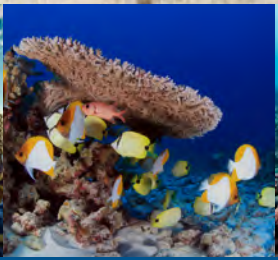
11.C(4)
187th CM

2020 STATE OF

PAPAHĀNAUMOKUĀKEA MARINE NATIONAL MONUMENT

STATUS AND TRENDS 2008-2019



National Marine Sanctuaries
NOAA Fisheries
Hawai'i Division of Aquatic Resources
Office of Hawaiian Affairs

papahanaumokuakea.gov

This report represents a joint effort by the monument co-managing agencies and partners to assess the condition of monument resources:

NOAA, National Ocean Service, Office of National Marine Sanctuaries (ONMS)

NOAA, National Marine Fisheries Service (NMFS)

U.S. Fish & Wildlife Service, National Wildlife Refuge System (FWSNWRS)

U.S. Fish & Wildlife Service, Ecological Services (FWS-ES)

State of Hawaiʻi, Department of Land and Natural Resources (DLNR), Division of Aquatic Resources (DAR)

State of Hawaiʻi, Department of Land and Natural Resources (DLNR), Division of Forestry & Wildlife (DOFAW)

Office of Hawaiian Affairs (OHA)

Cover images clockwise from top: A ʻīlioholoikauaua or Hawaiian monk seal (*Neomonachus schauinslandi*) and a honu or Hawaiian green turtle (*Chelonia mydas*) rest on a beach on Tern Island, French Frigate Shoals (Image: Mark Sullivan/NOAA). Mōlī or Laysan albatross (*Phoebastria immutabilis*) cover the shores of Midway Atoll (Image: Dan Clark/USFWS). Dr. Kelly Keogh investigates a ginger jar at the *Two Brothers* shipwreck site (Image: Greg McFall/NOAA). French Frigate Shoals reefscape (Image: Greg McFall/NOAA). Nihoa as seen from aboard the Polynesian voyaging canoe *Hikianalia* (Image: Brad Kaʻaleleo Wong/OHA). Wisdom and her chick on Midway Atoll National Wildlife Refuge and Battle of Midway National Memorial (Image: Dan Clark/USFWS). Boobies perch atop ceremonial shrines on Mokumanamana (Image: Kaleomanuʻiwa Wong).

2020 STATE OF

PAPAHĀNAUMOKUĀKEA
MARINE NATIONAL MONUMENT

STATUS AND TRENDS 2008-2019

This report represents a joint effort by the Papahānaumokuākea Marine National Monument co-managing agencies and partners and is published by:

U.S. Department of Commerce
Wilbur Ross, Secretary

National Oceanic and Atmospheric Administration
Neil A. Jacobs, Ph.D.
Assistant Secretary of Commerce for Environmental Observation and Prediction, performing the duties of Under Secretary of Commerce for Oceans and Atmosphere

National Ocean Service
Nicole LeBoeuf, Assistant Administrator (Acting)

Office of National Marine Sanctuaries
John Armor, Director

EDITORS

NOAA Papahānaumokuākea Marine National Monument
Nicole Evans
Jonathan Martinez, Ph.D.
Alyssa Miller, Ph.D.

NOAA Office of National Marine Sanctuaries
Kathy Broughton
Stephen R. Gittings, Ph.D.

State of Hawaii Department of Land and Natural Resources
Maria Carnevale

Layout and design by Kahi Fujii, NOAA Papahānaumokuākea Marine National Monument

Suggested Citation
NOAA Office of National Marine Sanctuaries. 2020. 2020 State of Papahānaumokuākea Marine National Monument: Status and Trends 2008–2019. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, Office of National Marine Sanctuaries, Silver Spring, MD. 221 pp.

TABLE OF CONTENTS

On the north end of Pearl and Hermes Atoll near the sand berm, divers check out the drop off from the reef, a hot spot where derelict fishing nets collect. Image: Steven Gnam/NOAA

ABSTRACT

Papahānaumokuākea Marine National Monument is the single largest conservation area under the U.S. flag, encompassing an area of 582,578 square miles of the Pacific Ocean—an area larger than all the country's national parks combined. Home to the highly endangered Hawaiian monk seal, threatened green turtles, and many species found nowhere else on earth, the complex and highly productive marine ecosystems of the monument are significant contributors to the biological diversity of the ocean.

Despite multiple past and current threats, the terrestrial and marine ecosystems of Papahānaumokuākea are among the least modified in the Hawaiian Archipelago. Due to Papahānaumokuākea's isolation, past management efforts, and current regulations controlling access, impacts from local human uses have been relatively few, and thus its reefs and other resources are considered to be in nearly pristine condition across most of the region. Marine habitat condition in particular locations has, however, been impacted by derelict fishing gear, large storms, aggressive nuisance algae, and coral bleaching, though most locations have not been significantly affected and are in good to fair condition. In contrast, terrestrial habitats have been affected by past human activities that altered soils and vegetation, introduced non-indigenous species, and left behind contamination on many of the islands. These habitats continue to be affected by human activities taking place outside the monument, such as those resulting in the deposition of marine debris. Monument-wide, inland and coastal water quality parameters have indicated relatively good conditions. In contrast, oceanic and atmospheric conditions have been affected by accelerated sea level rise, increased frequency of storms, and increased regional sea surface temperature. Time series data on erosion are lacking for a majority of terrestrial and abiotic habitats in the monument, however limited studies and inference drawn from studies in the Main Hawaiian Islands indicate that some terrestrial habitats are severely eroding, and that submerged abiotic habitats, with the exception of lagoon settings, are likely experiencing gradual net erosion. Additionally, while information on known contaminant concentrations is limited, conditions appear to be improving overall at studied sites.

Most living resources in the monument appear to be in healthy condition, owing in part to years of layered protections by the co-managing agencies. Many populations of endangered and other vulnerable species appear vigorous, and endangered species status is largely attributed to factors inherent in isolated locations, such as limited distributions, small populations, and vulnerability to perturbations. Further, management actions such as translocations, non-indigenous species removal, and habitat restoration have successfully contributed to improvements in habitat quality and species abundance and distribution. Shallow-water coral reefs vary by location, with localized natural disturbance events and coral bleaching affecting different reefs. In contrast, deep-sea habitats remain in nearly pristine condition, with little

disturbance. However, several concerns remain. Perhaps one of the most significant threats to living resources in the monument is global climate change and its manifestations, including changes in ocean chemistry, rising sea levels, and rising sea surface temperatures, with resultant coral bleaching, in addition to increased frequency and severity of storms. Other concerns include marine debris, diseases affecting both terrestrial and marine organisms, non-indigenous species that threaten native biodiversity and degrade habitats, and a reduced capacity for long-term resource monitoring and restoration activities taking place on land.

The maritime, historic, and cultural resources in the monument vary in condition, ranging from good to fair, depending upon the resource, although in all cases, trends in the condition of these resources were assessed as declining. These resources are finite and non-renewable, and over time, natural processes of degradation occur, largely due to weathering, corrosion, and erosion. Though little can be done to prevent natural deterioration of these resources, the information they contain may be preserved through timely archaeological study, documentation, and conservation of artifacts.

This "2020 State of Papahānaumokuākea Marine National Monument Report" updates the 2009 Papahānaumokuākea Marine National Monument Condition Report, documenting the status and trends of Papahānaumokuākea resources from 2008–2019, unless otherwise noted. The report is intended to support ongoing adaptive management of Papahānaumokuākea by helping to identify not only the status of resources, but also gaps in current monitoring efforts, and causal factors that may require monitoring and management actions in the future. The report also provides a framework that can serve to inform discussions among resource managers, researchers, communities, and other stakeholders about preserving the integrity of Papahānaumokuākea.

PAPAHĀNAUMOKUĀKEA MARINE NATIONAL MONUMENT

Papahānaumokuākea Marine National Monument (PMNM) is one of the largest fully protected conservation areas in the world. It encompasses 582,578 square miles (1,508,870 square kilometers) of the Pacific Ocean. The monument, created expressly to protect an exceptional array of natural and cultural resources, was originally established on June 15, 2006 and expanded on August 26, 2016, under the authority of the Antiquities Act. The region has received previous protections, including designation of the Hawaiian Islands National Wildlife Refuge, Kure Atoll State Wildlife Sanctuary, Northwestern Hawaiian Islands Coral Reef Ecosystem Reserve, Northwestern Hawaiian Islands State Marine Refuge, Midway Atoll National Wildlife Refuge, and Battle of Midway National Memorial. Subsequent international protections include designation in 2008 as a Particularly Sensitive Sea Area and inscription as the nation's first mixed (natural and cultural) United Nations Educational, Scientific and Cultural Organization (UNESCO) World Heritage site.

MONUMENT CO-TRUSTEE MANAGEMENT

Four principal entities, collectively known as the Co-Trustees, are responsible for managing the lands and waters of the monument: the Secretary of Commerce through the National Oceanic and Atmospheric Administration (NOAA), the Secretary of the Interior through the U.S. Fish and Wildlife Service (USFWS), the State of Hawaiʻi through the Governor and the Office of Hawaiian Affairs.

Two masked boobies enjoy an afternoon chat astride two threatened Hawaiian green turtles at French Frigate Shoals. More than 95% of the green turtles in Hawai‘i nest and breed on and around the tiny islets of French Frigate Shoals. Just like the management agencies, the animals of Papahānaumokuākea partner for protection. Image: Mark Sullivan/NOAA

A memorandum of agreement (MOA) among the Co-Trustees establishes a joint governance regime where all parties share in management and coordinate by jointly issuing permits for activities in the monument (Memorandum of Agreement [MOA], 2006, 2017). The Co-Trustees have established a goal to provide seamless and unified management in the spirit of cooperative conservation, and they are committed to preserving the ecological integrity of Papahānaumokuākea and perpetuation of its ecosystems, Native Hawaiian culture, and historic resources.

Integrated Management

The name Papahānaumokuākea is reflective of the region’s natural and cultural heritage and its future as a vast, sacred, protected, and procreative place. Inscribed as a UNESCO World Heritage site for its outstanding natural and cultural significance (State of Hawai‘i et al., 2008), Papahānaumokuākea is a place of deep cosmological significance to Kānaka Maoli (Native Hawaiians), with a revered kinship connection. Papahānaumokuākea’s establishing laws, mission, and current management practices emphasize the incorporation of Native Hawaiian values and knowledge into everyday management. This principle is reflected in a Papahānaumokuākea motto, “where nature and culture are one,” and operationalized through continuing efforts by managers to increase integration in all areas of management.

Blackfoot ʻopihi in a tidepool at Nihoa. Image: Hoku Johnson/NOAA

ABOUT THIS REPORT

PURPOSE

The purpose of this State of the Monument Report is to use the best available science and most recent data to assess the status and trends of the resources of Papahānaumokuākea Marine National Monument. The predecessor to this document, the Papahānaumokuākea Marine National Monument Condition Report was released in 2009 (NOAA Office of National Marine Sanctuaries [ONMS], 2009); a summary of condition ratings from that report is provided in Appendix D.

This update describes pressures on Papahānaumokuākea resources, the current condition of the resources, and the management responses to the pressures that threaten the integrity of the Monument's terrestrial and marine environments. Specifically, the findings in this report document status and trends in the physical environment, living resources, and historical and cultural archaeological resources. **The time frame for this report includes the years 2008–2019, unless otherwise noted.**

Papahānaumokuākea was significantly expanded in 2016, but the analyses and ratings presented in this report do not include resources in the expansion area. **The geographic scope of the report is limited to the 2006 designation area.** Contextual discussions of the expansion area, however, appear throughout the report.

The findings in this report will provide critical support for identifying high-priority management actions for PMNM, specifically helping to shape future updates to the 2008 Papahānaumokuākea Marine National Monument Management Plan and to identify gaps in current monitoring efforts. The report also provides a framework and resource that can serve to inform dialogue among resource managers, researchers, communities, and other stakeholders about protecting Papahānaumokuākea.

FRAMEWORK AND PROCESS

This State of the Monument Report retains the basic NOAA Office of National Marine Sanctuaries (ONMS) condition report framework that was used in the 2009 Papahānaumokuākea Marine National Monument Condition Report, however elements of this report differ from the previous format in two significant ways. Modifications have been made to assessment categories in order to fulfill data needs specific to PMNM management, and new analytical elements introduced to the condition report framework since 2009 have been incorporated. Condition reports are used as a standardized summary throughout the National Marine Sanctuary System, and this State of the Monument Report adopts a similar framework. It employs a Pressure-State-Response (PSR) conceptual model (Figure SOM.1) to describe the role of pressures on resources, status and trends for resources, and existing management responses to pressures that threaten the integrity of the marine environment. The PSR model recognizes that the pressures that natural events and human activities place on both natural and heritage resources can alter their state (i.e., the quality or condition of the resources), which prompts targeted management responses intended to prevent, reduce, or mitigate the undesirable changes. The PSR analytic used in this document differs somewhat from the current ONMS condition report format, which incorporates a Driver-Pressure-State-Response (DPSR) format to describe the role of drivers to pressures and includes an assessment of ecosystem services.

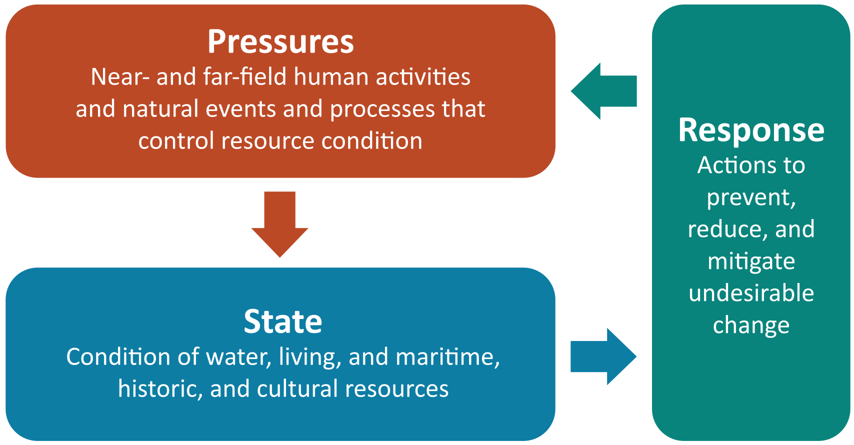


Figure SOM.1. Visual depiction of the Pressure-State-Response (PSR) framework, illustrating connectivity between each aspect of the model and showing how management responses can be incorporated to modify pressures and state. Image: NOAA

Pressures, state, and response are assessed for a suite of resource targets identified by experts as key ecological and cultural assets of PMNM. The State of the Monument Report's resource categories resemble the categories found in the 2009 condition report, however they have been revised and expanded to include other management targets not covered in the previous report, namely terrestrial resources, cultural resources, and historical resources.

The assessments in this report are grouped within three broad categories: physical environment, living resources, and historical and cultural archaeological resources. Within these categories, twelve resource assessment questions shape and guide inquiry:

Physical Environment

1. Have recent, accelerated changes in climate altered water conditions and how are they changing?

2. What are the area and distribution of abiotic habitat types and how are they changing?

3. What is the water quality condition of nearshore and inland waters and how is it changing?

4. What are the known contaminant concentrations in habitats and how are they changing?

Living Resources

5. What is the status of biodiversity and how is it changing?

6. What is the status of historically targeted fish stocks and how is it changing?

7. What is the status of non-indigenous and invasive species and how is it changing?

8. What is the status of key species and how is it changing?

Historical and Cultural Archaeological Resources

9. What is the condition of known maritime archaeological resources and how is it changing?

10. What is the condition of known historic resources and how is it changing?

11. What is the condition of known Native Hawaiian archaeological resources and how is it changing?

12. Do known historic and archaeological resources pose an environmental hazard and how is this threat changing?

Findings associated with each of these questions are described in detail in the State of Monument Resources section of this report and are also summarized in the Resource Condition and Trends Summary Table.

The development of this report relied heavily upon the contributions of subject matter experts, who assisted both in the design of the framework guiding inquiry and in the execution of assessments. These processes, which occurred over a multi-year period, are summarized here and fully described in Appendix B.

In order to rate the status and trends of PMNM resources, staff convened a Papahānaumokuākea Marine National Monument interagency science review team, a group of experts familiar with the resources and with knowledge of previous and current scientific and archaeological investigations. Initially, a contractor, PMNM staff, and science team members jointly reviewed the set of evaluation targets used in the 2009 condition report and revised and expanded these to include terrestrial and cultural resources, as well as a broader range of living resources. As in the 2009 condition report, a guiding research question and scoring guide were developed for each key assessment target identified. In total, twelve State of the Monument assessment questions, with accompanying standardized rating criteria, were developed. Based on this system, a template-based reviewer form was developed. This State of the Monument Review Template (Appendix A) is the basis for assessments found in this report. The template was distributed among subject matter experts by PMNM agency leads.

The results of this template-based review were first gathered in 2013 and compiled into a draft State of the Monument document. In 2016 and 2017, staff from ONMS and the State of Hawai‘i reviewed the preliminary draft and determined that there was a need to update the status and trend ratings and incorporate additional data. In 2018–2019, the subject-matter expert review process was reconstituted and all sections of the report were updated. Thus, the present document represents a synthesis of results from both of these efforts.

Each review in this report consists of three parts: an assessment of the status of the resource, an identification of trends, and a summary of future management implications (including future research and management needs). Evaluations of status and trends are based upon interpretation of quantitative and, when necessary, non-quantitative assessments, including the observations of scientists, managers, and users. Status of resources is rated on a five point scale from good to poor. Identified trends in the status of resources are generally based on observed changes in status since the 2009 Papahānaumokuākea Marine National Monument Condition Report. Trends are rated on a four point scale as improving, not changing, declining, or undetermined. Status and trend ratings also include a strength of evidence score. In the 2009 report, inferences regarding the level of confidence for each status and trend rating were drawn from the literature reviewed. The State of the Monument Report employs a new approach that incorporates a description of the assessed level of evidence that was relied upon when determining ratings for each question. The level of evidence is determined to be robust, medium, or limited, based on the quantity and quality of the data utilized to determine the rating (e.g., peer-reviewed literature, expert opinion). The specific criteria used are provided in Appendix B.

To the greatest extent possible, the editors of this report have attempted to make each section's narrative consistent and comparable in terms of content, detail, and length; however, each section contains different types and amounts of information, reflecting the realities and confines of datasets and expert opinions that were available. In addition, because this report is the result of a multi-year, collaborative effort across multiple editors, contributors, and reviewers, it contains slight stylistic variations across sections. These differences do not diminish the validity or utility of the content. Lastly, ratings reflect the collective interpretation of subject matter experts and editorial staff, based on their knowledge and perception of local conditions.

The editors take full responsibility for discrepancies or errors associated with the content of this document. This report has been peer reviewed and complies with the White House Office of Management and Budget's peer review standards, as outlined in the Final Information Quality Bulletin for Peer Review (Office of Management and Budget, 2004).

SUMMARY TABLE: RESOURCE STATUS AND TRENDS

The following table summarizes the status and trends of Papahānaumokuākea Marine National Monument resources as represented in the State of Monument Resources section of this report. The first two columns list the 12 questions used to rate the condition status and trends of the monument's physical environment, living resources, and historical and cultural archaeological resources. The Rating column displays four pieces of information: a color and term that indicate status, a symbol that indicates trend, and a shaded scale for both that indicates evidence (see Key for definitions). The Status Description column presents a statement that best characterizes resource status and corresponds to the assigned color rating and definition as described in Appendix A. These statements are customized for all possible ratings for each question. The Indicators column consists of a short statement or list of criteria used to justify the rating. Finally, the Management Considerations column includes information on remaining gaps, research, or management needs, and issues that may be considered during future management plan revisions.

Status:

Good	Good/Fair	Fair	Fair/Poor	Poor	Undetermined

Trends:

- ▲ = Conditions appear to be improving
- — = Conditions do not appear to be changing
- ▼ = Conditions appear to be declining
- ? = Undetermined trend
- N/A = Question not applicable

Evidence Score:

Robust =
Medium =
Limited =

Example:

This symbol indicates the condition was rated "fair" with "medium evidence" and "declining trend" with "medium evidence."

PHYSICAL ENVIRONMENT

#	Question	Rating	Status Description	Indicators	Management Considerations
1	Have recent, accelerated changes in climate altered water conditions and how are they changing?	Oceanographic and Atmospheric Conditions			
		Fair/Poor ▼	Climate-related changes have caused severe degradation in some, but not all, attributes of ecological integrity.	Increasing ocean temperature has resulted in four mass coral bleaching events. The number of hurricanes and tropical storms has increased. Calcification and aragonite saturation states are relatively low.	Monitoring the physical environment across the monument is important to understand how it is changing over time and space.
2	What are the area and distribution of abiotic habitat types and how are they changing?	Terrestrial and Marine Abiotic Habitats			
		Fair/Poor ?	Selected habitat loss or alteration has caused, or is likely to cause, severe declines in some, but not all, living resources or water quality.	Terrestrial habitats are severely eroding; data are lacking to evaluate the status of submerged habitats, but they are generally eroding on the seaward side of reef crests.	Measurements of net carbonate accretion rates on reef crests and sediment accretion rates on land are critical for understanding the future of these habitats. Completing high-resolution bathymetry and substrate mapping is important for monitoring large-scale changes in marine abiotic habitats. Erosion control is needed to preserve terrestrial ecosystems.

#	Question	Rating	Status Description	Indicators	Management Considerations
3	What is the water quality condition of PMNM nearshore and inland waters and how is it changing?	Nearshore and Inland Waters			
		Good/Fair ?	Selected conditions may preclude full development of living resource assemblages and habitats but are not likely to cause substantial or persistent declines.	Data on nearshore water quality are lacking. Avian botulism has occurred in inland waters at Midway Atoll, Laysan Island and Kure Atoll, causing mortality in protected bird species.	Consistent water quality monitoring and threat prevention and mitigation strategies are needed for both nearshore and inland waters.
4	What are the known contaminant concentrations in PMNM habitats and how are they changing?	Contaminants			
		Fair —	Selected contaminants may inhibit the development of assemblages and may cause measurable, but not severe, declines in living resources or water quality.	Historical contaminants remain despite remediation. Most efforts have taken place at Kure, Midway, and French Frigate Shoals (Tern Island), but contamination sites are also present at Laysan Island and Pearl and Hermes Atoll. Protected species continue to be exposed to these contaminants.	Prioritize investigations to address data gaps regarding local sources and exposures, and develop containment and disposal strategies to prevent future contaminant releases from hazardous marine debris.

LIVING RESOURCES

#	Question	Rating	Status Description	Indicators	Management Considerations
5	What is the status of biodiversity and how is it changing?	Marine Biodiversity			
		Good ?	Biodiversity appears to reflect pristine or near-pristine conditions and promotes ecosystem integrity (full community development and function).	Biodiversity is characteristic of pristine conditions, which promotes ecosystem integrity. Endemism is high.	Monitoring biodiversity is important for understanding the monument's resilience as the nature, frequency, and intensity of disturbances change.
		Terrestrial Biodiversity: Kure Atoll			
		Good/Fair ▲	Selected biodiversity loss has taken place, precluding full community development and function, but it is unlikely to cause substantial or persistent degradation of ecosystem integrity.	Seabird species are recovering following rat eradication in 1995. Native plant richness, abundance, and distribution are increasing due to invasive weed control measures.	Continued weed management is essential to restore native plant communities and improve reproductive success of seabirds.
6	What is the status of historically targeted species and how is it changing?	Spiny Lobster, Slipper Lobster, Bottomfish, Black-Lipped Pearl Oyster			
		Fair ?	The reduced abundance of species has caused, or is likely to cause, severe declines in some, but not all, ecosystem components and reduce ecosystem integrity; or, species are at substantially reduced levels, and prospects for recovery are uncertain.	As of the late 2000s, lobster stocks remain depressed from historical levels, while bottomfish stocks remain healthy. The black-lipped pearl oyster was overharvested in 1930 and had not recovered as of 2006.	Research surveys are needed to provide updated population status and other information.

#	Question	Rating	Status Description	Indicators	Management Considerations
7	What is the status of non-indigenous species and how is it changing?	Terrestrial Non-Indigenous Species			
		Good/Fair ▲	Non-indigenous and/or invasive species exist, precluding full community development and function, but are unlikely to cause substantial or persistent degradation of ecosystem integrity.	Habitat restoration programs have improved native terrestrial ecosystems, but the non-indigenous plant seed bank will threaten ecosystem integrity for many years to come.	Reestablishing year-round operations, continuing eradication projects, and continuing habitat restoration are critical to improve biodiversity of flora and fauna and protect abiotic structures from erosion.
		Marine Non-Indigenous Species			
		Fair —	Non-indigenous and/or invasive species may inhibit full community development and function and may cause measurable, but not severe, degradation of ecosystem integrity.	Surveys have revealed a number of established non-indigenous marine species; some are broadly distributed. Marine invertebrates make up the largest category of non-indigenous species.	Continuing best practices to minimize transport of marine non-indigenous species will help protect the integrity of marine habitats in PMNM. Continued monitoring and characterization are also needed.

#	Question	Rating	Status Description	Indicators	Management Considerations
8	What is the status of key species and how is it changing?	Hawaiian Monk Seal			
		Fair/Poor ▲	The reduced abundance of selected keystone species has caused, or is likely to cause, severe declines in some, but not all, ecosystem components and reduce ecosystem integrity; or, selected key species are at substantially reduced levels, and prospects for recovery are uncertain.	Monument populations increased by 2% from 2013–2017. Site-specific trends in population have been observed.	Monitoring populations for demographic trends, as well as detecting and mitigating threats to seal survival, are the highest priorities for recovery of the species. Limited funding has shortened field seasons, curtailing this work and introducing uncertainty about future monitoring.
		Sea Turtles			
		Good/Fair ▲	The condition of selected key resources is not optimal, perhaps precluding full ecological function, but substantial or persistent declines are not expected.	The Central North Pacific population of the threatened green turtle ranges throughout the Hawaiian Archipelago and Johnston Atoll. About 96% of nesting takes place at French Frigate Shoals, and nesting activity there is improving.	Data and models are needed to predict the impacts of sea level rise on nesting sites and rising sand temperature on hatchling success and sex ratios. Monitoring of nesting sites throughout the monument is needed to assess the impact from the catastrophic habitat loss at East Island, French Frigate Shoals, caused by Hurricane Walaka.

#	Question	Rating	Status Description	Indicators	Management Considerations
8	What is the status of key species and how is it changing?	Reef Fish			
		Good	Key and keystone species appear to reflect pristine or near-pristine conditions and may promote ecosystem integrity (full community development and function).	Reef fish assemblages exhibit high biomass across the majority of family and trophic groups, particularly for large-bodied taxa. The high abundance of large apex predators on monument reefs contrasts with that of the eight inhabited Main Hawaiian islands.	The large area and diversity of reef fish habitats in the monument present challenges for assessment. Deeper reef habitats (>30m), soft-sediment habitats, and diurnally active reef fish species are particularly undersampled. Reef fish assemblages are likely vulnerable to future impacts of climate change.
		Shallow-Water Corals			
		Fair	The diminished condition of selected key resources may cause a measurable, but not severe, reduction in ecological function, but recovery is possible.	Mass coral bleaching occurred in 2009, 2010, 2014 and 2019. The 2014 event caused a 68% loss in coral cover at Lisianski and reduced habitat complexity and volume. Mortality from the 2019 event, observed at Lisianski, French Frigate Shoals, Pearl and Hermes, Midway, and Kure, is unknown. In 2018, Hurricane Walaka destroyed Rapture Reef, a known habitat for uncommon acroporid corals at FFS.	Annual monitoring of coral reefs is needed to assess and address impacts from natural disasters such as coral bleaching, hurricane damage, and invasive species. Assisted restoration should be considered for these reefs, which already have calcification limitations, are near the thermal limit for coral growth, and will continue to experience climate change impacts such as ocean warming and changing ocean chemistry.

#	Question	Rating	Status Description	Indicators	Management Considerations
8	What is the status of key species and how is it changing?	Deep-Sea Corals			
		Good ?	Key and keystone species appear to reflect pristine or near-pristine conditions and may promote ecosystem integrity (full community development and function).	Only a small portion of potential deep-water coral habitat in the monument has been explored. Only a few sites have been revisited, making it difficult to report temporal trends.	The large geographic area and extreme depths of deep-water corals in the monument challenge our ability to assess their status. A plan is needed to resurvey known locations of deep-water corals in PMNM to assess temporal trends and life histories, as well as the effects of climate change and ocean acidification.
		Seabirds			
		Good/Fair —	The condition of selected key resources is not optimal, perhaps precluding full ecological function, but substantial or persistent declines are not expected.	Recent data on seabird nesting and abundance have mostly been limited to colonies of Laysan albatross and black-footed albatross. Although nesting activity has remained stable or increased slightly, albatross populations have been negatively affected by flooding and tsunami events, mouse predation, commercial fishing, and contamination from legacy contaminants. Monument expansion has increased the protections for foraging seabirds.	Only 12 of the 21 seabird species in the monument have been monitored. Resuming annual Tern Island monitoring is necessary to track albatross breeding in PMNM. Monument expansion and the removal of predatory mice at Midway Atoll will reduce threats to Laysan albatross.

#	Question	Rating	Status Description	Indicators	Management Considerations
8	What is the status of key species and how is it changing?	Endemic Land Birds: Nihoa Millerbird, Nihoa Finch, Laysan Duck, Laysan Finch			
		Fair/Poor ?	The reduced abundance of selected key species has caused, or is likely to cause, severe declines in some, but not all, ecosystem components and reduce ecosystem integrity; or, selected key species are at substantially reduced levels, and prospects for recovery are uncertain.	All four species are endemic, listed as endangered, and threatened by the introduction or spread of invasive species. The Laysan duck is found on three islands, the Laysan finch and Nihoa millerbird on two, and the Nihoa finch on only Nihoa. With the 2011 translocation of the Nihoa millerbird to Laysan Island, Laysan now supports three of the four land bird species.	High-priority management actions include ongoing monitoring of established populations and identifying habitat on other islands for establishing additional populations. Translocation of the Nihoa finch, the only PMNM land bird restricted to a single island, would reduce extinction risk.
		Endemic Terrestrial Plants			
		Poor ?	The reduced abundance of selected key species has caused, or is likely to cause, severe declines in ecosystem integrity; or, selected key species are at severely reduced levels, and recovery is unlikely.	Five species of terrestrial plants are endemic to PMNM. Two others are endemic to the broader archipelago, but the majority of their population is in PMNM. All seven are protected under the Endangered Species Act due to disruptions caused by humans, principally the introduction of invasive species.	Strict controls on access, as well as long-term commitments to monitoring, outplanting, and invasive species control are needed to maintain, restore, and establish new populations outside historical ranges, and safeguard the genetic diversity of these species.

HISTORICAL AND CULTURAL ARCHAEOLOGICAL RESOURCES

#	Question	Rating	Status Description	Indicators	Management Considerations
9	What is the condition of known maritime archaeological resources and how is it changing?	Maritime Archaeological Resources			
		Fair ▼	The diminished condition of selected archaeological resources has reduced, to some extent, their historical, scientific, or educational value and may affect the eligibility of some sites for listing in the National Register of Historic Places.	Due to their remoteness, maritime heritage sites in the monument are less threatened by humans than those in the MHI. Natural degradation is the greatest threat to these sites.	Fulfilling mandates to protect known maritime heritage resources and identify new sites, as well as inventorying and interpreting these sites, is critical, given the ongoing loss of information to natural degradation. Long-term management should prioritize monitoring, National Register of Historic Places nominations, and focused interpretive efforts.
10	What is the condition of known historic resources and how is it changing	Historic Resources: Midway Atoll			
		Fair ▼	The diminished condition of selected historic resources has reduced, to some extent, their historical, scientific, or educational value and may affect the eligibility of some sites for listing in the National Register of Historic Places.	Approximately half of the remaining 56 historic structures on Midway are in good to fair condition and are in use by the USFWS as a biological station. Deterioration due to exposure is apparent in the remaining half, potentially affecting their eligibility for listing in the NRHP.	Degradation by harsh environmental conditions, exacerbated by the high cost of working in such remote locations, make much-needed maintenance and repair a significant challenge. Web-based tools facilitate public access to ongoing research and other efforts.

#	Question	Rating	Status Description	Indicators	Management Considerations
11	What is the condition of known Native Hawaiian archaeological resources and how is it changing?	Native Hawaiian Archaeological Resources			
		Good/Fair ?	Selected archaeological resources exhibit indications of disturbance, but there appears to have been little or no reduction in cultural, scientific, or educational value.	Pre-contact Native Hawaiian cultural and archaeological sites are abundant on Nihoa and Mokumanamana. They have not been significantly impacted by human disturbance, but natural degradation is ongoing.	These resources contain high-quality information and benefit greatly from their inclusion in the monument and designation as a World Heritage site. Continued study by archaeologists is important to document and interpret these resources. One management strategy could be to decrease on-island visits to Mokumanamana in particular.

#	Question	Rating	Status Description	Indicators	Management Considerations
12	Do known historic and archaeological resources pose an environmental hazard and how is this threat changing?	Maritime Archaeological Resources			
		Good	Known heritage resources pose few or no environmental threats.	Prior threats that could have been posed by known historic sites, all of which are at least 50 years old, are most likely negligible or gone.	With the expansion of PMNM in 2016, the maritime heritage resource inventory increased to include the sunken ship and aircraft sites associated with the Battle of Midway in deeper water. Once discovered, assessment of these sites should include their potential impacts to the environment, including any visible fluid leaks from the vessels.
		Historic Resources: Midway Atoll			
		Good/Fair	Selected heritage resources may pose isolated or limited environmental threats, but substantial or persistent impacts are not expected.	The exterior of historic properties on Midway have been treated for lead paint by encapsulation. Rehabilitation of officers' houses and Midway House included removal of lead paint and asbestos materials. Most historic shop buildings are sided with transite, which contains an inert form of asbestos. Deterioration could increase the risk of exposure to lead and asbestos.	TUSFWS has abated lead paint on all historic properties. Continued monitoring and maintenance is needed. Removal of buildings and infrastructure may be necessary to reduce risks.

#	Question	Rating	Status Description	Indicators	Management Considerations
12	Do known historic and archaeological resources pose an environmental hazard and how is this threat changing?	Native Hawaiian Archaeological Resources: Nihoa and Mokumanamana			
		Good —	Known heritage resources pose few or no environmental threats.	Though no significant threats from archaeological resources exist, unexploded ordnance, shells embedded in stone outcrops, and metal fragments in bomb pits still exist on Mokumanamana. It is possible that eroding structures on the islands could present a hazard to birds or native plants.	In order to assess changes in the risk posed by these resources, more detailed and frequent monitoring and research are needed. However, the relative contribution of cultural resources as sources of environmental hazards is expected to be minimal.

Nihoa as seen from aboard the Polynesian voyaging canoe *Hikianalia*. Image: Brad Kaʻaleleo Wong/OHA

SITE HISTORY AND RESOURCES

Papahānaumokuākea Marine National Monument is unique among marine protected areas on the planet. Its expansive marine area encompasses one of the few intact, large-scale, predator-dominated reef ecosystems left in the world. This remote region comprises small islands, islets, and atolls and a complex array of shallow coral reefs, deep-water slopes, banks, seamounts, and abyssal and pelagic oceanic environments. These marine ecosystems support a diversity of marine life and have demonstrated significant degrees of recorded endemism, with frequency as high as 100% among some taxonomic groups.

The coral reefs of the monument are the foundation of an ecosystem that hosts a distinctive assemblage of marine mammals, fish, sea turtles, birds, algae, and invertebrates, including species that are rare, threatened, endangered, or have special legal protection status. The Census of Coral Reefs (in 2006) and Northwestern Hawaiian Islands Reef Assessment and Monitoring Program (RAMP) expeditions (between 2000 and 2010) revealed many previously unreported and undescribed species of shallow-reef invertebrates and corals, evidence that the marine systems within the monument have not been sufficiently explored and surveyed. Recent expeditions have taken place to map the seafloor of the monument and to identify and characterize deep-water marine environments, leading to the discovery of highly vulnerable deep-sea communities of corals and sponges, as well as many new species. Continued explorations and analyses are needed to adequately characterize and document rare habitats and species, especially vulnerable endemic species that may require special management (NMSP, 2005). Land areas support fragile ecosystems that provide homes for many endemic species. These include the entire populations of five species of endangered plants and four species of birds, including the world's most endangered duck, the koloa pōhaka or Laysan duck (*Anas laysanensis*). With a few notable exceptions, the terrestrial ecosystems and species of the monument are infrequently monitored and generally understudied.

EARLIEST DISCOVERIES AND SETTLEMENT

One of the most remarkable feats of open-ocean voyaging and settlement in all of human history was the movement of ancestral oceanic peoples across the largest ocean on the planet, beginning as early as 1500 B.C. (Irwin, 2006). There was a decline in long-distance voyaging around 1500 A.D., which coincides with the Hawaiian expansion period, when the The Northwestern Hawaiian Islands (NWHI) were thought to be central locations for the religious and political pursuits of Hawaiian society. The NWHI were intentionally explored, colonized, and in some cases, settled by Native Hawaiians between 1400 A.D. and 1815 A.D. (Kikiloi, 2012). Now commonly referred to as the Kūpuna (ancestral or elder) Islands, the NWHI contain remarkable man-made cultural structures that inform us about the origins of the first people of Hawaiʻi and hold great significance in Native Hawaiian culture and history. Nihoa and Mokumanamana (also known as Necker Island) have more than 140 archaeological sites that include agricultural, habitation, and religious structures. Based on radiocarbon data, it has been estimated that Nihoa and Mokumanamana Islands could have been inhabited from 100 A.D. to 1700 A.D. (Kikiloi, 2012; PMNM, 2008).

European discovery of Hawai‘i occurred in 1778, and subsequently the Hawaiian Islands underwent substantial changes, which included the establishment of the Hawaiian Kingdom. The NWHI (with the exception of Midway Atoll) were claimed by the Kingdom of Hawai‘i in the 1800s. In the 1890s, following the illegal overthrow of the Hawaiian Kingdom in 1893, the islands became a part of all public lands under the Provisional Government of Hawai‘i. Upon annexation by the United States in 1898, the public lands, including the NWHI, became ceded lands, currently held in trust by the State of Hawai‘i.

LOCATION

Located in a vast, remote, and largely uninhabited area of the Pacific Ocean, Papahānaumokuākea Marine National Monument comprises all emergent and submerged lands, and all waters of the NWHI (Figure SH.1). The region includes a number of existing federal and state conservation areas: the Hawaiian Islands National Wildlife Refuge, the Northwestern Hawaiian Islands Coral Reef Ecosystem Reserve, the Kure Atoll State Wildlife Sanctuary, the Midway Atoll National Wildlife Refuge, the Battle of Midway National Memorial, and the State of Hawai‘i Northwestern Hawaiian Islands Marine Refuge. Located to the southeast of Papahānaumokuākea are the inhabited islands of the State of Hawai‘i, otherwise known as the Main Hawaiian islands (MHI)[1].

DESIGNATION & EXPANSION

In 2006, President Bush issued Presidential Proclamation 8031 designating the Northwestern Hawaiian Islands Marine National Monument. Presidential Proclamation 8112 amended 8031, renaming the area Papahānaumokuākea Marine National Monument a year later in 2007. In 2008, the monument was designated a Particularly Sensitive Sea Area by the International Maritime Organization, a specialized agency of the United Nations. The monument is only the second marine protected area in the United States to receive this designation. Domestic protective measures were augmented as a result of this designation, alerting international mariners to exercise extreme caution when navigating through the area. Four special zones known as “Areas to be Avoided” were established on international nautical charts to direct ships away from coral reefs, shipwrecks, and other ecologically or culturally sensitive areas that may pose a navigation hazard within the monument. Additionally, a ship monitoring strategy was set in place through the CORAL SHIPREP ship reporting system. All transiting vessels (<300 gross tons) on their way to or from a U.S. port must notify managers when entering and exiting the monument boundaries. Other international transiting vessels are recommended to avoid monument waters or participate in the reporting system.

In 2010, the monument was inscribed as a mixed UNESCO World Heritage site for its outstanding natural and cultural significance. It is one of the largest World Heritage sites in the world, and is the only site in the United States with the distinction of receiving a mixed designation for both cultural and natural features.

[1]Portions of this document use “main Hawaiian islands” or MHI to refer to the islands of Hawaiʻi, Maui, Molokaʻi, Lānaʻi, Kahoʻolawe, Oʻahu, Kauaʻi, Niʻihau, and their adjacent islets.

On August 26, 2016, President Obama expanded the boundaries of the monument by Presidential Proclamation 9478 under the authority of the Antiquities Act. The boundaries of the monument west of 163° W were extended from 50 nautical miles to 200 nautical miles (the full extent of the U.S. Exclusive Economic Zone). The existing 50 nautical mile boundary of PMNM east of 163° W was maintained. The total size of the monument increased from an area of 139,792 square miles to 582,578 square miles. While the analyses in this report did not include resources in the expansion area, and that area did not factor into ratings of status and trends, the expansion area is discussed in numerous places throughout the report.

GOVERNANCE

Papahānaumokuākea Marine National Monument is administered jointly by four Co-Trustees: the Secretary of Commerce through NOAA, the Secretary of the Interior through USFWS, the State of Hawai‘i through the Governor, and the Office of Hawaiian Affairs (OHA). A memorandum of agreement established a joint governance regime in which all parties share in monument management, including managing access and implementing regulations.

NOAA has primary responsibility regarding the management of the marine areas of the monument. The National Marine Fisheries Service (NMFS) has responsibility for marine mammals and other protected species under the Marine Mammal Protection Act, joint management responsibility for species protected under the Endangered Species Act and other authorities, as well as responsibilities for fisheries stewardship under the Magnuson-Stevens Fishery Conservation and Management Act. The Office of National Marine Sanctuaries is the NOAA lead for implementation of monument regulations.

USFWS has primary responsibility for management of the areas of the monument that overlay the Midway Atoll National Wildlife Refuge and the Battle of Midway National Memorial, and the terrestrial and marine areas of the Hawaiian Islands National Wildlife Refuge.

The State of Hawai‘i Department of Land and Natural Resources (DLNR) has stewardship responsibility for managing, administering, and exercising control over all coastal and submerged lands, ocean waters, and marine resources under state jurisdiction, which extends out to three nautical miles offshore of each of the Northwestern Hawaiian Islands, except Midway Atoll, which was excluded by the Hawai‘i Statehood Act of 1959. The State of Hawai‘i also manages the emergent lands and reefs at Kure Atoll as a State Wildlife Sanctuary.

OHA is a constitutionally established body, set as a separate state entity independent of the executive branch of the State of Hawai‘i. OHA’s primary responsibility as a Co-Trustee is representing the interests of the Native Hawaiian community in the monument through the perpetuation of Hawaiian cultural resources, including the customary and traditional rights and practices of Native Hawaiians exercised for subsistence, cultural, and religious purposes under the Hawai‘i Constitution.

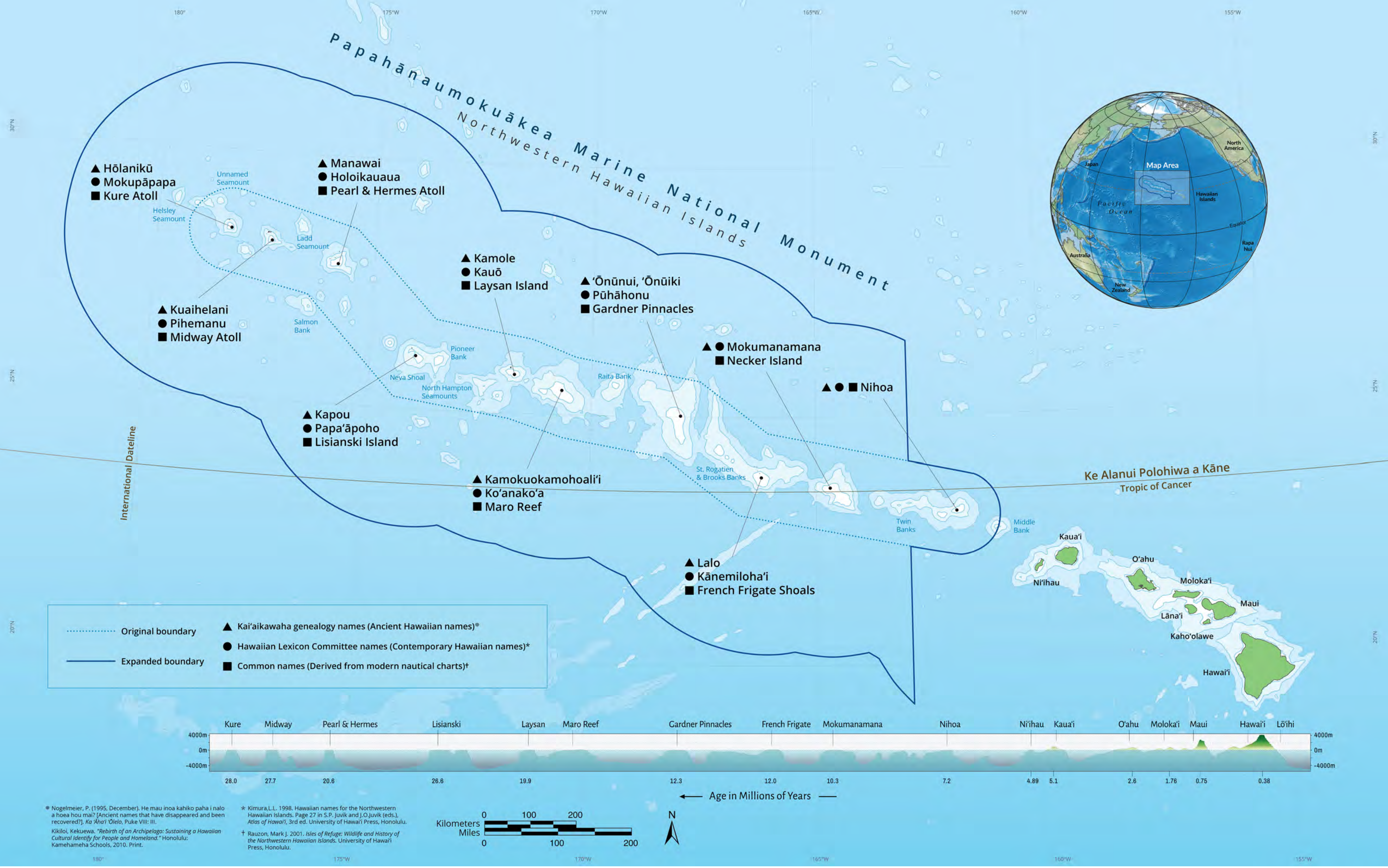


Figure SH.1. Map of Papahānaumokuākea Marine National Monument and its location relative to the inhabited Main Hawaiian Islands. Image: PMNM

Spire-like Mokumanamana is one of the many dramatic features in the monument. Image: Wayne Levin

GEOLOGY

Over the past 70 million years or more, the combined processes of magma formation, volcanic eruption and growth, and continued movement of the Pacific Plate over a magmatic "hotspot" have left a long trail of volcanoes across the Pacific Ocean floor. The Hawaiian Ridge-Emperor Seamount chain extends 3,728 miles from the "Big Island" of Hawai'i to the Aleutian and Kamchatka trenches off Alaska and Siberia, respectively. The Hawaiian Islands themselves are a very small part of the chain and are the youngest islands in the immense, mostly submarine mountain chain composed of more than 80 volcanoes (Clague, 1996).

A sharp bend in the chain indicates that the motion of the Pacific Plate abruptly changed about 43 million years ago as it took a more westerly turn from its earlier northerly direction. The formation of the bend coincides with a major reorganization of northern Pacific seafloor spreading centers and the initiation of subduction at the Mariana arc-trench system (Sharp & Clague, 2006).

As the Pacific Plate continues to move west-northwest, the seamounts, which are remnants of ancient geological features from the Hawaiian-Emperor Seamount Chain, along with portions of the Pacific Plate, are subducted under the Okhotsk plate at the Kuril-Kamchatka Trench and returned to the interior of the earth.

Papahānaumokuākea constitutes the northwest three-fourths of the vast chain of the Hawaiian Archipelago. This protected area comprises small rocky basaltic islands, banks and seamounts, atolls, coral islands, and reefs, which become progressively older geologically. Over millennia, invertebrate animals and algae have constructed massive reefs in the shallow seas surrounding the islands. Corals and coralline algae, initially attached to the basalt of the ancient volcanoes, accreted gradually by secreting calcium carbonate skeletons. The basaltic islands eventually eroded away and subsided under their own massive weight. However, the upward growth of the coral reefs kept pace with the gradual sinking of the volcanic remnants, resulting in the reefs we see today.

Hōlanikū or Kure, Kuhaihelani or Midway, Manawai or Pearl and Hermes, and Lalo or French Frigate Shoals are atolls with islets enclosed within the outer reef crest of the atoll. Kapou or Lisianski Island is surrounded by an open atoll called Neva Shoals, without an atoll rim. Kamole or Laysan Island is the only low coral atoll in the NWHI that is not associated with an atoll (Rooney et al., 2008). These islands and islets are primarily composed of marine-derived materials such as coral rubble and sand, mostly sourced from calcifying species. Kamokuokamohoali'i or Maro Reef is composed of a matrix of coral reefs with no permanent emergent land. The emergent land at Gardner Pinnacles (also known as 'Ōnūnui or 'Ōnūiki), La Perouse Pinnacle at French Frigate Shoals, Mokumanamana, and Nihoa are all composed of volcanically originated basalt and are surrounded by fringing coral reefs. Submerged seamounts, banks, and guyots are composed of a complex of calcified materials capping basalt foundations.

OCEANIC CONDITIONS

Ocean currents transport and distribute material, including larvae and marine debris, among and between different atolls, islands, and submerged banks of the Hawaiian Archipelago, as well as distant regions. Upper ocean currents in the monument are highly variable and both speed and direction are largely driven by eddy variability. Currents in the Central North Pacific that relate to the Hawaiian Archipelago are the North Pacific Current and the North Equatorial Current, which cycle around the archipelago to form the North Pacific Subtropical Gyre (Figure SH.2). Additionally, a subtropical convergence zone forms when currents converge and organisms or passive particles become concentrated (Howell et al., 2012). Averaged over time, the resulting mean flow of surface waters tends to be predominantly from east to west in response to the prevailing northeast trade winds (Firing & Brainard, 2006).

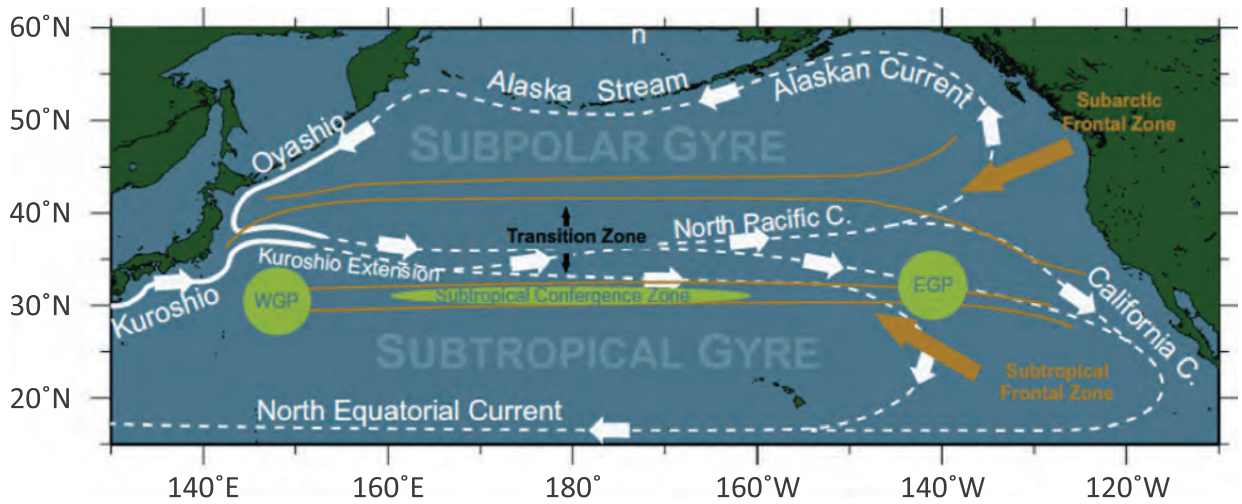


Figure SH.2. Major ocean currents in the central North Pacific Ocean and resultant oceanographic features. Image: PIFSC

Significant wave events vary over interannual (occurring between two or more years) and decadal time scales, which can also determine distributions of coral and algal species and their associated fish and invertebrate assemblages. Interannually, the waters of the monument experience greater or lesser amounts of cumulative wave energy or numbers of extreme wave events during some years than others. This apparent decadal variability of wave power is possibly related to well-documented Pacific Decadal Oscillation events, which are a mode of North Pacific climate variability at multi-decadal time scales that has widespread climate and ecosystem impacts (Mantua et al., 1997).

The more northern coral reefs of the monument, particularly Kure, Midway, and Pearl and Hermes Atolls, lie at the same northerly subtropical latitudes as the coasts of Texas and Louisiana, and are consequently exposed to larger seasonal temperature fluctuations. Sea surface temperatures at these northerly atolls can range from less than 19°C in the late winter to highs exceeding 26°C in the late summer months of some years, (Gove at al., 2013). Compared to most reef ecosystems around the globe, these fluctuations are extremely high. While the summer temperatures are generally similar along the entire NWHI chain, winter temperatures tend to be up to 4°C cooler at the northerly atolls than at the southerly islands and banks (Gove et al., 2013) as the subtropical front migrates southward. Sea surface temperature varies across the latitudinal range of the monument. Climatology from 1985–2008 (Figure SH.3.) shows as much as a three degree difference between lower and higher latitude areas.

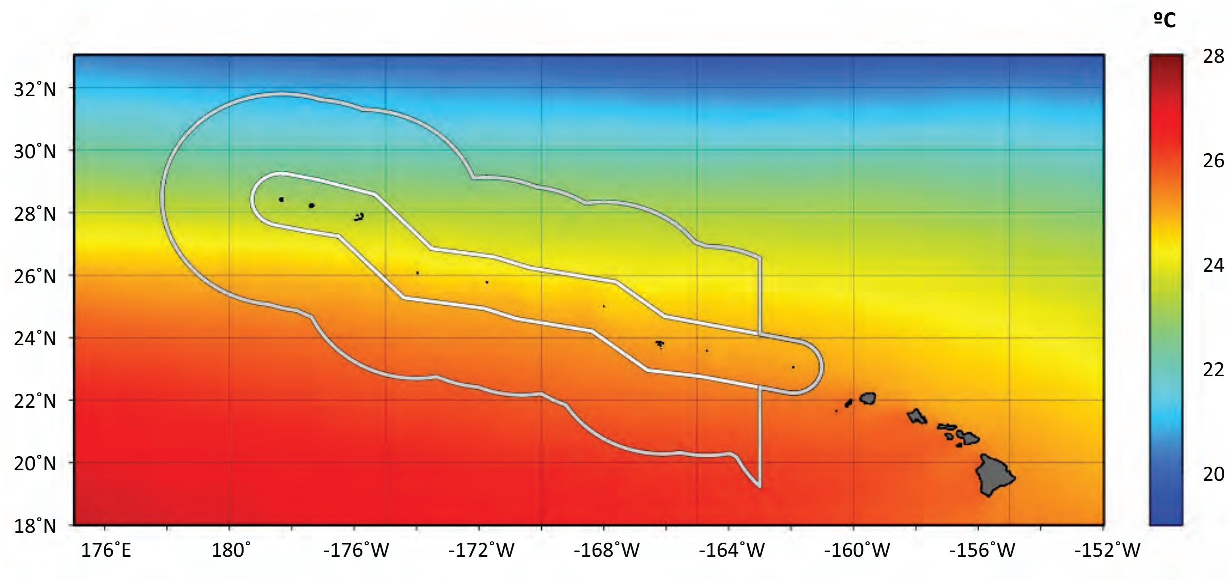


Figure SH.3. Climatology of temperature across the monument between 1985 - 2008. Image: Melanie Abecassis/PIFSC

Satellite observations reveal a significant chlorophyll front associated with the subtropical front, with high chlorophyll north of the front and oligotrophic waters south of the front. These observations reveal significant seasonal and interannual migrations of the front northward during the summer months and southward during the winter months (Seki et al., 2002). The southward migration of the subtropical front generally brings these high-chlorophyll waters into the northern portions of the Northwestern Hawaiian Islands. During some years, these winter migrations of the subtropical front extend southward to include the southern end of the monument. Additional evidence suggests decadal scale movements in the southward extent of the subtropical front (Friedlander et al., 2005). Climatologically, there are higher nutrients and productivity in waters at the higher latitude northern atolls, with an overall difference of 0.5 mg/m^3 between southern and northern portions of monument waters (Figure SH.4).

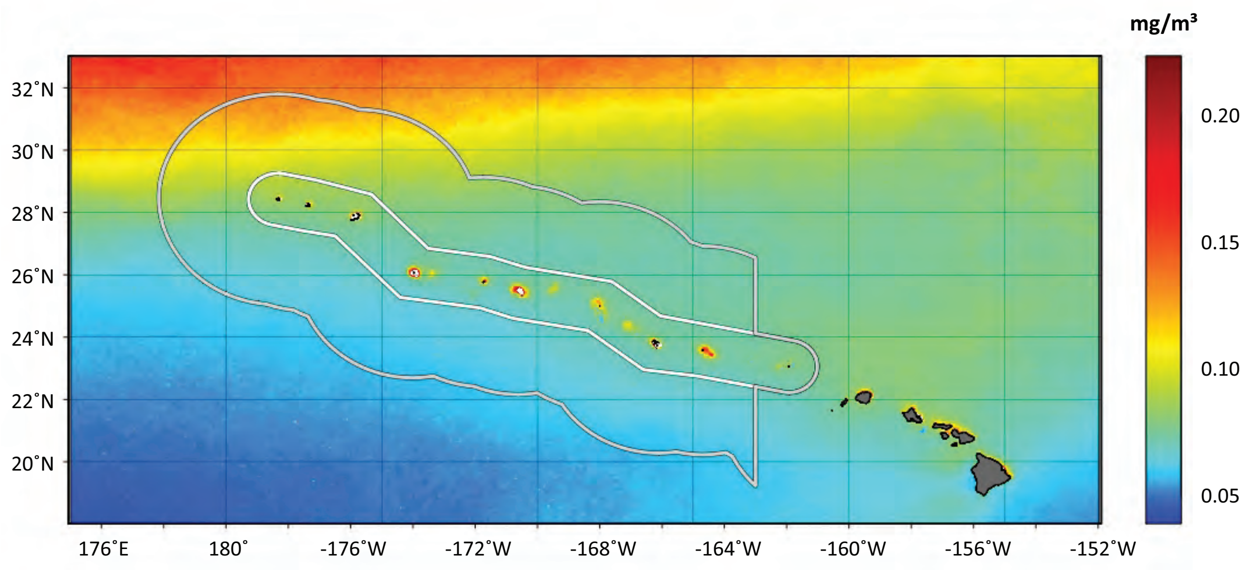


Figure SH.4. Climatology of chlorophyll across the monument between 1998 - 2008. Image: Melanie Abecassis/PIFSC

HABITATS

The monument is composed of a complex array of islands, reefs, slopes, banks, seamounts, abyssal and pelagic marine environments. The majority of the monument includes pelagic and seafloor habitats, with the majority deeper than 4,000 m (Figure SH.5). Seamounts are important habitats for deep-sea coral and fish. While the importance of seamounts to the pelagic ecosystem of the monument is still uncertain, studies support hypotheses that shallower seamounts (i.e., summits less than 800 m deep) may be areas of special interest for management of pelagic predators. They generate conditions, such as increased vertical nutrient fluxes and material retention, that promote productivity and fuel higher trophic levels and may become "hotspots" of pelagic biodiversity (Morato et al., 2010).

The monument protects 3.5 million acres of coral reef—70% of the total coral reef area in the United States. Pearl and Hermes Atoll, French Frigate Shoals, Maro Reef, and Lisianski Island have the most extensive nearshore reefs. Gardner Pinnacles, Lisianski Island, Maro Reef, and Mokumanamana have the most extensive shallow-water bank areas (Miller & Crosby, 1998). Reefs within the monument differ in terms of coral cover and species composition. Due to the remote location of these reefs, the dispersal and recruitment of reef species from the rest of the Pacific is an uncommon event. Long periods of isolation for successful recruits have led to the evolution of species distinct from those on the ancestral reefs, resulting in the highest levels of marine endemism recorded for any large archipelago in the world (Randall, 1992; Eldredge & Miller, 1995; Miller & Eldredge, 1996).

The land areas of the monument consist of two basalt islands (Mokumanamana and Nihoa), three additional smaller basalt features (La Perouse Pinnacle at French Frigate Shoals, and two features at Gardner Pinnacles), two carbonate islands (Lisianski and Laysan), and four multi-island coral atolls (Kure, Midway, Pearl and Hermes, and French Frigate Shoals). These diverse environs provide habitats of global importance for 21 species of breeding seabirds, four endemic land birds, four migratory shorebirds, ʻīlioholokauaua or Hawaiian monk seals (*Neomonachus schauinslandi*), turtles, five endemic plants, and an array of endemic invertebrate species that include a trap door spider, giant tree cricket, giant earwig, rare land snails, and moths. Many of the islets and atolls have remained relatively untouched. Nihoa Island is one of the most biologically pristine islands in the Pacific and probably most closely represents the original state of an island prior to the arrival of humans.

Krause et al. (2012) identified 17 land cover classes for the low-lying islands. These include six general vegetation classes (tree/shrub, mixed shrub, grass/herbaceous cover, vine/ground cover, wetland vegetation, and partially vegetated former runways), five species-specific vegetation categories, unvegetated areas (mudflats, standing water, bare ground, hardpan, beach), and human infrastructure. The higher-elevation islands of Nihoa and Mokumanamana consist mainly of rocky, vegetated and unvegetated slopes and cliffs; these support some of the most unique and varied insect, seabird, and plant life of all the NWHI.

The monument's native terrestrial ecosystems are vulnerable to disruptions and can experience severe alteration in their plant and wildlife community structures when impacted by non-indigenous vegetation or invasive herbivores and predators, such as grasshoppers and ants. Recent habitat restoration work at several locations in the monument has decreased or eliminated invasive plants and insects, and increased cover of native plant species.

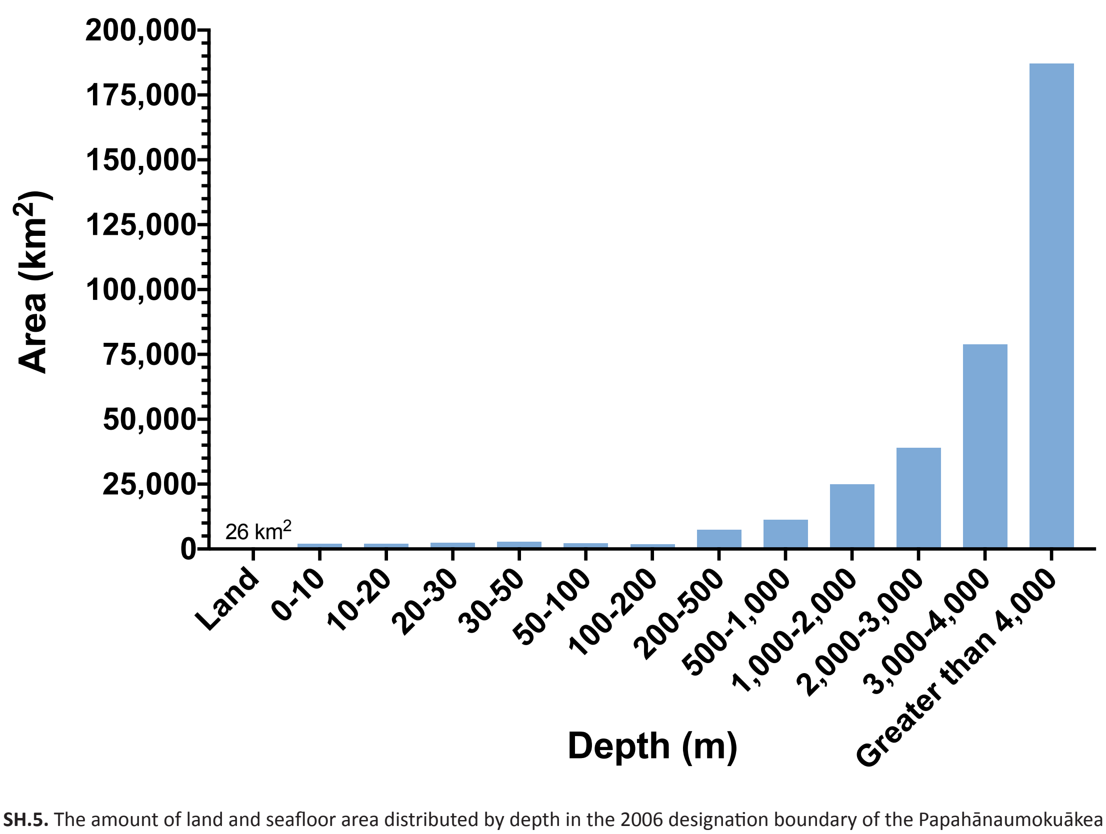


Figure SH.5. The amount of land and seafloor area distributed by depth in the 2006 designation boundary of the Papahānaumokuākea Marine National Monument. Image: PMNM

LIVING RESOURCES

The terrestrial and marine ecosystems of the monument support over 7,000 known species of plants, mammals, birds, fish, and invertebrates. The isolation of the archipelago has led to extremely high rates of endemism (species found only in Hawai‘i). Some of the key species groups addressed in this report include:

Marine Mammals

The Northwestern Hawaiian Islands ecosystems play an important role in supporting more than 20 species of marine mammals. The endemic Hawaiian monk seal, the most endangered marine mammal in the United States, is a year-round resident, and is the only seal known to be dependent upon coral reefs for its existence. Some species of dolphins (nai'a) are year-round residents in the monument; these include spinner (*Stenella longirostris*) and bottlenose dolphins (*Tursiops truncatus*). Wide-ranging and migratory species such as spotted dolphins (*Stenella frontalis*), nu‘ao or false killer whales (*Pseudorca crassidens*), koholā or humpback whales (*Megaptera novaeangliae*) and numerous other cetaceans also occur within the monument.

Sea Turtles

The monument provides vital habitat for the threatened honu or green turtle (*Chelonia mydas*), which occupies three habitat types: open beaches; shallow, protected waters; and open sea. French Frigate Shoals is the principal rookery site for the entire Hawaiian green turtle stock, with more than 90% of the archipelagic population nesting there (Balazs & Chaloupka, 2004). Upon hatching, the young turtles crawl from the beach, swim over shallow reef areas and expansive shoal areas, and eventually reach the open ocean, where they reside for several years. Once their shells grow eight to 10 inches long, they move to shallow feeding grounds over coral reefs and rocky bottoms. Green turtles reach sexual maturity at 25 to 50 years of age, then return to nest at the beach where they hatched (Bowen et al., 1992). Whereas the green turtle is a resident species occurring throughout the entire archipelago, the endangered honu‘ea or hawksbill turtle (*Eretmochelys imbricata*) is considered a resident of the MHI. Three other endangered turtle species, the leatherback (*Dermochelys coriacea*), the olive ridley (*Lepidochelys olivacea*), and the loggerhead (*Caretta caretta*) are considered transient species that occur seasonally in the archipelago.

Fish

The monument waters support some unique species of fish that are rare elsewhere in the Hawaiian Archipelago, but are found in geographically distant ecosystems, including the hīnālea or slingjaw wrasse (*Epibulus insidiator*), the masked angelfish (*Genicanthus personatus*), and the spotted knifejaw (*Oplegnathus punctatus*). It is believed that the NWHI are linked to these other remote ecosystems via associated seamounts and the island groups adjacent to them. The extreme isolation of the monument and its distance from the diverse fish population centers of the western Pacific contribute to its lower fish species diversity relative to other sites to the west (Mac et al., 1998). Structurally, apex predators, such as sharks and ulua aukea or giant trevally (*Caranx ignobilis*) dominate fish communities on monument forereefs, making up over 54% of the total fish biomass in underwater visual surveys, compared to 3% in the MHI. In addition, abundance and biomass estimates indicate that the monument reef community is characterized by relatively fewer herbivores, such as surgeonfishes, and more secondary consumers, such as kūmū or goatfish (*Parupeneus porphyreus*), scorpionfishes, and snappers. Pelagic fish species that occur in the monument are prey items for many cetaceans. While less frequently studied, pelagic fish

A breeding colony of ʻewaʻewa or sooty terns (*Onychoprion fuscatus oahuensis*). Image: Mark Sullivan/NOAA

such as ahi or yellowfin tuna (*Thunnus albacares*) have demonstrated high fidelity to seamount features elsewhere in the Hawaiian Archipelago (Klimley & Holloway, 1999; Itano & Holland, 2000) and the same may hold true for the features in the monument due to the presence of highly suitable habitats (e.g., banks, seamounts). Additionally, there are species of fish that use both forereef and pelagic environments in the monument (Meyer et al., 2010).

Land Birds

Four species of endangered endemic land birds live and breed in the monument: the Laysan duck, ʻainohu kauo or Laysan finch (*Telespiza cantans*), palihoa or Nihoa finch (*Telespiza ultima*), and Nihoa millerbird (*Acrocephalus familiaris kingi*), known as ulūlu on Nihoa and ulūlu niau on Laysan. Translocations of the Nihoa millerbird and the Laysan duck were conducted to reduce the risk of catastrophic species loss. The Nihoa millerbird occurs on Nihoa and Laysan Islands. The Laysan finch occurs on Laysan Island and on Southeast Island at Pearl and Hermes Atoll. The Laysan duck occurs on Midway Atoll, Kure Atoll, and Laysan Island. The Nihoa finch survives only on its namesake island.

Seabirds

Papahānaumokuākea is home to more than 14 million seabirds living seasonally in what is collectively the largest seabird rookery under unified management in the Pacific. Twenty-one species of tropical and subtropical seabirds breed in Papahānaumokuākea. Virtually all of the world's populations of mōlī or Laysan albatross (*Phoebastria immutabilis*) and ka'upu or black-footed albatross (*Phoebastria nigripes*) breed there, as well as populations of global significance of koa'e kea or red-tailed tropicbirds (*Phaethon lepturus dorotheae*), Bonin petrels (*Pterodroma hypoleuca*), 'akihikē'ehi'ale or Tristram's storm-petrels (*Oceanodroma tristrami*), and manu o kū or white terns (*Gygis alba candida*).

Endemic Plants

At least five species of terrestrial plants found only in the NWHI region are listed under the U.S Endangered Species Act, some so rare that because of the difficulty of surveying these remote islands, they have not been documented for many years. The IUCN lists *Cenchrus agrimonioides* var. *laysanensis* from Laysan Island as extinct, though biologists hold hope that it may still exist. Similarly, *Achyranthes atollensis*, endemic to Kure Atoll, Midway Atoll, Pearl and Hermes Atoll, Lisianski Island, and Laysan Island, has not been seen for decades. *Amaranthus brownii* and *Schiedea verticillata*, endemic to Nihoa, and *Cyperus pennatiformis* var. *bryanii*, endemic to Laysan, are all considered endangered. Many more Hawaiian (archipelagic) endemic plant species are also found in the NWHI. Species composition differs from island to island due to human-caused disruptions (such as introduction of invasive plant species) as well as natural conditions and features.

Corals

The extensive shallow-water coral reefs in Papahānaumokuākea Marine National Monument are the largest in the U.S. While relatively isolated from human impacts, they remain threatened by global disturbances. Large, precious corals, such as gold coral (*Gerardia* spp.), pink coral (*Corallium secundum*), and 'ēkaha kū moana or black coral (*Antipatharia*) also are found in the deep waters of the banks. Unlike shallow reef corals, which are able to harness sunlight as an energy source due to photosynthesizing symbiotic dinoflagellates in their tissues, deep-water precious corals live in near total darkness and are dependent upon capturing plankton from the water column with their tentacles. Research in 2014–2016 discovered large gold corals estimated to be thousands of years old. While recent data collections provide extremely valuable information about PMNM shallow-water and deep-water coral communities, most of these remain unexplored and unknown.

HERITAGE RESOURCES

The Hawaiian Islands have a rich maritime history. Though Native Hawaiian traditions retained knowledge of the NWHI, regular visits had ceased by the time Captain Cook's two ships made the first European contact with the Hawaiian Islands in 1778. In the 1800s, many of the reefs and atolls in the Northwestern Hawaiian Islands were encountered by Westerners either intentionally or when ships unintentionally ran aground. Some of the locations, such as Maro Reef, Laysan Island, and Pearl and Hermes Atoll, received their English names from shipwrecked vessels.

During the late 18th and early 19th centuries, European and American traders began to call at the MHI, and by 1825, Honolulu had become the most important port in the Pacific. During the 19th and 20th centuries, the NWHI experienced a series of extractive activities, including fishing, guano mining, shipwreck salvage cruises, artifact looting, bird poaching (feathers & eggs), and pearl oyster collection, as well as commercial exploitation of other marine and terrestrial wildlife. The opening of the Japan whaling grounds in 1820 sent ships through the NWHI in pursuit of whale oil. During this era, the NWHI also became increasingly important to commercial and military planners. Midway Atoll was claimed by the U.S. government in 1867 and by the turn of the century had become an important transpacific cable station and stopping point for the flying "Clippers" carrying passengers and mail between San Francisco and Manila. In 1940, the U.S. Navy constructed the Pacific Naval Air Base, and subsequently a submarine base, at Midway. During World War II, patrol vessels were stationed at most of the islands and atolls.

Due to the low elevation and low visibility of the islands, their faulty placement on historical marine charts, and the numerous activities occuring in the region over the past few centuries, there have been many groundings and shipwrecks in the NWHI. A scattered legacy of artifacts exists, both on and around the islands, serving as windows to the past. Submerged sites include sunken 19th century British and American whaling ships, Japanese junks, navy steamers, Hawaiian fishing sampans, Pacific colliers, salvage vessels, and naval aircraft. The earliest sites discovered so far are the whaling ships Pearl and Hermes, dating back to 1822. In total, there are 60 known shipwreck sites. Combined with sunken aircraft sites, over 130 potential maritime resource sites are currently known (PMNM, 2008). To date, only 23 of these sites have been documented, including 18 vessels and five World War II-era aircraft. The remaining vessels have yet to be surveyed. Many of these heritage resources, as defined by state and federal preservation laws, are of historical and national significance. For example, some ship and aircraft wreck sites fall into the category of war graves associated with major historic events, such as the Battle of Midway in June 1942. They are physical records of past activities in the Northwestern Hawaiian Islands and embody unique aspects of island and Pacific history.

NATIVE HAWAIIAN CULTURAL RESOURCES

A revered connection exists between Native Hawaiians and the Northwestern Hawaiian Islands that extends back hundreds of years into antiquity. Ancient Polynesians traveled thousands of miles over generations, exploring the far reaches of the archipelago and eventually settling in the larger islands located to the southeast. A rich tradition of orature, chants, songs, dance, and other customs document many aspects of early Hawaiian society including voyaging, genealogies, religious spiritual pursuits, and resource management.

These traditions, which are continued to the present day, perpetuate and provide a window into the Native Hawaiian way of life and worldview, including the all-important familial relationships between the Native Hawaiian people and nature. Most of the Northwestern Hawaiian Islands have an ancient Hawaiian name, contemporary Hawaiian name, and a common name. The original names that Native Hawaiians gave to the islands they encountered prior to Western contact are found in various chants (oli) and stories (moʻolelo).

Papa and Wākea. Painting by Native Hawaiian artist Solomon Enos.

Native Hawaiian cosmology recognizes a direct genealogical relationship between humans and the natural world. The kinship between Native Hawaiians and the natural world was comparable to that of a parent and a child: nurturing and reciprocal. Native Hawaiians depended on the land for sustenance and shelter, while the land was cared for in return. This concept is perpetuated today through the restoration of natural habitats and continued preservation of the ancestral environment. Native Hawaiians were excellent observers of their environment and documented natural relationships in various chants. The most well-known of these chants, the Kumulipo (Source of Deep Darkness), chronicles the birth of the natural world in and from Pō (the darkness), beginning with the simplest known form of life, the coral polyp, and progressing to more complex forms such as seaweed, fish, birds, and islands.

Native Hawaiians regard these atolls, islands, and surrounding waters as an ʻāina akua (sacred region) from which all life springs and to which ancestral spirits return after death (Kikiloi, 2006). The Native Hawaiian belief system regarding this genealogical relationship informs a set of responsibilities, rights, and privileges (kuleana) that Hawaiian people have inherited to honor and protect their ancestors as described in the creation stories. According to this belief system, all these ancestors, whether coral polyp, human, island, or other form, continue to reside in the Northwestern Hawaiian Islands in a multitude of body forms. This is a powerful aspect of the region, an origin place of the Hawaiian people that continues to connect them to their cultural heritage.

Manu ʻā or masked boobies (*Sula dactylatra personatta*) and ʻiwa or great frigate birds (*Fregata minor palmerstoni*) at rest on the upright structures at Mokumanamana. Image: Brad Kaʻaleleo Wong/OHA

One story contained within the Kumulipo tells of Papahānaumoku (a mother figure personified by the earth) and Wākea (a father figure personified by the expansive sky). These two deified ancestors are revered by Native Hawaiians, as their union and others along their family line resulted in the creation, or birthing, of the entire Hawaiian Archipelago and the Native Hawaiian people themselves. The naming of the monument as Papahānaumokuākea honors and preserves these beliefs, strengthening the cultural foundation of Hawaiʻi and connecting Hawaiians to an important part of their history.

Because the Northwestern Hawaiian Islands hold deep cosmological significance for indigenous Hawaiians, they are considered a puʻuhonua (place of refuge). Traditional and historical records show that the islands were visited by monarchs of the Hawaiian Kingdom, with archaeological evidence of human occupation in the region, particularly on the islands of Mokumanamana and Nihoa.

The significance of these islands is attributed to their position in relation to Ke Ala Polohiwa a Kāne (the Tropic of Cancer or "the black shimmering road of Kāne"). This conceptual line is a natural boundary of sorts that traces the sun's northernmost path of travel during the year on the summer solstice. In Native Hawaiian culture, this path delineates the border between the realms of Pō (dark; the spirit realm) and Ao (light; the realm of the living).

Mokumanamana is located on the Tropic of Cancer, occupying a position of great importance in traditional Hawaiian society. Mokumanamana contains one of the highest concentrations of ceremonial sites in the Hawaiian Archipelago and is thought to have acted as a spiritual gateway and a ritual center of power for the Hawaiian system of heiau (temples, places of worship) established by the ali'i (chiefly elites). Rituals, established to honor ancestors (kūpuna) and gods (akua) in order to gain mana (spiritual power), had long-lasting implications and led to a religion that spread widely throughout the inhabited MHI.

Nihoa is the only island of the monument that is south of the Tropic of Cancer, in the realm of Ao, and is thought to have served as a bridge or staging ground to access Mokumanamana for religious ceremonies. Archaeological explorations on Nihoa have revealed numerous religious structures, habitation sites, and agricultural terraces spanning a period of 500 to 700 years and displaying a considerable investment from this earlier Hawaiian society. In recognition of their status in Hawaiian history and culture, the islands of Nihoa and Mokumanamana are listed in the National Register of Historic Places.

The Native Hawaiian community continues to regularly access and utilize Papahānaumokuākea for physical and spiritual sustenance. For example, Hawaiians annually connect with Papahānaumokuākea through the practices of traditional voyaging and wayfinding aboard double-hulled sailing canoes. A renewed interest in ancient Polynesian navigation techniques reveals a need for continued foundational training and skills development. This knowledge is often place-specific and can only be acquired in home waters. For a novice navigator, the voyages from Ni'ihau to Nihoa and then Mokumanamana are considered one of the significant benchmarks of achievement. Ceremonies and protocol associated with visits to Nihoa, Mokumanamana, and other islands can only be performed off those shores, where appropriate respect can be paid to one's ancestors, in their particular spiritual, natural, and geological manifestations.

Connections between Papahānaumokuākea and the MHI to the southeast are also being revived and strengthened through continued access and research (or ways of knowing) by new generations of Native Hawaiian scholars and practitioners. These individuals are combining traditional skills with modern methods and technologies and historical resources to rediscover ancient place names, monitor and observe ecosystems and species, conduct archaeological studies, and apply cultural knowledge to habitat restoration efforts.

New species discovered in the monument have received Hawaiian names through traditional naming practices using specific identifying characteristics or telling a story of the plant or animal's interactions with Native Hawaiians or its environment. The blending of modern and traditional techniques has served to perpetuate these connections and deepen the understanding of records left by Native Hawaiians who once accessed the region regularly and complements many centuries-old biological, geophysical, and even spiritual assertions.

A Hawaiian monk seal hauls out on a mass of derelict fishing gear at Pearl and Hermes Atoll. Image: NOAA

PRESSURES ON THE MONUMENT

Numerous human activities and natural processes and events affect the condition of natural and archaeological resources in Papahānaumokuākea. This section describes the nature and extent of the most prominent pressures on the monument.

CLIMATE CHANGE

Changes in the global climate are being brought about by three factors: increasing concentrations of carbon dioxide and other gases in the atmosphere, alterations in the biogeochemistry of the global nitrogen cycle, and ongoing land use and cover change. The primary global climate change-induced stressors of concern include: temperature, weather, sea level rise, and changes in ocean chemistry (PMNM, 2008).

Ocean heat content is increasing globally (Cheng et al., 2020), with consequent ecological impacts reported in the NWHI. Mass coral bleaching was first recorded during late summer 2002 (Aeby et al., 2003; Kenyon & Brainard, 2006). Coral bleaching occurs when corals are pushed beyond their thermal tolerance for extended periods of time, causing them to expel their resident symbiotic algae. Until the 2002 event, the region was believed to be less susceptible to bleaching because of its high-latitude location. Coral bleaching occurred again in 2004, but was detected at only low rates in 2006 (Kenyon et al., 2006). Within the past 10 years, there has been reported coral bleaching in 2009, 2010, 2014, and 2019, all with varying degrees of severity and localities. Bleaching was most severe at the three northernmost atolls (Kure, Midway, and Pearl and Hermes). Lisianski Island, located further south in the chain, also experienced coral bleaching, but the extent was less severe.

Beyond coral bleaching, warming oceans are more conducive to the formation of tropical storms and cyclones, which are now tracking further northward (Murakami et al., 2020). The frequency of tropical cyclones in the Hawaiian Archipelago, including the monument, is predicted to increase over the coming decades (Murakami et al., 2013; Nakamura et al., 2017; Chand et al., 2017).

Climatic events also play an important role in ecosystem productivity. Periodic fluctuations in the abundance of monk seals, reef fishes, and chlorophyll have been documented from the early 1980s to the present and may be associated with multidecadal climate oscillations. Weather changes, such as reductions in the amount of precipitation and changes in soil moisture and temperature, will affect vegetation communities by changing species compositions, seasonality, and biomass. These changes in turn may affect the reproductive capabilities of insects and land birds that depend on them. Increased storm frequency and intensity will impact coral health as the movement of sand causes damage in the form of breakage and smothering. These effects will also impact terrestrial systems through overwashing of islands.

Climate models predict that global average sea level rise will range from 1 to 8.2 feet (0.3 to 2.5 meters) this century (Sweet, Kopp, et al., 2017). A rise of 1.6 feet (0.48 meters) is predicted to cause the loss of

3 to 65 percent of the terrestrial habitat in the monument (Baker et al., 2006). Most of the Northwestern Hawaiian Islands are low-lying and therefore potentially vulnerable to increases in global average sea level.

The effects of changes in seawater chemistry on the monument are uncertain, as the various impacts to oceans and associated ecosystems are still under study. However, current research suggests that decreasing ocean pH impedes coral skeletal growth (Crook et al., 2014). The result is a drastic reduction in a coral reef's ability to overcome the balance of erosion and deposition, leaving these ecosystems (and the carbonate-based island atolls) vulnerable to the additional threats of sea level rise and increased storm activity.

NON-INDIGENOUS AND INVASIVE SPECIES

Non-indigenous species are defined as organisms that are not native to a particular ecosystem and have been accidentally or purposely introduced into new ecosystems. In some instances, non-indigenous species may coexist with the indigenous ones, although in many cases they result in negative ecological, economic, or human health impacts.

A species becomes invasive when it demonstrates rapid growth and spread, invades habitats, and displaces native organisms. Though not all introduced species will become invasive, those that do could potentially have some of the following environmental impacts to the monument:

- Loss of native biodiversity;
- Functional changes of ecosystems;
- Alterations in nutrient cycling pathways; and
- Decreased water quality.

An estimated 61 marine non-indigenous invertebrate, fish, and algal species have been recorded in the monument. Species may be introduced unintentionally by vessels, marine debris, or aquaculture, or intentionally, as in the case of some species of groupers, snappers, and algae. Eleven species of shallow-water snappers and groupers were purposely introduced to the waters of the MHI in the late 1950s (Randall, 1987). Two of these introduced fish, the taʻape or bluestripe snapper (*Lutjanus kasmira*) and the roi or peacock hind (*Cephalopholis argus*) are now established in Papahānaumokuākea. Populations of non-indigenous marine species that have already colonized areas of the southeastern portion of the archipelago represent the most likely source of invasive species in the monument. Most can be found from littoral zones to deep-water coral beds. Thus far, the marine non-indigenous species known from the monument have mainly been detected in areas of higher human activity at Midway Atoll and French Frigate Shoals (Godwin et al., 2005). However, in 2019, a previously unrecorded species of red algae *Chondria tumulosa* was discovered spreading across Pearl and Hermes Atoll (Sherwood, Huisman, et al., 2020).

Hundreds of terrestrial non-indigenous species have been introduced. Human occupation at Midway Atoll has continued uninterrupted since 1903. To aid in the cultivation of gardens and small livestock, barge loads of soil were brought in from Oʻahu and Guam. This soil contained associated organisms such as ants, centipedes, and fungi. In addition to vegetables, ornamentals and trees, including ironwoods, eucalyptus, and acacia, were planted. Livestock and poultry were introduced during this time, along with mice, rats, and various species of wasps, ticks, and mosquitoes. The black rat (*Rattus rattus*) was

Nihoa is dominated by native, endangered plant species such as *Portulaca villosa* (lower left) and *Solanum nelsonii* (right). Note the highly invasive grass *Cenchrus echinatus* growing amongst the natives. The spiny seeds of *C. echinatus* stick to animals and clothing and are easily dispersed around and among islands. Image: Sheldon Plentovich/USFWS

eradicated on Midway Atoll in 1997, however mice, wasps, ants, ticks, and mosquitoes continue to plague humans and wildlife (PMNM, 2008).

On Laysan Island, the introduction of domestic rabbits, hares, and guinea pigs by Max Schlemmer in 1903 resulted in the extirpation of most of the vegetation and associated insects, and the extinction of three species of birds: ʻapapane or the Laysan honeycreeper (*Himatione fraithii*), the Laysan rail (*Zapornia palmeri*), and the Laysan millerbird (*Acrocephalus familiaris familiaris*). After an initial attempt by the crew of Thetis in the winter of 1912 and 1913, the rodent population was finally exterminated in 1923 by the Tanager Expedition, which was a joint expedition by the U.S. Bureau of Biological Survey, the Bishop Museum, and the U.S. Navy (Rauzon, 2001).

As early as 1870, explorers documented the presence of ʻiole or Polynesian rats (*Rattus exultans*) at Kure Atoll. These rodents influenced the species composition and reproductive performance of the seabird community at Kure, until they were eradicated in 1995. Additionally, the U.S. Coast Guard operated a long range navigation (LORAN) station at Kure Atoll from 1960 until 1993, with far-reaching effects on native plants and animals. Habitat was drastically altered and invasive species populations greatly increased.

The number of known non-indigenous terrestrial plants in Papahānaumokuākea varies from eight species at Nihoa Island to over 170 introduced species at Midway Atoll (Starr & Starr, 2015). The level of threat also varies among species. The adaptive shift of ʻiole liʻiliʻi or house mice (*Mus musculus*) on Sand Island at Midway to prey on nesting seabirds has recently become a major concern (U.S. Fish and

Wildlife Service [USFWS], 2019). The spread of the invasive golden crownbeard (*Verbesina encelioides*) and several other invasive weeds has severely threatened recovery by degrading and displacing seabird nesting habitat on a large scale (Starr et al., 2001). Golden crownbeard also causes Laysan finches to suffer severe food and cover restrictions. Other non-indigenous plants considered to be high-level threats include common sandbur (*Cenchrus echinatus*) and Indian pluchea (*Pluchea indica*). Non-indigenous invasive insects, including ants and locusts, have also made their way to these remote Islands, leading to predation on seabird eggs and chicks and damage to native plant communities (PMNM, 2008).

DISEASES

There have been increases worldwide in the reports of diseases affecting marine organisms. However, the factors contributing to disease outbreaks are poorly understood due to lack of information on normal disease levels in the ocean. The large coral reef ecosystems of the monument are considered to be some of the last remaining relatively pristine reefs in the world. As such, the monument provides the unique opportunity to document what may be a normal level of disease in a coral reef system exposed to limited human influence (Friedlander et al., 2005; Harvell et al., 1999).

Early studies in the monument have begun to document baseline levels of coral disease in the relative absence of a human population (Work et al., 2004; Aeby, 2006). Though the incidence of coral disease is lower in the NWHI than in the rest of the archipelago, tumors, as well as lesions associated with parasites, ciliates, bacteria, and fungi, have been found on a number of coral species in the monument.

Threatened green turtles are affected by fibropapillomatosis, a disease that causes tumors in turtles. Although most cases of the disease have been observed in the MHI, green turtles are highly migratory, and most adults breed in the monument. During an outbreak in the 1980s and 1990s, prevalence of fibropapillomatosis in the Hawaiian green turtle population was estimated at 40 to 60%, with the majority of cases found among juvenile turtles (Balazs & Pooley, 1991). As of 2007, prevalence was estimated at 9.4% (Chaloupka et al., 2009). In the monument's terrestrial environments, periodic outbreaks of avian botulism have been observed among populations of endangered, endemic land birds. Avian botulism, caused by the ingestion of toxic bacteria found in soils, has caused significant mortality in populations of Laysan duck at all locations where this species occurs (Laysan Island, Midway Atoll, and Kure Atoll).

MARINE POLLUTION

Marine Debris

Reefs and shorelines in PMNM are regularly inundated with large amounts of debris lost or discarded by North Pacific commercial fishing operations or dispersed from other marine or terrestrial sources. The location of the Northwestern Hawaiian Islands in the path of the Subtropical Convergence Zone, coupled with its extensive shallow reefs, make it a particularly likely location for debris deposition and accumulation. Derelict fishing gear may circulate for years in ocean gyres and currents until it snags on a shoal. These objects degrade reef health by abrading, poisoning, smothering, and dislodging corals and other benthic organisms, preventing recruitment on reef surfaces (Donohue & Brainard, 2001). In addition, the entanglement of marine mammals, fish, and crustaceans is known to cause significant mortality. Marine debris and derelict fishing gear hinder the recovery of the critically endangered Hawaiian monk seal and threatened sea turtles through entanglement, drowning, and suffocation

A black-footed albatross chick consuming marine debris. Image: Holly Richards/USFWS

(Boland & Donohue, 2003; PMNM, 2008). Marine debris is often consumed by foraging seabirds and fed to brooding chicks. Recent studies have found high incidence of plastic debris in gut contents from examined seabirds (Hyrenbach et al., 2017; Rapp et al., 2017; Youngren et al., 2018).

In addition, microplastic debris (<5 mm) accumulates in the water column and benthic and beach sediments, where it can enter every level of the marine food web, from primary producers to higher trophic-level organisms (do Sul & Costa, 2014). Because these tiny plastic particles can be contaminated with chemical additives and pollutants absorbed from the surrounding environment, their ingestion potentially creates a new vector for toxic exposure within both marine and terrestrial communities. Numerous studies have documented effects of microplastic internalization ranging from sublethal responses such as reduced fecundity, altered growth, and increased stress to mortality at higher particle concentrations (Baechler et al., 2020). However, the amount of toxic compounds entering food chains in this manner and their short- and long-term effects on the health of biota in the NWHI are unknown.

Coastal and Terrestrial Pollution

An array of historical, polluting human activities, including guano mining, fishing camps, U.S. Coast Guard LORAN stations, various Cold War military missions, and U.S. Navy airfields and bases, have left a legacy of contamination from past operations, spills, leaking containers, and unlined dumps on islands at Kure Atoll, Midway Atoll, and French Frigate Shoals. Onshore and offshore contamination from batteries (lead and mercury), PCB-containing transformers, capacitors, barrels of petroleum, unexploded ordnance, and other sources have been observed. Seabird chicks are known to ingest lead-contaminated paint chips or contaminated soil. Many of the common contaminants can bioaccumulate so that small amounts found in sediment can result in significant concentrations in organisms feeding at higher trophic levels.

FISHING

Between 1750 and the 1920s, Western explorers harvested monk seals, whales, turtles, fish, seabirds, and guano from various parts of the present-day monument. More recently, the history of fishing and other resource extraction included the overexploitation of the indigenous black-lipped pearl oyster (1928 to 1931), the beginning of a Hawai‘i-based fishing fleet (1910s to 1940s), a cessation of commercial uses during World War II, a resumption of commercial fishing (1945 to 1960) during which Tern Island was used as a transshipment point for fresh fish flown to Honolulu, and a proliferation of foreign fishing vessels from Japan and Russia (1965 to 1977), which targeted seamount-associated stocks. Commercial fisheries in the Northwestern Hawaiian Islands were previously managed under federal fishery management plans developed for bottomfish, pelagics, precious corals, crustaceans, and coral reef fisheries. All commercial fishing activities are now prohibited in waters within the monument boundaries.

Bottomfish Fishery

Bottomfish is the name given to a complex of species of snappers (family Lutjanidae), groupers (family Serranidae), jacks (family Carangidae), and emperor fish (family Lethrinidae) that share a deep-water, demersal habit, living near the ocean floor, typically in association with underwater headlands, hard-bottom, and high-relief habitats. Compared to many other species, most Hawai‘i bottomfish mature slowly, grow slowly, reproduce slowly, and have long life spans. Many species from these families form traditional spawning aggregations, predictably gathering at certain locations during certain seasons. These are characteristics that make them susceptible to overfishing and less resilient to impacts. In 2005, the State of Hawai‘i established regulations creating a ”no-extraction” marine refuge in the state waters of the NWHI. A year later in 2006, Presidential Proclamation 8031 specified that the commercial bottomfish fishery was to cease entirely in the monument by June 15, 2011 (71 FR 51134).

Longline (Pelagic) Fishery

The Hawai‘i commercial longline fishery has been regulated as a limited entry fishery since the 1990s, with a maximum of 164 available permits (Western Pacific Regional Fishery Management Council [WPRFMC], 2016). The deep set component targets ahi or bigeye tuna (*Thunnus obesus*) and the shallow set component targets swordfish (*Xiphius gladius*). Other species of retained catch include yellowfin tuna and a‘u or marlin, specifically blue marlin (*Makaira mazara*) and striped marlin (*Kajikia audax*). Commercial pelagic longlining was prohibited within 50 nautical miles of the NWHI in 1991 because of interactions with endangered and threatened species.

Lobster Fishery

The NWHI commercial lobster fishery ran from 1976 until its closure in 2000 by federal court orders related to the National Environmental Policy Act and protected species issues and by NOAA Fisheries to protect lobster stocks. The creation of the Papahānaumokuākea Marine National Monument in 2006 instituted a zero annual harvest limit, effectively closing the lobster fishery in perpetuity (NMSP, 2004a).

Recreational Fishing Activities

Prior to the establishment of PMNM, recreational fishing had taken place at Midway Atoll and near Nihoa Island, although catch and effort data are unavailable for those activities. Recreational fishing is currently allowed only at Midway Atoll and in the monument expansion area.

Trade in Coral and Reef Species

The harvest of live rock and live coral is currently prohibited throughout the Hawaiian Archipelago by both state and federal regulations. The harvest of other coral reef species has been prohibited in federal waters of the NWHI since the establishment of the Northwestern Hawaiian Islands Coral Reef Ecosystem Reserve in 2000 by executive order and is also prohibited in state waters. No domestic or commercial precious coral fishery has ever operated in the monument, although a fishery management plan was issued in 1981 (WPRFMC, 2016).

Other Fishing Activities

A short-lived commercial shark fishing operation at French Frigate Shoals and nearby banks took place in 2000. During one 21-day fishing trip, one vessel caught 990 sharks, consisting mainly of manō, or sandbar (*Carcharhinus plumbeus*) and Galapagos sharks (*C. galapagensis*), at 69% and 18%, respectively, and niuhi or tiger sharks (*Galeocerdo cuvier*) at 10% (Vatter, 2003).

There is evidence that during the pre-contact era, Native Hawaiians harvested pelagic fish species, especially aku or skipjack tuna (*Katsuwonus pelamis*) (Glazier et al., 2007). Native Hawaiian subsistence fishing (state waters) and sustenance fishing (federal waters) occurs at extremely low levels in PMNM. Presidential Proclamation 8031 allows for sustenance fishing in the original monument waters and defines it as fishing for bottomfish or pelagic species in which all catch is incidental to an activity permitted by the monument and is consumed within the monument. Sustenance fishing for pelagic, reef, and bottomfish

Lobster traps from previous fishing efforts in the NWHI. Image: NOAA Fisheries Observer Program species is done using trolling, handline, and pole and line techniques. Sustenance fishing by permit has taken place aboard research vessels, U.S. Coast Guard vessels, and military vessels.

Some illegal fishing activities continue to occur within the monument. Regulations are enforced primarily by the U.S. Coast Guard, but enforcement is challenging, mainly due to the size and isolation of the monument. There have been several successful enforcement cases in the monument due to detection of violations and gathering of photographic evidence by aircraft.

VESSEL HAZARDS AND GROUNDINGS

Hazards to shipping and other forms of maritime traffic are inherent in PMNM's 1,200 miles of islands, islets, shallow submerged reefs, and shoals. The region is exposed to open ocean weather and sea conditions all year, punctuated by severe winter storms and wave events. Vessel groundings and the release of fuel, cargo, rats, and other items pose real threats to the monument. The region contains 130 known potential maritime resource sites. Some represent environmental threats, while others consist chiefly of marine debris and are of little specific value. Wrecks of historic sailing vessels in high-energy environments are considered artifact "scatter sites," and do not pose an immediate or critical threat to their surroundings. More modern shipwrecks, such as the fishing vessels *Hoei Maru #5* and *Paradise Queen II* at Kure Atoll, or the tanker *Mission San Miguel* at Maro Reef, are greater threats to reef ecosystems. Mechanical damage from the initial grounding, subsequent redeposition of wreck material by storm surge, fishing gear damage to reef and species, and fuel, oil, or hazardous substances are all issues to be considered. In some cases, it may be more detrimental to remove the grounded vessel than to leave it where it is, and this option must be weighed when deciding how to respond to these threats.

Since 1976, at least 15 vessels have run aground in the NWHI. Among these are two recent incidents: the M/V *Casitas* was engaged in marine debris removal when it ran aground at Pearl and Hermes Reef in 2005, and the S/V *Grendel* is thought to have been adrift without a pilot when it landed on the reef at Kure Atoll in 2007 (PMNM, 2008; Friedlander et al., 2005). Earlier incidents include the 1998 grounding of *Paradise Queen II* at Kure Atoll and the 2000 grounding of *Swordman I*, an 85-foot longliner, at Pearl and Hermes Reef. These incidents resulted in the loss of thousands of gallons of diesel fuel, hundreds of gallons of hydraulic fluids, 11 miles of lobster pot mainline, and 1,040 lead-weighted plastic lobster traps. The bodies of two monk seals were found among piles of nets surrounding the decaying wheelhouse of *Paradise Queen II* (Maragos & Gulko, 2002). *Swordman I* was equipped with vessel monitoring system technology, allowing agents to track the disaster and quickly send out equipment for a clean-up, however, the government had to sue to recover these costs.

TOURISM AND RECREATION

Due to the monument's remoteness and isolation, tourism and recreational activities have historically been extremely limited. Midway Atoll served as a base for an ecotourism operation conducted by the U.S. Fish and Wildlife Service from 1996 until its closure in 2012. Prior to the closure, Midway Atoll National

Wildlife Refuge accommodated visitors participating in historic preservation service projects, guided tours, diving and snorkeling trips, and fishing operations (extractive and non-extractive). In addition, Midway Atoll was a destination for a limited number of cruise ships.

Potential impacts from tourism at Midway Atoll include damage to reefs and marine life and disturbances to wildlife, such as nesting seabirds, Hawaiian monk seals, Hawaiian green turtles, and spinner dolphins. Historic shipwrecks in the vicinity of Midway Atoll may be made more vulnerable by activities of divers and snorkelers, including artifact removal and damage from improper diving techniques. Many of these impacts can be mitigated with education and outreach efforts that inform visitors of site preservation protocols (Friedlander et al., 2005). Visitor use in the years leading up to the closure had been minimal due to a lack of routine affordable air charter service to and from Midway Atoll National Wildlife Refuge.

COASTAL DEVELOPMENT

Coastal development in the Northwestern Hawaiian Islands has consisted of infrastructure to support a guano mining operation at Laysan Island a century ago (including a small railroad), naval base construction at Midway Atoll and French Frigate Shoals in the first half of the 20th century, and U.S. Coast Guard LORAN station construction and operations at Pearl and Hermes Atoll, Kure Atoll, and French Frigate Shoals for several decades following World War II. The largest development was the Midway Naval Air Station, which supported several hundred to several thousand soldiers and dependents pre- to post-World War II. Construction of this site included the dredging of a harbor and navigation channels, as well as the enlarging of Sand Island to more than double its size through seawall construction and landfill techniques. Construction at Tern Island, on French Frigate Shoals, included dredge-and-fill activities and the installation of seawalls to enlarge the island and create an airstrip. These types of coastal development activities alter water current flows, temperature regimes, and shoreline configurations, and as a result may significantly alter coastal erosion patterns. Operation of housing and other facilities in the past has contributed to point and nonpoint sources of pollution to the marine environment.

Since the closure of Navy and U.S. Coast Guard facilities, coastal development activities have been limited. In previous decades, small-scale conversion of abandoned U.S. Coast Guard buildings on Tern Island at French Frigate Shoals and Green Island at Kure Atoll into biological field stations has occurred. However, in recent years, the only coastal construction was the repair of a portion of seawall and construction of a small boat ramp at French Frigate Shoals in 2004, the construction of a wood-frame bunkhouse at Kure Atoll in 2014, and repair of the Old Bulky Waste Landfill at an artificial peninsula at Sand Island, Midway by the Navy in 2018. Current co-management activities include preparation for the restoration of failing seawalls at Midway Atoll and evaluating options to fortify shoreline areas of Tern Island to reduce entrapment hazards from deteriorating sheet pile seawalls. Current human populations at Laysan Island, Lisianski Island, French Frigate Shoals, and Pearl and Hermes Atoll are limited to a few seasonal agency staff and volunteers. Kure Atoll presently has a year-round population of approximately 8 staff and volunteers. At Midway Atoll, a handful of staff and volunteers manage the Midway Atoll National Wildlife Refuge and the Battle of Midway National Memorial, while approximately 50 contract employees operate the infrastructure required to maintain Henderson Airfield as an emergency landing site for commercial transpacific airliners (PMNM, 2008).

ʻĪlioholoikauaua or Hawaiian monk seal (*Neomonachus schauinslandi*) at French Frigate Shoals. Image: Mark Sullivan/NOAA

STATE OF MONUMENT RESOURCES

This section provides summaries of the conditions and trends of resources within three areas: physical environment, living resources, and heritage resources. Staff considered a series of questions regarding the status and trends of each resource area (Appendix A). The set of questions derive from the National Marine Sanctuary System's mission and a system-wide monitoring framework (NMSP, 2004b) developed to ensure the timely flow of data and information to those responsible for managing and protecting resources in the ocean and coastal zone and to those that use, depend on, and study the ecosystems encompassed by national marine sanctuaries (and in this case, a marine national monument).

Appendix A (Rating Criteria for Evaluating the State of Monument Resources) describes the set of questions and presents statements that were used to judge the status and assign a corresponding color code on a scale from "good" to "poor." These statements are customized for each question.
In addition, the following options are available for all questions: "N/A"—the question does not apply; and "undetermined"—resource status is undetermined.

In addition, symbols are used to indicate trends:

"▲" conditions appear to be improving;
"▬" conditions do not appear to be changing;
"▼" conditions appear to be declining; and
"?" trend is undetermined.

This section of the report provides answers to the set of questions. Answers are supported by specific examples of data, investigations, monitoring, and observations, and the rationale is provided in the text (and summarized in the Resource Conditions and Trends Summary Table at the beginning of this report). Where published or additional information exists, the reader is provided with appropriate references.

Judging an ecosystem as having "integrity" implies the relative wholeness of ecosystem structure, function, and associated complexity, along with the spatial and temporal variability inherent in these characteristics, as determined by its natural evolutionary history. Ecosystem integrity is reflected in the system's "ability to generate and maintain adaptive biotic elements through natural evolutionary processes" (Angermeier & Karr, 1994, p. 694). The natural fluctuations of a system's native characteristics, including abiotic drivers, biotic composition, complex relationships, and functional processes are unaltered and are either likely to persist or be regained following natural disturbance. Assessments of the condition of maritime, historic, and Native Hawaiian cultural resources refer only to the physical condition of the resources. The integrity of the resources, which can include intangible values, is not addressed in the assessments presented here.

It is important to note that although Papahānaumokuākea was significantly expanded in 2016, the analyses and ratings presented in this report do not include resources in the expansion area. **The geographic scope for the following questions is limited to the 2006 designation area.** In some cases, contextual discussions of the expansion area are included.

PHYSICAL ENVIRONMENT

1. Have recent, accelerated changes in climate altered water conditions and how are they changing?

Oceanic and Atmospheric Conditions

Fair/Poor

Status

The expanse of the monument included in this assessment encompasses a distance of 1,350 miles, crossing approximately 12 degrees of latitude and 15 degrees of longitude. The area encompasses a wide range of oceanic and atmospheric conditions at a multitude of scales.

Oceanic and atmospheric conditions are rated Fair/Poor with medium confidence, due largely to increases in sea level, increased frequency of storms, and increased regional sea surface temperature, the latter of which has resulted in coral bleaching events in the monument and associated coral mortality.

Ocean Temperature

Globally, the oceans have been warming, and 2010–2020 were the top ten warmest years on record (Cheng et al., 2020). Sea surface temperature varies across the latitudinal range of the monument. However, an analysis of temperature anomalies comparing temperatures from 1984–2008 and 2009–2018 (Figure S.PE.1.1.) shows that temperatures have increased as much as a 0.6°C in portions of monument waters.

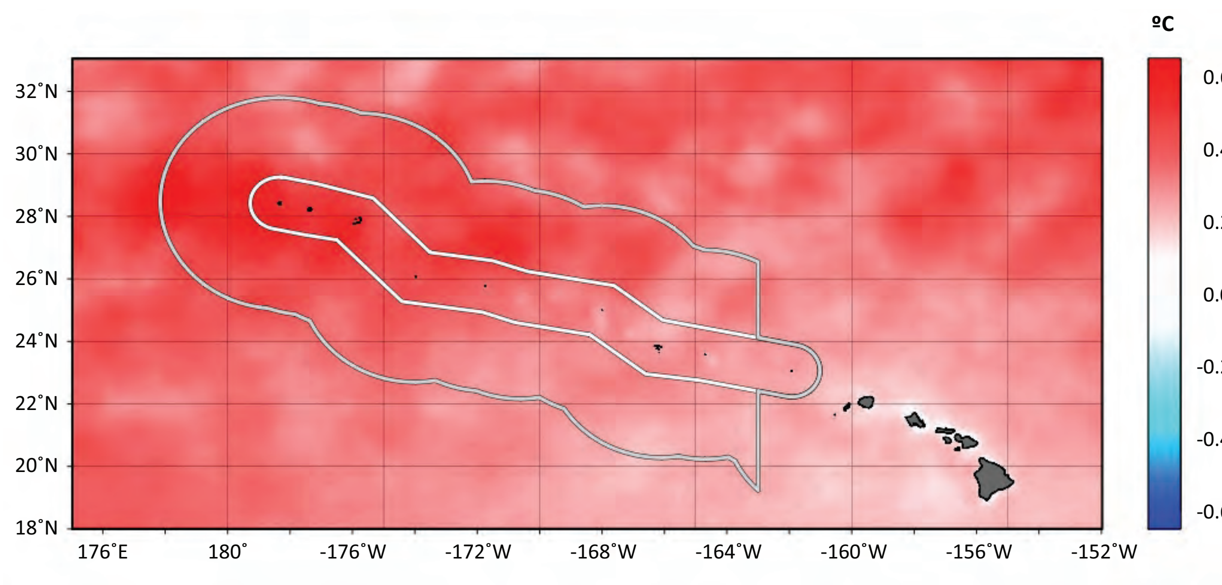


Figure S.PE.1.1. Temperature anomalies between periods of 1984–2008 and 2009–2018 across the monument. For example, a location with an anomaly of 0.6°C indicates that on average, temperatures between 2009 and 2018 were 0.6°C higher than those between 1984 and 2008. Image: Melanie Abecassis/PIFSC

Understanding the specific temperatures experienced at the reef scale is extremely important for evaluating changes driven by temperature. Heat-induced coral bleaching is caused by corals experiencing warmer than average conditions for a number of sustained weeks. In the monument, the bleaching threshold temperature generally varies from 28–28.5°C. Long-term monitoring by the NOAA Fisheries Pacific Islands Fisheries Science Center (PIFSC) shows that over the past nine years, the temperature at 15–20 m depth has exceeded the maximum monthly mean (the average temperature of the climatologically hottest month of the year) at least seven times at Kure Atoll, eight times at Pearl and Hermes Atoll, six times at Lisianski Island, and five times at French Frigate Shoals (Figure S.PE.1.2).

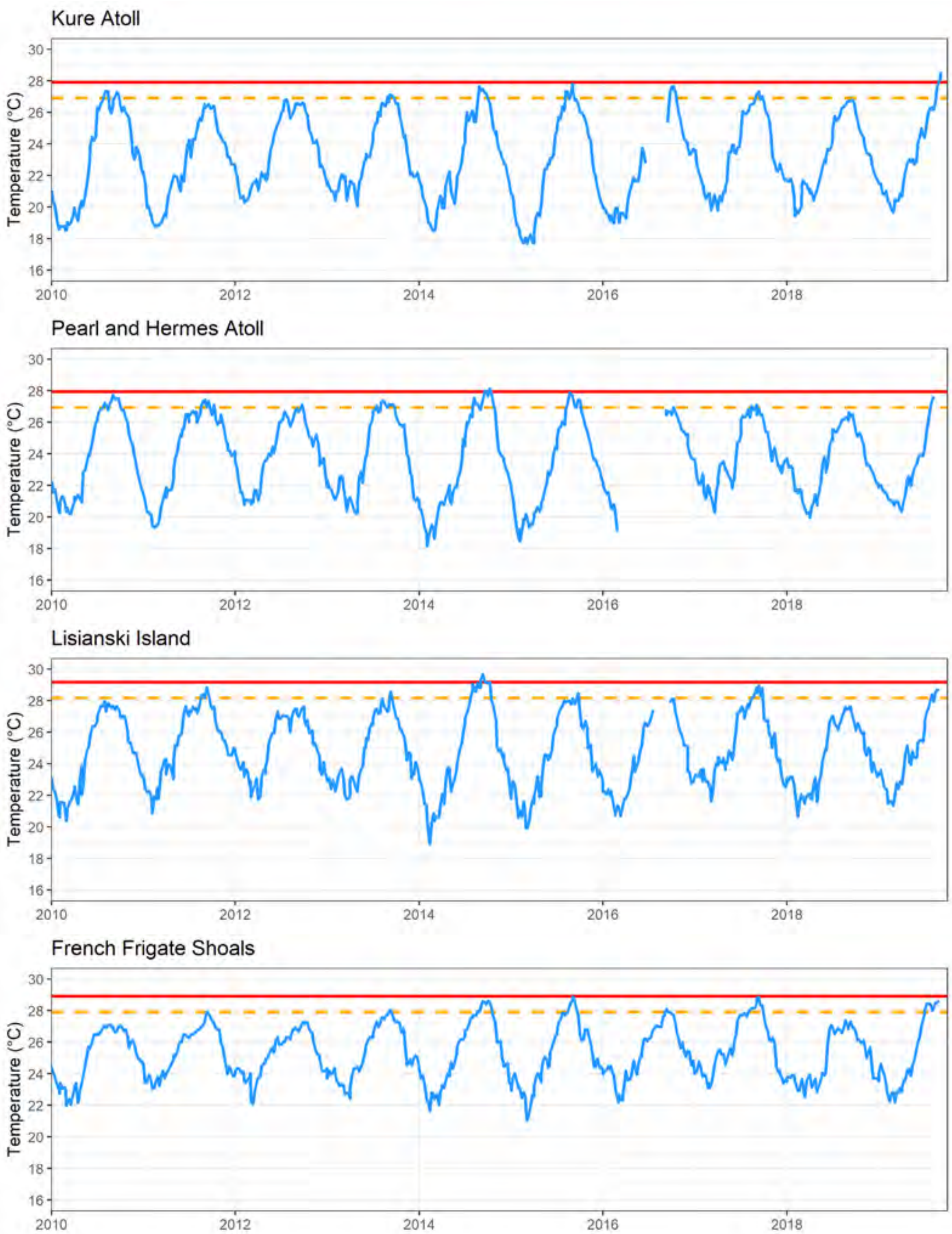


Figure S.PE.1.2. Weekly in situ time series from 2010–2019 from one representative site at each island (15-20m depth). The orange line for each island is the maximum monthly mean, and the red line is the bleaching threshold. Image: Hannah Barkley/PIFSC

Temperatures approached the coral bleaching threshold in 2014, 2015, and 2019 at Kure Atoll; in 2014 and 2015 at Pearl and Hermes Atoll; in 2014 at Lisianski Island (coinciding with a mass coral bleaching event); and in 2015 and 2017 at French Frigate Shoals. Temperature increases are not uniform across the monument, which is evident from more severe warming at Lisianski Island in 2014 and Kure Atoll in 2019.

Productivity

The biological resources in the NWHI, especially at the northern atolls, appear to respond to the El Niño-Southern Oscillation and Pacific Decadal Oscillation. Specifically, during El Niño periods and positive phases of the Pacific Decadal Oscillation, productive northern waters reach PMNM's northern atolls during winter, enhancing ecosystem productivity (Baker et al., 2012; Baker et al., 2007; Polovina et al., 2008). Seasonally, the subtropical front and the transition zone chlorophyll front both include waters of the northern atolls of the monument. Comparing the average chlorophyll density between the years of 1998–2008 and 2009–2018 shows that there has been little change in productivity across the monument (Figure S.PE.1.3). Maximum changes of ±0.01 mg/m^3 have been observed.

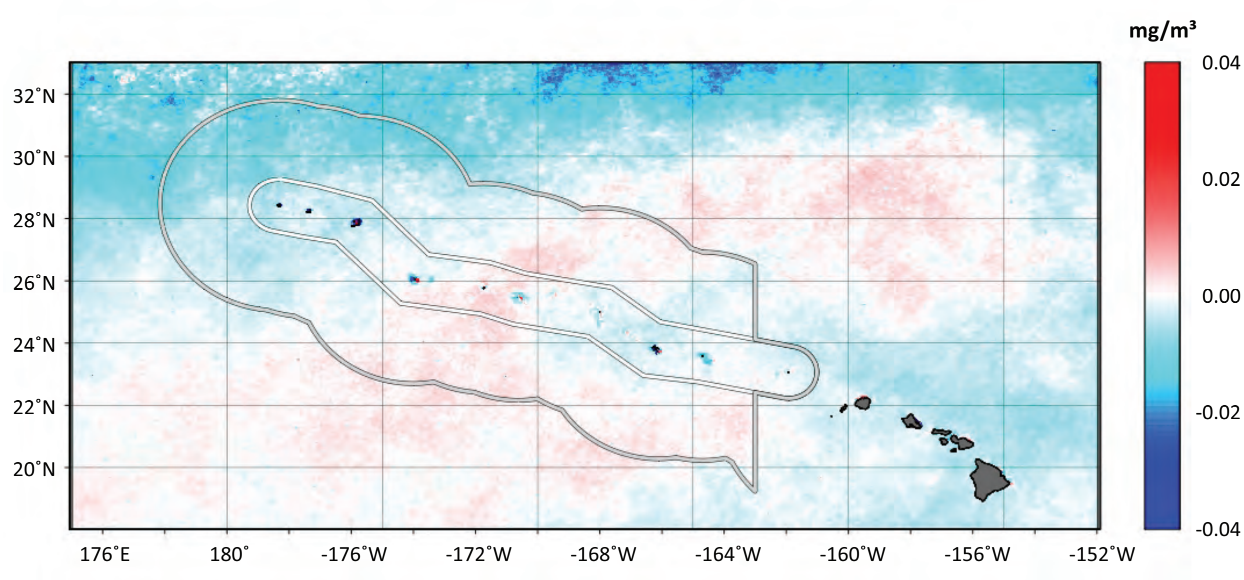


Figure S.PE.1.3. Relative chlorophyll difference between the years of 1998–2008 and 2009–2018 across the monument. Image: Melanie Abecassis/PIFSC

Productivity is also assessed regionally by measuring the subtropical front and the transition zone chlorophyll front for the winter months of January–March, when these zones typically reach the farthest south (Figure S.PE.1.4). Generally, within expanded monument boundaries, the locations of these fronts have largely remained constant. However, the locations of both fronts indicate that from 2009–2018, these zones of productivity, and presumably the ecosystems they support, have generally not extended as far southward as they have historically to the east of the monument.

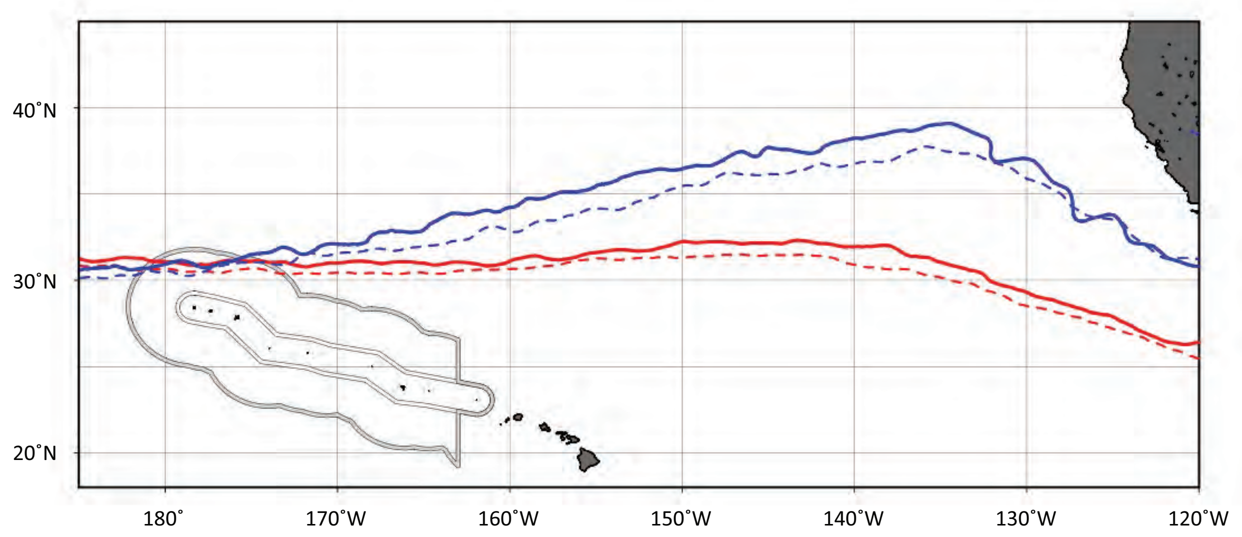


Figure S.PE.1.4. The subtropical front is highlighted in red for the periods 1982–2008 (dashed) and 2009–2018 (solid). The transition zone chlorophyll front is highlighted in blue for the periods of 2003–2008 (dashed) and 2009–2018 (solid). The positions of each line indicate changes in the mean locations for each front during the periods of January–March for the two time periods. Image: Melanie Abecassis/PIFSC

Sea Level Change

While global mean sea level has risen 16–21 cm between 1900 and 2016 (Sweet, Horton, et al., 2017), and the rate of acceleration has ranged between 2.4 ± 0.2 mm yr−1 in 1993 to 2.9 ± 0.3 mm yr−1 in 2014 (Chen et al., 2017), it has varied throughout the monument across the past 10 years. Sea level depressions (as much as 9 mm yr−1) have occurred in open ocean portions of the northwestern part of the monument; stable to slight increases in sea level were recorded at Midway Atoll (0.1 mm yr−1); and sea level increases (as much as 12 mm yr−1) have occurred in the southeastern part of the monument (Figure S.PE.1.5). Some of this variability may be due to the influence of ocean circulation, gravity, and isostasy.

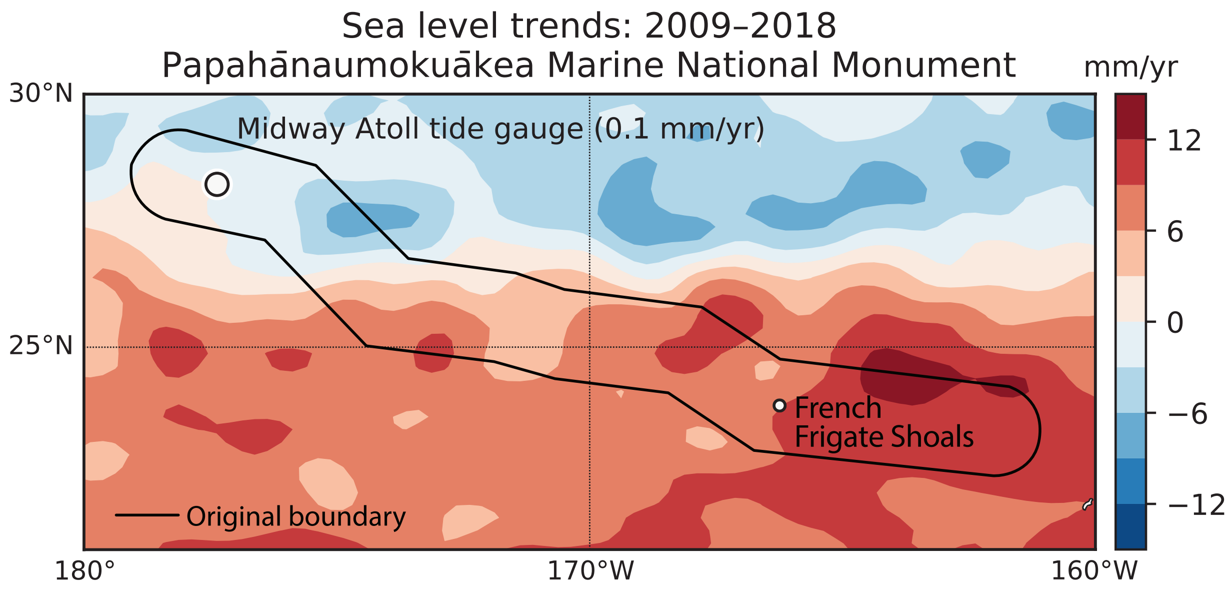


Figure S.PE.1.5. Average sea level position between 2009–2018 was collected from satellite altimetry data. Trends were calculated using (1) tide gauge data from the UHSLC Fast-Delivery database, and (2) Ssalto/Duacs altimeter products that were produced and distributed by the E.U. Copernicus Marine and Environment Monitoring Service (CMEMS). The latter are identical to the products formerly distributed by Aviso. Image: Philip Thompson/University of Hawaiʻi at Manoa Sea Level Center

Higher rates of sea level rise are particularly concerning at French Frigate Shoals, where very low-lying islets have experienced general coastal erosion and degradation from Hurricane Walaka, which transited the atoll in 2018. These islets are important breeding, nesting, basking, and pupping grounds for many species, most notably the Hawaiian monk seal, the green turtle, and several types of seabirds.

The cumulative effects of sea level rise and tidal flooding can result in flood inundation of these low-lying islets. However, the number of days of flood inundation at Midway Atoll has remained stable from 1955–2016 (Figure S.PE.1.6). There were seven recorded tidal flooding events between 2009–2016 at Midway Atoll, compared with 11 from the decade before (Sweet et al., 2018).

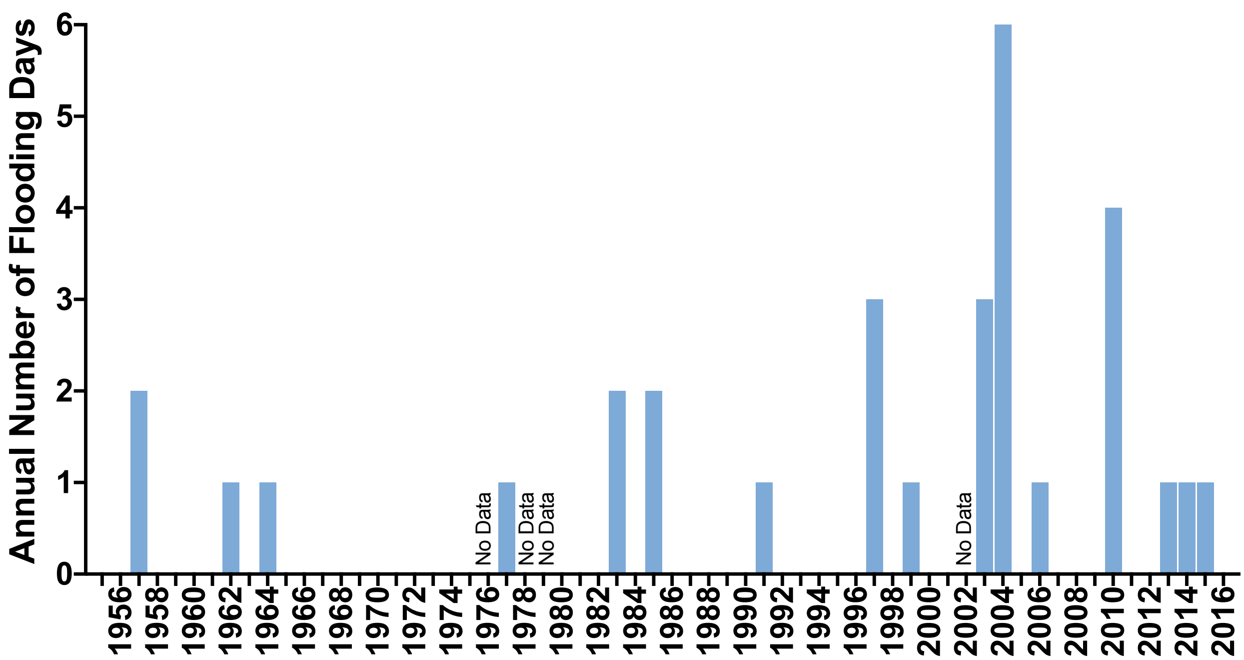


Figure S.PE.1.6. The number of days of recorded tidal flood inundation at Midway Atoll. Source: Sweet et al., 2018

Precipitation and Storms

The percentage of time with storm level winds ≥ 34 knots for 2009–2019 is less than it was for the ten-year period prior (1998–2008). Longer-term data suggest a decline in storm level wind events between 1981–2018 (Figure S.PE.1.7). However, the number of tropical cyclones was higher for the time period of 2009–2019, with two cyclones, five tropical storms, and three tropical depressions transiting the monument compared to the previous ten year period (1999–2008), which had no cyclones or tropical storms and only one tropical depression.

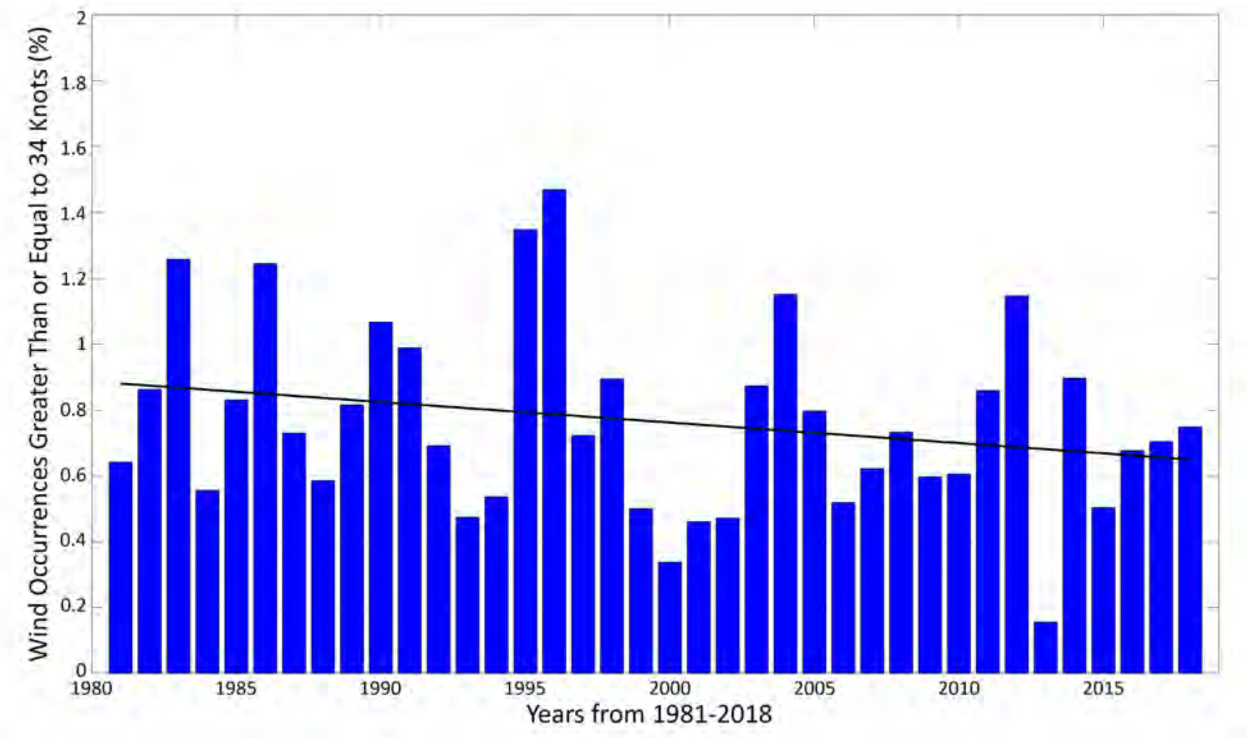


Figure S.PE.1.7. Percentages by year of wind occurrences greater than or equal to 34 knots for the years 1981–2018. Data: Kanamitsu/NOAA

Carbonate Chemistry

Calcification and aragonite saturation monitoring data by PIFSC suggest that there is relatively lower coral reef calcification and aragonite mineral saturation in the monument compared to other regions in the Pacific Islands (Figure S.PE.1.8). Aragonite is a mineral necessary for composing calcium carbonate, which is a fundamental component of calcifying species such as stony corals, mollusks, and calcifying algae, and generally forms the reef structure and sediments. The quantity of available minerals can hinder calcification. Lower aragonite saturation and relatively lower temperatures decrease metabolism and cumulatively hinder calcification.

It is also notable that calcification and aragonite saturation are both lower at Lisianski Island compared to other island reefs monitored in the Pacific Islands. It is possible that the extensive calcifying community across Neva Shoals and Lisianski Island draws aragonite from seawater faster than oceanic currents can replenish the minerals from the open ocean. However, aragonite levels are still above the threshold where experimental studies have shown that calcification ceases (Langdon et al., 2000; Albright et al., 2008).

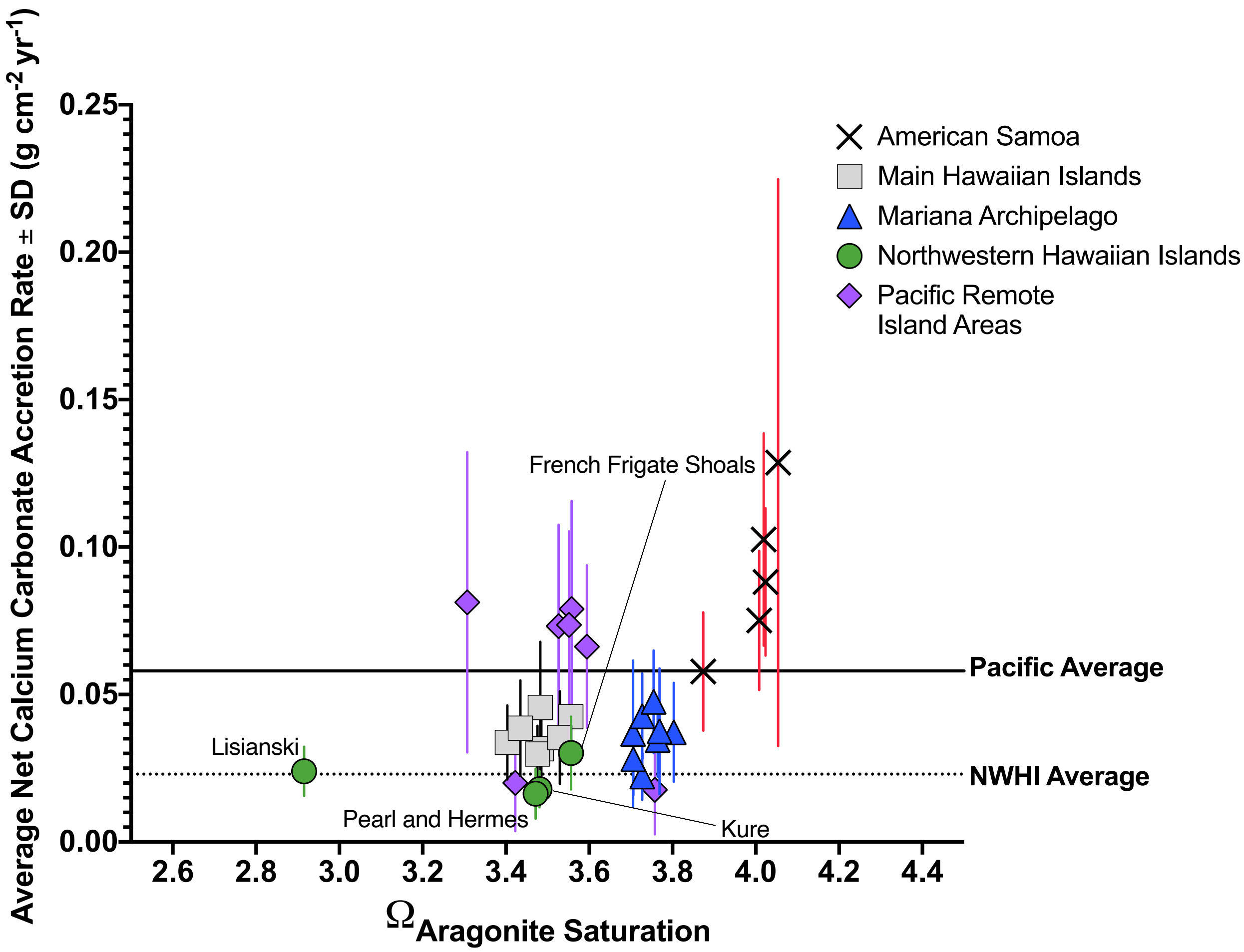


Figure S.PE.1.8. Aragonite saturation state and average net calcification (± SD) on shallow coral reefs in the Pacific Islands for the time periods of 2010-2013 and 2013-2016. Data: Hannah Barkley/PIFSC

Trends

Oceanic and atmospheric conditions are rated with a Declining trend with medium confidence, due largely to sea level rise, increased frequency of storms, and increased regional sea surface temperature, all of which have impacted ecological integrity. It is also worth noting that sea level change has been spatially variable, in situ temperature has exceeded the maximum monthly mean and bleaching threshold values at a handful of locations, and productivity has remained unchanged. In addition, trends cannot be currently assessed for calcification and related mineralogic conditions.

Climate-related impacts appear to be reducing environmental quality, particularly with regard to temperature and storm frequency. These are concerning trends, and may account for recent stress and bleaching events, as well as increases in inundation and erosion at some islands (e.g., French Frigate Shoals). In addition, while average storm intensity may have declined, the frequency of tropical storms and cyclones has increased, and the strongest storms have become more intense.

Management Implications

Focused, regular monitoring of oceanic and climatic conditions of the monument continues to be needed. Monitoring should include the spatial and temporal dynamics of the entire expanse of the monument as well as discrete locations. Specifically, climate change impacts on intensity and size of storm events, ocean warming, coastal erosion, and sea level rise inundation of low-lying areas are of concern. Satellite-derived products continue to improve and are highly useful for monitoring climate and sea level rise, however in situ and subsurface monitoring continue to be critical for understanding small-scale, location-specific conditions.

Climatic and oceanic conditions are changing and will continue to change. Thus, it is imperative that conditions are assessed on a regular basis and adaptive management is implemented. It is predicted that at least one to two days of consistent annual tidal flooding will occur in low lying shores at Midway Atoll, eventually reaching as many as 54 flooding days by the year 2100 (Sweet et al., 2018). Average aragonite saturation levels are predicted to reach 2.5 in the northwestern portion of the monument by the year 2040 (Feely et al., 2009), and 2.0 (where calcification accretion ceases) in the whole of the Hawaiian Archipelago by the year 2100 (Feely et al., 2009) under the Intergovernmental Panel on Climate Change IS92a "business as usual" CO_2 emissions scenario.

Acknowledgements

Dr. John Marra, Dr. Hannah Barkley, Melanie Abecassis, and Dr. Jonathan Martinez contributed to this assessment.

2. What are the area and distribution of abiotic habitat types and how are they changing?

Terrestrial and Marine Abiotic Habitats

Fair/Poor ?

Status

The condition of abiotic habitat types is assessed as Fair/Poor with limited evidence on the basis that selected habitat loss or alteration has caused, or is likely to cause, severe declines in some, but not all, living resources or water quality.

Abiotic habitats consist of non-living, physical aspects of the environment. These are the foundational physical substrate or spatial locations that support a variety of species. Examples of terrestrial features include rocky islands and beaches, while submarine examples include sand, unconsolidated rubble, and deep-water banks. Their total area and distribution is unknown, as these habitats have been only partially mapped within Papahānaumokuākea, with emphasis on terrestrial features, such as beaches, and shallow-water (between the shoreline and 30-meter isobath) features, such as rocky or sandy substrate. There has been little monitoring of the physical condition of deeper benthic habitats. Known natural and human-induced factors contributing to abiotic habitat alteration include historical shoreline armoring and dredge-and-fill operations, coastal erosion processes, and altered frequency of storm events (high waves, storm surge).

The coastlines of some atolls in Papahānaumokuākea have been rapidly eroding over the last several decades, leaving them particularly susceptible to the effects of climate change, such as an accelerated sea level rise (Baker et al., 2006; Rooney et al., 2008; Reynolds, Berkowitz, et al., 2012). Net accretion occurred on reef crests during the mid-Holocene sea level highstand about 1,000–5,000 years ago, as evidenced by fossil reef crest features elevated above present-day sea level at Kure and Midway Atolls (Gross et al., 1969). Global sea level subsequently subsided and began to rise again in 1900 (Sweet, Horton, et al., 2017). Recent climatological sea level rise analyses indicate that average sea level varies across the monument (see Figure S.PE.1.5.).

Abiotic marine habitats within atoll lagoons appear to be in good condition and generally accreting (Siciliano, 2005). Calcification was assessed for the periods of 2010–2013 and 2013–2016 at Kure Atoll, Pearl and Hermes Atoll, Lisianski Island, and French Frigate Shoals (Figure S.PE.1.8). Each location was found to have general net calcium carbonate accretion (meaning the reefs continue to build) across both time periods, however all sites had relatively lower accretion than the Pacific average. Pearl and Hermes Atoll and Kure Atoll had net accretion below the average for the NWHI (NOAA, 2018).

On October 4, 2018, Hurricane Walaka transited through French Frigate Shoals as a Category 4 hurricane, resulting in total destruction of a significant islet on the southern reef slope and significant erosion of East Island within the atoll's lagoon. Historically, the area of East Island has been ~11 acres (44,515 m^2) (Amerson, 1971). Overnight, East Island lost over 95% of emergent land, with 100% of the land submerged with tidal fluctuations. Satellite imagery has documented this transformation, with images taken prior to Hurricane Walaka, days after the hurricane, and after a year of sand reaccumulation (Figure S.PE.2.1). The area lost at East Island was a significant reproductive habitat for many species, including green turtles and Hawaiian monk seals. Four months later, accretion of sediment (sand) at East Island had increased the total area of emergent land to slightly less than half of its pre-hurricane state (Table S.PE.2.1) (Lopes, 2020). However, the new emergent sediment is unconsolidated and therefore unstable and unlikely to be usable by nesting sea turtles. Due to the dynamic nature of coastal erosion and accretion processes, the future of East Island is uncertain. It is worthy to note that East Island was the most impacted islet of French Frigate Shoals. The other major islets (Gins, Shark, Tern, and Disappearing Islands) were only moderately impacted by Hurricane Walaka.

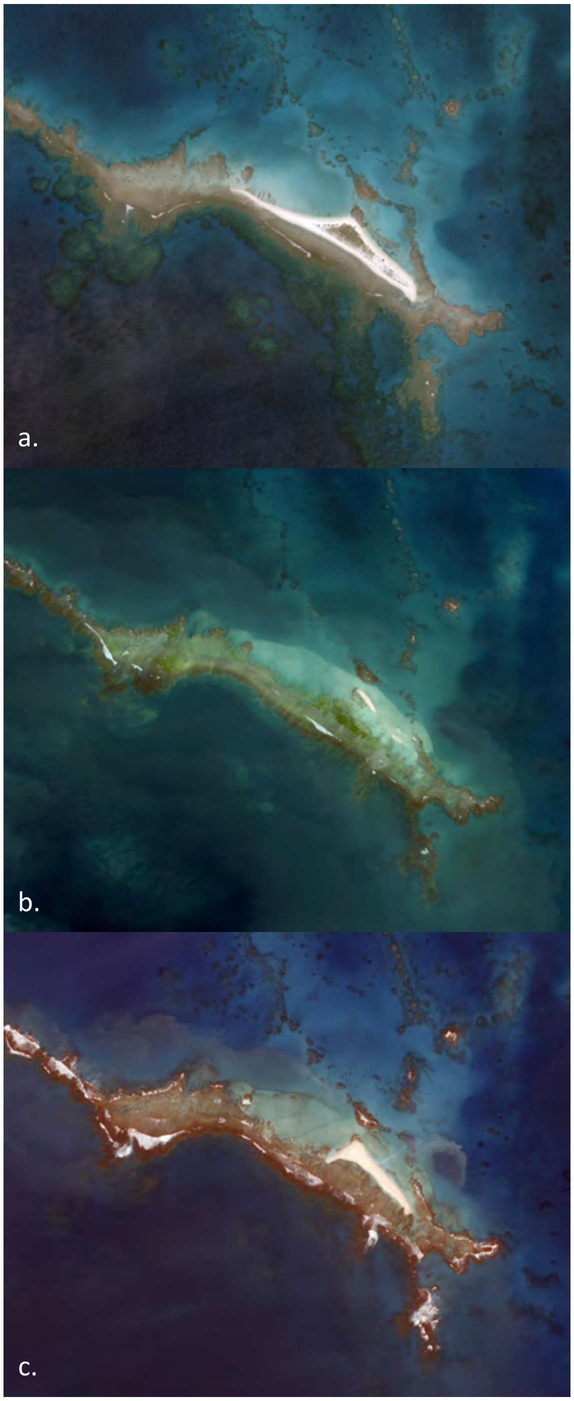


Figure S.PE.2.1. East Island, French Frigate Shoals (a) before Hurricane Walaka on May 4, 2018, (b) 17 days after Hurricane Walaka on October 21, 2018, and (c) nearly 14 months after Hurricane Walaka on November 20, 2019. Imagery © 2018 DigitalGlobe NEXTVIEW License

Table S.PE.2.1 Area changes of emergent land primarily consisting of unconsolidated sediment. Source: Lopes, 2020

East Island Area	Area (m^2)
9/25/2018	27927
10/12/2018	0
11/18/2018	7623
12/23/2018	7767
1/26/2019	10476
2/23/2019	11628
3/24/2019	13041
4/21/2019	16929
5/20/2019	16353
6/13/2019	15345
7/17/2019	16470
8/15/2019	16524
9/14/2019	9900
10/6/2019	14130

Trends

The expert-rated trend is Unknown with limited evidence. This trend was selected due to a lack of time-series data on geomorphic change and sediment characteristics for a majority of terrestrial and abiotic habitats in the monument. Based upon data from the MHI, which are the youngest landforms in the archipelago, it would appear that PMNM abiotic habitats, not including lagoon settings, are experiencing gradual net erosion (Fletcher & Sherman, 1995; Grigg, 1998; Rooney et al., 2008). However, while the islands of Papahānaumokuākea are part of the same archipelago, they do have distinct properties and it is unknown whether systems in the southeast part of the island chain are a good indicator for processes which occur in the northwest. Additional data and new approaches are needed to confirm these assumptions of existing conditions.

Management Implications

Projected climate change phenomena including warming, relative sea level rise, enhanced storm activity, and North Pacific Swell are likely to cause long-term declines in abiotic marine habitats in Papahānaumokuākea (Dickinson 2003; Rooney et al., 2004; Rooney et al., 2008; Hoegh-Guldberg & Bruno, 2010).

Models of passive sea level rise scenarios suggest that a sea level rise of 1.0 to 8.2 ft (0.3 to 2.5 m) may occur globally by the year 2100 (Sweet et al., 2017). For perspective, a rise of 1.6 ft (0.48 m) is predicted to cause the loss of 3 to 65% of the terrestrial habitat in the monument (Baker et al., 2006). Most of the NWHI are low-lying and therefore potentially vulnerable to increases in global average sea level. The most vulnerable location is Pearl and Hermes Atoll (Figure S.PE.2.2), which is predicted to lose between 43 and 92% of its total land area under these scenarios. Modeling further suggests hydrodynamic forcing is several times more important than passive sea level rise in causing terrestrial erosion (Reynolds, Berkowitz, et al., 2012). Dynamic models (accounting for wave-driven effects) illustrate the impact of storm events on the monument islands under the same scenarios of sea level rise. In each of these scenarios, shoreline orientation is a key factor determining wave inundation (Storlazzi et al., 2015). Up to three times as much land area is predicted to be lost in the dynamic models as compared with the passive models, suggesting that large wave events would cause inundation to occur much faster (Reynolds, Berkowitz, et al., 2012; Storlazzi et al., 2018).

Terrestrial abiotic habitats are critical for numerous species, some of which are endangered. The sensitivity of species to habitat loss due to sea level changes is heightened for those nearing the islands' carrying capacity, particularly for populations residing in low-lying areas of islands where wave exposure leaves them vulnerable to inundation. Therefore, when threatened, these habitats require active mitigation measures such as planting of endemic vegetation and construction of sand trapping structures (Baker et al., 2006; Reynolds, Berkowitz, et al., 2012).

Understanding rates of net coastal and reef crest accretion and erosion in the monument will be important for modeling future changes in terrestrial abiotic habitats and supporting informed management of these resources. Data are currently lacking to adequately evaluate the rate of erosion or long-term impacts of sea level rise and habitat loss, and more attention should be put toward monitoring shoreline erosion

Figure S.PE.2.2. An aerial view of North Island, Pearl and Hermes Atoll. Image: NOAA while accounting for storm and seasonal variability. As a first step toward developing the ability to detect large changes in abiotic marine habitats, high-resolution bathymetry and substrate mapping should be continued for the entire monument. High-resolution seafloor mapping using multibeam echosounders with backscatter should be continued using NOAA and partner assets to map the mid-depth and deep seafloor. Depths too shallow for acoustic surveys most likely need to be assessed using bathymetric light detection and ranging (LiDAR), with depths and substrate types derived from satellite imagery as an interim measure. The resulting datasets would also support many other monument management needs.

Projected climate change and changing ocean chemistry are likely to exacerbate erosion of all abiotic habitats, particularly carbonate platforms and reefs. As sea level overtops such platforms, their alluvial caps will erode away at an accelerating rate.

Acknowledgements
Dr. John Rooney, Keo Lopes, Dr. Frank Parrish, and Dr. Michelle Reynolds contributed to this assessment.

3. What is the water quality condition of nearshore and inland waters and how is it changing?

Nearshore and Inland Waters

Good/Fair ?

Status
The expert rated status is Good with limited evidence on the basis that limited contaminants and infectious agents are present in monument waters, and existing conditions are not likely to cause substantial or persistent declines in living resource assemblages and habitats.

Nearshore Waters
Water quality, including excessive nutrient or microbiological contamination, has not been a major issue in nearshore areas of the monument. Overall, adverse water quality conditions throughout most of the monument's oceanic waters are not expected, except near direct pollutant sources at Midway Atoll, Kure Atoll, and Tern Island at French Frigate Shoals. However, hazardous marine debris could potentially be sources of contamination and, as every emergent and submerged location in the monument is not regularly monitored for hazardous marine debris, the potential for contamination does exist at any location of the monument. Contamination with disease-causing microbiota in nearshore marine waters is not expected to be problematic or to occur at levels that exceed water quality standards.

Inland Waters
Inland waters have been a concern, particularly in the last two decades. Inland waters consist of ponds, seeps, and the hypersaline Laysan Lake. Freshwater sources are found at Nihoa, Mokumanamana, and Laysan Islands, and Midway and Kure Atolls. Contamination and proliferation of the avian botulism-

Figure S.PE.3.1. Laysan Lake is an important habitat for the Laysan duck. Image: Wayne Levin

inducing bacterium *Clostridium botulinum* in fresh and brackish water and soil have resulted in the deaths of individuals from multiple bird species, including the endemic Laysan duck, the koloa māpu or Northern pintail (*Anas acuta*), and potentially the least tern (*Sterna antillarum*), ʻakeke or ruddy turnstone (*Arenaria interpres*), ʻūlili or wandering tattler (*Heteroscelus incanus*), and lesser scaup (*Aythya affinis*) (Work et al., 2010). Periodic outbreaks occur at Midway Atoll, Laysan Island and Kure Atoll, resulting in some mortality (Work et al., 2010; State of Hawaiʻi Division of Forestry and Wildlife [DOFAW], personal communication, August 02, 2018).

Trends

Data have not been analyzed over time across nearshore and inland waters, so the trend is assessed as Undetermined at this time. Contamination in nearshore marine waters is not expected to have changed significantly over time.

Management Implications

Water quality of seeps and ponds should be monitored and interpreted regularly at Midway Atoll, which is the most densely human-inhabited location in the monument. It is also important that monitoring of freshwater seeps at Green Island, Kure Atoll is continued.

The lack of regular monitoring for hazardous marine debris can result in potential hazards going unaddressed. Ideally, the detection, isolation, and removal of such hazardous debris would be beneficial.

Laysan Lake is an important feature of Laysan Island and one of only five inland lakes in Hawaiʻi. The central hypersaline lake supports several species, including the Laysan duck and brine fly insects. Laysan Lake was previously monitored for several parameters (salinity and lake level, algal growth) between approximately 2001–2012, however there has been only opportunistic monitoring since the 2012 closure of the year-round USFWS Laysan field camp. The lake fluctuates in size depending on precipitation, and in recent years, its extent has declined substantially.

Comprehensive monitoring of water quality conditions beyond limited salinity monitoring (i.e., nutrients and bacteria) has not occurred and is needed to assess the condition of the lake.

Acknowledgements
Fenix Grange contributed to this assessment.

4. What are the known contaminant concentrations in PMNM habitats and how are they changing?

Contaminants

Fair

Status
The expert-rated status for contaminants is Fair with medium evidence on the basis that limited remaining contaminants may inhibit the development of assemblages and may cause discrete, but not severe, declines in living resources or water quality. The majority of information on known contaminant concentrations is from a limited number of studies at discrete point sources in the monument. These are the result of historical uses, spills, and dumping of hazardous materials, and they occur primarily at three locations: Tern Island at French Frigate Shoals, Green Island at Kure Atoll, and Sand Island at Midway Atoll. The assessment of condition is mainly based on information from these known point sources of contaminants. Elsewhere in the monument, contaminant concentrations have not been determined, but in general they are expected to be low given the historically low level of human use.

Tern Island, French Frigate Shoals
Tern Island, a part of the French Frigate Shoals atoll, was formed into a runway to serve as a refueling stop for planes enroute to Midway Atoll during World War II, and also served as the site of various Cold War missions. Multiple sources of contaminants have been identified at Tern Island. The island was also the site of a U.S. Coast Guard LORAN station between 1952 and 1979. Leaking underground storage tanks were a source of petroleum contamination until remediated (closed in place) by a U.S. Army Corps of Engineers contractor in 1991 (U.S. Environmental Protection Agency [EPA], 2014a). The island also contains various hazardous dump sites subject to exposure by erosion. Contaminant surveys conducted on land between 1992–2004 identified: polychlorinated biphenyl compounds (PCBs), lead, arsenic, cadmium, chromium, copper, selenium, total petroleum hydrocarbon, dioxins and furans, dichlorodiphenyltrichloroethane (DDT) and its metabolites (DDE and DDD), benzene, toluene, ethylbenzene, and xylene contaminants; these are summarized in a 2014 U.S. Environmental Protection Agency (EPA) report (EPA, 2014b). The most significant contaminant threat to be identified in the monument is buried PCB waste at Tern Island, which is distributed on all sides of the island

(Figure S.PE.4.1) and is affected by significant erosion and weather events. One contaminated site, "Bulky Dump," on the north end of the island was excavated by the U.S. Coast Guard in 2001, although an area of approximately 60 by 95 ft was left intact and PCB levels were not reduced to the targeted 2 ppm or less. In 2018, the EPA conducted a removal assessment study of contaminants in oceanic water, porewater, and sediment at Tern Island. The highest levels of contaminants were found on the northwestern portion of the island near the Bulky Dump site (Figure S.PE.4.2). Levels of lead in porewater (Table S.PE.4.1) exceed acute levels for Hawai'i water quality standards (Department of Health, 2014). Levels of PCBs identified across the island ranged from 0–600 ppb in soil and 0–24 ppt in pore water (below Hawai'i seawater quality standards). Water quality standards for polycyclic aromatic hydrocarbons (PAHs) in seawater have not been set for Hawai'i. In 2018, after the EPA study, Hurricane Walaka scoured concrete and sediment cover from the former Bulky Dump site, exposing potentially hazardous materials (Figure S.PE.4.2).

Table S.PE.4.1. Maximum concentrations of PCBs, PAHs, and lead in soil and pore water at Tern Island.

Sample Site	Maximum PCBs	Maximum PAHs	Maximum Lead
Soil	611.71 ppb	443 ppb	418 ppm
Porewater	24 ppt	191 ppt	248 ppb*

*indicates values greater than Hawai'i State Department of Health water quality standards for acute levels of lead in seawater. Source: EPA, 2018

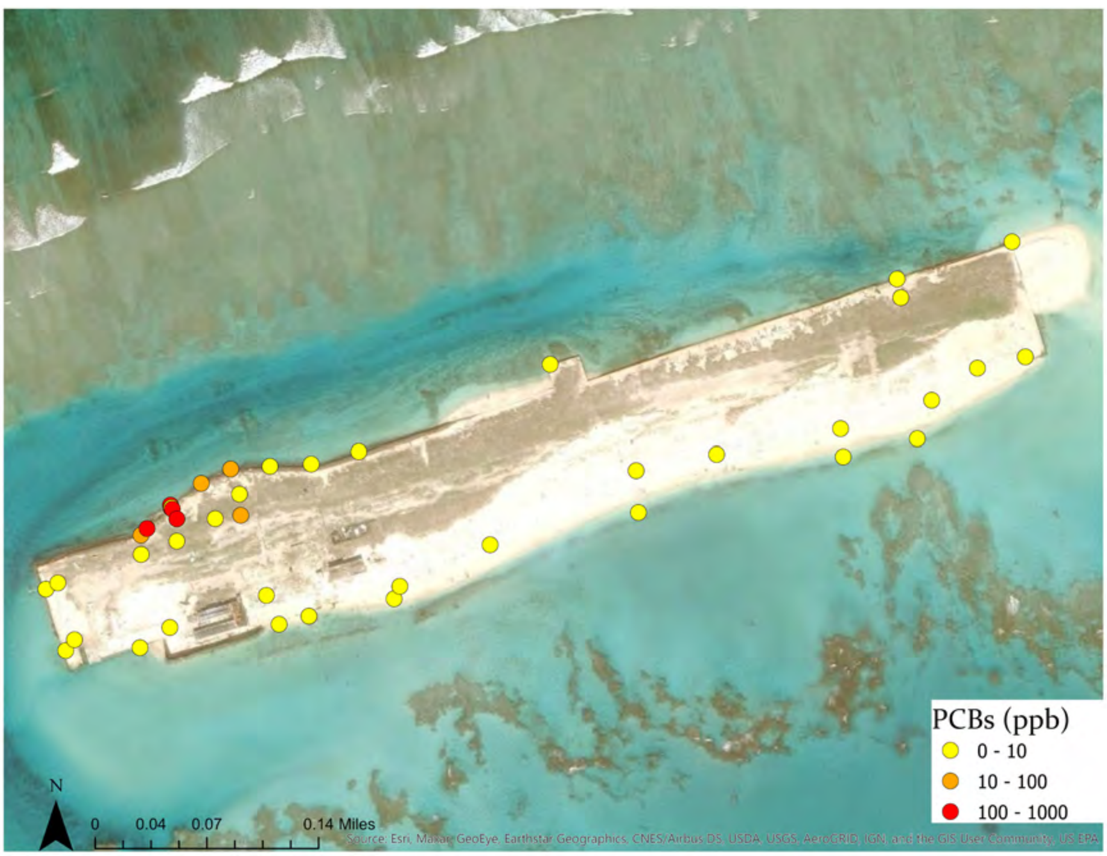


Figure S.PE.4.1. PCBs detected in soil and sediment at Tern Island, French Frigate Shoals from the 2018 EPA remediation study. Source: EPA, 2018

Figure S.PE.4.2. In 2018, Hurricane Walaka removed concrete and sediment covering the Bulky Dump site and exposed potentially hazardous materials. Image: Amanda Boyd/USFWS

Midway Atoll

The U.S. Navy built a naval air facility and submarine base at Midway Atoll and, during base reduction and closure, identified and cleaned up numerous sites contaminated with petroleum, pesticides, PCBs, and metals (USFWS, 2019a). While some of the worst areas of contamination were remediated, several areas, including unlined, eroding landfills, warrant continuous monitoring for potential releases (PMNM, 2008; USFWS, 2019a).

Legacy organochlorine pesticide concentrations, including DDT, its metabolites (DDE and DDD), and hexachlorocyclohexane, were identified in 111 soil samples at Midway Atoll (Ge et al., 2013). In addition, PCBs were detected in plasma and preen oil of black-footed albatross chicks at Midway Atoll, and the concentrations and congeners present indicated exposure to local sources of legacy contaminants in and around nests (Wang et al., 2015).

Studies conducted by USFWS and others at Sand Island between the late 1980s and 2009 found that Laysan albatross chicks exhibited symptoms of lead toxicity, and that their exposure was likely related to ingestion of lead-based paint chips and soil contaminated with these chips. The primary sources of paint chips in nesting areas are structures on Sand Island, some of which date back to the early 1900s. From 2005 to February 2010, USFWS remediated lead-based paint on 24 of the 95 affected buildings on Sand Island, spending approximately $841,000 in direct costs. This included American Recovery and Reinvestment Act funding received in fiscal year 2009 to restore seven historic officers' quarters. Restoration included the removal of all lead-based paint from the interior and the encapsulation of all lead-based paint on the exterior.

Kure Atoll

The U.S. Coast Guard established a LORAN station at Green Island, Kure Atoll in 1960 and occupied it until 1993. Several areas of known and potential contamination remain. These include a buried former scrap metal dump that was used as a disposal point for non-functioning, PCB-containing electrical devices (such as capacitors and transformers) and a zone surrounding a former LORAN complex building that is suspected to be contaminated with lead-based paint.

In 2016, a remediation project was completed by the U.S. Coast Guard to relocate and carbon treat soils contaminated with PCBs from the vulnerable, low-elevation scrap metal dump site to a higher-elevation, encapsulated burial site away from the shoreline. This treatment is expected to minimize future risk of release of these materials through storms or other erosive forces.

DLNR routinely monitors known and suspected contaminant sites at Kure Atoll, conducting regular wildlife health checks, as well as visual inspections and water quality monitoring at seeps utilized by wildlife. Each year since 2002, albatross chicks with droopwing syndrome have been observed around the main building. Droopwing is the inability of a chick to lift its wings due to lead's toxic effect on the nervous system. Chicks are unable to fly and eventually die, often from starvation. Lead paint chips from a former LORAN station building are suspected to be the cause of these symptoms. A proposal has been made to have the area covered with uncontaminated sand.

Potential Monument-Wide Contaminant Threats

Besides specific locations where hazardous materials were purposely used, other potential major sources of contaminants are unintended spills from vessels transiting through the monument and marine debris. Accidental discharges of oil or other contaminants may occur when vessels collide or experience problems at sea (e.g., engine breakdown, fire, explosion) and break open or run aground. These events are unpredictable and, due to the monument’s size and remoteness, not easily detected or remediated. Marine debris can include containers filled with hazardous substances and/or consist of materials that absorb contaminants. A better understanding of contaminant levels associated with marine debris is needed. Additionally, the toxicity risk to birds, fish, and other organisms from ingesting plastics and the persistent organic pollutants and other chemical pollutants that cling to them, or from consuming prey that has consumed microplastics, requires further study.

Trends

The expert-rated trend for contaminants is Not Changing with limited evidence on the basis that there have been no new known sources of contaminants in the monument for several years. Legacy contaminants continue to persist in soil and water. Buried contaminants can potentially become exposed as erosion and storm events reduce their containment. Threats from contaminants at Kure Atoll have been reduced somewhat by the 2016 relocation and remediation project, however remnants may persist in the soil. For the entire monument, the status of contaminants does not appear to have changed over this assessment period.

Management Implications

While there are no new military or industrial activities occurring in the monument, there is the potential for leaching of legacy contaminants from poorly-contained dumps at Tern Island, Sand Island, and Green Island. Additionally, buried waste and degrading metal equipment (including transformers and capacitors containing acutely toxic substances), which are already in the marine or nearshore environment, could be sources of contaminants. Hazardous marine debris, including intact drums, barrels, and plastic containers may wash ashore in the monument. Currently, shoreline debris monitoring is limited to Midway and Kure Atolls, with opportunistic monitoring occurring at seasonal research camps on other islands and atolls.

Hurricane Walaka, which damaged Tern Island, may have affected the status of buried contaminants, and future research is needed to evaluate any potential impacts. Four strategies are indicated here:

1. Identification of local issues: Work to identify ongoing source areas, encourage research to assess local risk to key species associated with sources, and include consideration of subtle, sublethal contaminant impacts in species-focused management plans.
2. Risk reduction: Include contaminant considerations when enhancing habitat and use deterrence techniques to discourage habitat use in impacted areas.
3. Source removal: Working with partner agencies, develop and fund a hazardous materials disposal program to identify, contain, and remove hazardous materials from the monument.
4. Research: Work with research partners to support data gathering to assess local risk to keystone species and pinpoint source areas, include contaminant considerations when enhancing habitat, and use various techniques to discourage habitat use in impacted areas.

Acknowledgements
Fenix Grange contributed to this assessment.

LIVING RESOURCES

5. What is the status of biodiversity and how is it changing?

Marine Biodiversity

Good ?

Status
Marine biodiversity is assessed as Good with medium evidence on the basis that the marine ecosystem in the monument reflects near-pristine conditions with limited human influences and promotes ecosystem integrity.

The expansive systems of coral reefs in the monument support a dynamic assemblage of marine species. Up to 25% of the shallow-water organisms found in the Hawaiian Islands are endemic. Studies on gene flow and biogeography indicate that migration and larval transport for coral reef organisms occurs from the southeastern to the northwestern Hawaiian Islands (Toonen et al., 2011).

For decades, scientists have been conducting surveys to characterize marine biodiversity for shallow and mesophotic reef species in Papahānaumokuākea. Surveys conducted on reefs at depths of up to 330 ft revealed an extremely high proportion of species unique to the Hawaiian Archipelago. Some of the reefs surveyed had recorded extremely high levels of fish endemism.

The research community is still in an exploratory phase with regard to its understanding of biodiversity in terms of taxonomic, genetic, and functional diversity of marine organisms, particularly cryptic invertebrates and algae. There are more than 7,000 known marine species in the monument, mostly represented by coral reef and invertebrate species and pelagic fish. Several of these species are listed as threatened or endangered under the Endangered Species Act.

Corals

The waters of the monument are home to an abundant array of coral, algae, and invertebrate species. Fifty-seven species of stony corals are known in the shallow reefs, 17 of which are found only in the Hawaiian Archipelago. Deep-water corals in the monument are even more diverse, with 137 documented species of gorgonian octocorals and 63 species of azooxanthellate non-reef-building scleractinians.

Algae

There are 372 species of macroalgae and two seagrasses found within the monument (McDermid et al., 2002; Tsuda, 2014; Tsuda et al., 2015; Spalding et al., 2016; Sherwood, Paiano, et al., 2020). Within the past nine years, over 70 undescribed species of macroalgae and turf algae have been collected at mesophotic depths. It is likely that there are more species, however a lack of sampling and expert evaluation have been major limitations to fully characterizing algal biodiversity.

Fish

There are approximately 338 species of shallow and mesophotic fish in the monument. This includes at least 133 shallow coral reef fish, 36 mesophotic reef fish, and at least an additional 169 species that live in both shallow and mesophotic reefs. The particular composition varies by island reef system (Figure S.LR.5.1). Previous estimates of fish endemism for the Hawaiian Archipelago suggested that 20.5% of fish species are endemic (Randall, 1998). New research has revealed higher levels of endemism, particularly among mesophotic fish in the monument. This endemism has been estimated to range from 21–46% of observed fish taxa, and surveys have documented extremely high endemism among mesophotic fish at Kure Atoll (Figures S.LR.5.1 & S.LR.5.2) (Kane et al., 2014; Kosaki et al., 2017).

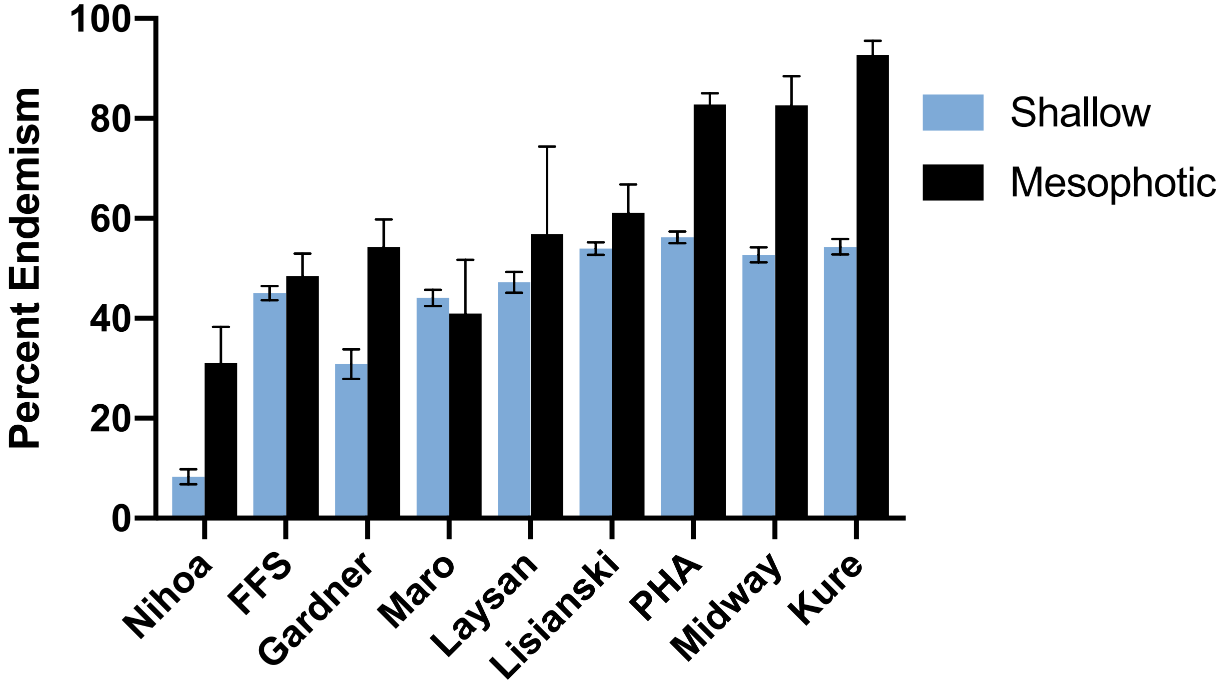


Figure S.LR.5.1. Mean percent (±SE) of shallow and mesophotic fish endemism by reef location. Source: PMNM and PIFSC, 2019

Figure S.LR.5.2. A high-endemism deep reef fish community at 300 feet, Kure Atoll, Papahānaumokuākea Marine National Monument. Every fish in the picture is a Hawaiian endemic species. Image: PMNM

Invertebrate Species

The coral reefs of Papahānaumokuākea support diverse communities of benthic macroinvertebrates, yet prior to 2000 very little was known about their abundance, distribution, and diversity. From 2001 to 2005, RAMP identified a total of 838 species from 12 orders in monument waters. In 2006, over 1,000 species of macroinvertebrates were identified at French Frigate Shoals during the Census of Marine Life Expedition (Maragos et al., 2009), and potentially as many as 2,300 unique morphospecies were identified from French Frigate Shoals alone. In 2010, RAMP changed their invertebrate survey method from roving diver surveys to the installment of stacked settlement plates called Autonomous Reef Monitoring Structures (ARMS). These 9-cubic-inch devices were deployed in the monument in 2010 and 2013 and recovered three years later in 2013 and 2016, respectively. After ARMS units were recovered, motile organisms >2 mm were visually identified, and motile organisms < 2mm, as well as sessile organisms that settled on the plates, were molecularly identified. Results from these ARMS units indicated that mollusks, decapods, and echinoderms dominate the invertebrate fauna >2 mm. When these standardized collection devices were deployed across the Hawaiian Archipelago and in other Pacific Island locations, analyses revealed that the number of species (richness) found on ARMS was similar in the monument and the MHI. However, the distribution of individuals across species was more even (evenness) in the monument compared to the MHI, indicating higher diversity of cryptofauna in the monument (Figure S.LR.5.3). The abundance of cryptic invertebrates that occupied the ARMS units in Lisianski Island was notably lower compared to other places in the Pacific Islands.

New research using DNA metabarcoding to examine fauna <2 mm and sessile organisms on the ARMS is shedding light on cryptic marine biodiversity. Preliminary results suggest that this community of organisms is far more diverse than previously thought, and species richness is likely 8–10 fold greater than formerly documented values (M. Timmers, personal communication, May 05, 2019).

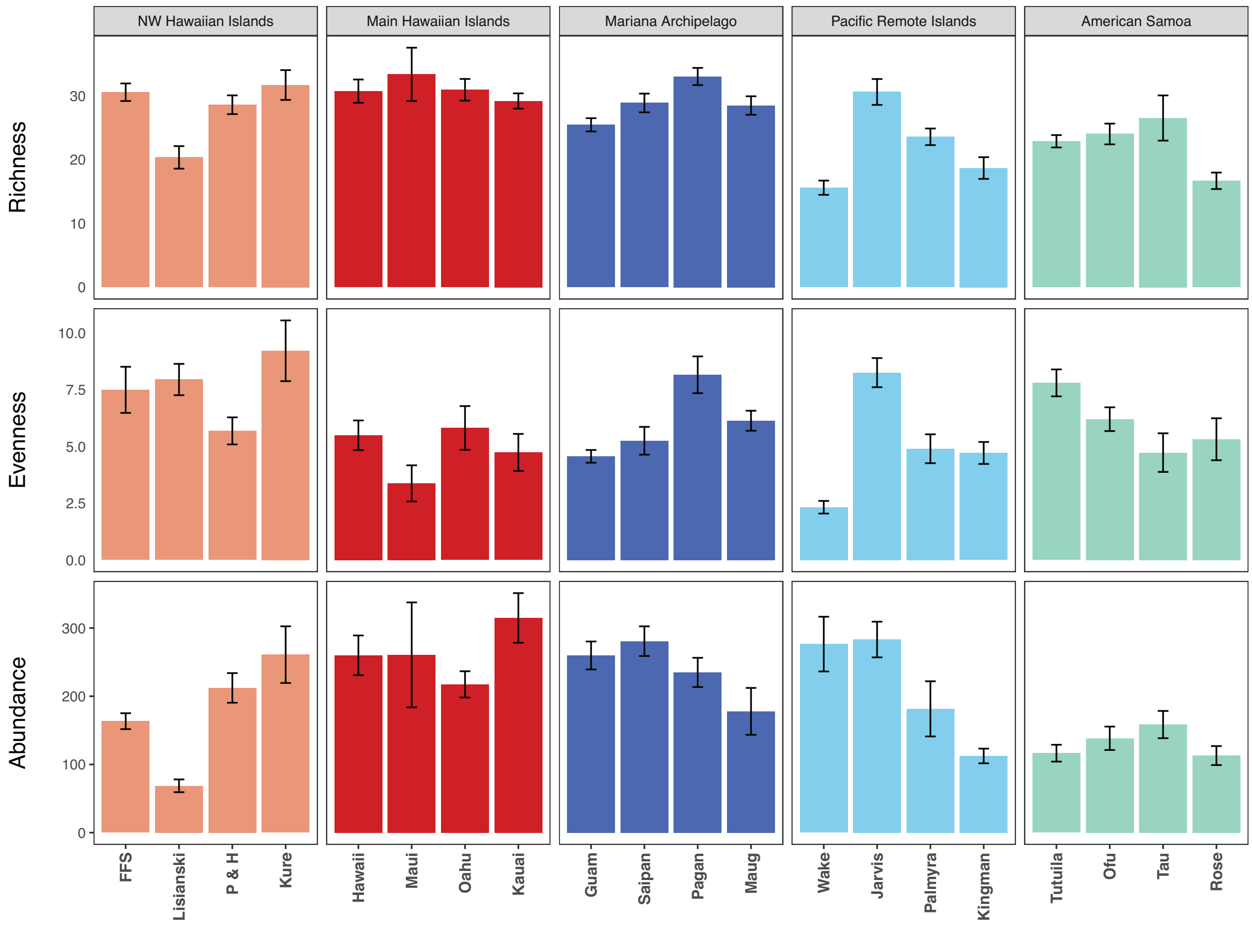


Figure S.LR.5.3. Abundance, evenness, and richness of cryptic invertebrate species recovered on Autonomous Reef Monitoring Structures in the monument. Source: Molly Timmers/PIFSC

Trends

The expert-rated trend for marine biodiversity is Undetermined with limited evidence on the basis that there are insufficient data on marine biodiversity over time to identify a trend. However, one study on shallow-water fish assemblages indicated that assemblages have remained stable and within the range of natural variation in the NWHI between 2009–2016. The only exceptions were in 2012 and 2015 in the southern region, including reefs at Nihoa, Mokumanamana, and French Frigate Shoals (Fukunaga & Kosaki, 2017). Those differences were due to changes in relative abundances of some reef fish species and may also have been influenced by small sample sizes in the southern region in those years. Temporal analyses of biodiversity for all species are needed.

Management Implications

Because biodiversity is a key variable for ecosystem resilience and productivity (Stachowicz et al., 2007; Palumbi et al., 2009), increased efforts to monitor it are needed. Challenges include both limited sampling and limited capacity for the evaluation of potentially new species due to the shortage of taxonomic experts and the lack of taxonomic expertise among field biologists, particularly for cryptic and algal species.

Biodiversity of fish and coral on coral reefs has been studied for many years, however there has been limited work to assess coral reef invertebrate and algal biodiversity, non-fishery pelagic fish and invertebrates, and deep sea animals. A comprehensive biodiversity assessment and updated species inventory for the entire monument is needed, as well as repeat assessments, which would enable the assessment of trends. An updated estimate of the total number of species in both marine and terrestrial areas of the monument is needed.

Acknowledgements
Dr. Randy Kosaki, Dr. Rusty Brainard, and Dr. Molly Timmers contributed to this assessment.

Terrestrial Biodiversity: Kure Atoll

Good/Fair

Status
The expert-rated status for terrestrial biodiversity as it relates to Kure Atoll is Good/Fair with medium evidence. The native terrestrial biota of Kure Atoll comprises 27 plants, 18 species of breeding seabirds, the resident endemic Laysan duck, 38 seasonal resident or migrant bird species, the green turtle, the Hawaiian monk seal, at least three endemic land snails, and incompletely known native arthropod fauna in excess of 20 species. A significant number of non-indigenous species are also present (Table S.LR.5.1).

Table S.LR.5.1. Species richness at Kure Atoll (estimated numbers of terrestrial and coastal species).

Category	Native Species	Non-Native Species	Notes
Plants	27	39	Sources: Starr et al., 2001; DOFAW, 2012, 2014, 2016; Reynolds & Parrish, 2015
Birds	56	46	Non-native includes 43 vagrants (species outside their normal range) and 3 transitory species. Source: Pyle & Pyle, 2017
Invertebrates	24	141	Sources: Nishida, 2001; Cooke & Kondo, 1960; Goff, 1982
Mammals	1	0	Hawaiian monk seal.
Reptiles	1	1	Native: green turtle; non-native: mourning gecko. Source: DOFAW, 2019
Total:	**109**	**227**	

Figure S.LR.5.4. Native flora at Kure Atoll. Image: Andrew Sullivan-Haskins/DOFAW

An unknown number of native plants, vertebrates, and invertebrates were extirpated at Kure Atoll in the 1800s and 1900s due to human disturbances. These disturbances included a period of visits by commercial whalers, sealers, and egg and feather collectors, followed by a period of military use by the U.S. Navy, which constructed a radar reflector. The U.S. Coast Guard built a runway, buildings, and associated infrastructure and occupied the site until 1992. Polynesian rats were an early introduction, and were observed as early as the 1890s at Kure Atoll.

A short survey by a naturalist in 1915 and a more thorough survey during the Tanager Expedition of 1923 provided the first systematic observations of Kure Atoll's flora and fauna (Christopherson & Caum, 1931). The Tanager expedition documented 13 native species and noted that Green Island's vegetation was dominated by naupaka (*Scaevola sericea*), with an open plain of approximately 10 hectares toward the east central part of the island. Here they described a diverse, low-lying vegetation association dominated by *Tribulus cistoides*, *Ipomoea* spp., and *Eragrostis variabilis*, with rare plants found nowhere else on the island interspersed (among them pōpolo [*Solanum nelsonii*] and *Lipochaeta integrifolia*). The central plain also supported nesting ʻā, or masked boobies (*Sula dactylatra*) and brown boobies (*Sula leucogaster*), and was "honeycombed" with petrel burrows. During the same expedition, Fullaway conducted the first terrestrial arthropod survey, documenting 35 species (Bryan, 1926).

It was not until 34 years later that Kure began to receive regular visits from biologists. Research during this period was primarily focused on seabirds, with occasional surveys of plants and arthropods. It is known that all 13 vascular plant species reported in 1923 by the Tanager Expedition were still present as of 1961 (Lamoureux, 1961) along with one undocumented endemic species. At that time, 22 species of newly introduced weeds and cultivated plants were also documented. However, the introduced plant species were not observed to significantly affect the ecological equilibrium of the island.

This situation changed drastically by 1968, with the overgrowth of the invasive golden crownbeard and other weeds. Rarer natives started to disappear in 1979, and by 2002 six native plant species were no longer found. A similar change was evident in invertebrate populations. A 1963 survey documented a dramatic increase in invertebrate species, many of which were likely introduced inadvertently by the U.S. Coast Guard (Woodward, 1972). A 2001 arthropod survey found the Kure Atoll arthropod community to be 12% native and 86% non-native. This study documented 164 species: 11 endemic, nine indigenous, 132 adventive (introduced, but by an unknown agent), nine human-introduced, and three of unknown status (Nishida, 2001). The most recent arthropod survey was conducted in 2007 by DLNR Division of Forestry and Wildlife (DOFAW) volunteers Sheldon Plentovich and Heather Eijzenga. Specimens collected were archived at Bishop Museum and are pending analysis.

Three snail species endemic to the NWHI, *Tornatellides*, *Tornatellinops*, and *Lamellidea*, were documented at Kure Atoll in 1960 (Cooke & Kondo, 1960). A new species of mite, *Hemicheyetia kureatollensis*, was identified and named after Kure Atoll by Goff (1982).

There are two known reptile species found on Kure Atoll: the native green turtle (*Chelonia mydas*), which has been documented nesting on Green Island, and the introduced mourning gecko (*Lepidodactylus lugubris*), documented since 2002 (DOFAW, 2009).

Kure Atoll is an important pupping and resting area for the Hawaiian monk seal. The Kure Atoll subpopulation of monk seals apparently declined during the 1960s due to increased human disturbance but has been increasing in recent years. The monk seal population size at Kure is currently about 91 animals (Pacific Islands Fisheries Science Center [PIFSC], 2019).

In 2010, the State of Hawai‘i established year-round field camps for Kure Atoll Wildlife Sanctuary. This has enabled managers to expand research and monitoring efforts and to implement comprehensive island-wide restoration efforts for habitats and species.

Figure S.LR.5.5. Restored seabird habitat at Kure Atoll. Image: Cynthia Vanderlip/DOFAW

A successful year-round program for the eradication of golden crownbeard was launched in the spring of 2010. All of Green Island's 188 acres are now cleared of stands of golden crownbeard and are again available for seabird nesting. Native plant biodiversity has also improved, as native plants naturally increase their range when non-indigenous species are removed. An associated program to propagate and outplant native plant species (2,000 to 16,000 plants per year over the last decade) has also increased the diversity and range of native plants. Among the program's successes are the reintroductions of the endemic pōpolo in 2015 and ʻanaunau (*Lepidium bidentatum var. owaihiense*) in 2018. Another native plant, ʻenaʻena (*Pseudognaphalium sandwicensium var. sandwicensium*) was presumed extinct on Kure until a small population was found in 2013. Within four years of discovery, ʻenaʻena was reestablished throughout the island (DOFAW, 2019).

The establishment of year-round field camps and achievement of large-scale habitat improvements enabled the introduction of a population of the endangered Laysan duck to Kure Atoll. Green Island lies within the presumed historic range of the Laysan duck, and additional translocation sites are urgently needed to protect this rare species. In September 2014, 28 juvenile birds were translocated from Midway Atoll to Kure Atoll. This population represents an important safety net for the species, reducing risk of extinction from random disasters, introduced species, or disease until higher-elevation sites can be ecologically restored and predator-proofed (USFWS, 2009; Reynolds, Hatfield, et al., 2012).

Trends

The expert-rated trend for terrestrial biodiversity as it relates to Kure Atoll is Improving with medium evidence. Kure Atoll became a fully protected Hawaiʻi wildlife sanctuary in the 1990s, and in 2010, a year-round management presence was established at Green Island. Subsequently, programs for the elimination of invasive and predatory species and the restoration of native plants have resulted in more robust and resilient flora and fauna on Green Island.

Management actions have increased the diversity and distribution of native plants. The removal of invasive species and the propagation and outplanting of natives have increased the occurrence and range of nine species, including rare plants and some species that had previously been extirpated at Kure (e.g., pōpolo). Native plants are naturally increasing their range as non-indigenous species are removed. Restoration of native vegetation has also enhanced seabird habitat and increased its resilience to storm and climate change damage. Breeding populations of several seabirds are increasing, and two ground-nesting species have been reestablished.

Numbers of breeding albatross (black-footed and Laysan) have been increasing since the 1990s. These increases are likely due to multiple factors, including rat eradication, habitat restoration, and longline bycatch mitigation. In recent censuses (2012–2017), numbers of nesting black-footed albatross have remained relatively stable, while the number of Laysan albatross nests has increased.

Since 2012, the reestablishment of two ground-nesting seabird species—ʻou or Bulwer's petrel (*Bulweria bulwerii*) and Tristram's storm petrel—have been documented. Approximately 10 pairs of Bulwer's petrel were estimated to be breeding during the early to mid-2000s (VanderWerf & David, 2000; Vanderlip 2005, 2006, 2007; DOFAW, 2012). The reestablishment of the Tristram's storm petrel at Kure Atoll has been dramatic since the first sighting of a single fledgling in 2006. Increased sightings since then have been anecdotal, but are supported by estimated numbers of nests based on marking and documented fatalities (carcasses of individuals taken by vagrant owls and raptors). Since 2013, dozens of nests have been marked, and the current breeding population is estimated to be 40 pairs (Pyle & Pyle, 2017), although over 200 carcasses were found in 2017, and at least 48 carcasses were found in 2018–2019.

Since the 2014 translocation of 28 Laysan ducks to Kure Atoll, the population of this fragile species has continued to increase, in spite of several high mortality events associated with avian botulism (DOFAW, 2017). As of November 2018, the Kure Atoll population is estimated to be 76 adults, including 10 founders (DOFAW, 2018).

Management Implications

Managing for biodiversity requires long-term threat management. Introduced plants, animals, and diseases are still the primary threats to biodiversity. Continuing preventive biosecurity measures and threat monitoring, as well as control of species that behave invasively or exhibit predatory or allelopathic characteristics, are required.

At Kure Atoll, continued habitat restoration is required. Propagation and outplanting of native plants is an essential component of creating biologically structured habitats and suitable habitat for seabirds.

Continued monitoring of the health of native populations is needed to understand trends. Year-round monitoring of plant communities and reproductive success and survival of a suite of 10 seabird species is recommended.

In anticipation of negative effects of climate change, managers should promote translocation of endangered species to higher-elevation islands in the MHI and long-term preservation of threatened and endangered plant seeds.

Continued protection and management of translocated Laysan ducks is needed. This species continues to be threatened by avian disease, severe storms, and sea level rise. Year-round monitoring for reproductive success and survival is recommended. Since avian botulism outbreaks have taken many adults, preventive measures, including daily water source checks and removal of albatross chick carcasses and abandoned eggs, should be continued at Kure Atoll.

Reintroduction of the Laysan duck to the MHI is necessary for recovery over the long term, because these islands can provide suitable habitat at higher elevations. Laysan duck habitat in the NWHI is likely to be significantly diminished or lost within a century because of increased storm severity and sea level rise resulting from global climate change. In the coming decades, threats from climate change effects, including severe storms and sea level rise, will increase in severity (Reynolds, Berkowitz, et al., 2012). Limited funding poses a significant challenge to protecting biodiversity and to monitoring its status and trends.

Acknowledgements

Cynthia Vanderlip contributed to this assessment.

6. What is the status of historically targeted species and how is it changing?

Spiny Lobster, Slipper Lobster, Bottomfish, Black-Lipped Pearl Oyster

Fair ?

Status

The overall expert rating on the status of historically targeted species is Fair with limited evidence. This rating is based on a combined rating for three separate groups: spiny and slipper lobsters (Fair), bottomfish (Good/Fair), and black-lipped pearl oysters (Fair/Poor) and considers that recovery is unlikely for black-lipped pearl oysters.

Lobster

The NWHI lobster fishery, dating to the mid-1970s, primarily targeted ula or spiny lobster (*Panulirus marginatus*) and ula pāpapa or slipper lobsters (*Scyllarides squammosus*). A combination of increased fishing effort, particularly beginning in 1984 when new traps were introduced, and ecosystem regime shifts (Polovina et al., 1994; Polovina, 2005) led to the decline of many local populations of spiny lobster

Figure S.LR.6.1 An ula or spiny lobster (*Panulirus marginatus*) at Gardner Pinnacles. Image: Greg McFall/NOAA in the monument. Status assessments of lobster stocks are limited, with the last assessment occuring in 2001 (DiNardo & Marshall, 2001). At that time, data showed that since 1983, lobster catch per unit effort from the commercial fishery had declined, and many subpopulations were overfished. In 1999, spatial management of the fishery was adopted and redistributed fishing effort throughout the NWHI (DiNardo & Marshall, 2001). The fishery was eventually closed in 2000 due to increasing uncertainty in the population models used to assess stock status and the establishment of the Northwestern Hawaiian Islands Coral Reef Ecosystem Reserve in 2000 by President Clinton through Executive Order 13178 and later through Executive Order 13196, which prohibited commercial lobster fishing in the NWHI. Despite the cessation of commercial fishing activities in PMNM, lobster abundances remain depressed. Fishery-independent lobster tagging cruises from 2002–2008 indicated that the catch per unit effort of both species remained low, with no signs of recovery (O'Malley, 2009, 2011).

Bottomfish

Prior to the bottomfish fishery closure put in place in 2010, the Hawaiian bottomfish fishery targeted several species of snapper and jacks, as well as a grouper. Data from the last decade are limited, as the most recent NWHI bottomfish assessment was conducted using fishery data through 2007 (Brodziak et al., 2009). Overfishing was observed in 1989, however assessments completed through 2007 indicated that NWHI stocks were not overfished or experiencing overfishing and were generally healthy, especially relative to MHI bottomfish stocks (Brodziak et al., 2009). Given the current monument protections, it is unlikely that the stocks will be overfished or experience overfishing in the future.

Black-lipped Pearl Oyster

The pā or black-lipped pearl oyster (*Pinctada margaritifera*) is now uncommon throughout the monument, however, there once was a large population at Pearl and Hermes Atoll (Keenan et al., 2006). This resource was overharvested between 1928 and 1930, when approximately 150,000 oysters were taken for their pearls and shells. Surveys through 2006 showed that the Pearl and Hermes Reef populations had not recovered to pre-exploitation levels (Keenan et al., 2006). Research during 2007–2011 found that a small reproductive population may exist at Midway Atoll, or that larvae may be recruiting to Midway Atoll from other locations, such as Pearl and Hermes Atoll (McCully, 2013), but the prospect for recovery of the species is uncertain at this point.

Trends

Due to a lack of data over the last decade, the trend of the historically targeted species mentioned above is Undetermined with limited evidence. The last fishery-independent lobster tagging cruise (2008) did not indicate recovery of the lobster stock (O'Malley, 2009, 2011). As of 2007, NWHI bottomfish stocks were assessed to be healthy (Brodziak et al., 2009). Pearl and Hermes Atoll populations of black-lipped pearl oysters were still depressed as of 2006.

Management Implications

The NWHI lobster fishery has been closed since 2000, and the bottomfish fishery has been closed since 2010. Annual fishery-independent resource assessments, which previously provided information on lobster and bottomfish populations and were conducted by PIFSC, ceased in 2009 with no plans to resume. However, a recent study of larval dispersal and connectivity in three bottomfish species: opakapaka or Hawaiian pink snapper (*Pristipomoides filamentosus*), ʻulaʻula koaʻe or onaga or long tail red snapper (*Etelis coruscans*), and ʻehu or yellow striped red snapper (*Etelis carbunculus*) concluded that

Figure S.LR.6.2. Black-lipped pearl oyster (*Pinctada margaritifera*) at French Frigate Shoals. Image: James Watt/NOAA

populations of these species in PMNM are locally settled and not exported to other regions outside the monument (Vaz, 2012). The finding of these self-sustaining zones and limited direct larval connectivity between the MHI and NWHI (predominantly from the southeastern MHI to the NWHI) is supported by earlier population genetics studies by Toonen et al. (2011) and Rivera et al. (2011), which found genetic differentiation and population structure between the MHI and NWHI.

It is vital to protect stocks and habitat located around these islands to maintain their vital ecological function. There are no current plans for black-lipped oyster surveys at Pearl and Hermes Atoll. If recovery of pearl oysters is possible, it will take time. They are sessile as adults, so recruitment is constrained by reproductive activities of remaining adults and the recruitment of larvae from elsewhere in the Pacific. Due to the isolation of the Hawaiian Archipelago and the rarity of the species, external recruitment is unlikely (Schultz et al., 2011). Translocation may be a viable strategy for this species. In 2019, trials were launched through a partnership between the University of Hawaiʻi, Joint Base Pearl Harbor-Hickam, and Oʻahu Waterkeeper to grow black-lipped oysters in Pearl Harbor (Waterkeeper Alliance, 2019). Future studies should include investigation of the genetic connectivity of pearl oysters throughout the archipelago (McCully & Potts, 2008).

It is also important to understand the status and trends of historically targeted species in the 2016 monument expansion area. Pelagic longline fisheries, which operated in this area until 2016, have extracted various tuna and swordfish species in pelagic waters between 50–200 nautical miles offshore. In addition, the slender armorhead (*Pseudopentaceros wheeleri*) and splendid alfonsino (*Beryx splendens*) were targets on the Hancock Seamounts, 190 nautical miles northwest of Kure Atoll (Baco et al., 2019). The Hancock Seamounts were designated as an Ecosystem Management Area, with a moratorium on all seamount groundfish including: armorhead, splendid alfonsino and raftfish (*Hyperoglyphe japonica*) that will remain in place until the species is determined to have recovered (WPRFMC, 2010). Future assessments should include evaluations of the monument expansion area.

Fishery closures and the elimination of research cruises and surveys prevent a more current status determination for many of these populations. Annual research cruises are recommended to monitor these resources, particularly the response of lobster populations to the fishery closure.

Acknowledgements
Dr. Joseph O'Malley contributed to this assessment.

7. What is the status of non-indigenous and invasive species and how is it changing?

Terrestrial Non-Indigenous and Invasive Species

Good/Fair

Status
The expert-rated status for terrestrial non-indigenous and invasive species is Good/Fair with medium evidence on the basis that non-indigenous species are present in terrestrial habitats and, in some cases, preclude community development and function but are unlikely to cause substantial or persistent degradation of ecosystem integrity. This is due in large part to agency restoration efforts. Monitoring and management of non-indigenous species have focused more on flora than fauna. There is a clear pattern of islands with a history of human habitation having greater numbers of non-indigenous species.

A comprehensive inventory of PMNM non-indigenous[2] fauna has yet to be conducted. However, for some islands, certain faunal species and groups have been identified as priority threats requiring management. These include mice, ants, wasps, mosquitoes, and mites at Midway Atoll and Kure Atoll, and gray bird grasshoppers (*Schistocerca nitens*) and ants at Nihoa Island (PMNM, 2008). Actions to monitor and control these priority threats are described below.

[2]Non-indigenous species are non-native species. Some are considered problematic nuisance species as they can compete with, or prey upon, other species and disturb native habitat.

Figure S.LR.7.1. Non-indigenous ants attack a native seabird. Image: Cynthia Vanderlip/DOFAW

Invasive plants brought to the NWHI in the course of human activity have caused extensive damage through the years by displacing native plants and changing the structure and composition of the vegetation community to make it less useful as habitat for native organisms.

Inventories of non-indigenous flora have been conducted for some islands and atolls, and some priority threats have been identified. Estimated or known numbers of non-indigenous terrestrial plant species are shown in Table S.LR.7.1. These numbers reflect the most recent estimated or known numbers for the reporting period, however fluctuations occur. For example, historically eight non-indigenous plants have been found on Nihoa Island; in 2017, four were present; in 2019, six were present.

Table S.LR.7.1. Non-indigenous terrestrial plant species by island or atoll. Sources: DOFAW, 2017; Starr & Starr, 2013, 2015; USFWS, 2013, 2016, 2018

Island or Atoll	Number of Non-Indigenous Plant Species	Year	Estimated (E) or Known (K)
Nihoa	6	2019	E
Mokumanamana	Unknown (none detected)	2017	N/A
French Frigate Shoals	19	2013	E
Gardner	0	2015	K
Maro	N/A	n/a	N/A
Laysan	9	2013	K
Pearl & Hermes	10	2017	K
Lisianski	5	2017	K
Midway	172	2015	K
Kure	34	2016	E

At the northern end of the archipelago, Midway and Kure Atolls have the greatest known numbers of non-indigenous terrestrial plant species. French Frigate Shoals has the next largest number, followed by Laysan Island. Elsewhere in the monument, numbers of non-indigenous plant species present remain low.

Table S.LR.7.2. Priority threats: non-indigenous species targeted for control, by island /atoll.

Island or Atoll	Priority Non-Indigenous Plant Species
Nihoa Island	*Cenchrus echinatus, Tetragonia tetragonioides, Eleusine indica*
Mokumanamana Island	n/a
French Frigate Shoals	*Cenchrus echinatus, Sporobolus pyramidatus Chenopodium spp, Sonchus oleraceus, Malva parvifolia*
Gardner Pinnacles	n/a
Maro Reef	n/a
Laysan Island	*Pluchea indica, Sporobolus pyramidatus, Cenchrus echinatus, Coronopus didymus, Cynodon dactylon*
Pearl & Hermes Atoll	*Verbesina encelioides, Cenchrus echinatus, Setaria verticillata*
Lisianski Island	*Cenchrus echinatus*
Midway Atoll	*Verbesina encelioides, Cenchrus echinatus, Bidens alba, Bidens pilosa, Amaranthus spinosus, Leucaena leucocephala, Ricinus communis, Abutilon grandifolium, Ficus microcarpa, Cynodon dactylon, Casuarina equisetifolia, Pluchea carolinensis*
Kure Atoll	*Verbesina encelioides, Heliotropium foertherianum, Cassytha filiformis, Chenopodium murale, Cenchrus echinatus*

Priority invasive plant species targeted for control are summarized at Table S.LR.7.2. Between 2000 and 2016, removal of targeted non-indigenous species in terrestrial habitats was the focus of management actions at five terrestrial sites in PMNM. Focused management efforts at Laysan Island, Midway Atoll, Kure Atoll, French Frigate Shoals, and Nihoa Island have yielded significant progress in the removal or reduction of harmful plants and arthropods. At most of these sites, removal of invasive plant species was coupled with the propagation and outplanting of native plant species. Opportunistic management of non-indigenous, invasive plant species also occurs annually at Nihoa Island.

Laysan Island

Year-round intensive habitat restoration at Laysan started in 1989 with an eradication project for common sandbur (*Cenchrus echinatus*). This project was expanded in 2000 to target four additional invasive plants and to ramp up native plant propagation and outplanting to promote restoration.

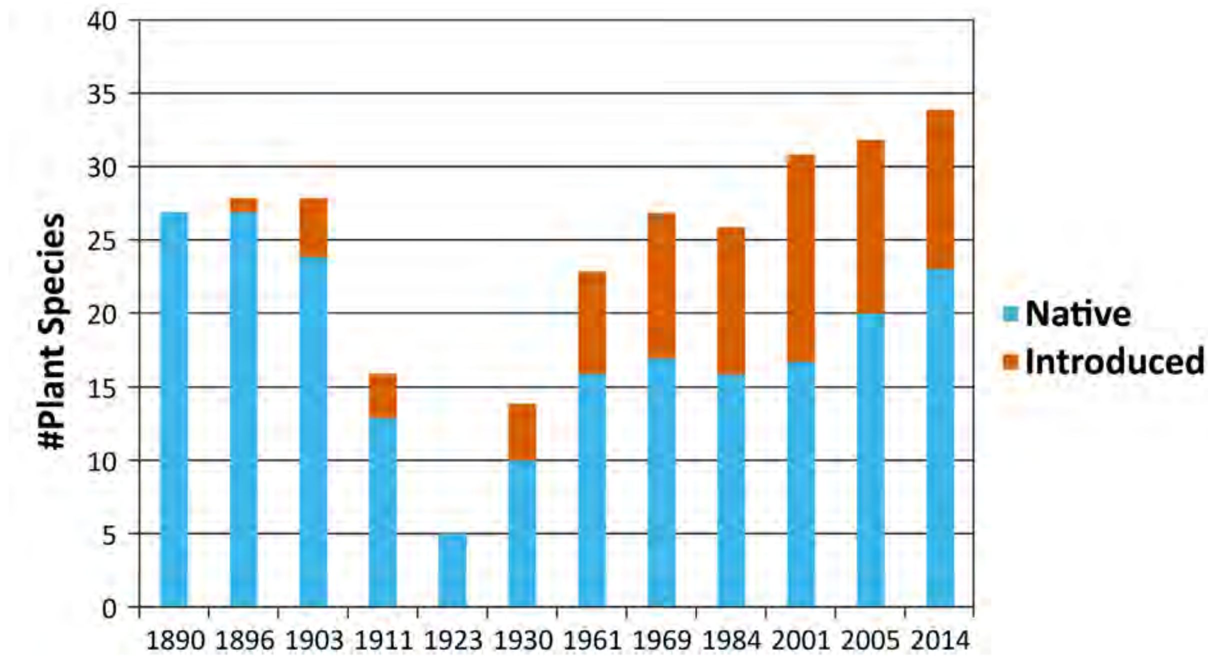


Figure S.LR.7.2. Changes in Laysan Island floristic composition from 1890 to 2014. Native plant diversity has improved with the removal of non-indigenous species. Source: USFWS

Only the most aggressive, habitat-altering, invasive plant species were identified for eradication projects at Laysan Island, although nine other, less aggressive, non-indigenous plant species exist on the island. Between 2002 and 2013, eradication methods were developed and applied for common sandbur, swinecress (*Coronopus didymus*), Bermuda grass (*Cynodon dactylon*), Indian pluchea (*Pluchea indica*), and Indian dropseed (*Sporobolus pyramidatus*). Time from germination to seed production was determined in order to systematically remove plants prior to seeding until the soil seed bank was completely exhausted. By 2012, live plants for three of the five species targeted for eradication (common sandbur, swinecress, and Bermuda grass) were observed so infrequently that a rebound of these species was considered unlikely. However, in 2013, year-round occupation by USFWS personnel at Laysan Island was suspended due to financial shortfalls. A rebound of Bermuda grass was observed in 2019 (Plentovich et al., 2019). Manager reports indicate that Indian pluchea still has a large seed bank in the soil on Laysan, and substantial rebounds also were observed in 2019 (Plentovich et al., 2019). Consistent, systematic removal is necessary to prevent this species from continuing to spread. The eradication of the last target species, Indian dropseed, is now considered unachievable at Laysan Island.

Midway Atoll

Midway Atoll has an expanding and visibly successful invasive and non-indigenous plant removal program. Annual weed monitoring has been conducted since 2012, with a majority of efforts focused on trends in cover of golden crownbeard. By the late 1990s, this plant blanketed the majority of Midway Atoll's three islands. An intensive effort to remove mature plants and seedlings between 2012 and 2017 resulted in the steep decline of golden crownbeard, which decreased from over 50% of land cover to less than 1% of cover. Work continues there to deplete the soil seed bank of this very prolific invader. Other species targeted for control are common sandbur, ironwood (*Casuarina equisetifolia*), Spanish needles (*Bidens alba*), beggar's ticks (*Bidens pilosa*), spiny amaranth (*Amaranthus spinosus*), koa haole (*Leucaena leucocephala*), castor bean (*Ricinus communis*), hairy Indian mallow (*Abutilon grandifolium*), Chinese banyan (*Ficus microcarpa*), sourbush (*Pluchea carolinensis*) and Bermuda grass. Midway Atoll Wildlife Refuge has a robust plant propagation and outplanting program that has restored native vegetation to over 20 acres of Sand Island.

Invasive house mice and black rats became established at Sand Island more than 75 years ago during military occupancy. Rats were eradicated from Midway Atoll in 1996. Actions to control the house mouse at Sand Island were identified in the 2008 PMNM Management Plan. The need for action was reinforced when mice were confirmed to be feeding on the backs and necks of nesting adult albatross in 2015. Spot control of mice is underway, and an expanded, island-wide eradication project is planned (USFWS, 2019a). Efforts to control ants and mosquitoes have been occurring since 2008.

French Frigate Shoals

Invasive species control was conducted regularly at Tern Island, French Frigate Shoals from 2009–2012. Non-indigenous species targeted for control were Indian dropseed, nut sedge (*Cyperus rotundus*), lambsquarters (*Chenopodium spp.*), common sandbur, sow thistle (*Sonchus oleraceus*), and cheeseweed (*Malva parvifolia*). A common sandbur eradication project was one of several priority efforts by staff for several years, and for a time, this invader was thought to have been eliminated at French Frigate Shoals. However, the return of common sandbur to East Island was observed in December 2011. Year-round occupation by USFWS personnel at Tern Island was suspended in December 2012 when a storm damaged the facility, and control since then has been opportunistic. A USFWS team visiting in 2013 spent three days removing common sandbur regrowth in a six-acre area of East Island, and also treated regrowth of two other problem species, cheeseweed and sow thistle.

Kure Atoll

At Kure Atoll, historical introductions of non-indigenous plant and animal species reduced biodiversity on Green Island (Butler & Usinger, 1963; Plentovich et al., 2009; Starr et al., 2001). Invasive plants displaced native plant habitat and seabird nesting areas, entrapped seabirds in dense vegetative mass, and outcompeted native plants for natural resources. Invasive plant species identified in the 2008 Monument Management Plan include golden crownbeard, common sandbur, kauna‘oa pehu or love-vine (*Cassytha filiformis*), ironwood (*Casuarina equisetifolia*), tree heliotrope (*Heliotropium foertherianum*), nettle-leaf goosefoot (*Chenopodium murale*), Bermuda grass, and scarlet spiderling (*Boerhavia coccinea*).

The 2010 establishment of year-round field camps at Kure Atoll enabled DOFAW to conduct comprehensive monitoring and management for Kure‘s habitats and species. An island-wide vegetation map, including indigenous and non-indigenous species, was completed for Kure Atoll in 2013.

Three priority invasive (nuisance) plant species are currently targeted for eradication: golden crownbeard, tree heliotrope, and love-vine; the first two species are non-indigenous, and the latter is native. These plants outcompete dune-forming native plants, leading to erosion and loss of habitat (DOFAW, 2017).

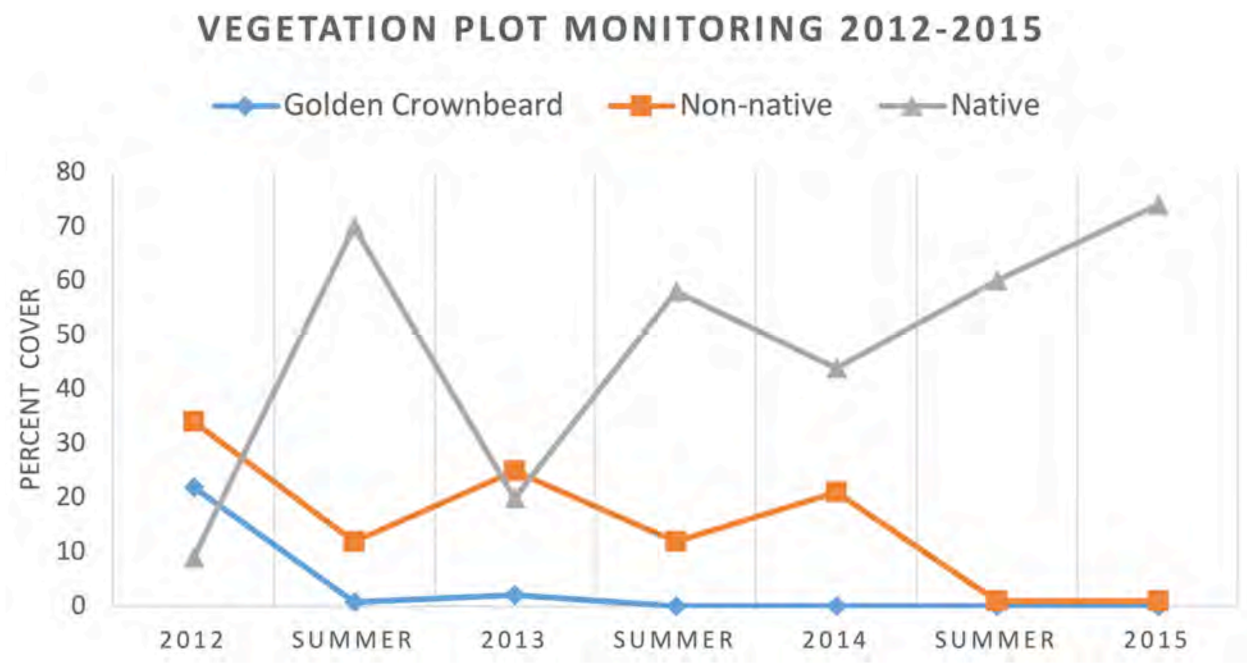


Figure S.LR.7.3. Percent cover of invasive golden crownbeard, other non-indigenous (non-native), and native plants between 2012–2015 at Kure Atoll. Source: DOFAW

Over a period of 10 years, the non-indigenous, invasive golden crownbeard invaded 188 acres of Green Island, posing a severe threat to seabird recovery (Starr et al., 2001). DLNR initiated an eradication program for golden crownbeard in the spring of 2010. Since then, over 120 acres have been treated (Figure S.LR.7.4.), thereby remedying the most significant damage caused by dense stands of mature plants. By 2013, the improved habitat began recruiting Tristram's storm petrels, a species previously extirpated by rats. Additionally, a control program for tree heliotrope has effectively limited the expansion of this recent introduction and prevented the loss of biologically structured habitats such as the high dunes.

Figure S.LR.7.4. One of the golden crownbeard eradication areas at Green Island, Kure Atoll, before and after removal of golden crownbeard. Images: DOFAW

Both native and non-native species can demonstrate invasive behavior by spreading prolifically and harmfully. Although love-vine is a native plant, this parasitic vine acts invasively at Kure Atoll. It alters plant communities by overgrowing and killing host species, causing concern for naupaka (*Scaevola sericea*) stands that are critical for dune stabilization and nesting habitat for seabirds. Love-vine was first detected on Kure Atoll in 1960 and first identified as exhibiting invasive behavior in 2001. By 2012, its range increased on Green Island from 10 to over 30 acres. In 2014, its range was contained within a buffer zone and eradication efforts began. As of 2017, love-vine was being controlled in all areas of the island (DOFAW, 2017).

Non-indigenous Polynesian rats preyed upon seabirds and their eggs for over a century at Kure Atoll until they were eradicated in 1995. Many invertebrates were introduced during the early period of human occupation, and in the early 2000s, alarming densities of big-headed ants (*Pheidole megacephala*) began disrupting the ecosystem (Plentovich et al., 2009). Big-headed ants had a devastating impact on the smallest seabird species, such as terns and Bulwer's petrel. Soldier ants were observed to kill newly hatched chicks. Big-headed ants also are known exterminators of native insects, and the ants protect and cultivate a non-indigenous scale insect, from which they collect honeydew or nectar. The scale insect is damaging to native plants, especially naupaka.

An eradication program initiated in the summer of 2014 has reduced the big-headed ant population to numbers that no longer have a negative impact on plants and animals. Monitoring surveys will continue twice a year until eradication is certain. Active colonies are treated using bait stations with Amdro® (active ingredient hydramethylnon).

Mosquitoes were introduced to Kure Atoll in 2006. Regular treatments began in 2008, and mosquitoes are now presumed to have been eradicated, as they have not been detected since 2016.

Nihoa Island

Nihoa Island is only visited once or twice per year. Its native plant community is almost completely intact, so the importance of removing the few non-indigenous plants that have reached this difficult-to-access island is magnified. USFWS crews conduct annual monitoring and remove invasive plants such as common sandbur and New Zealand spinach (*Tetragonia tetragonioides*).

The invasive common sandbur, an annual grass, occurred in low numbers on Nihoa Island from 1961–1983. It was detected again in 2011 (VanderWerf et al., 2011), and an average of four plants per year was found from 2011–2017. In 2018, significant expansion was discovered and at least 600 plants at 22 locations were observed, including seven larger (>10 m diameter) patches. In 2019, an invasive species strike team visited Nihoa Island and used hand-pulling, seed collecting, and application of a pre-emergent herbicide to control common sandbur. Over 860 common sandbur plants and ~112,900 burrs were removed from 102 locations (Figure S.LR.7.5). The pre-emergent herbicide Esplanade® was applied over ~0.3 acres and at 90 of the 102 locations. Continued action is needed to eradicate this species before it spreads farther and displaces the native vegetation community. During the 2015 trip, all plants and seedlings were pulled, and fruits were collected from the soil.

Figure S.LR.7.5. Distribution of common sandbur on Nihoa Island in 2019. Image: DigitalGlobe, created by Elyse Sachs/USFWS

New Zealand spinach is removed annually at two locations on Nihoa Island, Pinnacle Peak and Devil's Slide. Numbers oscillate but remain relatively low at both sites, ranging from 0 to 213 over the last five years (Figure S.LR.7.6).

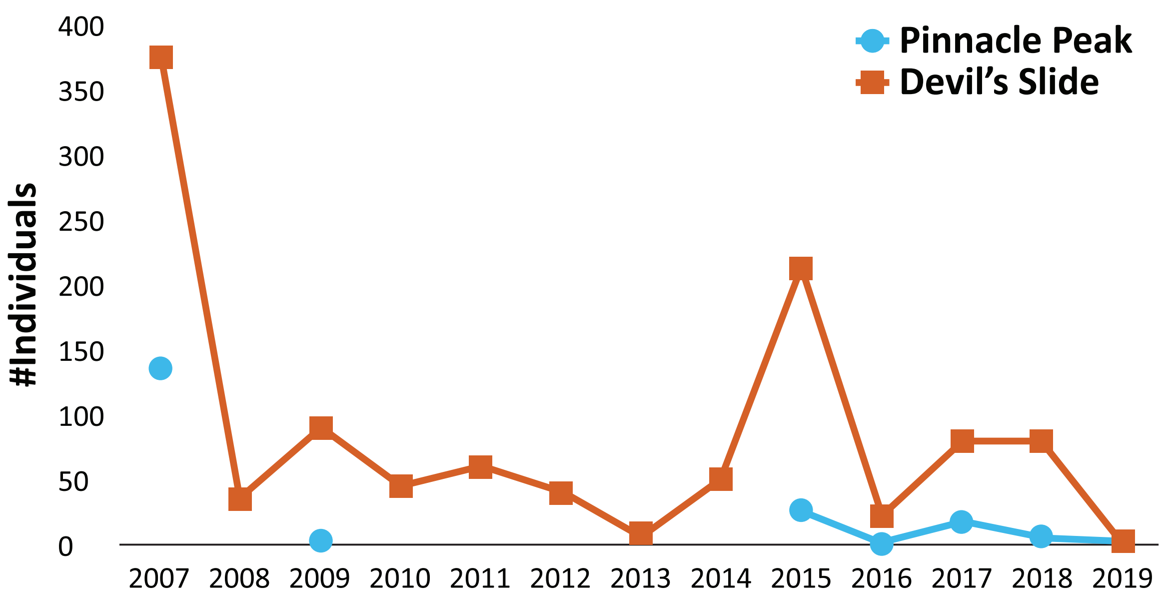


Figure S.LR.7.6. Location and number of individuals of New Zealand spinach encountered and removed from the Devil's Slide and Pinnacle Peak locations on Nihoa from 2007–2019. Note: Pinnacle Peak was not visited every year. Source: USFWS

Two new invasive plants were found on Nihoa Island in 2019: wiregrass (*Eleusine indica*) and jack bean (*Canavalia cathartica*) (Rounds et al. 2019). All individuals of both species were removed, but a seedbank persists.

Pearl and Hermes Atoll

Pearl and Hermes Atoll is also only visited sporadically by monument staff, and a very serious infestation of golden crownbeard on Southeast Island continues to go untreated, causing great harm to native plants and wildlife.

Trends

Trends for different locations and species are mixed. Overall, restoration and control have been successful in many habitats, and the trend is assessed as Improving with limited evidence. Eradication of the Polynesian rat at Midway Atoll and Kure Atoll has, over time, resulted in the return of some seabird species and significant increases in population sizes of others. Mice continue to be a threat to seabirds at Midway Atoll. Recently, control of the big-headed ant at Kure Atoll has broken a cycle of seabird predation, native plant predation, and other disruptions to habitat.

At Kure Atoll and Midway Atoll, significant improvements to the quantity and quality of seabird habitat have been achieved through the removal of non-indigenous plants. Restoration efforts, particularly the removal of large swaths of the invasive golden crownbeard, have freed up a significant amount of nesting habitat for seabirds. Indigenous plants are naturally increasing their range, a process hastened by programs for propagating and outplanting native species.

For the period 2008–2012, significant progress in the control and eradication of non-indigenous invasive plants was also reported at Laysan Island and at Tern Island (French Frigate Shoals). However, active management ceased in 2012–2013 with the closure of year-round field stations at these sites, and the extent to which these invasive plants have rebounded since then is largely unknown. Up until now, annual efforts to monitor and control two non-indigenous invasive plant species at Nihoa Island have been marginally effective, however in 2018, abundance of common sandbur had increased significantly and expanded to areas throughout the island. This trend continued in 2019. Additionally, two new invasive plants, wiregrass and jack bean, were found on Nihoa Island in 2019.

Management Implications

The primary management actions needed for non-indigenous species are prevention through strict biosecurity, population monitoring, removal, control, and eradication.

Maintaining current biosecurity measures is essential as threats remain (Table S.LR.7.2). Strict regulation of access throughout the monument has been a major factor in preventing introduction of non-indigenous species and limiting the spread of those already occurring within the monument. Current biosecurity measures include both pre-access and on-island best management practices. Provided these measures continue, there is a good chance that the terrestrial biota of the monument can remain relatively undisturbed.

Time and resources have historically limited the monitoring of non-indigenous species across the monument. Operation of the year-round USFWS Habitat Restoration Program at Laysan Island was suspended in 2013 due to federal budget shortfalls. Additionally, the year-round operations at Tern Island Field Station were suspended in 2012 due to budget shortfalls and a storm that destroyed staff housing. This effectively terminated monitoring, predator/invasive species control work, active habitat restoration, and native plant propagation at these sites. The closure of year-round camps at Laysan and Tern Islands may result in lost ground, as non-indigenous species reduced by previous continuous management will likely rebound. If programs for consistent, systematic removal are not possible, opportunistic removal of invasive species should be attempted for priority invasive species such as common sandbur, swinecress, and Bermuda grass, targeting the last recorded locations of these plants. This approach would slow the reestablishment of these species in large areas of the islands.

Monitoring has occurred intermittently at other uninhabited and infrequently visited islands. Under such circumstances, near-pristine islands like Nihoa could develop irreversible changes to the endemic habitat. Due to the high density of endemic species in the small area of Devil's Slide and the invasive nature of common sandbur and New Zealand spinach, continued monitoring and removal of non-indigenous invasive plants should remain a priority for future trips to Nihoa Island, as well as continued monitoring of other non-indigenous species (e.g., ants, gray bird grasshopper).

In addition, new and innovative strategies and technologies for monitoring and access are needed for islands that are infrequently visited, or where the probability of detecting invasive plants and animals may not correspond with the time of year when safe landing conditions facilitate access.

Management successes at Kure Atoll, Midway Atoll, Laysan Island, and Tern Island highlight the importance of a long-term commitment to restoration. The eradication of common sandbur, an invasive grass, took 12 years to complete on Laysan Island, but contributed significantly to the restoration of Laysan's seabird nesting habitat and facilitated the restoration of native vegetation. The removal of golden crownbeard at Midway Atoll and Kure Atoll restored over 120 acres of important seabird nesting habitat, but continued treatments are needed for many more years to extinguish the seed bank. The control program for love-vine at Kure Atoll is designed to limit its range beyond the 2012 assessed distribution and eventually eradicate it. Continuation of this program will prevent the loss of the west and south beach dune structures of Green Island. The long-term control program for tree heliotrope at Kure Atoll has prevented the loss of biologically structured habitats such as the high dune structures on the west-facing beaches. Thus, many management actions to control non-indigenous vegetation will need to be in place for a substantial period of time to be effective or to enable a reasonable assessment of their effectiveness.

Finally, along with the removal and control of non-indigenous and invasive species, the propagation and outplanting of native plants is an essential component of creating biologically structured habitats and suitable habitat for seabirds.

Acknowledgements

Dr. Beth Flint, Dr. Cindy Rehkemper, Dr. Sheldon Plentovich, and Cynthia Vanderlip contributed to this assessment.

Marine non-indigenous and invasive species

Fair

Status

The expert-rated status for marine non-indigenous and invasive species is Fair with medium evidence on the basis that invasive species may inhibit full community development and function and may cause degradation of ecosystem integrity, particularly at Pearl and Hermes Atoll.

Of the more than 400 species of non-indigenous marine species recorded in the Hawaiian Archipelago, only about 10–15% are known to be established in the monument. Focused marine invertebrate surveys, in conjunction with other dedicated ship- and land-based missions, have been ongoing since 2010 in an effort to categorize all known non-indigenous marine species. The PMNM marine non-indigenous species inventory project was created to combine historical non-indigenous algae, invertebrate, and fish inventory records with recent surveys to produce a precise checklist of documented findings. The complex taxonomic nature of invertebrate fauna makes positive identification difficult and further taxonomic resolution may be possible from cataloged museum specimens collected during previous surveys. Researchers have also identified some species found in PMNM as cryptogenic species, meaning they may be either a native species or an introduced species, with clear evidence for either origin being absent.

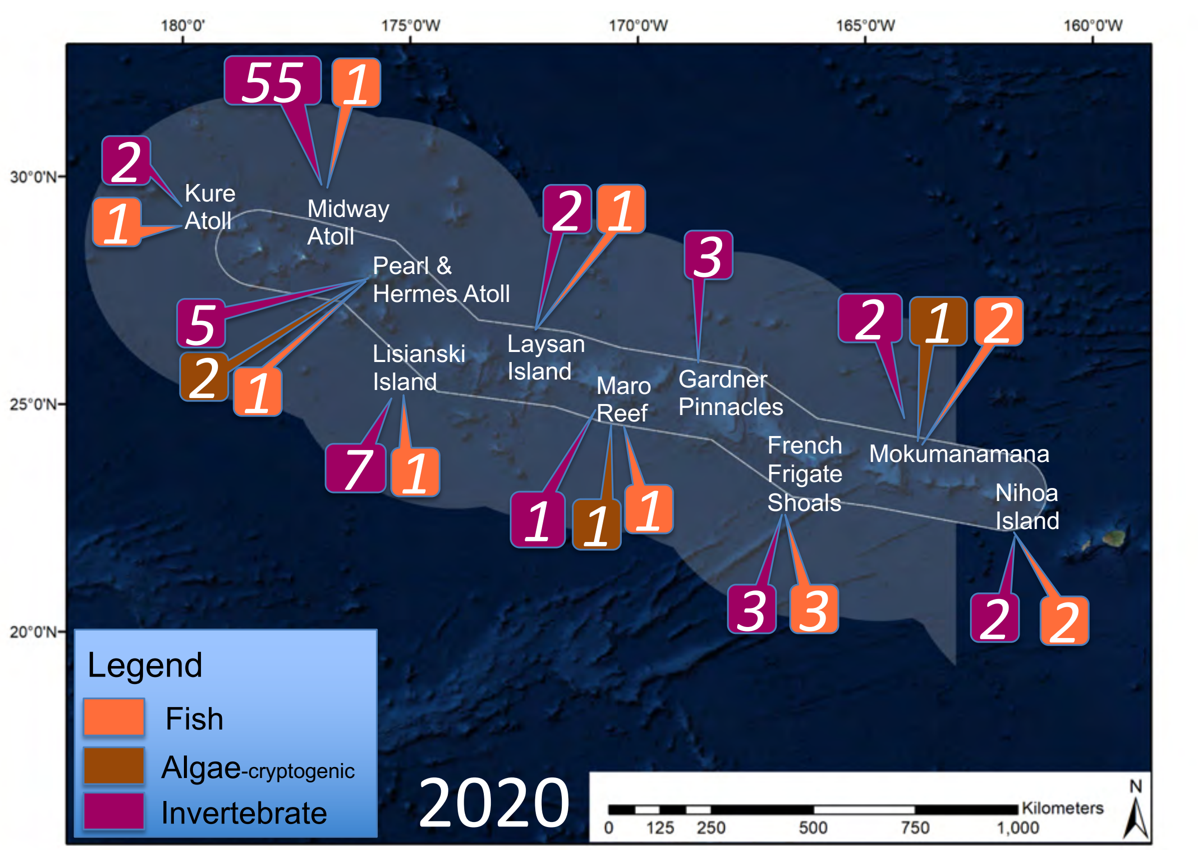


Figure S.LR.7.7. The distribution of marine non-indigenous and/or cryptogenic species throughout the monument. Image: PMNM

In 2006, a total of nine established marine non-indigenous species were known in the monument (Godwin et al., 2005). This number included one species of algae, three species of fish, and five species of invertebrates. By 2009, four additional invertebrate species had been detected, bringing the total to 13 non-indigenous species (See et al., 2009). As of March 2020, findings from the marine non-indigenous species inventory project have now documented that there are potentially 61 non-indigenous species in the monument. These marine species are listed in Table S.LR.7.3. Of those species, 39 are established, 21 are cryptogenic, and one is thought to be present but not established (Tsuda et al., 2015; Godwin et al., 2020). The 61 non-indigenous species consist of two cryptogenic species of red algae, three species of fish, and 56 species of marine invertebrates with fairly disjunctive distributions (Figure S.LR.7.7). One of the cryptogenic red algae species has recently been identified as *Chondria tumulosa* (Sherwood, Huisman, et al., 2020), which is explained in further detail below.

Table S.LR.7.3. Marine non-indigenous species throughout the monument. Species in red indicate they are cryptogenic or unknown. Islands: NIH (Nihoa), MOK (Mokumanamana), FFS (French Frigate Shoals), GAR (Gardner Pinnacles), MAR (Maro), LAY (Laysan), LIS (Lisianski), P&H (pearl & Hermes Atoll), MID (Midway), and KUR (Kure Atoll).

Marine Non-Indigenous Species throughout the Monument												
		Distribution by Island/Atoll										
Taxon		Status	NIH	MOK	FFS	GAR	MAR	LAY	LIS	P&H	MID	KUR
PHYLUM ANNELIDA												
Class Polychaeta												
Family Chaetopteridae												
	Chaetopterus variopedatus	A									X	
Order Eunicida												
Family Lumbrineridae												
	Kuwaita (Lumbrineris) heteropoda	C									X	
	Lumbrineris sphaerocephala											
Order Sabellida												
Family Sabellidae												
	Branchiomma cingulatum	A									X	
	Potamethus elongatus	C									X	
	Sabellastarte spectabilis	A	X	X		X		X	X		X	
	Potamilla sp.	C									X	
Family Serpulidae												
	Hydroides brachyacantha	A									X	
	Hydroides elegans	A									X	

Marine Non-Indigenous Species throughout the Monument												
		DISTRIBUTION BY ISLAND/ATOLL										
TAXON		STATUS	NIH	MOK	FFS	GAR	MAR	LAY	LIS	P&H	MID	KUR
	Hydroides exaltata	A									X	
	Pseudovermilia pacifica	A									X	
	Salmacina tribranchiata	A									X	
	Protula cf. atypha	C									X	
	Vermiliopsis sp.	C									X	
Order Terebellida												
Family Terebellidae												
	Lanice conchilega	A									X	
PHYLUM ARTHROPODA												
Class Hexanauplia												
Order Sessilia												
Family Chthamalidae												
	Chthamalus proteus	A									X	
Class Malacostraca												
Order Amphipoda												
Family Caprellidae												
	Caprella scaura	A							X			
Order Isopoda												
Family Ligiidae												
	Ligia (Megaligia) exotica	A									X	
PHYLUM BRYOZOA												
Class Gymnolaemata												
Order Ctenostomatida												
Family Vesiculariidae												
	Amathia distans	A									X	
	Amathia verticillata	A							X		X	
Order Cheliostomatida												
Family Schizoporellidae												
	Schizoporella cf errata	A									X	
Family Bugulidae	*Bugula sp.*	A									X	

Marine Non-Indigenous Species throughout the Monument												
		DISTRIBUTION BY ISLAND/ATOLL										
TAXON		**STATUS**	**NIH**	**MOK**	**FFS**	**GAR**	**MAR**	**LAY**	**LIS**	**P&H**	**MID**	**KUR**
PHYLUM CHORDATA												
SUBPHYLUM UROCHORDATA												
Class Ascidiacea												
Order Aplousobranchia												
Family Didemnidae												
	Diplosoma listerianum	A									X	
	Didemnum perlucidum	A									X	
	Didemnum sp.	A									X	
	Lissoclinum fragile	A									X	
Family Polyclinidae												
	Polyclinum constellatum	A									X	
Order Phlebobranchia												
Family Ascidiidae												
	Ascidia archaia	A									X	
	Ascidia sydneiensis	A				X					X	
	Phallusia nigra	A									X	
	Ascidia sp.	A									X	
Order Stolidobranchia												
Family Pyuridae												
	Microcosmus exasperatus	A							X	X	X	X
	Herdmania pallida	A									X	
Family Styelidae												
	Cnemidocarpa irene	A			X				X		X	
	Polycarpa aurita	C			X				X	X	X	
	Styela canopus	A									X	
	Symplegma sp.	A								X		
	Botrylloides sp	A									X	
	Botryllus sp.	A									X	

MARINE NON-INDIGENOUS SPECIES THROUGHOUT THE MONUMENT

TAXON		DISTRIBUTION BY ISLAND/ATOLL										
		STATUS	NIH	MOK	FFS	GAR	MAR	LAY	LIS	P&H	MID	KUR
SUBPHYLUM VERTEBRATA												
Class Osteichthyes												
Family Lutjanidae												
	Lutjanus fulvus	A			X							
	Lutjanus kasmira	A	X	X	X		X	X	X	X	X	X
Family Serranidae												
	Cephalopholis argus	A	X	X	X							
PHYLUM CNIDARIA												
Class Hydrozoa												
Oreder Anthoathecata												
Family Pennariidae												
	Pennaria disticha	A	X	X	X	X	X	X	X	X	X	X
Class Anthozoa												
Family Diadumenidae												
	*Diadumene lineata**	AN										
PHYLUM PORIFERA												
Class Calcarea												
Order Leucosolenida												
Family Heteropiidae												
	Heteropia glomerosa	A									X	
Class Demospongiae												
Order Dendroceratida												
Family Darwinellidae												
	Chelonaplysilla violacea	C									X	
	Darwinella australiensis	C									X	
Family Dictyodendrillidae												
	Dictyodendrilla dendyi	C									X	
Order Dictyoceratida												
Family Dysideidae												
	Dysidea arenaria	C									X	

Marine Non-Indigenous Species throughout the Monument												
		DISTRIBUTION BY ISLAND/ATOLL										
TAXON		**STATUS**	**NIH**	**MOK**	**FFS**	**GAR**	**MAR**	**LAY**	**LIS**	**P&H**	**MID**	**KUR**
Order Haplosclerida												
Family Chalinidae												
	Cladocroce burapha	C									X	
	Haliclona sp.	C									X	
Family Callyspongiidae	*Callyspongia sp.*	C									X	
Order Hadromerida												
Order Poecilosclerida												
Family Coelosphaeridae												
	Lissodendoryx (Lissodendoryx) similis	C									X	
Family Crambeidae												
	Monanchora cf. unguiculata	A									X	
	Monanchora quadrangulata	A									X	
Family Crellidae												
	Crella (Yvesia) spinulata	C									X	
Family Hymedesmiidae												
	Phorbas burtoni	C									X	
Family Tedaniidae												
	Strongylamma wilsoni	C									X	
	Tedania (Tedania) strongylostyla	C									X	
Order Tethyida												
Family Tethyidae												
	Tethya deformis	C									X	
PHYLUM RHODOPHYTA												
Class Florideophyceae												
Order Gigartinales												
Family Cystocloniaceae												
	Hypnea sp.	C		X			X			X		

Marine Non-Indigenous Species throughout the Monument												
		DISTRIBUTION BY ISLAND/ATOLL										
TAXON		STATUS	NIH	MOK	FFS	GAR	MAR	LAY	LIS	P&H	MID	KUR
Order Ceramiales												
Family Rhodomelaceae												
	Chondria tumulosa	C								X		
Total Species		61	4	5	6	3	3	3	8	8	56	3
A = Alien Established		39										
C = Cryptogenic		21										
*AN = *Alien (not established)*		1										

Midway Atoll Project

Partial surveys to evaluate maritime heritage resources and monitor for non-indigenous species were conducted in 2017 by monument staff at Midway Atoll, primarily in the central lagoon and the western and northwestern channels (Figure S.LR.7.8). As surveys were only conducted in the portions of the

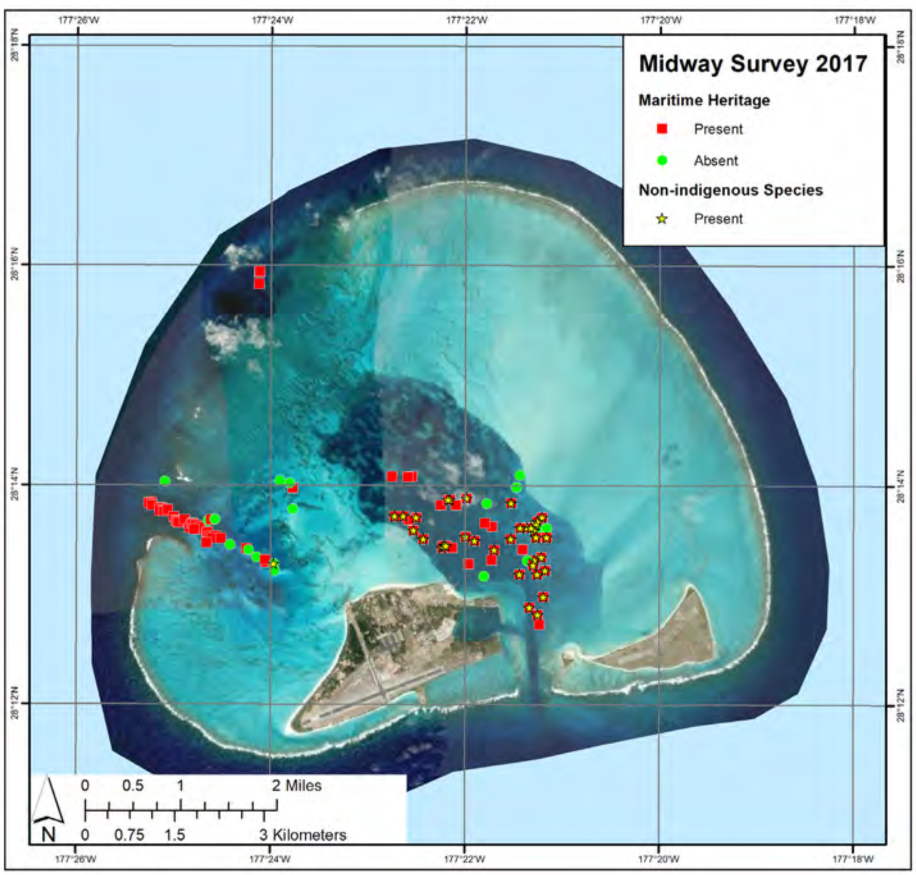


Figure S.LR.7.8. Maritime heritage resources and non-indigenous species at Midway Atoll. Red squares indicate locations of heritage sites with non-indigenous species present and green dots indicate heritage sites absent of non-indigenous species. Yellow stars indicate locations with non-indigenous species not coincident with maritime heritage sites. (Surveys were conducted in the portions of the atoll where indicated, and the figure is not comprehensive of the entire atoll.) Image: PMNM atoll where indicated, the entire distribution of maritime heritage sites and non-indigenous species are not fully described. As many as 36 of 107 suspected maritime heritage artifacts were found to harbor non-indigenous fouling species. Numerous non-indigenous species are established at Midway Atoll due to variation of habitat types and historical exposure to marine non-indigenous species vectors such as ships, which were commonly used in military activities before, during, and after World War II.

Many non-indigenous marine invertebrates that become established are "biofouling" organisms that easily adapt to artificial or manufactured substrates (e.g., wood, metal, concrete) in the marine environment. These anthropogenic substrates provide a habitat in which these organisms have a competitive edge, due in part to a lack of natural predators, over native species within the same environment (Figure S.LR.7.9).

Figure S.LR.7.9. NOAA diver Brian Hauk surveys historical material for non-indigenous species. Image: Brett Seymour/NPS

Midway Atoll is a prime example of this type of dynamic in both shoreline and submerged reef habitats. Stabilization of shorelines through seawalls and docks provided a foothold for new introductions in harbor environments, but nearshore and offshore habitats can also be influenced by anthropogenic substrates. Historically, lagoon and reef habitats at former military bases have been altered by the intentional dumping of man-made debris but also the unintentional loss of equipment during training and active hostilities. These objects of maritime history can act as substrates for the establishment of non-indigenous species, as well as stepping stones within and across habitats that would otherwise be difficult to invade for these biofouling species.

Finally, the historically and archaeologically documented ages of aircraft and shipwrecks now colonized by invasive species allow for a solid, scientifically documented maximal time point for the invasion by colonizing species. As such, cultural resources provide key temporal insights into potential mechanisms of ecosystem change by species invasion. Paradoxically, the same military infrastructure that fended off a cultural and military invasion of the U.S. in 1942 facilitated a different, more successful biological invasion that affects the island chain today.

Pearl and Hermes Atoll

In August 2019, a nuisance red algae species *Chondria tumulosa* was discovered in large mats overgrowing corals and native algae at Pearl and Hermes Atoll from 5 to at least 70 ft depth and covering large expanses (Figure S.LR.7.10). Rapid surveys documented the algae primarily on the northern, southeastern, and southwestern forereef environments (Figure S.LR.7.11). This alga has been observed at Pearl and Hermes Atoll as far back as 2014, when it was growing on the northern backreef in cryptic assemblages with other algae species. Genetic analysis and morphological taxonomy has determined a 98% match to the genus *Chondria*. Further taxonomic research resulted in the first scientific description and naming of this species of algae (Sherwood, Huisman, et al., 2020). It is still unknown if this is an introduced or native species. Microscopic analyses indicate that samples are either clonal or in the tetrasporophyte phase of the red alga's life cycle and have produced tetraspore propagules. This is particularly concerning, as tetraspores may disperse over a larger range than fragments.

This alga fragments readily, producing 2–4 cm long cylindrical to flattened fragments with spinous branches that easily snag on dive gear and equipment. While the alga was obvious when in high abundance and mat-forming, it was difficult to distinguish from the native community and less visible to divers when in low abundance. Because species-level identification is difficult, and surveys were limited, trends for this species are not known at this time.

Figure S.LR.7.10. Research diver Heather Spalding surveys reefs smothered in *Chondria tumulosa*. Image: Taylor Williams/NOAA

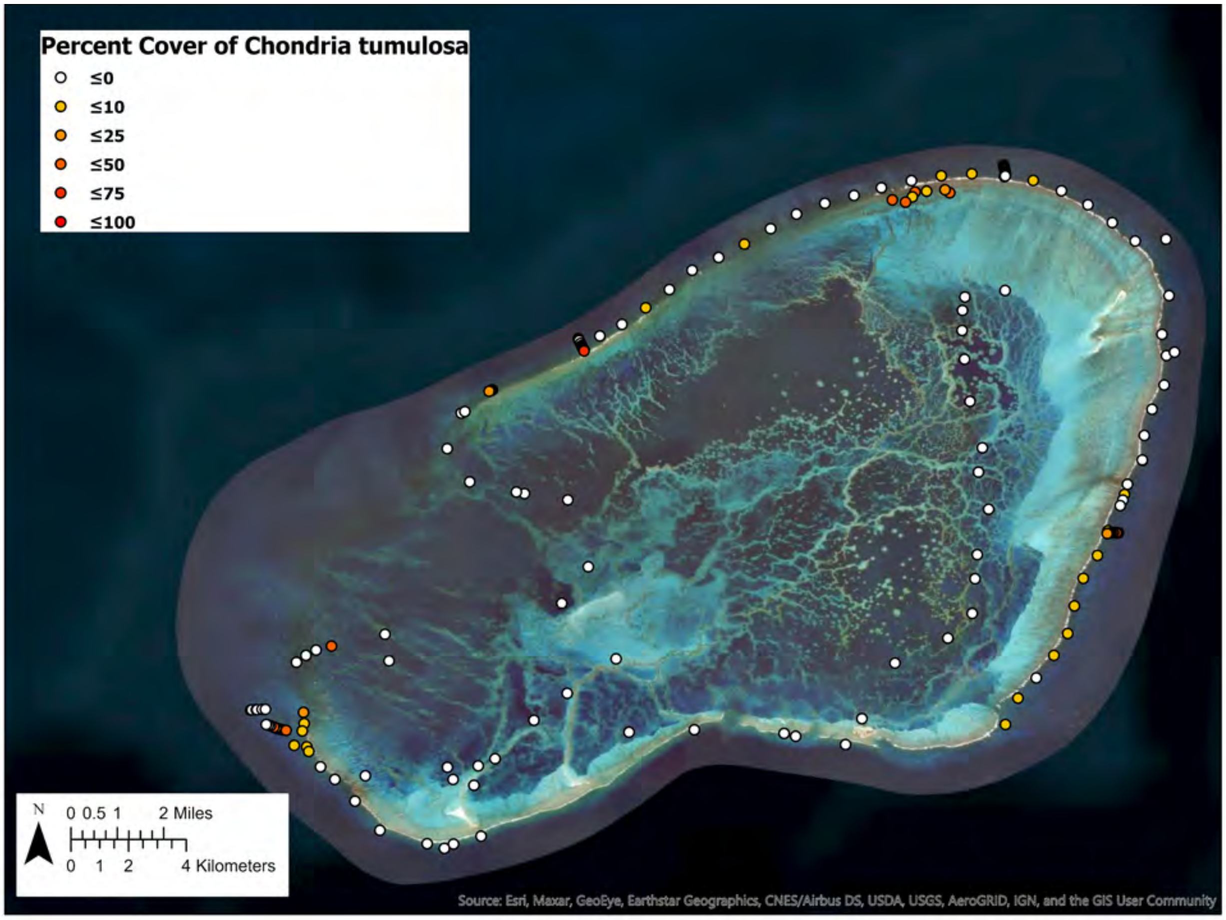


Figure S.LR.7.11. Observations of invasive red alga *Chondria tumulosa* at Pearl and Hermes Atoll at both shallow and mesophotic depths in 2019. Image: PMNM

Trends

The trend is assessed as Not Changing with limited evidence based on the limited data on non-indigenous and cryptogenic species and a lack of understanding of the biogeographical origins of many marine species, including *Chondria tumulosa*. The increase in numbers of non-indigenous marine invertebrate species in 2019 likely does not represent new introductions, but is probably a factor of expanded sampling effort since 2010.

Management Implications

Established management practices to minimize the likelihood of the transport of marine non-indigenous species continue to be relevant in protecting the integrity of marine habitats in the monument. Prevention of introductions should be prioritized. Best management practices should be continued to provide guidance to prevent the spread of non-indigenous species and disease across terrestrial and marine environments in the monument. Continued characterization and monitoring also are necessary to evaluate non-indigenous marine species in the monument.

Given the potential of the invasive alga at Pearl and Hermes Atoll to be transported unintentionally by researchers and their gear, scientists initiated a series of experiments using commercial-grade bleach (8.25% of sodium hypochlorite) to determine what percentage of bleach, active chlorine, and duration of exposure were needed to kill algal fragments of this species. Basic decontamination assays have been performed to address decontamination opportunities with this invasive alga. The Monument Management Board formed an interagency working group to address resource protection and research needs related to the invasive alga at Pearl and Hermes Atoll, and to advise the board on recommended actions and policies. Best management practices have been developed and implemented to prevent the spread of this alga within and outside of Pearl and Hermes Atoll.

Continued meetings of the aquatic invasive species working group are recommended in order to maintain information flow and develop capacity among co-managers. Biosecurity strategies related to marine debris as vectors for non-indigenous species should align with NOAA's Hawai'i Marine Debris Action Plan (NOAA Marine Debris Program, 2018).

Acknowledgements
Brian Hauk, Scott Godwin, Dr. Heather Spalding, and Holly Bolick contributed to this assessment.

8. What is the status of key species and how is it changing?

Hawaiian Monk Seal

Fair/Poor ▲

Status
The status of Hawaiian monk seals in Papahānaumokuākea is considered Fair/Poor with robust evidence, because its population is still far below historical abundance levels, juvenile survival has been chronically or sporadically low at several locations, and threats, both human-caused (entanglement in marine debris, entrapment in the Tern Island seawall) and natural (shark predation, male seal aggression) limit recovery potential. Additionally, large-scale perturbations (e.g., sea level rise, novel infectious diseases, climate change, and environmental variability) present either potential or near certain long-term threats to NWHI Hawaiian monk seals. Recovery is possible but not certain.

Yuri Lisiansky (also spelled Lisianski), a Russian explorer, provided the first written account of the Hawaiian monk seal in 1805. Population abundance was described at that time as "numerous" and "considerable" (Lisiansky, 1814; Hiruki & Ragen, 1992). However, over the next 80 years, hundreds to thousands of seals were killed for their oil, skin, and meat. By the early 1900s, few seals remained and commercial hunting ceased; it was assumed that the species was extinct. However, a handful of seals survived, and by the 20th century, 916 seals over the age of one were counted in the first systematic beach surveys of all six Hawaiian monk seal subpopulations from Kure Atoll to French Frigate Shoals (Kenyon & Rice, 1959). The sum of current counts at the same sites have fallen by about two-thirds compared to that historic benchmark. The NWHI monk seal population apparently reached a low point around 2013 and has been slowly growing since. The total NWHI population size as of 2017 was estimated at approximately 1,100 individuals. Total range-wide abundance in 2017, including seals in the MHI, was approximately 1,350.

Figure S.LR.8.1. A mother Hawaiian monk seal and her pup rest on the beach of French Frigate Shoals. Image: Mark Sullivan/NOAA

The Hawaiian monk seal was listed as endangered throughout its range in 1976. NMFS designated critical habitat for the Hawaiian monk seal in 1988. In 2015, critical habitat was revised to include a portion of NWHI lands and marine habitat through the water's edge, including the seafloor, all subsurface waters, and marine habitat within 10 m of the seafloor, out to the 200-m depth contour line around the following 10 areas: Kure Atoll, Midway Atoll, Pearl and Hermes Atoll, Lisianski Island, Laysan Island, Maro Reef, Gardner Pinnacles, French Frigate Shoals, Mokumanamana Island, and Nihoa Island.

Trends

The expert-rated trend is Improving with robust evidence. As noted above, total abundance of Hawaiian monk seals in the NWHI underwent several decades of decline, but has been slowly growing since 2013 (Figure S.LR.8.2; Baker et al., 2016). Improvements in juvenile survival in several of the NWHI subpopulations account for the improved population trend.

Monk seals occur in eight subpopulations within the NWHI from Kure Atoll to Nihoa Island, with approximately 70 to 250 seals residing in each (Table S.LR.8.1). Approximately 300 monk seals reside in the MHI. Some seals have been documented moving between the NWHI and MHI.

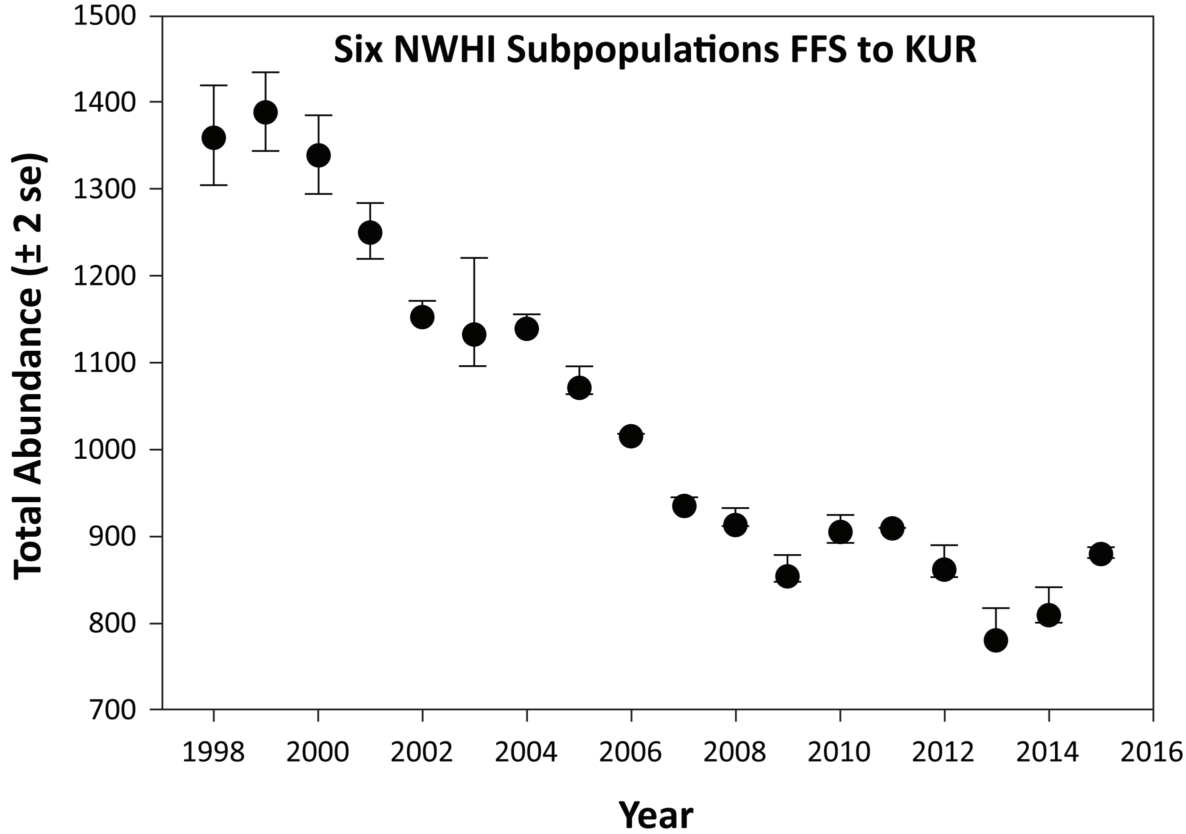


Figure S.LR.8.2. Hawaiian monk seal abundance in the NWHI subpopulations from 1998 to 2016. Source: PIFSC

Although there is a small degree of inter-island migration, each subpopulation is semi-isolated and experiences unique ecological pressures and conditions that affect monk seal survival. Survival rates among islands are variable, though the overall body condition of seals across the NWHI suggests that they have been affected by limited foraging success and food availability. Direct competition for prey resources among Hawaiian monk seals and other top-level predators, such as abundant sharks and jacks, likely impacts monk seal foraging success. Relatively poor physical condition of some seals residing in the NWHI likely limits their ability to fight parasitic infections and recover from injury (often caused by shark bites or male aggression). Additionally, seals may become injured and die from entanglement in the large amount of marine debris that is washed ashore or ensnared on the reefs in the NWHI.

There are a number of habitat-related threats to monk seals in the NWHI. Loss of terrestrial habitat at French Frigate Shoals is a serious threat to the viability of the resident monk seal population. Prior to 2018, several important pupping and resting islets had shrunk (Trig Island) or disappeared (Whale Skate Island) (Antonelis et al., 2006). In 2018, the two remaining primary islands where pups were born at French Frigate Shoals (Trig and East Islands) were obliterated due to progressive erosion and Hurricane Walaka (in September 2018).

Table S.LR.8.1. Summary of Hawaiian monk seal abundance estimates throughout their range in 2017. Source: Carretta et al., 2020

	Total		
Location	**Non-pups**	**Pups**	**Total**
French Frigate Shoals	173	42	215
Laysan Island	197	28	225
Lisianski Island	133	19	152
Pearl and Hermes Atoll	117	24	141
Midway Atoll	69	12	81
Kure Atoll	90	23	113
Mokumanamana Island*	63	7	70
Nihoa Island	65	6	71
MHI (excluding Niʻihau/ Lehua)	133	20	153
Niʻihau/Lehua	101	14	115
Range-wide	1244	195	1351

*No surveys were conducted at Mokumanamana Island in 2017, so the values estimated in 2016 were used.

Hawaiian monk seals are rare, have low genetic diversity, and may not have been exposed to many mammalian diseases due to their isolation in the Hawaiian Archipelago for millions of years. Consequently, outbreaks of diseases to which monk seals have not been previously exposed could have devastating impacts. Exposure to other species that can carry infectious agents like morbilliviruses and West Nile virus are of particular concern. At least three immature elephant seals have stranded on Midway Atoll, Hawaiʻi Island, and Maui and Molokai in 1978, 2002, and 2005–2006, respectively, and a northern fur seal stranded on Oʻahu in 2012. Strandings of these species clearly demonstrate that disease risks are real and that preparedness is crucial.

Management Implications

Continuing to monitor the Hawaiian monk seal population to understand demographic trends and threats is critical. Limited funding periodically jeopardizes the ability of NMFS to monitor Hawaiian monk seals and intervene when necessary and is causing uncertainty in evaluating population status and trends. Incomplete surveillance introduces uncertainty about trends in demographic parameters such as abundance, survival, and reproductive rate. Furthermore, when field seasons are shorter, researchers simply have fewer opportunities to detect and mitigate threats to seals' survival. In 2017 (when field seasons were several months in duration), researchers intervened on 71 occasions to improve the survival of individual seals in the NWHI. In contrast, in 2012 and 2013, when field seasons were particularly short, only 21 and 33 interventions occurred, respectively. More seals could have been saved if those field seasons had been longer.

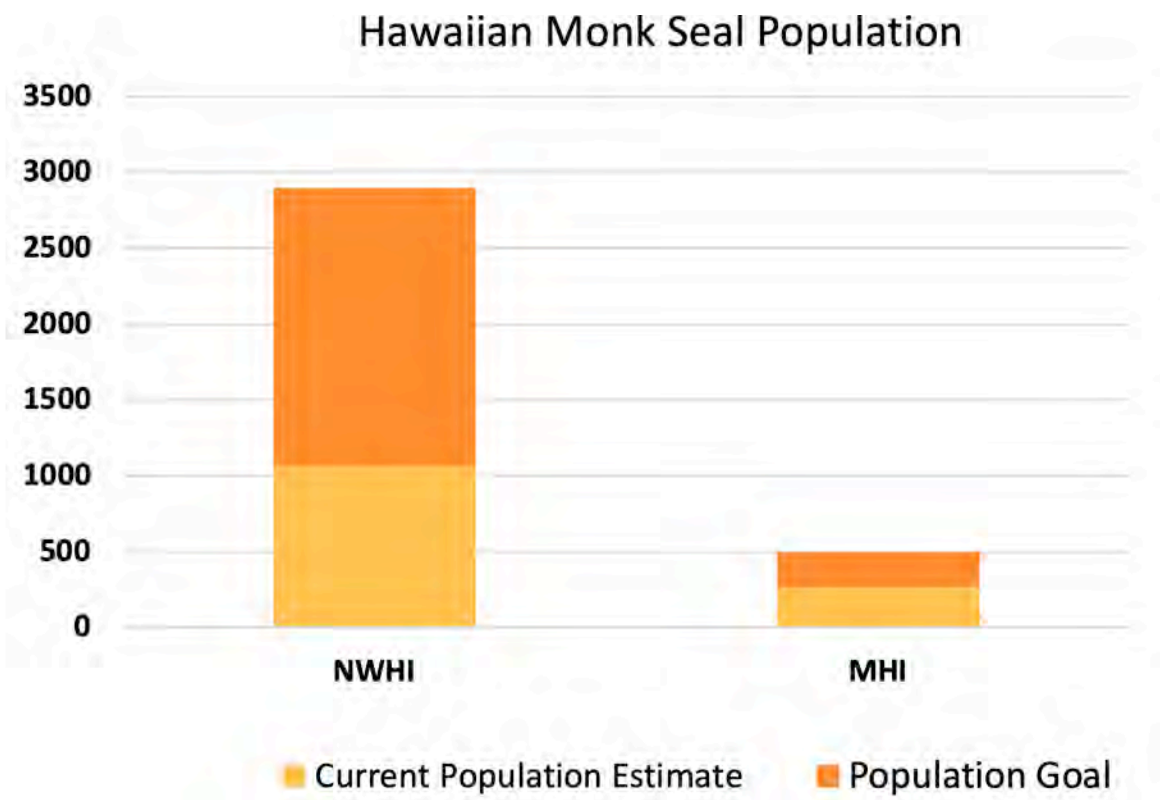


Figure S.LR.8.3. Hawaiian monk seal populations in the NWHI and the MHI as of 2017 and the eventual population goal. Source: NMFS

Additionally, the loss of Whale Skate, East and Trig Islets at French Frigate shoals portend future management challenges associated with sea level rise throughout the NWHI, which threatens not only Hawaiian monk seals but all species that rely on terrestrial habitats. Projected increases in global average sea level are expected to further reduce terrestrial habitat for monk seals at all the low-lying NWHI (Baker et al., 2006; Reynolds, Berkowitz, et al., 2012). The resilience of other island habitats needs to be evaluated. Tern Island has become more important for monk seals than it had been previously. Hazards, including contaminant release and entrapment in eroding riprap and sediment-retaining structures, remain a threat, and remediation and restoration will have to be considered well into the future. Vessel groundings pose a continuing threat to monk seals and their habitat through potential physical damage to reefs, oil spills, and release of debris into habitats.

While populations have increased from 2013–2017 by as much as 2% per year, the road ahead to meet the population goal as specified in the Recovery Plan (NMFS 2007) for this species will require continued intervention support for Hawaiian monk seals (Figure S.LR.8.3).

NMFS is currently working under a Marine Mammal Protection Act and Endangered Species Act permit that authorizes research and enhancement activities directed toward recovering Hawaiian monk seals across their range. These activities are currently underway and should be supported by monument managers and partners as appropriate. With limited funds supporting NMFS, other partners may need to play a more proactive role in Hawaiian monk seal recovery efforts.

Acknowledgements
Dr. Charles Littnan, Dr. Michelle Barbieri, Thea Johanos, and Jason Baker contributed to this assessment.

Sea Turtles

Good/Fair

Status

The status of green turtles in the monument is considered Good/Fair with medium evidence due to increasing numbers of female nesters.

Green turtles in the Hawaiian Archipelago are considered as part of a distinct population called the Central North Pacific Distinct Population Segment (also commonly referred to as "Hawaiian green turtles"). In 1974, the State of Hawaiʻi placed a commercial ban on turtle harvest and enacted enforcement. This regulation took place four years before the green turtle was listed under the U. S. Endangered Species Act in 1978. As stated in the most recent status review for green turtles by the USFWS and NOAA (Seminoff et al., 2015, p. 334), "the Hawaiian Archipelago is the most geographically isolated island group on the planet and, therefore, it is perhaps unsurprising that green turtles in this [distinct population segment] are geographically discrete in their range and movements, as evidenced by mark-recapture studies using flipper tags, [passive integrated transponder] tags, satellite-linked transmitter tracking, and genetic analyses." Over 18,000 green turtles (all size classes) have been tagged since 1965 and 99.96% of those that were later recaptured were within the Hawaiian Archipelago. Data from turtles tagged across the archipelago reveal that reproductive females and males migrate to French Frigate Shoals from the MHI (Figure S.LR.8.4). Identification tags (e.g., implanted microchips [passive integrated

Figure S.LR.8.4. Green turtles (*Chelonia mydas*) rest on the shores of French Frigate Shoals. Image: Koa Matsuoka/NOAA transponders] and metal flipper tags) have revealed the seasonal breeding migration of over 200 turtles from MHI foraging grounds to French Frigate Shoals (Seminoff et al., 2015). Females typically nest every 2–6 years and dig 3–6 nests per season. Current estimates suggest 96% of the nesting activity for Hawaiian green turtles takes place on the French Frigate Shoals islands of East, Tern, Trig, Gin, and Little Gin.

Trends

The expert-rated trend for sea turtles is Improving with medium evidence. There has been a documented increase in the number of nesting green turtles on East Island, French Frigate Shoals (Table S.LR.8.2 and Figure S.LR.8.5) since surveys began in the early 1970s (Balazs & Chaloupka, 2004, 2006). The nesting population increased by 4.8% annually between 1973 and 2013 (Seminoff et al., 2015). Until 2017, the population was recovering, but not fully recovered. In 2018, Hurricane Walaka traversed French Frigate Shoals and caused significant erosion to East Island, which has historically been the most significant green turtle nesting location in the Hawaiian Archipelago. It is unknown how the loss of nesting habitat will affect the abundance of Hawaiian green turtles. However, the 2019 nesting season revealed increased numbers of nesting at Tern Island at French Frigate Shoals with as many as 263 nesting females, which suggests that Tern Island may become a more important nesting site for the green turtle into the future. An analysis of trends in nesting at Tern Island will be included in future reports.

Table S.LR.8.2. Nesting trends of Hawaiian green turtles at East Island, French Frigate Shoals, from 1973–2019. Source: PIFSC

Year	Observed Hawaiian Green Turtle Nests	Year	Observed Hawaiian Green Turtle Nests	Year	Observed Hawaiian Green Turtle Nests
1973	67	1989	294	2005	344
1974	105	1990	150	2006	423
1975	120	1991	107	2007	348
1976	39	1992	384	2008	589
1977	82	1993	191	2009	295
1978	101	1994	132	2010	278
1979	77	1995	252	2011	843
1980	52	1996	367	2012	439
1981	149	1997	504	2013	No Data
1982	130	1998	64	2014	889
1983	35	1999	209	2015	587
1984	199	2000	353	2016	88
1985	162	2001	314	2017	412
1986	69	2002	467	2018	113
1987	143	2003	201	2019	106
1988	180	2004	548		

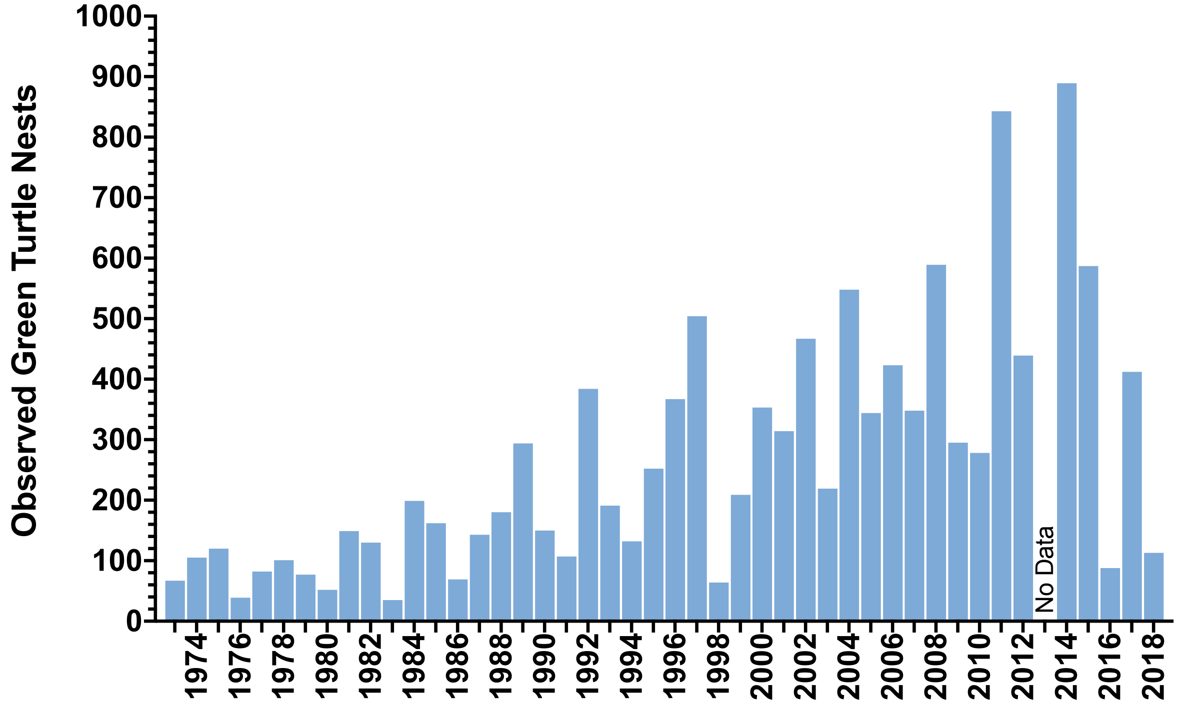


Figure S.LR.8.5. Nesting trends of Hawaiian green turtles at East Island, French Frigate Shoals from 1973–2018. Source: PIFSC

Data from non-systematic, opportunistic surveys by PIFSC staff indicate low-level nesting at Pearl and Hermes Atoll, Lisianski Island, and Laysan Island, with no apparent trend. Nesting activity from French Frigate Shoals is used as a proxy for the monument.

Management Implications

The islands of French Frigate Shoals, mainly East and Tern, are vulnerable to sea level rise from climate change (Baker et al., 2006; Reynolds, Berkowitz, et al., 2012), yet they remain the only observed major nesting area for green turtles within the Central North Pacific. High-resolution digital elevation data and models are necessary to describe observed sea level rise and its modeled future potential impact at French Frigate Shoals and other nesting sites. Models, including climate forecasts, are needed to understand the impacts of rising temperatures (e.g., sand temperatures) on hatchling sex ratios and hatching success. Specific interagency efforts are needed to monitor nesting throughout the monument, not just at East Island. This is important to establish the risk to the population of potential catastrophic habitat loss at one location. More immediately, it is important to understand the impact of the significant loss of breeding habitat from the destruction of East Island by Hurricane Walaka in 2018. Monitoring of disease outbreaks, such as the fibropapillomatosis epizootic of the 1980s and 1990s, is also necessary, as this threat may represent a cofactor impairing recovery of the species.

The hawksbill turtle is listed as endangered throughout its range. The Endangered Species Act recognizes one global population; however, some have suggested that Hawaiian hawksbill turtles could be considered a distinct population (Bowen & Karl, 2007; Wallace et al., 2010). While hawksbill turtles are not common in the monument, there have been reports of juvenile hawksbill turtles at Laysan Island, Midway Atoll, and Pearl and Hermes Atoll (Van Houtan et al., 2012). The lack of observations suggests that hawksbill turtles are likely to be non-resident visitors to the monument.

Acknowledgements

Dr. T. Todd Jones and Dr. Summer Martin contributed to this assessment.

Reef Fish

Good

Status

The expert rated status for reef fish is Good with medium evidence due primarily to the fact that reef fish assemblages in the monument appear to be in a near-pristine state. The clearest evidence for this is the continuing high abundance and biomass of reef fishes across the majority of family and trophic groups compared to the human-populated lower eight Hawaiian Islands (Figure S.LR.8.6); this trend has been assessed in numerous studies (Williams et al., 2011; Nadon et al., 2012; McCoy et al., 2016; Asher et al., 2017). The monument has been found to have significantly higher abundance and biomass of apex predator fish (Friedlander & DeMartini, 2002; Nadon et al., 2012; McCoy et al., 2016; Asher et al., 2017).

Fish assemblages associated with mesophotic coral ecosystems (30–100+ m) also appear to be in pristine condition, as evidenced by higher overall fish densities than on shallow reefs (Fukunaga et al., 2016). Additionally, mesophotic assemblages are characterized by the low relative abundance of invasive or introduced fish species such as ta‘ape and roi, both of which are abundant in the MHI and on shallow

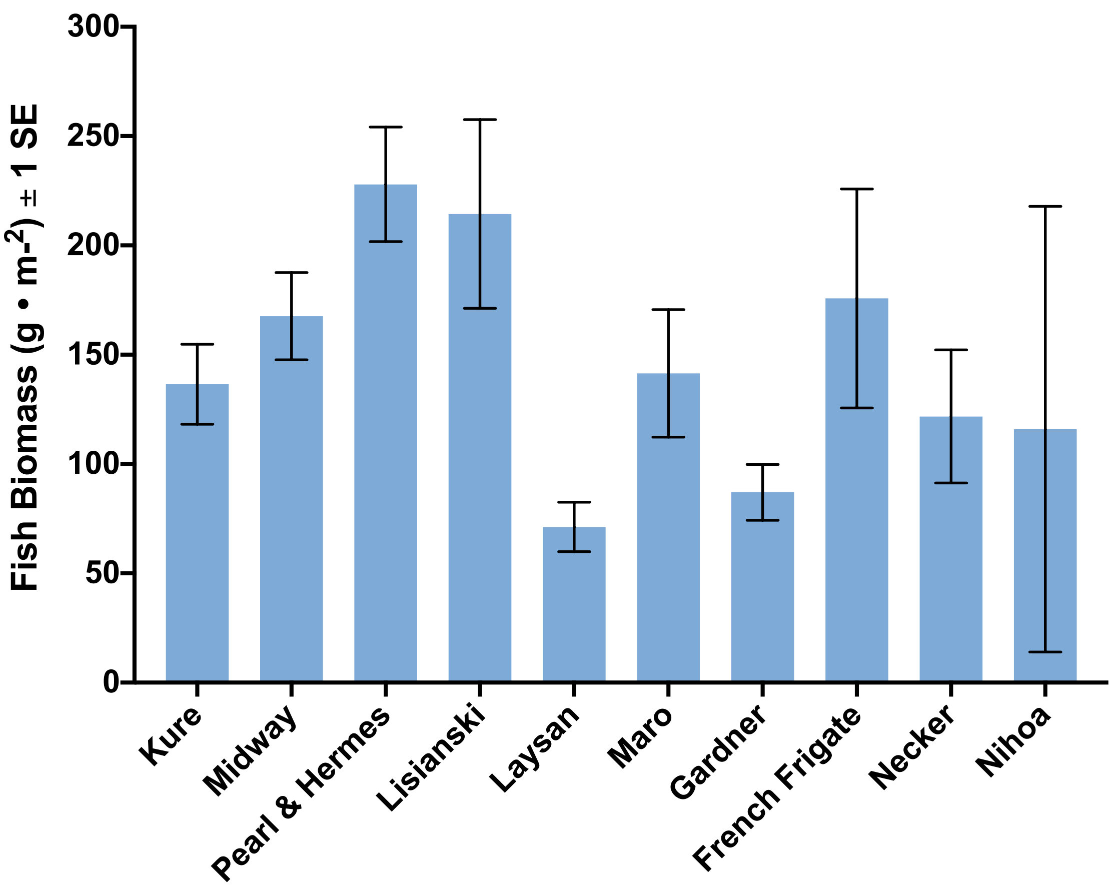


Figure S.LR.8.6. Mean fish biomass in g·m-2 (± 1 standard error) for shallow water (0-30 m) depths surveyed at islands in the Hawaiian Archipelago. Data are compiled from 2007–2018. Source: PMNM and PIFSC reefs in PMNM (Fukunaga, Kosaki, & Hauk, 2017). Very high proportions of endemic species have been observed in PMNM's mesophotic coral ecosystems, with the proportion of endemism increasing with latitude (Kane et al., 2014; Fukunaga, Kosaki, & Wagner, 2017) and peaking at nearly 100% endemism on deep reefs at Kure Atoll (Kosaki et al., 2017). This extraordinarily high level of endemism makes the deep coral reefs of PMNM a biodiversity hotspot of global significance. Ongoing exploration of this habitat continues to yield discoveries of new endemic reef fish species (Pyle & Kosaki, 2016; Pyle et al., 2016).

Roving apex predatory fishes tend to have higher abundance in mesophotic (30–100 m) depths compared to shallow (0–30 m) depths, with the exception of *Carangoides orthogrammus*, *Caranx ignobilis* and *Caranx melampygus* (Asher et al., 2017). Additionally, mean size was found to be higher for *Carcharhinus galapagensis* and *Caranx ignobilis* in mesophotic depths than shallow depths (Asher et al., 2017).

Biomass of herbivorous reef fishes is also higher in the monument than in the MHI, and the difference is particularly pronounced for large-bodied parrotfishes (McCoy et al., 2016). Biomass of planktivorous reef fishes also tends to be higher in the monument, although this is likely not an effect of fishing in the MHI, as that difference is also evident for non-targeted taxa, including planktivorous damselfishes and butterflyfishes (Williams et al., 2011). Instead, this may be related to the natural effect of oceanic productivity bolstering coral reef fish assemblages. Williams et al. (2015) demonstrate that islands in areas of higher oceanic productivity, such as those within the monument, have increased total fish biomass but in particular greater piscivore and planktivore biomass.

Trends

The trend is assessed as Not Changing with medium evidence, primarily because long-term coral reef survey data give no indication of a consistent upward or downward trend (McCoy et al., 2016). Changes in habitat quality and oceanic conditions may have substantial impacts on monument reef fish

Figure S.LR.8.7. A mix of reef fish including kikakapu or milletseed butterflyfish (*Chaetodon miliaris*), pennant butterflyfish (*Heniochus diphreutes*), and ta'ape at French Frigate Shoals. Image: James Watt/NOAA assemblages and the habitats they depend on, although these changes are not clearly manifesting among reef fish assemblages at this time. No statistically significant changes in mesophotic fish community structure have been noted over time (Fukunaga et al., 2016).

Management Implications

As noted above, the current condition of reef fish assemblages is good, but likely vulnerable to impacts of global climate change.

Also worth noting is that, in spite of recent increases in sampling effort and improved interagency cooperation and coordination, the enormous size of PMNM, with such a diversity of habitats, presents significant challenges for coral reef monitoring programs. Such efforts are highly dependent on continuing availability of large vessels capable of sustaining scientific operations in rough seas and over medium to long time periods and large distances.

The reliance on visual survey data gathered by divers allows for meaningful comparison with data gathered elsewhere in the archipelago and more widely. But this reliance also means that the information is biased toward shallow-water and diurnally active reef fish species. Therefore, some potentially important components may not be well sampled (Dale et al., 2011; Asher et al., 2017). Mesophotic fish populations in particular need to be surveyed over time in order to assess trends at these depths.

Acknowledgements

Dr. Ivor Williams contributed to this assessment.

Shallow-Water Corals

Fair ▼

Status

Coral reefs have been monitored with varying methodologies and frequencies in the monument since 2000. This has made the interpretation of change over time challenging for different scales and indicator variables. In addition, the large geographical range of the monument's 3.5 million acres of coral reefs, which span approximately 17 degrees of longitude and 5 degrees of latitude, contains distinct coral reef seascapes with differing ecosystems (fringing, barrier, patch, and atoll reefs) with varying environmental dynamics. In addition to the overall condition rating of Fair with medium evidence, the condition of corals is assessed for each reef system individually in this report. Reef conditions within individual reef systems are compared to similar reef systems and are discussed below and summarized in Table S.LR.8.3.

In the 2009 Papahānaumokuākea condition report, corals were assessed as in Good condition with a Stable trend (ONMS, 2009). In the present report, the rating is Fair with medium evidence due to several disturbance events that contributed to changes in coral reef conditions. Coral bleaching events occurred in the monument in 2009, 2010, 2014, and 2019. Unlike earlier bleaching events in 2002 and 2004, which were primarily restricted to backreefs of the northernmost atolls, the 2014 event was widespread and severe, with the greatest impact documented at Lisianski Island, which experienced 19 consecutive weeks of heat stress and water temperatures reaching over 24°C (85°F) at a depth of 200 ft. Across the 2002, 2004, and 2014 bleaching events, bleaching prevalence varied from <5% to >75% across French Frigate Shoals, Lisianski Island, Pearl and Hermes Atoll, and Midway Atoll (Couch et al., 2017). Also unlike previous events, the 2014 event affected both highly sensitive species and those that had historically resisted bleaching. Another mass coral bleaching event occurred in the summer and late fall of 2019, with bleaching documented and quantified at Kure Atoll, Pearl and Hermes Atoll, Lisianski Island, and French Frigate Shoals by PIFSC. There were also unquantified reports of coral bleaching within the lagoon at Midway Atoll. In addition, Hurricane Walaka caused significant damage in late 2018 to an important segment of reef (Rapture Reef) at French Frigate Shoals and an invasive algal outbreak was observed at Pearl and Hermes Atoll. The two latter events are discussed in more detail below. Individual island reef systems are rated below.

Table S.LR.8.3. Condition and trend summary for each reef unit in the monument.

Reef	Status	Trend	Evidence Score
Kure Atoll	Fair/Poor	Not changing	Medium
Midway Atoll	Fair/Poor	Not changing	Medium
Pearl & Hermes Atoll	Fair/Poor	Declining	Medium
Lisianski Island	Fair	Declining	Medium
Laysan Island	Good/Fair	Not changing	Medium
Maro Reef	Good/Fair	Not changing	Medium
Gardner Pinnacles	Undetermined	Undetermined	Low
French Frigate Shoals	Good/Fair	Declining	Medium
Mokumanamana Island	Undetermined	Undetermined	Low
Nihoa Island	Undetermined	Undetermined	Low

Kure Atoll

Coral reefs at Kure Atoll are considered to be in Fair/Poor condition. As a result of Kure's close proximity to the Darwin point (the highest latitudes at which net coral growth can keep pace with sea level) in combination with harsh winter conditions, Kure's reefs naturally have low coral cover (<5% cover) and low colony density. But in recent years, repeated bleaching and heat stress events have resulted in high mortality on the backreefs, which have shown minimal recovery.

Midway Atoll

The condition of coral reefs at Midway Atoll is challenging to assess and is considered Undetermined. Activities during World War II severely damaged the reefs, and harsh winter conditions, including cooler, high-latitude waters and wave action, hinder regrowth. As a result, coral colony density is extremely low across the forereef and consists of small, encrusting colonies. While much of the backreef also has low coral cover, several areas of the northern backreef have up to 20–30% cover of *Montipora* spp. These corals bleached less in 2014 than in 2002 despite higher thermal stress in 2014, suggesting that there may be some level of acclimation occurring on these reefs. However, an analysis of partial mortality from 2014–2015 found that among all island reefs, Midway had significantly more cumulative partial mortality with a 48.6% loss of live coral cover (Pascoe, 2019).

Pearl and Hermes Atoll

Coral reefs at Pearl and Hermes Atoll are considered to be in Fair/Poor condition. Coral cover is typically low at Pearl and Hermes Atoll due to its high latitude and harsh winter conditions. As of 2016, coral cover was lower compared to historical values across many of the reefs at Pearl and Hermes Atoll, likely as a result of bleaching impacts. Bleaching events in 2002 and 2004 caused mortality across portions of the backreef. In 2014, coral bleaching resulted in mortality in *Montipora* spp., especially *Montipora flabellata/turgescens*, which was no longer found at any of the permanently monitored sites in 2015. Bleaching was reported in September 2019 across portions of the southern central and southwestern forereef, with less bleaching observed at the northern forereef. Bleaching affected primarily *Pocillopora* and *Montipora* species, with more bleaching in shallower depths. In August 2019, extensive spread of invasive algal mats of an unknown species was detected at Pearl and Hermes Atoll at northern, southeastern, and southwestern portions of the forereef of the atoll. The alga was subsequently identified to be an undescribed red algae species in the genus *Chondria*. Massive algal mats were observed mostly in 20–30 ft depths but may also occur at depths up to 70 ft. No live coral was found underneath the algal mats, and it is presumed that coral mortality occurred in locations colonized by these algal mats.

Lisianski Island

Coral reefs at Lisianski Island are considered to be in Fair condition. The reef condition is highly variable across Lisianski Island, with corals in shallow depths on the east side of the island in Poor condition, corals in northern areas in Fair condition, and corals farther from the island on the Neva Shoals platform surrounding the island in Good condition. The middle and southern extent of Lisianski Island is characterized by moderate coral cover (20–40%), consisting of large *Porites* spp. colonies. Shallow reefs at less than 20 ft depth have extremely low coral cover (<1%). The 2014 bleaching event resulted in widespread and severe bleaching across Lisianski reefs and across taxa. This resulted in coral mortality and significantly lower coral cover at Lisianski Island, including a 68% loss in coral cover across permanent sites, as well as changes in habitat complexity and volume due to coral mortality (Couch et al., 2017). The most severe mortality occurred along the eastern coast of the island following the complete mortality of the dominant reef builder *Montipora dilatata*. Bleaching across Lisianski Island was low to moderate during the September 2019 coral bleaching event, affecting primarily pocilloporid and montiporid corals.

Laysan Island

Coral reefs at Laysan Island are considered in Good/Fair condition. Unlike most of the other islands, Laysan Island's reefs consist primarily of pavement habitats. Laysan Island's reefs are considered to be in good condition relative to other islands with similar habitats. Although coral cover and colony density are relatively low compared to islands consisting of aggregate reef habitat, monitoring has suggested that coral reefs at this island have remained relatively stable. The oceanic and physical habitat at Laysan Island is not conducive to the formation of expansive coral reefs and thus the current low abundance of coral probably reflects natural habitat suitability for coral reef development. Regardless, the corals at Laysan Island were found to have the lowest partial mortality across the entire monument (Pascoe, 2019).

Maro Reef

Corals at Maro Reef are considered to be in Good/Fair condition. Despite reports of bleaching in 2002, 2004, and 2009, long-term monitoring indicates this reef system has remained relatively stable. As of 2015, Maro Reef exhibited moderate coral cover (~21%), suggesting corals there were not as severely affected by the 2014 bleaching event as those at the neighbouring Lisianski Island/Neva Shoals. The reticulated reef at Maro is heavily dominated by colonies of *Porites* and *Montipora* spp.

French Frigate Shoals

Coral reefs at French Frigate Shoals are considered to be in Fair/Poor condition. Prior to 2018, portions of the northern and southern forereefs were dominated by *Acropora cytherea*, and much of the protected reef slope had moderate coral cover. However, Hurricane Walaka caused extensive mortality, converting the acroporid stands on the southern reef slope to a rubble field. The protected reef slope across the middle section of French Frigate Shoals fared better, however the full extent of damage is unknown as comprehensive post-hurricane surveys have not been conducted. In July and September 2019, moderate coral bleaching was observed across the shallow backreef areas and within the lagoon by ONMS and PIFSC.

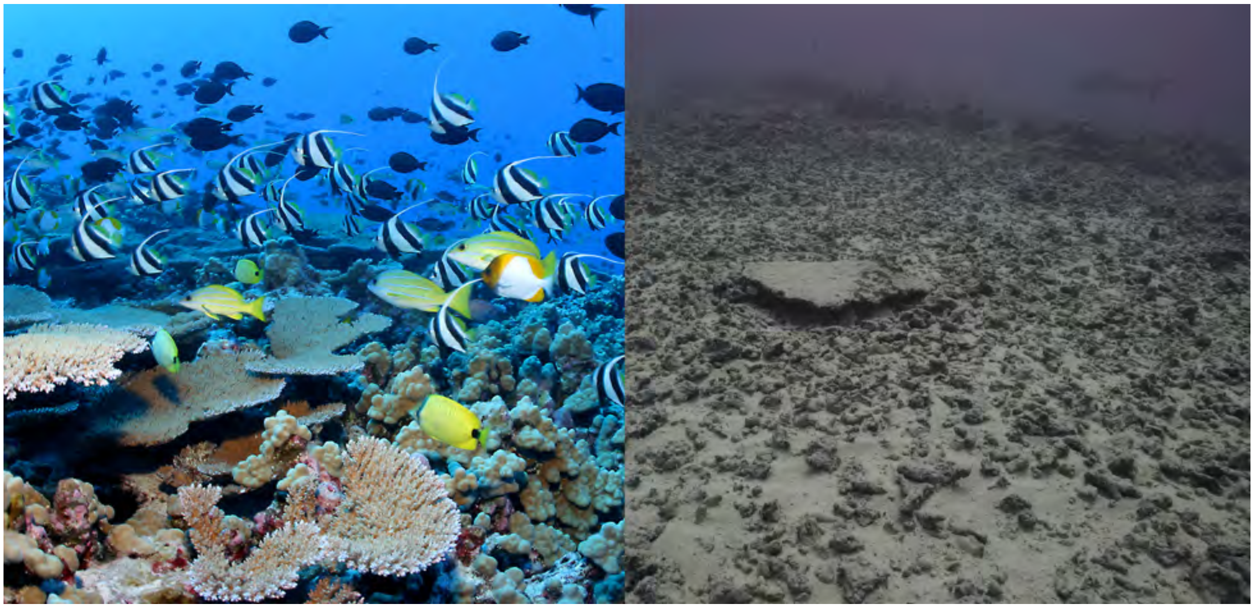


Figure S.LR.8.8. Left: Fish school at French Frigate Shoals prior to Hurricane Walaka. Right: Divers observed devastating damage to coral reef sites at French Frigate Shoals. Images: (left) James Watt/NOAA; (right) Kailey Pascoe/NOAA

Gardner Pinnacles, Mokumanamana Island, & Nihoa Island

Coral reef surveys at Gardner Pinnacles, Mokumanamana Island, and Nihoa Island have been extremely limited. Thus, the conditions of coral reefs at these islands are unknown.

Trends

The overall trend rating for shallow-water coral reefs is Declining with limited evidence, based on decreasing coral cover post 2011–2012 and coral mortality from bleaching events and the invasive alga *Chondria tumulosa* at Pearl and Hermes Atoll. Coral percent cover data collected by the PIFSC and ONMS as part of RAMP are presented in Figure S.LR.8.9. The following trends were assessed using changes in coral cover as well as data presented above in the condition section.

Kure Atoll

Coral reefs at Kure Atoll are not changing as indicated by monitoring data from 2012, 2015, 2016, and 2017.

Midway Atoll

Monitoring data from 2012, 2015, and 2017 indicate that coral reefs at Midway Atoll are not changing. Additionally, there is some evidence that the backreef at Midway may be showing signs of increased growth among montiporids.

Pearl and Hermes Atoll

Coral reefs at Pearl and Hermes Atoll are considered to be declining due to coral mortality and decreases in coral cover resulting from the invasive algal outbreak, which was detected in 2019, and monitoring data from 2012, 2014, 2016, and 2017.

Lisianski Island

Based on coral declines in 2014 from bleaching-induced mortality and monitoring data from 2012, 2015, 2016, and 2017 indicating a moderate decline in coral cover, coral reefs at Lisianski are assessed as declining.

Laysan Island

Monitoring data from 2012, 2015, and 2017 indicate that coral reefs at Laysan are not changing.

Maro Reef

Monitoring data from 2012 and 2015 indicate that coral reefs at Maro are not changing.

French Frigate Shoals

Due to the extensive damage from Hurricane Walaka on the southern reef slope, coral reefs at French Frigate Shoals are assessed as declining. The broader extent of damage is unknown, as comprehensive post-hurricane surveys have not been conducted. However, monitoring data collected in years prior to Hurricane Walaka indicated declines between 2011–2012 and 2013–2014, with improving conditions in 2016 and 2017.

Gardner Pinnacles, Mokumanamana Island, & Nihoa Island

Coral reef surveys at Gardner Pinnacles, Mokumanamana, and Nihoa have been extremely limited, and the trend is assessed as unknown.

Management Implications

The natural variability of coral reef habitats across the expanse of latitudinal and longitudinal gradients in the monument and the physical and oceanic characteristics of the available coral reef habitat necessitate evaluating each of these reef systems individually. In general, it is more informative to compare the condition of corals at discrete locations over time, because each location has different baseline habitat considerations.

Consistent and uninterrupted monitoring and evaluation is needed. Observations recently made in 2019 emphasize the need to conduct annual monitoring. The inability to survey coral reefs in 2018 (due to lack of ship transport) resulted in nearly a full year delay in observing the damage to Rapture Reef at French Frigate Shoals and the invasive algal outbreak at Pearl and Hermes Atoll. Consistent monitoring is needed now to evaluate recovery from these disturbances, as well as from the most recent mass coral bleaching event.

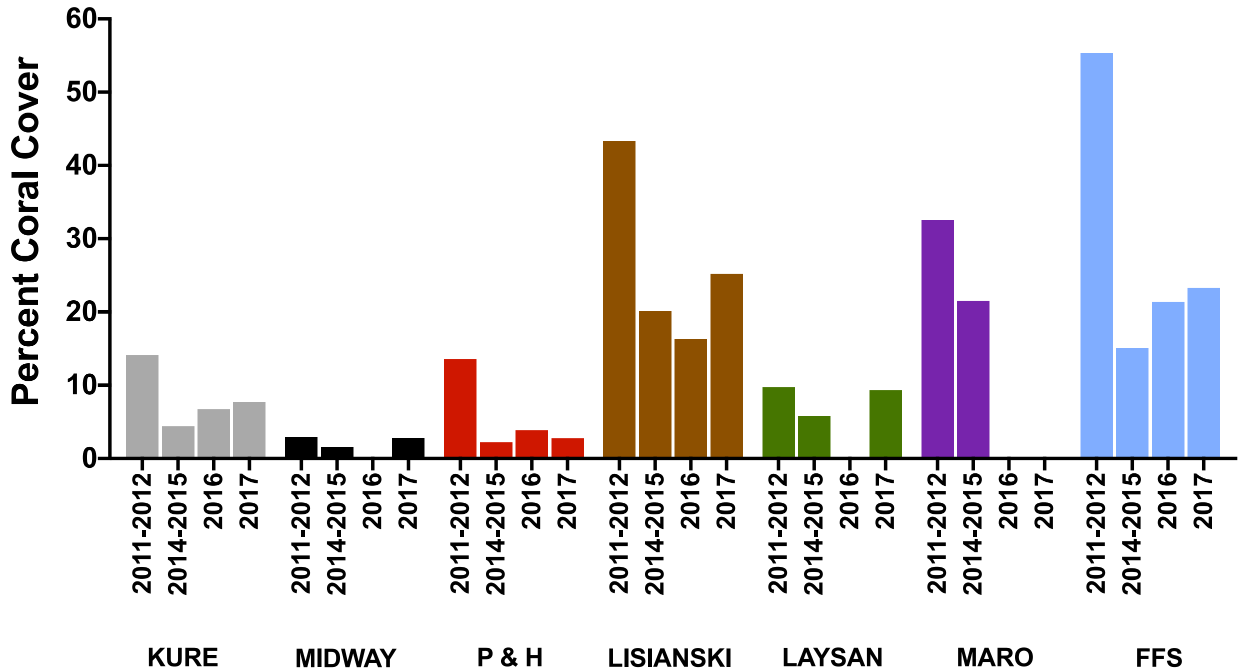


Figure S.LR.8.9. Benthic cover of coral over time at French Frigate Shoals (FFS), Kure (KUR), Laysan (LAY), Lisianski (LIS), Maro (MAR), Midway (MID), Pearl and Hermes (PHR) for the time periods of: 2011–2012 (labelled 1112), 2014–2015 (1415), 2016, and 2017. Data: PMNM and PIFSC

Applied research is also critical to interpreting the impacts of disturbance events such as Hurricane Walaka, outbreaks of invasive species and disease, and mass coral bleaching. Management opportunities such as carefully planned coral reef restoration at Rapture Reef at French Frigate Shoals should be considered. Monitoring for changes in the spread of the invasive algal mats at Pearl and Hermes Atoll should be evaluated, as well as options for control, mitigation, and restoration of corals.

Gardner Pinnacles, Mokumanamana Island, and Nihoa Island reef systems are relatively undersampled and would benefit from more regular monitoring. The spatial coverage of monitoring at locations already regularly surveyed should be increased to allow higher spatial resolution and statistical power for inferences.

Acknowledgements

Dr. Courtney Couch, Dr. Bernardo Vargas-Angel, and Dr. Jonathan Martinez contributed to this assessment.

Deep-Sea Corals

Good ?

Status

The expert-rated status for deep-sea corals is Good with medium evidence, on the basis that corals appear to be in pristine condition and promote ecosystem integrity. Investigations of deep-sea corals in the NWHI were historically limited to sample collection from the dredging efforts of the Albatross Expedition in 1902 (Vaughan, 1907; Nutting, 1908). No other deep-sea collections were made in the NWHI until 1970, when the University of Hawaiʻi began to investigate the distribution and abundance of precious corals across the Hawaiian Islands through dredges and tangle nets, a program commonly known as the Sango Expeditions (Grigg & Bayer, 1976; Cairns, 1984). In 1980, the Hawaiʻi Undersea Research Laboratory (HURL), a University of Hawaiʻi research center dedicated to deep-sea exploration around Hawaiʻi and the Western Pacific, began its operations (Chave & Malahoff, 1998). The earliest expeditions to deep-sea habitats in the NWHI using HURL's remotely operated vehicles and submersibles took place in 1984 and 1998 (Chave & Malahoff, 1998). Since then, HURL has been exploring deep-water corals of the NWHI more regularly, with deep-sea missions in 2000, 2001, 2002, 2003, 2007, 2009, and 2011.

To date, HURL has performed a total of 256 dives across the NWHI and made important discoveries on every expedition. For instance, a HURL expedition to the NWHI in 2003 recorded eight new species of bamboo corals in six new genera, three new species of stylasterid corals, and four new species of antipatharian corals (Baco, 2007; Parrish & Baco, 2007).

In 2015, 94,157 km^2 of multibeam mapping and up to 37 optical remotely operated vehicle surveys were conducted, and approximately 70 specimens of potential new records or species were collected in the monument as part of the NOAA Office of Ocean Exploration and Research "Campaign to Address Pacific Monument Science, Technology, and Ocean Needs" (Kelley et al., 2016; Kennedy et al., 2019), and results are pending analysis. Some of this effort was dedicated to exploring the NWHI with attention focused on coral and sponge communities growing on ridge crests that were deeper than what could be surveyed in prior years with HURL submersibles.

Despite many new and important discoveries, research on deep-water corals in the NWHI is still in an early exploratory phase, as more than 60% of deep-water areas of PMNM have not been mapped in high resolution, and only a miniscule percentage has been surveyed for sea life.

In contrast to the lower eight Hawaiian Islands, which have an active commercial black coral fishery and supported a commercial fishery on red and gold corals until 2001, precious corals have never been commercially harvested in the NWHI (Parrish & Baco, 2007; Grigg, 2010). Based on discoveries and findings to date, the region is considered a diversity hotspot for deep-water corals (Rogers et al., 2007; Baco, 2007; Parrish & Baco, 2007).

The majority of the limited surveys of deep-water corals in the original designation area of PMNM (Chave & Malahoff, 1998; Baco, 2007; Parrish & Baco, 2007) did not report any anthropogenic impacts (e.g., bottom trawling or other fishing gear impacts, pollution, invasive species), suggesting that these foundational species are in good condition.

Figure S.LR.8.10. The deep-sea gorgonian coral *Iridogorgia magnispiralis*. Individuals of this species can attain sizes approaching 6 meters, thereby making them the largest deep-sea coral known to date. Image: NOAA

Trends

The expert-rated trend is Undetermined with limited evidence due to the lack of repeated surveys in the same locations. Only a few specific deep coral sites in the NWHI (French Frigate Shoals, S.E. Brooks, Westpac coral bed) have been resurveyed (some sites as much as nine years later) to validate growth estimates and other life history characteristics of gold coral (Parrish et al., 2015). No other trend data have been collected for deep corals in the NWHI.

Management Implications

Continued monitoring of deep-water corals is important, as mounting scientific evidence suggests that deep-water corals are set to be substantially affected by impending global climate change and ocean acidification (Kleypas et al., 2006; Turley et al., 2007). Research efforts should center on establishing a baseline for these foundational resources, and repeat surveys of known locations of deep-water corals in the NWHI are needed to better understand how resources are changing over time.

Further analysis of recently collected deep sea data from 2015–2018 should be completed to evaluate the condition of deep-sea species. Additionally, a 2017 survey conducted in the monument expansion area found evidence of past trawling, derelict fishing gear, and deep-sea coral damage, as well as signs of recovery, on both the Northwest and Southeast Hancock Seamounts (Baco et al., 2019). The continued monitoring for the recovery of historically fished and damaged seamounts such as Northwest and Southeast Hancock would enhance understanding of the vulnerability and resilience of deep-sea species.

Acknowledgements

Dr. Daniel Wagner and Dr. Frank Parrish contributed to this assessment.

Seabirds

Good/Fair

Status

The expert-rated status is assessed as Good/Fair with medium evidence on the basis that these species are recovering from previous human disturbance, but are subject to current predation and bycatch impacts, though substantial and persistent declines from these threats are not expected. The IUCN designation for Laysan and black-footed albatross species remains “Near Threatened” based on precautionary projections of future declines over the next three generations. These projections are based in part on potential risk to nesting habitat from sea level rise (Storlazzi et al., 2013; Reynolds, Courtot, Berkowitz, et al., 2015).

There are as many as 21 breeding species of seabirds in PMNM (Table S.LR.8.4). Nearly the entire global populations of Laysan albatross (Figure S.LR.8.11) and black-footed albatross breed in the monument, as do globally significant populations of red-tailed tropicbirds, Bonin petrels, Tristram’s storm petrels, and white terns. Seabird habitat includes the entire monument boundary, however seabird monitoring has focused on nesting colonies at Kure Atoll, Midway Atoll, and Tern Island at French Frigate Shoals.

Some of the breeding seabird species found in PMNM: (a) manu o Kū or white tern; (b) short-tailed albatross; (c) Tristram’s storm petrel; (d) christmas shearwater. Images: (a) Eric Dale/USFWS; (b) Eric Dale/USFWS; (c) USFWS; (d) USFWS

Recent data on seabird nesting and abundance have been limited to nesting colonies of Laysan albatross and black-footed albatross at Kure Atoll, Midway Atoll, Laysan Island, and Tern Island (French Frigate Shoals). Breeding populations of all three Northern Hemisphere albatross species, Laysan albatross, black-footed albatross, and short-tailed albatross (*Phoebastria albatrus*), are monitored over a large portion of their range with the objective of assessing the status of these species. While many aspects of their lives at sea are poorly understood, they are easily counted and observed in breeding colonies and have been censused at all sites where biologists have access during the winter months, when they are breeding. Population sizes and trends have been tracked for these species since 1897, when the earliest recorded large-scale exploitation of their populations, the feather harvests, started (Spenneman, 1998). By 1914, more than 3.5 million birds, a large proportion of these three species, were harvested in the central tropical Pacific. Underlying trends may reflect recovery from those events, disturbance and habitat loss due to activities at breeding sites during World War II and the Cold War, and threats occurring from the 1950s on, including commercial fishing, high seas driftnets, and pelagic and demersal longlines (Arata et al., 2009).

Table S.LR.8.4. Breeding seabird species in Papahānaumokuākea.

English Name	Scientific Name	Hawaiian Name
Black-footed albatross	*Phoebastria nigripes*	Ka‘upu
Laysan albatross	*Phoebastria immutabilis*	Mōlī
Short-tailed albatross	*Phoebastria albatrus*	
Bonin Petrel	*Pterodroma hypoleuca*	
Bulwer's Petrel	*Bulweria bulwerii*	‘Ou
Wedge-tailed shearwater	*Puffinus pacificus*	‘Ua‘u kani
Christmas shearwater	*Puffinus nativitatis*	
Tristram's storm petrel	*Oceanodroma tristrami*	
Red-tailed tropicbird	*Phaethon rubicauda rubicauda*	Koa‘e‘ula
White-tailed tropicbird	*Phaethon lepturus dorotheae*	Koa‘e‘kea
Masked booby	*Sula dactylatra personatta*	‘A
Brown booby	*Sula leucogaster*	‘A
Red-footed booby	*Sula sula rubripes*	‘A
Great frigatebird	*Fregata minor palmerstoni*	‘Iwa
Little tern	*Sternula albifrons sinensis*	
Gray-backed tern	*Onchoprion lunatus*	Pakalakala
Sooty tern	*Onychoprion fuscata oahuensis*	‘Ewa‘ewa
Blue noddy	*Procelsterna cerulea saxatilis*	
Brown noddy	*Anous stolidus pileatus*	Noio koha
White tern	*Gygis alba candida*	Manu o kū
Black noddy	*Anous minutus*	Noio

Impacts from Hazards and Natural Disasters

Most of the world's populations of Laysan albatross and black-footed albatross nest in the monument. Midway Atoll is a significant breeding ground that has been monitored for decades. Midway's historical military use has affected seabirds in numerous ways, including historical population control, seabird strikes, entrapment hazards with man-made structures and aircraft, and contamination from legacy pollutants. A recent study found PCBs in plasma and preen oil of black-footed albatross at Midway Atoll in concentrations and congeners indicating that chicks at Midway Atoll are exposed to local PCB contaminants (Wang et al., 2015).

Annually, an estimated 2,500 Laysan albatross and 5,228 black-footed albatross are taken as fishing bycatch in the North Pacific (Arata et al., 2009). The dynamics of the bycatch threat to seabirds in the North Pacific have been extensively described (Arata et al., 2009; Anderson et al., 2011).

The tsunami generated by the 2011 earthquake off the Pacific coast of Tōhoku, Japan generated waves that washed ashore at nesting islands in the monument. It is estimated that the 2011 tsunami flooded 26 to 52% of the black-footed albatross nests concentrated on the coasts of Laysan Island and the three islands of Midway Atoll, where in total more than 275,000 black-footed and Laysan albatross and Bonin petrel nests were flooded (Reynolds et al., 2017). This single event foreshadowed the accelerating loss of substantial amounts of breeding habitat on low-lying islands in the atoll due to sea level rise and increased storm frequency and intensity. Months before the 2011 tsunami occurred, more than 10,000 albatross chicks were lost to storm waves at Midway Atoll and Laysan Island. In October of 2018, Hurricane Walaka washed away East Island at French Frigate Shoals. East Island was an important albatross breeding site, with 1,700 black-footed albatross pairs and 300 Laysan albatross pairs. These totals represented roughly 40% of black-footed albatross and 13% of Laysan albatross breeding populations in French Frigate Shoals. Since the hurricane, the island has continued to accrete and erode, however the capacity for nesting at historical levels is greatly reduced. In December 2019, Spit Island at Midway was overwashed, and over 2,000 albatross nests were destroyed.

Impacts from Mouse Predation

Predation of nesting albatross on Sand Island at Midway Atoll by invasive house mice has been observed since 2015. Mouse predation resulted in the known loss of 42 adults and 70 abandoned nests in the 2015/2016 breeding season and 242 adults, 1,218 bitten birds, and 994 abandoned nests in the 2016/2017 breeding season. This amounted to a six-fold increase in affected birds between 2015 and 2017 (USFWS, 2019a). In total, this represents a low proportion of the 360,000 estimated breeding pairs on Sand Island. However, because the majority of the global populations of Laysan and black-footed albatross nest in the monument and breeding is a sensitive time in the albatross life cycle, if birds continue to experience increased rates of mortality and nest abandonment, there could be greater impacts to these populations over time.

Figure S.LR.8.11. Laysan albatross breeding colony at Midway Atoll. Image: Dan Clark/USFWS

Trends

Trends for Laysan albatross, black-footed albatross, brown booby, and Bonin petrel are considered Not Changing with limited evidence. The most consistent and repeatable metrics for population time series are counts of active nests or breeding pairs. Both Laysan and black-footed albatross are strongly synchronous and initiate breeding within a short window in the boreal winter. Counts at sites with field stations occupied year-round are initiated as soon as all eggs have been laid in mid-December, and all counting is done before 7 January, if possible, to minimize the effects of egg loss. Colonies that cannot be accessed in winter are counted opportunistically, and an error factor, using best available reproductive performance data, is used. A previous trend assessment for Laysan albatross populations showed an increase from 1923 to 2005, with a stable population from 1992 to 2005 (Arata et al., 2009). The last trend assessed for black-footed albatross was an increase from 1923 to 2005, with a stable population from 1998 to 2005 (Arata et al., 2009). More recent estimates utilizing nest count data from 1980 to 2019 and different statistical methodologies have been conducted (Van Strien et al., 2004; USFWS, 2020 unpublished data). Total world population of black-footed albatrosses, using the most recent count for each site, is estimated at 65,026 pairs. The trend of the total counts of black-footed albatross from the Midway-French Frigate Shoals-Laysan populations (which represents 79% of the total world population) was stable from 1983 to 2019 (Figure S.LR.8.12).

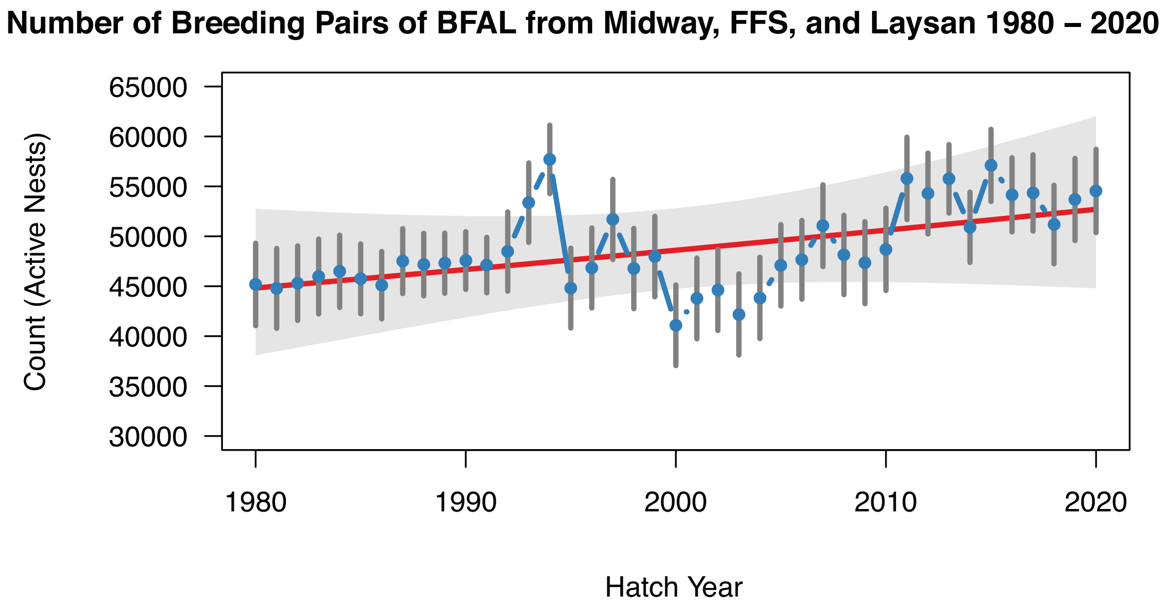


Figure S.LR.8.12. Rtrim analysis of black-footed albatross (BFAL) data 1983 to 2020 from Midway, French Frigate Shoals, and Laysan Island. Total imputed counts (± SE bars) of BFAL across all three sites (Midway, French Frigate Shoals, and Laysan) from years 1980 to 2020, as computed by Model 2 where time point 1 is also the only possible change point. The trend (red line) and its 95% confidence interval (gray shaded area) are plotted. Source: USFWS

Laysan albatross are now found in 18 breeding colonies world-wide, an increase from three previously known colonies (USFWS, 2020 unpublished data). They are also distributed across the North Pacific, but a larger proportion of the world's population occurs in the Hawaiian Islands. Laysan albatross have a world population of 659,508 breeding pairs, an order of magnitude larger than black-footed albatross. An rtrim model, used to estimate population trends based on count data, indicated an upward trend for Laysan albatrosses (Figure S.LR.8.13).

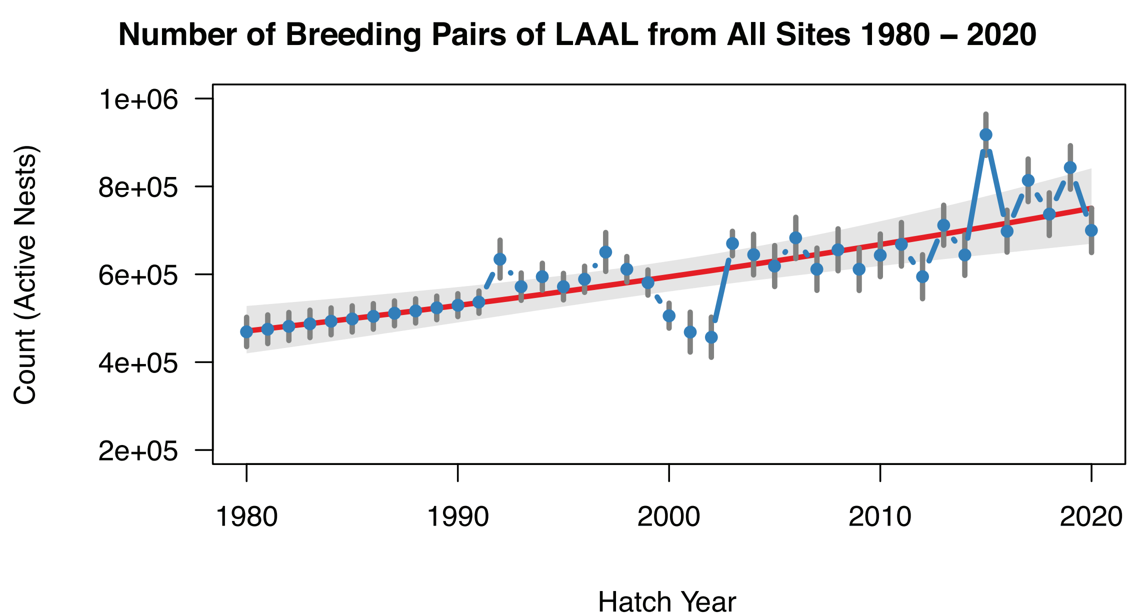


Figure S.LR.8.13. Rtrim analysis of Laysan albatross (LAAL) data 1980 to 2020 from all colonies. Total imputed counts (± SE bars) of LAAL as computed by Model 2 where time point 1 is also the only possible change point. The trend (red line) and its 95% confidence interval (gray shaded area) are plotted. Source: USFWS

Limited inferences can be made when using the number of nests as indicators of albatross populations, as most birds do not reproduce every year. However, active nest count data can give an indication of the number of birds initiating reproductive efforts for the year, if interpreted carefully.

Counts of albatross nests from Kure Atoll indicate increasing numbers of nests and stable numbers of chicks for Laysan albatross (Figure S.LR.8.14) and slightly decreasing numbers of nests and chicks for black-footed albatross (Figure S.LR.8.15).

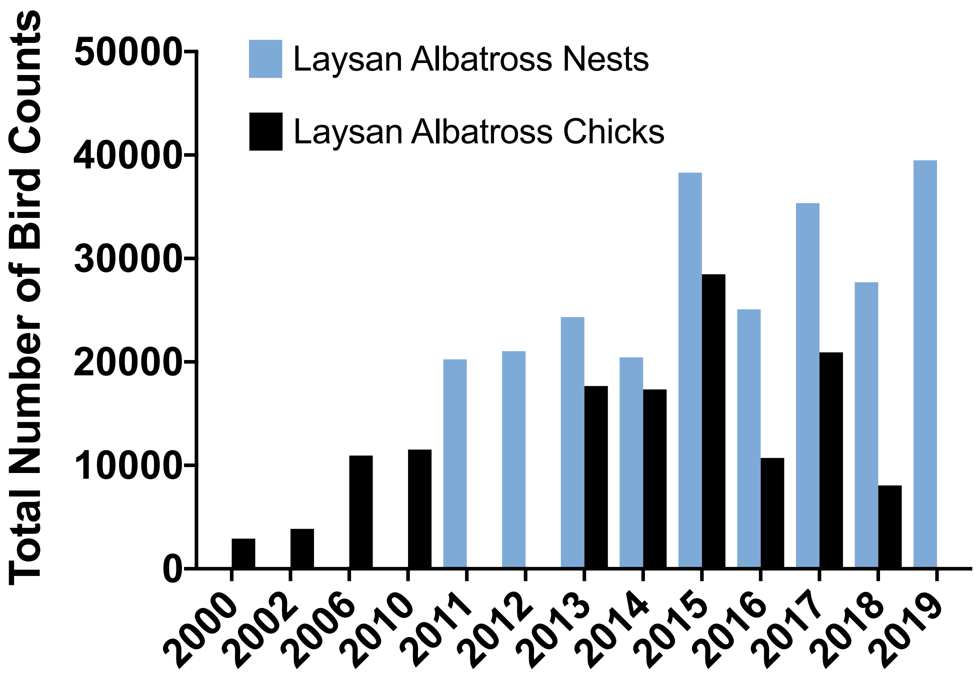


Figure S.LR.8.14. Numbers of nests and chicks of Laysan albatross at Kure Atoll from 2000–2019. Source: DOFAW

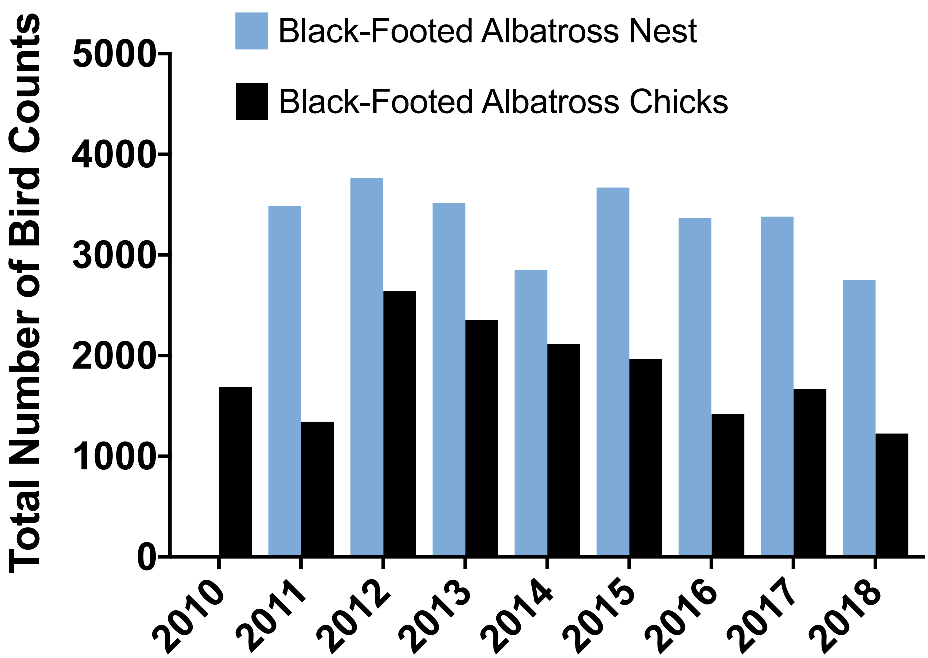


Figure S.LR.8.15. Numbers of nests and chicks of black-footed albatross at Kure Atoll from 2010–2018. Source: DOFAW

Brown booby breeding has been monitored at Kure Atoll since 1997. The number of confirmed nests, banded chicks, and total fledged chicks has increased from 2009–2017 (Figure S.LR.8.16), however the number of failed nests also increased from seven in 2014 to 30 in 2017.

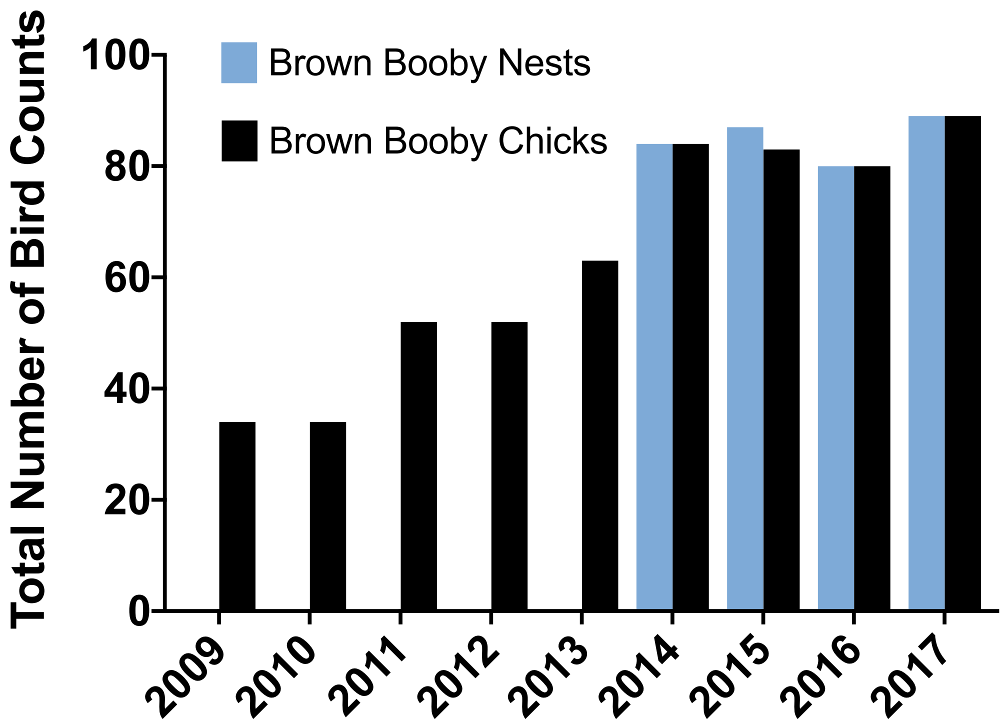


Figure S.LR.8.16. Numbers of confirmed nests and brown booby (*Sula leucogaster*) chicks at Kure Atoll between 2009–2017. Source: DOFAW

Bonin petrels are small, burrow-nesting seabirds that breed in high densities at Midway Atoll National Wildlife Refuge in PMNM. However, they have not always been plentiful. The breeding population was estimated to be 5,000 breeding pairs in 1979 and increased to 32,066 breeding pairs in 1994. Following eradication of rats from Midway Atoll in 1996, the Bonin petrel population swelled to 129,773 pairs by 2008 (Moore, 2009). Additional conservation measures, such as restricting lights and nighttime motor vehicle use and removing above-ground utility lines at Midway, have also enhanced survival. The increase in the Bonin petrel population, one of the only *Pterodroma* species to live in small towns, has resulted in increased human-wildlife conflicts, as resident staff implement management activities such as construction, demolition, tree removal, and preservation of historic resources. Burrow-nesting seabirds, especially those that breed in fragile burrows in sandy soil, are notoriously difficult to count in a non-destructive manner. Estimates of Bonin petrel populations have been made only rarely for this reason. The most recent full characterization of the population at Midway Atoll was done by Moore (2009). This study included estimates of the number of nests using the traditional method of mapping colony area and multiplying it by sampled burrow density and percent occupancy to estimate colony population size. More recently, Fleishman et al. (2018) attempted to relate sound density of Bonin calls to population size and also made density and occupancy rate measurements. This study also included new maps of the distribution of Bonin petrel burrows throughout the atoll. Nest density and percent occupancy have remained stable since 2008, but the total area of the atoll used by the petrels has more than doubled. New estimates for the breeding population at Midway Atoll are 329,373 burrows with eggs, representing 658,746 breeders. Using mark-recapture methods, Moore (2009) found that the total population was roughly 3.65 times the breeding population in 2008, so there could be as many as 2.4 million Bonin petrels now using Midway Atoll.

Figure S.LR.8.17. Bonin petrel (*Pterodroma hypoleuca*) at Midway Atoll. Image: Eric Dale/USFWS

Management Implications

Monitoring seabirds in the monument has been challenging due to logistical, staffing, and financial constraints. In the monument, some level of seabird monitoring occurs on approximately 63% of the islands; on at least half of the islands, as many as 14 of 21 total species are monitored (VanderWerf & Young, 2017). The critical reproductive phase of seabird life cycles has been the focus of monitoring, and there has been little monitoring of seabirds throughout the extent of their habitats, including the open ocean, owing largely to logistical and resource constraints. Varying methods of historical data collection, in addition to non-continuous time series, make population assessments particularly challenging. USFWS is working with partners on the Albatross Demography Project, which aims to resolve some demographic data gaps. Coordinated monitoring frameworks and time series in more locations (including resuming data collection at Tern Island, French Frigate Shoals) would be valuable in the future. In addition, complementary population assessments and data interpretation at regular intervals are needed.

In 2021, USFWS will proceed with a mouse eradication effort to eliminate the threat of mouse predation at Midway Atoll. Continued monitoring of seabirds after this action is necessary to evaluate the success of this mitigation effort.

Seabirds remain highly vulnerable to the loss of breeding habitat caused by climate change and storms as illustrated by the impacts of Hurricane Walaka to Tern Island at French Frigate Shoals.

Improved understanding of threats to foraging and food supply is also needed. Ingestion of and entanglement in marine debris continue to be concerns for foraging seabirds (Figure S.LR.8.18), although

Figure S.LR.8.18. Black-footed albatross parents with chick. Image: Mark Sullivan/NOAA

these have not been demonstrated to have population-level effects. Marine debris is often consumed by foraging seabirds and fed to brooding chicks. Recent studies have found high incidence of plastic debris in gut contents from examined seabirds (Hyrenbach et al., 2017; Rapp et al., 2017; Youngren et al., 2018).

In 2016, with the expansion of Papahānaumokuākea Marine National Monument by President Obama, an additional 442,760 mi^2 of seabird feeding habitat was protected from take by commercial longline fishing. The monument expansion area extended the boundary and protections from 50 nautical miles offshore out to the seaward boundary of the U.S. Exclusive Economic Zone (200 nautical miles or 370 km offshore) west of the 163° W meridian. During the chick brooding period, Laysan albatross parents can forage as far as 510 km and black-footed albatross can forage as far as 303 km from the nest (Hyrenbach et al., 2002; Arata et al., 2009). The 2016 expansion increased protection to these birds across 70% of the foraging range for Laysan albatross and the entire foraging range for black-footed albatross during chick brooding. This expanded protection also protects the first 200 nautical miles of adult albatross transit during longer foraging trips. The long-term and population-wide implications of these additional protections should be monitored.

Acknowledgements
Dr. Beth Flint and Dr. Jonathan Martinez contributed to this assessment.

Endemic Land Birds: Nihoa Millerbird, Nihoa Finch, Laysan Duck, Laysan Finch

Fair/Poor ?

Status

Although the status of endemic land bird populations varies by location, the overall status rating for endemic land birds is determined to be Fair/Poor, because all four species are endangered, populations are small and isolated, considerable variation in population estimates exist, and prospects for recovery are uncertain. Individual status and trend varies by species, therefore information for each is described below and ratings are summarized in Table S.LR.8.5.

Table S.LR.8.5. Status summary for subpopulations of PMNM endemic landbirds.

Species	Status	Evidence	Trend	Evidence
Nihoa millerbird	**Fair**	**Medium**	**Undetermined**	**Limited**
Nihoa subpopulation	Fair	Medium	Undetermined	Limited
Laysan subpopulation	Fair	Medium	Improving	Limited
Nihoa finch	**Fair/Poor**	**Medium**	**Undetermined**	**Limited**
Nihoa only	Fair/Poor	Medium	Undetermined	Limited
Laysan duck	**Fair**	**Medium**	**Improving**	**Medium**
Laysan subpopulation	Fair	Limited	Improving	Limited
Midway subpopulation	Fair	Medium	Improving	Medium
Kure subpopulation	Fair	Medium	Improving	Medium
Laysan finch	**Fair/Poor**	**Limited**	**Undetermined**	**Limited**
Laysan subpopulation	Undetermined	Limited	Undetermined	Limited
Pearl & Hermes subpopulation	Poor	Limited	Declining	Limited

Four species of endemic land birds occur within the monument: the Nihoa millerbird, the Nihoa finch, the Laysan duck, and the Laysan finch. All four are listed as endangered under the Endangered Species Act due to their limited geographic range and anthropogenic threats, specifically the introduction or spread of invasive species. Of the four endemic and endangered land birds, the Laysan duck has subpopulations on three islands, the Laysan finch and Nihoa millerbird have subpopulations on two islands, while the Nihoa finch occurs only on Nihoa Island. Population estimates and relevant factors that may affect the annual estimates for each bird species are enumerated in Table S.LR.8.6.

These endemic birds face multiple threats. Non-indigenous and invasive species (e.g., mammalian predators, ants, grasshoppers, invasive plants) can prey on land birds or modify their habitats, which can reduce their food source, introduce diseases, and limit nesting and foraging. The limited range of these species also presents a significant risk, as a catastrophic event could wipe out an entire population.

Table S.LR.8.6. Population estimates and relevant factors that may affect yearly abundance estimates for PMNM's endemic land birds.

Species	Island	Population Estimate ± SD (Year)	Factors
Nihoa millerbird Ulūlu (Nihoa), Ulūlu niau (Laysan)	Nihoa, Laysan*	Nihoa: 893± 303 (2014) Laysan: 164 (2014)	Fluctuating population estimates
Nihoa finch Palihoa	Nihoa	2,963 ± 477 (2014)	Single island endemic
Laysan duck Koloa pōhaka	Laysan, Midway, Kure**	Laysan: 339 ± 74 (2012) Midway: 598 ± 80 (2019) Kure: 37-40 (2016)	Fluctuating populations, avian botulism
Laysan finch 'Ainohu kauo	Laysan, Pearl and Hermes	Laysan: 9,433 ± 1,353 (2012) Pearl and Hermes: ~800 confined to Southeast Island (2018)	Fluctuating population estimates, 2011 tsunami

*Nihoa millerbird (n = 50) was translocated to Laysan Island in 2011 and 2012.
**Laysan ducks were translocated to Kure Atoll from Midway Atoll in 2014.
Sources: Nihoa millerbird: Gorresen et al., 2016; Freifeld et al., 2016; Nihoa finch: Gorresen et al., 2016; Laysan duck: Reynolds, Courtot, Brinck, et al., 2015; M. Duhr-Schultz & C. Vanderlip, personal communication, 2018; Laysan finch: Underwood, 2013; Rounds et al., 2019.

Nihoa Millerbird

The Nihoa millerbird population on Nihoa Island was estimated at 610 ± 210 SD in 2012, 468 ± 166 SD in 2013, and 893 ± 303 SD in 2014 (Gorresen et al., 2016). While resources such as space and food may limit the size of the population on Nihoa, the translocation of millerbirds to Laysan Island increased population size and range, thus reducing extinction risk. Fifty birds were translocated to Laysan over a two-year period (2011–2012) and the project showed initial success, with an estimated population of more than 164 birds on Laysan as of 2014 (Dalton et al., 2014). In 2019, the species was observed using habitat throughout Laysan Island, signifying a significant range expansion from the release sites in the north. Therefore, the status of this species is assessed as Fair. However, its limited range and reduced genetic diversity (Addison & Diamond, 2011) indicate that the species is still vulnerable.

Figure S.LR.8.19. Endangered and endemic Nihoa millerbird in flight. Image: Robby Kohley/USFWS

Nihoa Finch

The status of the Nihoa finch is considered to be Fair/Poor, as survival of this species is uncertain due to its limited range, with all individuals in one population on its namesake island. Prior to 2011, fluctuating numbers and large errors associated with estimates made it difficult to determine population status for this species. The Nihoa finch is at risk of extinction due to stochastic and environmental factors and species introductions. Translocation to either Kure Atoll or Lisianski Island was recommended by Morin and Conant (2020) to increase the species' chances for survival. In 2014, a small number of breast feathers were collected from 100 Nihoa finches that were captured and released unharmed at points throughout the island (Plentovich et al., 2014). These samples preliminarily showed two specific populations of Nihoa finch: an Eastern and a Western population. This information will be important if Nihoa finches are translocated in the future.

Laysan Duck

The risk of catastrophic loss of this species has been significantly reduced with the establishment of populations on three separate islands. Over a two year period (2004–2005), 42 Laysan ducks were translocated from Laysan Island to Midway Atoll to establish a second population, and as of 2019, the population at Midway was estimated to be 598 individuals. Twenty-eight ducks were translocated from Midway to Kure Atoll in 2014, and as of 2016, the Kure population was estimated to be 37–40 birds (DOFAW, 2017). The status of this species is determined to be Fair due to increases in its distribution and observed population size. However, populations have periodically experienced wide fluctuations.

Figure S.LR.8.20. A Laysan duck with her brood near Brad's Pit at Kure Atoll. Image: Matthew Saunter/DOFAW

Additionally, all three subpopulations rely upon fragile island ecosystems where rising sea level, increasing storm surge, and lower precipitation associated with global climate change are expected to have serious impacts. The Laysan duck remains vulnerable to outbreaks of avian botulism, which periodically result in high mortality in all three subpopulations.

Laysan Finch

The status of this species is assessed as Fair/Poor, as prospects for recovery are uncertain. The Laysan finch is confined to two locations: Laysan Island and Pearl and Hermes Atoll.

The status of the subpopulation at Laysan Island is assessed as Fair. Carrying capacity for the species at Laysan has been estimated at 10,000 individuals (Underwood, 2013). The Laysan Island subpopulation estimate was last updated in 2012, when there were 9,433, ± 1,353 birds (Underwood, 2013). Additional surveys were completed in 2017 and 2019, and data are being analyzed by the U.S. Geological Survey (USGS). The status of the Laysan finch subpopulation at Pearl and Hermes Atoll is Poor. This subpopulation was estimated at 1,000 individuals in 2007 and currently exists on a single islet (Southeast) at Pearl and Hermes Atoll (VanderWerf, 2012). This subpopulation was likely negatively affected by the 2011 tsunami, as a rapid assessment in November 2018 estimated approximately 200 birds (USFWS, 2018). The Pearl and Hermes subpopulation is not expected to persist given the current population trend and low elevation of the atoll (which increases susceptibility to projected sea level rise and increased storm intensity).

Trends

While trend varies by species, the overall trend for endemic birds is assessed as Undetermined with limited evidence due to data limitations for all species. Trend considerations for each species are discussed below.

Nihoa Millerbird

The long-term population trend for this species is Undetermined, as previous data collection was irregular and showed wide population fluctuations. A new survey method intended to reduce error was tested in 2012 and adopted in 2013 (Gorresen et al., 2012, 2016). Data from 2015–2019 will be analyzed in 2020 through a partnership between USGS and USFWS. The Nihoa millerbird subpopulation at Laysan Island is likely Improving.

Nihoa Finch

The population trend for the Nihoa finch was determined by Gorrensen et al. (2016) to be marginally positive, however 2019 surveys suggest a substantial decline could be underway. Therefore, the trend is assessed as Undetermined.

Prior to 2011, fluctuating numbers and large errors associated with estimates made it difficult to determine a population status and trend for this species. The population estimate was 4,024 ± 642 birds in 2012, 2,193 ± 337 in 2013, and 2,963 ± 477 in 2014. An analysis of strip transect and distance-based surveys indicated a marginally positive trend in the Nihoa finch population between 1979 and 2012 (Gorresen et al., 2016). A detailed analysis of data collected between 2015 and 2019 data is underway via a USGS and USFWS partnership. Nihoa Island access is intermittent, with surveys limited to short annual trips, therefore data are limited.

Laysan Duck

The Laysan duck population is considered to be gradually increasing, particularly at Midway and Kure Atolls. Therefore, the trend is assessed to be Improving. However, despite an overall positive trend in numbers, populations have periodically experienced wide fluctuations (Reynolds, Hatfield, et al., 2012). For example, at Laysan Island, estimated population size has varied from 322 to 688 over the last several decades (USFWS, 2014). Reproduction is highly variable, and few or no ducklings are produced at some locations in some years. Avian botulism outbreaks periodically resulted in high mortality, such as the 2008 event at Midway Atoll that killed an estimated 181 birds (Work et al., 2010). The 2011 tsunami is believed to have reduced the Laysan Island population by 50% (J. R. Walters, personal communication, April 7,, 2013), and at Midway Atoll, approximately 20 to 30% of the banded adult birds observed before the tsunami were not observed afterwards (USFW 2012). Frequency of data collection for the three subpopulations varies, with bimonthly surveys at Midway Atoll and Kure Atoll and irregular, opportunistic surveys at Laysan Island.

Laysan Finch

The population trend for the Laysan subpopulation of this species was considered stable up until 2012 (Underwood, 2013). The trend over the last seven years is unknown due to lack of regular surveys. The population trend for the subpopulation at Pearl and Hermes Atoll is unknown but is likely to be declining. The current trend is assessed to be Undetermined, as the overall population is judged to have experienced unquantified fluctuations over the last ten years.

Management Implications

These small, isolated populations of endangered, endemic bird species are extremely vulnerable to extinction from stochastic events, natural disturbance, invasive species, diseases, and sea level rise.

All of the species are data deficient in terms of reproductive biology, population trends, and survival rates. More frequent, preferably annual, monitoring of populations is required. The lack of long-term ecological data makes it difficult to assess conservation status and trends. As noted, at Nihoa Island, monitoring of the Nihoa finch and Nihoa millerbird is constrained by the short duration of annual research trips. Monitoring of the Laysan duck occurs year-round at Kure and Midway Atolls, but has not been conducted at Laysan Island since 2012. Monitoring of the Laysan finch subpopulation at Laysan Island has also been curtailed since 2012, and the Pearl and Hermes subpopulation has only been rapidly assessed once (in 2018) since 2007.

Continued habitat protection, restoration, and management are key to the conservation of these species. Ongoing, preventive biosecurity measures and onsite monitoring are needed to identify and manage key threats: predators, competitors (such as non-indigenous arthropods), pathogens, toxins, and invasive species.

Research is needed to identify appropriate, safe locations to establish additional populations of these species in the monument (Nihoa Finch) and on high islands in the MHI (all species). The Nihoa finch, which occurs only on Nihoa, is the first priority for translocation. An interim translocation site is needed to ensure this species' survival over the next 50–100 years before it can be translocated to a high island. Suitable habitat for translocation exists, as does the expertise and capacity for translocation. Prior work by Morin and Conant (2020) identified Lisianski Island and Kure Atoll as suitable sites for a translocated population of Nihoa finch, and a habitat assessment trip completed by USFWS in 2013 corroborated these findings (S. Plentovich, personal communication, June 14, 2019).

Translocation of all four species to safe habitat on high islands is necessary to ensure long-term survival. Appropriate habitat will need to be identified, and translocations within the historic ranges of these species are preferred.

Elimination of mosquitoes is required prior to translocation. Avian diseases that are transmitted by non-indigenous mosquitoes, particularly avian malaria (*Plasmodium relictum*) and avian pox virus (*Poxvirus avium*) have decimated Hawaiian avifauna in the southeastern MHI. Mosquitoes and the diseases they carry are also present at Midway Atoll. Large-scale mosquito control techniques are being evaluated for use in the MHI and may be field tested as early as 2025. Additional research on avian pox and other diseases is also required.

Finally, the aggressive monitoring and control of avian botulism outbreaks for the Laysan duck should be continued.

Acknowledgements

Dr. Sheldon Plentovich, Rachel Rounds, Dr. Annie Marshall, and Dr. Jared Underwood contributed to this assessment.

Endemic Terrestrial Plants

Poor ?

Status

The overall combined status rating for five NWHI endemic species and two Hawaiian Archipelago endemic species is assessed as Poor with limited evidence, although the status of endemic plant populations varies somewhat by species and location. All five species endemic to the NWHI are endangered and considered at very high risk of extinction due to extreme rarity, limited geographic range, and anthropogenic threats, in particular the introduction or spread of invasive species. All species are data deficient, and overall prospects for survival are uncertain. Ratings are described below for each species and summarized in Table S.LR.8.7.

There are five managed (endangered) species of terrestrial plants known to be endemic to the islands and atolls of Papahānaumokuākea: Hawai‘i chaff flower (*Achyranthes atollensis*), Nihoa carnation (*Schiedea verticillata*), *Amaranthus brownii*, kāmanomano (*Cenchrus agrimoniodes* var. *laysanensis*), and ahu‘awa (*Cyperus pennatiformis* var. *bryanii*). All are protected under the Endangered Species Act of 1973 (16 U.S.C. § 1531 et seq.).

Figure S.LR.8.21. Nihoa carnation is endemic to the island of Nihoa, where it was first described in 1923 by the Tanager expedition. It has been listed as endangered since 1996. Image: Tim Kroessig/UHM

Additionally, at least 20 other plant species found in PMNM are endemic to the broader Hawaiian Archipelago. Some are endangered. Because these species fill important ecosystem roles and have historically established subpopulations in the protected PMNM, they are enumerated in this report. Status ratings are not provided for this group, with the exception of two managed species, loulu (*Pritchardia remota*) and puaokama (*Sicyos maximowiczii*), for which the PMNM populations are considered to constitute the majority of the global population. Brief descriptions and provisional ratings are provided for those species.

Hawaiʻi Chaff Flower

Hawaiʻi chaff flower is a small- to medium-sized shrub that is endemic to Kure Atoll, Midway Atoll, Pearl and Hermes Atoll, Lisianski Island, and Laysan Island. Its status is assessed as Poor, as it was last collected on Kure Atoll in 1964 and has not been observed since. It is either extinct or existing as seeds in the soil (Wagner, Bruegmann, et al., 1999).

Nihoa Carnation

The Nihoa carnation is found only on Nihoa Island. The condition of this species is considered to be Fair/Poor due to limited geographic distribution and historically fluctuating population numbers. At the time of Endangered Species Act listing in 1996, an estimated 170–190 wild individuals were known on Nihoa. In 1998, an estimated 359 individuals were observed. Heavy predation by the non-indigenous gray bird grasshopper was documented from 2002–2004, with extensive defoliation of Nihoa carnation and other plants (Evenhuis & Eldredge, 2004). A 2008 census subsequently noted a large increase in Nihoa carnation, with over 1,000 individuals in 10 colonies counted from Dog's Head to Derby's Beach, at Devil's Slide, Needle Rock, Miller's Peak, Albatross Plateau, Middle Valley, Tanager Peak, and Tunnel Cave. As of 2015, there are estimated to be 1,000 individuals at the same locations (Plentovich et al., 2015). Genetic analysis has shown that the Nihoa carnation maintains a high level of genetic diversity despite being a single island endemic.

Amaranthus brownii

Amaranthus brownii is a member of the amaranth family. This plant also is endemic to Nihoa Island. The current status rating for this species is Poor. In 1983, there were two known *A. brownii* colonies on Nihoa totaling about 35 plants. Since then, no individuals have been observed, although until recently, all surveys were conducted in the dry summer months when *A. brownii* is difficult to distinguish from other desiccated herbaceous plants. Despite a significant search effort during the wet season in June 2015, this species was not found and may be extinct (Plentovich et al., 2015).

Kāmanomano

Kāmanomano is a perennial tufted grass that is endemic to Laysan Island, Kure Atoll, and Midway Atoll. The status of this species is assessed as Poor. According to Morin and Conant (1998), kāmanomano was last observed in the wild in 1902 at Midway and in 1923 at Laysan. The species was reintroduced to Laysan in 1963 from seeds collected at Kure Atoll, but has not been observed at Laysan since 1973. The last observation of kāmanomano at Kure Atoll was around 1980. The species may be extirpated in the wild (USFWS, 2010; Wagner, Herbst, & Sohmer, 1999).

Ahuʻawa

Ahuʻawa is a sedge endemic to Laysan Island. The status of this species is considered to be Poor due to limited geographic distribution and varying population numbers. Threats to this population include seed consumption by the Nihoa finch, damage from burrowing and nesting seabirds, and competition for habitat by invasive species. The population of ahuʻawa on Laysan Island appears to have fluctuated dramatically since it was first listed (USFWS, 1994). In 1994, 30 individuals were observed. During the ensuing 13 years, population estimates ranged from a single individual to 488 plants (C. Rehkemper, personal communication, April, 2008). USFWS reintroduced 65 individuals in 2009 and 38 individuals in 2010. A total of 962 surviving individuals were counted in a 2010 survey (Kristof & Stelmach, 2010). An additional 187 individuals were reintroduced in 2011 (C. Rehkemper, personal communication, August 28, 2012; Farmer et al., 2011).

The combined impact of the 2011 tsunami and the lake flood it caused affected an estimated 90% of the ahu‘awa population on Laysan. Nearly all of the colonies adjacent to the lake were inundated and killed by the flood waters, and many individuals in the camp colonies were uprooted during the tsunami. Subsequent appearance of ahu‘awa sprouts in many of these areas indicated that the seed bank was resilient to prolonged salt water inundation. While some areas did not appear to recover, likely due to an insufficient or absent seed bank, these natural events also provided a powerful vector for relatively long-distance seed dispersal. An island-wide mapping effort in 2013 provided the first comprehensive distribution of ahu‘awa on Laysan following the unusual conditions of 2011. Approximately one acre of ahu‘awa containing both mature seeding plants and small recruits was located and mapped (Kristof et al., 2013). The population on Laysan in late 2014 was estimated to be between 800 and 850 plants (Kristof et al., 2014, however the potential for survival of this species is uncertain.

Ahu‘awa has also been propagated and outplanted at Midway Atoll. Its presence there was last documented by Starr and Starr (2015).

Figure S.LR.8.22. Ahu‘awa. Image: Forest and Kim Starr

Table S.LR.8.7. Status and trend for populations of PMNM endemic terrestrial plants.

Species Name and Common Name(s)	Status	Trend	Evidence
Achyranthes atollensis Hawaiʻi chaff-flower	Poor (potentially extinct)	Undetermined	Limited
Amaranthus brownii	Poor (potentially extinct)	Undetermined	Limited
Cenchrus agrimonioides* var. *laysanensis Kāmanomano, Laysan agrimony sandbur	Poor (potentially extinct)	Undetermined	Limited
Cyperus pennatiformis* var. *bryanii Ahuʻawa, Laysan sedge, Bryanʻs flatsedge	Poor	Undetermined	Limited
Schiedea verticillata Nihoa carnation	Fair/Poor	Undetermined	Limited

Trends

The overall trend for the five species endemic to Papahānaumokuākea is Undetermined with limited evidence, mainly due to data deficiencies. On most islands in PMNM, access and other limitations result in a lack of population-level monitoring for endemic plants. Trends for each species are discussed below.

Hawaiʻi Chaff Flower

Undetermined. No trend can be assessed for this species, as it has not been observed since 1964.

Nihoa Carnation

Although the population on Nihoa currently may be stable, fluctuating populations and intermittent monitoring have made it difficult to determine trends. The trend is assessed as Undetermined.

Amaranthus brownii

Undetermined. No trend can be assessed for this species, as it has not been observed since 1983.

Kāmanomano

Undetermined. No trend can be assessed for this species, as the last observation of kāmanomano was at Kure Atoll around 1980.

Ahuʻawa

Populations may be recovering. However, as noted above, fluctuating populations have made it difficult to determine trends. Access to sites where this species is found is intermittent, with attendant data limitations. Therefore the trend is Undetermined.

Hawaiian (Archipelago-Wide) Endemics Found in the NWHI

Occurring in Papahānaumokuākea are at least twenty terrestrial plant species endemic to the broader Hawaiian Archipelago (Table S.LR.8.8). These are enumerated by island below. The PMNM populations of two of these species, loulu and puaokama, are considered to constitute a majority of the global population, therefore ratings are provided for them here (see text box).

Ratings for two Hawai‘i endemic plants whose principal populations occur in PMNM

Puaokama

Puaokama is a bur cucumber endemic to Laysan Island, Lisianski Island, Pearl and Hermes Atoll, Midway Atoll, Kure Atoll, Ni‘ihau, and O‘ahu (Wagner, Herbst, & Sohmer, 1999). The majority of the global population of this species is believed to occur at Laysan, Midway, and Kure, although it reportedly has become more rare (DOFAW, 2018). Therefore, the status and trend of populations of this species in the monument are assessed as Undetermined. Outside of the monument, a subpopulation at Ni‘ihau is small and degraded, while the status of an O‘ahu subpopulation is unknown.

Loulu

Loulu is a fan palm endemic to Nihoa and Ni‘ihau, however the principal global population of wild loulu occurs at Nihoa (estimated at 1,000–1,500 individuals), with only two older palms found on Ni‘ihau (Hodel, 2012). At Nihoa, loulu occurs in colonies in two separate valleys (West Palm Valley and East Palm Valley). The current condition rating for this species is Fair. The population trend for this species is unknown due to irregular surveys.

Figure S.LR.8.23. The seed branch of an endangered loulu in bloom. Image: Wayne Levin

Nihoa Island

Nihoa supports ten species that are endemic to the Hawaiian Archipelago: ʻaweoweo (*Chenopodium oahuense*), hākonakona, kākonakona, or torrid panicgrass (*Panicum torridum*), ʻakoko (*Euphorbia celastroides*), kāwelu (*Eragrostis variabilis*), huʻahuʻakō (*Rumex albescens*), pōpolo (*Solanum nelsonii*), ʻihi (*Portulaca villosa*), ʻōhai (*Sesbania tomentosa*), kūpala (*Sicyos pachycarpus*), and loulu. The latter five species are listed as endangered under the Endangered Species Act.

Mokumanamana

Mokumanamana is known to support at least three Hawaiian islands endemics: ʻaweoweo, hākonakona, and the endangered ʻōhai.

French Frigate Shoals

At French Frigate Shoals, vegetation is mostly limited to Tern Island. Of the 24 plant species documented at Tern Island, one is endemic to the Hawaiian Archipelago: ʻaweoweo.

Laysan Island

Laysan Island is well vegetated, with very few non-indigenous species (Athens et al., 2007). Eleven species endemic to the Hawaiian Archipelago have been recently documented at Laysan: ʻaweoweo, kāwelu (*Eragrostis variabilis*), puaokama, kūpala, maiapilo (*Capparis sandwichiana*), ʻanaunau (*Lepidium bidentatum* var. *owaihiense*), hinahina kahakai (*Nama sandwicensis*), ʻiliahioloʻe (*Santalum ellipticum*), nehe (*Melanthera integrifolia*), and the endangered loulu and pōpolo (Starr & Starr, 2013; USFWS, 2015). Additionally, ʻānunu (*Sicyos semitonsus*) may exist at Laysan but has not been documented since 1983 (Morin & Conant, 1998).

The establishment of a population of endemic loulu was in progress at Laysan Island for several years. This restoration effort experienced severe setbacks due to the 2011 tsunami and a record breaking flood, which killed all of the 70+ outplanted, established trees. Outplanting of 200 seedlings occurred prematurely in 2012 due to the November evacuation of Laysan (USFWS, 2012). In 2013, sixty-two loulu plants approximately 2–3 ft in height were located in four locations on the island (Kristof et al., 2013). By contrast, only 19 individuals were located in 2014 (Kristof et al., 2014).

Lisianski Island

Lisianski Island is well vegetated with relatively intact flora. Fifteen species of native terrestrial plants have been documented there, including a single individual of the indigenous tree *Pisonia grandis*, currently the only known occurrence of this species in the entire archipelago. Five species are endemic to the archipelago: kāwelu, puaokama, hinahina kahakai, ʻaweoweo, and alena (*Boerhavia herbstii*) (Imada, 2012). Three of these endemics, ʻaweoweo, kāwelu, and hinahina kahakai, were documented in a 2018 survey (USFWS, 2018).

Pearl and Hermes Atoll

The seven sandbar islets of this atoll were previously known to support 16 indigenous terrestrial plants, six of which are Hawaiian endemics: pōpolo, kāwelu, maiapilo, ʻanaunau, alena, puaokama, (Imada, 2012; USFWS, 2019b). Vegetation on these low-lying islets likely encounters occasional overwash during storm events or tsunamis, and is susceptible to sea level rise, which changes the abundance and distribution of plant species. A 2018 USFWS survey found three of these species: kāwelu, puaokama, and pōpolo. Hawaiʻi chaff flower and maiapilo were last seen on Seal Island in 1963 (Amerson et al., 1974), and ʻanaunau was last documented in 2005 (USFWS, 2016). Terrestrial plant data gathered by the 2019 Hawaiian monk seal research crew survey at Pearl and Hermes Atoll are presently being analyzed.

Midway Atoll

Midway Atoll's native vegetation has been greatly altered by over a century of human occupation. However, habitat restoration efforts for seabirds and the Laysan duck have significantly improved the status of native flora. Starr and Starr (2008) noted that between 1999 and 2008, the number of native plants at Midway Atoll more than doubled, and some native species, such as kāwelu, expanded in range due to outplanting efforts and natural regeneration. Continued propagation and outplanting of native plants since 2008 has magnified these efforts. Endemic plant species include: pōpolo, ʻōhai, kāwelu, ʻaweoweo, maiapilo, ʻenaʻena, ʻanaunau, alena, loulu, kokiʻo kea (*Hibiscus waimeae*); ʻiliahioloʻe, puaokama, ʻānunu, kūpala, loulu, hinahina kahakai, ʻākia (*Wikstroemia uva-ursi*), and loulu lelo (*Pritchardia hillebrandii*) (Starr & Starr, 2015; USFWS, 2015, 2017).

Kure Atoll

There are eight Hawaiian endemics found at Kure Atoll: ʻenaʻena, kāwelu, pōpolo, maiapilo, 'āweoweo, nehe, ʻanaunau, and puaokama (Reynolds & Parrish, 2015; DOFAW, 2018). Two of these were recently reintroduced to Kure: pōpolo (in 2015) and ʻanaunau (in 2018).

Table S.LR.8.8. Species name and locations of Hawaiian endemics found in PMNM.

Species (E) = endangered	Common Name	Main Hawaiian Islands	Papahānaumokuakea
Boerhavia herbstii	Alena	Hawaiʻi, Kahoʻolawe, Maui, Lānaʻi, Oʻahu	Lisianski, Pearl and Hermes, Midway
Capparis sandwichiana	Maiapilo	Hawaiʻi, Kahoʻolawe, Maui, Lānaʻi, Molokaʻi, Oʻahu, Kauaʻi, Niʻihau, Kaʻula	Laysan, Pearl and Hermes, Midway (introd), Kure (introd)
Chenopodium oahuense	ʻĀweoweo	Hawaiʻi, Kahoʻolawe, Maui, Lānaʻi, Molokaʻi, Oʻahu, Kauaʻi, Niʻihau, Kaʻula	Mokumanamana, Nihoa, French Frigate Shoals, Laysan, Lisianski, Midway (introd), Kure (introd)
Eragrostis variabilis	Kāwelu	Hawaiʻi, Kahoʻolawe, Maui, Lānaʻi, Molokaʻi, Oʻahu, Kauaʻi, Niʻihau	Nihoa, Mokumanamana, Laysan, Pearl and Hermes, Lisianski, Midway, Kure
Hibiscus waimeae	Kokiʻo kea	Kauaʻi	Midway (introd) Unidentified subspecies
Lepidium bidentatum var. o-waihiense	ʻAnaunau	Hawaiʻi, Maui, Lānaʻi, Molokaʻi, Oʻahu, Kauaʻi	Laysan, Pearl and Hermes, Midway (reintrod), Kure (reintrod)
Melanthera integrifolia	Nehe	Hawaiʻi, Kahoʻolawe, Maui, Lānaʻi, Molokaʻi, Oʻahu, Kauaʻi, Niʻihau	Laysan, Kure
Nama sandwicensis	Hinahina kahakai	Hawaiʻi, Maui, Lānaʻi, Molokaʻi, Oʻahu, Kauaʻi, Niʻihau, Lehua	Laysan, Lisianski, Midway (introd)
Portulaca villosa (E)	ʻIhi	Hawaiʻi, Kahoʻolawe, Maui, Lānaʻi, Molokaʻi, Oʻahu, Kaʻula	Nihoa
Pritchardia hillebrandii	Loulu lelo	Molokaʻi	Midway (introd)

Species (E) = endangered	Common Name	Main Hawaiian Islands	Papahānaumokuakea
Pritchardia remota (E)	Loulu or Nihoa fan palm	Niʻihau	Majority of the global population of this species is found at Nihoa
Pseudognaphalium sandwicensium var. sandwicensium	ʻEnaʻena	Hawaiʻi, Maui, Lānaʻi, Molokaʻi, Oʻahu, Kauaʻi, Niʻihau	Midway, Kure
Santalum ellipticum	ʻIliahioloʻe or coastal sandalwood	Hawaiʻi, Kahoʻolawe, Maui, Lānaʻi, Molokaʻi, Oʻahu, Kauaʻi, Niʻihau	Laysan, Midway (introd)
Sesbania tomentosa (E)	ʻŌhai	Hawaiʻi, Kahoʻolawe, Maui, Lānaʻi, Molokaʻi, Oʻahu, Kauaʻi, Niʻihau	Nihoa, Mokumanamana, Midway, Kure
Solanum nelsonii (E)	Pōpolo	Hawaiʻi, Maui, Molokaʻi, Oʻahu, Kauaʻi, Niʻihau	Nihoa, Laysan, Pearl and Hermes, Midway, Kure
Sicyos maximowiczii	Puaokama or ʻānunu	Niʻihau, Oʻahu	Majority of the global population is likely in the NWHI: Kure, Midway, Pearl and Hermes, Laysan, Lisianski
Sicyos pachycarpus	Kūpala or ʻānunu	Hawaiʻi, Maui, Lānaʻi, Molokaʻi, Oʻahu, Kauaʻi	Nihoa, Laysan, Midway (introd)
Sicyos semitonsus	ʻĀnunu		Laysan, Midway May be a hybrid of the two Sicyos species listed above (Wagner, Herbst, & Sohmer, 1999)
Wikstroemia uva-ursi	ʻĀkia	Maui, Molokaʻi, Oʻahu, Kauaʻi	Midway (introd)
Euphorbia celastroides var. celastroides	ʻAkoko	Niʻihau, Kauaʻi	Nihoa
Rumex albescens	Huʻahuʻako	Oʻahu, Kauaʻi	Nihoa
Panicum torridum	Hākonakona	Hawaiʻi, Kahoʻolawe, Maui, Lānaʻi, Molokaʻi, Oʻahu, Kauaʻi, Niʻihau, Lehua, Kaʻula	Nihoa, Mokumanamana

Sources: Imada, 2012; Starr & Starr 2013, 2015; Taylor, 2017; USFWS, 2013, 2014, 2015, 2016, 2017, 2018; DOFAW, 2018; Klavitter, 2006

Management Implications

Access and Data Limitations

Limited time and resources have historically limited the scope of data collection for these species. Midway Atoll and Kure Atoll are the only locations in the monument where monitoring and management of endemic endangered plants occurs year-round. Operation of the year-round USFWS Habitat

Restoration Program at Laysan Island was suspended in 2013 due to federal budget shortfalls, and the field station at Tern Island (French Frigate Shoals) was closed in 2012 due to infrastructure and resource considerations. These closures effectively terminated species monitoring, active habitat restoration, invasive species removal, and native plant propagation at these locations. Additionally, Nihoa Island monitoring remains subject to resource availability and seasonal access factors.

Propagation and Habitat Management

Good progress has been made in managing habitats and propagating native species, especially at Midway and Kure Atolls. Since 1999, a number of native plant species have been reintroduced to the NWHI, notably Laysan, Midway, and Kure, from stock elsewhere in the islands. Additionally, some of the rarer native plants already occurring on Laysan, Kure, and Midway were propagated and planted onsite. Propagation and outplanting of native plants also was a focus of management for more than a decade at Laysan Island and French Frigate Shoals. Combined with non-indigenous species control, these propagation efforts have resulted in increased distributions of endemic plants in the monument. However, most populations of these species remain small and therefore vulnerable. Managers should consider a plan for ex situ storage, propagation, and cloning of wild specimens with the goal of maximizing genetic diversity.

Translocation

Climate change may pose a risk to all of these narrowly distributed plants, although specific impacts are not known due to a lack of sufficient spatial resolution in modeling efforts. However, if the recent storms are any indication, populations of these species are unlikely to survive on the low islands (i.e., all NWHI except Mokumanamana and Nihoa). Long-term planning and preparation of high island habitats may provide safe haven for these populations in the event low-lying areas become inhospitable.

Biosecurity

Strict regulation of access throughout the monument has been a major factor in maintaining the overall health of the terrestrial ecosystems and all of the endangered species on which they rely. Particularly, strict protocols for managers and visitors to the monument should be consistently enforced to minimize the threat of introduction of non-indigenous species and limit the spread of those already occurring within the monument.

Non-Indigenous Species Management

Continued monitoring and control of non-indigenous species is needed. Non-indigenous plant species are a serious threat, as they degrade habitat and outcompete native species (see section 8 of this report). Invasive plant species of concern include golden crownbeard, common sandbur, New Zealand spinach, bristly foxtail (*Setaria verticillata*), and pigweed (*Portulaca oleracea*). The non-indigenous gray bird grasshopper is a threat to all native plant species on Midway, Laysan, and Nihoa (Richardson, 2007; PMNM, 2008). This recent invader previously caused widespread destruction of native plants on Nihoa by defoliation (Wegman et al., 2002). Introduced ants both feed on plants and cultivate sucking insects (such as aphids and scale) from which they collect honeydew or nectar. Predation by rodents is another significant threat to all endangered plant species (Cuddihy & Stone, 1990).

Acknowledgements

Dr. Sheldon Plentovich, Rachel Rounds, and Cindy Rehkemper contributed to this assessment.

HERITAGE RESOURCES

The condition of historic and Native Hawaiian cultural resources assessed in this report refers only to the physical state of the resources. The integrity, which includes the intangible values of the resources, is not reflected in the assessments presented here.

9. What is the condition of known maritime archaeological resources and how is it changing?

Maritime Archaeological Resources

Fair

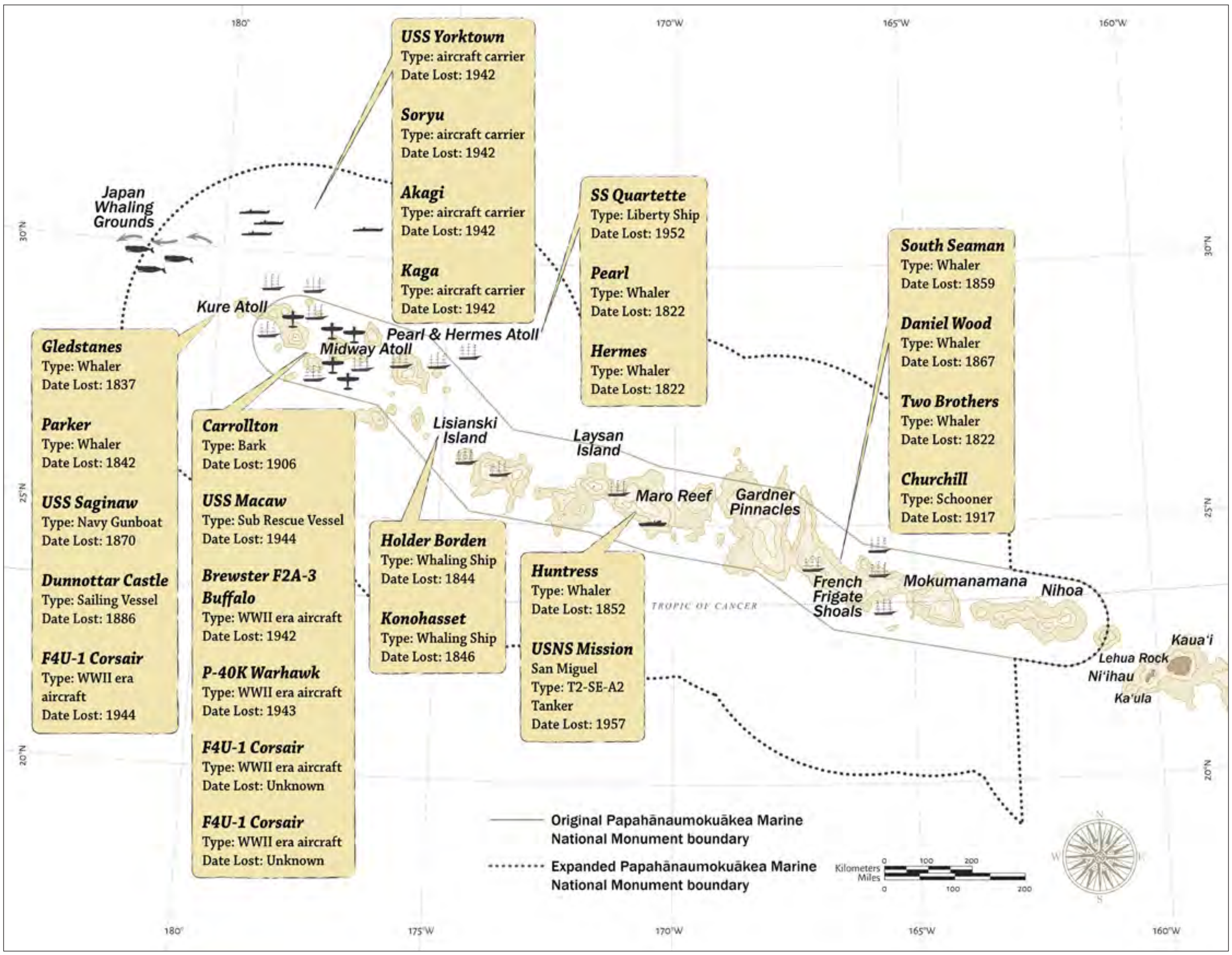


Figure S.HR.9.1. Distribution of select maritime heritage sites in the monument. Image: PMNM

Status

The expert rated status is Fair with medium evidence on the basis that the diminished condition of maritime heritage resources has reduced their historical and scientific value and may affect the eligibility of some sites for listing in the National Register of Historic Places. Maritime archaeologists conduct archaeological surveys to characterize maritime heritage resources on the seafloor as a pivotal part of the effort to develop an inventory and gain a better understanding of the resources in PMNM. Characterization begins with a historical inventory of the potential resources and proceeds to the field research component, which involves physically locating and documenting these sites. Field research conducted annually by NOAA archaeologists has resulted in the documentation of 26 maritime heritage sites (of potentially more than 126 sites), including 18 shipwreck sites and seven World War II-era sunken aircraft sites, as well as one submerged historic seaplane landing area (Table S.HR.9.1).

Table S.HR.9.1. Inventory of maritime heritage sites, including both known wrecks and documented and verified sites.

Resources	Nihoa	Mokumanamana	French Frigate Shoals	Gardner Pinnacles	Maro Reef	Laysan Island	Lisianski Island	Pearl & Hermes Atoll	Midway Atoll	Kure Atoll	TOTAL
Whaling Shipwreck Sites											
Known historic whaling sites	0	0	3	0	0	1	2	2	0	2	10
Documented historic whaling sites	0	0	1	0	0	0	0	2	0	2	5
Military Craft (Shipwreck Sites)											
Known historic military shipwreck sites	0	0	1	0	1	0	0	1	3	1	7
Documented historic military shipwreck sites	0	0	1	0	1	0	0	1	3	1	7
Other Vessels											
Known historic sites (non-whaling/ military)	0	0	5	0	2	5	10	4	6	6	38
Documented historic shipwreck sites (non-whaling/ military)	0	0	1	0	0	1	3	1	1	2	9
Aircraft Sites											
Known historic aircraft sites	0	1	0	0	0	0	0	0	63	2	66

Resources	Nihoa	Mokumanamana	French Frigate Shoals	Gardner Pinnacles	Maro Reef	Laysan Island	Lisianski Island	Pearl & Hermes Atoll	Midway Atoll	Kure Atoll	TOTAL
Documented historic aircraft sites	0	0	1	0	0	1	3	1	1	2	9
Non-Historic Sites Documented	0	0	1	0	0	1	4	3	1	4	14

These sites have been documented at both Phase 1 (general site description) and Phase 2 (thorough site documentation and evaluation of a site for eligibility for inclusion in the National Register of Historic Places) levels. To date, one site, the *Two Brothers* whaling shipwreck at French Frigate Shoals, has been successfully listed on the Hawai'i and National Register of Historic Places. Because most shipwreck events in PMNM occurred due to faulty navigation through low-lying reefs, these shipwreck sites are often shallow and broken apart upon near the reef crest surrounding the atolls. In addition, rapid deterioration occurs from exposure to seawater and harsh weather conditions. For example, a heavy iron whaling trypot at the *Hermes* shipwreck site, which was visibly intact in 2005, was broken apart in subsequent years. A sunken aircraft site, an F4U-1 Corsair at Midway Atoll, was turned upside down on the seafloor from one year to the next following a dramatic storm event. PMNM's remoteness, and the extensive protections afforded through its designations as a coral reef ecosystem reserve, national wildlife refuge, marine national monument, and World Heritage site, have resulted in minimal to nonexistent human impacts on its maritime archaeological sites. This contrasts with the Main Hawaiian Islands, where maritime archaeological resources have been disturbed by the illegal removal of historic artifacts at deep-water shipwreck and sunken aircraft sites, as well as from coastal construction and dredging projects.

Trends

The expert-rated trend is assessed as Declining with medium evidence based on the fact that these resources are continuously experiencing weathering and deterioration, and unlike many natural resources, maritime heritage resources are nonrenewable: once lost, they are gone forever. Though sites are, for the most part, protected from human impacts in the NWHI, heavy storms and dynamic ocean conditions on shallow (<60 ft) reef sites actively degrade site condition, and sites have been observed to break apart and virtually disappear from one season to the next. For example, the *Hoei Maru* shipwreck experienced severe deterioration between 2002 and 2008, and the partially emergent bow section became nearly completely submerged, as seen in Figure S.HR.9.2. Additionally, an F4U-1 Corsair at Midway Atoll was turned upside down by a storm.

Figure S.HR.9.2. *Hoei Maru* shipwreck at Kure Atoll. (a) The wreck in approximately 1976; (b) the bow was still visible emerging from the water in 2003; (c) the bow had deteriorated and was nearly completely submerged in 2008. Photos: (a) Bishop Museum A5764, February 1976; (b) Kelly Keogh; (c) Tane Casserley/NOAA

Management Implications

Monument managers are responsible for managing maritime heritage resources in accordance with the body of laws pertaining to maritime heritage resources. Additionally, inventories of maritime heritage resources meet ONMS performance measure criteria. To date, 26 of over 126 potential maritime heritage sites have been archaeologically surveyed and documented. Ongoing surveys to identify new sites, as well as efforts at long-term protection of sites, fulfill mandated legislation relative to maritime heritage sites and add to what we know about human history in PMNM. Long-term management efforts include monitoring, National Register of Historic Places nominations, and focused interpretive efforts that bring the place to the people (PMNM, 2011a).

The dynamic weather conditions, depth, and vast geography in the NWHI challenge documentation, interpretation, and monitoring of these sites. The resources' vulnerability to the elements and the intensity of the conditions in the NWHI make inventory, documentation, and protection of these sites particularly urgent.

In 2016, PMNM's boundaries were expanded by presidential proclamation. This had profound impacts for the management of maritime heritage resources. An additional 436 sunken aircraft sites and an additional seven shipwreck sites were added to the inventory of potential losses within the boundaries of the monument. Of these, only the USS Yorktown and Japanese aircraft carriers *Kaga* and *Akagi* have been located and investigated; however, the sites are extremely deep and costly to explore. Nevertheless, the Battle of Midway is one of the most significant historical events that took place in the monument and it is important to adequately interpret and protect the resources associated with the event. More research is needed to fully inventory and assess additional resources within the expanded PMNM boundary area.

Shipwrecks present the challenge of being nonrenewable resources that have become integrated into the environment, often as habitat for fish and other marine organisms. In many cases, maritime heritage sites are threatened from the moment of discovery; without careful management, they may vanish entirely. Monitoring provides the information necessary to adjust the protection of a given site to a level commensurate with its vulnerability.

PMNM's ongoing efforts to inventory, document, and protect its maritime heritage sites have been instrumental in opening a window to the seafaring past. Using the cultural landscape approach (a method for integrating and interpreting the relationships between archaeological, historical, and cultural resources and the environment; Marine Protected Areas Federal Advisory Committee, 2011) to examine the broad themes of human presence in the NWHI and examining the potential for bioerosion measurements at maritime heritage sites will contribute to better long-term protection of these sites. High priority should also be placed upon nominating sites to the National Register of Historic Places. The first PMNM site was nominated to the National Register of Historic Places in August of 2016.

Acknowledgements

Dr. Kelly Keogh contributed to this assessment.

10. What is the condition of known historic resources and how is it changing?

Historic Resources: Midway Atoll

Fair

Status

The expert-rated status for historic resources as they pertain to Midway Atoll is Fair with medium evidence on the basis that the diminishing physical condition of historic resources is beginning to affect their eligibility for listing in the National Register of Historic Places.

In the past, PMNM has defined historic resources as "the non-marine sites, structures, [and] artifacts in the monument associated with the historic period (after first Western contact with Native Hawaiians in 1778). Historic resources in the monument fall into two broad categories: Midway Atoll historic period resources, and those elsewhere in the monument" (PMNM, 2008, p. 143). There has been no comprehensive survey of all the islands in the monument for historic resources, and thus resources at Midway Atoll are used for this assessment.

Historic resources are fragile and once lost cannot be replaced. In Native Hawaiian history, there are accounts of ali'i (Hawaiian nobility) visiting the more remote islands in the chain; however, outside of the archaeological resources found at Nihoa and Mokumanamana, no inventory of historic resources linking these visits currently exists and the condition of these potential resources remains unknown. There have been no pre-contact Native Hawaiian artifacts or structural remains identified at Midway Atoll to date.

The harsh sea air climate has deleterious effects on metal, wood, and reinforced concrete materials. The diminished physical condition of existing historic resources at Midway Atoll is beginning to affect their ability to be used.

Currently, there are 56 pre-1945-era resources determined to be eligible for listing in the National Register of Historic Places or designated as National Historic Landmarks (NHLs); those resources are located on Sand Island and Eastern Island within the atoll. Additionally, seven resources associated with the Cold War era were determined to be eligible for listing in the National Register of Historic Places. Of the 63 resources, less than half are in good condition and being used by the USFWS. For instance, the 10 officers' houses have been rehabilitated are in good condition and in use as residences. The transportation building is still in use and the roof has been replaced, but additional structural repairs are needed. Three shop buildings, the seaplane hangar, theater, and remaining cable station building are in a state of slow deterioration, indicating Fair/Poor ratings. One of the NHL structures has been rehabilitated and is in Good/Fair condition. However, the other five structures are in a state of deterioration, indicating Fair/Poor ratings.

Of the six Cold War-era resources, three are structures that are in Good/Fair condition; three are in deteriorated (Poor) condition, and one is an archaeological ruin in Fair/Poor condition. Table S.HHR.10.1 provides a listing of the 63 historic properties and specific conditions identified at Midway Atoll.

Table S.HHR.10.1. Midway Atoll's historic properties and noted conditions.

Bldg. No.	Common Name	Theme	2019 Rating Notes
S2115	Seaplane ramp	1940–1942	In use, Good/Fair
151	Seaplane hangar	Kahn architecture; 1940–1942	No longer used, Poor
414	OIC, senior	Kahn architecture; 1940–1942	In use, Good
415, 416. 417, 418, 419, 421, 422, 423, 424	Officers' quarters	Kahn architecture; 1940–1942	In use, Good
356	General squadron storehouse, "transportation building"	Kahn architecture; 1940–1942	In use, Good/Fair
363	Torpedo shop with parachute tower	Kahn architecture; 1940–1942	Partial use, Fair
342	Paint and oil storehouse	Kahn architecture; 1940–1942	No longer in use, Fair/Poor
S5247	Brackish water reservoir	1942–1945	Closed
349	Commissary and cold storage	Kahn architecture; 1940–1942	No longer in use, Fair
S3126, S3127	Water reservoirs	1942–1945	In use, Good
361	Electrical switch station	1942–1945	Partial use, Fair/Poor
S6194	ARMCO hut (NHL structure)	Battle of Midway	N/A, Fair
357	Torpedo shop (machine shop)	Kahn architecture; 1940–1942	No longer in use, Poor
259	Theater and offices	Kahn architecture; 1940–1942	No longer in use, Poor
S-1	5-inch gun battery C—"Charlie" (NHL structure)	Battle of Midway	N/A
S-2	3-inch gun battery D—"Dog" (NHL structure)	Battle of Midway	N/A

Bldg. No.	Common Name	Theme	2019 Rating Notes
S-3	Pillbox (NHL structure) near S7125	Battle of Midway	N/A
S-6	Pillbox, south shore	Battle of Midway	N/A
S7124	ARMCO hut (NHL structure)	Battle of Midway	N/A
S7125	ARMCO hut (NHL structure)	Battle of Midway	N/A
643	Cable station-mess hall	Colonization	Not in use, Fair/Poor
N/A (S-9)	5-inch gun battery A—"Able" (SW end of beach)	Battle of Midway	N/A
6-24, 12-30, 3-21	Eastern Island runways	Battle of Midway	N/A
S-7	Metal pillboxes, north side on inner harbor	Battle of Midway	N/A
353	Carpentry shop	Kahn architecture; 1940–1942	No longer in use, Poor
E-3	Metal pillbox, Eastern Island	Battle of Midway	N/A
5187	Small radar building	1942–1945	N/A
631	Radar tower bunker and base	1942–1945	N/A
S956	Underground shelter	Battle of Midway	N/A
S2123	Plaque in Midway memorial	1942–1945	N/A
S2409	Two 5-inch naval guns in Midway memorial	1942–1945	N/A
E-6	Revetments	Battle of Midway	N/A
E-1	3-inch anti-aircraft gun	1942–1945	N/A
S-4	Cemetery: Bauer Road	No theme	N/A

Bldg. No.	Common Name	Theme	2019 Rating Notes
S-5	Three Japanese memorials	No theme	N/A
144	Diesel power plant and salt water pumping station	1942–1945	Poor
354	Power plant	Battle of Midway	Poor
521	Command post	1942–1945	Poor
S9132, S2117	Seaplane ramps	1940–1942	N/A
E-2 (E-21)	Underground bunker, east of runway	Battle of Midway	N/A
E-7, E-8	Possible gun positions, south shore	Battle of Midway	N/A
S-8a and -8b	Torpedo and bomb	1942–1945	N/A
E-4	Metal pillbox (turret)	1942–1945	N/A
E-5	Submarine netting	1942–1945	N/A
Cold War-Era Resources			
2401	Pier 5	Pre-1951, tug pier in inner harbor	Fair
2410 8349	Fallout shelter, cross bunker	Air raid shelter, Cold War-specific, 1957	Fair
2404	All Hands Club	Cold War-specific, recreation, 1957	Fair/poor
5306	Hangar	Cold War-specific, DEW line, etc., 1958	Poor
5309	Transmitter building	Communications, 1960	Poor
963	MILS building remains	Missile Impact Location System, 1967	N/A

Trends

The expert rated trend is Declining with medium evidence on the basis that buildings and structures continue to deteriorate. Unlike many natural resources, historic resources are nonrenewable. Midway Atoll retains buildings related to the World War II base and a few Cold War-era buildings and structures. Six NHL structures are associated with the Battle of Midway. Environmental conditions continue to cause buildings and structures to corrode and deteriorate. Without ongoing, aggressive maintenance and repairs, all of the buildings and structures are at risk for failure.

Management Implications

Due to the remote location of Midway Atoll within PMNM, historic resources are threatened by the high cost of repairs due to lack of local suppliers, the expense of shipping materials to Midway, and the shortage of skilled labor. Environmental conditions and lack of funding for essential maintenance are factors that continue to present the greatest threat to historic resources. USFWS is responsible for managing the historic resources on Midway Atoll National Wildlife Refuge in accordance with the body of laws pertaining to heritage resources. Maintenance and repair of the 63 historic resources is an enormous management responsibility. Midway Atoll is a remote location with no visitor services. Yet, the public has a vested interest in the historic resources, especially those resources related to World War II and the Battle of Midway. Additionally, surveys for historic resources at additional locations within the monument are needed, including Tern Island at French Frigate Shoals. The public expects that historic resources will be well cared for, even if they cannot visit them firsthand.

Acknowledgements

Lou Ann Speulda-Drews, Anan Raymond, and Dr. Kekuewa Kikiloi contributed to this assessment.

11. What is the condition of known Native Hawaiian archaeological resources and how is it changing?

Native Hawaiian Archaeological Resources

Good/Fair ?

Status

The expert-rated status of Native Hawaiian archaeological resources is Good/Fair with medium evidence on the basis that the majority of resources have not been significantly impacted by human disturbance, and historic, scientific, cultural, or educational value have not been diminished; however, natural processes of degradation are ongoing.

Cultural resources (pre-contact Native Hawaiian cultural and archaeological sites) are abundant on Nihoa and Mokumanamana. Though field studies have taken place on these islands over the past decade, the amount of time available to accurately document and study these sites has been limited by the remote nature of these places.

For the last 10 years, field studies on Nihoa and Mokumanamana have focused on baseline mapping and documentation of site content, artifacts, construction, and architecture (Figures S.HR.11.1 & S.HR.11.2). However, many sites and artifacts may remain to be documented. The general assessment of these resources is therefore based solely upon known resources.

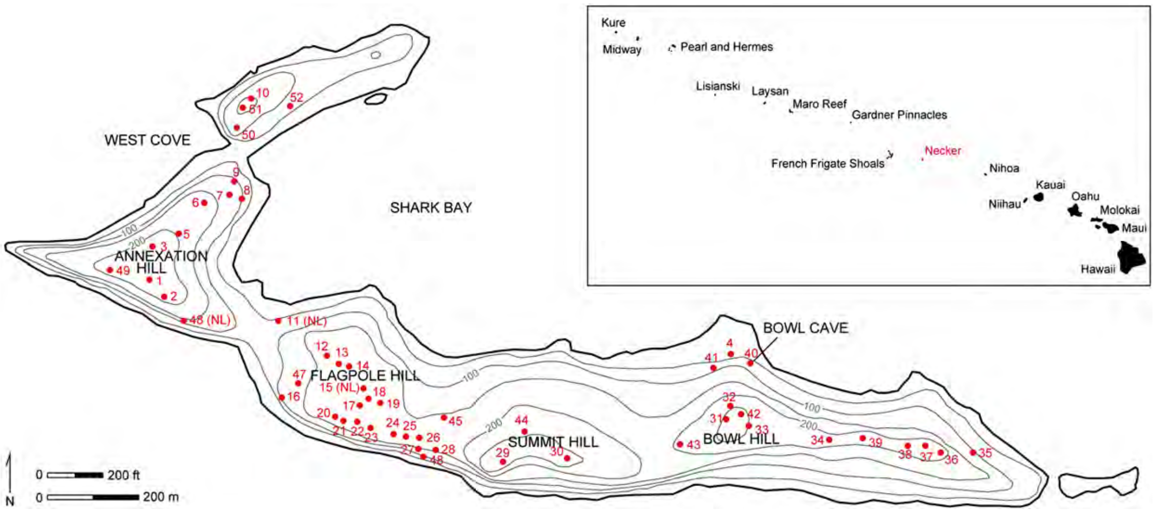


Figure S.HR.11.1. Archaeological resources at Nihoa. Source: Lebo & Johnson, 2007

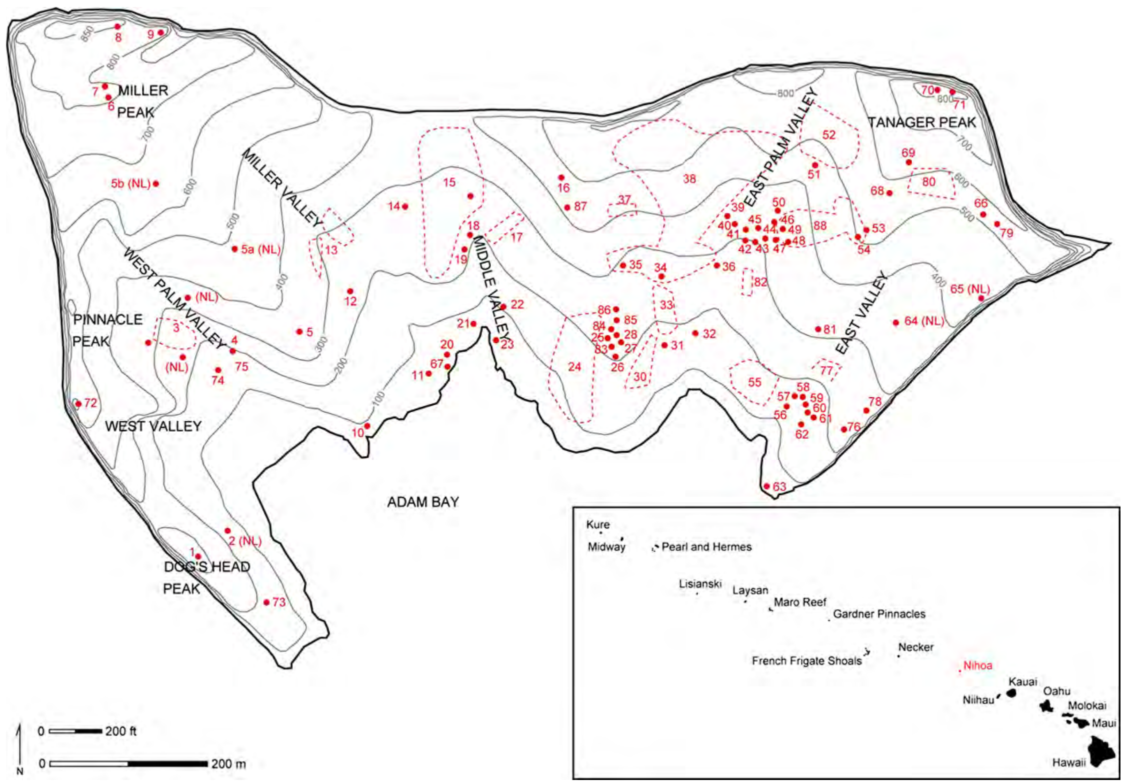


Figure S.HR.11.2. Archaeological resources at Mokumanamana (labeled Necker on the map). Source: Lebo & Johnson, 2007

There are currently 89 known sites at Nihoa and 52 at Mokumanamana, which makes these the two islands with the highest concentration of cultural resource sites in the monument (Tables S.HR.11.1 & S.HR.11.2). Different types of cultural sites have been identified at both Nihoa and Mokumanamana, with the highest number of sites at Nihoa and the highest density of sites at Mokumanamana. Additionally, the physical condition of cultural and historic resources is not necessarily indicative of the integrity and intangible value of resources and, as such, only the physical condition of known cultural resources is assessed and presented in this section.

Table S.HR.11.1. Inventory of Native Hawaiian archaeological resources at Nihoa. Source: Kikiloi, 2012

Attributes	West & West Palm Valleys	Miller & Middle Valley	Middle-East Palm Ridge	East Palm Valley	East Valley	Totals
Number of sites	8	21	17	25	18	89
Habitation Sites						
Residential sites	0	3	4	8	3	18
Open shelters	0	1	4	2	0	7
Cave shelters and overhangs	1	5	1	2	7	16
Total area (m^2)	14	169	160	438	105	886
Religious Sites						
Temples	3	6	0	4	2	15
Shrines	0	2	0	1	0	3
Total area (m^2)	272	301	0	275	115	963
Burial sites	3	0	1	0	3	7
Other Sites						
Agricultural sites	1	3	7	7	2	20
Lithic production sites	absent	present	absent	present	absent	n/a
Unknown function	0	1	0	1	1	3

Total areas for habitation sites were taken from (1) an average of 13.4 m2 per cave and applied per the number of caves in each section of the island and (2) an average of 11.4 m2 per open shelter and applied per number of shelters in each section of the island. Final calculations were rounded to the nearest whole number.

Table S.HR.11.2. Inventory of Native Hawaiian archaeological resources at Mokumanamana. Source: Kikiloi, 2012

Attributes	NW Cape	Annexation Hill	Flagpole Hill	Summit Hill	Bowl Hill	Totals
Number of sites	4	10	21	3	14	52
Habitation Sites						
Cave shelters and overhangs	2	1	1	0	4	7
Total area (m^2)	27	13.5	13.5	0	54	108
Religious Sites						
Temples	1	8	18	2	4	33
Total area (m^2)	42	603	1506	146	426	2723
Other Sites						
Agricultural sites	0	0	2	1	0	3
Lithic production sites	absent	absent	absent	absent	present	n/a
Unknown function	1	1	0	0	5	7

Total areas for habitation sites were taken from an average of 13.5 m2 per cave and applied per the number of caves in each section of the island. Final calculations were rounded to the nearest whole number.

The archaeology of Nihoa and Mokumanamana is integrated with and reflective of Native Hawaiian cosmology, genealogy, spiritual practices, ocean wayfinding and settlement, and the maturation of Native Hawaiian cultural systems. For example, astronomical alignments of site features, particularly large, upright stones (Figure S.HR.11.3), during equinox and solstice periods have been described in recent studies. This research has been informed by previous archaeological publications, Hawaiian language newspaper articles from the 19th and 20th centuries, and traditional stories and migration chants.

Cultural resources are determined to be in good to fair condition because there has been relatively low impact by historical or modern development. However, exceptions are known to exist. A few archaeological sites on Nihoa, including “Site 20” and possibly “Site 21,” have suffered impacts from the activities of historical and recent shore parties that visited the island for scientific work. In addition, a 2016 survey of “Site 20,” which has served as a campsite for the USFWS for over 17 years, found that a front retaining wall was badly broken, an upright stone may have been moved, and a modern terrace had been built to support signage (Kikiloi, 2015). On Mokumanamana, some heiau (Hawaiian temples or sacred sites) were moderately damaged by surveyors of the U.S. Coast and Geodetic Survey in the early 20th century, and others were significantly damaged by practice bombing during World War II (Kikiloi, 2012). A significant amount of degradation and collapse of the upright stones was also noted. There has also been removal of stone idols, upright stones, and artifacts from the island. Upright stones have been removed or relocated to be used to place flags, store documents, and mount beacons for military purposes during the 1800s and 1900s. Bomb craters, metal fragments, and parts of ordnance remain on the island as evidence of past disturbance.

Figure S.HR.11.3. Masked boobies perch atop upright stones at Mokumanamana. Years of guano and weathering have contributed to erosion. Photo: Kaleomanuiwa Wong

The pre-contact Native Hawaiian cultural and archaeological sites in the monument have been significantly altered by natural processes, particularly erosion, mass wasting, and bioturbation due to nesting seabirds and growing vegetation. Many of these sites are located on slopes where thousands of burrowing, subsurface-nesting birds could destabilize the ground, putting them at risk for collapse. While these impacts are common and ongoing, they are natural and mostly unpreventable.

Trends

The expert rated trend for Native Hawaiian resources is Undetermined with limited evidence on the basis that limited research has occurred to assess the condition of Native Hawaiian resources over time in Papahānaumokuākea. However, as discussed above, there are some significant issues of both natural and human origin impacting resource conditions. Over time, the condition of resources is likely to change due to human presence and natural processes.

Management Implications

From a broad perspective, the cultural resources on these islands provide significant traditional and contemporary cultural value to Native Hawaiians while retaining considerable archaeological and historical significance. Although the resources on Nihoa and Mokumanamana benefit greatly by their inclusion in the monument and World Heritage site, it is important that the high-quality information they contain be preserved and documented through Native Hawaiian research and traditional archaeology before further degradation occurs. Research on the heiau and habitation sites has been conducted by Dr. Kekuewa Kikiloi from the early 2000s to present, but more work is needed in these areas, and large areas, such as agricultural sites, have yet to be studied. There also is a need to further document contemporary human impacts to campsites and frequently traveled paths and locations at Nihoa and Mokumanamana as well as other islands in Papahānaumokuākea.

The development of a cultural resource management plan for Nihoa should be considered. The greatest threats to cultural resources are damage from human activities, damage from introduced invasive species, natural processes of weathering and erosion, and damage from climate change-related effects, including increased storm intensity and sea level rise.

Current management efforts for these sites should continue and evolve where appropriate, including: providing a cultural orientation curriculum and workshops to all visitors, minimizing the number of on-island visitations, supporting traditional ocean sailing voyages to the islands for cultural practices that don't require on-island visits, and stabilizing vulnerable sites from the effects of bioturbation, human intrusions, erosion, and increasingly intense and frequent weather events.

Lastly, the integrity and intangible value of resources were not assessed as part of this effort, but they are important aspects that warrant consideration in future condition reports.

Acknowledgements

Anan Raymond, Kalani Quiocho, Kalei Nu'uhiwa, and Dr. Kekuewa Kikiloi contributed to this assessment.

12. Do known historic and archaeological resources pose an environmental hazard and how is this threat changing?

Maritime Archaeological Resources

Good

Status

The expert-rated status is Good with limited evidence on the basis that historical and archaeological sites that might have posed threats in the past are all at least 50 years old, and the threats are most likely negligible or gone. Often the wrecking event itself presents the greatest impact to the site, particularly when the resource is broken apart. In addition to the limited threat that maritime heritage sites present 50 years after the wrecking or crash event, there are no known hazardous cargoes on archaeological sites currently threatening the environment. One maritime heritage site, the USNS Mission San Miguel, was listed on a database maintained by ONMS to identify potentially hazardous maritime heritage resources. Prior to its rediscovery, it was a potential threat due to the cargo it carried and fuel that may have been on board. In 2016, the current location of the USNS Mission San Miguel was discovered and the site was documented by a team of maritime archaeologists. Archaeologists and resource protection specialists determined that the USNS Mission San Miguel was not a threat to the environment. Of the sites that have been discovered and documented in PMNM, none pose a threat to the environment. Maritime heritage surveys allow for the assessment of sites and their environmental impact. For this reason, it is important that any newly discovered maritime heritage sites are adequately surveyed and assessed.

Trends

The trend is rated as Not Changing because historic sites in the monument are at least 50 years old, and they are likely to have reached an equilibrium with their surrounding environment.

Management Implications

Maritime archaeologists are able to work in collaboration with resource protection specialists in order to evaluate environmental threats from maritime heritage resources or more recent shipwrecks. In many cases, historic shipwreck sites have become part of their surrounding environment and serve as artificial reefs (Smith, 2010).

With the expansion of monument boundaries in 2016, the maritime heritage resource inventory increased to include the sunken ship and aircraft sites associated with the Battle of Midway in deeper water. Once discovered, assessment of these sites should include their potential impacts to the environment, including any visible fluid leaks from the vessel.

Acknowledgements

Dr. Kelly Keogh contributed to this assessment.

Historic Resources: Midway Atoll

Good/Fair —

Status

The expert rated status is Good/Fair with limited evidence on the basis that rehabilitation and abatement efforts have mitigated the risk of hazards. Comprehensive surveys of environmental hazards from archaeological sites on land have been conducted. There are two dumps on Midway Atoll (Bulky Waste and Rusty Bucket), but they are not considered to be archaeological sites. Historic properties on Midway have been identified to have lead paint, some of which dates back to the early 1900s. Laysan albatross chicks have been found to show symptoms of lead toxicity, which may be a result of exposure to lead paint chips. Between 2005–2010, USFWS treated historic properties for lead paint. All of the historic properties on Midway Atoll have now been treated for lead paint by encapsulation. Officers' houses and Midway House have been rehabilitated by removing lead paint and asbestos materials. Most of the historic shop buildings are sided with transite, which contains an inert form of asbestos. As buildings deteriorate, there is an increased threat of exposure to the environment from lead and asbestos. Removal of buildings may be necessary to reduce the environmental risk. Deteriorating concrete, such as the seawall and paved surfaces, is also of concern.

Trends

The trend is rated as Not Changing with limited evidence on the basis that remediation and rehabilitation work has been ongoing by USFWS to encapsulate exterior lead paint, but there are still threats from deteriorating buildings with interior contaminants, as well as concrete surfaces and infrastructure.

Management Implications

USFWS has abated lead paint on all historic properties. Continued monitoring and maintenance is needed.

Acknowledgements

Lou Ann Speulda-Drews contributed to this assessment.

Native Hawaiian Archaeological Resources: Nihoa & Mokumanamana

Good —

Status

The status is rated as Good with limited evidence. These archaeological resources do not pose any environmental hazard, as most of the sites consist only of low dry stack stone masonry. Some sites in East Palm Valley on Nihoa do contain large retaining walls, which could potentially harm birds or plants should they ever become destabilized or collapse.

Unexploded ordnance left over from the military bombing on Mokumanamana can be found rusting on stone outcrops, and shells are still embedded there. Metal fragments were found in the bomb pits documented during a survey in 2008–2009. At least 23 bomb craters (presumably World War II-era) were identified and documented at or near archaeological sites on Mokumanamana (Raymond, 2009).

Trends

Limited research has occurred to assess the condition of Native Hawaiian resources over time in Papahānaumokuākea and for this reason, the trend is assessed as Undetermined. However, as previously discussed, as weathering and erosion progress, some structures could topple or roll.

Management Implications

To be able to thoroughly assess changes in the potential for resources to pose hazards, more detailed and frequent monitoring and research are needed. However, the relative contribution of cultural resources as sources of environmental hazards is expected to be minimal.

Acknowledgements

Anan Raymond, Dr. Kekuewa Kikiloi, and Kalani Quiocho contributed to this assessment.

The Marine Debris Team loads a small boat with derelict fishing gear at Lisianski Island. Image: NOAA

RESPONSE TO PRESSURES

This section provides a summary of existing and proposed responses to pressures on marine resources of Papahānaumokuākea Marine National Monument. A spectrum of agency responses include: regulations, zoning, management plans, programs, and specific responses to individual pressures. Existing management responses and actions are enacted to implement the final Papahānaumokuākea Marine National Monument regulations issued by NOAA and U.S. Fish and Wildlife Service on August 29, 2006, which codified the prohibitions and management measures set forth in Presidential Proclamation 8031. There are additional federal and state regulations that apply to the Hawaiian Islands National Wildlife Refuge, Midway Atoll National Wildlife Refuge, and the State of Hawaiʻi Northwestern Hawaiian Islands Marine Refuge. Select applicable (but non-exhaustive) jurisdictional authorities include:

- Antiquities Act, 54 U.S.C. § 320301, et seq.;
- Proclamation 8031 of June 15, 2006, 71 FR 36443 (June 26, 2006);
- Proclamation 8112 of February 28, 2007, 72 FR 10031 (March 6, 2007);
- Proclamation 9478 of August 26, 2016, 81 FR 60227 (August 31, 2016);
- Papahānaumokuākea (aka Northwestern Hawaiian Islands) Marine National Monument regulations, codified in 50 CFR Part 404 (2006);
- Executive Order 13178 of December 4, 2000, 65 FR 76903 (December 7, 2000);
- Executive Order 13196 of January 18, 2001, 66 FR 7395 (January 23, 2001);
- Executive Order 10,413, 17 FR 10,497 (November 17, 1952);
- State of Hawaiʻi Organic Act of April 30, 1900, c339, 31 Stat. 141, § 2; and Hawaiʻi Admission Act of March 18, 1959, Pub. L. 86-3, 73 Stat. 4, § 2;
- Submerged Lands Act, Pub. L. No. 31, ch. 65, title I,§ 2, 67 Stat. 29 (1953) (codified as amended at 43 U.S.C. §§ 1301-1315 (2013));
- Hawaiʻi Constitution, Article XI, §§ 1, 2, 6, and 9; and Article XII, §§ 5, 6 and 7;
- Hawaiʻi Revised Statutes, Title 1, Chapters 6E and 10; Title 10, § 128D-4; Title 12, §§ 171-3, 183D-8, 187A-8, 188-37, 188-53, 195D-5, 199-3; and Hawaiʻi Administrative Rules Title 13, Chapters 60.5 and 126, and other applicable law;
- National Marine Sanctuaries Act, as amended, 16 U.S.C. § 1431, et seq., including National Marine Sanctuaries Amendments Act of 2000, Pub. L. 106-513 § 6(g);
- Endangered Species Act of 1973, as amended, 16 U.S.C. § 1531, et seq.; Marine Mammal Protection Act of 1972, 16 U.S.C. § 1361, et seq.;
- Magnuson-Stevens Fishery Conservation and Management Act, 16 U.S.C. § 1801, et seq.;
- National Wildlife Refuge System Administration Act of 1966, as amended, 16 U.S.C. §§ 668dd-ee;
- Refuge Recreation Act, 16 U.S.C. § 460k-3;
- Fish and Wildlife Act of 1956, 16 U.S.C. § 742f;
- Fish and Wildlife Improvement Act of 1978, 16 U.S.C. § 742;
- Fish and Wildlife Coordination Act of 1934, 16 U.S.C. § 661;
- Organization of Executive Agencies, Executive Order 6166 (June 10, 1933);
- An Act Ratifying All Reorganization Plans, Public Law 98-532 (Oct. 19, 1984), 98 Stat. 2705.

Special Preservation Areas are discrete, biologically important areas of the monument. Uses within Special Preservation Areas are subject to access restrictions. Special Preservation Areas are used to avoid concentrations of uses that could result in declines in species populations or habitats, to reduce conflicts between uses, to protect areas that are critical for sustaining important marine species or habitats, or to provide opportunities for scientific research. The Special Preservation Areas cover a total of 6,802 square miles, including the 924-square-mile Midway Atoll Special Management Area. The Ecological Reserves cover a total of 37,762 square miles.

NOAA and USFWS monument regulations for Special Preservation Areas and Special Management Areas state that except due to emergencies and law enforcement activities, the following activities are prohibited without a valid permit:

- Discharging or depositing any material into Special Preservation Areas or the Midway Atoll Special Management Area except vessel engine cooling water, weather deck runoff, and vessel engine exhaust; and
- Swimming, snorkeling, or closed- or open-circuit scuba diving within any Special Preservation Area or Midway Atoll Special Management Area.

PERMITTING TO ADDRESS PRESSURES

Papahānaumokuākea's permitting program is designed to manage and minimize human impact, while increasing the conservation protection for Papahānaumokuākea's natural, cultural, and historic resources and essentially functions as the implementation of management. The permitting program was developed as a specific tool to implement the Co-Trustee regulations outlined above and eliminate the need for multiple permits to be issued by the co-managing agencies. All activities, regardless of location within PMNM, are either prohibited (not allowed), exempted (no permit is needed), or regulated.

Activities proposed to occur in State of Hawai‘i waters (0–3 nautical miles from all emergent lands, excluding Midway Atoll) must also be approved by the State of Hawai‘i Board of Land and Natural Resources, pursuant to Section 13-60.5-6 Hawai‘i Administrative Rules.

The following activities are prohibited in Papahānaumokuākea:

- Exploring for, developing, or producing oil, gas, or minerals within the monument;
- Using or attempting to use poisons, electrical charges, or explosives in the collection or harvest of a monument resource;
- Introducing or otherwise releasing an introduced species from within or into the monument; and
- Anchoring on or having a vessel anchored on any living or dead coral with an anchor, anchor chain, or anchor rope.

The following activities are exempted from Papahānaumokuākea's permitting program:

- Response to emergencies threatening life, property, or the environment;
- Law enforcement activities;
- Activities and exercises of the Armed Forces (including the United States Coast Guard); and
- Passage without interruption. (For notification requirements when passing through the monument, please visit https://www.papahanaumokuakea.gov.

The following activities are regulated through the monument's permitting process:

- Further the understanding of monument resources and qualities through research;
- Further the educational value of the monument;
- Assist in the conservation and management of the monument;
- Allow Native Hawaiian practices;
- Allow a special ocean use;
- Allow recreational activities within the Midway Atoll Special Management Area.

The monument issues permits in six categories:

1. Research
2. Education
3. Conservation and Management
4. Native Hawaiian Practices
5. Special Ocean Use
6. Recreation (limited to Midway Atoll Special Management Area)

Together, these permits and the regulations listed above make up the framework for addressing responses to pressures. In addition, monument Co-Trustees developed and are currently implementing a joint management plan (released in December 2008) containing 22 action plans that address six priority management needs. Further examples of management responses to pressures are also outlined below.

CLIMATE CHANGE, DISEASES, AND CORAL BLEACHING

The direct and indirect effects of climate change are significant concerns. Current science suggests that climate change is likely to have profound effects on the ecosystems and protected species found in the Monument (PMNM, 2011). With coral reefs around the world in decline, the Northwestern Hawaiian Islands present a unique opportunity to characterize an intact coral reef ecosystem and to begin to understand the degree of natural variability in an ecosystem relatively free of local anthropogenic influences. Studying these remote ecosystems may also make an important contribution toward understanding the impacts of global climate change on coral reefs.

The Monument Management Board and partners have developed a Climate Change Vulnerability Assessment with the purpose of understanding the likely effects of climate change on natural and cultural resources of the Monument and providing guidance for Monument managers (Wagner & Polhemus, 2016).

Ecosystem- and climate change-specific monitoring efforts are being conducted by management agencies. Examples include assessments of fundamental changes in species composition and distribution for climate sensitive species such as corals, as well as direct monitoring of calcification rates and calcification minerals in the ocean. For example, multi-year monitoring was conducted to evaluate the impacts to corals and the ecosystem from the 2014 coral bleaching event. Using cutting edge technology, such as 3-D photogrammetry, the monument is in a better position than ever to assess the impacts of climate change to coral reef ecology and habitats. However, research gaps related to other aspects of climate change must continue to be evaluated.

Figure R.1. Bleached coral (*Montipora dilatata*) at Lisianski Island. The lavender-colored coral in the left foreground retained its normal healthy pigmentation; all of the pale coral surrounding it was bleached due to high ocean temperature. Image: NOAA and Courtney Couch/Hawai'i Institute of Marine Biology

Another example includes protected species monitoring and translocations. The significant damage to important protected species breeding habitat in the monument (see Question 2 in the State of Monument Resources section) has spurred conversations about species translocation. To date, seabirds, land birds, and Hawaiian monk seals have been translocated within the monument and between the monument and the MHIs.

NON-INDIGENOUS AND INVASIVE SPECIES

Due to the fact that it is difficult, if not impossible, to determine whether a species will become invasive in a given environment, the majority of efforts are focused on preventing all non-indigenous species from entering monument ecosystems. Existing NOAA and USFWS regulations prohibit introducing or otherwise releasing an introduced species from within or into the monument. Additionally, best management practices are typically required of permittees to prevent the spread of non-indigenous species or disease.

One of the most proactive ways the monument prevents the introduction of non-indigenous species is by performing hull inspections, which permitting requires. Biosecurity experts complete a risk assessment coupled with the visual inspection of hulls for every vessel which transits into the monument. Inspections are performed using a variety of methods, including remotely operated vehicles and scuba diving. If vessels are fouled with marine organisms, these must be removed before they can transit to the monument. Additionally, vessels are required to be professionally inspected for rodents and be rodent-free before accessing monument waters.

Monitoring of established non-indigenous species is also conducted in conjunction with interagency coordination, education, and outreach activities.

In 2019, the Monument Management Board designated an interagency technical Invasive Algal Working Group comprised of scientists and biosecurity specialists to: 1) identify data gaps and 2) develop best management practices (BMPs) for biosecurity regarding the invasive alga Chondria tumulosa found at Pearl and Hermes Atoll in 2019 (see Question 7 in the State of Monument Resources section). The BMPs that were developed were adopted in early 2020 as part of the standard biosecurity conditions that apply to all persons operating at Pearl and Hermes Atoll.

Figure R.2. A biosecurity expert diver inspects a hull for non-indigenous species on a vessel before it transits to the monument. Image: NOAA

MARINE POLLUTION

The impacts of marine debris upon the ecological health of Papahānaumokuākea Marine National Monument have not been fully documented due to the large size and remoteness of the region, as well as the historical and ongoing nature of the problem. Mortality as the result of entanglement in derelict fishing gear, primarily nets, has been documented for several mobile marine species in the NWHI. Marine debris impacts upon the Hawaiian monk seal are of particular concern due to its highly endangered status. Between 1982 and 2019, up to 404 Hawaiian monk seals were observed to be entangled in derelict fishing gear in the monument. Monument management agencies actively disentangle animals, which directly prevents mortality of entangled individuals.

Existing NOAA and USFWS regulations prohibit discharging or depositing any material into the monument or that subsequently enters the monument and injures any resources.

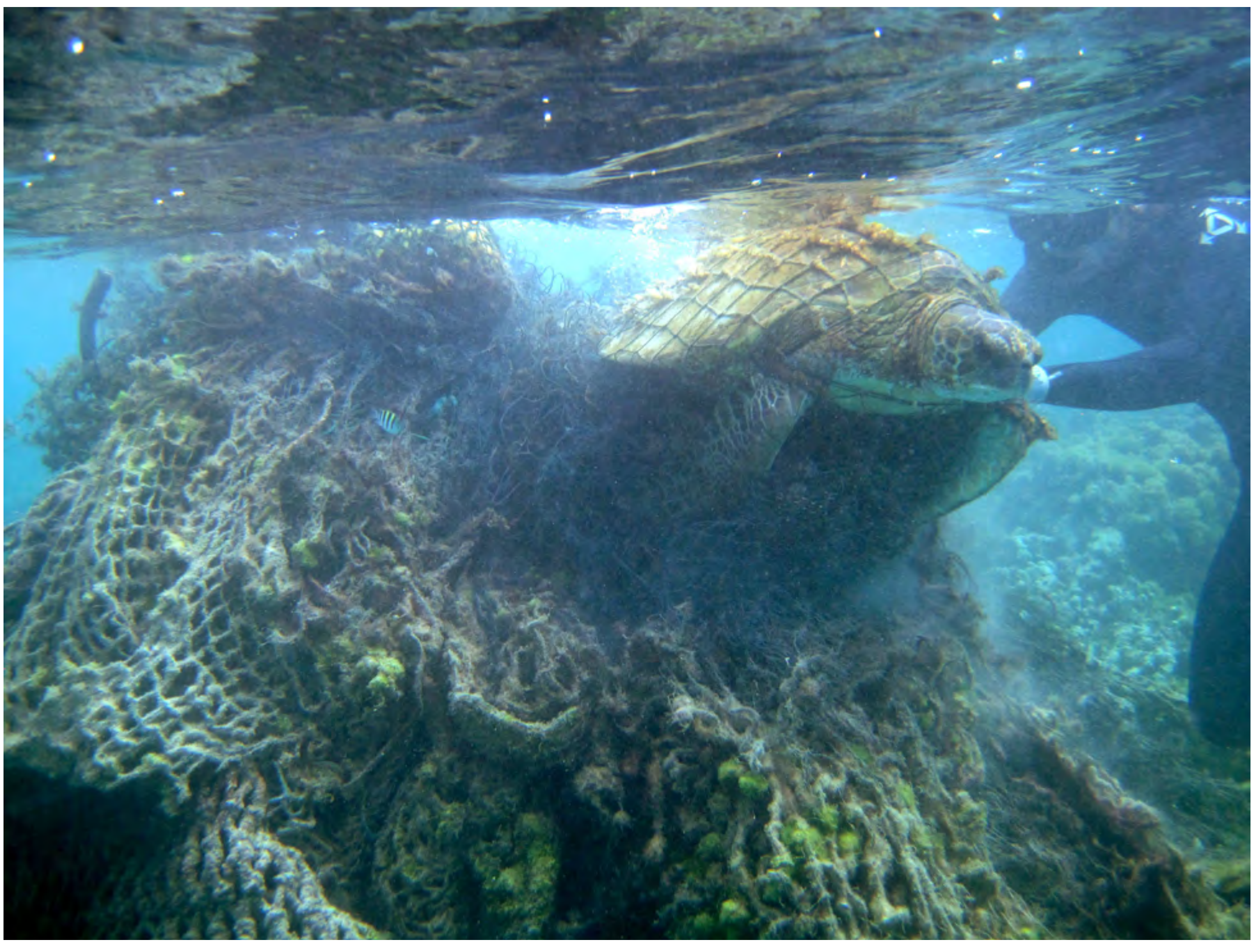


Figure R.3. A NOAA diver frees a green turtle entrapped in marine debris in the monument. Image: PIFSC

The desired outcome of the monument managing agencies is the elimination of marine debris and derelict fishing gear from the monument. However, complete elimination of marine debris in the near future is impractical due to the cost, the size of the area, and continual influx of new debris. Ultimately, the only solution is to change the human behaviors that produce debris. Nonetheless, removal of existing debris, detection and prevention of incoming debris, and education to prevent generation of more debris are the achievable strategies to reduce overall impacts.

Between 2009–2018, PIFSC removed 318 metric tons of marine debris from the monument and 923 metric tons in total since efforts started in 1996. In 2018, a 41-day mission involving two ships successfully removed over 74 metric tons of marine debris from shallow coral reef and shoreline environments (Figure R.4).

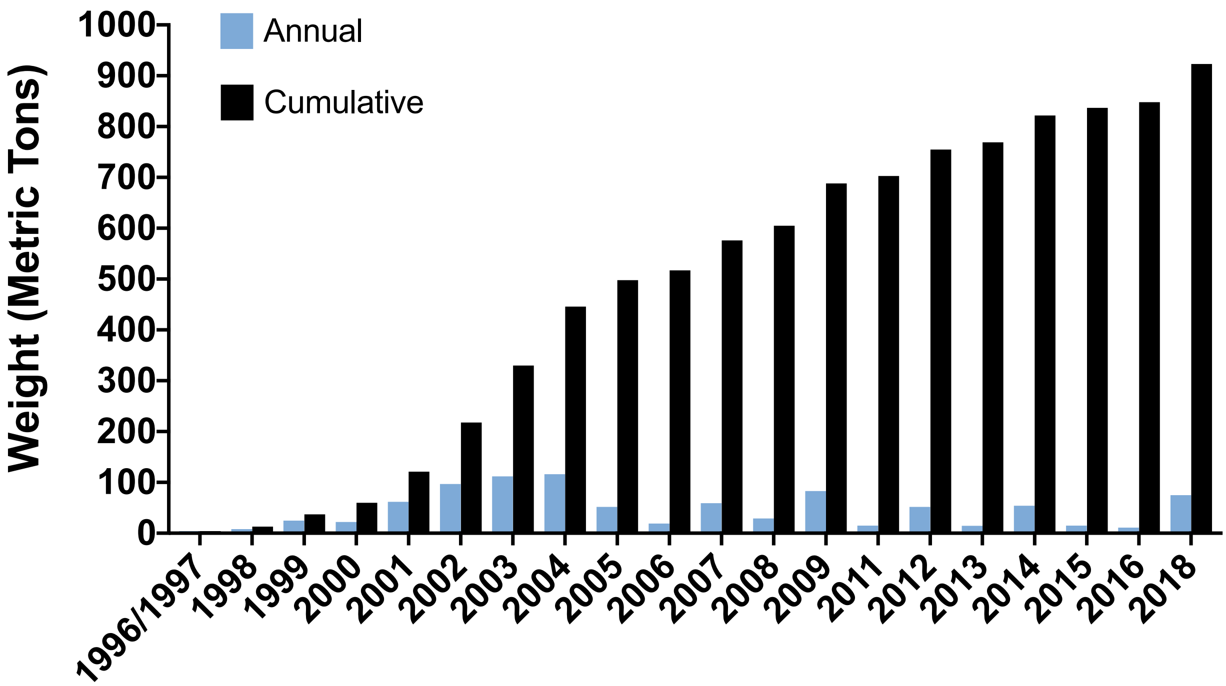


Figure R.4. Annual and cumulative weight of marine debris removed by PIFSC from the Northwestern Hawaiian Islands. Source: PIFSC

FISHING

Previously established commercial fisheries have been closed and other commercial fishing has been prohibited in the monument since its establishment in 2006 and in State of Hawai‘i waters since 2005, with the exception of bottom fishing, which ended in January of 2010. In addition, removing, moving, taking, harvesting, possessing, injuring, disturbing, or damaging, or attempting to remove, move, take, harvest, possess, injure, disturb, or damage any living or nonliving monument resource is also prohibited by the 2006 designation. Recreational fishing is allowed at Midway Atoll and in the monument expansion area.

The NOAA Office of Law Enforcement, together with USFWS, the Hawai‘i Division of Conservation and Resources Enforcement, and the U.S. Coast Guard, enforce fishing regulations, conduct investigations, and work with prosecutors to address both domestic and international illegal fishing activities. The collaborative monitoring, control, and surveillance program consists of both electronic monitoring as well as physical law enforcement patrols. The NOAA Office of Law Enforcement and U.S. Coast Guard monitor fishing vessel activity 24 hours a day through a variety of electronic systems, including NOAA's domestic fishing vessel monitoring system, international regional fisheries management organizations' vessel monitoring systems, and automatic identification system reporting. Additionally, both opportunistic as well as directed aerial and surface law enforcement patrols are conducted by the U.S. Coast Guard in coordination with the NOAA Office of Law Enforcement. Between 2009–2019, these efforts identified a number of illegal fishing incidents, including four domestic cases involving Hawai‘i-based longline vessels that resulted in initial assessments totalling over $154,000 (NOAA Office of General Counsel, 2020).

VESSEL HAZARDS AND GROUNDINGS

Vessel activities can introduce hazards to the marine environment. Some are biological in nature (e.g., the threat of non-indigenous species introductions and interaction with protected marine species). Other environmental threats from vessels include: waste, effluent, bilge and ballast water discharge, light and noise pollution, and anchor damage.

NOAA and USFWS monument regulations stipulate that, except due to emergencies and law enforcement activities, deserting a vessel aground, at anchor, or adrift is prohibited within the monument. Most significantly, the 2008 International Maritime Organization designation of PMNM as a Particularly Sensitive Sea Area (1 of only 14 in the world) ensures that nautical charts inform mariners of areas to be avoided and requires reporting when conducting innocent passage through the monument.

Responses to vessel hazards and groundings include prevention, research, removal, and salvage. Strategies for prevention include: developing protocols and practices for safe vessel operations with jurisdictional partners; informing monument users about hazards, regulations, permit requirements, and compliance regarding vessel operations; investigating domestic and international shipping designations; working with NOAA and the U.S. Coast Guard to update nautical charts and notices to mariners; and risk assessment.

Monument management agencies respond to groundings to the extent possible. Two buoy grounding incidents occurred at Lisianski Island in 2015 and 2019. The buoy grounded in 2015 was salvaged (Figure R.5), the resulting damage was surveyed using 3D photogrammetry, and recovery will be monitored. At the time of publication, the buoy lost in 2018 remains grounded, however there are active plans for salvage and damage assessment.

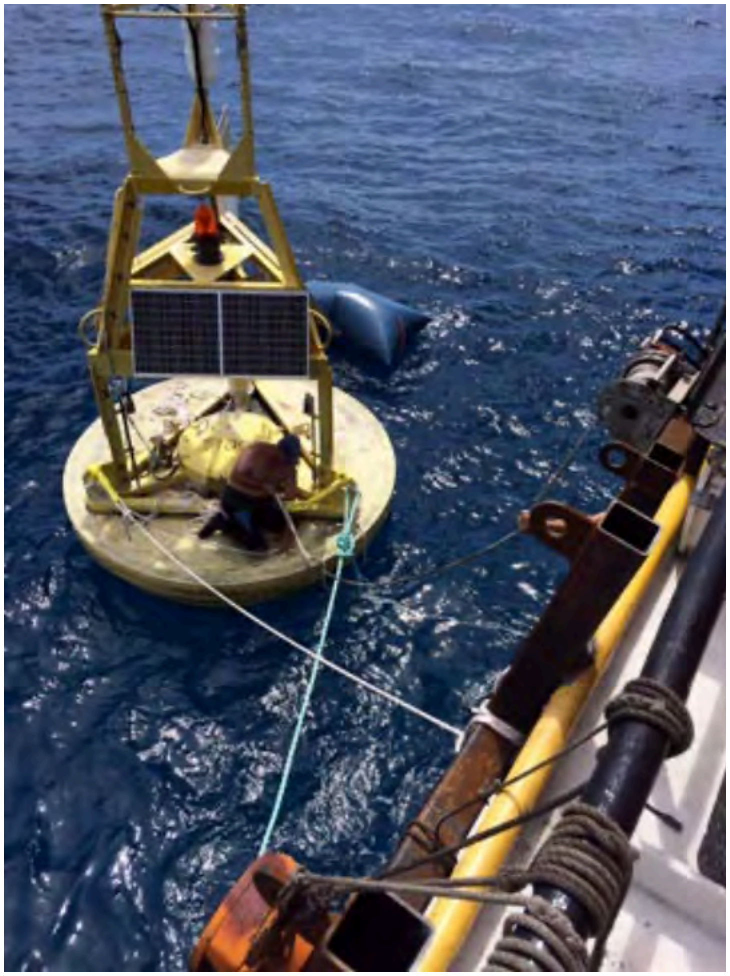


Figure R.5. Buoy grounded in 2015 was removed in 2016 from Lisianski Island. Image: PMNM

TOURISM AND RECREATION

Ocean-based ecotourism and recreation can provide significant educational opportunities, build constituencies, and provide assistance to natural resource managers. However, these activities can also lead to wildlife disturbance, habitat degradation, and pollution.

It is a goal of the monument to prevent, avoid, or minimize negative human impacts associated with ocean-based ecotourism and recreation by allowing access only for those activities that do not threaten the natural character or biological integrity of the monument or Native Hawaiian cultural, historic, or maritime heritage resources. Midway Atoll National Wildlife Refuge is the only area of the monument where recreational activities are permitted. Access was previously controlled by issuing special ocean use permits. However, the Midway Atoll Visitor Program closed in 2012, and no visitor access is currently available. USFWS will evaluate when and if this activity will be able to resume based on a number of logistical and financial factors.

PROTECTED SPECIES

There are three federal acts, as well as multiple state statutes, which safeguard protected species in Papahānaumokuākea. The federal acts include the Migratory Bird Treaty Act, the Marine Mammal Protection Act, and the Endangered Species Act. The Migratory Bird Treaty Act of 1918 implements various treaties and conventions between the United States and Canada, Japan, Mexico, and the former Soviet Union for the protection of migratory birds. The Marine Mammal Protection Act of 1972 and the Endangered Species Act of 1973 provide for the conservation of species at risk of extinction throughout all or a significant portion of their range, as well as the conservation of the ecosystems on which they depend.

An example of a management response for protected species in the monument is the Hawaiian Monk Seal Recovery Plan, developed by NOAA Fisheries in 2007. The goal of this plan is to ensure the long-term viability of the Hawaiian monk seal in the wild by promoting recovery such that the species can initially be reclassified as threatened and, ultimately, removed from the list of endangered and threatened wildlife (NMFS, 2007). This plan identified four recovery strategies, two of which are focused on the NWHI. These include ensuring the survivorship of reproductive females in the NWHI and maintaining a presence in the NWHI during the breeding season to allow for adaptive management. Additionally, a Monk Seal Management Plan was developed by NOAA Fisheries in 2016 to focus the recovery of the species in the MHI through partnerships and stakeholder-based management (NMFS, 2015). The effects of climate change-induced habitat loss on NWHI biota are difficult to predict, but may be greatest for endangered Hawaiian monk seals and threatened Hawaiian green turtles (Baker et al., 2006).

Monument management-specific goals include coordination on protected species issues, assisting in the implementation of threat reduction assessment, supporting and facilitating research on protected species to enhance populations, and incorporating data into the NWHI biogeographic database.

The efforts of the NOAA Hawaiian Monk Seal Recovery Team provide many examples of management responses to protect this endangered species. These recovery actions have included basic veterinary care and immunizations, direct threat mitigation and removal, disentangling animals (Figure R.6), and translocation of troubled or vulnerable animals to other islands.

Figure R.6. Seasonal field camp staff disentangle a Hawaiian monk seal in the monument. Image: PIFSC

HERITAGE RESOURCES

Maritime and historical archaeological resources are not replaceable. Natural processes of corrosion and degradation occur and are generally not abatable. For this reason, management has focused on limiting human access and disturbance to these resources.

A number of laws govern the protection and management of maritime heritage resources. The Abandoned Shipwreck Act of 1987 charges each state with the preservation management for "certain abandoned shipwrecks, which have been deserted and to which the owner has relinquished ownership rights with no retention." In the state of Hawai‘i, the preservation and protection of historic properties on state submerged lands fall under HRS Chapter 6E, which established the State Historic Preservation Program. For both NOAA and USFWS, preservation mandates for maritime heritage resources derive directly from elements of the Federal Archaeology Program, including the National Historic Preservation Act of 1966. Section 110 of the act states that each federal agency shall establish a preservation program for the protection of historic properties. Other relevant preservation guidelines include the Antiquities Act of 1906, the National Environmental Policy Act of 1982, the Preserve America Executive Order (EO 13287 2003), and the Sunken Military Craft Act of 2004. These laws codify the protection of heritage sites from illegal salvage and looting. NOAA's Maritime Heritage Program and the monument's Maritime Heritage Action Plan are specifically designed to address these preservation mandates and also inventory and protect these special resources for the benefit of the public.

Management has focused on protecting information on the location of the resources, permitting to manage access; conducting pre-access briefings for projects that may operate in the same general areas, occasionally monitoring the condition of the resources themselves, coordinating agency efforts, and conducting and supporting education and outreach in partnership with Native Hawaiians and to all communities.

One of the most notable advances in protection was the 2017 inclusion of the shipwreck of *Two Brothers* on the National Register of Historic Places due to its significant contribution to learning about Pacific maritime history and the North American whaling industry. It is the first shipwreck site in Papahānaumokuākea to be listed on the national register, and joins the USS *Arizona* and the USS *Utah* as the only other listed shipwreck sites in Hawai‘i. Inclusion in the National Register of Historic Places affords additional protections to the site.

NATIVE HAWAIIAN CULTURAL RESOURCES

Native Hawaiian practices exercised for subsistence and other cultural purposes are based on a system that is consistent with resource protection and preservation and serve as long-term conservation measures. Understanding Papahānaumokuākea from a Native Hawaiian perspective benefits monument management in many ways. Native Hawaiian research contributes to an ecosystem-based approach to management and complements other types of research. Education and outreach to the Native Hawaiian community can elicit greater involvement by Native Hawaiians in monument management.

In addition to monument regulations, additional protections to cultural resources are afforded through the National Historic Preservation Act and state of Hawai‘i preservation laws, which mandate consultations for Section 106, including the assessment of potential impacts (associated with federal undertakings) to properties eligible for or nominated for listing in the National Register of Historic Places.

The monument co-managers protect Native Hawaiian cultural resources by integrating Native Hawaiian traditional knowledge and management concepts into their management practices, safeguarding information on the location of resources, operating a permitting system to manage access, conducting pre-access briefings using Native Hawaiian cultural values for projects that operate in the vicinity of cultural resources, supporting and facilitating Native Hawaiian cultural research, conducting and supporting education and outreach, and seeking state and federal protected status for relevant resources.

The permitting process in particular is an example of a Hawaiian value-laden process that aligns with cultural norms. The Native Hawaiian Cultural Working Group provides advice to the Monument Management Board on issues related to cultural heritage. Permitting reviews for all proposed projects in the monument include an evaluation of relevance and impacts to Native Hawaiian cultural resources. Additionally, permittees accessing Nihoa, one of the locations with the most Native Hawaiian archaeological resources in the monument, are typically required to adhere to a set of best management practices. These practices include working with a cultural liaison to provide guidance during field visits, participating in Hawaiian protocol, maintaining awareness of documented cultural sites, and avoiding disturbance of cultural sites or resources.

An Edith Kanaka'ole Foundation team member watches sunset on Mokumanamana. Image: Brad Ka'aleleo Wong/OHA

CONCLUDING REMARKS

The State of the Monument Report is a comprehensive update to the 2009 Condition Report for Papahānanumokuākea Marine National Monument. It covers the time frame of 2008–2019 and summarizes the status and trends of our marine, terrestrial, maritime, historic, and cultural resources over this period. While it builds off of the model used to create condition reports for NOAA national marine sanctuaries, it diverges from this framework in that we look holistically at all portions of the monument, from the depths of the ocean to the tops of the islands, and include detailed assessments of our historical and cultural resources. We have made numerous improvements and changes to the report in order to enhance its utility to scientists, resource managers, stakeholders, and the general public. This product is based on a decade of work by all the co-managing partners. The region consists of small islands, islets, atolls, and a complex array of shallow coral reefs, deep-water slopes, banks, seamounts, and abyssal and pelagic oceanic environments. These systems support a diversity of life, including thousands of distinct native species. Native Hawaiians regard these atolls, islands, and surrounding waters as an ʻāina akua (sacred region), from which all life springs and to which ancestral spirits return after death (Kikiloi, 2006). Among the agencies, we collectively manage a vast ocean wilderness and the 10 small islands and atolls, encompassing an area that is larger than the Gulf of Mexico. No one agency can do this alone, and it takes the expertise of each partner to manage this site.

Due to Papahānaumokuākea's isolation, past and current management efforts, and current regulations controlling access, impacts from local human uses have been relatively few. Much of the monument appears healthy and stable. Regardless, the report has also documented new threats to monument resources and resulting impacts since 2009 that will require additional monitoring. It highlights the need to fill gaps in research and monitoring, especially in the monument expansion area and in the areas where new and existing threats to resources exist. There is also a need to continue to be more holistic in our research approach, incorporating both biological and social science into our assessments of ocean ecosystem health, and to continue to include traditional ecological knowledge practices in assessing the status and trends of our resources.

There is no greater example of co-management than in the creation of this report. Its completion would not have been possible without the dedicated involvement of the 35 researchers who contributed time, expertise, and data on the status and trends of the resources. We also acknowledge the three peer reviewers and staff, both at NOAA and the state of Hawaiʻi, who have seen this massive project through from first draft to final copy. It's this team, along with numerous research partners, that give us hope for making a positive difference moving forward. On behalf of the Monument Management Board, we want to express our sincerest gratitude for these efforts, in addition to past and ongoing contributions to monitoring and management. It is only through these continued collaborations and partnerships that we will successfully protect, conserve, and restore this special and sacred place for generations to come.

As we write this summary, we are in the middle of an unprecedented biological crisis for mankind on a global scale. The findings on the status and trends of our resources give us hope as we look at the resilience of species and habitats that have faced and are facing past and current threats such as climate change and weather-related effects on habitat and our historic and cultural resources. One of the most remarkable feats of human heritage is the purposeful movement of ancestral oceanic peoples, who demonstrated remarkable ingenuity and advancements in non-instrument navigation and open-ocean voyaging that led to settlement across the largest portion of ocean on Earth thousands of years ago. Native Hawaiian migrations have documented the Northwestern Hawaiian Islands within genealogical chants and in centuries-old oral traditions. Our role is to learn from the data provided in this report and the knowledge from our Native Hawaiian partners, consider the recommendations in our management and planning, and use this information to chart our future course.

Athline Clark
Superintendent Papahānaumokuākea Marine National Monument and UNESCO World Heritage Site, on behalf of the Papahānaumokuākea Marine National Monument Management Board

CITED RESOURCES

Addison J. A., & Diamond, A. W. (2011). Population genetics and effective population size of the critically endangered Nihoa millerbird (*Acrocephalus familiaris kingi*). *The Auk*, *128*(2), 265–272. https://doi.org/10.1525/auk.2011.10149

Aeby, G. S. (2006). Baseline levels of coral disease in the Northwestern Hawaiian Islands. *Atoll Research Bulletin*, *543*, 471–488.

Aeby, G. S., Kenyon, J. C., Maragos, J. E., & Potts, D. C. (2003). First record of mass coral bleaching in the Northwestern Hawaiian Islands. *Coral Reefs*, *22*(3), 256. https://doi.org/10.1007/s00338-003-0309-2

Albright, R., Mason, B., & Langdon, C. (2008). Effect of aragonite saturation state on settlement and post-settlement growth of *Porites astreoides* larvae. *Coral Reefs*, *27*, 485–490. https://doi.org/10.1007/s00338-008-0392-5

Amerson, A. B., Jr. (1971). The natural history of French Frigate Shoals, Northwestern Hawaiian Islands. *Atoll Research Bulletin*, *150*, 14–17. https://doi.org/10.5479/si.00775630.150.1

Amerson, A. B., Jr., Clapp, R. B., & Wirtz, W. O., II (1974). The natural history of Pearl and Hermes Reef, Northwestern Hawaiian Islands. *Atoll Research Bulletin*, *174*, 1–306. https://doi.org/10.5479/si.00775630.174.1

Anderson, O. R. J., Small, C. J., Croxall, J. P., Dunn, E. K., Sullivan, B. J., Yates, O., & Black, A. (2011). Global seabird bycatch in longline fisheries. *Endangered Species Research*, *14*, 91–106. https://doi.org/10.3354/esr00347

Angermeier, P. L., & Karr, J. R. (1994). Biological integrity versus biological diversity as policy directives: Protecting biotic resources. In F. B. Samson & F. L. Knopf (Eds.), *Ecosystem management: Selected readings* (pp. 264–275). Springer. https://doi.org/10.1007/978-1-4612-4018-1_24

Antonelis, G. A., Baker, J. D., Johanos, T. C., Braun, R. C., & Harting, A. L. (2006). Hawaiian monk seal (*Monachus schauinslandi*): Status and conservation issues. *Atoll Research Bulletin*, *543*, 75–101.

Arata, J. A., Sievert, P. R., & Naughton, M. B. (2009). *Status assessment of Laysan and Black-footed albatrosses, North Pacific Ocean, 1923-2005*. U.S. Department of the Interior, U.S. Geological Survey. https://pubs.usgs.gov/sir/2009/5131/pdf/sir20095131.pdf

Asher, J., Williams, I. D., & Harvey, E. S. (2017). An assessment of mobile predator populations along shallow and mesophotic depth gradients in the Hawaiian Archipelago. *Scientific Reports*, *7*, 3905. https://doi.org/10.1038/s41598-017-03568-1

Athens, J. S., Ward, J. V., & Blinn, D. W. (2007). Vegetation history of Laysan Island, Northwestern Hawaiian Islands. *Pacific Science*, *61*(1), 17–37. https://doi.org/10.1353/psc.2007.0001

Baco, A. R. (2007). Exploration for deep-sea corals on North Pacific seamounts and islands. *Oceanography*, *20*(4), 108–117. https://doi.org/10.5670/oceanog.2007.11

Baco, A. R., Roark, E. B., & Morgan, N.B. (2019). Amid fields of rubble, scars, and lost gear, signs of recovery observed on seamounts on 30- to 40-year time scales. *Science Advances*, *5*(8), eaaw4513. https://doi.org/10.1126/sciadv.aaw4513

Baechler, B. R., Stienbarger, C. D., Horn, D. A., Joseph, J., Taylor, A. R., Granek, E. F., & Brander, S. M. (2020). Microplastic occurrence and effects in commercially harvested North American finfish and shellfish: Current knowledge and future directions. *Limnology and Oceanography Letters*, *5*(1), 113–136. https://doi.org/10.1002/lol2.10122

Baker, J. D., Littnan, C. L., & Johnston, D. W. (2006). Potential effects of sea level rise on the terrestrial habitats of endangered and endemic megafauna in the Northwestern Hawaiian Islands. *Endangered Species Research*, *2*, 21–30. https://doi.org/10.3354/esr002021

Baker, J. D., Polovina, J. J., & Howell, E. A. (2007). Effect of variable oceanic productivity on the survival of an upper trophic predator, the Hawaiian monk seal *Monachus schauinslandi*. *Marine Ecology Progress Series*, *346*, 277–283. https://doi.org/10.3354/meps06968

Baker, J. D., Howell, E. A., & Polovina, J. J. (2012). Relative influence of climate variability and direct anthropogenic impact on a sub-tropical Pacific top predator, the Hawaiian monk seal. *Marine Ecology Progress Series*, *469*, 175–189. https://doi.org/10.3354/meps09987

Baker, J. D., Harting, A. L., Johanos, T. C., & Littnan, C. L. (2016). Estimating Hawaiian monk seal range-wide abundance and associated uncertainty. *Endangered Species Research*, *31*, 317–324. https://doi.org/10.3354/esr00782

Balazs, G. H., & Chaloupka, M. Y. (2004). Thirty-year recovery trend in the once depleted Hawaiian green sea turtle stock. *Biological Conservation*, *117*(5), 491–498. https://doi.org/10.1016/j.biocon.2003.08.008

Balazs, G. H., & Chaloupka, M. Y. (2006). Recovery trend over 32 years at the Hawaiian green turtle rookery of French Frigate Shoals. *Atoll Research Bulletin*, *543*, 147–158.

Balazs, G. H., & Pooley, S. G. (Eds.). (1991). *Research plan for marine turtle fibropapilloma*. *NOAA Technical Memorandum NMFS-SWFSC-156*. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Southwest Fisheries Science Center. https://swfsc.noaa.gov/publications/TM/SWFSC/NOAA-TM-NMFS-SWFSC-156.pdf

Boland, R.C., & Donohue, M. (2003). Marine debris accumulation in the nearshore marine habitat of the endangered Hawaiian monk seal, *Monachus schauinslandi* 1999–2001. *Marine Pollution Bulletin*, *46*(11), 1385–1394. https://doi.org/10.1016/S0025-326X(03)00291-1

Bowen, B. W., & Karl, S. A. (2007). Population genetics and phylogeography of sea turtles. *Molecular Ecology*, *16*, 4886–4907. https://doi.org/10.1111/j.1365-294X.2007.03542.x

Bowen, B. W., Meylan, A. B., Ross, J. P., Limpus, C. J., Balazs, G. H., & Avise, J. C. (1992). Global population structure and natural history of the green turtle (*Chelonia mydas*) in terms of matriarchal phylogeny. *Evolution*, *46*(4), 865–881. https://doi.org/10.1111/j.1558-5646.1992.tb00605.x

Brodziak, J., Moffitt, R., & DiNardo, G. (2009). *Hawaiian bottomfish assessment update for 2008*. *Administrative report H-09-02*. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Pacific Islands Fisheries Science Center. https://origin-apps-pifsc.fisheries.noaa.gov/adminrpts/2000-present/PIFSC_Admin_Rep_09-02.pdf

Bryan, E. H., Jr. (1926). *Insects of Hawaii, Johnston Island and Wake Island*. *Tanager Expedition, Publication No. 3*. *Bulletin 31*. Bishop Museum.

Butler, G. D., Jr., & Usinger, R. L. (1963). Insects and other arthropods from Kure Island. *Proceedings of the Hawaiian Entomological Society*, *18*(2), 237–244.

Cairns, S. D. (1984). New records of ahermatypic corals (Scleractinia) from the Hawaiian and Line Islands. *Bishop Museum Occasional Papers*, *25*(10), 1–30.

Carretta, J. V., Forney, K. A., Oleson, E. M., Weller, D. W., Lang, A. R., Baker, J., Muto, M. M., Hanson, B., Orr, A. J., Huber, H., Lowry, M. S., Barlow, J., Moore, J. E., Lynch, D., Carswell, L., Brownell, R. L., Jr. (2020). *U.S. Pacific marine mammal stock assessments: 2019*. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Southwest Fisheries Science Center. https://www.fisheries.noaa.gov/national/marine-mammal-protection/marine-mammal-stock-assessment-reports-region

Chaloupka, M., Balazs, G. H., & Work, T. M. (2009). Rise and fall over 26 years of a marine epizootic in Hawaiian green sea turtles. *Journal of Wildlife Diseases*, *45*(4), 1138–1142. https://doi.org/10.7589/0090-3558-45.4.1138

Chand, S. S., Tory, K. J., Ye, H., & Walsh, K. E. (2017) Projected increase in El Niño-driven tropical cyclone frequency in the Pacific. *Nature Climate Change*, *7*, 123–127. https://doi.org/10.1038/nclimate3181

Chave, E. H., & Malahoff, A. (1998). *In deeper waters: Photographic studies of Hawaiian deep-sea habitats and life-forms*. University of Hawai‘i Press.

Chen, X., Zhang, X., Church, J. A., Watson, C. S., King, M. A., Monselesan, D., Legresy, B., & Harig, C. (2017). The increasing rate of global mean sea-level rise during 1993–2014. *Nature Climate Change*, *7*, 492–495. https://doi.org/10.1038/nclimate3325

Cheng, L., Abraham, J., Zhu, J., Trenberth, K. E., Fasullo, J., Boyer, T., Locarnini, R., Zhang, B., Yu, F., Wan, L., Chen, X., Song, X., Liu, Y., & Mann, M. E. (2020). Record-setting ocean warmth continued in 2019. *Advances in Atmospheric Sciences*, *37*, 137–142. https://doi.org/10.1007/s00376-020-9283-7

Christophersen, E., & Caum, E. L. (1931). *Vascular plants of the Leeward Islands, Hawaii*. Bishop Museum.

Clague, D. A. (1996). The growth and subsidence of the Hawaiian-Emperor volcanic chain. In A. Keast & S.D. Miller (Eds.), *The origin and evolution of the Pacific Island biotas, New Guinea to eastern Polynesia: Patterns and processes* (pp. 35–50). SPB Academic Publishing.

Cooke, C. M., Jr., & Kondo, Y. (1960). *Revision of Tornatellinidae and Achatinellidae (Gastropoda, Pulmonata)*. Bernice P. Bishop Museum.

Couch, C. S., Burns, J. H., Liu, G., Steward, K., Gutlay, T. N., Kenyon, J., Eakin, C. M., & Kosaki, R. K. (2017). Mass coral bleaching due to unprecedented marine heatwave in Papahānaumokuākea Marine National Monument (Northwestern Hawaiian Islands). *PLoS ONE*, *12*(9), e0185121. https://doi.org/10.1371/journal.pone.0185121

Crook, E. D., Cohen, A. L., Rebolledo-Vieyra, M., Hernandez, L., & Paytan, A. (2014). Reduced calcification and lack of acclimatization by coral colonies in areas of persistent natural acidification. *Proceedings of the National Academy of Sciences of the United States of America*, *110*(27), 11044–11049. www.pnas.org/cgi/doi/10.1073/pnas.1301589110

Cuddihy, L. W., & Stone, C. P. (1990). *Alteration of native Hawaiian vegetation: Effects of humans, their activities and introductions*. University of Hawaiʻi, Cooperative National Park Resources Studies Unit.

Dale, J. J., Stankus, A. M., Burns, M. S., & Meyer, C. G. (2011). The shark assemblage at French Frigate Shoals atoll, Hawaiʻi: Species composition, abundance and habitat use. *PLoS ONE*, *6*(2), e16962. https://doi.org/10.1371/journal.pone.0016962

Dalton, M., Kohley, R., & Heindl, B. (2014). *Trip report: Population Monitoring of Millerbirds on Laysan, June 28–September 28, 2014*. [Unpublished report]. U.S. Department of the Interior, U.S. Fish and Wildlife Service.

Department of Health (2014). *Hawaiʻi administrative rules, title 11, Department of Health, chapter 54, water quality standards*. State of Hawaiʻi, Department of Health, Clean Water Branch. https://health.hawaii.gov/cwb/hawaii-administrative-rules-har/har-11-54/

Department of Land and Natural Resources (DLNR) (2003). *State of Hawaiʻi aquatic invasive species management plan*. State of Hawaiʻi, Department of Land and Natural Resources, Division of Aquatic Resources. https://dlnr.hawaii.gov/ais/files/2013/12/HAWAII-mgt-PLAN-03.pdf

Department of Land and Natural Resources (DLNR) (2017). Proposal: Restoring seabird breeding habitat on Kure Atoll. NFWF Keystone Initiative, Pacific Seabird Program.

Dickinson, W.R. (2003). Impact of mid-Holocene hydro-isostatic highstand in regional sea level on habitability of islands in Pacific Oceania: Journal of Coastal Research, 19, p. 489–502.

Dickinson, W. R. (2009). Pacific atoll living: How long already and until when? *GSA Today*, *19*(3), 4–10. https://doi.org/10.1130/GSATG35A.1

DiNardo, G. T., & Marshall, R. (2001). *Status of lobster stocks in the Northwestern Hawaiian Islands, 1998–2000*. *Administrative Report H-01-04*. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Southwest Fisheries Science Center. http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.556.3561&rep=rep1&type=pdf

Division of Forestry and Wildlife (DOFAW) (2009). *Annual report for Kure Atoll State Wildlife Sanctuary 2009* [Unpublished report]. State of Hawaiʻi, Department of Land and Natural Resources.

Division of Forestry and Wildlife (DOFAW) (2012). *Annual report for Kure Atoll State Wildlife Sanctuary 2011*. [Unpublished report]. State of Hawaiʻi, Department of Land and Natural Resources.

Division of Forestry and Wildlife (DOFAW) (2014). *Annual report for Kure Atoll State Wildlife Sanctuary 2014*. [Unpublished report]. State of Hawaiʻi, Department of Land and Natural Resources.

Division of Forestry and Wildlife (DOFAW) (2016). *Annual report for Kure Atoll State Wildlife Sanctuary 2016*. [Unpublished report]. State of Hawaiʻi, Department of Land and Natural Resources.

Division of Forestry and Wildlife (DOFAW) (2017). *Annual report for Kure Atoll State Wildlife Sanctuary 2017*. [Unpublished report]. State of Hawaiʻi, Department of Land and Natural Resources.

Division of Forestry and Wildlife. (DOFAW) (2018). *Annual report for Kure Atoll State Wildlife Sanctuary 2018*. [Unpublished report]. State of Hawaiʻi, Department of Land and Natural Resources.

Division of Forestry and Wildlife. (DOFAW) (2019). *Annual report for Kure Atoll State Wildlife Sanctuary 2019*. [Unpublished report]. State of Hawaiʻi, Department of Land and Natural Resources.

Donohue, M. J., & Brainard, R. E. (2001, November 5–8). *A comprehensive effort to mitigate marine debris and restore coral reef habitat in the Northwestern Hawaiian Islands*. [Oral presentation] For Oceans 2001, Honolulu, Hawaiʻi.

do Sul, J. A. I., & Costa, M. F. (2014). The present and future of microplastic pollution in the marine environment. *Environmental Pollution*, *185*, 352–364. https://doi.org/10.1016/j.envpol.2013.10.036

Eldredge, L. G., & Miller, S. E. (1995). How many species are there in Hawaii? In N. L. Evenhuis & S. E. Miller (Eds.), *Records of the Hawaiʻi biological survey for 1994* (pp. 3–18). Bishop Museum Press.

Evenhuis, N. L., & Eldredge, L. C. (Eds.) (2004). *Natural history of Nihoa and Necker Islands*. Bishop Museum Press.

Farmer, C., Freifeld, H., Kohley, R.,Luscomb, P., Rounds, R., Rutt, C., Wallace, G., Work, T., Aldeguer, W., Amidon, F., Tsukayama, D., & VanderWerf, E. (2011). *Millerbird translocation trip report, 2–16 September 2011*. [Unpublished report]. U.S. Department of the Interior, U.S. Fish and Wildlife Service.

Feely, R. A., Doney, S. C., & Cooley, S. R. (2009). Ocean acidification: Present conditions and future changes in a high-CO_2 world. *Oceanography*, *22*(4), 36–47. https://doi.org/10.5670/oceanog.2009.95

Firing, J., & Brainard, R. E. (2006). Ten years of shipboard ADCP measurements along the Northwestern Hawaiian Islands. *Atoll Research Bulletin*, *543*, 347–364.

Fleishman, A. B., Youngren, S., Rapp, D., McKown, M., Roberts, P. (2018). *Testing the efficacy of acoustic monitoring for Bonin petrel at Sand Island on Midway Atoll NWR*. Conservation Metrics, Inc. https://ecos.fws.gov/ServCat/DownloadFile/156052

Fletcher, C. H., III, & Sherman, C. E. (1995). Submerged shorelines on Oʻahu, Hawaiʻi: Archive of episodic transgression during the deglaciation? *Journal of Coastal Research*, *Special Issue No. 17*, 141–152.

Freifeld, H. B., Plentovich, S., Farmer, C., Kohley, C. R., Luscomb, P., Work, T. M., Tsukayama, D., Wallace, G. E., MacDonald, M. A., & Conant, S. (2016). Long-distance translocations to create a second millerbird population and reduce extinction risk. *Biological Conservation*, *199*, 146–156. https://doi.org/10.1016/j.biocon.2016.05.006

Friedlander, A. M., & DeMartini, E. E. (2002). Contrasts in density, size, and biomass of reef fishes between the northwestern and the main Hawaiian islands: The effects of fishing down apex predators. *Marine Ecology Progress Series*, *230*, 253–264. https://doi.org/10.3354/meps230253

Friedlander, A., Aeby, G., Brainard, R., Clark, A., DeMartini, E., Godwin, S., Kenyon, J., Kosaki, R., Maragos, J., Vroom, P. (2005). The state of coral reef ecosystems of the Northwestern Hawaiian Islands. In J. E. Waddell (Ed.), T*he state of coral reef ecosystems of the United States and Pacific Freely Associated States: 2005*. *NOAA Technical Memorandum NOS NCCOS 11* (pp. 270–311). U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Ocean Service, National Centers for Coastal Ocean Science. https://repository.library.noaa.gov/view/noaa/17792

Fukunaga, A., Kosaki, R. K., Wagner, D., & Kane, C. N. (2016). Structure of mesophotic reef fish assemblages in the Northwestern Hawaiian Islands. *PLoS ONE*, *11*(7), e0157861. https://doi.org/10.1371/journal.pone.0157861

Fukunaga, A., Kosaki, R. K., & Hauk, B. B. (2017). Distribution and abundance of the introduced snapper *Lutjanus kasmira* (Forsskål, 1775) on shallow and mesophotic reefs of the Northwestern Hawaiian Islands. *BioInvasions Records*, *6*(3), 259–268. https://doi.org/10.3391/bir.2017.6.3.12

Fukunaga, A., Kosaki, R. K., & Wagner, D. (2017). Changes in mesophotic reef fish assemblages along depth and geographical gradients in the Northwestern Hawaiian Islands. *Coral Reefs*, *36*, 785–790. https://doi.org/10.1007/s00338-017-1569-6

Fukunaga, A., & Kosaki, R. K. (2017). Use of multivariate control charts to assess the status of reef fish assemblages in the Northwestern Hawaiian Islands. *PeerJ*, *5*, e3651. https://doi.org/10.7717/peerj.3651

Ge, J., Woodward, L. A., Li, Q. X., & Wang, J. (2013). Composition, distribution and risk assessment of organochlorine pesticides in soils from the Midway Atoll, North Pacific Ocean. *Science of the Total Environment*, *452–453*, 421–426. https://doi.org/10.1016/j.scitotenv.2013.03.015

Glazier, E. W. (2007). Hawaiian fishermen. In G. Spindler & J. E. Stockard (Series Eds.), *Case studies in cultural anthropology*. Wadsworth Publishing.

Godwin, S., Rodgers, K. S., & Jokiel, P. L. (2005). *Reducing potential impact of invasive marine species in the Northwestern Hawaiian Islands Marine National Monument*. Hawai‘i Coral Reef Assessment and Monitoring Program (CRAMP), Hawai‘i Institute of Marine Biology. http://cramp.wcc.hawaii.edu/Downloads/Publications/TR_Godwin_et_al%20_Invasives_Final%20Draft.pdf

Godwin, S., Hauk, B., & Bolick, H. (2020). *Non-indigenous species in Papahānaumokuākea Marine National Monument* [Manuscript in preparation]. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, Papahānaumokuākea Marine National Monument.

Goff, M. L. (1982). A new species of *Hemicheyletia* (Acari: Cheyletidae) from Kure Atoll, Northwestern Hawaiian Islands. *Proceedings of the Hawaiian Entomological Society*, *24*(1), 83–86.

Gorresen, P. M., Camp, R. J., Brinck, K. W., & Farmer, C. (2012). *Developing accurate survey methods for estimating population sizes and trends of the critically endangered Nihoa millerbird and Nihoa finch*. Hawai‘i Cooperative Studies Unit Technical Report HCSU-034. University of Hawai‘i at Hilo.

Gorresen, P. M., Brinck, K. W., Camp, R. J., Farmer, C., Plentovich, S. M., & Banko, P. C. (2016). State-space modeling of population sizes and trends in Nihoa Finch and Millerbird. *The Condor*, *118*(3), 542–557. https://doi.org/10.1650/CONDOR-15-214.1

Gove, J. M., Williams, G. J., McManus, M. A., Heron, S. F., Sandin, S. A., Vetter, O. J., & Foley, D. G. (2013). Quantifying climatological ranges and anomalies for Pacific coral reef ecosystems. *PLoS ONE*, *8*(4), e61974. https://doi.org/10.1371/journal.pone.0061974

Grigg, R. W. (1998). Holocene coral reef accretion in Hawai‘i: A function of wave exposure and sea level history. *Coral Reefs*, *17*, 263–272. https://doi.org/10.1007/s003380050127

Grigg, R. W. (2010). The precious corals fishery management plan of the Western Pacific Regional Fishery Management Council. *Pacific Islands Fishery Monographs*, *1*, 1–9.

Grigg, R. W., & Bayer, F. M. (1976). Present knowledge of the systematics and zoogeography of the order Gorgonacea in Hawai‘i. *Pacific Science*, *30*(2), 167–175.

Gross, M.G., Milliman, J.D., Tracey, J.I., and Ladd, H.S. (1969). Marine geology of Kure and Midway Atolls, Hawai‘i: A preliminary report. *Pacific Science*, *23*(1), 17–25.

Harvell, C. D., Kim, K., Burkholder, J. M., Colwell, R. R., Epstein, P. R., Grimes, D. J., Hofmann, E. E., Lipp, E. K., Osterhaus, A. D. M. E., Overstreet, R. M., Porter, J. W., Smith, G. W., Vasta, G. R. (1999). Emerging marine diseases – Climate links and anthropogenic factors. *Science*, *285*(5433), 1505–1510. https://doi.org/10.1126/science.285.5433.1505

Hiruki, L. M., & Ragen, T. J. (1992). *A compilation of historical monk seal,* Monachus schauinslandi*, counts*. *Technical Memorandum NMFS-SWFSC-172*. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Southwest Fisheries Science Center. https://repository.library.noaa.gov/view/noaa/6085

Hodel, D. R. (2012). *Loulu: The Hawaiian palm*. University of Hawaiʻi Press.

Hoegh-Guldberg, O., & Bruno, J. F. (2010). The impact of climate change on the world's marine ecosystems. *Science*, *328*(5985), 1523–1528. https://doi.org/10.1126/science.1189930

Howell, E. A., Bograd, S. J., Morishige, C., Seki, M. P., & Polovina, J. J. (2012). On North Pacific circulation and associated marine debris concentration. *Marine Pollution Bulletin*, *65*(1–3), 16–22. https://doi.org/10.1016/j.marpolbul.2011.04.034

Hyrenbach, K. D., Fernandez, P., & Anderson, D. J. (2002). Oceanographic habitats of two sympatric North Pacific albatrosses during the breeding season. *Marine Ecology Progress Series*, *233*, 283–301. https://doi.org/doi:10.3354/meps233283

Hyrenbach, K. D., Hester, M. M., Adams, J., Titmus, A. J., Michael, P., Wahl, T., Chang, C.- W., Marie, A. & Vanderlip, C. (2017). Plastic ingestion by black-footed albatross *Phoebastria nigripes* from Kure Atoll, Hawaiʻi: Linking chick diet remains and parental at-sea foraging distributions. *Marine Ornithology*, *45*, 225–236.

Imada, C. T. (Ed.). (2012). *Hawaiian native and naturalized vascular plants checklist: December 2012 update*. *Bishop Museum Technical Report 60*. Bishop Museum.

Irwin, G. (2006). Voyaging and settlement. In K. R. Howe (Ed.), *Vaka Moana: Voyages of the Ancestors: The Discovery and Settlement of the Pacific* (pp. 54–91). University of Hawaiʻi Press.

Itano, D. G., & Holland, K. N. (2000). Movement and vulnerability of bigeye (*Thunnus obesus*) and yellowfin tuna (*Thunnus albacares*) in relation to FADs and natural aggregation points. *Aquatic Living Resources*, *13*(4), 213–223. https://doi.org/10.1016/S0990-7440(00)01062-7

Kane, C., Kosaki, R. K., & Wagner, D. (2014). High levels of mesophotic reef fish endemism in the Northwestern Hawaiian Islands. *Bulletin of Marine Science*, *90*(2), 693–703. https://doi.org/10.5343/bms.2013.1053

Keenan, E. E., Brainard, R. E., & Basch, L. V. (2006). Historical and present status of the pearl oyster, *Pinctada margaritifera*, at Pearl and Hermes Atoll, Northwestern Hawaiian Islands. *Atoll Research Bulletin*, *543*, 333–344.

Kelley, C., France, S., Parrish, F., Wagner, D., Gerringer, M., & Garcia, M. (2016). CAPSTONE's first year – 2015 Hohonu Moana: Exploring deep waters off Hawaiʻi. In K. L. C. Bell, M. L. Brennan, J. Flanders, N. A. Raineault, & K. Wagner (Eds.), New frontiers in ocean exploration: The E/V *Nautilus* and NOAA Ship *Okeanos Explorer* 2015 field season (pp. 68–73). *Oceanography*, *29*(1), supplement. https://doi.org/10.5670/oceanog.2016.supplement.01

Kennedy, B. R. C., Cantwell, K., Malik, M., Kelley, C., Potter, J., Elliott, K., Lobecker, E., Gray, L. M., Sowers, D., White, M. P., France, S. C., Auscavitch, S., Mah, C., Moriwake, V., Bingo, S. R. D., Putts, M., & Rotjan, R. D. (2019). The unknown and the unexplored: Insights into the Pacific deep-sea following NOAA CAPSTONE expeditions. *Frontiers in Marine Science*, *6*, 480. https://doi.org/10.3389/fmars.2019.00480

Kenyon J. C., Aeby, G. S., Brainard, R. E., Chojnacki, J. D., Dunlap, M. J., & Wilkinson, C. B. (2006). Mass coral bleaching on high-latitude reefs in the Hawaiian Archipelago. In Y. Suzuki, T. Nakamori, M. Hidaka, H. Kayanne, B. E. Cassareto, K. Nadooka, H. Yamano, & M. Tschiya (Eds.), *Proceedings of the 10th International Coral Reef Symposium* (pp. 631–643). Japanese Coral Reef Society.

Kenyon, J. C., & Brainard, R. E. (2006). Second recorded episode of mass coral bleaching in the Northwestern Hawaiian Islands. *Atoll Research Bulletin*, *543*, 505–524.

Kenyon, K. W., & Rice, D. W. (1959). Life history of the Hawaiian monk seal. *Pacific Science*, *13*(3), 215–252.

Kerr, L. M. (1996). Developmental defects in damselfish (*Abudefduf sordidus*: Pomacentridae) embryos from metal artificial reefs. *The Biological Bulletin*, *191*(2), 306–307. https://doi.org/10.1086/BBLv191n2p306

Kikiloi, S. (2006). *Reconnecting with ancestral islands: Examining historical relationships between kānaka maoli and the Northwestern Hawaiian Islands*. *Report to NOAA for the Kia'i Kai (Guardians of the Sea) Project*. University of Hawaiʻi at Mānoa, Kamakakūokalani Center for Hawaiian Studies.

Kikiloi, K. S. T. (2012). *Kūkulu manamana: Ritual power and religious expansion in Hawaiʻi the ethno-historical and archaeological study of Mokumanamana and Nihoa Islands*. [Doctoral dissertation, University of Hawaiʻi at Mānoa].

Kikiloi, K. (2015). *Permit report to Papahānaumokuākea Marine National Monument* [Unpublished report].

Klavitter, J. (2006). *Native plants of Midway Atoll NWR*. U.S. Department of the Interior, U.S. Fish and Wildlife Service. https://www.fws.gov/uploadedFiles/Region_1/NWRS/Zone_1/Midway_Atoll/Documents/Midway%20Native%20Plants.pdf

Kleypas, J. A., Feely, R. A., Fabry, V. J., Langdon, C., Sabine, C. L., & Robbins, L. L. (2006). *Impacts of ocean acidification on coral reefs and other marine calcifiers: A guide for future research*. Report from a workshop sponsored by the National Science Foundation, the National Oceanic and Atmospheric Administration, and the U.S. Geological Survey. https://www.carboncyclescience.us/sites/default/files/documents/Final_acidification.pdf

Klimley, A. P., & Holloway, C. (1999). School fidelity and homing synchronicity of yellowfin tuna, *Thunnus albacares*. *Marine Biology*, *133*, 307–317. https://doi.org/10.1007/s002270050469

Kosaki, R. K., Pyle, R. L., Leonard, J. C., Hauk, B. B., Whitton, R. K., & Wagner, D. (2017). 100% endemism in mesophotic reef fish assemblages at Kure Atoll, Hawaiian Islands. *Marine Biodiversity*, *47*, 783–784. https://10.0.3.239/s002270050469

Krause, C. M., Courtot, K. N., Berkowitz, P., Carter, J., & Reynolds, M. H. (2012). Climate change vulnerability assessment of the low-lying Northwestern Hawaiian Islands. In M. H. Reynolds, P. Berkowitz, K. N. Courtot, & C. M. Krause (Eds.), *Predicting sea-level rise vulnerability of terrestrial habitat and wildlife of the Northwestern Hawaiian Islands*. *Open-File Report 2012–1182* (pp. 3–71). U.S. Department of the Interior, U.S. Geological Survey. https://pubs.usgs.gov/of/2012/1182/of2012-1182.pdf

Kristof, A. A., & Stelmach, M. W. (2010). *Trip Report: Laysan Island 11 August 2009–22 March 2010*. U.S. Department of the Interior, U.S. Fish and Wildlife Service.

Kristof, A. A., Bridges, A. E., Ordung, B. M., Thomas, I., & Yeh, J. (2013). *Inventory, monitoring, and adaptive management of the vegetation assemblage on Laysan Island, Hawaiian Islands NWR*. U.S. Department of the Interior, U.S. Fish and Wildlife Service.

Kristof, A. A., Watson, J. C., Ordung, B. M., Fleishman, A. B., Tafoya, D. A., & VanDeusen, A. (2014). *Trip report: Biological work conducted on Laysan Island, September 17th to October 2nd, 2014*. U.S. Department of the Interior, U.S. Fish and Wildlife Service.

Lamoureux, C. H. (1961). Botanical observations on leeward Hawaiian atolls. *Atoll Research Bulletin*, *79*, 1–10. https://doi.org/10.5479/si.00775630.79.1

Lebo, S. A., & Johnson, K. T. M. (2007). Geochemical sourcing of rock specimens and stone artifacts from Nihoa and Necker Islands, Hawaiʻi. *Journal of Archaeological Science, 34*(6), 858–871. https://doi.org/10.1016/j.jas.2006.08.009

Langdon, C., Takahashi, T., Sweeney, C., Chipman, D., Goddard, J., Marubini, F., Aceves, H., Barnett, H., & Atkinson, M. J. (2000). Effect of calcium carbonate saturation state on the calcification rate of an experimental coral reef. *Global Biogeochemical Cycles*, *14*(2), 639–654. https://doi.org/10.1029/1999GB001195

Lisiansky, Y. (1814). *A voyage round the world in the years 1803–1806: performed, by order of His Imperial Majesty Alexander the First, Emperor of Russia, in the ship* Neva. Kessinger Publishing.

Lopes, K.H. (2020). East Island, French Frigate Shoals emergent land analysis [Unpublished data set].

Mac, M. J., Opler, P. A., Haecker, C. E. P., & Doran, P. D. (1998). *Status and trends of the nation's biological resources* (Vol. 2). U.S. Department of Interior, U.S. Geological Survey.

Mantua, N. J., Hare, S. R., Zhang, Y., Wallace, J. M., & Francis, R. C. (1997). A Pacific interdecadal climate oscillation with impacts on salmon production. *Bulletin of the American Meteorological Society*, *78*(6), 1069–1079.

Maragos, J., & Gulko, D. (Eds.). (2002). *Coral reef ecosystems of the Northwestern Hawaiian Islands: Interim results emphasizing the 2000 surveys*. U.S. Fish and Wildlife Service & State of Hawaiʻi, Department of Land and Natural Resources.

Maragos, J., Kenyon, J. Aeby, G., Vroom, P., Vargas-Angel, B., Brainard, R., Wedding, L., Friedlander, A., Asher, J., Zgliczynski, B., & Siciliano, D. (2009). Benthic communities. In A. Friedlander, K. Keller, L. Wedding, A. Clarke, & M. Monaco (Eds.), *A marine biogeographic assessment of the Northwestern Hawaiian Islands*. *NOAA Technical Memorandum NOS NCCOS 84* (pp. 105–154). National Oceanic and Atmospheric Administration. https://repository.library.noaa.gov/view/noaa/506

Marine Protected Areas Federal Advisory Committee (2011). *Recommendations for integrated management using a cultural landscape approach in the national MPA system*. https://nmsmarineprotectedareas.blob.core.windows.net/marineprotectedareas-prod/media/archive/pdf/helpful-resources/mpafac_rec_cultural_landscape_12_11.pdf

McCoy, K., Heenan, A., Asher, J., Ayotte, P., Gorospe, K., Gray. A., Lino, K., Zamzow, J., & Williams, I. (2016). *Pacific Reef Assessment and Monitoring Program: Ecological monitoring 2015 – reef fishes and benthic habitats of the main Hawaiian Islands, Northwestern Hawaiian Islands, Pacific Remote Island Areas, and American Samoa*. *PIFSC data report DR-16-002*. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Pacific Islands Fisheries Science Center. https://repository.library.noaa.gov/view/noaa/17254.

McCully, K. M. (2013). *Uncharted waters: Bivalves of Midway Atoll and integrating mathematics into biology education* (Publication No. AAT 3599213) [Doctoral dissertation, University of California, Santa Cruz]. ProQuest Dissertations and Theses.

McCully, K. M., & Potts, D. C. (2008). Distribution and recruitment of the black-lipped pearl oyster *Pinctata margaritifera* at Midway Atoll, Northwestern Hawaiian Islands: A pilot study. [Poster presentation.] 11th Coral Reef Symposium, Fort Lauderdale, Florida.

McDermid, K. J., Gregoritza, M. C., & Freshwater, D. W. (2002). A new record of a second seagrass species from the Hawaiian Archipelago: *Halophila decipiens* Ostenfeld. *Aquatic Botany*, *74*(3), 257–262. https://doi.org/10.1016/S0304-3770(02)00081-5

Memorandum of Agreement (MOA) among the state of Hawai'i, Department of Land and Natural Resources, and the Office of Hawaiian Affairs and the U.S. Department of the Interior, U.S. Fish and Wildlife Service, and the U.S. Department of Commerce, National Oceanic and Atmospheric Administration, for promoting coordinated management of the Papahānaumokuākea Marine National Monument (2006). https://nmspapahanaumokuakea.blob.core.windows.net/papahanaumokuakea-prod/media/archive/new-library/pdf/MOA_Dec06_Color.pdf

Memorandum of Agreement (MOA) among the state of Hawai'i, Department of Land and Natural Resources, and the Office of Hawaiian Affairs and the U.S. Department of the Interior, U.S. Fish and Wildlife Service, and the U.S. Department of Commerce, National Oceanic and Atmospheric Administration, for promoting coordinated management of the Papahānaumokuākea Marine National Monument and expansion (2017). https://governor.hawaii.gov/wp-content/uploads/2017/01/MEMORANDUM-OF-AGREEMENT-SIGNED-FINAL.pdf

Meyer, C. G., Papastamatiou, Y. P., Holland, K. N. (2010). A multiple instrument approach to quantifying the movement patterns and habitat use of tiger (*Galeocerdo cuvier*) and Galapagos sharks (*Carcharhinus galapagensis*) at French Frigate Shoals, Hawaii. *Marine Biology*, *157*, 1857–1868. https://doi.org/10.1007/s00227-010-1457-x

Miller, S. L., & Crosby, M. P. (1998). *State of the coastal environment: The extent and condition of U.S. coral reefs*. U.S. Department of Commerce, National Oceanic and Atmospheric Administration. http://oceanservice.noaa.gov/websites/retiredsites/sotc_pdf/CRF.pdf

Miller, S. E., & Eldredge, L. G. (1996). Numbers of Hawaiian species: Supplement 1. *Bishop Museum Occasional Papers*, *45*, 8–17.

Moore, J. (2009). A comparative analysis of population estimation methods for a burrow-nesting seabird: a novel ground-count method and closed population capture-recapture modeling. [Unpublished master's thesis]. Saint Mary's University.

Morato, T., Hoyle, S. D., Allain, V. & Nicol, S. J. (2010). Seamounts are hotspots of pelagic biodiversity in the open ocean. *Proceedings of the National Academy of Sciences of the United States of America*, *107*(21), 9707–9711. https://doi.org/10.1073/pnas.0910290107

Morin, M., & Conant, S. (1998). *Laysan Island ecosystem restoration plan*. Department of Zoology, University of Hawai'i at Mānoa.

Morin, M. P., & Conant, S. (2020). Nihoa finch (*Telespiza ultima*), version 1.0. In A. F. Poole (Ed.), *Birds of the world*. Cornell Lab of Ornithology. https://doi.org/10.2173/bow.nihfin.01

Murakami, H., Delworth, T. L., Cooke, W. F., Zhao, M., Xiang, B., & Hsu, P. (2020). Detected climatic change in global distribution of tropical cyclones. *Proceedings of the National Academy of Sciences of the United States of America*, *117*(20), 10706–10714. https://doi.org/10.1073/pnas.1922500117

Murakami, H., Wang, B., Li, T., & Kitoh, A. (2013). Projected increase in tropical cyclones near Hawaii. *Nature Climate Change*, *3*, 749–754. https://doi.org/10.1038/nclimate1890

Nadon, M. O., Baum, J. K., Williams, I. D., McPherson, J. M., Zgliczynski, B. J., Richards, B. L., Schroeder, R. E., & Brainard, R. E. (2012). Re-creating missing population baselines for Pacific reef sharks. *Conservation Biology*, *26*(3), 493–503. https://doi.org/10.1111/j.1523-1739.2012.01835.x

Nakamura, J., Camargo, S. J., Sobel, A. H., Henderson, N., Emanuel, K. A., Kumar, A., LaRow, T. E., Murakami, H., Roberts, M. J., Scoccimarro, E., Vidale, P. L., Wang, H., Wehner, M. F., & Zhao, M. (2017). Western North Pacific tropical cyclone model tracks in present and future climates. *Journal of Geophysical Research: Atmospheres*, *122*(18), 9721–9744. https://doi.org/10.1002/2017JD027007

National Marine Fisheries Service (NMFS) (2007). *Recovery plan for the Hawaiian monk seal* (Monachus schauinslandi)*: Revision*. https://repository.library.noaa.gov/view/noaa/3521/noaa_3521_DS1.pdf

National Marine Fisheries Service (NMFS) (2015). Main Hawaiian Islands monk seal management plan. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service. https://www.fisheries.noaa.gov/resource/document/main-hawaiian-islands-monk-seal-management-plan#:~:text=The%20management%20plan%20is%20an,and%20strengthening%20partnerships%20and%20communication.

National Marine Sanctuary Program (NMSP) (2004a). *Proposed Northwestern Hawaiian Islands National Marine Sanctuary: Advice and recommendations on development of draft fishing regulations under the National Marine Sanctuaries Act Section 304(a)(5)*. U.S. Department of Commerce, National Oceanic and Atmospheric Administration. https://nmspapahanaumokuakea.blob.core.windows.net/papahanaumokuakea-prod/media/archive/management/designation/pdfs/Final_NMSA_304a5.pdf

National Marine Sanctuary Program (NMSP) (2004b). *A monitoring framework for the National Marine Sanctuary System*. U.S. Department of Commerce, National Oceanic and Atmospheric Administration. https://nmssanctuaries.blob.core.windows.net/sanctuaries-prod/media/archive/library/national/swim04.pdf

National Marine Sanctuary Program (NMSP) (2005). *Northwestern Hawaiian Islands Coral Reef Ecosystem Reserve: Final reserve operations plan*. U.S. Department of Commerce, National Oceanic and Atmospheric Administration. https://repository.library.noaa.gov/view/noaa/446

National Oceanic and Atmospheric Administration (NOAA) (2018). *U.S. Coral Reef Monitoring Data Summary 2018*. *NOAA Technical Memorandum CRCP 31*. Coral Reef Conservation Program. https://www.coris.noaa.gov/monitoring/data_summary_report_2018/NCRMP_Data_Summary_2018.pdf

National Oceanic and Atmospheric Administration (NOAA) Marine Debris Program (2018). *2018 Hawai'i marine debris action plan*. U.S. Department of Commerce. https://marinedebris.noaa.gov/report/hawaii-marine-debris-action-plan

National Oceanic and Atmospheric Administration (NOAA) Office of the General Counsel (2020). *Enforcement decisions and orders (March 18, 2010 through September 25, 2019)*. https://www.gc.noaa.gov/enforce-office6.html#fn1

National Park Service (2020). Inventory & monitoring: Vital signs monitoring. Retrieved from https://www.nps.gov/im/vital-signs.htm#:~:text=%22Vital%20signs%22%20are%20elements%20and,trends%20of%20park%20natural%20resources

Nishida, G. M. (2001). *NOWRAMP 2000 terrestrial arthropod report*. U.S. Department of the Interior, U.S. Fish and Wildlife Service. http://hbs.bishopmuseum.org/pdf/nowramp2000.pdf

Nutting, C. C. (1908). Descriptions of the Alcyonaria collected by the U.S. Bureau of Fisheries steamer *Albatross* in the vicinity of the Hawaiian Islands in 1902. *Proceedings of the United States National Museum*, *34*(1624), 543–601.

Office of Management and Budget (2004). *Memorandum for heads of departments and agencies: Issuance of OMB's final information quality bulletin for peer review*. Executive Office of the President. https://georgewbush-whitehouse.archives.gov/omb/memoranda/fy2005/m05-03.html

Office of National Marine Sanctuaries (ONMS) (2009). *Papahānaumokuākea Marine National Monument Condition Report 2009*. U.S. Department of Commerce, National Oceanic and Atmospheric Administration. https://sanctuaries.noaa.gov/science/condition/pmnm/summary.html

O'Malley, J. M. (2009). Spatial and temporal variability in growth of Hawaiian spiny lobsters in the Northwestern Hawaiian Islands. *Marine and Coastal Fisheries*, *1*, 325–342. https://doi.org/10.1577/C09-031.1

O'Malley, J. M. (2011). Spatiotemporal variation in the population ecology of scaly slipper lobsters (*Scyllarides squammosus*) in the Northwestern Hawaiian Islands. *Marine Biology*, *158*, 1887–1901. https://doi.org/10.1007/s00227-011-1701-z

Pacific Islands Fisheries Science Center (PIFSC) (2019). *Population summary for Hawaiian monk seals in 2018*. *PIFSC Internal Report IR-19-003* [Unpublished report]. U.S. Department of Commerce, National Oceanic and Atmospheric Administration.

Palumbi, S. R., Sandifer, P. A., Allan, J. D., Beck, M. W., Fautin, D. G., Fogarty, M. J., Halpern, B. S., Incze, L. S., Leong, J. A., Norse, E., Stachowicz, J. J., & Wall, D. H. (2009). Managing for ocean biodiversity to sustain marine ecosystem services. *Frontiers in Ecology and the Environment*, *7*(4), 204–211. https://doi.org/10.1890/070135

Papahānaumokuākea Marine National Monument (PMNM) (2008). *Papahānaumokuākea Marine National Monument Management Plan*. National Oceanic and Atmospheric Administration, U.S. Fish and Wildlife Service, & state of Hawai‘i, Department of Land and Natural Resources. https://www.papahanaumokuakea.gov/management/mp.html

Papahānaumokuākea Marine National Monument (PMNM) (2011a). *Maritime heritage research, education, and management plan: Papahānaumokuākea Marine National Monument*. National Oceanic and Atmospheric Administration, State of Hawai‘i, & U.S. Fish and Wildlife Service. https://nmspapahanaumokuakea.blob.core.windows.net/papahanaumokuakea-prod/media/archive/pdf/mh_plan.pdf

Papahānaumokuākea Marine National Monument (PMNM) (2011b). *Papahānaumokuākea Marine National Monument Natural Resources Science Plan*. National Oceanic and Atmospheric Administration, U.S. Fish and Wildlife Service, & state of Hawai‘i, Department of Land and Natural Resources. https://nmspapahanaumokuakea.blob.core.windows.net/papahanaumokuakea-prod/media/archive/pdf/nrsc_plan.pdf

Papahānaumokuākea Marine National Monument (PMNM), & National Marine Fisheries Service (2019). *Shallow and mesophotic reef fish data* (Version 1). [Data set]. U.S. Department of Commerce, National Oceanic and Atmospheric Administration.

Parrish FA, Baco AR, Kelley C, Reiswig H (2017) State of Deep-Sea Coral and Sponge Ecosystems of the U.S. Pacific Islands Region. In: Hourigan TF, Etnoyer, PJ, Cairns, SD (eds.). The State of Deep-Sea Coral and Sponge Ecosystems of the United States. NOAA Technical Memorandum NMFS-OHC-4, Silver Spring, MD. 40 p. http://deepseacoraldata.noaa.gov/library.

Parrish, F. A., & Baco, A. R. (2007). State of deep coral ecosystems in the U.S. Pacific Islands region: Hawai'i and the U.S. Pacific territories. In S. E. Lumsden, T. F. Hourigan, A. W. Bruckner, & G. Dorr (Eds.), *The state of deep coral ecosystems in the United States*. *NOAA Technical Memorandum CRCP-3* (pp. 155-194). U.S. Department of Commerce, National Oceanic and Atmospheric Administration. https://www.coris.noaa.gov/activities/deepcoral_rpt/DeepCoralRpt2007.pdf

Pascoe, K. H. (2019). *Community structure and demographic drivers of partial mortality in corals throughout the Papahānaumokuākea Marine National Monument* (Publication No. 13897390). [Master's thesis, University of Hawaii at Hilo]. ProQuest Dissertations Publishing.

Plentovich, S., Farmer, C., Laut, M., Marshall, A., & Rounds, R. (2014). *Nihoa Island biological monitoring and management, 23 September–3 October 2014*. [Unpublished report]. U.S. Department of the Interior, U.S. Fish and Wildlife Service.

Plentovich, S., Rounds, R., Bruegmann, M., Caraway, V., Javar-Salas, C., Kroessig, T., Higashino, J., Sischo, D., Sprague, J., & Conant, S. (2015). *Nihoa Island trip report, 1-11 June, 2015*. U.S. Department of the Interior, U.S. Fish and Wildlife Service.

Plentovich, S., Hebshi, A., & Conant, S. (2009). Detrimental effects of two widespread invasive ant species on weight and survival of colonial nesting seabirds in the Hawaiian Islands. *Biological Invasions*, *11*, 289–298. https://doi.org/10.1007/s10530-008-9233-2

Polovina, J. J., Mitchum, G. T., Graham, N. E., Craig, M. P., Demartini, E. E., & Flint, E. N. (1994). Physical and biological consequences of a climate event in the central North Pacific. *Fisheries Oceanography*, *3*(1), 15–21. https://doi.org/10.1111/j.1365-2419.1994.tb00044.x

Polovina, J.J. (2005). Climate variation, regime shifts, and implications for sustainable fisheries. *Bulletin of Marine Science*, *76*(2), 233–244.

Polovina, J. J., Chai, F., Howell, E. A., Kobayashi, D. R., Shi, L., & Chao, Y. (2008). Ecosystem dynamics at a productivity gradient: A study of the lower trophic dynamics around the northern atolls in the Hawaiian Archipelago. *Progress in Oceanography*, *77*(2–3), 217–224. https://doi.org/10.1016/j.pocean.2008.03.011

Pyle, R. L., Greene, B. D., & Kosaki, R. K. (2016). *Tosanoides obama*, a new species of basslet (Perciformes, Serranidae, Anthiinae) from deep coral reefs in the Northwestern Hawaiian Islands. *ZooKeys*, *641*, 165–181. https://doi.org/10.3897/zookeys.641.11500

Pyle, R. L., & Kosaki, R. K. (2016). *Prognathodes basabei*, a new species of butterflyfish (Perciformes, Chaetodontidae) from the Hawaiian Archipelago. *ZooKeys*, *614*, 137–152. https://doi.org/10.3897/zookeys.614.10200

Pyle, R. L., & Pyle, P. (2017, 1 January). *The birds of the Hawaiian Islands: Occurrence, history, distribution, and status, version 2*. Bishop Museum. http://hbs.bishopmuseum.org/birds/rlp-monograph/

Randall, J. E. (1987). Introductions of marine fishes to the Hawaiian Islands. *Bulletin of Marine Science 41*(2), 490–502.

Randall, J. E. (1992). Endemism of fishes in Oceania. In *Coastal resources and systems of the Pacific Basin: Investigation and steps toward protective management. UNEP Regional Seas Reports and Studies No. 147* (pp. 55–67). UNEP Regional Seas Reports and Studies No. 147. United Nations Environment Programme.

Randall, J. E. (1998). Zoogeography of shore fishes of the Indo-Pacific region. *Zoological Studies*, *37*(4), 227–268.

Rapp, D. C., Youngren, S. M., Hartzell, P., & Hyrenbach, K. D. (2017). Community-wide patterns of plastic ingestion in seabirds breeding at French Frigate Shoals, Northwestern Hawaiian Islands. *Marine Pollution Bulletin*, *123*(1–2), 269–278. https://doi.org/10.1016/j.marpolbul.2017.08.047

Rauzon, M. J. (2001). *Isles of refuge: Wildlife and history of the Northwestern Hawaiian Islands*. University of Hawaiʻi Press.

Raymond, A. (2009). *A cultural resource inventory at Mokumanamana, Hawaiian Islands National Wildlife Refuge, Papahānaumokuākea Marine National Monument, July 2008 Trip Report*. [Unpublished report]. U.S. Department of the Interior, U.S. Fish and Wildlife Service.

Reynolds, M. H., Berkowitz, P., Courtot, K. N., & Krause, C. M. (Eds.) (2012). *Predicting sea-level rise vulnerability of terrestrial habitat and wildlife of the Northwestern Hawaiian Islands*. *Open-File Report 2012–1182*. U.S. Department of the Interior, U.S. Geological Survey. https://pubs.usgs.gov/of/2012/1182/of2012-1182.pdf

Reynolds, M. H., Hatfield, J. S., Laniawe, L. P., Vekasy, M. S., Klavitter, J. L., Berkowitz, P., Crampton, L. H., & Walters, J. R. (2012). Influence of space use on fitness and the reintroduction success of the Laysan teal. *Animal Conservation*, *15*(3), 305–317. https://doi.org/10.1111/j.1469-1795.2012.00520.x

Reynolds, M. H., Courtot, K. N., Berkowitz, P., Storlazzi, C. D., Moore, J., & Flint, E. (2015). Will the effects of sea-level rise create ecological traps for Pacific island seabirds? *PLoS ONE*, *10*(9), e0136773. https://doi.org/10.1371/journal.pone.0136773

Reynolds, M. H., Courtot, K. N., Brinck, K. W., Rehkemper, C. L., & Hatfield, J. S. (2015). Long-term monitoring of endangered Laysan ducks: Index validation and population estimates 1998–2012. *Journal of Fish and Wildlife Management*, *6*(1), 92–101. https://doi.org/10.3996/032014-JFWM-017

Reynolds, L., & Parrish, J. (2015). *Guide to the plants of Kure Atoll*. State of Hawaiʻi, Department of Land and Natural Resources, Division of Forestry and Wildlife. http://kureatollconservancy.org/wp-content/uploads/2012/07/Kure_Plant_Guidebook_28FEB2015.pdf

Reynolds, M. H., Berkowitz, P., Klavitter, J. L., & Courtot, K. N. (2017). Lessons from the Tōhoku tsunami: A model for island avifauna conservation prioritization. *Ecology and Evolution*, *7*(15), 5873–5890. http://dx.doi.org/10.1002/ece3.3092

Richardson, M. 2007. U.S. Fish and Wildlife Service, Memo to file regarding nonnative grasshopper on Northwestern Hawaiian Islands, April 17, 2007.

Rivera, M. A. J., Andrews, K. R., Kobayashi, D. R., Wren, J. L. K., Kelley, C., Roderick, G. K., & Toonen, R. J. (2011). Genetic analyses and simulations of larval dispersal reveal distinct populations and directional connectivity across the range of the Hawaiian grouper (*Epinephelus quernus*). *Journal of Marine Sciences*, *2011*, 765353. https://doi.org/10.1155/2011/765353

Rogers, A. D., Baco, A., Griffiths, H., Hart, T., & Hall-Spencer, J. M. (2007). Corals on seamounts. In T. J. Pitcher, T. Morato, P. J. B. Hart, M. R. Clark, N. Haggan, & R. S. Santos (Eds.), *Seamounts: Ecology, Fisheries and Conservation* (pp. 141–169). Blackwell Publishing.

Rooney, J., Fletcher, C., Engels, M., Grossman, E., & Field, M. (2004). El Niño influence on Holocene reef accretion in Hawai‘i. *Pacific Science*, *58*(2), 305–324.

Rooney, J. J., Wessel, P., Hoeke, R., Weiss, J., Baker, J., Parrish, F., Fletcher, C. H., Chojnacki, J., Garcia, M., Brainard, R., & Vroom, P. (2008). Geology and geomorphology of coral reefs in the Northwestern Hawaiian Islands. In B. Riegl & R. E. Dodge (Eds.), *Coral reefs of the USA* (pp. 519–571). Springer Netherlands.

Rounds, R., Plentovich, S., Sachs, E., Vetter, J., Dalton, M. and Frohlich, D. (2019). Nihoa Island biological monitoring and management, September 2019. Unpublished report to the U.S. Fish and Wildlife Service.

Schultz, J. K., O’Malley, J. M., Kehn, E. E., Polovina, J. J., Parrish, F. A., & Kosaki, R. K. (2011). Tempering expectations of recovery for previously exploited populations in a fully protected marine reserve. *Journal of Marine Sciences*, *2011*, 749131. https://doi.org/10.1155/2011/749131

See, K., Godwin, S., & Menza, C. (2009). Nonindigenous and invasive species. In A. Friedlander, K. Keller, L. Wedding, A. Clarke, M. Monaco (eds.). In A. Friedlander, K. Keller, L. Wedding, A. Clarke, M. Monaco (Eds.), *A marine biogeographic assessment of the Northwestern Hawaiian Islands*. *NOAA Technical Memorandum NOS NCCOS 84* (pp. 275–290). U.S. Department of Commerce, National Oceanic and Atmospheric Administration. https://repository.library.noaa.gov/view/noaa/506

Seki, M. P., Polovina, J. J., Kobayashi, D. R., Bidigare, R. R., & Mitchum, G. T. (2002). An oceanographic characterization of swordfish (*Xiphias gladius*) longline fishing grounds in the Subtropical North Pacific. *Fisheries Oceanography*, *11*(5), 251–266. https://doi.org/10.1046/j.1365-2419.2002.00207.x

Seminoff, J. A., Allen, C. D., Balazs, G. H., Dutton, P. H., Eguchi, T., Haas, H. L., Hargrove, S. A., Jensen, M., Klemm, D. L., Lauritsen, A. M., MacPherson, S. L., Opay, P., Possardt, E. E., Pultz, S., Seney, E., Van Houtan, K. S., & Waples, R. S. (2015). *Status review of the green turtle (*Chelonia mydas*) under the U.S. Endangered Species Act*. *Technical Memorandum NMFS-SWFSC-539*. U.S. Department of Commerce, National Oceanic and Atmospheric Administration. https://repository.library.noaa.gov/view/noaa/4922

Sharp, W. D., & Clague, D. A. (2006). 50-Ma initiation of Hawaiian-Emperor bend records major change in Pacific plate motion. *Science*, *313*(5791), 1281–1284. https://doi.org/10.1126/science.1128489

Sherwood, A. R., Huisman, J. M., Paiano, M. O., Williams, T. M., Kosaki, R. K., Smith, C. M., Giuseffi, L., & Spalding, H. L. (2020) Taxonomic determination of the cryptogenic red alga, *Chondria tumulosa* sp. nov., (Rhodomelaceae, Rhodophyta) from Papahānaumokuākea Marine National Monument, Hawai‘i, USA: A new species displaying invasive characteristics. *PLoS ONE*, *15*(7), e0234358. https://doi.org/10.1371/journal.pone.0234358

Sherwood, A. R., Paiano, M. O., Wade, R. M., Cabrera, F. C., Spalding, H. L., & Kosaki, R. K. (2020). Biodiversity of Hawaiian Peyssonneliales (Rhodophyta). 1. Two new species in the genus *Ramicrusta* from Lehua Island [Manuscript in press]. *Pacific Science*.

Siciliano, D. (2005). *Latitudinal limits to coral reef accretion: Testing the Darwin Point hypothesis at Kure Atoll, Northwestern Hawaiian Islands, using new evidence from high resolution remote sensing and* in situ *data* (Publication No. 3187699). [Doctoral dissertation, University of California, Santa Cruz]. ProQuest Dissertations Publishing.

Smith, D. M. (2010). *The ecology of shipwrecks: An assessment of biodiversity*. [Master's thesis, University of Hawai'i at Mānoa].

Spalding, H. L., Conklin, K. Y., Smith, C. M., O'Kelly, C. J., & Sherwood, A. R. (2016). New (Ulvaceae, Chlorophyta) from mesophotic ecosystems across the Hawaiian Archipelago. *Journal of Phycology*, *52*(1), 40–53. https://doi.org/10.1111/jpy.12375

Spennemann, D. H. R. (1998). Excessive exploitation of Central Pacific seabird populations at the turn of the 20th century. *Marine Ornithology*, *26*, 49–57.

Stachowicz, J. J., Bruno, J. F., & Duffy, J. E. (2007). Understanding the effects of marine biodiversity on communities and ecosystems. *Annual Review of Ecology, Evolution, and Systematics*, *38*, 739–766. https://doi.org/10.1146/annurev.ecolsys.38.091206.095659

Starr, F., Martz, K., & Loope, L. (2001). *Botanical inventory of Kure Atoll*. United States Geological Survey. http://www.hear.org/starr/publications/botanical_inventory_of_kure_text.pdf

Starr, F., & Starr, K. (2008). *Botanical survey of Midway Atoll*. Report prepared for U.S. Fish and Wildlife Service. http://www.starrenvironmental.com/publications/2008_botanical_survey_of_midway_atoll.pdf

Starr, F., & Starr, K. (2013). *Botanical survey of Laysan Island, Hawaiian Islands National Wildlife Refuge*. Report prepared for U.S. Fish and Wildlife Service. http://www.starrenvironmental.com/publications/2013-botanical_survey_of_laysan_island-starr.pdf

Starr F., & Starr, K. (2015). *Botanical survey of Midway Atoll* [Unpublished report]. U.S. Department of the Interior, U.S. Fish and Wildlife Service.

State of Hawai'i, National Oceanic and Atmospheric Administration, Office of Hawaiian Affairs, and U.S. Fish and Wildlife Service (2008). *Nomination of Papahānaumokuākea Marine National Monument for Inscription on the World Heritage List*. https://nmspapahanaumokuakea.blob.core.windows.net/papahanaumokuakea-prod/media/archive/management/wh_docs/wh_full_app.pdf

Storlazzi, C. D., Berkowitz, P., Reynolds, M. H., & Logan, J. B. (2013). *Forecasting the impact of storm waves and sea-level rise on Midway Atoll and Laysan Island within the Papahānaumokuākea Marine National Monument – A comparison of passive versus dynamic inundation models*. *Open-File Report 2013–1069*. U.S. Department of the Interior, U.S. Geological Survey. https://pubs.usgs.gov/of/2013/1069/

Storlazzi, C. D., Shope, J. B., Erikson, L. H., Hegermiller, C. A., & Barnard, P. L. (2015). *Future wave and wind projections for United States and United States-affiliated Pacific Islands*. *Open-File Report 2015–1001*. U.S. Department of the Interior, U.S. Geological Survey. https://doi.org/10.3133/ofr20151001

Storlazzi, C. D., Gingerich, S. B., van Dongeren, A., Cheriton, O. M., Swarzenski, P. W., Quataert, E., Voss, C. I., Field, D. W., Annamalai, H., Piniak, G. A., McCall, R. (2018). Most atolls will be uninhabitable by the mid-21st century because of sea-level rise exacerbating wave-driven flooding. *Science Advances*, *4*(4), eeap9741. https://doi.org/10.1126/sciadv.aap9741

Sweet, W. V., Kopp, R. E., Weaver, C. P., Obeysekera, J., Horton, R. M., Thieler, E. R., & Zervas, C. (2017). *Global and regional sea level rise scenarios for the United States*. *NOAA Technical Report NOS CO-OPS 083*. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Ocean Service, Center for Operational Oceanographic Products and Services. https://tidesandcurrents.noaa.gov/publications/techrpt83_Global_and_Regional_SLR_Scenarios_for_the_US_final.pdf

Sweet, W. V., Horton, R., Kopp, R. E., LeGrande, A. N., & Romanou, A. (2017). Sea level rise. In D. J. Wuebbles, D. W. Fahey, K. A. Hibbard, D. J. Dokken, B. C. Stewart, & T. K. Maycock (Eds.), *Climate science special report: Fourth national climate assessment* (Vol. 1) (pp. 333–363). U.S. Global Change Research Program. https://doi.org/10.7930/J0VM49F2

Sweet, W. V., Dusek, G., Obeysekera, J., & Marra, J. (2018). *Patterns and projections of high tide flooding along the U.S. coastline using a common impact threshold*. *Technical Report NOS CO-OPS 086*. U.S. Department of Commerce, National Oceanic and Atmospheric Administration.

Taylor, R. V. (2017). *Findings from a Survey of Native and Exotic Species on Midway Atoll National Wildlife Refuge*. Technical report prepared for the U.S. Fish and Wildlife Service, Honolulu, HI.

Timmers, M. (2019). Cryptic invertebrate species biodiversity at Pacific Islands coral reefs. [Unpublished data set]. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service.

Toonen, R. J., Andrews, K. R., Baums, I. B., Bird, C. E., Concepcion, G. T., Daly-Engel, T. S., Eble, J. A., Anuschka, F., Gaither, M. R., Iacchei, M., Puritz, J. B., Schultz, J. K., Skillings, D. J., Timmers, M. A., & Bowen, B. W. (2011). Defining boundaries for ecosystem-based management: A multispecies case study of marine connectivity across the Hawaiian Archipelago. *Journal of Marine Sciences*, *2011*, 460173. https://doi.org/10.1155/2011/460173

Tsuda, R. T. (2014). Bibliographic catalogue of the marine benthic algae in the Papahānaumokuākea Marine National Monument (Northwestern Hawaiian Islands). *Phytotaxa*, *167*(1), 35–60. http://dx.doi.org/10.11646/phytotaxa.167.1.2

Tsuda, R. T., Spalding, H. L., & Sherwood, A.R. (2015). New species records of marine benthic algae in the Papahānaumokuākea Marine National Monument (Northwestern Hawaiian Islands). In N. L. Evenhuis & S. E. Miller (Eds.), Records of the Hawaii Biological Survey for 2014. Part I: Articles. *Bishop Museum Occasional Papers*, *116*, 41–47.

Turley, C. M., Roberts, J. M., & Guinotte, J. M. (2007). Corals in deep-water: Will the unseen hand of ocean acidification destroy cold-water ecosystems? *Coral Reefs*, *26*, 445–448. https://doi.org/10.1007/s00338-007-0247-5

Underwood, J. (2013). Population status of the endangered Laysan finch. *The Wilson Journal of Ornithology*, *125*(1), 159–164. https://doi.org/10.1676/11-176.1

U.S. Environmental Protection Agency (EPA) (2014a). *Technical support document to the preliminary assessment of the FWS – Hawaiian Islands National Wildlife Refuge: Tern Island site in the French Frigate Shoals, Hawai'i*. https://www.epa.gov/sites/production/files/2015-12/documents/ternisland-tsd.pdf

U.S. Environmental Protection Agency (EPA) (2014b). *Preliminary assessment report FWS—Hawaiian Islands National Wildlife Refuge: Tern Island French Frigate Shoals, Hawai'i*. Report prepared for U.S. Environmental Protection Agency by Weston Solutions, Inc. https://www.epa.gov/sites/production/files/2015-12/documents/ternisland-pa.pdf

U.S. Environmental Protection Agency (EPA) (2018). Tern Island preliminary assessment. Retrieved from https://response.epa.gov/TernIsland

U.S. Fish and Wildlife Service (USFWS) (1994). 50 CFR Part 17. Endangered and threatened wildlife and plants; endangered status for 12 plants from the Hawaiian Islands. *Federal Register*, *59*(217), 56333–56351.

U.S. Fish and Wildlife Service (USFWS) (2009). *Laysan duck revised recovery plan*. https://www.fws.gov/pacific/ecoservices/documents/LaysanDuckRRP/LaysanDuckRRP.html

U.S. Fish and Wildlife Service (USFWS) (2010). *5-year review*. *Short form summary*. *Species reviewed:* Mariscus pennatiformis. https://ecos.fws.gov/docs/five_year_review/doc3329.pdf

U.S. Fish and Wildlife Service (USFWS) (2012). *Trip report: Laysan Island* [Unpublished report].

U.S. Fish and Wildlife Service (USFWS) (2013). Midway base closure. Retrieved from https://www.fws.gov/refuge/Midway_Atoll/preserving_the_past/Midway_Base_Closure.html

U.S. Fish and Wildlife Service (USFWS) (2014). *Trip report: Laysan Island* [Unpublished report].

U.S. Fish and Wildlife Service (USFWS) (2015). *5-year review*. *Short form summary*. *Species reviewed:* Pritchardia remota *(Loulu)*. https://ecos.fws.gov/docs/five_year_review/doc5360.pdf

U.S. Fish and Wildlife Service (USFWS) (2016). *Trip Report: Hawaiian Islands NWR.* [Unpublished report].

U.S. Fish and Wildlife Service (USFWS) (2018). *Trip Report: Hawaiian Islands NWR.* [Unpublished report].

U.S. Fish and Wildlife Service (USFWS) (2019a). *Midway seabird protection project: Final environmental assessment: Sand Island, Midway Atoll, Papahānaumokuākea Marine National Monument*. https://www.fws.gov/uploadedFiles/Region_1/NWRS/Zone_1/Midway_Atoll/Sections/What_We_Do/Resouce_Management/Final_Midway_Seabird_EA_Jan_2019.pdf

U.S. Fish and Wildlife Service (USFWS) (2019b). Northwestern Hawaiian Islands flora. [Unpublished data set].

U.S. Fish and Wildlife Service (USFWS) (2020). Breeding pairs of black-footed albatross and Laysan albatross from Midway, French Frigate Shoals and Laysan Island 1980–2020. [Unpublished data set].

Vanderlip, C. (2005). *Kure Atoll Seabird Sanctuary, final field report, 5 May–13 October 2005* [Unpublished report]. State of Hawai'i, Department of Land and Natural Resources, Division of Forestry and Wildlife.

Vanderlip, C. (2006). *Kure Atoll Wildlife Sanctuary, Northwestern Hawaiian Islands, 2006 field report, field season dates May 8–September 28, 2006* [Unpublished report]. State of Hawai'i, Department of Land and Natural Resources, Division of Forestry and Wildlife.

Vanderlip, C. (2007). *Kure Atoll Seabird Sanctuary, Papahānaumokuākea Marine National Monument, 2007 field report, May 18–September 9, 2007* [Unpublished report]. State of Hawai‘i, Department of Land and Natural Resources, Division of Forestry and Wildlife.

VanderWerf, E., & David, R. (2000). *Kure Atoll seabird survey* [Unpublished report]. State of Hawai‘i, Department of Land and Natural Resources, Division of Forestry and Wildlife.

VanderWerf, E. A., Tsukayama, D. H., Amidon, F. A. & Aldeguer, W. (2011). *Nihoa Island biological monitoring and management, 2–16 September 2011* [Unpublished report]. U.S. Department of the Interior, U.S. Fish and Wildlife Service.

VanderWerf, E. A. (2012). *Hawaiian bird conservation action plan*. Pacific Rim Conservation.

VanderWerf, E. A., & Young, L. C. (2017). *A summary and gap analysis of seabird monitoring in the U.S. tropical Pacific*. Report prepared for the U.S. Fish and Wildlife Service.

Van Houtan, K. S., Kittinger, J. N., Lawrence, A. L., Yoshinaga, C., Born, V. R., & Fox, A. (2012). Hawksbill sea turtles in the Northwestern Hawaiian Islands. *Chelonian Conservation and Biology*, *11*(1), 117–121. http://dx.doi.org/10.2744/CCB-0984.1

Van Strien, A., Pannekoek, J., Haggemeijer, W., & Verstrael, T. (2004). A loglinear Poisson regression method to analyse bird monitoring data. In A. Anselin (Ed.), Bird Numbers 1995, Proceedings of the International Conference and 13th Meeting of the European Bird Census Council. *Bird Census News*, *13*, 33–39.

Vatter, A. (2003). *Bottom longline fishing for sharks in the Northwestern Hawaiian Islands*. *National Marine Fisheries Service Pacific Islands Region Administrative Report ARPIR-03-01*. U.S. Department of Commerce, National Oceanic and Atmospheric Administration.

Vaughan, T. W. (1907). *Recent Madreporaria of the Hawaiian Islands and Laysan*. Smithsonian Institution: United States National Museum (Bulletin 59). https://doi.org/10.5479/si.03629236.59.i

Vaz, A. C. (2012). *Here today, gone tomorrow: Flow variability, larval dispersal and fisheries management in Hawai‘i*. [Doctoral dissertation, University of Hawai‘i at Mānoa].

Wagner, D., & Polhemus, D. A. (2016). *Climate change vulnerability assessment for the Papahānaumokuākea Marine National Monument*. *Marine Sanctuaries Conservation Series ONMS-16-03*. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, Office of National Marine Sanctuaries.

Wagner, W. L, Bruegmann, M. M., Herbst, D. M., & Lau, J. Q. C. (1999). Hawaiian Vascular Plants at Risk: 1999. *Bishop Museum Occasional Papers*, *60*, 1–64.

Wagner, W. L., Herbst, D. R., & Sohmer, S. H. (1999). *Manual of the flowering plants of Hawai‘i* (Vols. 1 & 2). University of Hawai‘i Press.

Wallace, B. P., Lewison, R. L., McDonald, S. L., McDonald, R. K., Kot, C. Y., Kelez, S., Bjorkland, R. K., Finkbeiner, E. M., Helmbrecht, S., & Crowder, L. B. (2010). Global patterns of marine turtle bycatch. *Conservation Letters*, *3*(3), 131–142. https://doi.org/10.1111/j.1755-263X.2010.00105.x

Wang, J., Caccamise, S. A. L., Woodward, L. A., & Li, Q. X. (2015). Polychlorinated biphenyls in the plasma and preen oil of black-footed albatross (*Diomedea nigripes*) chicks and adults on Midway Atoll, North Pacific Ocean. *PLoS ONE*, *10*(4), e0123041. https://doi.org/10.1371/journal.pone.0123041

Waterkeeper Alliance (2019, July 31). *Native oysters return to their namesake waters: Pearl Harbor*. https://waterkeeper.org/news/native-oysters-return-pearl-harbor/

Wegman, A., David, R., & Costa, M. (2002). *Biological monitoring expedition: Nihoa Island, September 2–9, 2002*. U.S. Fish and Wildlife Service.

Western Pacific Regional Fisheries Management Council (WPRFMC). (2010). *Amendment 2 to the fishery ecosystem plan for the Hawaii archipelago: Management Measures for the Hancock Seamounts to address the overfished condition of armorhead* (Pseudopentaceros wheeleri).

http://www.wpcouncil.org/fep/Amendments/HI%20FEP%20A2%20Hancock%20Seamounts%20(2010-08-06).pdf

Western Pacific Regional Fisheries Management Council (WPRFMC). (2016). *Draft fishery ecosystem plan for the Pacific pelagic fisheries*. http://www.wpcouncil.org/wp-content/uploads/2016/01/DRAFT-Pelagic-FEP-011516_with-Appendices.pdf

Williams, I. D., Richards, B. L., Sandin, S. A., Baum, J. K., Schroeder, R. E., Nadon, M. O., Zgliczynski, B., Craig, P., McIlwain, J. L., & Brainard, R. E. (2011). Differences in reef fish assemblages between populated and remote reefs spanning multiple archipelagos across the central and western Pacific. *Journal of Marine Sciences*, *2011*, 826234. https://doi.org/10.1155/2011/826234

Williams, I. D., Baum, J. K., Heenan, A., Hanson, K. M., Nadon, M. O., & Brainard, R. E. (2015). Human, oceanographic and habitat drivers of central and western Pacific coral reef fish assemblages. *PLoS ONE*, *10*(4), e0120516. https://doi.org/10.1371/journal.pone.0120516

Woodward, P. W. (1972). The natural history of Kure Atoll, Northwestern Hawaiian Islands. *Atoll Research Bulletin*, *164*, 1–317. https://doi.org/10.5479/si.00775630.164.1

Work, T. M., Balazs, G. H., Rameyer, R. A., & Morris, R. A. (2004). Retrospective pathology survey of green turtles *Chelonia mydas* with fibropapillomatosis in the Hawaiian Islands, 1993–2003. *Diseases of Aquatic Organisms*, *62*, 163–176. https://doi.org/10.3354/dao062163

Work, T. M., Aeby, G. S., & Maragos, J. E. (2008). Phase shift from a coral to a corallimorph-dominated reef associated with a shipwreck on Palmyra Atoll. *PLoS ONE*, *3*(8), e2989. https://doi.org/10.1371/journal.pone.0002989

Work, T. M., Klavitter, J. L., Reynolds, M. H., & Blehert, D. (2010). Avian botulism: A case study in translocated endangered Laysan ducks (*Anas laysanensis*) on Midway Atoll. *Journal of Wildlife Diseases*, *46*(2), 499–506. https://doi.org/10.7589/0090-3558-46.2.499

Youngren, S. M., Rapp, D. C., Hyrenbach, K. D. (2018). Plastic ingestion by Tristram's storm-petrel *(Oceanodroma tristrami*) chicks from French Frigate Shoals, Northwestern Hawaiian Islands. *Marine Pollution Bulletin*, *128*, 369–378. https://doi.org/10.1016/j.marpolbul.2018.01.053

ACKNOWLEDGEMENTS

This report would not have been possible without significant contributions from many state and federal agencies, academic and non-governmental organizations, consortia, partners, funders, and researchers. Subject matter experts who contributed substantial time, data and interpretation, and authorship to various sections of the report are listed below and are also acknowledged in their relative sections. In addition to those individuals, Papahānaumokuākea Marine National Monument would like to acknowledge Tetra Tech, Inc., Atsuko Fukunaga, and David Graham for supporting the development and review of the report.

We also would like to extend a special thanks to the peer reviewers of his document: Cynthia Hunter (University of Hawai‘i), Dan Polhemus (U.S. Fish and Wildlife Service), and Donald Schug (Northern Economics).

Lastly, we are grateful to Katie Lohr and Dayna McLaughlin (NOS ONMS) for providing copy edits and Kahi Fujii (PMNM) for designing the final report.

SUBJECT MATTER EXPERTS

State of Hawai‘i Department Of Health
Fenix Grange

State of Hawai‘i Department of Land and Natural Resources
Cynthia Vanderlip

U.S. Fish and Wildlife Service
Beth Flint
Annie Marshall
Sheldon Plentovich
Anan Raymond
Cindy Rehkemper
Rebecca Rounds
Lou Ann Speulda-Drews
Jared Underwood
Leann Woodward

NOAA National Marine Fisheries Service
Melanie Abecassis
Hannah Barkley
Rusty Brainard
Courtney Couch
Kyle Van Houtan
T. Todd Jones
Charles Littnan
Joseph O’Malley

Frank Parrish
John Rooney
Molly Timmers
Bernardo Vargas-Angel
Ivor Williams

NOAA National Ocean Service, Office of National Marine Sanctuaries

Athline Clark
Scott Godwin
Brian Hauk
Kelly Keogh
Randall Kosaki
Jonathan Martinez
Kalani Quiocho
Dan Wagner

NOAA National Environmental Satellite, Data, and Information Service

John Marra

U.S. Geological Survey

Michelle Reynolds

Other

Holly Bolick
Kekuewa Kikiloi
Kalei Nuuhiwa
Heather Spalding

APPENDIX A: Rating Criteria for Evaluating the State of Monument Resources

This rating system consists of resource evaluation questions and a set of standardized responses used to report the condition of the monument's resources. Staff from the NOAA Office of National Marine Sanctuaries met with subject matter experts and used this guidance, as well as their own understanding of the condition of resources, to make judgments about the status and trends of the monument's resources.

The resource condition questions utilized in the State of the Monument Report largely derive from the National Marine Sanctuary System-wide monitoring framework. A number of these questions were modified or omitted in the process of developing a suite of priority resource categories pertinent to Papahānaumokuākea. Evaluations of status and trends were based on interpretation of quantitative and, when necessary, non-quantitative assessments and observations of scientists, managers, and users.

Ratings for some of the questions depend on judgments of the ecological integrity within the monument. The term ecological integrity is used to imply "the presence of naturally occurring species, populations and communities, and ecological processes functioning at appropriate rates, scales, and levels of natural variation, as well as the environmental conditions that support these attributes" (modified from National Park Service, 2020). Protected areas such as Papahānaumokuākea have ecological integrity when they have their native components intact, including abiotic components (i.e., physical forces and chemical elements, such as water), biotic elements (such as habitats), biodiversity (i.e., the composition and abundance of species and communities), and ecological processes (e.g., competition, predation, symbioses). For purposes of this report, the level of integrity that is judged to exist is based on the extent to which humans have altered specific components of the system and the effect of that change on the ability of an ecosystem to resist continued change and recover from it. The statements for many questions are intended to reflect this judgment. Reference is made in the rating system to "near-pristine" conditions; for the purposes of this report, the term near-pristine denotes a status as near to an unaltered ecosystem as can reasonably be presumed to exist, recognizing that there are virtually no ecosystems on Earth completely free from human influence.

Subject matter experts discussed each question and available data, literature (e.g., published scientific studies, reports), and experience associated with the topic. They then discussed the status descriptions provided as options for judgments about status; these descriptions have been customized for each question. Once a particular description was agreed upon, a color code and status rating (e.g., good, fair, poor) was assigned. Experts could also decide that the most appropriate rating was "N/A" (i.e., the question does not apply) or "Undetermined" (i.e., resource status is undetermined due to a paucity of relevant information). A subsequent discussion was then held about the trend. Conditions were determined to be improving, remaining the same, or declining in comparison to the results found in the first round of condition reports. Symbols used to indicate trends are the same for all questions: "▲"—conditions appear to be improving; "▬"—conditions do not appear to be changing; "▼"—conditions appear to be declining; and "?"—trend is undetermined.

PHYSICAL ENVIRONMENT

1. Have recent, accelerated changes in climate altered water conditions and how are they changing?

The purpose of this question is to capture shifts in water quality and associated impacts on sanctuary resources due to climate change. Though temporal changes in climate have always occurred on Earth, evidence is strong that changes over the last century have been accelerated by human activities. Indicators of climate change in sanctuary waters include water temperature, acidity, sea level, upwelling intensity and timing, storm intensity and frequency, changes in erosion and sedimentation patterns, and freshwater delivery (e.g., rainfall patterns). Climate-related changes in one or more of these indicators can impact the condition of habitats, living resources, and maritime archaeological resources in sanctuaries.

Increasing water temperature has been linked to changing growth rates, reduced disease resistance, and disruptions in symbiotic relationships (e.g., bleaching on coral reefs). Changes in water temperature exposure may also affect a species' resistance or its capacity to adapt to disturbances. Ocean acidification can affect the survival and growth of organisms throughout the food web, as well as the persistence of skeletal material after death (through changes in rates of dissolution and bioerosion). Recent findings also suggest acidification impacts at sensory and behavioral levels, which can alter vitality and species interactions. Sea level change alters habitats, as well as their use and persistence. Variation in the timing and intensity of upwelling is known to change water quality through factors such as oxygen content and nutrient flow, further disrupting food webs and the natural functioning of ecosystems. Changing patterns and intensities of storms alter community resistance and resilience within ecosystems that have, over long periods of time, adapted to such disturbances. Altered rates and volumes of freshwater delivery to coastal ecosystems affect salinity and turbidity regimes and can disrupt reproduction, recruitment, growth, disease incidence, phenology, and other important processes.

Status Description

Good	Climate-related changes in water conditions have not been documented or do not appear to have the potential to negatively affect ecological integrity.
Good/Fair	Climate-related changes are suspected and may degrade some attributes of ecological integrity but have not yet caused measurable degradation.
Fair	Climate-related changes have caused measurable, but not severe, degradation in some attributes of ecological integrity.
Fair/Poor	Climate-related changes have caused severe degradation in some, but not all, attributes of ecological integrity.
Poor	Climate-related changes have caused severe degradation in most, if not all, attributes of ecological integrity.

2. What are the area and distribution of abiotic habitat types and how are they changing?

The area and distribution of abiotic habitat are of paramount concern to living resources in the monument. Abiotic habitats include terrestrial features, such as rocky islands and beach strand, and submarine features, such as sand, unconsolidated rubble, and deep-water banks. Of greatest concern to the monument are changes caused, either directly or indirectly, by human activities, such as dredging and construction or maintenance activities. Severe storms and sea level rise can result in significant loss of beach strand, affecting green turtle nesting sites, Hawaiian monk seal pupping and resting sites, and nesting areas for seabirds.

Prior to and during World War II, several of the atolls were dredged to create ship channels, harbors, and turning basins and to create or enlarge islands using the dredge spoils. This dredging greatly changed water flow. Channels were created or deepened, which increased water flow and altered nearshore currents. Dredging also removed some coral heads and reefs that protected the islands. These channels are not being maintained so will potentially fill, changing the atoll water dynamics over time. While the altered currents and the aging seawalls and constructs will destroy the made lands, it is not known how they will also alter the original islands.

Status Description

Good	Habitats are in pristine or near-pristine condition and are unlikely to preclude full community development.
Good/Fair	Selected habitat loss or alteration has taken place, precluding full development of living resource assemblages, but it is unlikely to cause substantial or persistent degradation in living resources or water quality.
Fair	Selected habitat loss or alteration may inhibit the development of assemblages and may cause measurable, but not severe, declines in living resources or water quality.
Fair/Poor	Selected habitat loss or alteration has caused or is likely to cause severe declines in some, but not all, living resources or water quality.
Poor	Selected habitat loss or alteration has caused or is likely to cause severe declines in most, if not all, living resources or water quality.

3. What is the water quality condition of monument nearshore and inland waters and how is it changing?

Nearshore and inland water quality are critical characteristics in the assessment of ecosystem health. Nearshore and inland water quality can be altered by weather, land-based and sea-based sources of contaminants, sediments, and nutrients. Facility construction, maintenance, and dredging activities can affect light penetration, salinity regimes, oxygen levels, productivity, waste transport, and other factors that influence habitat and living resource quality. Fertilizers, pesticides, hydrocarbons, organochlorines, heavy metals, and sewage can cause environmental degradation. Most chemical and metal contaminants are greatly affected by their physical environment. A reducing or anoxic environment can alter a relatively non-toxic metal and materials into highly toxic or reactive compounds. Several biotoxins flourish and propagate rapidly under reduced oxygen conditions. Alteration of currents that create or flush anoxic areas can send a pulse of toxic compounds and conditions (e.g., low pH) that could damage or potentially destroy sensitive, non-resistant areas. If these areas are populated with slow-growing or slow-reacting biota, it is likely that these biota would be replaced by more resilient invasive species.

Nutrient enrichment or depletion often leads to changes in primary productivity and can affect benthic communities directly through space competition. Overgrowth and other competitive interactions (e.g., accumulation of algal-sediment mats) often lead to shifts in dominance in the benthic assemblage. Disease incidence and frequency can also be affected by algae competition and the resulting chemistry along competitive boundaries. Blooms can also affect water column conditions, including light penetration and plankton availability, which can alter pelagic food webs. Harmful algal blooms often affect resources, as biotoxins are released into the water and air, and can lead to localized oxygen depletion.

Status Description

Good	Conditions do not appear to have the potential to negatively affect living resources or habitat quality.
Good/Fair	Selected conditions may preclude full development of living resource assemblages and habitats but are not likely to cause substantial or persistent declines.
Fair	Selected conditions may inhibit the development of assemblages and may cause measurable, but not severe, declines in living resources and habitats.
Fair/Poor	Selected conditions have caused or are likely to cause severe declines in some, but not all, living resources and habitats.
Poor	Selected conditions have caused or are likely to cause severe declines in most, if not all, living resources and habitats.

4. What are the known contaminant concentrations in PMNM habitats and how are they changing?

Known contaminants in the monument include uncharacterized terrestrial dumps, sea and nearshore disposal of equipment and debris, and residual contamination from former U.S. Coast Guard and military sites, primarily at Kure Atoll, Midway Atoll, and French Frigate Shoals. New sources of contamination include hazardous materials transported as marine debris or spilled as a result of ship groundings and the ship itself, as well as other sources. The contaminants of concern generally include polychlorinated biphenyls, pesticides, petroleum fuels, polycyclic aromatic hydrocarbons, and heavy metals.

Contaminants that become sequestered in sediments can accumulate over time, and may be resuspended during storms or other energetic events, impacting local water quality. Contamination sequestered in shoreline landfills may be released by shoreline erosion, shoreline or seawall breach caused by storms or other energetic events, and from the aging and deterioration of seawalls or other shoreline armoring. Factors resulting in regionally accelerated rates of change in sea level, storm surge intensity and frequency, and associated loss or accretion of beach strand are considered in relation to their impact on terrestrial habitats. Factors resulting in changes in local air temperature, wind patterns, and concentration of airborne particulates are considered in relation to their impact on air quality and potentially water, sediment, reef, and terrestrial quality.

Status Description

Good	Contaminants do not appear to have the potential to negatively affect living resources or water quality.
Good/Fair	Selected contaminants may preclude full development of living resource assemblages, but are not likely to cause substantial or persistent degradation.
Fair	Selected contaminants may inhibit the development of assemblages and may cause measurable, but not severe, declines in living resources or water quality.
Fair/Poor	Selected contaminants have caused, or are likely to cause, severe declines in some, but not all, living resources or water quality.
Poor	Selected contaminants have caused, or are likely to cause, severe declines in most, if not all, living resources or water quality.

LIVING RESOURCES

5. What is the status of biodiversity and how is it changing?

Biodiversity, including genetic, species, and ecosystem biodiversity, is an important measure of monument health for a variety of reasons. These include increased resilience from anthropogenic and natural stressors, including disease and climate change, maximizing productivity and nutrient and energy cycling across functional groups, as well as the intrinsic importance we place on diverse ecosystems. Intact ecosystems require that all parts not only exist, but that they function together, resulting in natural symbioses, competition, and predator-prey relationships. Community integrity, resistance, and resilience all depend on these relationships. Abundance, relative abundance, trophic structure, richness, H' diversity, evenness, and other measures are often used to assess these attributes.

Status Description

Good	Biodiversity appears to reflect pristine or near-pristine conditions and promotes ecosystem integrity (full community development and function).
Good/Fair	Selected biodiversity loss has taken place, precluding full community development and function, but it is unlikely to cause substantial or persistent degradation of ecosystem integrity.
Fair	Selected biodiversity loss may inhibit full community development and function and may cause measurable, but not severe, degradation of ecosystem integrity.
Fair/Poor	Selected biodiversity loss has caused, or is likely to cause, severe declines in some, but not all, ecosystem components and reduce ecosystem integrity.
Poor	Selected biodiversity loss has caused, or is likely to cause, severe declines in ecosystem integrity.

6. What is the status of historically targeted species and how is it changing?

Historically, bottomfish, lobsters, and black-lipped pearl oysters were fishery targets in the monument. While commercial fishing was prohibited when the monument was established, the data sets from these fisheries are among the longest, most complete, and most accurate in the world. Exhaustive baseline studies of these stocks were conducted in the 1970s, prior to the onset of a consistent fishing effort, and fisheries-independent data were generated for lobsters on an annual basis for much of the fishery's history. With the establishment of the monument came provisions for gradually closing the area to fishing. Tracking the status of historically targeted fish stocks provides insight into their recovery that can be valuable for fisheries management in the Main Hawaiian Islands and elsewhere.

Status Description

Good	Species appear to reflect pristine or near-pristine conditions and may promote ecosystem integrity (full community development and function).
Good/Fair	Species are at reduced levels, perhaps precluding full community development and function, but substantial or persistent declines are not expected. The condition is not optimal, perhaps precluding full ecological function, but substantial or persistent declines are not expected.

Fair	The reduced abundance of species may inhibit full community development and function and may cause measurable, but not severe, degradation of ecosystem integrity; or, selected species are at reduced levels, but recovery is possible. The diminished condition may cause a measurable, but not severe, reduction in ecological function, but recovery is possible.
Fair/Poor	The reduced abundance of species has caused, or is likely to cause, severe declines in some, but not all, ecosystem components and reduce ecosystem integrity; or, species are at substantially reduced levels, and prospects for recovery are uncertain.
Poor	The reduced abundance of species has caused, or is likely to cause, severe declines in ecosystem integrity; or, species are at severely reduced levels, and recovery is unlikely.

7. What is the status of non-indigenous and invasive species and how is it changing?

Non-indigenous species are generally considered problematic and candidates for rapid eradication, if found soon after introduction. For those that become established, their impacts can sometimes be assessed by quantifying changes in the affected native species. This question allows PMNM to report the threat posed by non-indigenous species. Throughout its history, non-indigenous species have been a greater problem for the terrestrial ecosystems of the NWHI than the aquatic ecosystems; terrestrial non-indigenous species include plants that have degraded seabird nesting habitat and ants that increase chick mortality. In the marine environment, the presence of a species alone may constitute a significant threat (e.g., certain invasive algae). In other cases, impacts have been measured and may or may not significantly affect ecosystem integrity. Some species in this region are of uncertain origin, but may also be considered here because they have become problematic. Additionally, some species may be indigenous to the region, but undergo population explosions that have localized, and potentially widespread impacts.

Status Description

Good	Non-indigenous and/or invasive species are not suspected or do not appear to affect ecosystem integrity (full community development and function).
Good/Fair	Non-indigenous and/or invasive species exist, precluding full community development and function, but are unlikely to cause substantial or persistent degradation of ecosystem integrity.
Fair	Non-indigenous and/or invasive species may inhibit full community development and function and may cause measurable, but not severe, degradation of ecosystem integrity.
Fair/Poor	Non-indigenous and/or invasive species have caused, or are likely to cause, severe declines in some, but not all, ecosystem components and reduce ecosystem integrity.
Poor	Non-indigenous and/or invasive species have caused, or are likely to cause, severe declines in ecosystem integrity.

8. What is the status and trend of key species and how is it changing?

For those species considered essential to ecosystem integrity, measures of the status of their condition and trends can be important to determining the likelihood that they will persist and continue to provide vital ecosystem functions. Some might be keystone species, that is, species on which the persistence of a large number of other species in the ecosystem depends—the pillar of community stability. Their functional contribution to ecosystem function is disproportionate to their numerical abundance or biomass, and their impact is therefore important at the community or ecosystem level. Their removal initiates changes in ecosystem structure and sometimes the disappearance of or dramatic increase in the abundance of dependent species. Keystone species may include certain habitat modifiers, predators, herbivores, and those involved in critical symbiotic relationships (e.g., cleaning or cohabitating species).

Other species may be key because they are "foundational," meaning that they regulate the structure and productivity of a community, or because they are the dominant biomass producers in an ecosystem. Foundation species exhibit similar control over ecosystems as keystone species, but their high abundance distinguishes them. In the monument, shallow and deep corals are considered foundational.

Other key species may include those that are indicators of ecosystem condition or change (e.g., particularly sensitive species), those targeted for special protection efforts, or charismatic species that are identified with certain areas or ecosystems. These may or may not meet the definition of keystone, but do require assessments of status and trends in the monument: Hawaiian monk seals, sea turtles, seabirds, endemic land birds, and endemic terrestrial plants are sensitive and targeted for special protection efforts.

Measures of condition may include varying and multiple indicators, such as population, growth rates, fecundity, recruitment, age-specific survival, tissue contaminant levels, pathologies (disease incidence tumors, deformities), the presence and abundance of critical symbionts, or parasite loads.

Key species or functional groups identified for the monument include:

- Hawaiian monk seals,
- sea turtles,
- reef fish,
- shallow-water corals,
- deep-sea corals,
- seabirds,
- endemic land birds, and
- endemic terrestrial plants.

Status Description

Good	Key and keystone species appear to reflect pristine or near-pristine conditions and may promote ecosystem integrity (full community development and function).
Good/Fair	The condition of selected key resources is not optimal, perhaps precluding full ecological function, but substantial or persistent declines are not expected.
Fair	The diminished condition of selected key resources may cause a measurable, but not severe, reduction in ecological function, but recovery is possible.
Fair/Poor	The reduced abundance of selected keystone species has caused or is likely to cause severe declines in some, but not all, ecosystem components and reduce ecosystem integrity; or, selected key species are at substantially reduced levels, and prospects for recovery are uncertain.
Poor	The reduced abundance of selected keystone species has caused, or is likely to cause, severe declines in ecosystem integrity; or, selected key species are at severely reduced levels, and recovery is unlikely.

HERITAGE RESOURCES

The condition of historic and Native Hawaiian cultural resources assessed in this report refers only to the physical state of the resources. The integrity, which includes the intangible values of the resources, is not reflected in the assessments presented here.

9. What is the condition of known maritime archaeological resources and how is it changing?

Maritime archaeological resources refers primarily to resources submerged or partially submerged in the ocean.

The physical condition of maritime archaeological resources in the monument significantly affects their value for science and education, as well as the resource's eligibility for listing in the National Register of Historic Places. Assessments of archaeological sites include evaluation of site integrity, which is affected by human disturbance and natural deterioration. The historical, scientific, and educational values of sites are also evaluated and are substantially determined and affected by site condition.

Many important archaeological resources worldwide are actually found in dumps used by past civilizations. The monument has several dumps (landfills) that are more than 50 years old and could potentially be regulated by historic preservation laws.

Status Description

Good	Known archaeological resources appear to reflect little or no unexpected disturbance.
Good/Fair	Selected archaeological resources exhibit indications of disturbance, but there appears to have been little or no reduction in historical, scientific, or educational value.
Fair	The diminished condition of selected archaeological resources has reduced, to some extent, their historical, scientific, or educational value and may affect the eligibility of some sites for listing in the National Register of Historic Places.
Fair/Poor	The diminished condition of selected archaeological resources has substantially reduced their historical, scientific, or educational value and is likely to affect their eligibility for listing in the National Register of Historic Places.
Poor	The degraded condition of known archaeological resources in general makes them ineffective in terms of historical, scientific, or educational value and precludes their listing in the National Register of Historic Places.

10. What is the condition of known historic resources and how is it changing?

Historic resources refers to resources remaining on land. The majority of these known resources are on islets at Midway Atoll. The condition of historic resources in the monument significantly affects their value for science and education, as well as their eligibility for listing in the National Register of Historic Places. Assessments of historic sites include evaluation of the apparent levels of site integrity, which are based on levels of previous human disturbance and the level of natural deterioration. The historical, scientific, and educational values of sites are also evaluated and are substantially determined and affected by site condition.

Status Description

Good	Known historic resources appear to reflect little or no unexpected disturbance.
Good/Fair	Selected historic resources exhibit indications of disturbance, but there appears to have been little or no reduction in historical, scientific, or educational value.
Fair	The diminished condition of selected historic resources has reduced, to some extent, their historical, scientific, or educational value and may affect the eligibility of some sites for listing in the National Register of Historic Places.
Fair/Poor	The diminished condition of selected historic resources has substantially reduced their historical, scientific, or educational value and is likely to affect their eligibility for listing in the National Register of Historic Places.
Poor	The degraded condition of known historic resources in general makes them ineffective in terms of historical, scientific, or educational value and precludes their listing in the National Register of Historic Places.

11. What is the condition of known Native Hawaiian archaeological resources and how is it changing?

The condition of Native Hawaiian archaeological resources in the monument significantly affects their cultural, scientific, and educational value. Assessments of archaeological sites include evaluation of the site's physical condition, which is based on levels of previous human disturbance and the level of natural deterioration. The cultural, scientific, and educational values of sites are also evaluated and are substantially determined and affected by site condition.

Status Description

Good	Known archaeological resources appear to reflect little or no unexpected disturbance.
Good/Fair	Selected archaeological resources exhibit indications of disturbance, but there appears to have been little or no reduction in cultural, scientific, or educational value.
Fair	The diminished condition of selected archaeological resources has reduced, to some extent, their cultural, scientific, or educational value and may affect the eligibility of some sites for listing in the National Register of Historic Places.
Fair/Poor	The diminished condition of selected archaeological resources has substantially reduced their cultural, scientific, or educational value and is likely to affect their eligibility for listing in the National Register of Historic Places.
Poor	The degraded condition of known archaeological resources in general makes them ineffective in terms of cultural, scientific, or educational value and precludes their listing in the National Register of Historic Places.

12. Do known maritime, historic, or archaeological resources pose an environmental hazard and how is this threat changing?

The sinking of a ship potentially introduces hazardous materials into the marine environment. This is a danger for historic shipwrecks as well. Dealing with the issue is complicated by the fact that shipwrecks older than 50 years may be considered historical resources and must, by federal mandate, be protected. Many historic shipwrecks, particularly those from the early to mid-20th century, may contain nets and other detrimental debris. Additionally, lubricants, oil, and fuel may be present in service lines, tanks, and bunkers; release of these substances would not only degrade the environment, but would also violate federal laws. As shipwrecks age and deteriorate, the potential for release of these materials increases. Additionally, the deterioration of the vessel itself may prove detrimental, as the degraded materials may act as nutrients or toxicants (Kerr, 1996; Work et al., 2008). Ship hulls have been treated with anti-biofouling methods since the 18th century, when oil laced with arsenic, sulfur, and gunpowder was applied. Later methods included the application of lead and copper sheeting, as well as the use of antifouling paints such as tributyltin starting in the 1960s–1970s.

Some attributes of historic resources can be detrimental to the environment. Deleterious effects may involve physical damage to biota (including humans) from entrapment and material falling from above ground structures (e.g., rusted drains and air systems, cave ins) or breakthroughs of buried objects such as storage tanks (water and fuel), bunkers, drainage systems, landfills, and hospitals. Additionally, substances used in the construction of some historic resources are now banned or considered harmful or toxic, such as asbestos, lead-based paint, and arsenic-treated wood or ceiling tiles (canec). Historic buried storage tanks were not always emptied and, over time, have or will rust through and leak potentially toxic material such as petroleum.

This is also true of structures such as historic buildings, which were likely built to different standards than those used today.

Status Description

Good	Known heritage resources pose few or no environmental threats.
Good/Fair	Selected heritage resources may pose isolated or limited environmental threats, but substantial or persistent impacts are not expected.
Fair	Selected heritage resources may cause measurable, but not severe, impacts to certain monument resources or areas, but recovery is possible.
Fair/Poor	Selected heritage resources pose substantial threats to certain monument resources or areas, and prospects for recovery are uncertain.
Poor	Selected heritage resources pose serious threats to monument resources, and recovery is unlikely.

Appendix B: Consultation with Experts, Documenting Evidence, and Document Review

In 2012, Tetra Tech, Inc. (Tetra Tech) was contracted to support an update process for the Papahānaumokuākea Marine National Monument (monument) Management Plan under National Oceanic and Atmospheric Administration (NOAA) Contract No. WC133F-11-CQ-0003; Task Order No. 0004. A requirement of that contract was to complete a science review that fed into a State of the Monument Report. This component involved an expert-driven approach that was designed to summarize the state of key resources in PMNM and highlight management implications that could, among other things, be used to inform decisions about updating management strategies and activities.

An interagency review team was convened by PMNM staff. The Science Review Team consisted of representatives and subject matter experts from the then-Co-Trustee agencies: Department of Interior through U.S. Fish and Wildlife Service (USFWS); the Department of Commerce through NOAA, and the state of Hawaiʻi through the Department of Land and Natural Resources (state). The Science Review Team met numerous times to design the approach, criteria, and template for developing the State of the Monument Report. The team reviewed and adopted the 2009 monument condition report (ONMS, 2009) framework as the basis for developing the State of the Monument Report. Meetings were held to review and refine the framework and develop the criteria to be used in the State of the Monument report. Based upon these criteria, a set of review templates was developed for assessing the condition of each monument resource category (Appendix A). Each agency then distributed assessment forms and instructions to selected subject matter experts to complete (Figure AppB.1). Tetra Tech reviewed and compiled completed draft assessments and prepared partial assessments for some resources. These, along with the templates and a description of the review process, were then combined into a preliminary draft State of the Monument Report.

Beginning in 2016, staff from NOAA Office of National Marine Sanctuaries (ONMS) and the State of Hawaiʻi reviewed the preliminary draft State of the Monument Report. It was determined that in order for the report to serve as a useful supporting tool for management planning, the status and trend ratings needed to be updated and additional data incorporated. Due to data limitations, resources in the newly designated monument expansion area were not analyzed for condition and trends.

In 2018, ONMS staff invited the participation of subject matter experts familiar with physical environmental conditions, living resources, and cultural, historical, and heritage resources in PMNM. Experts were tasked with reviewing the templates and draft summaries, as well as providing additional datasets and identifying content gaps and other needed revisions.

Technical Expert: [insert name(s) of technical expert(s)]

Resource: [insert applicable resource, e.g. Physical Environment, Living Resources, etc.]

Species/Habitat (if applicable): [insert species or habitat if relevant, e.g. monk seal, coral reef]

#	Question	Rating	Summary of Findings	Management Considerations
	[Insert question you are assigned to respond to]	[Insert rating]	[Prepare 1 sentence summary of findings]	[Prepare 1 sentence summary of management considerations]

Status:

Good	Good/Fair	Fair	Fair/Poor	Poor	Undetermined

Trends:

▲ = Conditions appear to be improving

— = Conditions do not appear to be changing

▼ = Conditions appear to be declining

? = Undetermined trend

N/A = Question not applicable

Basis for Rating: Prepare 2 – 3 sentences that addresses each of the following:

1. **Condition:** Describe the condition of the resource with references of published articles, reports, and other data used as a basis for judgment (Good, Good/Fair, Fair, Fair/Poor, Poor, Undetermined, N/A).
2. **Trends:** Describe the trend in resource condition with references of published articles, reports, and other data used as a basis for judgment (Improving, Not changing, Declining). Highlight threats or emerging issues.
3. **Management Implications:** Describe management implications for actions to be taken to improve or maintain the condition of the resource. These implications will be used to adapt management strategies and actions for the Monument Management Plan update.

List References Cited: Provide a list of references cited and pdfs for inclusion in the PMNM spatial bibliography.

Figure AppB.1. A template was provided to experts for the resource questions they were asked to assess.

Experts were also given the opportunity to document the amount of evidence available when determining status and trend ratings (Figure AppB.2). They were asked to characterize the level of evidence by considering three categories of evidence typically used to make status or trend ratings: 1) data, 2) published information, and 3) personal experience. For each status and trend rating, the experts rated the overall quality of evidence as “limited,” “medium,” or “robust,” depending on the type, amount, quality, and consistency of evidence available.

Evidence Scores		
Limited	**Medium**	**Robust**
Limited data or published information and little or no substantive personal experience	Data available, some peer reviewed published information or direct personal experience	Considerable data, extensive record of publication or extensive personal experience

Figure AppB.2. The three point scale experts were asked to consider when quantifying the amount of evidence relied on when determining a status and trend rating.

All subject matter expert assessments were compiled into a draft document. Besides the new and/or updated expert opinions and evidence scores, comments, data, and citations received from the experts were included, as appropriate, in text supporting the ratings. This initial draft was made available to all contributing agencies and data providers, allowing them to review and further revise the content.

This report is subject to the review requirements of both the Information Quality Act and the White House Office of Management and Budget Final Information Quality Bulletin for Peer Review guidelines (Office of Management and Budget, 2004). In May 2020, a draft final report was sent to three regional science experts for external review. Comments and recommendations of the peer reviewers were considered and incorporated, as appropriate, into the final text of this report. Office of Management and Budget guidelines further require that reviewer comments, names, and affiliations be posted on the agency website, http://www.cio.noaa.gov/. Comments by the external peer reviewers are posted concurrently with the formatted final document.

APPENDIX C: Index of Hawaiian Names and Terms

Numerous species are commonly known by Hawaiian names in addition to English and scientific names. Species for which Hawaiian names were available to authors and editors are presented in the table below. This appendix is intended to serve as a resource for each of the names described in this report.

English Name	Scientific Name	Hawaiian Name	Species Type
Nihoa millerbird	*Acrocephalus familiaris kingi*	Ulūlu (Nihoa), Ulūlu niau (Laysan)	Bird
Northern pintail	*Anas acuta*	Koloa māpu	Bird
Laysan duck, Laysan teal	*Anas laysanensis*	Koloa pōhaka	Bird
Black noddy	*Anous minutus*	Noio, lae hina	Bird
Brown noddy	*Anous stolidus pileatus*	Noio koha	Bird
Ruddy turnstone	*Arenaria interpres*	ʻAkeke	Bird
Bulwer's petrel	*Bulweria bulwerii*	ʻOu	Bird
Great frigatebird, man-of-war bird	*Fregata minor palmerstoni*	ʻIwa	Bird
White tern, fairy tern	*Gygis alba candida*	Manu o Kū	Bird
Wandering tattler	*Heteroscelus incanus*	ʻŪlili	Bird
Laysan honeycreeper, Laysan ʻapapane	*Himatione fraithii*	ʻApapane	Bird
Sooty tern	*Onychoprion fuscata oahuensis*	ʻEwaʻewa	Bird
Gray-backed tern	*Onchoprion lunatus*	Pakalakala	Bird
White-tailed tropicbird	*Phaethon lepturus dorotheae*	Koaʻe kea	Bird
Red-tailed tropicbird	*Phaethon rubricauda rubicauda*	Koaʻe ʻula	Bird
Laysan albatross	*Phoebastria immutabilis*	Mōlī	Bird
Black-footed albatross	*Phoebastria nigripes*	Kaʻupu	Bird
Wedge-tailed shearwater	*Puffinus pacificus*	ʻUaʻu kani	Bird
Masked booby	*Sula dactylatra personatta*	ʻĀ, Akeake	Bird
Brown booby	*Sula leucogaster*	ʻĀ, Akeake	Bird
Red-footed booby	*Sula sula rubipes*	ʻĀ, Akeake	Bird
Laysan finch	*Telespiza cantans*	ʻEkupuʻu, ʻAinohu kauo	Bird
Nihoa finch	*Telespiza ultima*	Palihoa	Bird

English Name	Scientific Name	Hawaiian Name	Species Type
Giant trevally	*Caranx ignobilis*	Ulua aukea	Fish
Galapagos shark	*Carcharhinus galapagensis*	Manō	Fish
Sand-bar shark	*Carcharhinus plumbeus*	Manō	Fish
Yellow striped red snapper	*Etelis carbunculus*	ʻEhu	Fish
Long tail red snapper or onaga	*Etelis coruscans*	ʻUlaʻula koaʻe	Fish
Tiger shark	*Galeocerdo cuvier*	Niuhi	FIsh
Milletseed butterflyfish	*Chaetodon milaris*	Kikakapu	Fish
Wrasses	*Family Labridae*	Hīnālea	Fish
Moray eel	*Family Muraenidae*	Puhi	Fish
Blue marlin	*Makaira nigricans*	Aʻu	Fish
Goatfish	*Parupeneus porphyreus*	Kūmū	Fish
Bigeye, bulleye	*Priacanthus meeki*	ʻĀweoweo	Fish
Hawaiian pink snapper	*Pristipomoides filamentosus*	Opakapaka	Fish
Striped marlin	*Tetrapturus audax*	Aʻu ki	Fish
Bigeye tuna	*Thunnus obesus*	Ahi	Fish
Yellowfin tuna	*Thynnus albacares*	Ahi	FIsh
Table coral	*Acropora cytherea*	Pōhaku	Invertebrate
Black coral	*Order Antipatharia*	ʻEkaha kū moana	Invertebrate
Lobe coral	*Porites lobata*	Pōhaku	Invertebrate
Nihoa trapdoor spider	*Nihoa mahina*	Nihoa mahina	Invertebrate
Spiny lobster	*Panulirus marginatus* *Panulirus penicillatus*	Ula	Invertebrate
Slipper lobster	*Parrabicus antarcticus*	Ula pāpapa	Invertebrate
Black-lipped pearl oyster	*Pinctada margaritifera*	Pā	Invertebrate
Hawaiian land snail	*Tornatellides*	Pūpū	Invertebrate
Humpback whale	*Megaptera novaeangliae*	Koholā	Mammal
Hawaiian monk seal	*Neomonachus schauinslandi*	ʻĪlioholokauaua	Mammal
Spotted dolphin	*Stenella frontalis*	Naiʻa	Mammal
Spinner dolphin	*Stenella longirostris*	Naiʻa	Mammal
Bottlenose dolphin	*Tursiops truncatus*	Naiʻa	Mammal
Red spiderling	*Boerhavia herbstii*	Alena, Nena	Plant
Hawaiian caper	*Capparis sandwichiana*	Maiapilo, Pua pilo	Plant
Love vine	*Cassytha filiformis*	Kaunaʻoa pehu	Plant

English Name	Scientific Name	Hawaiian Name	Species Type
Laysan agrimony sandbur	*Cenchrus agrimonioides var. laysanensis*	Kāmanomano, Kūmanomano	Plant
Hawaiian goosefoot	*Chenopodium oahuense*	ʻĀweoweo, Alaweo	Plant
Laysan sedge, Bryanʻs flatsedge	*Cyperus pennatiformis var. bryanii*	Ahuʻawa	Plant
Lovegrass	*Eragrostis variabilis*	Kāwelu, Kalamālō, ʻEmoloa	Plant
(None known)	*Euphorbia celastroides var. celastroides*	ʻAkoko	Plant
Hibiscus	*Hibiscus waimeae*	Kokiʻo kea	Plant
Beach morning glory	*Ipomoea spp.*	Pōhuehue, Pohuehue (*I. pes-caprae*); Koali ʻawa (*I. indica*)	Plant
Peppergrass, pepperwort	*Lepidium bidentatum var. owaihiense*	ʻAnaunau, Kūnānā	Plant
Nehe	*Melanthera integrifolia*	Nehe	Plant
(None known)	*Nama sandwicensis*	Hinahina kahakai	Plant
Torrid panicgrass	*Panicum torridum*	Hākonakona, Kākonakona	Plant
Hairy purselane	*Portulaca villosa*	ʻIhi	Plant
Nihoa fan palm	*Pritchardia remota*	Loulu	Plant
(None known)	*Pseudognaphalium sandwicensium var. sandwicensium*	ʻEnaʻena, Pūheu	Plant
Oʻahu dock, sorrel	*Rumex albescens*	Huʻahuʻakō	Plant
Coastal sandalwood	*Santalum ellipticum*	ʻIliahioloʻe	Plant
Naupaka	*Scaevola taccada*	Naupaka	Plant
ʻŌhai	*Sesbania tomentosa*	ʻŌhai	Plant
Bur-cucumber, Maximowitzʻs bur-cucumber	*Sicyos maximowiczii*	Puaokama, ʻĀnunu,	Plant
Bur-cucumber	*Sicyos pachycarpus*	Kūpala, ʻĀnunu	Plant
Bur-cucumber	*Sicyos semitonsus*	ʻĀnunu	Plant
Nelson's horsenettle	*Solanum nelsonii*	Pōpolo	Plant
Jamaican feverplant	*Tribulus cistoides*	Nohu, Nohunohu	Plant
Hawaiʻi false ʻōhelo	*Wikstroemia uva-ursi*	ʻĀkia	Plant
Green turtle	*Chelonia mydas*	Honu	Reptile
Hawksbill turtle	*Eretmochelys imbricata*	Honuʻea	Reptile

APPENDIX D: Papahānaumokuākea Marine National Monument 2009 Condition Summary Table

The following table summarizes the condition and trend ratings as presented in the 2009 *Papahānaumokuākea Marine National Monument Condition Report*.

#	Questions/ Resources	Rating	Basis for Judgment	Description of Findings	Monument Response
			Water		
1	Are specific or multiple stressors, including changing oceanographic and atmospheric conditions, affecting water quality and how are they changing?	▼	Published literature indicates temperature increases.	Selected conditions may preclude full development of living resource assemblages and habitats, but are not likely to cause substantial or persistent declines.	Monitoring of physical and biological parameters to evaluate extent of the issue.
2	What is the eutrophic condition of monument waters and how is it changing?	—	Lack of anthropogenic inputs.	Conditions do not appear to have the potential to negatively affect living resources or habitat quality.	Monument designation regulates access and requires reporting for on-going monitoring.
3	Do sanctuary waters pose risks to human health and how are they changing?	—	Lack of sources, causes, and human exposure.	Conditions do not appear to have the potential to negatively affect human health.	No current issues.
4	What are the levels of human activities that may influence water quality and how are they changing?	▲	Limited access; regulations prohibit discharges.	Few or no activities occur that are likely to negatively affect water quality.	Continuous evaluation of possible impacts of ship traffic.
			Habitat		
5	What are the abundance and distribution of major habitat types and how are they changing?	▼	Marine debris is degrading beaches and reefs. Potential loss of habitat from climate change and sea-level rise.	Selected habitat loss or alteration has taken place, precluding full development of living resources assemblages, but it is unlikely to cause substantial or persistent degradation in living resources or water quality. Possible sea-level rise could decrease the size of the small islands by moving the high water line up the beach.	Active detection and removal program to reduce accumulations of marine debris; monitoring of physical and biological parameters of climate change.

#	Questions/ Resources	Rating	Basis for Judgment	Description of Findings	Monument Response
			Habitat		
6	What is the condition of biologically-structured habitats and how is it changing?	▼	Marine debris, coral disease, and perhaps bleaching frequency.	Selected habitat loss or alteration has taken place, precluding full development of living resources, but it is unlikely to cause substantial or persistent degradation in living resources or water quality.	Supporting research to better understand the impacts; development of best management practices to minimize transfer between sites.
7	What are the contaminant concentrations in monument habitats and how are they changing?	—	Localized contamination is adversely affecting associated habitat and wildlife.	Selected contaminants may preclude full development of living resource assemblages, but are not likely to cause substantial or persistent degradation.	No management response.
8	What are the levels of human activities that may influence habitat quality and how are they changing?	—	Limited visitation.	Some potentially harmful activities exist, but they do not appear to have had a negative effect on habitat quality.	Rigorous permitting and monitoring of human activities to ensure limited cumulative effects.
			Living Resources		
9.	What is the status of biodiversity and how is it changing?	—	Assessment/ monitoring activities to date.	Biodiversity appears to reflect pristine or near-pristine conditions and promotes ecosystem integrity (full community development and function).	Continuing efforts to characterize biodiversity.
10.	What is the status of biodiversity and how is it changing?	▲	Limited activity; existing fishery to be phased out by June 2011.	Extraction does not appear to affect ecosystem integrity (full community development and function).	Developing fisheries independent stock assessment methods that will be implemented post fishing cessation.
11.	What is the status of non-indigenous species and how is it changing?	?	Few species with isolated distributions; uncertainty of potential impact.	Non-indigenous species exist, precluding full community development and function, but are unlikely to cause substantial or persistent degradation of ecosystem integrity.	Prevention through hull inspections and cleaning, marine debris removal, quarantines in place for most islands; monitoring programs may document distribution and abundance of non-indigenous species.
12.	What is the status of key species and how is it changing?	?	Monk seal decline; corals and predatory fish populations high and stable.	The reduced abundance of selected keystone species may inhibit full community development and function and may cause measurable but not severe degradation of ecosystem integrity; or selected key species are at reduced levels, but recovery is possible.	Mitigation efforts include predator removal and seal relocation to improve survivorship. Implementation of recovery plans for monk seals and ongoing research to understand foraging, diet and habitat.

#	Questions/ Resources	Rating	Basis for Judgment	Description of Findings	Monument Response
			LIVING RESOURCES		
13.	What is the condition or health of key species and how is it changing?	?	Monk seal starvation and body condition; debris ingestion by seabirds; predatory fish and most corals in good condition and stable.	The diminished condition of selected key resources may cause a measurable but not severe reduction in ecological function, but recovery is possible.	Intense research and monitoring target of key endangered species.
14.	What are the levels of human activities that may influence living resource quality and how are they changing?	—	Limited visitation.	Some potentially harmful activities exist, but they do not appear to have had a negative effect on living resource quality.	Through regulated activities visitation is monitored to ensure that impacts are minimized.
			MARITIME ARCHAEOLOGICAL RESOURCES		
15.	What is the integrity of known maritime archaeological resources and how is it changing?	▼	Natural deterioration (physical, biological and chemical).	The diminished condition of selected archaeological resources has reduced, to some extent, their historical, scientific or educational value and may affect the eligibility of some sites for listing in the National Register of Historic Places.	Documentation of known sites. Ongoing surveys to identify new sites.
16.	Do known maritime archaeological resources pose an environmental hazard and is this threat changing?	—	No known resources with hazardous cargos.	Known maritime archaeological resources pose few or no environmental threats.	Continued monitoring and exploration to locate potential threats.
17.	What are the levels of human activities that may influence maritime archaeological resource quality and how are they changing?	▲	Few instances of resource removal or damage.	Few or no activities occur that are likely to negatively affect maritime archaeological resource integrity.	All activities are regulated by permits; known locations are protected by federal law; outreach and education increasing awareness of importance of protection.

OHA
OFFICE OF HAWAIIAN AFFAIRS

papahanaumokuakea.gov