RESEARCH PRIORITIES FOR THE PACIFIC REMOTE ISLANDS MARINE NATIONAL MONUMENT

Workshop Report by Marine Conservation Biology Institute

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About Marine Conservation Biology Institute

Marine Conservation Biology Institute was founded in 1996 by Dr. Elliott Norse. Our mission is to advance the science of marine conservation biology and secure protection for ocean ecosystems. We advocate for the multidisciplinary science of marine conservation biology, and for actions that natural and social scientists tell us are essential to maintain the integrity of life in the sea.

Acknowledgements

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Executive Summary

In January of 2009 three marine national monuments were designated by President George W. Bush. One of these, the Pacific Remote Islands Marine National Monument (**PRIM**), includes seven dispersed US island territories and possessions in the central Pacific. The Monument is unique in spanning an enormous area of the central Pacific under one management authority, while protecting 86,888 square miles of lands and waters around Baker, Howland and Jarvis Islands, Wake, Johnston and Palmyra Atolls, and Kingman Reef. The sheer vastness of this realm poses a tremendous challenge to its managers. Marine Conservation Biology Institute (**MCBI**) took an active role in advocating for the protection of the **PRIM**, and is committed to supporting the best possible management plan to protect it. In October 2009, **MCBI** hosted a workshop of scientists and managers in Honolulu, Hawaii to review the state of knowledge and make recommendations concerning needed research in the Monument to address research gaps, threats and management concerns.

The seven areas that are now part of the **PRIM** are home to some of the healthiest and most 'natural' marine ecosystems remaining in the world. They are a unique window into the past; nowhere else do we have such a remarkably intact tropical ecosystem from which to develop baselines for scientific study and restoration management of similar sites. Compared to other areas, they are relatively intact and rich in biological diversity and natural resources and without many of the ailments associated with coral reef ecosystems in human populated regions such as land-based pollution, overfishing and habitat damage.

Despite the relatively excellent condition of the region's coral reef ecosystems, there are still many localized, site-specific concerns for managers to deal with, and the ongoing need to remain vigilant for illegal activity and impacts from ongoing pressures outside the Monument. Within the **PRIM**, workshop participants identified historical uses, primarily military, as having left the islands with lingering site-specific problems, some of them serious. These problems include altered landscapes from guano mining, construction of military bases and ports, World War II battles, and missile and nuclear weapons testing; discarded military debris; hazardous materials landfills; and grounded ships. Depletion and/or contamination of edible fishes, sea turtles, and possibly seabirds occurred at many different places over time. And introduced domestic-pets, rodents, and other alien species are still a concern. Some of these problems are being addressed, but much remains to be done. Human activities originating outside the Monument, but which are likely impacting coral reefs as well as fish, sea turtle, seabird and marine mammal populations, include

commercial fishing and warming sea temperatures, sea level rise and ocean acidification resulting from increasing atmospheric carbon dioxide levels.

In addition to addressing these threats, a broad suite of research activities are needed to establish baseline conditions for the region. The National Oceanic and Atmospheric Administration's Coral Reef Ecosystem Division has characterized the coral reef ecosystem, including oceanographic measurements, and bathymetric and habitat mapping, and this program is vital to Monument management. Expansion of this program to other habitats is needed. The pelagic ecosystem as well as the deep-benthic areas of the **PRIM** are almost unexamined and base-line ecosystem characterization and assessment is required for managers to understand the resources under their protection. In order to achieve the purposes for which the Monument was created, protection of the natural resources of this region, additional funding and logistical support is needed to improve the ability of agency personnel and scientists to visit and monitor the Monument on a regular basis.

Introduction: Purpose of this Report

In January of 2009 three marine national monuments were designated by President George W. Bush. One of these, the Pacific Remote Islands Marine National Monument, includes seven US island territories and possessions in the central Pacific. The Monument (hereinafter referred to as the Monument or **PRIM**) includes 5 distinct areas totaling 86,888 square miles of lands and waters surrounding Baker and Howland Islands, Jarvis Island, Johnston Atoll, Palmyra Atoll and Kingman Reef, and Wake Atoll. The **PRIM** is the third largest marine protected area in the world. The Monument is unique in spanning more of the Earth's surface than any other protected area under one authority, posing a tremendous challenge to its managers. Because of their tremendous natural values and relatively pristine condition, the President determined that the highest and best use of these islands and their surrounding waters was for conservation, restoration, research, and exploration of Pacific marine ecosystems.

Marine Conservation Biology Institute (**MCBI**) took an active role in advocating for the protection of **PRIM**, and is committed to supporting the best possible management to protect its various areas. In October 2009, **MCBI** hosted a workshop of scientists and managers in Honolulu, Hawaii to review the state of knowledge and make recommendations concerning needed research in the Monument to address threats and ongoing management concerns. This report briefly describes the region, summarizes information regarding the natural resources of the region, highlights the key points from the workshop and summarizes the recommendations from the workshop participants.

Overview of Pacific Remote Islands Marine National Monument

The seven areas that are now part of the **PRIM** are home to some of the healthiest and most 'natural' marine ecosystems remaining in the world. They are a unique window into the past; nowhere else do we have such a remarkably intact tropical ecosystem from which to develop baselines for scientific study and restoration management of similar sites. Compared to other areas, they are relatively intact and rich in biological diversity and natural resources. The islands individually have up to four times as many shallow-water, reef-building coral species as the Florida Keys, and are home to hundreds of fish species,

dozens of seabird species, and an untold number of invertebrate species, including many found nowhere else. An estimated 14 million seabirds representing 21 species use the atolls and islands as critical stopover points, as well as breeding areas and feeding grounds. These species include tropicbirds, boobies, frigatebirds, terns, noddies, petrels, shearwaters, albatrosses, and a variety of migratory shorebirds.

Dozens of marine and terrestrial threatened, endangered, depleted and endemic species still thrive here, but are missing or rapidly vanishing elsewhere in the world. The abundance of large predatory fish is quite high, including endemic and IUCN red-listed, rare species such as the Napoleon wrasse (*Cheilinus undulatus*) and bumphead parrotfish (*Bolbometopon muricatum*) (Zgliczyniski et al. 2008).

Abundant, large sharks still inhabit the coral reefs, keeping the ecological structure of the ecosystem intact. Foraging seabirds and schools of large tunas interact in dynamic foraging aggregations that facilitate nutrient and energy cycling between pelagic and coral reef ecosystems adjacent to seabird breeding colonies. Tunas drive and concentrate prey, such as small pelagic fishes and squid, towards the surface where they are accessible to seabirds. The islands serve as critical components of flyways for seabirds and migratory shorebirds, and as stepping stones

Significant Conservation Value of the Monument

- The PRIM is globally the most widespread collection of marine and terrestrial protected areas under a single jurisdiction, and the world's third largest MPA (86,888 sq. mi.); Kiribati's Phoenix Islands Protected Area is 158,453 sq. mi., the USA's Papahānaumokuākea Marine National Monument is 139,793 sq. mi;
- Wake may be the oldest living atoll in the world, containing one of the few remaining healthy populations of the globally threatened bumphead parrotfish;
- Waters surrounding Baker, Howland and Jarvis Islands have fish biomass double that of the Northwestern Hawaiian Islands, and 16 times that of the main Hawaiian Islands – predator biomass exceeds that of Great Barrier Reef and Kenyan MPAs;
- Jarvis Island has nearly 3 million pairs of sooty terns and reef shark biomass is the highest on record;
- Giant clams (*Tridacna* spp.) depleted throughout the Pacific, are common at many sites within the PRIM especially at Kingman Reef and Wake Atoll;
- Johnston Atoll has the deepest reef building zooxanthellate corals on record;
- PRIM contains many migratory and resident seabirds of international conservation concern;
- Palmyra Atoll and Kingman Reef are home to some of the healthiest coral reefs in the world, with large schools of melon-headed whales, and a recently rediscovered species of beaked whale.

for many coral reef species that are now established in the broader central Pacific.

Management of PRIM

Authority to manage the Monument is granted under the Antiquities Act. Howland, Baker, Jarvis Islands, Palmyra Atoll and Kingman Reef, their terrestrial areas, reefs and surrounding waters out 12 nautical miles (nm) are part of the US **FWS** National Wildlife Refuge System under the Department of Interior. Part of Palmyra Atoll is owned by The Nature Conservancy (Cooper Island), and it manages the island as a nature reserve in cooperation with the Refuge System. The land areas at Johnston and Wake Atolls remain under the Department of Defense authority, but the waters out to 12 nautical miles fall under National Wildlife Refuge System jurisdiction. National Oceanic and Atmospheric Administration (**NOAA**) under the Department of Commerce, in consultation with the Secretary of the Interior, manages fishery-related activities from the 12 nm refuge boundary to the 50 nm monument boundary.

Map of Pacific Remote Islands Marine National Monument

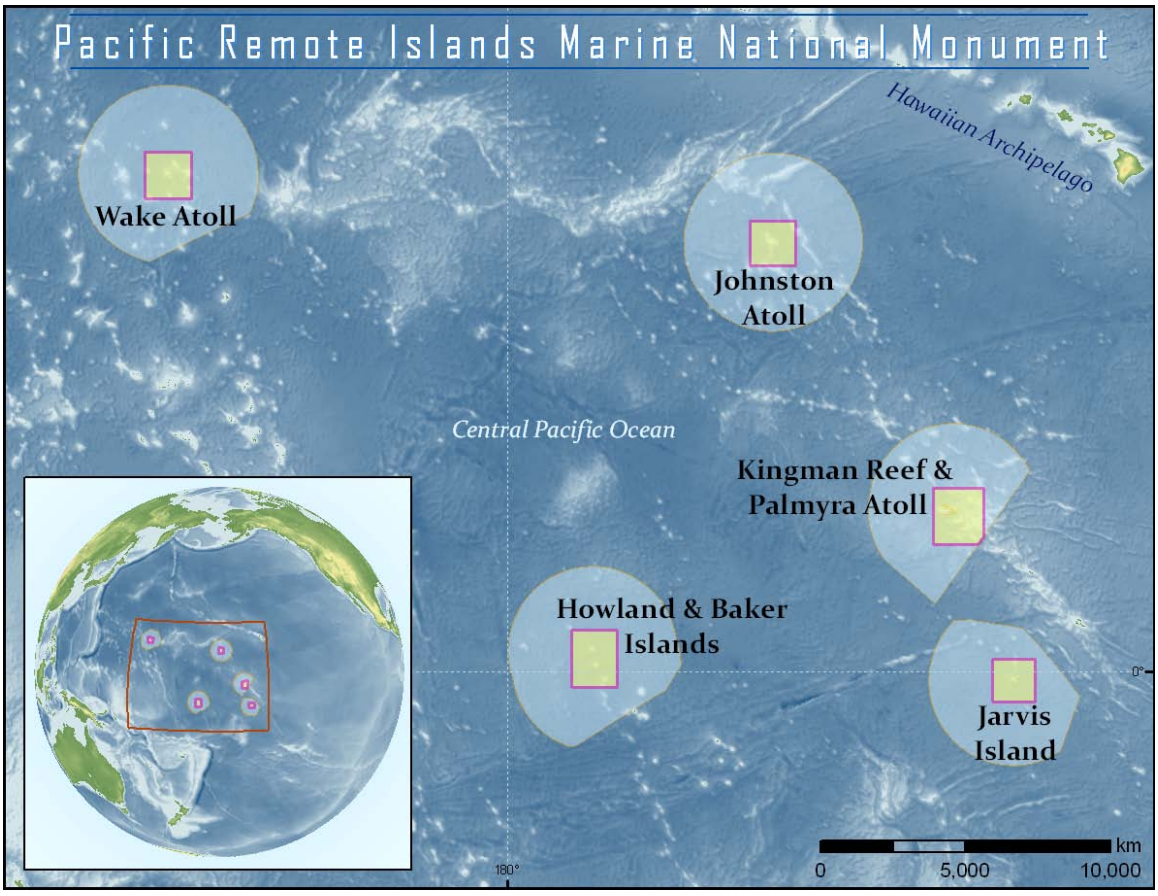


Table 1. Atolls, Reefs and Islands of the Pacific Remote Islands MNM.

Island	Land Area (acres)	Submerged Area (square miles)	Island Chain
Palmyra Atoll	415 acres	20, 695	Line Islands
Kingman Reef	0		Line Islands
Johnston Atoll	696 acres	13,925	Line Islands
Jarvis Island	1,273 acres	13,815	Line Islands
Howland Island	648 acres	20,570	Phoenix Islands
Baker Island	531 acres		Phoenix Islands
Wake Atoll	1,821 acres	14,195	Marshall Islands

Current State of Knowledge

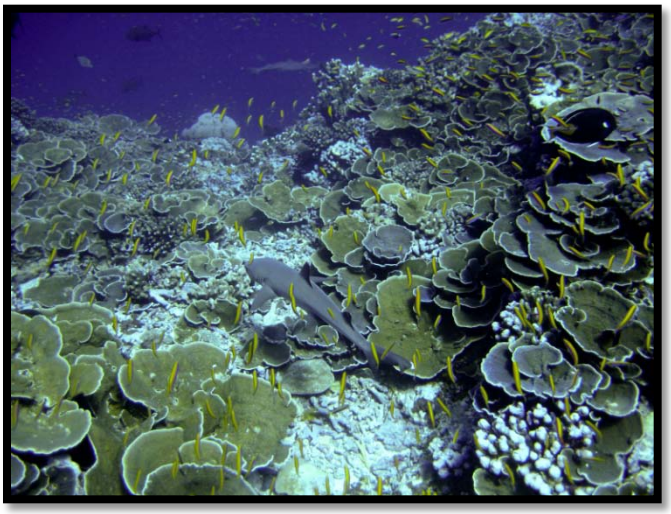
Island and Nearshore Habitats

The coral reefs of the Monument are relatively well sampled, despite the fact that comprehensive coral reef research only began in 2000. The National Marine Fisheries Service's Coral Reef Ecosystem Division (**CRED**) and the Fish and Wildlife Service (**FWS**) constitute the core partnership for monitoring work, and several academic institutions participate in **PRIM** research. Significant map and data resources are available for the **PRIM** through **CRED**[1], which monitors each area every other year. They have completed ecosystem assessments, collected oceanographic information, mapped and monitored all US territories and affiliated islands in the Pacific, allowing for status and health comparisons. In 2008 the coral reefs of the Pacific Remote Islands were comprehensively assessed (Miller et al. 2008) and found to be in excellent shape, albeit with some locally stressed areas that warrant additional study and possible restoration. Because these assessments are relatively recent, additional research is needed to continue to characterize the region and improve our understanding of inter-annual variation, similarities and differences between the coral reef ecosystems of the **PRIM**, and their relationship to coral reefs in other areas of the Pacific.

[1] Pacific Islands Fisheries Science Center http://www.pifsc.noaa.gov/cred/

Coral Reefs

The **PRIM** is one of the only known areas of the world that still possess healthy coral reefs with very high coral cover (> 50%) and intact trophic structure (Jackson 2008, Miller et al. 2008). Kingman Reef in particular has been described as one of the most pristine coral reefs on the planet (Sandin et al. 2008). The seven U.S. central Pacific reef areas collectively contain more than four times the number of shallow-water reef-building coral species as the Florida Keys (Maragos et al. 2008). Palmyra Atoll alone is estimated to harbor three times the number of coral species found in Hawaiian waters and the Florida Keys. Approximately 265 species of stony corals and 41 other prominent cnidarians such as anemones, black corals, corallimorphs and hydrozoans have been reported at the 7 **PRIM** reefs from a total of 329 sites surveys. For instance, Kingman Reef and Palmyra Atoll have 198 and 187 coral and other cnidarian species respectively, the highest in the central Pacific (Federal Register, 2007; J. Maragos pers. comm..); and the deepest reef building corals have been documented in Johnston Atoll waters (Maragos and Jokiel 1986; Lobel and Lobel 2008).



Palmyra Atoll and Kingman Reef lie within the inter-tropical convergence zone and the eastward moving Equatorial Countercurrent. These currents bring larvae from the biologically diverse western Pacific Ocean that then settle in the waters and reefs of these islands. Equatorial upwelling is an important aspect of the oceanography around Jarvis Island that may lead to the high productivity surrounding this island (Gove et al. 2006); Baker and Howland are likely to experience similar effects. Johnston Atoll is thought to be an important pathway of corals, fishes, mollusks and other marine species between the Papahānaumokuākea Marine National Monument and other neighboring reefs and islands within the Line Islands group (Maragos et al. 2008).

While the coral ecosystems of the central Pacific are relatively healthy, they are not without impacts. Human impacts to the **PRIM** include shipwrecks, invasive species, fishing debris, and the residual effects of WWII era construction, operations and warfare. Extensive bleaching due to El Niño-related thermal stress was observed at Howland and Baker Islands in early 2010 and is suspected to have also

occurred at Jarvis Island (R. Moffitt pers. comm.). Despite these problems these coral reefs have intact communities and food webs and are the best representative baseline reefs in the Pacific. The reefs of the central Pacific Islands also provide safe harbor for more than a hundred species of reef building corals with an "elevated risk of extinction" (IUCN), at least 33 of the 75 species proposed for endangered status by the Center for Biological Diversity (Oct. 2009), and have proven themselves to be remarkably resilient in the face of climate change.

Reef Fishes

Recent studies show that coral reefs within the **PRIM** are among the most biomass-rich reefs and atolls in the central, if not the entire, tropical Pacific. Fish assemblages at Howland, Baker, and especially Jarvis Islands have some of the highest biomass and the greatest number of predatory fish of any reefs yet described with densities as among the highest observed in the world; 3.4–8.0 mt/ha (Maragos et al. 2008). Kingman Reef in particular is recognized as a near-pristine relic of natural coral reef ecosystems, and now represents the new baseline standard against which to compare other central Pacific reefs degraded by human impact. Total reef fish biomass at Palmyra Atoll in 2005 was over twice as great as that found along the inhabited coastline of Kiritimati, where the human population is relatively dense; total fish biomass at Kingman was nearly twice that at Palmyra (Maragos et al. 2008). The top fish predator biomass is also significantly greater than other well-protected areas like the Great Barrier Reef in Australia, or the Northwestern Hawaiian Islands. Shark abundance and diversity at Kingman Reef (pristine) is much higher than Kiritimati (influenced by anthropogenic factors); in 2005 reef sharks comprised 62% of total fish biomass at Kingman, in stark contrast to their complete absence at Kiritimati during the same time period (Jackson 2008).

The number of reef fish species found in the **PRIM** continues increasing as scientific cruises document additional species. A recent summary report by Miller et al. (2008) documented the number of coral reef fish species by area; Wake – 190 species, Johnston – 120 species, Palmyra and Kingman – 176 species, Jarvis – 165 species, Howland and Baker – 210 species. Taken together over 500 reef fish species are documented in the remote US Pacific islands, and many are novel species to each island (**CRED** pers. comm.). The islands may also play an important role as larval sources, stepping stones or refuges for reef fish that are found elsewhere in the tropical Pacific. The fish community at Wake Atoll

represents a mixture of species from the Mariana Islands and Hawaii (Lobel 2008). Johnston Atoll's fish fauna is dominated by Hawaiian species; however, some species are indigenous only to Johnston and the Line Islands, and not found in Hawaii. As with other reef life, Johnston Atoll therefore represents an overlap point between fish species from the two regions (Lobel 2008). Some of the fish species on Johnston may be a sub-species of those found elsewhere; the pygmy angelfish has been identified as endemic to the island.

Terrestrial Flora and Fauna

While not the focus of the workshop, there was some discussion of terrestrial ecology. Every area, except Kingman Reef, includes emergent land that provides habitat to a variety of resident seabirds and migrant shorebirds. The islands and atolls contain native vegetation and endemic terrestrial plant species. For instance, Palmyra Atoll has one of the last stands of *Pisonia grandis* trees in the central Pacific. Due to human development and introduced species, *Pisonia* forests have been lost or severely degraded over much of their range. Palmyra Atoll gets large amounts of rainfall and has lush vegetation, but the invasive coconut palm is competing with the native vegetation there.

Relatively few surveys exist for the dry, equatorial islands of Howland, Baker, and Jarvis, which have very sparse vegetation and few terrestrial species because of the limited rainfall. Wake Atoll supports a rare grass species, *Lepturus gasparricensis*.

Pelagic Habitats

To date, there has been relatively little research of the pelagic habitats and species surrounding **PRIM** islands and atolls. Typically, pelagic or oceanic habitats extend from the surface to the depths penetrated by sunlight and exclude nearshore lagoons and reefs. Ocean scale surface currents drive the boundaries of pelagic habitats. Fronts, eddies, wakes, upwelling zones and other oceanographic features provide smaller scale structure within these areas which results in localized areas of increased productivity and prey concentration. These smaller scale oceanographic features attract large pelagic fish, seabirds, sea turtles, and marine mammals.

Large Pelagic Fishes

Large pelagic fishes, such as sharks, tunas and billfishes, are significant predators and key components of pelagic ecosystems. They are highly migratory and range widely throughout the tropical central and western Pacific, and beyond. Four species of tuna are common to this region: skipjack (*Katsuwonus pelamis*), yellowfin (*Thunnus albacares*), bigeye (*Thunnus obesus*) and albacore (*Thunnus alalunga*). There is growing concern over the status of bigeye and yellowfin tuna in the western and central Pacific Ocean. Bigeye tuna are subject to overfishing, and approaching an overfished condition. Yellowfin tuna are likely fished at maximum sustainable yield. Within the US exclusive economic zone

surrounding the **PRIM**, bigeye and yellowfin tuna are targets of the Hawaii-based deep-set (tuna-targeting) longline fishery in and around Johnston and Palmyra Atolls and Kingman Reef, while skipjack is more commonly targeted by the domestic purse seine fleet near Howland and Baker Islands. Other pelagic fishes that are caught and kept by the Hawaii-based deep-set (tuna-targeting) longline fleet are blue marlin (*Makaira mazara*), striped marlin (*Tetrapturus audax*), swordfish (*Xiphias gladius*), sailfish (*Istiophorus platypterus*), short-billed spearfish (*Tetraoturus angustirostris*), mahi mahi (*Coryphaena hippurus*) and wahoo (*Acanthocybium solandri*).

In 2003, a scientific report estimated the world-wide decline of large pelagic, predatory fishes such as tunas at nearly 90% (Myers and Worm 2003). This report was criticized as exaggerating the scale of the decline in the central Pacific (Hampton et al. 2005), and ongoing debate suggests a need to develop accurate and unbiased fish biomass estimates (Weng 2009). Among the populations of pelagic fishes that are greatly reduced are many species of oceanic sharks – the top fish predators in marine ecosystems. In 2006, another analysis further reported a 74% global decline in pelagic fishes from the pre-exploitation, pristine state (Lotze et al. 2006). Globally it is clear that pelagic fishes are being unsustainably fished. Improvements in international fishery management are clearly needed. The loss of these top predators has significant impacts on the structure of ecosystems (Heithaus et al. 2008).

Seabirds

Seabirds are a significant component of the pelagic ecosystem. An estimated 14 million seabirds (from 21 different species) use the emergent lands of the **PRIM** for breeding and those birds plus many more use the marine waters for foraging (**MCBI** & **EDF** 2008, **FWS** pers. comm.). Because tropical oceans have very low productivity, tropical seabirds are adapted to unpredictable and patchy prey distributions (Ashmole 1971). Pelagic ecosystem studies from the eastern tropical Pacific (**ETP**) provide some information from which to draw preliminary inferences about the pelagic habitats in the **PRIM**. For instance, in the **ETP** there is substantial research on the interactions of foraging seabirds and sub-surface predators, and seabirds (most species and most individuals) are pelagic feeders that obtain the fish and squid they consume and feed to their young by associating with schools of large predatory fish such as tuna (Au and Pitman 1986, Ballance and Pitman 1999). These predatory fish chase schools of small pelagic fish to the surface making them available to seabirds; otherwise the fish would be too deep or scattered for the seabirds to reach. Over 100 seabird species have been documented to feed in association with subsurface predators in the **ETP**; these subsurface predators provide the majority of feeding opportunities for some seabird species, and subsurface predators support the most abundant seabird species in this ecosystem (Au and Pitman 1986, Ballance 1993, Ballance and Pitman 1999, Pitman and Ballance unpublished data). This suggests that a decline in subsurface predators would negatively affect seabirds.

Much less is known about the seabirds within the **PRIM** but here too, predatory fishes are an important source of feeding opportunities for seabirds (Fefer et al. 1984). About half of the feeding bird flocks observed during the Gilbert cruises were confirmed to be associated with predatory fish (Harrison and Seki 1987). In the **PRIM**, island wakes and eddies downstream of islands and seamounts act to concentrate nutrients and further enhance feeding opportunities for seabirds. The high nutrients attract small pelagic fish and in turn attract tunas and, consequently, seabirds. The presence of natural densities of these tunas within the foraging radius of seabird colonies enhances the ability of birds to provide adequate food for themselves and their chicks (Ashmole 1967, FWS pers. comm.).

The strong and significant associations of seabirds and fishes in the **ETP** suggest a pressing need to better understand the relationships between seabirds and subsurface predators in the **PRIM**, and indeed, seabird foraging ecology and the interaction of seabirds with pelagic fishes was identified as a top research priority by scientists and managers in the workshop.

Sea Turtles

Five listed sea turtle species are known to occur in waters of the Pacific Islands region, including the Monument: green (*Chelonia mydas*), hawksbill (*Eretmochelys imbricata*), leatherback (*Dermochelys coriacea*), loggerhead (*Caretta caretta*), and olive ridley (*Lepidochelys olivacea*)(**NMFS** & **FWS** 1998 a,b,c,d,e). Green and hawksbill turtles have been documented foraging and nesting in the **PRIM**, while loggerhead, leatherback and olive ridley turtles are known to forage and migrate through these waters (Balazs 1982; Snover et al. 2007). Green turtles are reported nesting on Baker, Howland and Jarvis Islands (**NMFS** and **FWS** 1998a), and Johnston (unsuccessfully; **FWS** 2002) and Palmyra Atolls (Maragos et al. 2008).

Green and hawksbill turtles swim and forage in waters surrounding each of these islands, as well as those of Kingman Reef and Wake Atoll (Balazs 1982). From 1935-1942, Howland Island was inhabited by Americans (civilian and military) and during that time green turtles were reported to be 'abundant' in nearshore waters (Balazs 1982). Based on past surveys and observations, monument areas are more likely to provide important nearshore habitat, including important developmental habitat, for sea turtles than nesting beaches. A recent **NOAA** satellite tracking study of post-nesting western Pacific leatherback turtles from Indonesia, showed that several individuals migrated through or near waters of the **PRIM** on their way to foraging habitats off California (Benson et al. 2007).

Connectivity and population structure for sea turtles in the **PRIM** are not well understood. One turtle tagged at Midway was recovered in poor condition at Wake Island (Balazs 1980). Juvenile and adult green turtles have been noted foraging at Wake Island, although there is no record of nesting (Balazs 1982). Three turtles tagged at Johnston Atoll have been resighted at French Frigate Shoals (in the Northwestern Hawaiian Islands), including two nesting females and one basking male (Balazs et al. 1990). The documented migration of turtles between French Frigate Shoals and Johnston Atoll is consistent with theoretical mechanisms of larval transport (Kobayashi 2006) from the Hawaiian Archipelago to Johnston Atoll.

Currently, the only sea turtle research program within the **PRIM** occurs at Palmyra Atoll by the American Museum of Natural History in association with the Pacific Island Fishery Science Center. There is ongoing concern about US-based pelagic longline fisheries interactions with all five sea turtle species (**NMFS** 1998, **NMFS** Biological Opinions 2004 & 2008, Lewison et al. 2004).

Marine Mammals

Limited surveys have been conducted in the region. The Pacific Islands Cetacean Ecosystem Assessment (**PICEAS**) 2005 cruise surveyed the US EEZ waters surrounding Palmyra and Johnston Atolls (Barlow et al. 2008). At least 21 different species of cetaceans were observed during this cruise; combining this list with other previous reported cetaceans (see **MCBI** & **EDF** report 2008) brings the total number of known cetacean species to 27 for the region. The most commonly observed cetaceans in the 2005 cruise were spotted dolphins (*Stenella attenuata*), striped dolphins (*Stenella coeruleoalba*), short-finned pilot whales (*Globicephala macrorhynchus*), false killer whales (*Pseudorca crassidens*), sperm whales *(Physeter macrocephalus*) and bottlenose dolphins *(Tursiops truncatus).*

Extrapolating from research in the main Hawaiian Islands and elsewhere in the Pacific, it is likely that there exists island-associated resident populations within the region, genetically distinct sub-populations and stocks (e.g., **NMFS** recognizes a separate stock of false killer whales from the main Hawaiian islands), potential critical habitat for some threatened and endangered species (e.g., humpback whales), and possibly new species

(e.g., a resurrected species of beaked whale has been identified in waters surrounding Palmyra Atoll, *Mesoplodon hotaula*; Dalebout et al. 2007).

Deep Benthic Habitats

Deep benthic habitats (the seafloor below 660 ft) in this region have been seldom studied. The most extensively visited area is Johnston Atoll at which 35 submersible dives were conducted in 1983 (Kelley pers. comm.). Submersible and remotely operated vehicles (**ROVs**) have visited the deeper waters of the Line Islands including several each at Jarvis Island, Palmyra Atoll, and Kingman Reef in 2005 (Maragos pers. comm.), but there have been no recorded dives by submersible or **ROV** at Howland or Baker Islands or Wake Atoll. The deep fish community surrounding Johnston Atoll was sampled in the early 1980s and 69 species of fish were recorded from the submersible dives between 100-365 m depth (Ralston et al. 1986).

One key ecological factor driving the distribution and abundance of fish and invertebrates in the region is the depth of the oxygen minimum zone. In comparison to Hawaii the oxygen minima occur at a much shallower depths (200-300m) throughout the **PRIM** region. Similarly, the permanent thermocline occurs at a shallower depth (200m) at Kingman Reef and Palmyra Atoll. Preliminary description of the substrates suggests that carbonate extends to a depth of at least 1360m at Kingman and 1246m at Palmyra (Kelley pers. comm.). No significant manganese crusts were observed at any depth at any site. No basalt was observed at any depth at any site. The deep-water fish observed in the Line Islands, both within and below the oxygen minima depths, include a number of species similar to those found in Hawaiian waters, but also many that are not found there (Kelley pers. comm.). The same general findings apply to invertebrate species. The deep waters surrounding Jarvis appeared to have the richest communities of the three Line Island sites (Kelley pers. comm.). Deep sea corals collected in this region of the Pacific are known to be the longest-lived animals on Earth (*Leiopathes* - 4,265 years, Roark et al. 2009), suggesting additional deep sea discoveries will occur.

Threats to the Pacific Remote Islands Monument

Despite the remoteness of the **PRIM** from human activities and the relatively healthy coral reefs, there are threats to be dealt with by Monument managers. Workshop participants were asked to identify threats to the region. Historical uses, primarily military, have left the islands with lingering site-specific problems, some of them serious. Impacts from historical uses include altered landscapes from guano mining, construction of military bases and ports, dredging and island creation and expansion, World War II battles, missile and nuclear weapons testing, lagoon circulation alteration, discarded military debris, hazardous materials storage (e.g., plutonium deposition, groundwater contamination), and ship groundings. Depletion or contamination of edible fishes, sea

turtles, and possibly sea birds occurred at many different places over time and introduced domestic animals, pets, rodents, and other alien species is still a concern. Some of these problems are being addressed, but work remains to be done.

Commercial fishing and climate change are two threats that workshop participants believed needed additional examination. While commercial fishing is now illegal within **PRIM**, the ecological impact of large-scale commercial fishing throughout the central Pacific poses a threat to Monument species and habitats. These threats include trophic cascades from targeting top predators, bycatch of species that are moving through **PRIM** waters, lost gear (i.e., ghost-fishing and grounding of gear such as fish-aggregating devices (**FADs**) on reefs), shipwrecks on reefs, and invasive species introductions. Illegal fishing has occurred in the past within US waters, though its extent is not clear due to lack of documentation.

Increasing atmospheric carbon dioxide world-wide is driving a suite of environmental changes ranging from rising ocean temperatures and sea levels, to intensifying storms, to increasing acidification, coral bleaching and mortality. Climate change will undoubtedly alter the deep ocean ecosystem through possible changes in the depth of the oxygen minimum zone, acidity, and temperature. The central Pacific will not only experience these changes, but also provides us a chance to monitor and understand these impacts without the "background" noise found in more highly altered human occupied reef ecosystems. In an ocean where impacts from so many different activities weigh heavily on ecosystems, the **PRIM** offers unparalleled opportunities for the study of natural and intact ecosystems.

Other issues that are less immediately threatening or less well understood include; ship traffic and ocean noise, marine debris, disease and inability to detect and rapidly respond to illegal activities. Because there is almost no direct observation of the deep benthic ecosystem there is little known about potential threats to the area.

Pollution

Throughout the **PRIM** there are localized areas where pollution from military activities (i.e., releases of fuels and other chemicals from storage containers, failed missile attempts, eroded landfills, off shore dumps, munitions, World War II battles, and hazardous waste) can be found. In some areas there has been and currently is work in progress to mitigate this pollution. But while types and locations of most of the contamination are known, evaluation of low level and chronic effects of this contamination in atoll ecosystems is needed. There is ongoing accumulation of marine debris in some areas, but in general this is a much lower threat than in areas such as the Northwestern Hawaiian Islands. Pollution and debris from a number of activities persists in the **PRIM** including:

- Limited cleanup by previous/current military occupants (Wake, Johnston, Palmyra, Baker and Howland)

- Failed ventures for commercial activities (tourism, fish bases)
- Marine debris
- Shipwrecks at Wake, Baker, Kingman Reef and Palmyra Atoll
- Remaining primary and secondary impacts from hazardous materials released into the environment (i.e., petroleum, polyaromatic Hydrocarbons (**PAHs**), polychlorinated biphenyls (**PCBs**), metals, plutonium, dioxin)

Habitat Damage

Military activities, shipwrecks and ship groundings are the main cause of ongoing habitat damage from human activities (cyclones and perhaps tsunamis are other major causes of habitat damage). Human causes of habitat damage are:

- Terrestrial landscape alteration on all islands including island enlargement and creation from coral dredged from the lagoon
- Alteration of the lagoons in Palmyra, Johnston, and Wake Atolls from port dredging
- Habitat impacts to the coral reef environment from groundings of ships, eroding and leaking landfills, and debris
    - Inability to remove shipwrecks in a timely manner
    - Difficulty in finding and removing vessels in deepwater areas, Baker
    - Corallimorph proliferation (i.e., *Rhodactis howesii* on Palmyra, Baker and Howland and to a lesser extent on Kingman and Jarvis) from leaching iron. Recent studies (2006, 2010) have concluded there is increasing concern with *Rhodactis howesii* on the western ends of Howland and Baker Islands from remaining ship anchorages or shipwrecks, and other military debris. A greater analysis needs to be made on the exact sources of iron.
    - Research mitigation strategies and monitoring for expansion of corallimorph

Invasive Species

Island ecosystems are especially vulnerable to introduced species (Sax et al. 2002, Steadman 2006). Despite the relative isolation of these islands there are significant problems with introduced non-native species. While Pacific islands are highly vulnerable to invasive species, some species can be easily eradicated on the islands that are small in size and remote (PILN 2008). The primary invasive species include:

- Invasive animal species
    - Rodents - Most rodents have been eliminated from the **PRIM** islands but a few species (*Rattus tanezumi, Rattus exulans, Rattus rattus, and Mus muculus*) continue to plague a few of the islands. Today, the rats are still present in overwhelming numbers at Palmyra and Wake Atolls (**FWS** 2010; Global Invasive Species

Database 2010). Rats on Pacific islands can devastate seabird populations by attacking seabird nesting colonies, eating eggs and chicks, and in rare cases killing adult birds (Norris 2008).

- Ants - A recent survey conducted by **FWS**, discovered a newly established ant species, *Anoplolepis gracilipes* (yellow crazy ant) on Johnston Atoll. This species has literally taken over a large area on Johnston Island, devastating the ecosystem and warrants immediate removal (FWS 2010). They subdue or kill animals on the ground by spraying formic acid and have damaged a large portion of Johnston Island wildlife habitat by displacing hundreds of red-tailed tropicbirds (Global Invasive Species Database 2010; **FWS** 2010).

- Nuisance species
  - Corallimorph - An abandoned 121-foot Taiwanese fishing boat on Palmyra Atoll (Work et al. 2008) and an unidentified 85-foot vessel on nearby Kingman Reef have spurred the exponential growth of a nuisance species called a corallimorph, a close relative of stony corals that lacks an external skeleton. This corallimorph, *Rhodactis howesii*, is a native species, but the leaching of iron from these two abandoned shipwrecks has led to this species overgrowing corals on the reef. The corallimorph is also at Baker and Howland based on 2010 surveys and a minor nuisance at Jarvis Island from corroding metals left behind by humans (FWS 2010). An update on the Jarvis, Palmyra and Kingman infestations is planned in mid-2010.

- Invasive island vegetation
  - Coconut palm trees (*Cocos nucifera*) have been introduced to many the Pacific islands, overtaking many of the native forests. On Palmyra Atoll, coconut palms currently dominate 45% of the forests, overtaking the native *Pisonia*. Palmyra currently supports one of the largest remaining stands of *Pisonia* forests in the Pacific.

They have been degraded elsewhere due to human development (**FWS** 2010). The *Pisonia* forests provide important habitat for numerous seabirds and in effect the bird guano provides important nutrients to the forest understory (**FWS** 2010). *Pisonia* forests are crucial for boobies, frigate birds, terns and shearwater nesting (Smith 2001).

Fishing / Exploitation

Commercial fishing by the US long-line fleet targets bigeye and yellowfin tuna and other pelagic fishes, while purse seine fishing exclusively targets skipjack tuna. The former tends to occur in waters surrounding the more northerly atolls and islands, while the purse seine fleet is more common in equatorial waters surrounding Baker and Howland Islands. A number of potential threats related to fishing were considered important topics for managers of the Monument, even though commercial fishing with the **PRIM** is prohibited. The major concerns expressed by workshop participants were twofold; one concerning the impacts of ongoing fishing in surrounding waters, and a second related to illegal trespass into the Monument. These are summarized as:

- Expansion of commercial fishing and fishing bases in central Pacific
- Removal of top predators and alteration of food web
  - Sharks, billfishes and tunas
  - Impacts of fish declines on seabird feeding associations
  - Bycatch of **PRIM** species of concern (cetaceans, seabirds and sea turtles)
- Fishing debris, lost **FADs** and other lost or discarded gear. **FADs** are floating fishing gear used to attract species that like to congregate under floating objects, most notably tuna. Floating objects such as wood or seaweed mats that are usually found in convergence zones where food and nutrients are plentiful, in what is otherwise is a relatively 'barren' open ocean. **FADs** can have harmful effects on marine ecosystems and fish populations, such as grounding on reefs and beaches, potentially leading to overfishing and acting as an "ecological trap" for tuna and other species by congregating them in non-productive areas (IRD 2008). **FADs** are a becoming a concern globally, and according to FWS most of the **PRIM** islands are afflicted with lost **FADs**. Most recently a large **FAD** was reported snagged on Kingman Reef in 2007, and another removed from shallow waters Palmyra in 2009. At least 12 different **FADs** have been collected at Palmyra in the last 2 years and Baker in 2010.
- Illegal, unregulated and unreported fishing/ increased levels of trespass and unauthorized fishing:

        - Large shark biomass at **PRIM** islands is potentially inviting, especially at Jarvis Island, which is a target for shark-finning given plans to establish a new fishing base at nearby Kiritimati (Christmas Atoll).
        - Deep submersible dives at Kingman, Palmyra and Jarvis in 2005 reveal the presence of commercially value precious corals, including gold, red, and bamboo species. Without onsite surveillance these stocks are vulnerable to poaching, especially at the five uninhabited reefs (Baker, Howland, Jarvis, Johnston and Kingman) of the **PRIM**.
    - Subsistence and recreational fishing in the **PRIM:**
        - Subsistence and recreational fishing are allowed under the Monument Proclamation and will likely continue at Wake and Palmyra Atolls, although at low levels. Limited evidence from Wake suggests that the low numbers of grey reef sharks along the southern margin may be a result of the island's civilian work force frequently fishing for sharks and drying their fins, particularly in the south where access was easier and seas calmer than other parts of the island (Lobel and Lobel 2008). Moreover, coolers packed with fish are continually transported by aircraft to Honolulu and other destinations (**FWS** pers. comm.).

Climate Change and Ocean Acidification

Island ecosystems, the deep and shallow coral-dominated seafloor, and the open-ocean pelagic systems of the Pacific Ocean marine monuments are fundamentally vulnerable to future climate change. Rising sea temperatures, ocean acidification and rising sea levels threaten the capacity for these ecosystems to persist in a **CO_2**-elevated atmosphere. Carbon cycling in the ocean, subsequent shifts in chemistry, increasing temperature, altered oceanographic currents, and rising sea level are of central concern to marine scientists and managers; more specifically:

- Ocean acidification threatens the ability of a number of organisms to build and maintain skeletons or other calcareous structures:
    - Planktonic organisms including phytoplankton, holoplankton and larvae of benthic invertebrates are vulnerable
    - Benthic reef structure: corals, coralline algae and crustose coralline algae
    - Reef dwelling fauna with $CaCO_3$ structures (e.g., mollusks, echinoderms)
    - Increases toxicity of many contaminants
- Sea surface temperature increases:
    - Threaten marine invertebrate species as temperatures approach their thermal tolerance limits. Warm-adapted tropical species may

already live closer to their thermal tolerance limits than cold-adapted species. This means that tropical species may be much less capable of adapting to, and expanding their range because of, increasing seawater temperatures.
        - Coral/algal symbiosis and coral bleaching; High temperatures disrupt the physiological symbiosis between corals and their interstitial algal symbionts. The host coral expels the algal symbiont (and its pigment) – leading to the phenomenon of coral bleaching.
        - Increases toxicity of many contaminants
    - Sea level rise
        - Endemic terrestrial organisms; such as land crabs and vegetation on all islands are vulnerable to the loss habitat that will result from saltwater inundation of the land
        - Nesting seabirds are vulnerable; these islands are among the only breeding sites for seabirds in the central-equatorial Pacific. A reduction in terrestrial habitat has a one-to-one relationship with the reduction in the bird nesting habitat of central-equatorial bird populations. Certain species may be more or less vulnerable depending on the extent of their ranges and erosion of their island habitat.
        - Sea turtles, like seabirds, require terrestrial habitat for successful reproduction. Many turtles are already federally listed as endangered or threatened. A reduction in the terrestrial habitat and inundation of sandy habitat will limit the available nesting habitat for sea turtles
        - Migratory shorebirds, including Species of Concern also require overwintering habitat on islands that may already be dwindling in size.
        - Erosion of landfills will release toxic compounds
    - Disruption or modification of oceanic hydrographic features such as:
        - Ocean basin circulation
        - Equatorial upwelling
        - Convergence zones (gyres and eddies)

Research and Management Priorities for the Monument

Workshop participants were asked to integrate their understanding of the research gaps and threats to identify priority efforts for managers of the Monument. Three separate themes emerged from the discussion of priorities for the **PRIM**. The first was the

mitigation of immediate threats to **PRIM** resources, the second theme was the need to develop better baseline characterizations of **PRIM** ecosystems and species, and the third was the need to research and monitor threats, both now and into the future.

Restore or Mitigate Impacts from Past Activities

Past Military and Human Activities

All of the areas except Jarvis have been altered by military use, especially Palmyra, Wake, Baker and Johnston. Landscapes and seascapes were disturbed and changed by base and airfield construction, the dredging of shipping and sea plane channels, dredging and creation/enlargement of islands, building construction, and WWII battle damage and debris. Civilian settlements were built on Wake, Baker, Howland and Jarvis islands in the mid-1930s. Restoration and mitigation is needed at most of the islands, including restoring natural current flows at Johnston and Palmyra. The removal of shipwrecks, discarded equipment and structures may also have unintended negative impacts that need to be evaluated. There is also a need to study means of remediating waste disposal sites:

a. Research of sub-lethal effects of chronic exposure to remaining contamination
b. Removal and containment of contaminants and hazardous materials
    i. Sea level rise and erosion (release of "contained" materials) needs long-term monitoring
    ii. Burrowing seabirds can release contaminants in soil
    iii. Plutonium cannot be removed from soil and lagoon sediments on Johnston
    iv. Erosion of the metal seawall on Johnston needs monitoring
c. Removal of military debris, especially that which is toxic, hazardous, and/or stimulates the growth (through dissolved iron) of the corallimorph (*R. howesii*)
d. Restoration of the Palmyra lagoon circulation and selective removal of WWII road causeways that impede circulation, threaten adjacent living reefs, and maintain anoxic conditions in the deep lagoon

e. Monitor the health and evaluate the decline of coral communities in Johnston and Wake lagoons

Invasive Species

Human exploration and occupation brought many invasive species to the islands, including various plants, insects, cats and rodents that preyed on bird populations. The **FWS** has eliminated most invasive mammalian predators from islands under their authority, except Palmyra where rat eradication is still ongoing. The US Air Force is the current managing authority at Wake, which also has rats. A house mouse, *Mus musculus*, continues to populate Jarvis, Johnston and Baker. In addition, all of the central Pacific islands have alien ant species that have caused significant ecological damage.

a. Monitoring of introduced species
b. Mitigation and removal of rodents and other alien species from islands

Shipwrecks and Groundings

A major concern associated with vessels or freighters near the islands is the danger of a catastrophic grounding due to human error, weather or mechanical failure. Two fishing vessels have grounded in the islands in the recent past. The 1991 long-line fishing vessel wreck at Palmyra is still on the reef and continues to damage the ecosystem by accelerating the rapid growth of a corallimorph that smothers the living reef ecosystem. The Kingman Reef shipwreck also remains and the reef is showing early signs of the corallimorph, and also an elevated growth of blue-green algae which in time can out compete coralline algae and corals for living space on the reefs. Future groundings could create a major fuel spill that would be hard to contain and clean up because salvage vessels and oil spill response crews are far away.

a. Remove shipwrecks at Palmyra and Kingman
    i. Continue to monitor corallimorph populations
    ii. Research removal methods for corallimorph
    iii. Research detection methods for ghost ships (un-manned and adrift)

Marine Debris

Reports of death by entanglement of marine mammals, sea turtles and seabirds – many of them endangered or threatened - continue to grow. Marine debris comes in many shapes and sizes. Derelict fishing gear is a common source of marine debris, consisting of lines and nets that entangle marine mammals, sea turtles, seabirds and catch fish long after the gear is able to be retrieved. Pieces of plastic—often mistaken for food by sea birds, and plastic bags—mistaken for jellyfish (the primary diet of the critically endangered leatherback sea turtles), are also a huge contributor to marine debris. In recent years several lost **FADs** have washed up on coral reefs in the **PRIM**.

a. Remove debris such as **FADs** entangled on the reefs
    i. Continue to monitor
    ii. Research removal methods
    iii. Develop legislation requiring "cradle to grave" responsibilities for those who place **FADs** in US waters.

Research, Characterize and Monitor Threats

Commercial Pelagic Fishing

Fishing outside of the **PRIM** may affect the marine life inside the region and those species that are transiting through the **PRIM**. A number of significant research questions were posed in the workshop related to the scale of fishing and the impacts to **PRIM** natural resources.

a. What are the impacts to seabirds of large scale reduction in tuna biomass?
b. Does fishing alter the food-web structure (tropho-dynamics) of the pelagic ecosystem, and does it affect the **PRIM** resources?
c. What is the impact of **FADs**?
d. There is a need to understand the movements and abundance of large pelagic fish into, within and through **PRIM** waters
e. What is the extent and potential for illegal, unreported, and unregulated (**IUU**) fishing in the central Pacific?
f. Can remote surveillance technologies detect and help enforce the commercial no-fishing mandate within the **PRIM**?

Climate Change

Climate research, along with ecological monitoring and conservation, should be actively developed within the **PRIM**. Just as the **CO_2** records of Mauna Loa in Hawaii and the ice-cores of Antarctica are valuable tools in our understanding of human-driven climate change, the **PRIM** offers the same unique and globally significant opportunity to understand climate impacts on the ocean. These reefs are ideal laboratories for

monitoring the effects of global climate change, as other threats, such as coastal pollution, disease, and overfishing are mostly absent.

a. Direct measurement of ocean warming, acidification, sea level rise, hypoxia (oxygen minimum depth)
b. Unique opportunity to study the process in the absence of other human-caused stressors
c. Management opportunity to evaluate marine reserves as a tool to enhance resiliency of ecosystems
d. Establish baseline conditions in the **PRIM**

Surveillance and Enforcement

Potential for unauthorized and illegal trespass into the **PRIM** was a major concern to workshop participants. A number of discussions involved the potential for illegal fishing activities, but there is a lack of existing data with which to assess the threat. Participants suggested that a high priority was develop methods of surveillance and to work with the US Coast Guard to:

a. Increase capacity to monitor areas (vessels and planes)
b. Increase outreach
c. Expand and update surveillance technology
d. Use radar to detect ships in the **PRIM**
e. Establish on-site field camps
f. Couple remote sensing technology used for natural science with surveillance programs to better understand human activities
g. Partnerships with other nations in the region, Kiribati, French Polynesia, New Zealand on surveillance issues
h. Explore opportunities to use our understanding of natural history to aid the US Coast Guard's surveillance efforts (i.e., high shark biomass at Jarvis)

Monitoring

Along with maintaining the existing coral reef monitoring, several additional monitoring efforts were discussed and suggested for the **PRIM**. Maintaining and expanding **CRED's** biennial cruises and building additional partnerships is a primary objective for monitoring.

a. Expand Rapid Ecological Assessments and add permanent transect monitoring across multiple depths and habitats at each location
b. Measure microbial diversity (Partner - Dr. Forest Rohwer, San Diego State University)
    i. Valuable as a measure of disturbance to ecosystem
    ii. Study microbes across the **PRIM**
c. Community metagenomics – ongoing work includes the use of autonomous reef monitoring structures to measure cryptic reef biodiversity

d. Climate and natural disturbance
    i. Coral bleaching and recovery
    ii. Corallimorph spread and impacts
e. Acoustic monitoring (may also support surveillance and enforcement)
    i. High frequency acoustic recording package (HARPs) – used to monitor cetaceans, moored to the seafloor and retrieved at several month intervals (one currently at Palmyra) (work by **NMFS** Protected Species Division)
    ii. Ecological acoustic recorders (**EARs**) could be modified for real time vessel monitoring to assist with management – characterize vessel activity (part of the current **CRED** program)
f. Establish on-site field camps on all currently uninhabited islands to better understand seasonal changes in species patterns and abundance, especially at the equatorial islands of Howland, Baker and Jarvis (also supports surveillance and enforcement)
g. Use remote sensing to document vegetation changes
h. Eventually the **FWS** must obtain its own ship and be primarily responsible for monitoring and surveillance, and field camp maintenance, especially if **CRED** efforts diminish in future years

Characterize and Assess Ecosystems

Nearshore Ecosystem Characterization

Maintain partnership with **NOAA's CRED** and other research institutions to:

a. Conduct Coral Reef Ecosystem Surveys
    i. Corals (cover, species and abundance)
    ii. Algae (cover, species and abundance)
    iii. Fish (cover, species and abundance)
    iv. Benthic invertebrates (cover, species and abundance)
b. Maintain Oceanographic Observations
    i. Ocean temperature
    ii. Salinity
    iii. Wind and wave energy
    iv. Tides and currents
    v. Available UV-B
    vi. Photosynthetically active radiation (PAR)
c. Map and Characterize Benthic Habitats
    i. Bathymetry (especially shallow water areas)

ii. Backscatter imagery for habitat characterization
iii. Optical validation - The collection and analysis of photographic data to ground truth and interpret multi-beam data layers with the goal of characterizing seafloor habitats

d. Model hydrodynamics in the **PRIM**; critical to understanding ecosystem health and change
e. Research population connectivity; research the genetic patterns of **PRIM** species to other locations in the central Pacific and verification of species likely to be listed as endangered or threatened, (Partner - Hawaii Institute of Marine Biology)
f. Monitor coral reef diseases (Partner - Hawaii Institute of Marine Biology)
g. Monitor reef accretion and sea water chemistry to monitor effects of ocean acidification
h. Research sea turtle presence and abundance (monitor nesting)
    a. Research current demographic trends
    b. Examine regional population connectivity
    c. Develop baseline information necessary for management
i. Research seabird population and abundance trends (year round monitoring to understand breeding and nesting)
j. Identify contaminant effects

Pelagic Ecosystem Characterization

Characterize and assess the ecosystem; (Partner - NMFS Southwest Fisheries Science Center)

a. Pelagic Ecosystem Assessment Survey
    i. Cetacean survey – line transect surveys and photo-identification work
    ii. Seabird survey – line transect surveys
    iii. Plankton, jellyfish, fish collections
    iv. Acoustic monitoring
    v. Oceanographic monitoring
b. Understand the ecological role of top predators in the central Pacific pelagic ecosystem
    i. Tuna, shark, cetacean population structure and movements, foraging and diet studies
    ii. Seabird population structure and movements, foraging and diet studies
    iii. Scale and density of tunas that supports seabird foraging
c. Better information on lower trophic level species, flying-fish and squids, vertical migrating species
d. Research the degree to which there are subpopulations and island associated marine mammals and sea turtles

Deep Benthic Ecosystem Characterization

Very little survey work has been done in the meso-photic or deep sea reaches of the **PRIM**. Priorities are characterization and mapping.

a. Multi-beam bathymetric mapping of entire **PRIM** area, supplementing the current mapping of the individual islands
b. Habitat and environmental characterization (Partner - University of Hawaii Undersea Research Laboratory and **NOAA** Office of Ocean Exploration and Research)
    vi. Surface deployed instruments
    vii. Submersibles - **AUV**, **ROV**, submarines
c. Identify **PRIM** resources (geological, biological and mineral)
d. Identify fundamental research, including process science such as connectivity, tropho-dynamics, life history strategies and effects of potential natural and anthropogenic changes
e. Develop long term question-driven monitoring, through instrumentation and field activities
f. Establish transects in the meso-photic and deep zones for long term monitoring.
g. Identify and describe new species

The successful undertaking of these various activities is dependent on logistical support, inter-agency cooperation, and robust, dedicated funding. In addition to the research conducted by federal agencies there is also the Palmyra Atoll Research Consortium[2] that can provide additional support. The consortium focuses on managing facilities and coordinating research on Palmyra by consortium members under five different themes: biodiversity composition and multi-scale connectivity; the role of top predators; lagoon ecology and restoration; terrestrial ecology and restoration; and climate change.

The clear articulation of priorities will allow for scientists and researchers in other agencies to request additional support to undertake some of these tasks. Ongoing requirements for better field support and access to ship time is one of the key limitations to carry-out these activities. Of course, lack of funding for mitigation and monitoring, and field camps is also a key impediment. Over the short-term, continued communication with the larger community of interested scientists, and cooperation with agency colleagues will provide better planning and coordination of limited resources to explore this very large, remote and inaccessible area.

[2] http://www.palmyraresearch.org

Summary

The newly established Pacific Remote Islands Marine National Monument brings a diverse set of tropical coral reef island and atolls as well as significant areas of surrounding pelagic waters under one managing authority with the express purposes of conservation and research. There are a number of previous activities that continue to threaten localized sites within the region and that are a priority for mitigation, including 1) removal of military debris and hazardous materials and the research and monitoring of their impact on the island and marine ecosystems, 2) restoration of habitats damaged by military activities and shipwrecks, and 3) removal of invasive species. A broad suite of research activities are needed to establish baseline conditions for the region. The Coral Reef Ecosystem Division's Monitoring Program has made great progress in an initial quantitative characterization of the coral reef ecosystem, including oceanographic characterization and bathymetric mapping and this program is vital to the management of the region. Study of the pelagic and deep-benthic areas of the **PRIM** is almost at square one and basic ecosystem characterization is needed.

Other management issues that will also need to be addressed as the **PRIM** begins its new mandates are; 1) the role and potential impact of pelagic fishing outside of the **PRIM** to the resources inside and transitory through the **PRIM**, 2) monitoring and surveillance of the monument given the potential for trespass and illegal fishing, and 3) the very significant potential impacts from increasing global atmospheric carbon dioxide. The **PRIM's** rarely visited coral reef ecosystems offer a tremendous opportunity for research to identify ecological baselines for healthy coral reef ecosystems, understanding the ecological functioning of these ecosystems and providing an opportunity to understand future impacts of climate change in the absence of overwhelming human activities in other populated regions.

Citations

Ashmole, N.P. 1971. Seabird ecology and the marine environment. In: Farner, D.S. and J.R. King (eds) Avian Biology 1: 223–286.

Ashmole, N.P. and M.J. Ashmole. 1967. Comparative feeding ecology of sea birds of a tropical oceanic island. Peabody Museum of Natural History, Yale University Bulletin 24.

Au, D.W.K. and R.L. Pitman. 1986. Seabird interactions with dolphins and tuna in the Eastern tropical Pacific. Condor 88: 304-317.

Balazs, G. 1982. Status of sea turtles in the Central Pacific Ocean, pp. 243-252. In: K.A Bjorndal (ed), Biology and Conservation of Sea Turtles. Smithsonian Inst. Press. Washington D.C.

Ballance, L.T. 1993. Community ecology and flight energetics in tropical seabirds of the eastern Pacific: energetic correlates of guild structure. Ph.D. Dissertation. University of California Los Angeles.

Ballance, L.T. and R.L. Pitman. 1999. Foraging ecology of tropical seabirds. Proceedings of the 22nd International Ornithological Congress, Durban: 2057-2071. Adams, N. and R. Slotow (eds.). Johannesburg: BirdLife South Africa.

Barlow, J., S. Rankin, A. Jackson and A. Henry. 2008. Marine mammal data collected during the Pacific Islands Cetacean Ecosystem Assessment Survey (PICEAS) conducted aboard the NOAA ship *McArthur II*, July – November 2005. National Marine Fisheries Service. NOAA-TM-NMFS-SWFSC-420.

Benson, S., P. Dutton, C. Hitipeuw, B. Samber, J. Bakarbesy and D. Parker. 2007. Post nesting migrations of leatherback turtles (*Dermochelys coriacea*) from Jamursba-medi, Bird's Head Peninsula, Indonesia. Chel Cons Biol 6: 150-154.

Dalebout, M.L., C.S. Baker, D. Steel, K.M. Robertson, S.J. Chivers, W. Perrin, J.G. Mead, R.V. Grace and T.D. Schofield. 2007. A divergent mtDNA lineage among *Mesoplodon* beaked whales: Molecular evidence for a new species in the tropical Pacific? Mar Mam Sci 23: 954-966.

Diamond, A.W. 1978. Feeding strategies and population size in tropical seabirds. Am Nat 112: 215-223.

Federal Register. 2007. Palmyra Atoll National Wildlife Refuge and Kingman Reef National Wildlife Refuge. Federal Register. 287771-25773.

Fefer, S.I., C.S. Harrison, M.B. Naughton and R.J. Shallenberger. 1984. Synopsis of results of recent seabird research conducted in the Northwestern Hawaiian Islands. Proc. Res. Inv. NWHI UNIHI-SEAGRANT-MR-84-01.

Flint, E.N. 1991. Time and energy limits to the foraging radius of sooty terns *Sterna fuscata*. Ibis 133: 43–46.

Global Invasive Species Database. 2010. http://www.issg.org/database

Hampton, J., J.R. Sibert, P. Kleiber, M.N. Maunder and S.J. Harley. 2005. Decline of Pacific tuna populations exaggerated? Nature 434: E1-2.

Harrison, C.S., T.S. Hida and M.P. Seki. 1983. Hawaiian seabird feeding ecology. Wildl Monogr 85: 71.

Harrison, C.S. and M.P. Seki. 1987. Trophic relationships among tropical seabirds at the Hawaiian Islands. In: Croxall, J.P. (ed), Seabird feeding ecology and role in marine ecosystems. Cambridge University Press, Cambridge.

Heithaus, M.R., A. Frid, A.J. Wirsing and B. Worm. 2008. Predicting ecological consequences of marine top predator declines. TREE 23(4):202-210.

IRD, Institut de Recherche Pour le Développement. 2008. Does fishing on drifting fish aggregation devices endanger the survival of tropical tuna? Retrieved July 28, 2008. Science Daily. http://www.sciencedaily.com/releases/2008/05/080515094614.htm

Jackson, J. 2008. Ecological extinction and evolution in the brave new ocean. PNAS 105: 11458-11465.

Kobayashi, D.R. 2006. Colonization of the Hawaiian Archipelago via Johnston Atoll: a characterization of oceanographic transport corridors for pelagic larvae using computer simulation. Coral Reefs 25: 407–417.

Lewison, R.L., S.A. Freeman and L.B. Crowder. 2004. Quantifying the effects of fisheries on threatened species: the impact of pelagic longlines on loggerhead and leatherback sea turtles. Ecol Lets 7:221-231.

Lobel P.S. and L.K. Lobel. 2008. Aspects of the biology and geomorphology of Johnston and Wake Atolls, Pacific Ocean. In: Riegl, B. and R.E. Dodge (eds), Coral reefs of the USA. Coral reefs of the world, Vol. 1, Springer. 806 p.

Lotze, H.K., et al. 2006. Depletion, degradation, and recovery potential of estuaries and coastal seas. Science 312: 1806–1809.

Maragos, J.E. and P.L. Jokiel. 1986. Reef corals of Johnston Atoll: one of the world's most isolated reefs. Coral Reefs 4: 141-150.

Maragos, J., A.M. Friedlander, S. Godwin, C. Musburger, R. Tsuda, E. Flint, O. Pantos, P. Ayotte, E. Sala, S. Sandin, S. McTee, D. Siciliano and D. Obura. 2008. US Coral Reefs in the Line and Phoenix Islands: Chapter 16, pp. 643-654 in Riegl, B.M. and R.E. Dodge, editors. 2008. Coral Reefs of the USA.

Marine Conservation Biology Institute and Environmental Defense Fund. 2008. Potential Marine Conservation Management Areas. Bellevue, WA. 51 p. http://www.mcbi.org/what/what_pdfs/MCBI_EDF_Comments.pdf

Miller, J., J.Maragos, R. Brainard, J. Asher, B. Vargas-Ángel, J. Kenyon, R. Schroeder, B. Richards, M. Nadon, P. Vroom, A. Hall, E. Keenan, M. Timmers, J. Gove, E. Smith, J. Weiss, E. Lundblad, S. Ferguson, F. Lichowski and J.Rooney. 2008. The State of Coral Reef Ecosystems of the Pacific Remote Island Areas, pp. 353-386, in The State of Coral Reef Ecosystems of the United States and Pacific Freely Associated States: 2008. NOAA Technical Memorandum NOS, NCCOS 73.

NOAA/NCCOS Center for Coastal Monitoring and Assessment's Biogeography Team. Silver Spring, MD. 569 p.

Myers, R.A. and B. Worm. 2003. Rapid worldwide depletion of predatory fish communities. Nature 423: 280-283.

National Marine Fisheries Service. 2004. Endangered Species Act – Section 7 Consultation Biological Opinion, Assessment of the effects of the Fishery Management Plan for the Pelagic Fisheries of the Western Pacific Region. NMFS, Office of Protected Species. Honolulu. 252 p.

National Marine Fisheries Service. 2008. Endangered Species Act – Section 7 Consultation Biological Opinion, Assessment of the effects of the Fishery Management Plan for the Pelagic Fisheries of the Western Pacific Region. NMFS, Office of Protected Species. Honolulu. 91 p.

National Marine Fisheries Service and U.S. Fish and Wildlife Service. 1998a. Recovery Plan for U.S. Pacific Populations of the Green Turtle. Prepared by the Pacific Sea Turtle Recovery Team. National Marine Fisheries Service and U.S. Fish and Wildlife Service; Silver Spring, Maryland, and Arlington, Virginia.

National Marine Fisheries Service and U.S. Fish and Wildlife Service. 1998b. Recovery Plan for U.S. Pacific Populations of the Hawksbill Turtle (*Eretmochelys imbricata*). National Marine Fisheries Service, Silver Spring, Maryland.

National Marine Fisheries Service and U.S. Fish and Wildlife Service. 1998c. Recovery Plan for U.S. Pacific Populations of the Leatherback Turtle. Prepared by the Pacific Sea Turtle Recovery Team.

National Marine Fisheries Service and U.S. Fish and Wildlife Service. 1998d. Recovery Plan for U.S. Pacific Populations of the Loggerhead Turtle. Prepared by the Pacific Sea Turtle Recovery Team.

National Marine Fisheries Service and U.S. Fish and Wildlife Service. 1998e. Recovery Plan for U.S. Pacific Populations of the Olive Ridley Turtle. Prepared by the Pacific Sea Turtle Recovery Team.

Norris, S. (2008) "Rat Invasions Causing Seabird Decline Worldwide." *National Geographic Online*. 21 Feb 2010. http://news.nationalgeographic.com/news/2008/02/080221-rats-seabirds.html.

National Marine Fisheries Service and US Fish and Wildlife Service. 1998. Recovery plan for the U.S. Pacific populations of the green turtle (*Chelonia mydas*). National Marine Fisheries Service. Silver Spring. 84 p.

PILN. 2008. Introduction to the Pacific Invasives Learning Network. The Pacific Invasives Learning Network. 16 Feb 2010. http://www.sprep.org/piln/topics/PILN-overview.htm.

Pacific Remote Islands National Wildlife Refuge Complex. Baker Island National Wildlife Refuge Draft Comprehensive Conservation Plan and Environmental Assessment. 2007. 142 p.

Pacific Remote Islands National Wildlife Refuge Complex. Howland Island National Wildlife Refuge Draft Comprehensive Conservation Plan and Environmental Assessment. 2007. 139 p.

Pacific Remote Islands National Wildlife Refuge Complex. Jarvis Island National Wildlife Refuge Draft Comprehensive Conservation Plan and Environmental Assessment. 2007. 140 p.

Ralston, S., Gooding, R.M. and G.M. Ludwig. 1986. An ecological survey and comparison of bottom fish resource assessments (submersible versus handline fishing at Johnston Atoll). Fish Bull 84: 141-155.

Roark, E.B., T.P. Guilderson, R.B. Dunbar, S.J. Fallon and D.A. Mucciaronea. 2009. Extreme longevity in proteinaceous deep-sea corals. PNAS 106: 5204–5208.

Sandin, S.A., J.E. Smith, E.E. DeMartini, E.A. Dinsdale, S.D. Donner, A.M. Friedlander, T. Konotchick, M. Malay, J.E. Maragos, D. Obura, O. Pantos, G. Paulay, M. Richie, F. Rohwer, R.E. Schroeder, S. Walsh, J.B.C. Jackson, N. Knowlton and E. Sala. 2008. Baselines and degradation of coral reefs in the northern Line Islands. PLoS ONE 3(2): e1548.

Sax, D.F., S.D. Gaines and J.H. Brown. 2002. Species invasions exceed extinctions on islands worldwide: A comparative study of plants and birds. Am Nat 160: 766–783.

Snover, M., J. Baker and M. Sullivan. 2007. U.S. Pacific Islands research plan for green turtles (excluding Hawaii). Honolulu. Marine Turtle Assessment Program, PSD, NOAA/NMFS/Pacific Islands Fisheries Science Center.

Smith, D. and D. Papacek. 2001. Report on the levels of the scale insect *Pulcinaria urbicola* and its natural enemies on *Pisonia grandis*. http://www.environment.gov.au/coasts/mpa/publications/pubs/coringa-pest-scale-1.pdf.

Steadman, D.W. 2006. Extinction and Biogeography of Tropical Pacific Birds. University of Chicago Press, Chicago.

Weimerskirch, H., M. Le Corre, S. Jaquemet, M. Potier and F. Marsac. 2004. Foraging strategy of a top predator in tropical waters: great frigatebirds in the Mozambique Channel. Mar Ecol Prog Ser. 275: 297–308.

Weng, K., R. Domokos, K. Holland and J.J. Polovina. 2009. Synchronous assessment of bigeye tuna (*Thunnuus obesus*) and micronekton biomass, distribution and movement patters at Cross Seamount, and the effects of the seamount environment. JIMAR Annual Report: 73-75.

Western Pacific Fisheries Management Council. 2008. Pelagic fisheries of the western Pacific region 2006 Annual Report. Honolulu, HI. 282 pp.

Work, T.M., G.S. Aeby and J.E. Maragos. 2008. Phase Shift from a coral to a corallimorph-dominated reef associated with a shipwreck on Palmyra Atoll. PLoS One 3(8): e2989.

Zgliczynski, B., R. Schroeder, M. Nadon and B. Richards. 2008. Pacific-wide status of the rare/endangered humphead wrasse (*Cheilinus undulatatus*) and bumphead parrotfish (*Bolbometopon muricatum*). 11th International Coral Reef Symposium, Ft Lauderdale.

Appendix 1. Workshop Participants

Participant Name	Affiliation
Greta Aeby	Hawaii Institute of Marine Biology, University of Hawaii
Simone Alin	Pacific Marine Environmental Laboratory, NOAA
Andreas Andersson	Bermuda Institute of Ocean Sciences
Bud Antonelis	National Marine Fisheries Service, NOAA
Paula Ayotte	Pacific Island Fisheries Science Center, NOAA
Lisa Ballance	Southwest Fisheries Science Center, NOAA
Rusty Brainard	Pacific Island Fisheries Science Center, NOAA
Eric Conklin	The Nature Conservancy of Hawaii
Paul Dalzell	Western Pacific Regional Fishery Management Council
Jeff Drazen	Department of Oceanography, University of Hawaii at Manoa
Beth Flint	Pacific Reefs National Wildlife Refuge Complex, USFWS
Alan Friedlander	Hawaii Cooperative Fishery Research Unit, University of Hawaii
Tom Guilderson	Lawrence Livermore National Lab
Aaron Hebshi	United States Navy
Heidi Hirsh	National Marine Fisheries Service, NOAA
Chris Kelley	Hawaii Undersea Research Laboratory, University of Hawaii
Joanie Kleypas	Institute for the Study of Society and Environment, NCAR
Jim Maragos	Pacific Reefs National Wildlife Refuge Complex, USFWS
Maura Naughton	US Fish and Wildlife Service
Don Palawski	Pacific Reefs National Wildlife Refuge Complex, USFWS
Tiffany Patrick	United States Air Force
Donald Potts	University of California at Santa Cruz
Eric Roberts	United States Coast Guard
John Rooney	Pacific Island Fisheries Science Center, NOAA

Stuart Sandin	Scripps Institution of Oceanography, UCSD
Jennifer Smith	Scripps Institution of Oceanography, UCSD
Rob Toonen	Hawaii Institute of Marine Biology, University of Hawaii
Mike Tosatto	National Marine Fisheries Service, NOAA
Linda Wegley	San Diego State University
Kevin Weng	Joint Institute for Marine and Atmospheric Research
LeeAnn Woodward	Pacific Reefs National Wildlife Refuge Complex, USFWS

Appendix 2. Workshop Agenda

Ilima Hotel, Conference Center, 445 Nohonani Street, Honolulu, Hawaii

Monday, October 26, 2009

8:30 – 9:00 am Workshop Registration

9:00 – 9:10 am Workshop Introduction and Objectives

9:10 – 9:20 am Participant Introductions

9:20 – 11:40 am Setting the Stage: Presentations by Experts in the Pacific Remote Islands

- Introduction of agency roles (Don Palawski and Michael Tosatto)
- Brief description of each island/atoll/reef (Beth Flint)
- Nearshore ecosystem overview (Rusty Brainard)
- Pelagic ecosystem overview (Lisa Ballance)
- Deep sea ecosystem overview (Chris Kelley)
- Current threats overview (Jim Maragos)

11:40 – 12:00 pm Overview of Current Research Occurring within the Monument

12:00 – 1:00 pm Lunch

1:00 – 2:40 pm Research Priorities Breakout Groups (Nearshore, Pelagic, Deep)

3:00 – 5:00 pm Reconvene Large Group for Breakout Group Reports and Discussion

Tuesday, October 27, 2009

8:30 – 9:00 am Gathering

9:00 – 9:30 am Recap Day 1 and Introduce Day 2

9:30 – 12:00 pm Management Issues Breakout Groups (Climate, Ecosystem Monitoring, and Human Impacts and Enforcement/Surveillance Needs)

12:00 – 1:00 pm Lunch

1:00 – 2:40 pm Reconvene Large Group for Breakout Group Reports and Discussion

3:00- 5:00 pm Management Issues Breakout Groups Resume Discussions

Wednesday, October 28, 2009

8:30 – 9:00 am Gathering

9:00 – 9:30 am Recap Day 1 and Day 2 and Introduce Day 3

9:30 – 12:00 pm Day 1 Breakout Groups Reconvene and Review Research and Management Priorities by Ecosystem.

12:00 – 1:00 pm Lunch

1:00 – 1:30 pm Reconvene Large Group for Breakout Group Reports and Discussion

1:30– 3:10 pm Morning Breakout Groups Reconvene

3:30 – 5:00 pm Reconvene Large Group for Breakout Group Reports and Discussion

Adjourn