1-4 from Pressey and Bottrill (2009) will generally have already occurred (even if just partially) as part of the pre-designation process, and extensive literature already exists on scoping and costing the process and involvement of stakeholders (Gleason et al 2010, Lowry et al 2009, Klein et al 2008, Lundquist and Granek 2005, Suman et al 1999). These steps are unlikely to differ between pelagic MPAs versus coastal MPAs or terrestrial protected areas. Scoping and costing of the planning process for PMPAs may, however, be more expensive if there are more stakeholders ranging over a larger area in PMPAs (for example increased travel costs associated with bring stakeholders from far away), but the amount spent per unit area is lower in comparison to smaller MPAs (McCrea-Strub et al 2010). Similarly, involvement of stakeholders in PMPAs may be more challenging and costly because they are more widespread.

Pressey and Botrill (2009) describe the context for conservation areas as "understanding the social, economic and cultural conditions in the planning region and how these shape constraints or opportunities for conservation…

[including] understanding of which threats can be addressed spatially." The context for conservation areas will likely be completed upon designation, but if this was not done well it may need to be revisited if a negative discourse exists between stakeholders and government officials. Similarly if there is a mismatch between management authority and their ability to address or mitigate threats, further work will be necessary. Refining and revisiting the context in which an area has been designated – and the goals that follow from it – are built-in to the post-designation steps. Conservation goals are the broad statements that describe the reason for creating a protected area, usually defined as part of the designation process for the protected area. For example, the Executive Order establishing the Pacific Remote Islands Marine National Monument states that the purpose of the area is to "preserve the marine environment around the islands of Wake, Baker, Howland, and Jarvis Islands, Johnston Atoll, Kingman Reef, and Palmyra Atoll for the care and management of the historic and scientific objects therein." These conservation goals, though often broad, are critical for creating a common, united vision among diverse stakeholders (Pressey and Botrill 2009). Moreover, specific objectives and the management actions follow directly from these broad goals.

Sometimes steps 1-4 are skipped. MPAs designated via a top-down process don't always get stakeholders' input (Weible et al 2004). In these cases it may be useful to revisit these steps after designation. With this in mind, we move on to the steps that are conducted post-designation of PMPAs.

Collecting data on socio-economic variables and threats, and biodiversity and natural features (Steps 5 & 6; Pressey and Bottrill)

The large and dynamic nature of PMPAs represents some unique challenges for PMPAs. Threats in the open ocean (e.g., pollution, fishing and shipping) are often more diffuse than in coastal ecosystems making them more difficult to monitor. Likewise pelagic species typically undergo larger migrations, move greater distances and often track dynamic or ephemeral oceanographic processes (Game et al 2009). Monitoring threats and species relevant to static boundaries is likely to be difficult and provide a challenge to managers tasked with understanding the effectiveness of PMPAs once they have been designated.

Assessing existing information and addressing information gaps is one of the first steps in developing a management plan. For the PRIMNM an initial assessment was conducted during an expert workshop (Morgan et al 2010). In this case experts gathered and addressed three ecosystems – coral reefs, deep sea and pelagic. This group also discussed the nature and significance of human activities to the region. Other methodologies that could be applied to address knowledge gaps include literature reviews and stakeholder surveys and meetings.

Relevant baseline data on socio-economic and biological data variables is critical. Baseline surveys at the time an MPA is designated provide a 'snapshot' that can be used to evaluate future changes (Puotinen 1994). This applies equally to all MPAs, but some considerations, such as threats outside of the PMPA, are of greater importance, as wide-ranging, pelagic animals may spend significant portions of their life outside the PMPA exposed to these threats. Synthesizing these data into products relevant to managers will aid making informed and achievable objectives and targets (e.g., increasing populations to historical levels, maintaining current ecosystem integrity). These data are important for assessing the MPA's impacts on marine ecosystems (Edgar et al 2004, Dayton et al 2000). The following data types are particularly important to PMPAs such as PRIMNM.

1. Level of human uses and threats. Most MPAs are implemented to mitigate human threats to the marine ecosystem (Boersma and Parrish 1999, Fox et al 2011). Baseline understanding of threats shows how threat levels change over time, and affect biological variables such as population demographics (Gormley et al 2012). Relevant threats include those that impacted the PMPA in the past but are

restricted as part of MPA designation, as well as those that are still permitted (Claudet and Guidetti 2010). Examples of pelagic ecosystem threats that need to be considered for the PRIMNM include invasive species introduction, shipping, unauthorized fishing and pollution (including marine debris). For PMPAs in particular, threats must be considered beyond boundaries as well, given the highly dynamic conditions of pelagic ecosystems. Understanding the extent of human activities outside MPA boundaries is critical for gauging success or failure of the PRIMNM.

2. Assessment of key species or habitats. Many MPAs are created to protect certain species, assemblages of species or habitats deemed ecologically, economically or culturally valuable (Agardy 1994). A baseline assessment of population levels of these species or habitats – or relevant proxies for them – gives a baseline starting point for MPA management and effectiveness into the future. A number of authors have recommended Before-After-Control-Impact (BACI) designs to assess MPAs (Osenberg et al 2011). The BACI approach is a method for measuring the potential impact of an action on the ecology of an area. Such affects can be analyzed by measuring conditions before a planned activity and then comparing the findings to those conditions measured after the activity occurs. If it is an existing activity, it may not be possible to measure before conditions. In these cases, studies often make use of a control area (no activity) to compare those data to an affected area. Many species that use PMPAs, however, are highly mobile so their population levels must be considered across a seascape level, not just within the boundaries of the PMPA, and therefore local area paired studies become very difficult to design and execute. In the PRIMNM, monitoring breeding seabirds that have high site fidelity can give a local assessment of their population levels, but monitoring cetaceans and tunas that are highly mobile and may only use the PMPA for short intervals, will not. To understand the value of a particular PMPA to a particular species it will be important to know the movements of these species across the boundaries of the protected area. Couching PMPA level assessments in

larger-scale assessments of population trends (e.g., basin-scale assessments like those conducted as part of NOAA Fisheries stock assessments), is necessary to accurately understand the potential future impact of PMPAs on mobile populations.

3. Oceanographic context. A baseline understanding of a PMPA's oceanographic context is particularly important because pelagic environments are dynamic and species such as seabirds are highly influenced by oceanographic changes (Schreiber and Schreiber 1984, Schreiber 1994). Knowing how physical variables affect species' movements helps managers predict their movements as climates change. These data may include long-term climatologies of oceanographic variables, including years that are heavily influenced by El Niño-Southern Oscillation events (Cobb et al 2003). Baseline knowledge of variables such as sea surface temperature, upwelling, and primary productivity can be coupled with future movements and demographics of key species to link changes in the oceanographic environment (Hobday et al 2006). These data can also help predict future climate scenarios and management plans can be tailored to reflect that knowledge (Hobday et al 2011). Oceanographic components need to be monitored over the course of the entire year (and ideally several years) in order to establish a relevant baseline, keeping in mind that long-scale climatic shifts may further influence the system (i.e., Pacific Decadal Oscillation, regime shifts)(Mantua et al 2002). This kind of monitoring can be done from ships or via remote sensing, which may be a more cost-effective option for the PRIMNM.

Setting conservation objectives (Step 7; Pressey and Bottrill)

The effectiveness and successful management of an MPA begins in the early stages of designation and management plan development. As reviewed in, *How is Your MPA doing? A Guidebook of Natural and Social Indicators for Evaluating Marine Protected Area Management Effectiveness* (Pomeroy et al 2004), clear articulation of the goals and objectives of the MPA (i.e., what the MPA is being managed for) can guide managers in both long-term and day-to-day decision-making. Effective MPAs must have clearly articulated goals and measurable objectives (Notarbartolo-di-Sciara et al 2008, Hooker et al 2011, Hockings et al 2000, Pomeroy et al 2004, Thorpe et al 2011, Sowman et al 2011).

The dynamic nature of oceanographic features within PMPAs necessitates additional considerations for managers. Management objectives need to take into account the ability of PMPAs to mitigate threats that exist beyond PMPA borders to be effective for wide-ranging species or large-scale processes (Ban et al 2010, Game et al 2009). Identifying these threats can be a starting point for interagency and international cooperation regarding threats outside PMPA boundaries. To do this, the limitations of PMPAs can be explicitly stated in the management objectives through statements such as, "This management objective aims to mitigate 85% of the threats facing seabird species in the PRIMNM to include affects from climate change, ocean acidification, marine debris, invasive species introductions, and unauthorized fishing activities."

Targets will rarely be able to be explicitly quantified; rather in an example such as the one above, quantifiable targets could be determined using expert opinion. For example, in the Great Barrier Reef Marine Park, researchers used the Delphi technique of soliciting expert opinion on the risks facing dugongs in the park, and quantifying the impacts explicitly and spatially, finding that 96% of the habitat was well-protected, and using the findings to prioritize risk management in the remaining areas (Grech and Marsh 2008). Knowing this helps managers set realistic objectives for evaluating PMPA effectiveness.

Reviewing current achievement of objectives (Step 8; Pressey and Bottrill)

Pressey and Botrill (2009) largely discuss this step in the context of planning new protected areas; during this stage, managers review other conservation measures within the region (i.e., other MPAs, regulations, etc.) and how the objectives of these measures may overlap with those of the conservation planning process being undertaken. This is the point during which managers of existing PMPAs may determine if PMPA objectives are being met, and to coordinate with additional agencies as needed to meet the objectives. It allows them to identify agencies and local groups to partner with to manage threats.

Determining which groups to involve in the management process begins with reviewing the major threats in the PMPA, both within and beyond its boundaries. Identifying the agencies with jurisdictions related to these threats is necessary for carrying out conservation actions and for monitoring (see Step 10 below), as well as engaging stakeholders to create effective management structures (Leslie 2005).

Selecting additional conservation areas or determining priorities within an existing protected area (Step 9; Pressey and Bottrill)

Determining priorities when mandates are conflicting

Even with well-defined goals, objectives and targets, management actions can be difficult to prioritize and implement, particularly when there are conflicts among management objectives. One way of managing for conflicting objectives is to create a hierarchy of management objectives, detailing how conflicting management objectives should be handled by identifying conflicts *a priori* (Gerber et al 2011). For example, in the PRIMNM, management objectives will likely dictate the preservation of both seabirds and pelagic fishes. These two objectives may conflict, making some form of a pre-determined hierarchy particularly important. For example, a proposed management action that greatly increases the seabird population might also reduce the fish population. If the pre-determined hierarchy holds that protection of seabirds is the primary goal as long as pelagic fish populations do not fall below a certain level, this can determine whether to take a management action.

This kind of pre-structured decision-making can aid in both reducing conflict (and its financial costs) and speeding management action when ecological resources are at risk. Identifying potentially conflicting objectives in advance can help management plans for multiple agencies and resource uses (also see Threat Monitoring below, Costello et al 2008, Costello et al 2010, Gaines et al 2010). Gerber and colleagues (2011) state that: "Such an approach will require (1) long-term time series data to understand ecological interactions over space and time, and (2) an adaptive management framework for understanding the relevance of biological change to inform effective policy change." This kind of approach may be particularly applicable for PMPAs because so little is known about pelagic systems and how species and ecosystems interact (Game et al 2009).

Biological and Enforcement Priorities

Management and enforcement of any MPA requires priority setting, but because of their large size PMPAs managers will need to formalize this step. For a PMPA to be successful, actions must be linked to budgets (Pressey and Botrill 2009). Ideally, all areas would be fully monitored and enforced, however this is rarely logistically or financially possible. As a result, managers need to determine where and when management resources and enforcement efforts are needed most, and concentrate efforts in those times and places. Creating a framework for conservation action is about more than determining how an area will be enforced; it involves linking actions, budgets and agencies together by creating linked systems of prioritization: (1) defining biological priorities and (2) creating enforcement priorities.

Biological Priorities: Establishing biological priorities means determining when and where the key or most vulnerable biological components exist, and when and where these components are most vulnerable. Biological prioritization is built from the baseline data collected in Steps 5 and 6, particularly:

1. Key species and habitats: In this step, baseline data are compiled to determine where key habitats exist and/or where key species are concentrated, as well as where gaps exist in our knowledge. This may include actions such as compiling data on deep water coral habitats, using climatologies of sea surface temperature to determine where fronts or eddies known to concentrate vulnerable species exist, or conducting home range analyses using tracking or survey data from top predators. Predictive modeling or other analytical tools may be used to further understand species ranges or the distribution of key habitats (Redfern et al 2006). These analyses can identify key habitats for management actions and gaps in scientific knowledge.

2. Human impacts: Determining the extent of existing human impacts by compiling existing information both spatially and temporally is also important. This may include data on climate change, shipping traffic, fishing effort, bycatch or other threats, and may be supplemented by the use of predictive models. This will determine where threats are greatest in space and time, and where additional data and/or collaboration with key agencies are needed.

3. Integration of biological and impact data: Integrating the species and habitat data with the human impact data will determine where regions of the highest threat and ecological significance occur. Particularly important in this step is to consider where these areas occur *temporally* as well as spatially. Pelagic species often have seasonal movements, so impacts may be seasonal as well. Illegal fishing, for example, may not always coincide with peaks in fish abundance. Fishermen may be more likely to fish illegally during times of the year when they need income the most (i.e., during holidays), and these times may not be the most biologically productive times of the year. The temporal component is particularly important for determining enforcement priorities detailed below. Understanding the spatiotemporal patterns of threats is a prelude to conservation actions that can target illegal activity before it occurs.

Enforcement Priorities: Enforcement priorities stem from establishing biological priorities into actions for enforcement agencies. Enforcement agencies often are charged with a myriad of activities to monitor and enforce, and a reality of modern governing structures is that all areas cannot be adequately enforced. The US Coast Guard exemplifies an agency with multiple mandates in homeland security, fisheries and many other areas. Enforcement officers will often concentrate efforts on well-articulated problems for which they feel they will have an impact (Brett Hartl, personal communication). Providing well-articulated priorities for enforcement is essential for MPA managers.

1. Translating biological priorities into enforcement priorities: Biological priorities do not translate directly into enforcement priorities. For example, a map detailing the 25, 50, 75 and 100% contours of use for a protected species would not be adequate to an enforcement agent to know where to concentrate effort. Does the 50% contour or the 25% contour contain the most critical habitat? What if the 25% contour includes 50,000 km^2 of pelagic habitat; can that area be further prioritized? Does the same apply for September as for March or are there months or season when enforcement more critical than others? Adequate enforcement priorities involves distilling spatial and temporal biological priorities into maps and tables which clearly detail within an MPA the places and times where enforcement is most critical – *and* includes a hierarchy of priorities among the key sites. This ensures the maximum enforcement gain, even if enforcement agencies are overburdened with other mandates and can spend only limited effort on MPAs. For example, for PRIMNM, the target may be to give enforcement agencies a map of ten areas of key enforcement, with associated information on the months when these areas are most heavily used by key species are most vulnerable to human impacts. Accompanying this information, they may also provide a list of places – in order of importance – that are most critical to enforce during the different months of the year. This will allow for enforcement agencies to apply resources

when they are available, and also conduct enforcement missions opportunistically as part of other non-related work.

2. Determining effective enforcement measures: Different species and habitats will require different protections and enforcement measures. For example, protecting seabirds from bycatch in longline fisheries may require enforcing streamer lines on fishing vessels from the time they leave port cities, while protecting deep-sea corals from fishing impacts may require ensuring bottom trawling bans are enforced within a PMPA's boundaries. Highlighting the most effective enforcement measures and prioritizing among the measures, to the extent possible for different biological components, will allow enforcement agencies to determine appropriate conservation actions. For example, boat-based enforcement targeting illegal fishing in a sensitive area may be critical to reduce future infractions (95%), while fly-overs of a less sensitive area, followed by informal contact of offending vessels may be enough to reduce infractions to a level (say 50%) that will not adversely affect an area. Including information on effective enforcement measures (and a priority structure in which they should be used) in conjunction with enforcement priorities detailed above will aid effective management.

To further leverage its limited air and sea assets, the Coast Guard incorporates biological oceanography into enforcement planning. Because response time is a critical factor in intercepting and documenting illegal activity within the vast Pacific region, Coast Guard tries to place its air and sea assets in optimal locations where they are most likely to encounter fishing activity. A few years ago, the Coast Guard began using SeaStar, commercial oceanographic mapping software that combines remote sensing data, target species biology, and computer algorithms to identify potential fishing hotspots for US and foreign commercial fishing fleets. By using this software, Coast Guard can anticipate where they are likely to find the fish, and therefore where they are most likely to encounter fishing activity, both legal and illegal.

Applying conservation actions to selected areas (Step 10; Pressey and Bottrill)

Conservation actions span a myriad of activities, from implementing fishing regulations to reducing pollution discharge to creating opportunities for local livelihoods. Thus, conservation activities span biological and social sciences, and there is extensive literature on how to apply conservation action towards effective management in these realms (Lundquist and Granek 2005, Leslie 2005, Pollnac et al 2010, Christie and White 2007). While enforcement is an issue for all MPAs (Samoilys et al 2007, Walmasley and White 2003, Byers and Noonberg 2007), it is one of the limiting factors cited for managing PMPAs in particular (Kaplan et al 2010). Enforcing PMPAs will be challenging, given the large and often remote area to be monitored and the cost of reaching these areas, either by boat or aircraft. The larger an MPA is, the more effective it will be, even with limited enforcement (Kritzer 2004, Le Quesne 2009), because edge effects (encroachment along the "line" by humans) are less problematic for large areas than smaller ones, because larger areas have greater center to edge ratios, and because nearly all problems in MPAs enter through the edges. Still, cost-effective methods for enforcement and monitoring are important for the long-term viability of a PMPA. Below we focus on specific techniques for cost-effective monitoring.

Participatory Enforcement

One way to enhance enforcement is through engaging users and stakeholders. This concept of "participatory monitoring" is one means of extending enforcement responsibilities to resource users (Danielsen et al 2009, Aswani and Weiant 2004, Fox et al 2011). Involving PMPA users and stakeholders in the surveillance and enforcement process can help increase capacity in an MPA, inform users about the regulations in the PMPA, increase public perception of legitimacy of the regulations and build collective understanding of enforcement needs. For large regions, such as PMPAs, participatory monitoring can enlist the support of ocean voyagers with little cost to the agency, thereby creating a more cost-effective structure for enforcement.

Peer reporting is one example of participatory monitoring already being carried out within an existing PMPA. The Phoenix Islands Protected Area (PIPA) requires that boats report to multiple agencies (1) when they enter the MPA and (2) whenever they see other vessels. This allows enforcement agencies to both keep track of vessels and know which ones are following regulations by pairing boat sightings. This method is particularly useful in remote PMPAs as a cost-effective means of patrolling because it does not require government ship time. Moreover, in remote areas the potential for infractions is high because the chance of encounter by government vessels is low. Participatory monitoring increases the number of 'eyes on the water' and allows government agencies to apply vessel resources only where and when they are most needed. Certainly trust needs to be established with various stakeholders to gain their support, but strong engagement with communities accessing the protected area provides many benefits to managers (Lundquist and Granek 2005).

Enforcement Partnerships

A number of innovation approaches can aid in the enforcement of the PRIMNM. In the last several years the US Coast Guard has started using partnerships with the US Navy and foreign national fishery enforcement authorities as "force multipliers" to improve its maritime domain awareness. The US Coast Guard currently has "shiprider" agreements with the US Navy, whereby Coast Guard Liaison Officers (CGLOs) are placed on board a Navy vessel transiting the Pacific areas. The CG officer can utilize the Navy vessel as an observation platform (with enhanced surveillance technology) to complement data provided by the US Coast Guard operations center to track fishing vessel activity. The US Coast Guard and Navy are currently working on an arrangement that would allow US Coast Guard law enforcement boarding teams to travel on Navy ships, which would allow US Coast Guard to not only document illegally activity, but to actually interdict vessels. The agreement is awaiting approval by the US Coast Guard and Department of Defense.

The US Coast Guard also has shiprider agreements with six Pacific Island Nations that border the EEZ, allowing the seven nations (USA, Kiribati, Cook Islands, Marshall Islands, Micronesia, Palau, Tonga plus two more to be finalized soon i.e., Tuvalu and Nauru) to conduct joint enforcement exercises. During a typical patrol, a US Coast Guard cutter will carry a foreign law enforcement official, making the US Coast Guard cutter an extension of the foreign nation's sovereign authority to enforce laws within its EEZ. During these bilateral patrols, the US Coast Guard also has access to South Pacific Forum Fisheries Agency (FFA) VMS inside foreign EEZs. In the case of Kiribati or other nations that share an EEZ boundary with the US, this access provides the Coast Guard and NOAA with real-time visibility of fishing vessel activity on both sides of the US border. These bilateral exercises are vital to providing additional visibility into the maritime domain, but are infrequent.

Measures to Avoid MPAs

In some instances, the easiest way to prevent unwanted human activities is to make it easier for people to avoid a PMPA because if they do not enter a PMPA, they cannot violate MPA regulations. Below we give examples of how mandatory vessel monitoring systems (VMS) and International Maritime Organization (IMO) designations can work in existing PMPAs.

In countries where VMS systems are mandatory such as Peru, VMS data on vessel use of MPAs can be used to tailor management over time, which can be used to determine more targeted patrolling. Papahānaumokuākea MNM has been designated as a Particularly Sensitive Sea Area (PSSA) by the IMO. A PSSA "is an area that needs special protection through action by IMO because of its significance for recognized ecological, socio-economic or scientific reasons and which may be vulnerable to damage by international maritime activities" (IMO Resolution A.982(24)). To enter Papahānaumokuākea MNM, vessels must request permission to pass through the Monument. The number of vessels in the monument has dropped precipitously, presumably because requesting permission requires more effort than simply avoiding the PSSA (A. Wilhelm, pers. comm.).

The success of measures to reduce entry into a PMPA relies on several factors. First, the chance of both being caught and prosecuted for violating the regulation (avoiding the PSSA or traversing the PMPA without VMS) must be high enough to make compliance worthwhile. Second, the size of the MPA and its location is also important. For VMS requirements, the PMPA must be large enough that purchasing the VMS is preferable to traveling around it. For avoiding the PSSA, the shape, location and size of the MPA must be such that traveling around the PMPA is feasible enough to justify avoid it. These kinds of cost-benefit considerations are important for promoting compliance of PMPAs. Penalties for violators must also be significant. NOAA's National Marine Sanctuary program has an asset forfeiture program (authorized in the Sanctuaries Act 1972), which provides funding to the program and is one model to explore for the Monument (Sanctuaries Enforcement Asset Forfeiture Fund). Similarly the Magnuson-Stevens Act (2005) provides for funds from fishing violations to be used to assist with management objectives. According to the Act, "In the case of violations by foreign vessels occurring within the exclusive economic zones off Midway Atoll, Johnston Atoll, Kingman Reef, Palmyra Atoll, Jarvis, Howland, Baker, and Wake Islands, amounts received by the Secretary attributable to fines and penalties imposed under this Act, shall be deposited into the Western Pacific Sustainable Fisheries Fund ..." NOAA could explore the possibility of using these funds to help monitor fishing in the remote islands regions.

Maintaining and monitoring conservation areas (Step 11; Pressey and Bottrill)

To evaluate PMPA effectiveness and maintain or improve a site requires a comprehensive monitoring program designed to track human activities, threats, indicator species and habitats. Given that doing all of this is rarely financially, logistically or politically feasible, managers need to develop indicators to guide MPA management in an iterative, adaptive framework (Pomeroy et al 2000). There is also a need to tie monitoring plans to management actions. Selecting indicators and appropriate targets to monitor that will be informative to managers is not always straight-forward. Here we discuss several tiers of increasingly sophisticated monitoring to help assess priorities for data collection.

Given the paucity of experience with managing PMPAs and the difficulties of monitoring dynamic pelagic ecosystems and highly mobile species, we offer a tiered approach to determining the scientific components to incorporate in monitoring strategies. Beginning with the first tier and progressing down the tiers as resources become available should facilitate PMPA management from the beginning. This only improves with increasing resolution as more data layers are added to the picture.

Threat monitoring: At the simplest and most basic level, MPA managers need to understand human pressures on the MPA. If financial resources are so constrained as to not permit the monitoring of marine life and the biological integrity of the PMPA, then one starting point for managers is monitoring human activities. This lowest level of monitoring can help identify potential threats, but will not provide an understanding of how marine life is responding within the MPA. Most areas are designated to protect an ecosystem or species from current or future threats including living or nonliving resource extraction, pollution and habitat damage from human activities (Boersma and Parrish 1999, Agardy 2000, Fox et al 2011).

Threat assessment and monitoring provides a means of priority setting and an initial framework for management, but will not provide managers with information about the effectiveness of their actions.

Monitoring the extent of these threats will be a rough approximation of MPA effectiveness, but without matching baseline data it will be difficult to understand the level of impact. Ideally the two (baseline monitoring of marine life and threat monitoring) will be integrated. Following the suggestion of Sparks et al (2011), we suggest monitoring human activities should be the top priority, as understanding which activities pose the greatest threat and how they change through time allows managers to decide how to allocate scarce resources (e.g., enforcement, outreach, education, etc.) to protect the ecological integrity of the system. Threat assessment can also highlight needed baseline data to better quantify threats and their impacts on indicator species and habitats (Puotinen 1994). The most significant threats to monitor in the PRIMNM are illegal fishing, vessel traffic, abandoned vessels and groundings.

Baseline science for prioritizing management actions: As suggested above, establishing a baseline for the species and habitats found in a PMPA is a necessary step to evaluate effectiveness. Ideally it would be a mandatory part of the management. Collecting new data on indicator species and habitats, monitoring human uses and threats, and then assimilating these data with existing biological and human use data are all components of this baseline evaluation. Managers need baseline assessments and monitoring to determine when and where to focus management efforts and to create enforcement strategies. A number of relevant research programs and models exist for the PRIMNM (Morgan et al 2010) including the coral reef and nearshore monitoring that is conducted by the Coral Reef Ecosystem Division (http://www.pifsc.noaa.gov/cred/). The Pacific Islands Fisheries Science Center leads cetacean monitoring in the Pacific Islands and could look for opportunities to expand its Cetacean Ecosystem Assessment Surveys to the PRIMNM (http://www.pifsc.noaa.gov/psd) to help better characterize the pelagic ecosystem. Additionally the National Marine Sanctuary program has developed a simple to use, systematic approach to assessing their diverse sites, and these system wide condition reports (http://sanctuaries.noaa.gov/science/condition/) could be an appropriate model for the multiple sites within the PRIMNM.

Demographic responses and complex ecosystem interactions: Understanding demographic responses of key species as well as more complex ecosystem responses and interactions often takes long-term monitoring programs and extensive analytical knowledge and techniques. Understanding how species and habitats respond to management actions is critical to reaching management objectives (Gerber et al 2011). Process studies conducted on species and habitats in the PMPA will likely need to be funded by research institutions outside of the management structure of the protected area. Collaborating with research teams will be the best way to encourage these types of studies, because they often require significant commitments of time and resources. Ultimately understanding demographic responses and teasing apart complex ecosystem interactions will be the only way to evaluate the effectiveness of the MPA on maintaining or recovering marine life populations.

Ongoing Monitoring and Data Collection

In addition to establishing baseline conditions it is necessary to collect monitoring data. Even if only opportunistic collection efforts are likely, managers should take full advantage of them. Opportunistic data, such as data collected via ships of opportunity (e.g., in the PRIMNM this would most likely be recreational vessels) or via 'citizen scientists' is a form of participatory monitoring. Groups that could be included as part of monitoring programs are varied. For example recreational boaters could monitor seabirds or other marine life, as has been done for basking sharks in the UK (Witt et al in press). Other vessels of opportunity can also collect data; pollock fisheries in the Bering Sea collect acoustic data by towing an array behind the ship (Honkalehto et al 2011). Other examples of citizen science efforts include volunteer divers in the National Park Service's Channel Island Kelp Forest Monitoring program (David Kushner, CINPS), and crowd sourcing efforts to monitor and survey MPAs in California (http://mpawatch.org/).

As with participatory surveillance described above, participatory monitoring increases awareness of the PMPA, increases collective awareness of and investment in MPA goals and objectives, and increases management capacity (Aswani and Weiant 2004, Danielsen et al 2009, Fox et al 2011). Opportunistic data collection is generally viewed as less costly, though maintenance of opportunistic data and citizen science networks can be labor-intensive and may not lend itself well to straight-forward statistical analysis. As a result, the collection of systematic data that is reliable, replicable and controlled for precision and accuracy is also necessary to achieve monitoring objectives. This more "traditional" data collection usually results in datasets of higher quality, but is more expensive to collect, especially in remote areas. The combination of both of these data types can maximize our understanding of the system while being more cost-effective. Long-term monitoring should, however, always be a goal for PMPA management.

Several types of data need to be collected to inform the three tiers listed above: data on species, ecosystems, threats and socio-economics.

Designing a Monitoring System

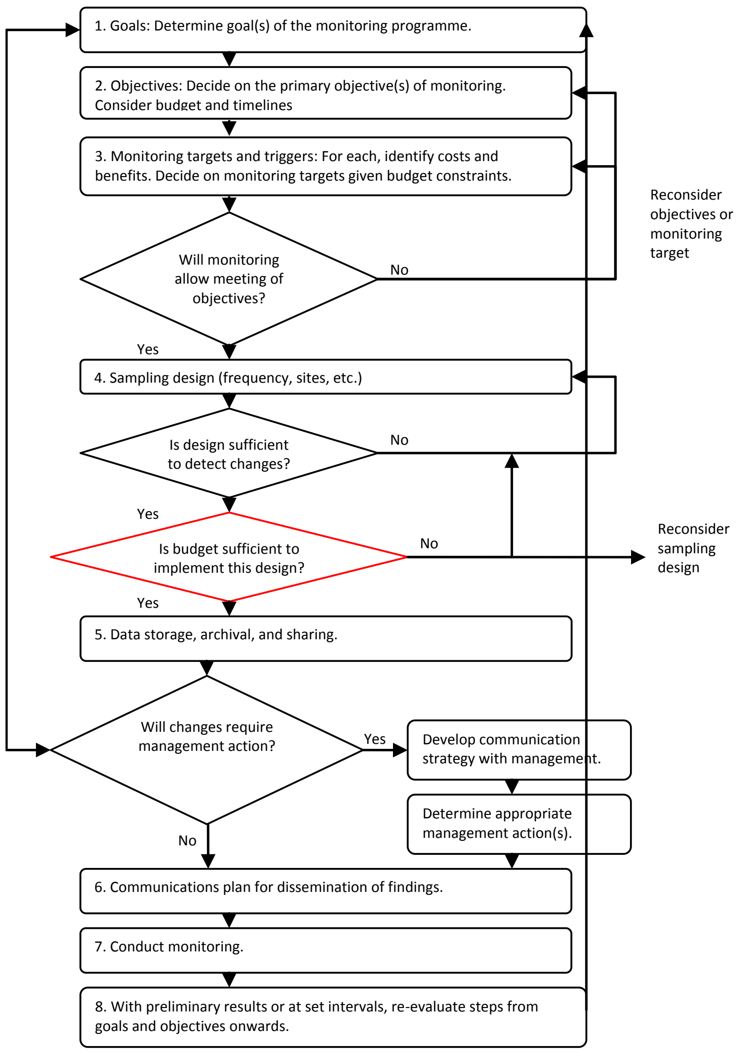


Figure 2. Systematic framework for setting up or re-evaluating a monitoring program with budget considerations embedded (from Ceccarelli et al in prep).

Selecting Indicators

Selecting indicators is not a simple question and the indicator literature is extensive and growing quickly. An entire journal –*Ecological Indicators*- is devoted solely to this topic. Opinions range widely but there are many relevant examples and lessons learned. We highlight some of the considerations for selecting indicators as we discuss monitoring species and habitats within the

PRIMNM below. Shin et al (2010) suggest selecting indicators based on the following three simple rules:

1. They fulfill four criteria:
   - ecological significance
   - sensitivity
   - measurability
   - general public awareness
2. There is least one indicator per category (for exploited marine ecosystems
   - size-based
   - species-based
   - tropho-dynamic
   - pressure
   - biomass-related
3. There is at least one indicator per management objective.

Affordable solutions that can be simply applied across a variety of situations are clearly important. Significantly, while scientists rightly point out that more monitoring, with a broad suite of indicators, should lead to a better understanding of ecosystems, the link between understanding and implementation of management measures is often unclear. In any case, developing a set of core cost-effective indicators will be required for monitoring PMPAs.

Ecosystem-level monitoring

Monitoring pelagic ecosystems is challenging because of complex circulation dynamics, variable oceanographic conditions and the wide-ranging movements of pelagic species. Methods of rapid ecological assessment have been developed for coral reef ecosystems (e.g., the Rapid Ecosystem Assessments conducted by the Coral Reef Ecosystem Division), however similar assessment tools for pelagic systems have yet to be developed, and further research and tools are required, particularly determination of a set of appropriate indicators. Because of the complexities of pelagic ecosystems, a variety of indicators will be necessary to monitor ecosystems and, when taken in concert, they can provide a picture of the larger ecosystem. Indicators for monitoring pelagic ecosystems will come primarily from two sources: (1) oceanographic processes and components, and (2) individual species.

Monitoring oceanographic processes and components can give information on how ecosystems are changing through time. For example, oceanographic and plankton monitoring can indicate how sea surface temperatures or productivity varies annually, across climatic regimes or as a result of climate change. These data can be collected via remote-sensing or *in situ* data collection. Remotely sensed data such as sea surface temperature and primary productivity data are widely and freely available on the web (e.g., Ocean Watch, http://las.pfeg.noaa.gov/oceanWatch/oceanwatch.php), including both current and past data from which baselines can be established (i.e., prior to the PMPA creation). Climatologies, which average oceanographic conditions through time, can be compared to individual years, giving a snapshot understanding of background ecosystem metrics. In addition, data collected *in situ* such as sub-surface oceanographic variables (oxygen minimum layer depths, mixed layer depth, thermoclines, etc.) and other data that cannot be collected via remote sensing, such as plankton surveys, can similarly be used to understand baseline ecosystem metrics that drive upper trophic level processes. Collection of *in situ* data, however, can be more time and resource intensive than remotely sensed data as it often involves expensive ship time.

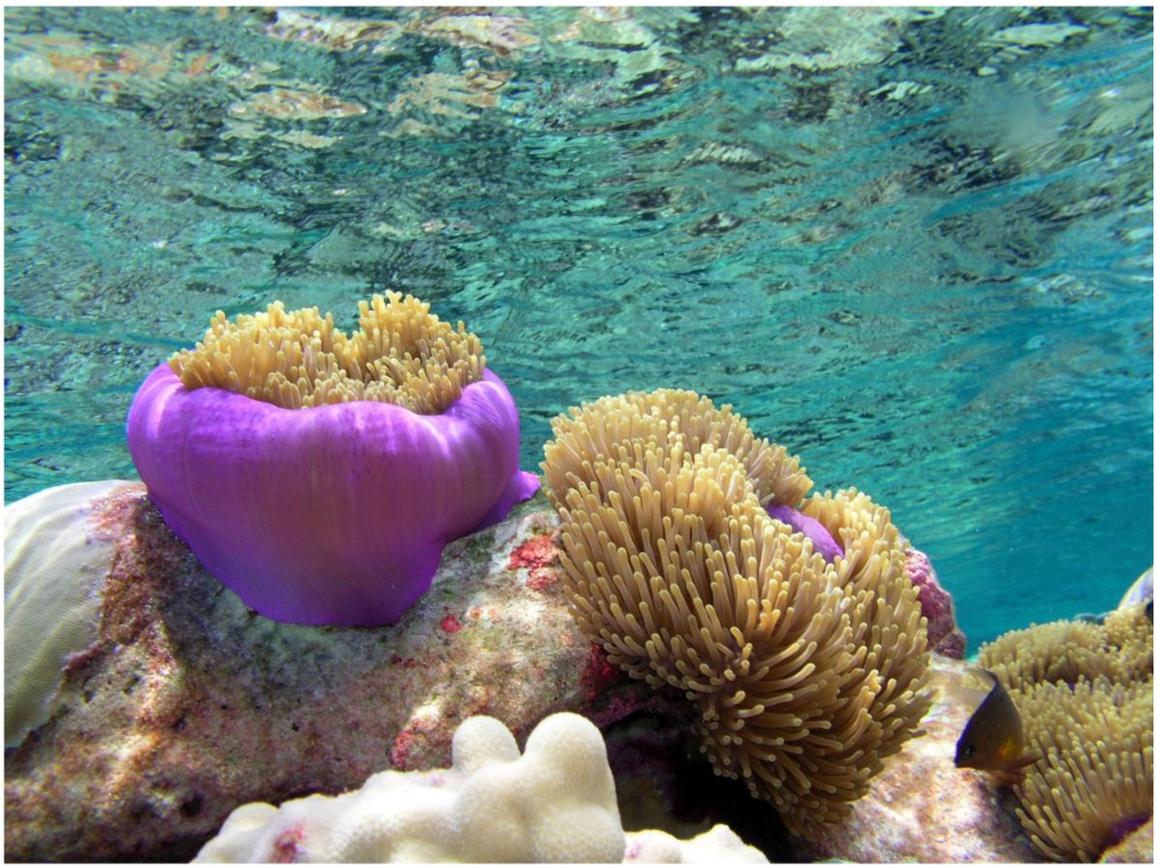
Indicator species, or species that are sensitive to changes in the ecosystem, are another primary means of monitoring ecosystems. By monitoring the reproductive success or foraging ecology of indicator species, we can determine patterns in the larger ecosystem (Zacharias and Roff 2001, Table 3). Determining which species to monitor is challenging, particularly in PMPAs where many of the species of interest are highly mobile. Many species may be appropriate for monitoring, but one of the first considerations is to monitor on scales relevant to the reserve boundary. Species whose life histories follow the boundary and scale of the PMPA (i.e., they live a significant portion of their life within the PMPA) are going to be more relevant to managers. Some species will also be monitored because their protection is one of the objectives for creating the PMPA, as is the case with the PRIMNM. In these cases, these species may or may not be appropriate indicators of ecosystem health but their populations will be monitored regardless.

Breeding seabirds may be ideal candidates for monitoring in the PRIMNM because their protection is one of the reasons for which the PMPA was established, their inherent charisma allows for easy ties back to the public, and they are top-level predators. Top predators are often chosen as indicator species because of their disproportionate impacts on ecosystems, however, not all top predators are ideal for monitoring (Table 3). Some are difficult to monitor or may range across large areas and many different ecosystems. Top predators that are good candidates for monitoring should be those that can be easily monitored (e.g., easily sighted, regularly occurring, adequate baseline biological knowledge), are representative of other species in the system that are not being monitored, and are likely to reflect positive and negative changes in the system.

Ideally, managers should choose indicator species that are (1) distributed over wide ranges, (2) easy to observe, and (3) not continually fished (Louazo et al 2010, Zacharias and Roff 2001). Breeding seabirds are good choices because they are relatively easy to monitor and provide a solid and visible link between foraging resources and breeding success, they are easily accessible on land (to tag and sample), they are amenable to diet studies without lethal taking (i.e., gastric lavage) and, most species integrate conditions over large areas, giving researchers an "ecosystem" picture, rather than one that is too particulate to indicate the health of the whole ecosystem. Pelagic seabirds in particular are likely to be a good measure of pelagic ecosystem health because they are largely fishery independent. Because they and their chicks have high metabolic rates and cannot long endure starvation, seabird monitoring also provides good indicators of short and long-term conditions in the PMPA. Chick hatching, rearing and survival success is a good indicator of short-term conditions within the PMPA, while adult survival is a good indicator of longer-term conditions and population levels (Dunlop et al 2002, Peck et al 2004, Devney et al 2010, Erwin and Congdon 2007).

Determining which seabird species are appropriate for monitoring is an iterative process with refining management objectives of the PRIMNM, and a number of completed studies are available that can be used as baselines for monitoring changes (Young et al 2010 a,b). Table 4 summarizes the seabirds found in the Monument and provides some guidance for interpreting the role of the MPA on the life history of different species, particularly with regard to population levels and the scale of their foraging ranges in relation to PMPA boundaries. It will be important to understand the local and global context of species found in Monument waters. For instance, a species which breeds in the Monument, but forages outside its boundaries will need to be interpreted differently from one that breeds and feeds inside the protected area. This table provides some context for considering factors that are relevant to population monitoring and the role of the MPA in species life histories (foraging in breeding versus non-breeding season).

Some fishes can similarly be useful for monitoring (Table 3). Those species that are fecund and quick to rebound might provide early short-term metrics (e.g., skipjack tuna and mahi-mahi). For longer lived species, however, it is critical to think in advance about potential complex trophic interactions that might lead to changes in abundance and biomass over time. Monitoring species that are likely to respond to management is critical to demonstrating PMPA effectiveness, but recognizing those species that are unlikely to respond is also important. For example managers might select a range of species to monitor; those they expect to benefit from reduced mortality inside a reserve to those that they think are unlikely to benefit.



Pacific Remote Islands MNM (photo: Jim Maragos).

Table 3. Indicator species for ecosystem monitoring.

Indicator Species Group	Benefits	Drawbacks	Monitoring Techniques	Suggested species*
Seabirds	Easily monitored Tied to a land during breeding season so reflective of local conditions Likely to reflect ecosystem changes: (1) chick growth & survival tightly coupled with short-term ecosystem conditions; (2) adult survival coupled with longer-term ecosystem conditions Distributed over wide ranges Fishery independent data Good baseline data in PRIMNM, particularly Palmyra Atoll Can sample non-lethally for diet	Range may be well outside of PMPA boundaries May be more sensitive to handling	Wet diet for foraging success & available prey Banding studies for survivorship (mark-recapture) Stable isotope for foraging patterns Chick growth for ecosystem productivity Satellite tracking for foraging areas and success	Red-footed boobies Sooty terns Wedge-tailed shearwaters Red-tailed tropicbirds
Fish	Distributed over wide ranges Highly fecund (mahi-mahi & skipjack) so reflective of shorter-term ecosystem conditions Good baseline data in PRIMNM, particularly Palmyra Atoll Need at-sea studies to monitor Can potentially partner with commercial fisheries to monitor	Far ranging and mobile so may not be reflective of local conditions Populations may be influenced by fishing levels and changes may not reflective of ecosystem changes Need at-sea studies to monitor	Wet diet for foraging success & available prey Conventional tagging studies for survivorship & movement (mark-recapture) Stable isotope for foraging patterns Satellite tracking for foraging areas and success	Mahi-mahi Skipjack tuna Sharks also possible (not mentioned in workshop)

Importance of long-term monitoring programs

Population abundance levels are an important indicator of success and need to be monitored through time. How monitoring data can be applied to PMPA management and indicators of success inevitably vary over different time periods. Short-term monitoring (i.e., 1-5 yrs) might be aimed at simply keeping track of removal of a species by humans either through bycatch, directed take or poaching, and relating that to overall population numbers (e.g., demonstrating a 45% reduction in take between pre-MPA designation and the current monitoring year). Regardless of the data collected, monitoring should focus on data that can be collected cost-effectively and efficiently, and that requires little need for complex analytical techniques to summarize or interpret.

In contrast, longer-term monitoring (i.e., 5-15 yrs) should be aimed at more complex studies that can incorporate long-term trends and predictions. These might include detailed demographic models based on multi-year mark-recapture studies that include human threats such as assumed levels of poaching or reduced reproductive capacity due to pollution levels. Demographic sensitivity analysis may be a particularly useful tool to apply to long-term monitoring datasets. These models allow researchers to analyze how much a small change in a demographic rate would influence a population's potential for recovery, allowing the prediction of different management actions (Hooker and Gerber 2004). Additionally, species abundance and distributions can be modeled based on limited sampling by using interpolation techniques and oceanographic proxies for species distributions based on the models (Hooker et al 2011). Breeding seabirds on PRIMNM islands provide an excellent system for long-term, demographic responses to management actions.

Table 4. Summary of tropical seabird ecology. Location to where data is relevant is noted, along with relevant citation. Data are primarily given for all locations for which there is data within the PRIMNM region. Otherwise, data are given for closest location. All squid species are Ommastrephidae unless otherwise noted.

Species	Body Size	Flock Feeding Level, Foraging Method	Subsurface Predator Associations	Prey Species	Prey Size	Breeding Foraging Range	Non-breeding Foraging Range
White-tailed tropicbird	Smaller of tropicbirds, 350 g (Diamond 1978)	Solitary foragers, surface plunging (Ashmole & Ashmole 1967, Spear et al 2007)	Independent, Christmas Is, ETP, Réunion Is* (Spear et al 2007, Spear & Ainley 2005, Jaquemet et al 2005); Yellowfin, skipjack, ETP (Spear & Ainley 2005); cetaceans, Réunion Isl (Jaquemet et al 2005);	Squid, flying fish, Christmas Is (Gibson-Hill 1947)	10-18 cm, Christmas Is (Gibson-Hill 1947)	Approximately 120 km, not reported (Lee & Walsh-Mcgehee 1998)	Unknown
Red-tailed tropicbird	Larger of tropicbirds, 650-780 g (Schreiber & Schreiber 2009)	Solitary foragers, surface plunging (Ashmole & Ashmole 1967, Spear et al 2007)	Independent, Christmas Is (Spear et al 2007); Tunas, ETP (Spear & Ainley 2005)	53% fish, 47% squid, Christmas Is (Ashmole & Ashmole 1967); flying fish, squid, mackerel, HI (Harrison 1990)	2-28 cm, Christmas Is (Ashmole & Ashmole 1967)	Mean of 1034.3 ± 86 km, Midway (Laniawe 2008)	Several thousand km from colony, ETP (Spear & Ainley 2005)
Masked booby	Largest of boobies, 1.5-2 kg (Weimerskirch et al 2008)	Flock feeders, plunge diving to 2 m (Weimerskirch et al 2008, Grace & Anderson 2009)	Cetaceans, ETP (Au & Pitman 1986)	99% flying fish, remainder squid, Palmyra (Young et al 2010b)	Average 26.6 cm, Palmyra (Young et al 2010b)	Incubation: 103 km, Clipperton (Weimerskirch et al 2008); early brooding: 30 km, Palmyra (Young et al 2010b); chick-rearing: 144 km, Clipperton (Weimerskirch et al 2008)	Unknown

Species	Body Size	Flock Feeding Level, Foraging Method	Subsurface Predator Associations	Prey Species	Prey Size	Breeding Foraging Range	Non-breeding Foraging Range
Brown booby	Mid-size of boobies, 1-1.7 kg (Schreiber & Norton 2002)	Flock feeders and independent, plunge diving to 0.9 m (Lewis et al 2005, Yoda et al 2007, Harrison et al 1983)	Skipjack, Hawaii (Hebshi et al 2008); cetaceans, ETP (Au & Pitman 1986)	Mainly flying fish, Christmas, Johnston (Harrison et al 1984, Schreiber & Norton 2002)	5-40 cm, Johnston (Schreiber & Norton 2002)	Incubation, early brooding: 35 (males) to 75 (females) km, ETP (Gilardi 1992)	More coastal, Palmyra (Young et al 2010a)
Red-footed booby	Smallest of boobies, 850-1100 g (Schreiber et al 1996)	Flock feeders, plunge diving to 0.75 m (Lewis et al 2005)	Skipjack, Hawaii** (Hebshi et al 2008); cetaceans, ETP (Au & Pitman 1986)	Mainly squid, remainder squid, Palmyra (Young et al 2010b)	Average 20.6 cm, Palmyra (Young et al 2010b)	Incubation, early brooding: 67.5 km max, Palmyra (Young et al 2010b)	Unknown
Great frigatebird	1-1.8 kg (Metz & Schreiber 2002)	Flock feeders, surface snatchers, surface dipping or kleptoparasitism (Metz & Schreiber 2002)	Skipjack & yellowfin, ETP (Spear et al 2007)	50% fish, 50% squid; flying fish, Christmas (Spear et al 2007); chicks of other species, Pacific (Metz & Schreiber 2002)	Variable, HI (Harrison 1990)	Incubation: 612 km; Brooding: 94 km, Europa, Indian Ocean (Weimerskirch et al 2004)	600 km max, Johnston (Dearborn et al 2003); 612 km, Europa Indian Ocean (Weimerskirch et al 2004)
Lesser frigatebird		Flock feeders, surface snatchers, surface dipping or kleptoparasitism (Metz & Schreiber 2002)	Independent, tuna, cetaceans, Mozambique Channel (Jaquemet et al 2005)	Flying fish, Pacific (Birdlife International 2011)	Unknown	Unknown	Unknown
Sooty tern	Largest of terns, 200 g (Schreiber et al 2002)	Flock feeders, air dipping (Ashmole & Ashmole 1967)	Skipjack, cetaceans, Hawaii, ETP, Réunion Is (Hebshi et al 2008, Spear et al 2007, Jaquemet et al 2005); Independent, ETP (Spear et al 2007)	38% fish, 62% squid; flying fish, mackerel/tuna, Christmas (Ashmole & Ashmole 1967)	0-18 cm, Christmas (Ashmole & Ashmole 1967)	Brooding: 290 km max; Chick-rearing: 522 km max, Johnston (Flint 1991)	Unknown but completely pelagic

Species	Body Size	Flock Feeding Level, Foraging Method	Subsurface Predator Associations	Prey Species	Prey Size	Breeding Foraging Range	Non-breeding Foraging Range
Gray-backed tern	Intermediate of terns, 95-145 g (Mostello et al 2000)	Flock feeders but independent of subsurface predators, plunge diving and air dipping (Gallagher 1960)	No data	92% fish, 4% squid; cowfish, flying fish, goatfish, HI (Harrison et al 1983); may take insects, Christmas, Howland (Gallagher 1960)	Average 20 cm (Harrison et al 1983)	Unknown	Unknown
White tern	Smallest of terns, 77-157 g (Niethammer & Patrick 1998)	Solitary feeders independent of subsurface predators, air dipping (Ashmole & Ashmole 1967); note: known to be flock feeders with tuna in ETP (Spear et al 2007)	Skipjack, Hawaii (Hebshi et al 2008); independent, ETP (Spear et al 2007)	47% fish, 53% squid; blennies, flying fish, Christmas (Ashmole & Ashmole 1967)	0-16 cm, most 2-8 cm, Christmas (Ashmole & Ashmole 1967)	Unknown	Unknown
Brown noddy	Largest of noddies, 180 g (Chardine & Morris 1996)	Flock feeders, plunge diving and air dipping (Ashmole & Ashmole 1967)	Skipjack, Hawaii*, Réunion Is (Hebshi et al 2008, Jaquemet et al 2005); tuna, ETP (Spear et al 2007); cetaceans, Réunion Is (Jaquemet et al 2005)	51% fish, 49% squid; flying fish, mackerel/tuna, Christmas (Ashmole & Ashmole 1967)	2-8 cm, Christmas (Ashmole & Ashmole 1967)	Approximately 20-80 km, HI (Harrison 1981, King 1974a)	Unknown
Black noddy	Intermediate noddy, 84-140 g (Gauger 1999)	Flock feeders, plunge diving and air dipping (Ashmole & Ashmole 1967)	Skipjack, Hawaii (Hebshi et al 2008)	77% fish, 23% squid; flying fish, mackerel/tuna, blennies, Christmas (Ashmole & Ashmole 1967)	1-4 cm, Christmas (Ashmole & Ashmole 1967)	Within 9 km of land, Christmas (Ashmole & Ashmole 1967, Ashmole 1968)	Unknown but thought to be close to nesting grounds (Gauger 1999)

Species	Body Size	Flock Feeding Level, Foraging Method	Subsurface Predator Associations	Prey Species	Prey Size	Breeding Foraging Range	Non-breeding Foraging Range
Blue-gray noddy	Smallest of noddies, 58 g (Harrison 1990)	Flock feeders, plunge diving and air dipping (Ashmole & Ashmole 1967)	No data	75% fish, 10% squid; water-striders (insects), snake mackerels, squid spp Loligo, Christmas (Ashmole & Ashmole 1967)	1-10 cm, most 2 cm, Christmas (Ashmole & Ashmole 1967)	Within 9 km of land, Christmas (Ashmole 1968)	Unknown
Christmas shearwater	Smaller of shearwaters, 354 g (Seto 2001)	Flock feeders, plunge diving (Ashmole & Ashmole 1967)	No data	29% fish, 71% squid, flying fish, mackerel/tuna, Christmas (Ashmole & Ashmole 1967)	0-14 cm, Christmas (Ashmole & Ashmole 1967)	Unknown	Unknown
Wedge-tailed shearwater	Largest of shearwaters; 390 g (Whittow 1997)	Small flock or solitary feeding, contact or air dipping (Ashmole & Ashmole 1967, Spear et al 2007)	Skipjack, Hawaii*, Réunion Is (Hebshi et al 2008, Jaquemet et al 2005); Independent, ETP (Au & Pitman 1988)	66% fish, 28% squid; goatfishes, jacks, squids (fall), HI (Harrison et al 1983)	5.7 cm, HI (Harrison et al 1983)	Within 480 km, Johnston (King 1974b)	Up to 3500 km, Seychelles (Catry et al 2009)

Threat monitoring

Understanding the nature of threats both inside and outside a PMPA is critical to understanding the role a PMPA can play in the protection or recovery of species and habitats. It is often important to collect information on the same indicators inside and outside of the MPA in order to adequately control for the effect of the MPA. Likewise monitoring the migratory species across its range (inside and outside of the PMPA) is necessary to have a complete picture of the PMPA's effectiveness. For example, a no-take PMPA designed to protect a portion of a sea turtle life history may not ensure success if fishing effort and associated bycatch in surrounding areas continues unabated (Maxwell et al 2011, Witt et al 2008). Consideration of threats inside and outside of MPAs helps managers and the local community identify where they can concentrate and synergize efforts. Identifying key agencies and local groups to partner with in order to manage threats outside of the MPA can be a means of synergizing efforts (see Step 9 above). Parallel conservation efforts to reduce threats such as region-wide overfishing will help to support overall ecosystem health and resilience.

Socio-economic monitoring

Except for cultural values, the socio-economic values of MPAs are often overlooked as part of a monitoring plan. Socio-economic monitoring provides a link between the biological gains of an MPA and the benefits to local communities. In addition to building support for the MPA, it also provides important political leverage for policy makers as they seeking funding for MPA and ocean resource management. One of the first steps in socio-economic monitoring is assessing what the surrounding community hopes to gain as a result of the MPA, or what fears they have. This kind of socio-economic monitoring can be continued through time to determine how well an area has become integrated into the community.

Quantifying socio-economic links is critical and can be done in a variety of ways. Metrics that relate the increase in fish populations inside the reserve to increased fish catches outside of an MPA are the most obvious examples. Further, understanding the distribution of financial resources related to ocean resources in the community surrounding the MPA will aid in understanding the positive and negative impacts of the MPA on individuals through time. This information can be used to understand how incomes are likely to shift given changes in resource management, including which sectors may benefit, which might not, and how evenly the wealth will be distributed.

For remote MPAs such as the PRIMNM, the user community is small and diverse. For these places it might be useful to determine the 'existence value' of the PRIMNM to the American public (Stevens et al 1991). Existence value is a quantifiable technique that assesses whether the US population knows that the PRIMNM exists, and to what extent their views of it are favorable. This knowledge can help to structure outreach campaigns, with the goal of increasing awareness for (1) the American public to know the intrinsic value of a shared resource and (2) to be used politically to show that the American people are behind the continued support and funding of the area.

Technologies for monitoring vessels

A number of technologies for monitoring vessel activity now exist (Brooke et al 2010), including cooperative and non-cooperative systems. Cooperative systems are those in which only participating vessels are monitored; for example, fisheries Vessel Monitoring Systems (VMS) can only observe those vessels which "cooperate" by carrying transceivers. Cooperative systems are also sometimes referred to as voluntary or participatory systems. Despite these terms however, their use is usually a legal requirement for participation in a fishery. This means some vessels participate unwillingly, and may interfere with onboard surveillance systems. Nonetheless, the level of information cooperative systems provide make them a valuable surveillance tool.

A number of non-cooperative technologies are available to monitor activities. For example, managers could use buoy-based sound monitoring for a number of human threats. Low frequency noise is indicative of boat noise, higher frequency is indicative of sonar. These could be particularly useful in remote areas such as the PRIMNM where not much boat-based activity is expected. The buoy systems could also double as monitors for ecological components by incorporating monitors for business card or acoustic tags that will monitor species movements and distribution. A wide variety of satellite systems are also available (see Brooke et al 2010 for a much more thorough discussion of different technologies; and Richardson 2011 for application to the PRIMNM).

Another tool now available for collecting ecological as well as oceanographic data uses satellite tags on animals as ocean sensors. This technique uses high-level satellite tracking and environmental sensor tags to determine both the location of the animal, as well as oceanographic conditions along the animal's path by simultaneously collecting data such as chlorophyll, sea surface temperature, salinity, etc. (Block et al 2011). While the tags and satellite time required to collect this data can be expensive, it is considerably less expensive than ship-based surveys, and provides an important window into what oceanographic conditions the animals prefer.

Giant clams in the Pacific Remote Islands MNM (photo: NOAA).

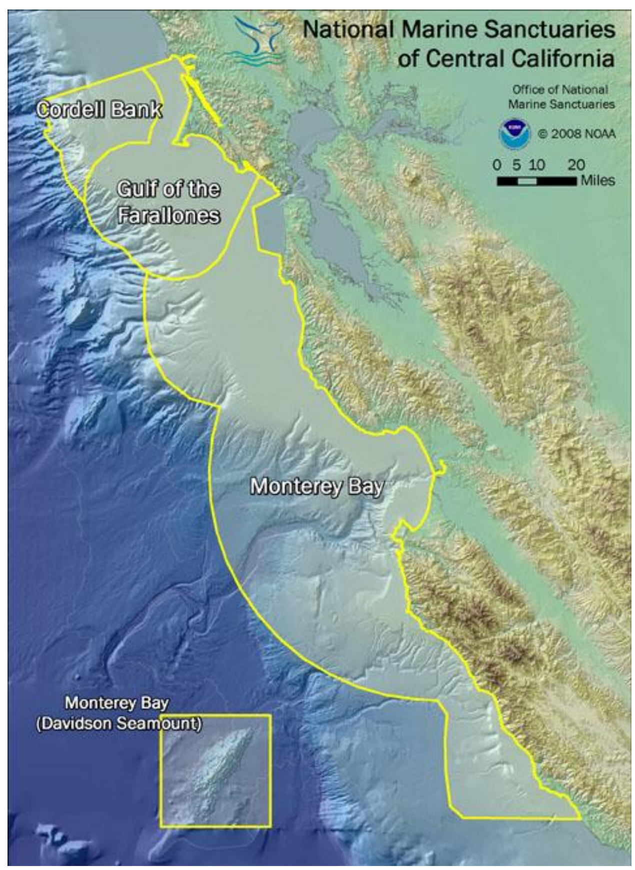
Large, Pelagic MPA Case Studies

In this section we detail where other large MPAs exist around the globe, what their management goals are, how they are being managed, the challenges being dealt with, anticipated and observed benefits of protecting these areas, and indicators of effective management. We start by reviewing management of the West Coast Sanctuaries in the US and then turn to several international case studies of MPA management.

West Coast US National Marine Sanctuaries

Location

Cordell Bank National Marine Sanctuary (NMS) (1163 km^2), Gulf of the Farallones NMS (3200 km^2) and Monterey Bay NMS (15,780 km^2) were created by the US government along the central coast of California.



Ratification

Cordell Bank NMS was established in 1989, Gulf of the Farallones in 1981 and Monterey Bay NMS in 1992.

Reason for Designation

The habitats within the Sanctuaries are considered treasures within the US. The sanctuaries contain a combination of banks and seamounts, canyons and estuaries, hard and soft bottom habitats and extensive kelp forests. Additionally, the Sanctuaries are home to commercially important fish species and a wide array of seabirds and marine mammals, as well as leatherback sea turtles. These animals use the Sanctuaries year-round or as a critical foraging destination.

Management strategy

The Sanctuaries primarily protect against oil and gas development, which are forbidden within their boundaries. Some fishing restrictions do exist within these Sanctuaries, but the primary aims of the Sanctuaries are science, monitoring and education, as the Sanctuaries do not have regulatory authority over fishing activities.

Indicators of effective management

The Sanctuaries Program has developed a comprehensive plan for evaluating performance. They do this by first identifying problems relative to site goals and objectives as part of their scoping process. From these they developed outcomes or targets based on needed changes, and performance measures from which they evaluate progress over both short (e.g., one year) and long time frames (over 10 years). One tool the Sanctuary Program has considered employing is to use 'logic models' to link outcomes on different time scales and help identify realistic and specific objectives. Logic models show how a step-wise series of activities, outputs and outcomes link together to meet desired near- and long-term goals given resource levels. The Sanctuaries also measure performance consistently over time; on an annual basis for individual sanctuaries, and on a quarterly basis for each action plan. The evaluation is reviewed by the overarching Sanctuary Advisory Council, and the sanctuaries are working to create similar regular evaluation programs for programs being conducted with partner agencies and institutions. Below is an example of a performance measure summary from a specific action plan. Notice the specific outcomes targeted, and that the performance measures are given target dates.

Action Plan	Outcome	Performance Measure
Marine Protected Areas	Collaborate with regional stakeholders and agencies in the consideration and possible designation of marine protected areas to ensure the protection of natural biological communities and habitats.	1) By 2009, complete an evaluation of the utility of and alternative location and network designs for MPAs within the MBNMS. 2) If MPAs are found to be appropriate for meeting Sanctuary mandates, by 2009, MBNMS will obtain 100% of the information required for an adequate NEPA alternatives analysis and initiate designation.

Key websites

http://farallones.noaa.gov/

http://cordellbank.noaa.gov/

http://montereybay.noaa.gov/

Application to the Pacific Remote Islands and other pelagic MPAs

The Sanctuary system has been in existence for several decades, and as a result has come far in their monitoring systems and coordination with other agencies, key challenges for the PRIMNM. Coordinating the PRIMNM monitoring and methods with those developed by the NMSP could lead to better US-wide MPA effectiveness reporting and data sharing across sites and agencies.

Coordinating among agencies

The Sanctuaries rely heavily on partners in order to monitor and manage the areas effectively. The Sanctuaries, particularly the Monterey Bay NMS with its Sanctuary Integrated Monitoring Network (SiMON), have established effective, lasting and valuable collaborations and partnerships with other government agencies, volunteer groups and, in particular, academic institutions. For the West Coast Sanctuaries, this collaboration is facilitated by the Sanctuaries proximity to population centers and academic institutions with a focus on marine research, but similar collaborations within the PRIMNM could be fostered. For example, the Palmyra Atoll Research Consortium is a great example of this kind of collaboration already at work, and one that could be expanded to other islands and regions of the PRIMNM.

Similarly to the PRIMNM, there are many overlapping jurisdictions in the Sanctuaries. For example along the coast of Big Sur, to ameliorate conflicting efforts and to combine resources, managers outlined a plan for coordinating with multiple agencies. This plan may be particularly useful for the PRIMNM given the co-management between NOAA and USFWS, as well as the need to coordinate with other agencies (i.e., USAF, USCG, etc.). They outlined three strategies for coordinating between agencies and a number of specific action steps for achieving each strategy.

The first strategy involves integrating relevant maps, data and documents into a central location for the public and partners. The second strategy lays out a framework for agencies to coordinate, and is the most relevant to the PRIMNM. They outline a number of actions, including facilitating an ad hoc coordination team. Through this they will facilitate regular coordination meetings between relevant agency representatives with progress from these meetings being reported to the Multi-Agency Advisory Council that will make final recommendations. Additionally, they create 'task forces' of representatives from various agencies, stakeholders, experts, and partners to coordinate between objectives, policies and resources allocated to determine the most effective, coordinated means of moving forward. They have developed task forces for oil spill responses in Big Sur, as well as issues related to landslides. Further, they estimate the timeline and resources necessary to implement the various strategies (see Tables below). Finally, in the 'Operations and Administration' section of the management plan, they outline the specific activities the MBNMS will undertake. A similar strategy that outlines the specific activities and responsibilities of both NOAA and USFWS, as well as other relevant agencies, would further aid in effective coordination between agencies.

Table BSP.2: Estimated Timelines for the Big Sur Coastal Ecosystem Coordination Action Plan

Big Sur Ecosystem Protection Plan	YR 1	YR 2	YR 3	YR 4	YR 5
Strategy BSP-1: Provide Integrated Data and Information to the Public					
Strategy BSP-2: Develop an Interagency Coordination Program					

Legend	
Year Beginning/Ending:	Major Level of Implementation:
Ongoing Strategy:	Minor Level of Implementation:

Table BSP.3: Estimated Costs for the Big Sur Coastal Ecosystem Coordination Action Plan

Strategy	Estimated Annual Cost (in thousands)*				
	YR 1	YR 2	YR 3	YR 4	YR 5
Strategy BSP-1: Provide Integrated Data and Information to the Public	$84	$52	$32	$32	$28
Strategy BSP-2: Develop an Interagency Coordination Program	$307	$255	$259	$251	$231
Total Estimated Annual Cost	*$391*	*$307*	*$291*	*$283*	*$259*

* Cost estimates are for both "programmatic" and "base" (salaries and overhead) expenses.

** Contributions from outside funding sources also anticipated.

Cross-cutting themes

The Gulf of the Farallones, Cordell Bank and Monterey Bank National Marine Sanctuaries occur adjacent to each other and share a number of overlapping, cross-cutting issues. In order to align efforts and resources, and to increase coordination between the sites, they have developed a cross-cutting framework to coordinate between the sites on key issues. The *Administration and Operations Action Plan* is partially targeted at increasing communication between the three sanctuaries. Examples of actions they will undertake include meeting at least three times a year to improve communication and assess implementation of the operation and management plans, holding team building exercises and encouraging staff to give presentations at other sanctuaries. They are also creating a list of equipment, facilities and other resources that are either housed at individual sanctuaries, or which are needed across multiple sanctuaries, and conducting coordinated field operations, as well as integrating across needs such as enforcement, staffing, etc.

This same framework of cross-cutting themes could be applied between NOAA and the USFWS for issues that overlap the land-sea interface, such as seabird population monitoring, nutrient input to coral reefs, etc.

Monitoring

The Sanctuaries have implemented a System-Wide Monitoring (SWiM) program to monitor specific ecological parameters and ensure a timely flow of data, and a long term monitoring dataset that can be compared across sanctuaries. This allows for sanctuaries to develop effective ecosystem-based monitoring programs, but within a design that can be applied across sites. It would be worthwhile for managers to also apply the tested SWiM program to the PRIMNM.

Coral reef ecosystem at Palmyra Atoll, PRIMNM (photo: The Nature Conservancy).

Phoenix Islands Protected Area

Location

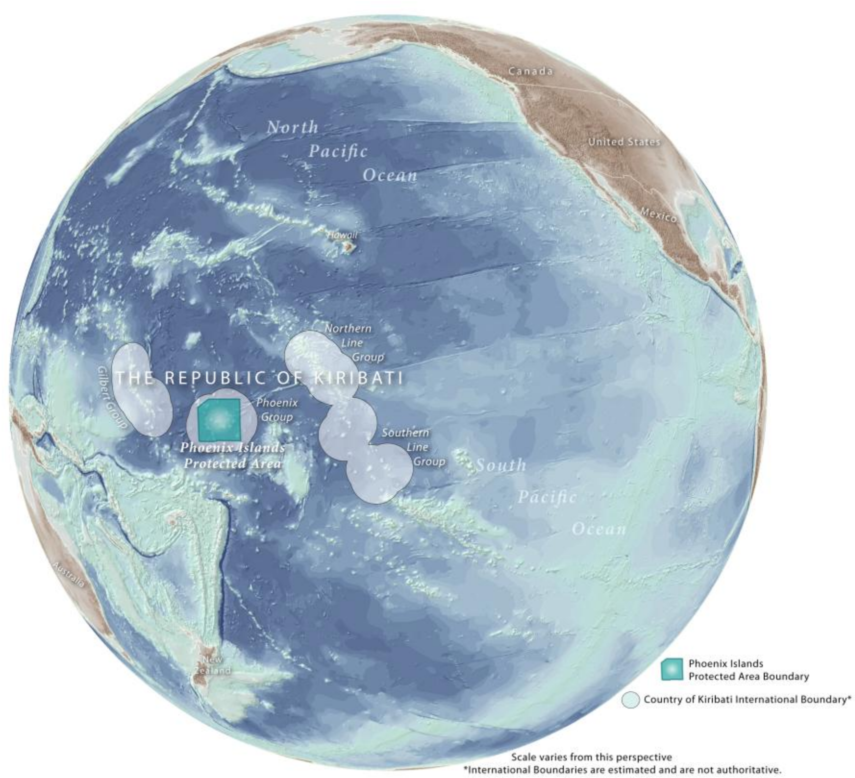
Phoenix Islands Protected Area (PIPA) (408,250 km^2) was created by the Government of Kiribati and is located in the Central Tropical Pacific Ocean, adjacent to the Line Islands of the Pacific Remote Islands Marine National Monument.

Ratification

Kiribati first declared the creation of PIPA at the 2006 Conference of the Parties to the Convention on Biological Diversity in Brazil. On January 30, 2008, Kiribati adopted formal regulations for PIPA that more than doubled the original size.

Reason for Designation

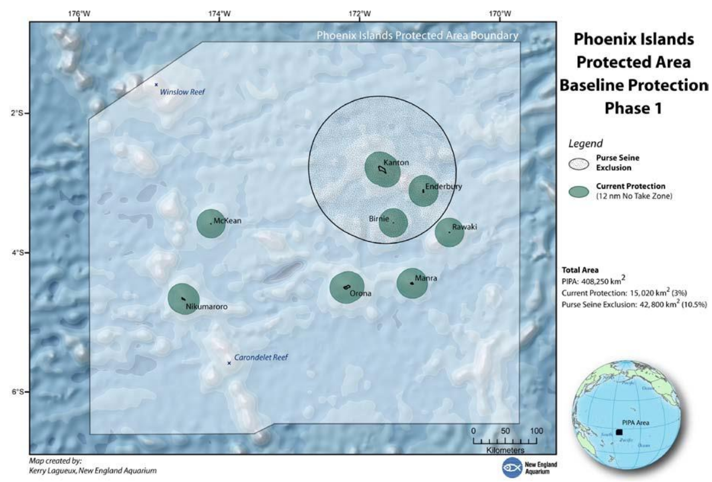
The Phoenix Islands were identified as a key biodiversity area within the Polynesia/Micronesia Biodiversity Hotspot Program under Conservation International's Critical Ecosystem Partnership Fund (CEPF) (Atherton 2008). This designation reflects the diversity, abundance and in some cases threatened species

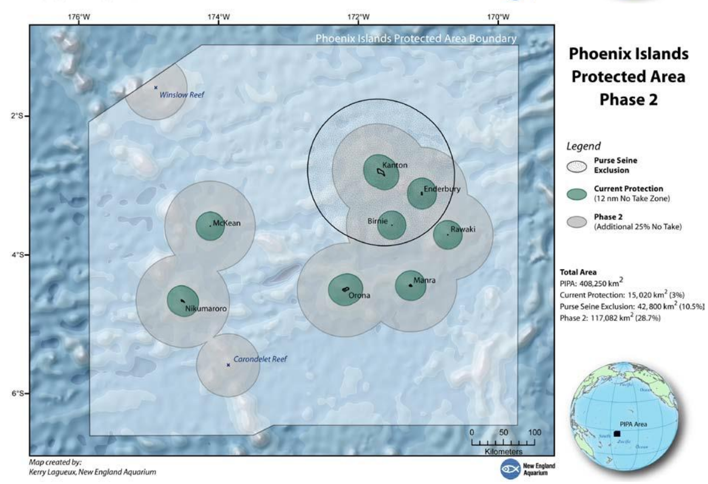


status of seabirds found in these islands. Coral reef and associated biota have now been well documented and PIPA contains populations of globally important and threatened species and are superb examples of intact coral reef ecosystems. In 2010, PIPA was inducted as a UNESCO World Heritage site, making it the largest such site in the world.

Management strategy

The PIPA Management Plan uses a zonation approach whereby certain areas are delineated within the PIPA boundary and will be specified with respect to permissible and prohibited uses or activities. The current no-take zonation of PIPA amounts to 3.87% of the total PIPA marine area. During the next phases of implementing the PIPA Management Plan, Kiribati intends to zone an additional 25% of the MPA as a no-take zone to conserve tuna stocks.





PIPA is guided by a set of eleven principles that include intergenerational equality, ecosystem sustainability and resilience, the precautionary principle, adaptive management, integrated planning and management, ecosystem approaches, stakeholder consultation and participation, capacity-building and technology transfer, and transparency of decision making. They target seven issues via strategic action plans: (1) atoll and reef island restoration, (2) coral reefs and coastal management, (3) endangered and threatened species, (4) offshore fisheries, (5) cultural and historical heritage, (6) seamount and deep seas, and (7) climate change.

Current management status

After declaration in 2006, a survey of the islands in PIPA was conducted, and eradication of non-native species (particularly rabbits and rats) from the islands occurred in 2008. In 2008, the Kiribati government doubled the size of PIPA and a management plan was written in 2009, though managers are still working to implement most of the assessments and actions. Managers and supporters of PIPA are still working to build the PIPA Conservation Trust Fund (see below) that will allow for increased monitoring and enforcement of the region.

Indicators of effective management

All of the Strategic Action Plans have targets and actions associated with them for each of the seven issues. The targets for each are listed below:

(1) Atoll and reef island restoration: By the end of 2014 a PIPA Atoll and Reef Islands Restoration programme will be implemented that ensures the continued recovery of native island biota, e.g., seabirds, through targeted invasive species eradications and follow up monitoring. Further a PIPA Biosecurity programme will be designed with the primary aim of preventing any further introductions of alien species and the implementation will be integrated into the PIPA Core Management programme.

(2) Coral reefs and coastal management: By the end of 2014 PIPA's coral reefs and coastal habitats around 7 of the 8 PIPA atoll and reef islands will have been fully protected for the 5 year period, through complete protection and recovery from past unsustainable practices, e.g., shark finning. Meteorological impacts, e.g. coral bleaching will be better understood through work undertaken in the PIPA Monitoring and Evaluation programme. For Kanton Atoll, a Sustainable Resource Use plan will be developed and implemented, inclusive of coral reef and coastal management needs. Further climate change adaptation measures as recommended by SAP2.7 Climate Change programme will be assessed and implemented as resources allow.

(3) Endangered and threatened species: By the end of 2014, effective PIPA Endangered and Threatened Species conservation will be fully integrated into the management of PIPA. Further, the PIPA Monitoring and Evaluation Programme will enable detection of trends in these species, and the threats facing them, in order to improve management interventions designed to improve their conservation status.

(4) Offshore fisheries: By the end of 2014, PIPA's offshore (tuna) fishing will be reduced by 25% on an area closure basis through increased no-take zonation commensurate with compensation from the PIPA Conservation Trust, as set forth in the PIPA Conservation Contract. Impacts of this decision will be monitored through landings and fishing effort data. Research will be identified to further clarify tuna spawning hot spots and special management zones within the PIPA.

(5) Cultural and historical heritage: By the end of 2014, a conservation and information programme for PIPA's cultural and historical heritage programme will be designed and implemented under the direction of the Kiribati Museum and Cultural Centre in partnership with the MELAD PIPA Office.

(6) Seamount and deep seas: By the end of 2014, increased understanding and conservation of PIPA seamount and deep sea habitat will be fostered through targeted research, a proposed seamount naming campaign and increased representative habitat protection in the Phase 2 Zonation no-take zones.

(7) Climate change: By the end of 2014, best practice measures for climate change adaptation in tropical marine protected areas will be investigated and implemented, as resources allow for PIPA. Further, a PIPA Climate Change Research Programme will be designed and promoted using PIPA as a globally important sentinel site in understanding the impacts of climate change on tropical marine and island atoll systems in the virtual absence of other anthropogenic factors.

Key website

http://www.phoenixislands.org/index.php

Application to the Pacific Remote Islands and other pelagic MPAs

The PIPA and PRIMNM have a number of similarities, particularly because both MPAs are exceedingly large and remote. Additionally, they are located in a similar geographic region, so there is overlap between the ecology, species and management issues. The PIPA Management Plan could serve as an excellent model for the PRIMNM management plan. It includes a comprehensive set of guiding principles (see *Management Strategy* above), and addresses many of the issues faced by a large pelagic MPA including:

- Illegal fishing and overfishing
- Climate change impacts: coral bleaching, sea level rise, ocean acidification
- Preservation of cultural heritage
- Unregulated visitors (e.g., yachts)
- Vessel groundings and oil spills
- Increased tourism
- Surveillance and enforcement of isolated regions
- Human capacity and resources

Below we highlight a few key applications for the PRIMNM, but suggest that the entire PIPA Management Plan be considered as a template for the PRIMNM.

Interagency responsibilities and disagreements

PIPA has established a management council that resolves interagency disagreements when they arise, and the management plan has a table that outlines the detailed responsibilities of different agencies. Further, they have a plan and language to make sure that the agencies have adequate structure and financial backing to be sure those responsibilities can be carried out. The management plan states:

> "During 2010, a description and costing will be completed for each of the above services, including promoting synergies and linkages between the various agency roles and responsibilities. The source of funding will be specified, including those from PIPA financing and from existing budget allocations from the National Treasury. Services that are to be contracted under this Management Plan will be budgeted and agreed on an annual basis under the auspices of the MELAD Minister. Modalities for financing these costs will be outlined in each annual work plan (e.g., from endowment income, grants, penalties, permits, fines, allocation from other ministries/departments)."

Given that the PRIMNM is managed by two different agencies (NOAA and USFWS) and that enforcement involves additional agencies such as the US Coast Guard, creating a similar management council and structure to handle disputes and assign responsibilities will aid in effective management. Additionally, determining the financial backing for responsibilities on a regular basis will ensure that agency responsibilities can feasibly be carried out.

Enforcement

PIPA managers have identified a number of tools to help effectively enforce this large, remote area. The key to a successful surveillance and enforcement for PIPA relies on the fact that vessels do not generally transit through the Phoenix Islands en route to anywhere else; rather it is a deliberate, purposeful decision to be in the Phoenix Islands area. The same is also true of PRIMNM, so many of the strategies below should be successful in PRIMNM as well. Additionally, PIPA managers have focused on finding cost-effective methods of monitoring and enforcement because PIPA encompasses such a large area and Kiribati is not a wealthy nation. They utilize a number of strategies for enforcement, outlined below.

Vessel Monitoring System (VMS): All licensed boats must carry VMS system to identify vessels and locations in real time. VMS data can be matched to a geo-fence operated by the fisheries agency that alerts managers when vessels are known to enter a particular area. Requirements for VMS to enter PRIMNM are a feasible option.

Visitor and resident reporting: All vessels must report their presence during their stay in the PIPA, as well as sightings of all other individuals or vessels, any suspicious activities, any out of the ordinary conditions. Sightings must be reported on the day observed. Reports will be sent to the Fisheries Licensing and Enforcement Unit, the Kiribati Maritime Police Service (KPS) and the PIPA Office. The reporting format is as follows: individual name / vessel name / vessel number / time in GMT / suspicious activity (short description, GPS co-ordinates). This would be a cost-effective means of surveillance of the PRIMNM as well and may also increase awareness of the monument.

Agreements with partner countries to increase capacity: Despite being a small island nation, the Kiribati Government is taking advantage of agreements with partner countries and its sister site MPA (Papahānaumokuākea MNM) to achieve additional enforcement and surveillance in PIPA:

1. ***Aerial surveillance:*** Aerial surveillance is provided by New Zealand and Australian Air Forces coordinated with regular and special surveillance operations run by the Kiribati fisheries agency.
2. ***Shipriders Agreement (USA):*** USA/Kiribati Shipriders Agreement (2008) states that Kiribati Maritime and Fisheries Officers are able to travel on US Coast Guard Ships and have the full power of arrest, of vessel and other related powers under Kiribati Law. This initiative has already proven highly successful with the impoundment and prosecution of a vessel caught illegally bunkering off Nikumaroro Atoll in PIPA (resulting in a $4.7M AUD fine). Similar agreements could be initiated with the Government of Kiribati given the proximity of PIPA to some islands in the PRIMNM.

The management plan states that "with additional PIPA resources for Fisheries Surveillance and Enforcement [presumably from the PIPA Conservation Trust, see below] coupled with the Government of Kiribati's requirement for VMS, geo-fencing capacity, and 100% observer coverage, that the surveillance of legally licensed vessels is manageable."

Trust to finance management

Prior to the creation of PIPA, surveillance of the region was financed by revenue from fishing permits. With the phasing out of fishing in much of PIPA, the Government of Kiribati, Conservation International and the New England Aquarium have worked to establish the PIPA Conservation Trust to support the financial needs of the MPA. No-take areas in PIPA are being established in phases as the trust grows with time. Currently, 3.87% is no-take area, and by the time Phase 2 (with 25% as a no-take area) is put in place, the trust will be able to support $300,000 USD in costs annually. Additional private and non-profit funders are also contributing well over $3 million/year. The establishment of a similar trust may be feasible for the PRIMNM to support some portion of its operating costs, maintaining a steady stream of income even in difficult budgeting years.

Monitoring

Given that PIPA occurs in the same biogeographic region as the PRIMNM, and the specific monitoring components they have outlined may be helpful for the PRIMNM. Additionally, coordinating monitoring between the two regions may reduce monitoring costs and will aid in determining landscape-wide assessments of key species. The PIPA Management Plan requires monitoring of the following environmental and management indicators:

1. Bird population trends
2. Ecosystem/vegetation monitoring
3. Live coral cover trends
4. Selected reef fish population trends
5. Reef shark population trends
6. Turtle population trends
7. Pelagic conditions within the PIPA, including fisheries landing trends
8. Annual visitor number trends

The management plan also includes a detailed table of the previous surveys of each of these components (see Table 5 below).

Issues to results

In the PIPA Management Plan, managers outline seven target issues (atoll and reef island restoration, coral reefs and coastal management, endangered and threatened species, offshore fisheries, cultural and historical heritage, seamount and deep seas, and climate change) and have a strategic action plan (also called 'issues to results') for each issue. More than just an action plan, it also considers the resources that will support resolving these issues, and assigns responsibilities to relevant parties. The use of 'Issues to Results' may be useful in the PRIMNM management plan. The management plan states:

> "For each 'issues to results' a summary end desired target state is identified for this Plan, the baseline status of the issue summarised as at January 2010, and a series of actions outlined. It is envisaged that significant fund raising effort will be used to package these 'issues to results' initiatives to secure additional project grant funding, resources, and expertise for their implementation in addition to core resources secured for the PIPA Core Management outlined above. For each of these 'issues to results' programs detailed work plans and budgets will developed as part of the PIPA Annual Operational Work Plan. Implementation progress in each will be reviewed as part of the core PIPA Monitoring and Evaluation and implementation subject to adequate resourcing. Design and implementation of these initiatives will be synergistic across the PIPA effort combining resources, accessing expertise, and maximizing efficient and coordinated effort and use of funds available."

An example of "Issues to Results" applied to offshore fisheries:

SAP 2.4 PIPA Offshore Fisheries

Target: by the end of 2014 PIPA's Offshore (tuna) Fishing effort will be reduced by 25% on an area closure basis through increased no take zonation commensurate with compensation from the PIPA Conservation Trust, as set forth in the PIPA Conservation Contract. Impacts of this decision will be monitored and understood through monitoring of landing catch and fishing effort data. Currently this excludes fishing effort and revenues from the US Fisheries Multilateral Treaty as the current treaty arrangements do not expire until end 2013. Research will be identified to further clarify tuna spawning *hot spots and special management zones within the PIPA.*

Baseline Situation:

Offshore fishing by distant water fishing nations (DWFN) is currently allowed under license except in the 60 nautical mile purse seine exclusion zone surrounding Kanton Atoll and in the 12 nautical mile no take zones surrounding the eight PIPA islands. PIPA is the world's first MPA to be used in part as a contribution to tuna conservation management and it's compatible with wider regional tuna and DWFN operational decisions that Kiribati is part of, e.g., 3rd Arrangement of the Parties to the Nauru Agreement. Additionally the basis of lost DWFN license fees is a principal component of the PIPA Conservation Trust construct. It is thus important over time to understand more fully the nature of the fishing currently allowed in PIPA, the impact of no- take or exclusion zones and the contribution of area-based closures to tuna conservation management.

In endowment discussions with Government of Kiribati (GoK), catch and revenue estimations have had to rely on a relatively short time-series of data. Consequently, analysis of fishery license revenues hinges on a number of assumptions that cannot be verified or disproved without additional, more precise data. For instance, an important assumption in calculating potential reductions in DWFN revenues associated with the establishment of a tuna "no-take" zone within the PIPA relates to the spatial distribution of the annual DWFN catch and the harvest implications of spatially constraining the DWFN fleet in PIPA waters. Uwate et al (2008) assumed that catch is evenly distributed throughout the Phoenix Islands EEZ. However, it is not clear to what degree foregoing harvests in all or part of PIPA will affect total DWFN landings in the Phoenix Islands EEZ. In addition, it is not clear whether a reduction in catch from the PIPA area results in an equivalent reduction in total catch (from open areas in the Phoenix Islands EEZ as well as DWFN operations in the rest of the Kiribati EEZ), because some or all of the catch and fishing effort that historically took place in potentially closed areas of the PIPA would be displaced to different areas. Indeed, the net effect of some MPAs has been to increase catches in adjacent areas, in what has been termed the "spillover effect." Skipjack tuna juveniles have been collected in the Phoenix Islands area, suggesting that skipjack tuna may spawn in that area. If the Phoenix Islands are a major tuna spawning area, then there may be positive spillover effects in adjacent waters of PIPA, actually enhancing catches in the EEZ areas that remain open to fishing. This dynamic could have significant implications for the impact of the PIPA zonation scheme on net DWFN revenues, and thus on the scope of the no-take zone that could be supported at any set level of the PIPA Conservation Trust.

Apart from tuna fisheries (long line and purse seine), no other offshore fisheries are operating in PIPA waters. Measures to sustainably manage and protect other offshore resources of PIPA must be developed and integrated with programmes for fisheries development and negotiations with DWFN. In particular, fishing methods that destroy habitat must be excluded. See SAP 2.6 on Seamounts.

2010-2014 Actions:

- *Early agreement by GoK and partners as part of the PIPA monitoring programme on which parameters are to be measured to understand fishing effort (catch landings, license revenues) and their relationship to PIPA management and no take fishing zonation. Implementation of this part of the monitoring programme is a high priority to inform the further development and use of the Conservation Contract with the PIPA Conservation Trust.*
- *Expanded tuna no-take zones will be identified and implemented through limitations on annual DWFN fleet licenses as necessary to comply with the terms of the Conservation Contract executed between the GoK and the PIPA Conservation Trust.*
- *Early discussions with the U.S. will be undertaken in advance of the re-negotiation of the U.S. Marine Fisheries Treaty (MFT) to access the potential impacts of various PIPA zonation approaches on potential U.S. MFT revenues.*

Table 5. Marine Ecosystem Monitoring Summary (From PIPA Management Plan)

Indicator	**Parameter**	**Periodicity**	**Location of Record**
Coral Reef Health	Coral cover, benthic cover	Previous (2000,2002,2005) @ 4 years	PIPA Office, MELAD NEAq, CI
	Coral Diversity and Health (Disease, Bleaching)	Previous (2000,2002,2005) @ 4 years	PIPA Office, MEALD NEAq,CI
	Water temperatures	Continuous water temperature loggers since 2000, satellite data, continuous since 1990s.	PIPA Office, MELAD NEAq, CI
Selected indicator Reef Fish and threatened species e.g., clams	Diversity, Abundance, Size class structure, Endemism	Previous (2000,2002,2005) @ 4 years	PIPA Office, MELAD NEAq, CI
Sharks	Diversity Abundance Lagoon nursery populations	Previous (2000,2002,2005) @ 4 years	PIPA Office, MELAD NEAq, CI
Turtles	Diversity Abundance – nesting surveys	Previous (2000,2002,2005) @ 4 years	PIPA Office, MELAD NEAq, CI
Tuna/Offshore Fishing	Effort Catch Bycatch	Continuous by GoK Fisheries as part of DWFN management, note 100% observer coverage is now mandatory in Kiribati waters.	Fisheries, SPC/FFA, PIPA Office, MELAD
Submerged Reefs/Seamounts	Baseline surveys Species diversity And abundance	2002 (partial survey down to 900 m) Effort will be based on resources available – deep sea mission planned for mid 2009.	NEAq, PIPA Office, MELAD

Chagos Marine Reserve Summary

Location

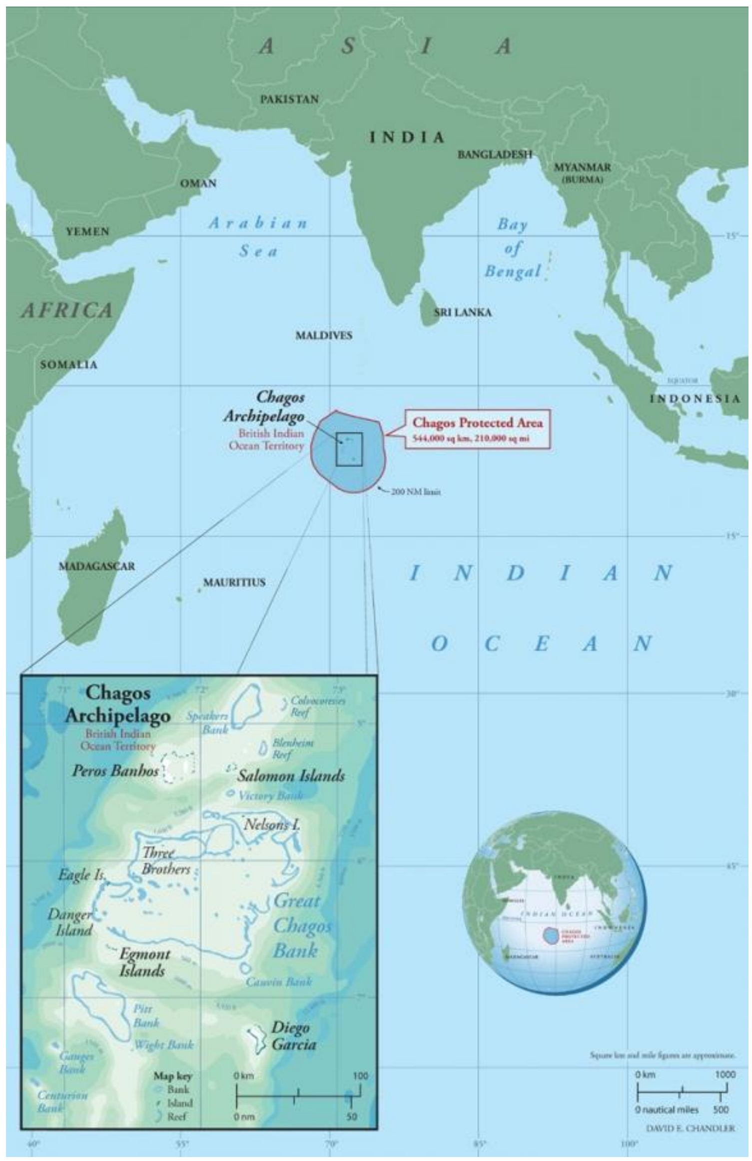
Chagos Marine Reserve (640,000 km^2) is located in the British Indian Ocean Territory of the Indian Ocean and encompasses the entire EEZ surrounding the Chagos Archipelago.

Ratification

The current reserve was designated as a no-take marine reserve on April 1, 2010.

Reason for Designation

Chagos Marine Reserve contains the world's largest coral atoll and 50% of the healthy reefs remaining in the Indian Ocean (Koldewey et al 2010). It has 17 seabird species that breed on the islands. Ten of the atolls have been designated Important Bird Areas by BirdLife International and the red-footed booby population is the largest in the Indian Ocean (Sheppard 2011). Additionally, Diego Garcia and its lagoons were designated as wetlands of international significance in 2004.



Management strategy

Sheppard and Spalding (2003):

- No-take marine reserve throughout
- Maintain or restore Chagos as an intact, functioning reef ecosystem
- Ensure sustainable human uses of the reserve and employ precautionary management
- Conserve or restore significant species to carrying capacity
- Eradicate, control and prevent establishment of non-native species.

Current management status

Before its designation, Chagos was managed under the Chagos Conservation Management Plan (Sheppard and Spalding 2003). Chagos Marine Reserve, however, does not have a management plan in place, though one is currently being written (C. and A. Sheppard, pers comm). Managers are targeting two key components in the management plan. First, one of the goals is to establish enforcement that will effectively keep out large fishing boats, though methods of doing this are currently unclear (Sheppard 2010). Second, they hope to shift the burden of proof to fishermen, allowing for fines to be issued if boats are suspected of fishing. Definitive proof of fishing is difficult to achieve in a large area; a patrol vessel can be spotted from a great distance and once it reaches the fishing vessel, catch has been disposed of and nets are dry (C. Sheppard, pers comm).

Sheppard and Spalding (2003) outlined three primary needs for the region: (1) extensive fully protected areas, (2) scientific advisory group and a program of regular monitoring and rapid managerial response, and (3) a practical mechanism for information gathering and monitoring. As part of Chagos Marine Reserve designation, the area has been fully protected, and a scientific advisory group has been created through the Chagos Conservation Trust. Monitoring and managerial support, as well as a mechanism for effective information gathering, however, has been more difficult.

Enforcement of such a large area is difficult, and an effective mechanism has not yet been determined. Diego Garcia Island serves as a military base for both US and British troops but efforts to engage the military in monitoring and enforcement have not been successful, though just the presence of the base is considered to be somewhat of an effective deterrent (C. Sheppard, pers comm). Enforcement and monitoring is currently conducted using a single British Indian Ocean Territory patrol ship that holds approximately 20 persons. Before the designation of the marine reserve, funding for this vessel came from fishing permit fees. Since the marine reserve creation, private donors have funded it (Graham et al 2010, Koldewey et al 2010). This strategy that may not be sustainable long term and the British Government claims to not have the resources to support the MPA (Paratian 2011).

Indicators of effective management

None outlined.

Key websites

http://www.chagos-trust.org/about/chagos-marine-reserve
http://www.chagossupport.org.uk/

Application to the Pacific Remote Islands and other pelagic MPAs

Similarities between the Chagos Marine Reserve and PRIMNM are that they are large tropical ocean areas that are mostly uninhabited with a military presence.

Explicit incorporation of military responsibilities into management plan

Prior to designation of the Chagos Marine Reserve, two-thirds of the current marine reserve was managed under the Chagos Conservation Management Plan. In this plan, the island of Diego Garcia (where the US and UK militaries reside) is explicitly incorporated into the management plan, including annual scientific monitoring trips to Diego Garcia undertaken by members of the scientific advisory board.

The specific restoration needs of the area under military control are the responsibilities of the UK and US governments that co-reside on the island (Sheppard and Spalding 2003). The US military refuses to conduct or support monitoring or enforcement of the region, claiming that US environmental regulations do not apply on Diego Garcia. The British military, however, is more cooperative because the base falls within British territory and the British military has conducted environmental assessments under the prevue of relevant laws and regulations that apply within the UK. Despite differences in the scenarios between Chagos and PRIMNM, the explicit incorporation of military responsibilities in their management plan should be considered for Wake Island military facilities that are part of PRIMNM. The forthcoming Chagos Marine Reserve management plan might have additional suggestions on incorporating the military into MPA management.

Management of visitors to the MPA

Both Chagos and the PRIMNM are remote and largely uninhabited however both islands receive visitors, largely in the form of yachts. In Chagos, the number of yachts has been increasing, and similar patterns can be expected for the PRIMNM. The anchoring of a large number of vessels in these reef dominated ecosystems could cause tremendous damage, but Chagos has moved towards allowing anchoring only areas defined by location or water depth to reduce impact on reef ecosystems. Additionally, they are considering the possibility of creating moorings within the reserve, and maintaining these moorings using a fee-based system (Sheppard and Spalding 2003). Similar techniques would be successful in the PRIMNM.

Pelagos Marine Sanctuary Summary

Location

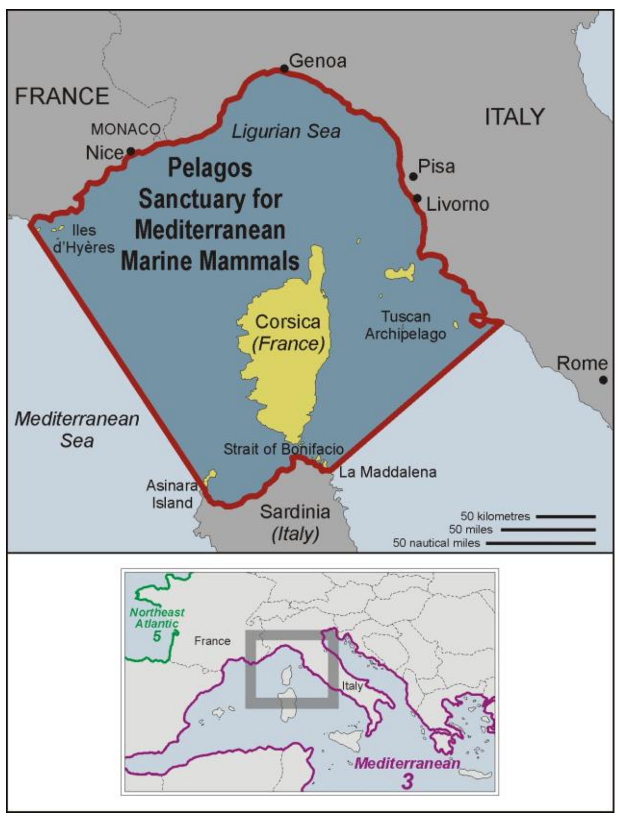
Pelagos Marine Sanctuary (87,492 km2) is located in the Mediterranean Sea on the High Seas between France, Italy and Monaco.

Ratification

The Sanctuary was ratified in 2005 by the Joint Declaration Concerning the Institution of a Mediterranean Sanctuary for Marine Mammals.

Reason for Designation

The Pelagos Sanctuary was designated because it was discovered as being a key area for Mediterranean cetaceans. The Sanctuary contains important foraging and breeding habitats for the entire complement of cetacean species regularly occurring in the Western Mediterranean, supports large resident genetically distinct populations, and provides "umbrella" protection to other marine predators in this area. In addition, the Sanctuary contains what was once suitable habitat for the highly endangered Mediterranean monk seal.



Management strategy

- No gillnet fishing permitted (Agreement, Article 7)
- Addressing threats to cetaceans with clear, targeted management actions

- Focus on monitoring potential impacts of whale-watching and high-speed boating (for offshore races)

Current management status

Pelagos has been designated and a management plan has been created, though it has not been implemented and is unlikely to be. No active management, enforcement or protection for the region is currently occurring, and political support for the MPA is waning. A strategy to shift management of the area to one that centers on marine spatial planning has been suggested as a means of reinvigorating the process (Notarbartolo di Sciara 2009, pers comm). This would require amending the existing agreement with a more detailed structure that gives specific management authority, financial backing and clearer roles to the contracting parties.

Indicators of effective management

None outlined.

Key websites

http://www.cetaceanhabitat.org/pelagos.php#

http://whc.unesco.org/en/tentativelists/2032/

Application to the Pacific Remote Islands and other pelagic MPAs

Incorporation of dynamic systems

The designation of Pelagos is an example of solid science-based priority setting, and one that effectively incorporated a dynamic oceanographic feature for effective boundary setting. Pelagos was created to protect cetaceans and their habitat, the Ligurian frontal system, known to be key feature for cetacean foraging. A scientific study was conducted to determine the distribution and nature of the frontal system, including its distribution in both time and space. The boundaries of Pelagos were then drawn to encompass the entire frontal region to ensure this critical habitat is incorporated in the protected area year-round.

Though the boundaries of the PRIMNM have already been designated, Pelagos illustrates the effective incorporation of a dynamic oceanographic feature in MPA management. The methods by which scientists determined the distribution of the Ligurian frontal system through time can be applied to determining the oceanographic features of importance within the PRIMNM overall, and relative to specific species or taxa such as pelagic fishes or seabirds. Knowledge of these key oceanographic features can then be applied to creating management priorities. For example, knowledge of a frontal system or persistent eddy within the PRIMNM could be critical for: (1) determining critical habitats that are important monitor as part of the PRIMNM enforcement to reduce illegal fishing and subsequent bycatch within the PRIMNM waters, or (2) key features to incorporate in an ecological monitoring plan, to monitor changes in species assemblages and abundance or oceanographic variables through time.

Protection of Functional Ecological Units

One of the goals of Pelagos is not to just to protect cetaceans, but to use these species as an umbrella for the protection of the larger ecosystem and to protect functional ecological units (Notarbartolo di Sciara 2008, Harwood 2002). For example, Pelagos is a krill sanctuary as well as a whale sanctuary because fin whales eat krill. The agreement specifically states "the term 'habitat' means any part of the range area of marine mammals, temporarily or permanently occupied by them, and utilized in particular for reproductive, birthing, feeding activities as well as a migration route" (Agreement Article 1). This concept is one that could be adopted as part of the PRIMNM management plan, and may help to strengthen arguments in favor of preservation should conflicts arise between extractive interests (i.e. fishing) in the future.

Need for effective management structure, including properly shared authority

Pelagos had all the indicators of success when it was designated. It had strong international political backing amongst the Agreement Contracting Parties, strong support from the EU and other international bodies, and solid scientific reasoning (Notarbartolo di Sciara 2009, personal communication). Despite this, it has largely been a failure. The Pelagos management structure was inappropriately designed and lacks detailed descriptions of the roles and responsibilities of the parties involved (Notarbartolo di Sciara 2009). The individual countries assume the Secretariat of the Agreement's Contracting Parties should act as the surrogate management body but the Secretariat has no authority or financial backing to manage the area; thus despite the existence of a management plan, it has not been revised from its poorly written state, nor has it been enacted (Notarbartolo di Sciara 2009b). None of the three countries involved in its designation take responsibility for managing the region, and instead have blocked the mandates that would give the region greater power for a variety of political reasons. As a result, Pelagos has almost completely failed as an MPA, despite excellent scientific and international backing (Notarbartolo di Sciara, personal communication).

While the PRIMNM exists entirely within the US, there are a number of management parallels between the PRIMNM and Pelagos. With the PRIMNM jointly managed between NOAA and the USFWS, a similar scenario is likely to occur without clearly defined roles, responsibilities and authorities being designated for each of the agencies, and a predetermined process for negotiating situations where authorities conflict or overlap. The experience of Pelagos suggests that defining the roles of the different agencies early in the management process and as clearly as possible will only lend to greater success in managing the area.

Recommendations

Management Plan Recommendations

Consider the Phoenix Islands Protected Area Management Plan as a template

PIPA and the PRIMNM have a number of similarities, and the PIPA management plan is excellently designed with a strong ecological focus and with structured, realistic guidelines for carrying out management plan components. Additionally, managers are eager to collaborate with the PRIMNM to combine enforcement and management efforts.

Coordinate with other federal agencies

Both the US National Marine Sanctuaries and PIPA have applied measures that will be useful to the PRIMNM for collaborative management by NOAA and FWS, as well as other agencies involved in managing, monitoring and enforcing the PRIMNM. The Sanctuaries have the Multi-Agency Advisory Council that consist of representatives from all agencies and facilitates coordination between them. They also have a system for establishing "work groups" with representatives from agencies, stakeholders, and partners that help to coordinate objectives that overlap between the agencies, including facilitating cost sharing. To aid in interagency disagreements, PIPA has a management council that resolves interagency disputes, and creates a detailed outline of responsibilities of different agencies as well as a structure to ensure that agencies have adequate financial backing to carry out responsibilities. Applying similar structures to the PRIMNM will create a realistic, functional management plan.

Explicitly include functional ecological units in the management plan

The Pelagos Sanctuary (see appended case studies) explicitly incorporates the protection of functional ecological units, meaning that in protecting cetaceans, they are also protecting krill, a major forage source, as well as all habitats. Explicitly incorporating this will strengthen protective measures for vulnerable species within the PRIMNM.

Explicitly incorporate US military responsibilities in the management plan

Chagos Marine Reserve explicitly incorporates military responsibilities into their management plan, for example outlining monitoring trips and restoration activities on the base. Similar measures would aid management of Wake Island within the PRIMNM.

Determine management priorities for potentially conflicting management objectives

PRIMNM may encounter conflicting management objectives such as those that have occurred between monk seal and shark populations in Papahānaumokuākea MNM. In this case, conflict has arisen because shark populations in the MPA pose a risk to monk seal recovery. Attempts by managers to address shark predation on seals through selective killing are met with mixed support by the public and agencies with similar but different management philosophies. Creating a hierarchy that defines management priorities *a priori* will aid in reducing the cost and time associated with determining management actions when priorities conflict (see Step 9 in Conservation Planning).

Enforcement

Designate anchorages and create moorings

Visitors arriving on yachts will undoubtedly increase with time, as has been observed in the Chagos Marine Reserve. Designating anchorages and creating moorings within the reserve will help avoid damage to coral reefs from anchoring. This has proved to be a successful strategy in Chagos (see Chagos Marine Reserve summary), and other coral reef MPAs around the world.

Promote peer reporting

PIPA employs a peer reporting system to monitor vessels within the MPA that would be highly useful in the PRIMNM. All vessels must report their presence during their stay in PIPA, as well as sightings of other individuals or vessels, to the Marine Police Service and the PIPA Office within 24 hours. This allows for managers to keep track of movements of vessels inside and outside of the MPA as well as increased awareness of unauthorized vessels (see PIPA summary and Step 10 in Conservation Planning).

Increase cooperative agreements with other countries

PIPA has a number of agreements with other countries to increase enforcement of the MPA, and the PRIMNM would benefit from agreements particularly with island nations such as Kiribati or other nations, such as Australia and New Zealand, who fly through the region regularly. These agreements could be similar to the Shipriders Agreement between the US and Kiribati and the aerial surveillance agreement between New Zealand and Kiribati (see PIPA summary).

Create both biological and enforcement priorities

Synthesize existing biological and human use data (i.e., threats) to determine when and where management actions are most important, and turn those biological priorities into explicit enforcement priorities to aid in enforcement officers to be as efficient as possible (see Step 9 in Conservation Planning).

Monitoring and Performance Measurements

Consider threats and ecological processes outside of the PRIMNM

In order to understand the extent of management actions, threats and processes occurring outside of PRIMNM need to be considered because of the fluid nature of the pelagic ocean. Coordinating with, for example NOAA Pacific marine mammal monitoring and Regional Fishery Management Organizations to monitor the extent of animal movement and threats on a larger basin-scale, will help put PRIMNM management measures in a realistic context. Consider using expert opinion to quantify management targets in the context of threats and processes occurring outside of the sanctuaries (see Step 7 in Conservation Planning).

Coordinate monitoring and research activities with PIPA

Because of the proximity and similarities between PIPA and PRIMNM, managers should consider monitoring similar indicators, and coordinate monitoring efforts to increase applicability across the sites and also potentially decrease the cost of these monitoring programs.

Consider the National Marine Sanctuary Program's tools for evaluating performance

The National Marine Sanctuary Program has developed a simple to use method for evaluating MPA performance (see West Coast Sanctuaries summary). Their system uses an action plan with specific targeted outcomes and performance measures that are similar to the PIPA "Issues to Actions" structure (see PIPA summary). Each site prepares a condition report based on available information, and this could be a reasonable model, adapted for the different sub-components of the PRIMNM, that could aid in helping to frame management actions.

Coordinate monitoring with outside partners

The Sanctuaries have one of the most extensive networks for monitoring via the Sanctuary Integrated Monitoring Network (SiMON) that consists of agencies and universities from around the California region. While the PRIMNM is more isolated than the West Coast Sanctuaries, facilitating similar partnerships in PRIMNM (such as the one already in existence through the Palmyra Atoll Research Consortium) will bolster scientific study and monitoring of PRIMNM.

Apply monitoring tiers

For monitoring to be cost-effective, we recommend first monitoring human activities as potential threats to aid in the identification of priorities and appropriate indicators of ecosystem health and MPA effectiveness. This is based on an assumption that much of this data for a remote area such as the PRIMNM will be more easily and economically collected than biological information. Tracking fish landings and observer reports in US waters surrounding the PRIMNM will provide valuable information to assist with setting biological monitoring. Second, we suggest increasing baseline monitoring data to help understand threats in the context of species and habitats of concern within the Monument. Information on population trends of key species and/or assimilating existing data will help determine priorities for monitoring and management action. Finally, we recommend increasing complex long-term monitoring to determine demographic responses and complex ecosystem interactions only as funding becomes available, as these kinds of studies tend to be more costly. These studies, however, can be excellent to consider in conjunction with academic partners, who have access to greater funding sources.

Monitor pelagic species

We recommend monitoring pelagic seabird species, in particular red-footed boobies and sooty terns because of their abundance and, in the case of boobies, their ability to carry satellite transmitters. These two species are abundant and easily monitored throughout the PRIMNM islands, breed on the islands but utilize different niches when foraging at sea. Still, little is known about details of breeding periodicity and population metrics at many of PRIMNM islands, and we recommend effort be put into understanding the breeding ecology, diet and reproductive ecology of these species throughout their range in PRIMNM.

Improve the scientific understanding of seabird-tuna interactions

As we found during our expert workshops (Maxwell and Morgan 2012), seabird-tuna interactions are poorly understood, particularly in the Central Tropical Pacific. We recommend integrated studies of seabirds and epipelagic fish to better understand the mechanisms by which this interaction occurs, as well as how it affects the breeding success of seabirds so that impacts of fishing on seabirds can be better put into a management context.

Coral reef in the Pacific Remote Islands MNM (photo: Jim Maragos)

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Seabirds and pelagic fishes feeding interaction (photo: USFWS).