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18F Does monitoring lead to improved coral reef management?

Monitoring supports establishment of Pacific Remote Islands Marine National Monument

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Abstract. The U.S. Pacific Remote Islands consist of Howland, Baker, and Jarvis Islands, Johnston, Wake, and Palmyra Atolls, and Kingman Reef. Except for Wake, these islands and nearshore reefs have been administered as National Wildlife Refuges by the U.S. Fish and Wildlife Service (USFWS) as early as 1926. Before regular marine assessment and monitoring efforts began in 2000, scientists had visited these locations to collect fishes, corals, and other reef life, but few systematic reef surveys were accomplished. Since 2000, systematic inventory and monitoring surveys for fishes, corals, and benthic algae have been conducted by NOAA and USFWS during biennial cruises. Knowledge of the biodiversity, community structure, and condition of these reefs has increased dramatically because of these cooperative monitoring efforts, exemplified by the increase in number of stony corals reported at Howland from 25 to 109, at Baker from 28 to 104, at Jarvis from 0 to 70, at Palmyra from 72 to 177, at Kingman from 0 to 182, at Johnston from 38 to 49, and at Wake from 52 to 97. Informed through these survey efforts of the diversity and abundance of marine biota supported on these central Pacific reefs, President George W. Bush in January 2009 established the Pacific Remote Islands Marine National Monument to protect its historic and scientific objects. Extending 92.6 km from the mean low water lines of its component islands/atolls, this Monument, compared to the Refuges, provides more inclusive protection of the marine ecosystems that sustain the terrestrial, nearshore, and pelagic bionetworks.

Key words: Monitoring, Coral, Algae, Fish, Marine National Monument.

Introduction

The National Wildlife Refuge System (NWRS, or System), a part of the U.S. Fish & Wildlife Service (USFWS) in the Department of the Interior, currently includes 556 refuges totaling more than 150 million acres. The statutory mission established for the System under the NWRS Administration Act of 1966 is "to administer a national network of lands and waters for the conservation, management, and where appropriate, restoration of the fish, wildlife, and plant resources and their habitats within the United States for the benefit of present and future generations of Americans." The mandate of the refuges to manage for "wildlife first" means the needs of wildlife and their habitats take priority, in contrast to other U.S. public lands that are managed for multiple uses. Found in every state and several U.S. Territories, 19 National Wildlife Refuges (NWRs) were located across the central and western Pacific Ocean as of 2008, with a subset of 6 refuges (Johnston Island, Howland Island, Baker Island, Kingman Reef, Palmyra Atoll, Jarvis Island) straddling the equator in the central Pacific (Fig. 1). Islands within Johnston Atoll were federally established as a breeding sanctuary for seabirds as early as 1926. Refuge boundaries at Howland, Baker, and Jarvis Islands, established in 1974, included submerged lands out to 5.5 km, and refuge boundaries at Kingman Reef and Palmyra Atoll, established in 2001, included submerged lands out to 22.2 km. These refuges are an important part of the most widespread collection of coral reef, seabird, and shorebird protected areas on the planet under a single country's jurisdiction (Code of Federal Regulations 2010). Terrestrial portions of the refuges have primarily been managed to contribute to the recovery and protection of native species, with special consideration given to seabirds, migratory shorebirds, and federally listed threatened and endangered species.

Varied histories of commercial and military use have resulted in environmental modifications on emergent refuge lands, including ecologically significant introductions of plant, vertebrate, and invertebrate species. Early terrestrial biological surveys (e.g., Edmondson et al. 1925, Christophersen 1927) typically took place after nearly a century of human contact, so the composition of the native communities can only be surmised by looking at other central Pacific islands that had been spared known introductions such as rats. Later scientific surveys

(e.g., Sibley et al. 1965, Amerson and Shelton 1977) and monitoring by refuge staff provided lists of resident terrestrial biota, but compared to terrestrial resources relatively little was known of the composition, structure, or functioning of the marine ecosystems at these remote locations. Though marine scientists had visited these locations to collect fishes, corals, and other reef life, before 2000 few systematic surveys of the reefs were accomplished or reported in the literature. While the fish fauna was the best known of the reef biota, with close to 300 shore-fish species reported from each of Johnston and Palmyra Atolls, records of stony corals and benthic algae were more impoverished. For Kingman Reef NWR, with close to 200,000 hectares of submerged reef and associated waters within its boundaries, there were no records of any stony coral or benthic algal species; for Jarvis Island NWR, with close to 15,000 hectares of submerged lands, only 5 species of marine algae had been reported but no stony coral species.

In 2000, cooperative reef assessment and monitoring activities were initiated by the NOAA Pacific Islands Fisheries Science Center's Coral Reef Ecosystem Division in collaboration with scientists from the USFWS as part of a larger multidisciplinary effort to assess and monitor coral reef ecosystems in the U.S. Pacific Islands (Brainard et al. 2008). Broad-scale towed-diver surveys were conducted to provide a spatial assessment of the composition and condition of shallow-water (< 30 m) benthic habitats and fishes coupled with site-specific surveys to assess species composition, abundance, and general health of salient reef-associated organisms. Informed by the results of these surveys of the biodiversity, community structure, and condition of these reefs, President George W. Bush on January 6, 2009 issued Presidential Proclamation 8336 to establish the Pacific Remote Islands Marine National Monument (PRIMNM) (Code of Federal Regulations 2010). The purpose of establishing this monument was to ensure the proper care and management of fish, wildlife, and other scientific and historic objects that are situated upon lands and in waters owned or controlled by the United States within approximately 92.6 km from the mean low water lines of Kingman Reef, Wake, Johnston and Palmyra Atolls, and Baker, Howland and Jarvis Islands. Consisting of approximately 225,000 square km, the PRIMNM provides broader spatial coverage of marine resources compared to Refuge boundaries, and the reserved lands are considered in the Proclamation to be the smallest area compatible with the proper care and management of the objects to be protected.

In this paper we present a summary of the dramatic increase in knowledge of the biodiversity of these remote coral reef ecosystems, generated through these cooperative monitoring surveys, which provided a substantial contribution towards the establishment of the Pacific Remote Islands Marine National Monument.

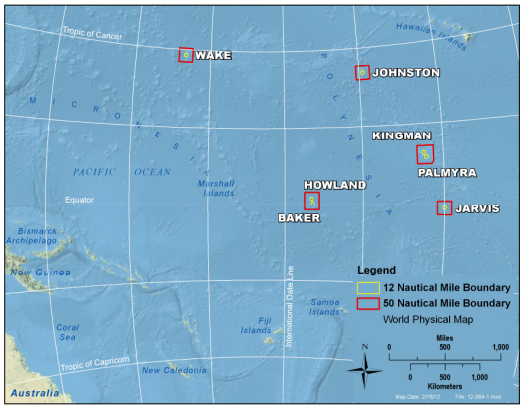

Figure 1: Location of 7 National Wildlife Refuges in the Pacific Remote Islands Marine National Monument

Material and Methods

Reef assessment and monitoring surveys were conducted at Howland, Baker, Kingman Reef, Palmyra Atoll, and Jarvis in 2000, 2001, 2002, 2004, 2006, 2008, and 2010. Biennial surveys at Johnston Atoll were initiated in 2004, and biennial surveys at Wake Atoll were initiated in 2005. At each location, standardized survey protocols and methods specific to each biotic group were used to sample and identify stony corals (Maragos et al. 2004), benthic algae (Preskitt et al. 2004), and reef-associated fishes (Mundy et al. 2010). The number of species of each taxon known from each location was assembled from peer-reviewed literature, agency reports, and unpublished data (Table 1).

	Stony Corals	Benthic Algae	Inshore Fishes
Howland	Maragos et al. 2008, USFWS 2008a, Maragos unpubl. data	Vroom et al. 2010 Tsuda et al. 2008	Maragos et al. 2008, Mundy et al. 2010
Baker	Maragos et al. 2008, USFWS 2008b, Maragos unpubl. data	Vroom et al. 2010 Tsuda et al. 2008	Maragos et al. 2008, Mundy et al. 2010
Jarvis	Maragos et al. 2008, USFWS 2008c, Maragos unpubl. data	Tsuda et al. in press	Maragos et al. 2008, Mundy et al. 2010
Palmyra	Maragos et al. 2008, Williams et al. 2008, Kenyon et al. 2011a, Maragos unpubl. data	Dawson 1959, Skelton & South 2007, Braun 2009, Tsuda et al. in press	Maragos et al. 2008, Mundy et al. 2010
Kingman	Maragos et al. 2008, Kenyon et al. 2011b	Tsuda et al. in press	Maragos et al. 2008, Mundy et al. 2010
Johnston	Maragos & Jokiel 1986, Lobel & Lobel 2008, Maragos unpubl. data	Tsuda et al. 2010a	Kosaki et al. 1991, Lobel & Lobel 2008
Wake	USFWS 1999, Kenyon et al. in press	Bailey & Harvey 1874, Tsuda et al. 2006, 2010b	Lobel & Lobel 2004, Lobel & Lobel 2008

Table 1: Reference sources for numbers of reef-associated species in the Pacific Remote Islands Marine National Monument.

	Stony Corals			Benthic Algae			Inshore Fishes		
	pre-2000	2008	2010	pre-2000	2008	2010	pre-2000	2008	2010
Howland	25	102	109	11	47	47	162	220	328
Baker	28	101	104	16	86	86	80	194	268
Jarvis	0	61	70	5	79	79	98	193	274
Palmyra	72	173	177	90	93	93	282	338	395
Kingman	0	181	182	0	95	95	58	229	270
Johnston	38	45	49	141	142	189	285	301	301
Wake	52	97	97	5	40	121	321	323	323

Table 2. Number of species of stony corals, benthic algae, and inshore fishes known at each of the seven islands/atolls in the Pacific Remote Islands Marine National Monument

Results

For all biotic groups at all locations, the number of species reported as of 2008, the year preceding the establishment of the PRIMNM, increased from the number reported before the initiation of cooperative reef assessment and monitoring surveys in 2000 (Table 2). Of the seven islands/atolls within the PRIMNM, the greatest collective increase in these 3 groups (771%) was at Kingman Reef, where records of stony corals increased from 0 to 181 species, benthic algae from 0 to 95 species, and inshore fishes from 58 to 229 species. More than a 200% increase in the collective number of species was reported at each of Jarvis (103 to 333 species, 223%) and Baker (124 to 381 species, 207%) by 2008. Smaller collective increases were reported at Howland (86%) and Palmyra Atoll (36%). The smallest collective increases were found at Johnston Atoll (464 to 488 species, 5%) and Wake Atoll (378 to 460 species, 22%).

Continuation of monitoring, in conjunction with specimen analysis and reporting after the establishment of the PRIMNM, has generated further increase in knowledge of biodiversity at each location (Table 2).

Discussion

Following indications from the Council on Environmental Quality (CEQ) in 2007 that President Bush was considering establishing marine reserves in waters within the United States' exclusive economic zone, CEQ collected scientific and historical information based on the research conducted by the Departments of the Interior, Commerce, and Defense to develop a short list of potential sites. Non-governmental organizations including Environmental Defense Fund and Marine Conservation Biology Institute teamed up to build key scientific, political, and public support to convince White House staff that the Central Pacific Islands were deserving of protection. Documents prepared by the USFWS as part of the CEQ scoping process testify to the high biodiversity and other distinctive aspects of the coral reef and terrestrial ecosystems at these locations. Illustrative excerpts from these documents include, "Palmyra Atoll and Kingman Reef have among the highest coral diversities of any island or atoll under U.S. jurisdiction. They harbor the most intact biological community structure and greatest fish biomass under U.S. jurisdiction. They support globally depleted species, including giant clams, sharks, groupers, bumphead parrotfish, napoleon wrasses, black-lipped pearl oysters, hawksbill and green turtles. Kingman Reef's coral reefs are the most pristine of any under U.S. jurisdiction. For marine biologists, Palmyra and Kingman provide a view of how coral reef ecosystems may have appeared and operated prior to human influences" (B. Flint, pers. comm.). These statements were substantiated by the data acquired and analyzed from the post-2000 cooperative monitoring surveys that revealed the rich biodiversity and other exceptional characteristics of these reefs.

Several portions of text in Presidential Proclamation 8336 demonstrate the role played by cooperative reef assessment and monitoring surveys in improving knowledge of the unique marine resources of these remote islands/atolls and the need to preserve their marine environments in the public interest. The Proclamation states, "The waters surrounding Baker, Howland, and Jarvis Islands have fish biomass double that of Papahānaumokuākea Marine National Monument, and 16 times that of the main Hawaiian Islands…These islands are high in coral cover and biodiversity and are predator-dominated systems…There are about 300 fish species found off the islands…Napoleon wrasses and Bumphead parrotfish are common, and sharks of many species are especially abundant at Jarvis and commonly larger than elsewhere….Despite its isolation, Johnston supports thriving communities of Table corals

(*Acropora*) and a total of 45 coral species, including a dozen confined to the Hawaiian and northern Line Islands. Some 300 species of reef fish are at Johnston…Palmyra Atoll and Kingman Reef are known to be among the most pristine coral reefs in the world, with a fully structured inverted food web. Kingman Reef is the most pristine of any reef under U.S. jurisdiction… Both Palmyra Atoll and Kingman Reef support higher levels of coral and other cnidarian diversity (180-190 species) than any other atoll or reef island in the central Pacific, twice as many as are found in Hawaii or Florida. Fish species diversity at Palmyra is higher than, while that of Kingman is comparable to, that of the other remote Pacific refuges…Shallow coral reefs thrive around the perimeter of Wake Island. Fish populations are abundant and support at least 323 species, including large populations of the Napoleon wrasse (*Chelinus*), sharks of several species, and large schools of the Bumphead parrotfish (*Bolbometapon*), all of which are globally depleted." (Code of Federal Regulations 2010).

Presidential Proclamation 8336 assigns responsibility for management of the Monument out to 92.6 km from the mean low water lines of its 7 component island/atolls to the Secretary of the Interior. The Proclamation prohibits commercial fishing within the monument, but gives the Secretary of Commerce, through the National Oceanic and Atmospheric Administration, primary responsibility for managing fishery-related activities from 22.2 to 92.6 km from the islands. On January 16, 2009, the Secretary of the Interior delegated his management responsibilities for the Monument to the USFWS through Secretary's Order 3284. This Order extended the boundaries of Howland Island, Baker Island, Jarvis Island, and Johnston Atoll NWRs to 22.2 km from the mean low water line of each island and established a Wake Island Unit of the monument to be managed as a National Wildlife Refuge out to 22.2 km from the mean low water line of the island. By terms of the Proclamation and Secretary's Order, the Secretary of Defense continues to manage Wake Island and terrestrial portions of Johnston Atoll until jurisdiction is returned to the Department of the Interior. At Johnston and Wake Atolls, where the Department of Defense has historically maintained facilities and defensive areas, biological inventories previous to those initiated by NOAA/USFWS in 2004 had been conducted in response to issues such as dredging and contaminants (e.g., USFWS 1999); consequently, the cooperative marine surveys generated the smallest collective increases in biodiversity records at those locations.

Extending 92.6 km from the mean low water lines of its component islands/atolls, this Monument, compared to the Refuges, provides more inclusive protection of the marine ecosystems that sustain the terrestrial, nearshore, and pelagic bionetworks. Shallow-water coral reefs in the Monument serve as one habitat within a larger pelagic and terrestrial ecosystem integrated through the flow of energy and recycling of nutrients. Seaward boundaries of the Monument were set in recognition of the foraging distances needed by many of the 20 seabird species that roost and breed on the islands to acquire adequate prey (B. Flint, pers. comm.). Through their feeding activities, seabirds act as a conduit between the marine and terrestrial environments by transferring nutrients between ecosystems (e.g., Allaway and Ashford 1984, Staunton-Smith and Johnson 1995). The magnitude of the infusion of nutrients being imported to the PRIMNM reef ecosystems from the guano being produced by birds in residence is no doubt significant to the energy and biogeochemical dynamics of these ecosystems.

For the long-term success of these integrated systems, coral reef, terrestrial, and pelagic habitats must be managed in an adaptive framework in which monitoring is conducted to assess the effectiveness of management actions. While the coral ecosystems of the central Pacific are relatively intact, they are not without impacts. Human impacts to the PRIMNM reefs include shipwrecks, invasive species, fishing debris, and the residual effects of WWII-era operations. Continued monitoring to document status and trends in reef structure and function is needed, with surveys extended to multiple depths and habitats in each location, but what is most needed to advance conservation success is monitoring threats and their response to management. The application of methods under development to control invasive corallimorphs and cyanobacteria on shipwrecks at Kingman Reef and Palmyra Atoll needs to be monitored to determine effectiveness and impacts to other reef biota. Eventually, the shipwrecks need to be removed and the natural or facilitated colonization of the impacted area monitored. Removal and follow-up monitoring of military debris that may be toxic or hazardous needs to be done at many of the islands. Monitoring for and removal of marine debris that entangles or abrades corals, fishes, sea turtles, marine mammals, and seabirds would benefit these residents of multiple habitats. Ecological monitoring in conjunction with climate research should be actively developed within the Monument; 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. Illegal trespass holds the capacity for introduction of invasive species, poaching, ship grounding, oil spills, and wreckage; increased surveillance via acoustic or other remote

sensing technology is needed to assess the magnitude of the threat and, if warranted, enhance law enforcement capability. Prioritization of threat-associated monitoring is critical to long-term conservation success.

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