Introduction

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BACKGROUND

The mission of NOAA's Office of National Marine Sanctuaries (ONMS) is to serve as the trustee for a system of marine protected areas, to conserve, protect and enhance biodiversity. To assist in accomplishing this mission, the ONMS has developed a partnership with NOAA's Center for Coastal Monitoring and Assessment's Biogeography Branch (CCMA-BB) to conduct biogeographic assessments of marine resources within and adjacent to the marine waters of NOAA's National Marine Sanctuaries (Kendall and Monaco, 2003).

Biogeography is the study of spatial and temporal distributions of organisms, their associated habitats, and the historical and biological factors that influence species' distributions. Biogeography provides a framework to integrate species distributions and life history data with information on habitats of a region to characterize and assess living marine resources within a marine protected area. The biogeographic data are integrated in a Geographical Information System (GIS) to enable visualization of species' spatial and temporal patterns and to predict changes in abundance that may result from a variety of natural and anthropogenic perturbations or management strategies (Monaco et al., 2005; Battista and Monaco, 2004). The complexity of products from biogeographic analysis range from simple species distribution maps of a particular habitat, to more complex products that combine single data layers to create maps of biodiversity or habitat complexity (NOAA, 2003b; Pittman et al., 2007). The biogeographic assessment approach was developed by the CCMA-BB in consultation with the ONMS in 2003 (Kendall and Monaco, 2003; Monaco et al., 2005; Figure 1.1).

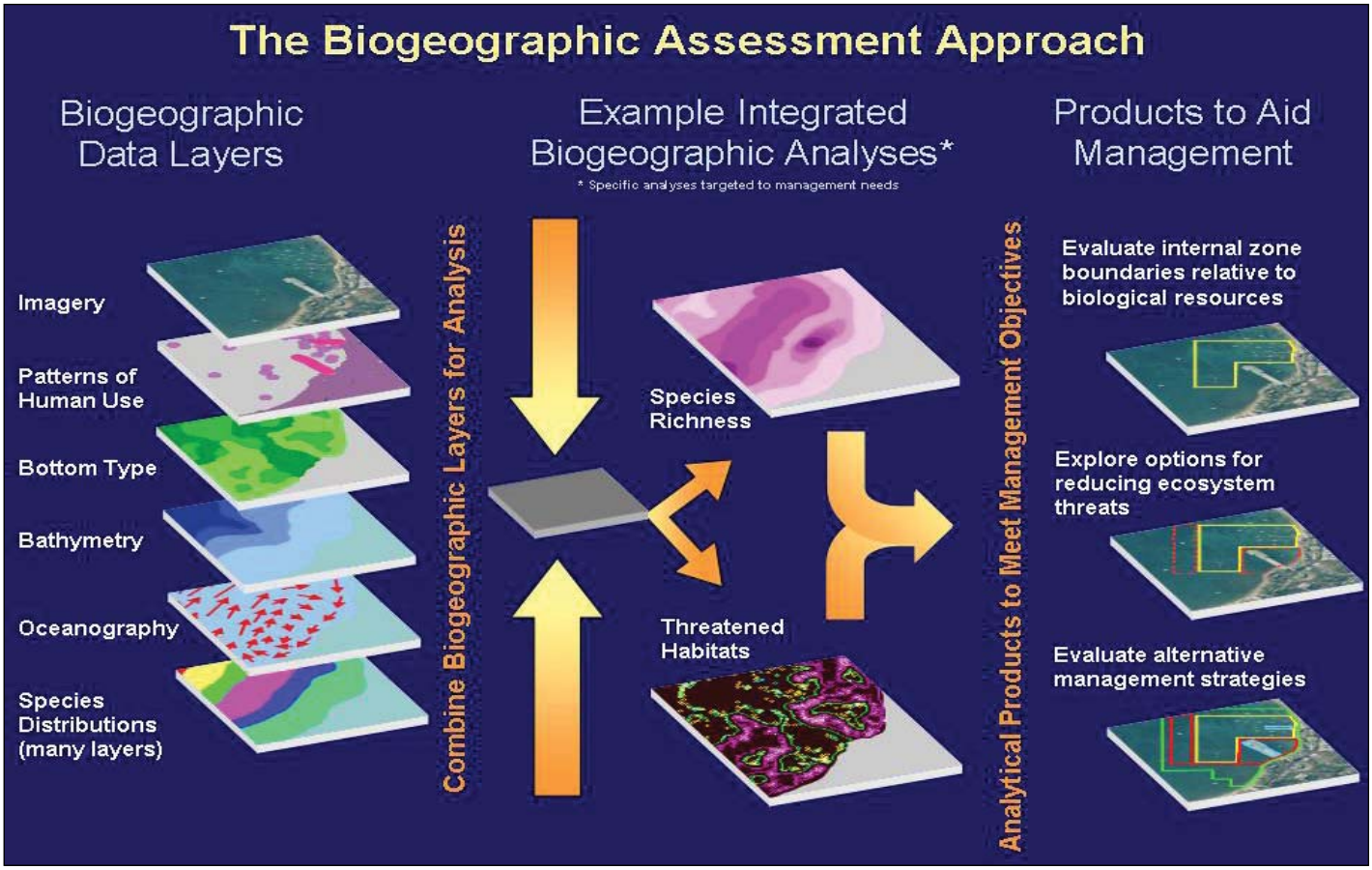

Figure 1.1. Generalized biogeographic assessment process developed by CCMA-BB. Source: Kendall and Monaco, 2003.

1. NOAA/NOS/NCCOS/CCMA Biogeography Branch
2. The Oceanic Institute
3. NOAA/NOS/ONMS/Papahanaumokuakea Marine National Monument

Typically a biogeographic assessment is comprised of the three primary activities: 1) compile individual biogeographic data layers, 2) perform integrated biogeographic analyses, and 3) develop products to aid in management (Figure 1.1). A key tool used to develop and implement the assessment is the use of GIS technology which aids in data compilation, spatial analyses, and visualization of results to support place-based management needs (Battista and Monaco, 2004). The assessment process shown in Figure 1.1 is based on geospatial and temporal analyses of existing physical and biological data and has resulted in many spatially-oriented products that help managers understand how ecosystems function. Often biogeographic analyses focus on determining the strength of coupling between habitats and species and defining discrete areas of biological significance (NOAA, 2003; NOAA, 2005; Monaco et al., 2005).

Defining biogeographic patterns of living marine resources found throughout the Northwestern Hawaiian Islands (NWHI) was identified as a priority activity at a May 2003 workshop designed to define scientific and management information needs for the NWHI. NOAA's Biogeography Branch and the Papahanaumokuakea Marine National Monument (PMNM) under the direction of the ONMS designed and implemented this biogeographic assessment to directly support the research and management needs of the Monument, such as, minimizing impacts of permitted research activities on NWHI marine resources. Successful implementation of this assessment required cooperation and participation with many federal, state, academic and private sector partners. Without participation of key partners, such as NOAA's Pacific Islands Fisheries Science Center, Coral Reef Ecosystem Division, the University of Hawaii, the University of Miami, the State of Hawaii's Division of Aquatic Resources, and the U.S. Fish and Wildlife Service, the biogeographic assessment would have not been completed.

THE NORTHWESTERN HAWAIIAN ISLANDS MARINE BIOGEOGRAPHIC ASSESSMENT

In an effort to provide further protection of the NWHI, the Monument was created by Presidential proclamation on June 15, 2006. The Co-Trustees for the Monument are NOAA, the Department of the Interior and the state of Hawaii. This biogeographic assessment was designed to support the Monument's scientific and management needs based on historical, recent and planned research and monitoring studies within the Monument (Table 1.1). The assessment has resulted in a suite of spatially-articulated products for use by the Monument

Table 1.1. The monitoring programs that are currently collecting data in the NWHI.

MONITORING PROGRAM	OBJECTIVES	YEAR EST.	FUNDING	AGENCIES
Fishery monitoring and economics program	Fisheries catch and effort statistics	1948	NOAA	PIFSC, DAR
Marine turtle research program	Monitor selected sea turtle breeding sites	1973	NOAA, USFWS	USFWS, PIFSC
Seabird monitoring	Monitoring selected nesting seabird species	1978	USFWS	USFWS, PIFSC
Fishery independent lobster monitoring	Monitor lobster using fisheries-independent sampling	1983	NOAA	PISSC
Marine mammal research program	Monitor and assess subpopulations	1985	NOAA	PIFSC, USFWS
Marine debris program	Rates of marine debris accumulation	1996	NOAA	CRED, UH, USFWS, DAR, USGS
Reef assessment and monitoring program	Monitor and assess reef communities through integrated ecosystem science	2000	CRCP	CRED, USFWS, NMSP, DAR, numerous collaborators
Oceanography & water quality program	Physical and chemical oceanographic conditions and processes influencing reef health.	2000	NOAA	PIFSC-CRED, UH
Coral monitoring	Monitoring corals at permanent sites	2000	HCRI, USFWS	USFWS, PIFSC-CRED
Connectivity and ecosystem health	Examine connectivity, ecosystem health, and genetic structure	2005	NMSP	HIMB

Abbreviatons: CRCP – NOAA's Coral Reef Conservation Program; CRED - Coral Reef Ecosystem Division; DAR - Hawaii Division of Aquatic Resources, Department of Land and Natural Resources; HCRI - Hawaii Coral Reef Initiative; HIMB - Hawaii Institute of Marine Biology; NMSP - National Marine Sanctuary Program; NOS - National Ocean Service; PIFSC - Pacific Islands Fisheries Science Center; UH - University of Hawaii; USGS – U.S. Geological Survey

and its partners to support ecosystem-based management and the long-term, comprehensive protection and conservation of the marine resources of the NWHI. Results of this assessment will also support the adaptive management process, identify gaps in information and direct research priorities.

Project Objectives

The biogeographic assessment of the NWHI contributes greatly toward ecosystem-based management of the marine resources of the NWHI. The study is broad in scope and includes characterization of the physical and biological environments (e.g., oceanography, habitats) that structure the spatial and temporal distribution of living marine resources within and adjacent to the Monument boundaries. The objectives of the study were:

1. Identify and synthesize relevant biological, physical and socioeconomic data sets for the study area. Organize the data in a common spatial framework within a GIS.

2. Conduct a marine biogeographic analysis of available data to identify important ecological linkages and biologically significant regions and time periods, based on species distributions, abundance, associated habitats and their ecological function.

The objectives were addressed using the biogeographic assessment process (Figure 1.1) and resulted in a synthesis of multiple data sets that range across the NWHI to enable characterization of the biological and physical environment that structures the biogeographic patterns in space and time of living marine resources found within the Monument. The data, analyses and supporting information are linked using statistical and GIS tools to visualize the location of significant biological areas or “hot spots.” There were many alternative approaches to analyze and organize the biological, physical and habitat data compiled for this assessment. However, only a limited number of analytical options were selected based on reviewer’s comments on the project work plan and technical review meetings. These key analyses are presented in this document. A critical step in assessment process was the extensive effort to have data, analytical approaches and results peer reviewed. Initial results from the suite of analyses were presented to experts on NWHI marine ecosystem, as well as to the originators of the data sources in an attempt to improve the analyses. The role of expert review and input has been considerable, and the contributions made by experts have significantly enhanced the study results.

The use of the GIS enabled species-specific data, such as distribution and abundance data or community metrics (e.g., species richness), to be directly linked to specific areas or habitats they correspond with across the study area. The GIS also facilitated integration of multiple data types and sources into a common spatial and temporal framework (Gill et al., 2001).

The chapters that follow focus on the spatial and temporal distribution data and analyses from the assessment. The report is organized by introducing the geology, habitats and oceanographic characteristics of the NWHI and then followed by the biogeography of living marine resource found within and adjacent to the Monument (Miller et al., 2003; Maragos et al., 2004). The Connectivity and Integrated Ecosystem Studies chapter addresses combinations of the individual biogeographic data layers to characterize the Monument based on the integration of physical and biological data, including ecological and genetic connectivity that define the PMNM ecosystem. Finally, the Management Concerns and Responsibilities chapter focuses on the management of the Monument including the management structure, protected species occurring within the Monument, the management of human activities and the greatest potential threats to the region. Below are brief summaries that characterize the PMNM ecosystem and are discussed in greater detail in individual sections.

Region of Interest

The remoteness and protective status of the NWHI has minimized reef degradation suffered by many other coral reefs around the world (Friedlander et al., 2005, 2008; Grigg et al., 2008). The NWHI consist of small islands, atolls, submerged banks, and reefs, that stretch for more than 2,000 km northwest of the high windward Main Hawaiian Islands (MHI; Figure 1.2). The majority of the islets and shoals remain uninhabited, although Midway, Kure, Laysan Island and French Frigate Shoals have all been occupied for extended periods over

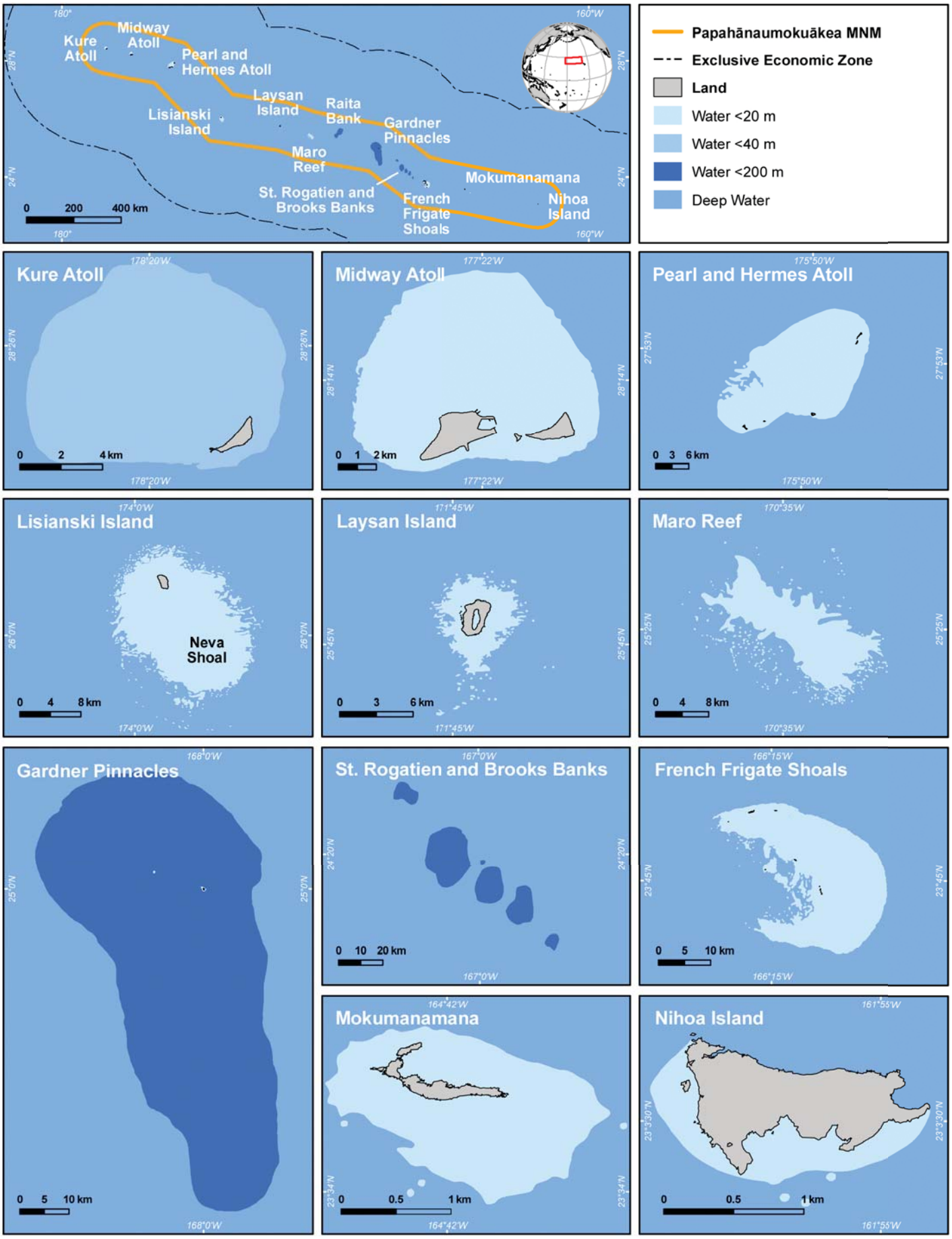

Figure 1.2. The Northwestern Hawaiian Islands, which extend across the north central Pacific, represent a vast, remote coral ecosystem that has been subjected to relatively minimal anthropogenic impacts. Map: K. Buja.

the last century by various government agencies. The inaccessibility, limited fishing and lack of other human activities in the NWHI have resulted in minimal anthropogenic impacts (Friedlander et al., 2005, 2008), therefore providing a unique opportunity to assess how a "natural" coral reef ecosystem functions in the absence of major localized human intervention and contrast these with anthropogenic influences experienced in the MHI and other comparable ecosystems (Friedlander and DeMartini, 2002; Grigg et al., 2008).

One of the most striking and unique components of the NWHI ecosystem is the abundance and dominance of large apex predators such as sharks and jacks (Figure 1.3; Hobson, 1984; Parrish et al., 1985; Friedlander and DeMartini, 2002), which exert a strong top-down control on the ecosystem (DeMartini et al., 2005; DeMartini and Friedlander, 2006) and have been depleted in most other locations around the world (Meyer and Worm, 2003; 2005). The NWHI flora and fauna include a large percentage of species that are endemic to the Hawaiian Islands, which are recognized for having some of the highest marine endemism in the world (Kay and Palumbi, 1987; Jokiel, 1987; Randall, 1998; Randall, 2007). Some of these endemics are dominant components of the community, resulting in a unique ecosystem that has extremely high conservation value and has identified Hawaii as an important global biodiversity hot spot (DeMartini and Friedlander, 2004; Maragos et al., 2004). The few alien species known from the NWHI are restricted to the anthropogenic impacted habitats of Midway Atoll and French Frigate Shoals (Friedlander et al., 2005, 2008; Godwin et al., 2006). Disease levels in corals in the NWHI are much lower than those reported from other locations in the Indo-Pacific (Aeby, 2006).
The NWHI represent important habitat for a number of threatened and endangered species.

*Figure 1.3. Apex predators are a conspicuous and important component of the PMNM ecosystem. Galapagos sharks (*Carcharhinus galapagensis*; left) sharks at Maro Reef and giant trevally (*Caranx ignobilis*; right), known as ulua in Hawaii, from French Frigate Shoals. Photos: J. Maragos.*

The Hawaiian monk seal is one of the most critically endangered marine mammals in the U.S. (approximately 1,200 individuals) and depends almost entirely on the islands of the NWHI for breeding and the surrounding reefs for sustenance (Antonelis et al., 2006). Over 90% of all sub-adult and adult Hawaiian green sea turtles found throughout Hawaii inhabit the NWHI (Balazs and Chaloupka, 2006). Additionally, seabird colonies in the NWHI constitute one of the largest and most important assemblages of seabirds in the world (USFWS, 2005).

On June 15, 2006, President George W. Bush designed the NWHI as a Marine National Monument, the largest no-take marine conservation areas on earth, through the signing of Proclamation 8031. In March 2007, First Lady Laura Bush renamed the Monument the Papahanaumokuakea Marine National Monument on behalf of the President. The Monument encompasses nearly 225,300 km^2 of ocean and includes all the islands, atolls, shoals and banks from Nihoa Island to Kure Atoll (Figure 1.4). The unique predator-dominated trophic structure, the dominance by large numbers of endemic species, and the occurrence of a number of threatened and endangered species makes the NWHI an ecosystem of global significance.

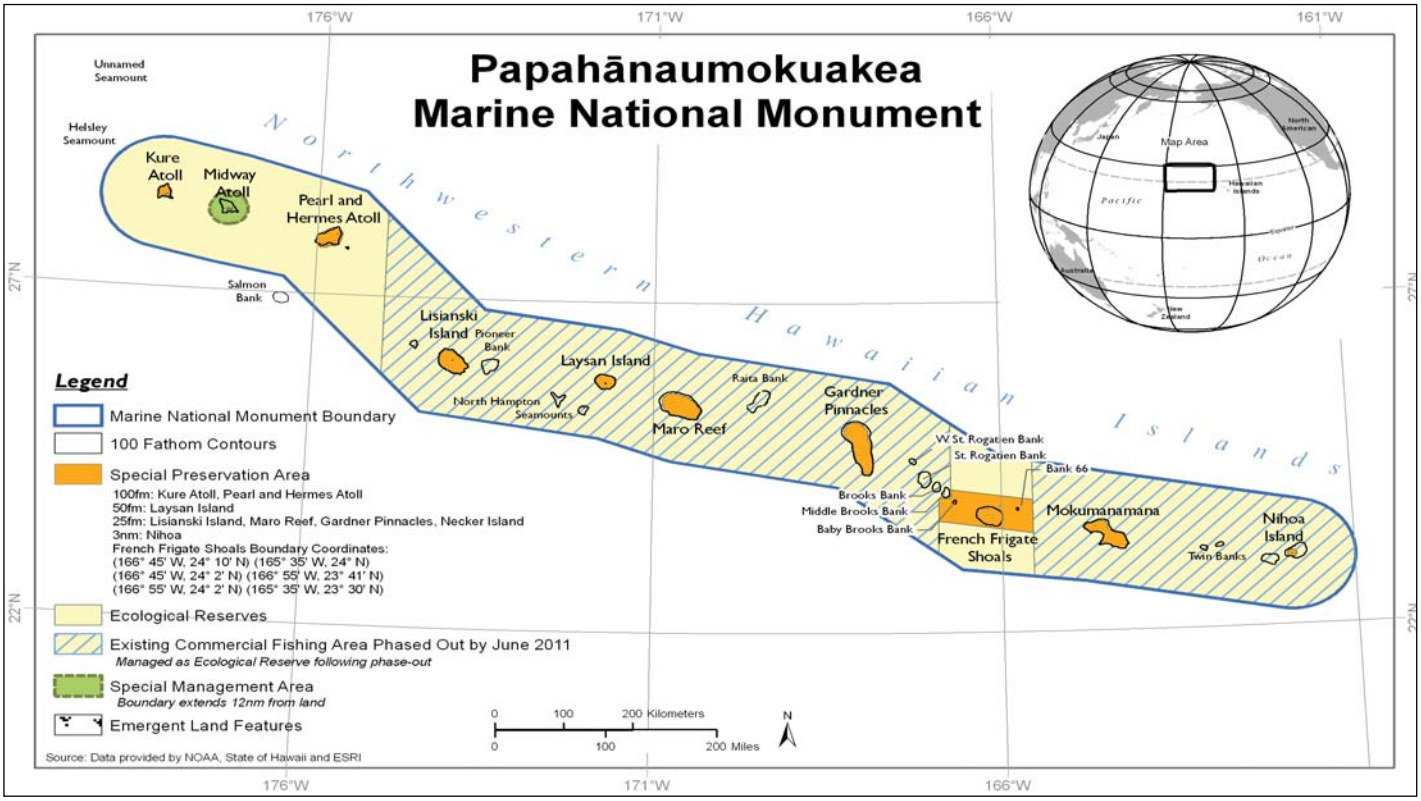

Figure 1.4. Papahanaumokuakea Marine National Monument boundaries. Map: PMNM.

THE REGION'S UNIQUE NATURAL ENVIRONMENT

The NWHI are influenced by a dynamic environment that includes large annual water temperature fluctuations, seasonally high wave energy, and strong inter-annual and inter-decadal variations in ocean productivity (Grigg, 1983; Polovina et al., 2001). As a result of these influences and the general absence of human interference, natural stressors play an important role in the structure of the NWHI ecosystem (Friedlander et al., 2005). Large swell events generated every winter commonly produce waves up to 10-12 m in height, which limits the growth and abundance of coral communities, and leads to species and growth forms that are adapted to these dynamic high wave energy environments (Grigg et al., 2008).

Compared with most reef ecosystems around the globe, the large annual fluctuation of sea surface temperatures (SSTs; >10˚C) found at the northernmost atolls of the NWHI is extremely high. Cooler water temperatures to the north restrict the growth and distribution of a number of coral species (Grigg, 1983), and the biogeographic distribution of many fish species in the NWHI is influenced by differences in water temperatures along the archipelago (DeMartini and Friedlander, 2004; Mundy, 2005).

Large-Scale Biogeographic Regions

The NWHI is set in a dynamic oceanographic and meteorological regime in the northern/central subtropical region of the Pacific Ocean (Figure 1.5). The NWHI archipelago extends such a great distance that the two opposite ends of the chain often experience somewhat different oceanographic and meteorological conditions (Table 1.2). The NWHI are not usually impacted by tropical storms but do experience large boreal winter wave events that assist in shaping the ecosystem. The boundary between the nutrient-poor, or oligotrophic, surface waters of North Pacific Subtropical Gyre and the nutrient-rich, or eutrophic, surface waters of the North Pacific Subpolar Gyre is frequently in the NWHI region (Leonard et al., 2001). This front shifts 15° (between 30º and 45ºN) seasonally (Polovina et al., 2001), reaching far enough south in the winter to encompass the northern most three atolls (Kure, Midway, and Pearl and Hermes). The southern extension of this front into the NWHI region, migrating on interannual and decadal time scales, brings colder and nutrient rich waters that are likely important to the productivity and ecology of these coral reef ecosystems. The location of this front also influences

marine debris concentrations (Kubota, 1994), which has been shown to most severely impact the northern atolls (Boland et al., 2004; Donohue et al., 2001).

Geology and Evolutionary History

The Hawaiian Archipelago originated over a relatively stationary melting anomaly or hot spot in earth's mantle located below the floor of the Pacific Plate, which is drifting over the hot spot to the northwest at a rate of about 8 cm/yr (Figure 1.6; Grigg et al., 2008; Rooney et al., 2008). Because the plate is slowly cooling as it moves away from the hot spot, the overriding islands and other volcanic features are slowly subsiding. Beginning at Nihoa and Mokumanamana Island (approximately seven and 10 million years old, respectively) and extending to Midway and Kure Atolls (approximately 28 million years old), the NWHI represent the older portion of the emergent Hawaiian Archipelago (Grigg, 1988; Juvik and Juvik, 1998; Rooney et al., 2008).

The Hawaiian Archipelago is 3,900 km from the west coast of the U.S. mainland, 3,800 km from Japan, and over 1,000 km from the nearest island archipelago (the Line Islands). This geographic isolation of the entire Hawaiian Island chain has resulted in a large number of species that are found nowhere else on earth, and the proportion of these endemic species (>25% for most taxa) to other native species is some of the highest recorded for any tropical marine ecosystem to date. Some of these endemics are dominant components of the coral reef community, resulting in a unique ecosystem that has extremely high conservation value (DeMartini and Friedlander, 2004; Maragos et al., 2004).

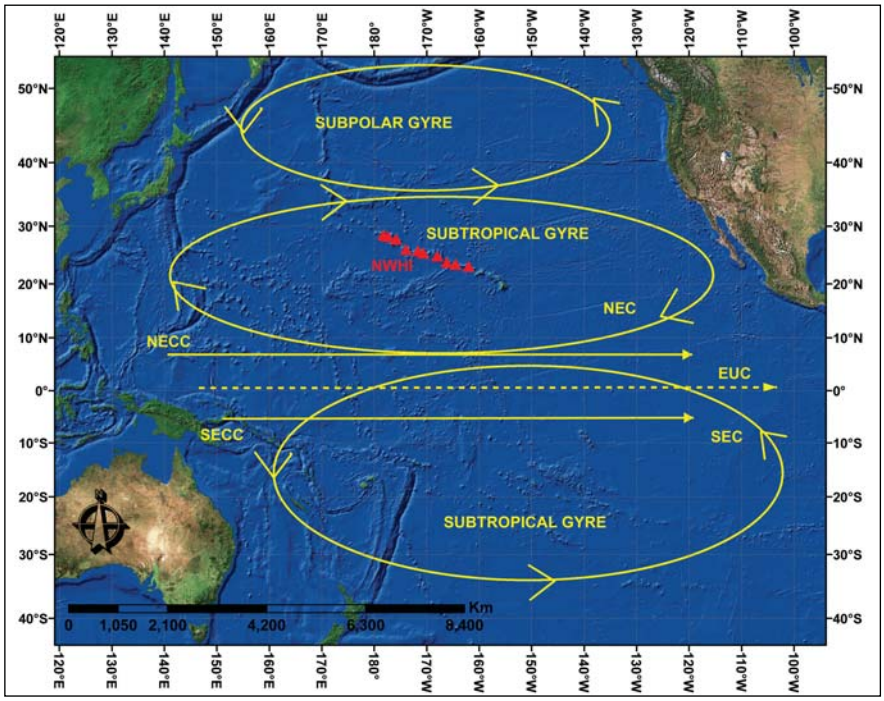

Figure 1.5. Topographic map showing location in Pacific Ocean of the Northwestern Hawaiian Islands (NWHI) and the major ocean currents in the region (North Equatorial Current (NEC, South Equatorial Current (SEC), North Equatorial Counter Current (NECC), South Equatorial Counter Current (SECC), Equatorial Under Current (EUC). Source: CRED.

Table 1.2. Coordinates and Hawaiian names of the 10 islands presented from north to south.

ISLAND	HAWAIIAN NAME	LATITUDE	LONGITUDE
Kure Atoll	Kanemilohai, Mokupapapa	28° 26'N	178° 19'W
Midway Atoll	Pihemanu	28° 14'N	177° 22'W
Pearl and Hermes Atoll	Holoikauaua	27° 51'N	175° 51'W
Lisianski Island and Neva Shoals	Papaapoho	26° 3'N	173° 58'W
Laysan Island	Kauo	25° 47'N	171° 44'W
Maro Reef	Nalukakala, Koanakoa	25° 27'N	170° 37'W
Gardner Pinnacles	Puhahonu	24° 52'N	168° 1'W
French Frigate Shoals	Mokupapapa, Kanemilohai	23° 46'N	166° 12'W
Mokumanamana Island	Mokumanamana	23° 27'N	164° 31'W
Nihoa Island	Nihoa	23° 5'N	161° 51'W

Figure 1.6. Lava flowing into the ocean off the southeast coast of the island of Hawaii. Photo: Hawaii Volcano Naitonal Park.

MAJOR TAXA OF MARINE RESOURCES

Benthic Communities

The composition and distribution of benthic communities in the NWHI reflect the interaction of numerous influences, including isolation, latitude, exposure, and the successional age of the island they inhabit. Mosaics of habitats range from coral-dominated areas to vast expanses of unconsolidated sediments such as sand and mud inhabited by a few epi-benthic fauna.

Despite their high latitude location, slightly more species of coral have been reported from the NWHI (52 species) compared with the MHI (48 species; Maragos et al., 2004), although a number of potentially new species have recently been discovered (Friedlander et al., 2008). Kure is the world's most northern atoll (28° 26'N) and is referred to as the Darwin Point, where coral growth and subsidence /erosion balance one another (Grigg, 1982). Beyond this point lies a chain of seamounts that get progressively deeper and older as they move away from a stationary melting point or hot spot in the Pacific plate located southeast of the big island of Hawaii (Grigg, 1988).

The coral assemblage in the NWHI contains a large number of endemics (approximately 30%), including at least seven species of table corals (acroporids), which are the dominant reef-building coral in the Indo-Pacific, but are absent from the MHI (Figure 1.7, Maragos et al. 2004). Coral disease is currently low in the NWHI; but increases in the frequency and intensity of bleaching events due to global warming could stress corals and make them more susceptible to disease.

*Figure 1.7. Table coral (*Acropora cytherea*) at French Frigate Shoals. Photo: J. Watt.*

Unlike the MHI where alien and invasive algae have overgrown many coral reefs, the shallow reefs in the NWHI appear to be free of invasive algae, and high natural herbivory (grazing) results in a pristine algal assemblage. Algal diversity appears similar across the NWHI chain even though brown algae tend to be more abundant at Midway and Kure Atolls than at most other islands (Vroom and Page, 2006). The cooler SSTs found at Kure and Midway Atolls during winter months may favor a higher abundance of brown algal species. Lower abundance of green algae at Midway may result from higher herbivorous fish densities at this atoll system, suggesting possible top-down control of the benthic habitat (DeMartini and Friedlander, 2004, 2006).

The NWHI are documented to contain the highest percent cover of algal species when compared to other geographic locations throughout the U.S. tropical Pacific, and the lowest percent cover of living coral (Vroom et al., 2006). This is likely due to the subtropical location of the NWHI and cool SSTs that bathe biological communities during winter months. Despite relatively high algal populations, the NWHI remain a healthy and thriving marine ecosystem.

Fishes

A total of 457 reef and shore fishes have been reported from the MHI while 258 are documented from Midway Atoll in the NWHI (Randall et al., 1993). Despite these differences, the total number of species observed on quantitative transects in the NWHI (210) and was similar to the 215 species reported in a recent comprehensive quantitative study around the MHI (Friedlander et al., 2005). The lowest overall fish species richness in

the NWHI occurs at the small basalt islands (Mokumanamana, Gardner, Nihoa). It is highest at French Frigate Shoals and Pearl and Hermes Atoll. Greater species richness at French Frigate Shoals may be related to higher coral richness and greater habitat diversity (Maragos et al., 2004) while large area, habitat diversity and the presence of subtropical and temperate species that occur at greater depths influence greater richness at Pearl and Hermes.

Reef fish trophic structure in the NWHI is strongly dominated by carnivores (Hobson, 1984; DeMartini and Friedlander, 2006). Fish biomass in the NWHI is nearly three times greater than in the MHI with most of the difference resulting from large apex predators (primarily sharks and jacks; Friedlander and DeMartini, 2002). Today, these top carnivores, analogous to lions and wolves on land, are seldom encountered by divers in the inhabited Hawaiian Islands. A number of species such as the endemic spectacled parrotfish (*Chlorurus perspicillatus*), the endemic Hawaiian hogfish (*Bodianus bilunulatus*), and bigeye emperor (*Monotaxis grandoculis*) are quite abundant and obtain large size in the NWHI. These species are heavily exploited for commercial, subsistence and recreational use in the MHI, and their reduced number and sizes in the MHI is likely the result of years of chronic overfishing (Friedlander and DeMartini, 2002).

Seabirds

Seabird colonies in the NWHI constitute one of the largest and most important assemblages of seabirds in the world, with approximately 14 million birds (5.5 million breeding annually) representing 22 species (Friedlander et al., 2005; USFWS, 2005). More than 95% of the world's Laysan albatross (*Phoebastria immutabilis*; Figure 1.8) and Black-footed albatross (*P. nigripes*) nest in the NWHI (USFWS, 2005). For several other species such as Bonin Petrel (*Pterodroma hypoleuca*), Christmas Shearwater (*Puffinus nativitatis*), Tristram's Storm-petrel (*Oceanoframa tristrami*) and Grey-backed Tern (*Sterna lunata*), the NWHI supports colonies of global significance. The last complete inventory of NWHI breeding populations was done between 1979 and 1984 (Fefer et al., 1984). Population trends since then have been derived from more intensive monitoring at three islands and are stable or increasing for most species at these locations but there is concern for a few, especially the albatross due to ingestion of plastics, loss of forage base and other large-scale issues (USFWS, 2005).

Figure 1.8. Laysan Albatrosses at Midway Atoll NWR. Photo: A. Friedlander.

Protected Species

Hawaiian Monk Seal

The Hawaiian monk seal (*Monachus schauinslandi*) is listed as Endangered under the Endangered Species Act (ESA) and Depleted under the Marine Mammal Protection Act. It is the only endangered pinniped occurring entirely within U.S. waters. Monk seals occur throughout the Hawaiian Archipelago, and although most are found in the NWHI, a small but increasing number pup in the MHI. They commonly occur on isolated beaches for resting, molting, birthing and nursing offspring, spending nearly two-thirds of their time in marine habitats (Antonelis et al., 2006). A recent monk seal recovery report estimates that there are only 1,200 Hawaiian monk seals still alive (Figure 1.9) and if the declining population trend continues there will be fewer than 1,000 within the next three or four years, a decrease of more than 60% since the 1950s. When compared historically, the monk seal beach count abundance index reached record lows in 2005.

Hawaiian Green Sea Turtle

The green sea turtle (*Chelonia mydas*) is the most abundant large marine herbivore globally (Bjorndal, 1997) and has a circumtropical distribution with distinct regional population structures (Figure 1.10; Bowen et al., 1992). Worldwide, the green turtle has been subject to a long history of human exploitation with some stocks now extinct and others in decline. Green sea turtles in U.S. waters have been protected under the federal ESA since 1978. The Hawaiian green turtle stock, or honu, comprises a single closed genetic stock that is endemic to the Hawaiian Archipelago (Bowen et al., 1992) with numerous distinct foraging grounds within the 2,200 km span of the Hawaiian Archipelago From the mid-1800s until about 1974, the Hawaiian stock was subject to human exploitation such as turtle harvesting at foraging grounds, harvesting of nesters and eggs, and nesting habitat destruction.

Figure 1.9. Hawaiian monk seal and endemic Hawaiian green sea turtle at NWHI. Photo: National Marine Fisheries Service.

Figure 1.10. Endemic Hawaiian green sea turtle at Midway Atoll. Photo: J. Watt.

The primary rookery for the Hawaiian green sea turtle is located on French Frigate Shoals which accounts for more than 90% of all nesting within the Hawaiian Archipelago. The main rookery island at French Frigate Shoals is East Island where at least 50% of all French Frigate Shoals nesting occurs. Nesting females exhibit strong island fidelity, and the Hawaiian green sea turtle stock has been continuously monitored for several decades. Annual surveys of the number of female green turtles coming ashore to nest each night have been conducted at East Island since 1973 (Balazs, 1980).

The long-term trends based on a population model for the East Island nester abundance illustrates a dramatic increase in abundance over the past 30-years, and substantial fluctuations in the number of annual nesters has been observed (Balazs and Chaloupka, 2006). Such fluctuations are characteristic of green turtle nesting populations and reflect a variable proportion of females in the population that breed each year in response to ocean-climate variability. The Hawaiian green sea turtle stock is showing signs of recovering after more than 25 years of protecting their nesting and foraging habitats in the Hawaiian Archipelago (Chaloupka and Balazs, 2007).

HISTORY OF USE AND MANAGEMENT

The designation of the Monument is the most recent increase in protections and management of the NWHI. The NWHI has a long history of human use and increasing efforts for conservation management (Figure 1.11). Native Hawaiians traversed and seasonally used the NWHI for hundreds of years and continue today to maintain their strong cultural ties to the land and sea of the NWHI. Post-Western-contact, the NWHI continued to be explored and the harvest of natural resources including guano mining, egg harvesting, fishing and other natural resource extraction occurred. The U.S. Military maintained active military bases during much of the 1900s. In 1909 the first natural resource protection was put in place with the designation of the Hawaiian Islands Bird Reservation. Since that time, additional reserves and refuges have been established to protect this unique ecosystem. The most recent protections were implemented with the designation of the Papahanaumokuakea Marine National Monument June 15, 2006.

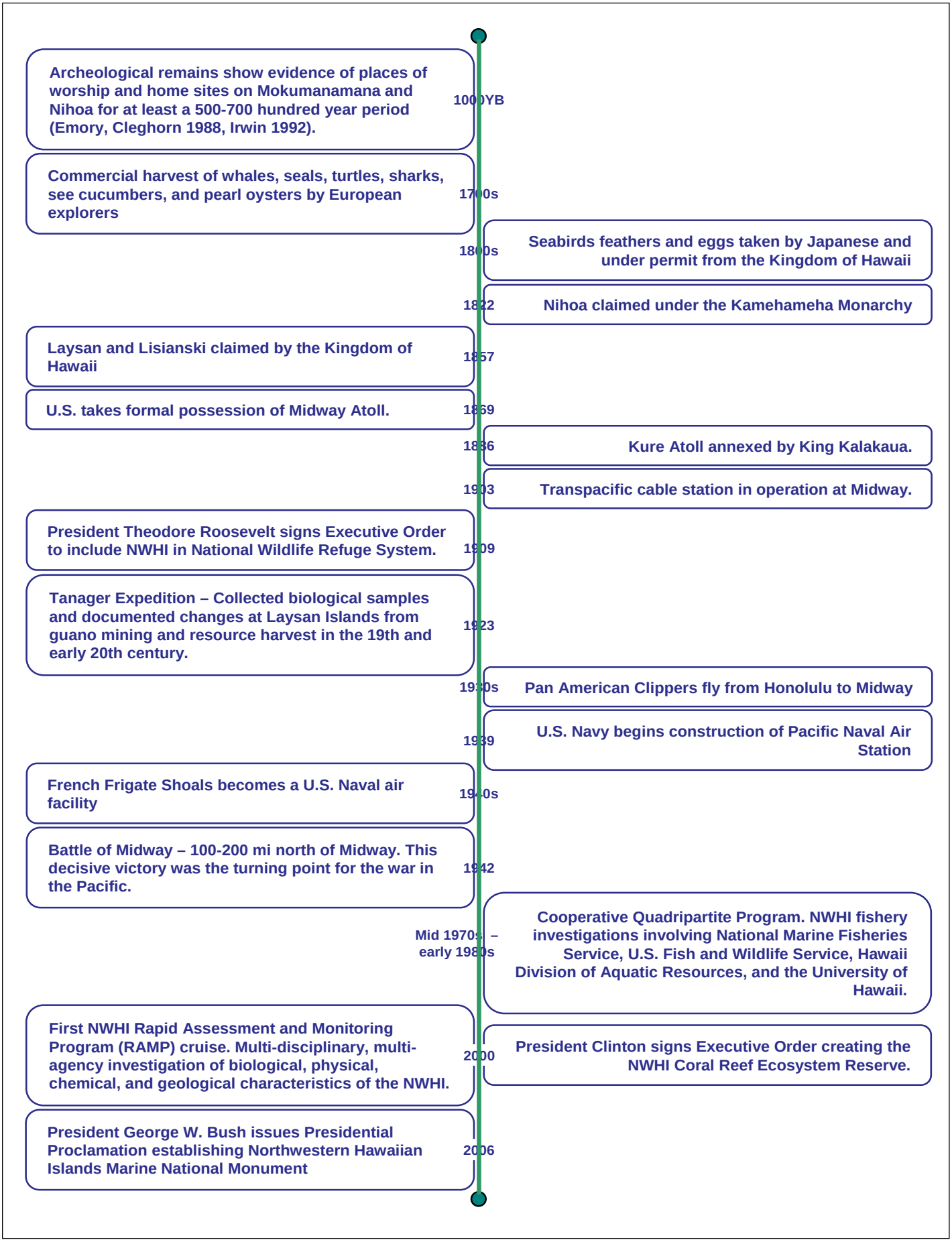

Figure 1.11. Time line of the history of the NWHI use and management.

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