THE HAWAIIAN ISLANDS

The Hawaiian Archipelago stretches for over 2,500 km from the island of Hawaii in the southeast to Kure Atoll (the world's highest latitude atoll) in the northwest. Hawaii is located in the middle of the Pacific Ocean (Figure HI-1), making it one of the most isolated archipelagos in the world. As a result of its location, Hawaii's coral reefs possess some of the highest marine endemism recorded for a number of taxa, and are structurally influenced by exposure to large open ocean swells. Within the archipelago, there are two distinct regions: the Main Hawaiian Islands (MHI) made up of populated, high volcanic islands and the Northwestern Hawaiian Islands (NWHI) consisting of mostly uninhabited atolls and banks.

Early Hawaiians recognized that coral reefs were a building block of the islands and used coral in religious ceremonies to demonstrate honor and care for ocean resources. Coral reefs were important to the ancient Hawaiians for food, cultural practices, recreation, and survival. Today, coral reef communities continue to provide Hawaiians with food and protection from storm waves, and are critically important to the state's approximately $800 million per year marine tourism industry (Cesar and van Beukering 2004).

Although the MHI and NWHI are one ecosystem, resource management and research for these regions have historically differed. This separation or regionalization has been maintained in this research plan when developing research priorities for the Hawaiian Archipelago.

Main Hawaiian Islands

Coral reef communities in the MHI range from newly formed colonies at the edges of recent lava flows to established fringing reefs (Figure HI-2). Many of these reef communities are located near urban areas. Over 70% of the State's 1.2 million people live on Oahu, mostly concentrated in the Honolulu metropolitan area. In addition to this resident population, nearly seven million tourists visit Hawaii each year. This large number of people has put pressure on Hawaii's coral reefs through various direct and indirect means. Many coastal areas adjacent to urban centers are impacted by land-based sources of pollution, fishing pressure, recreational overuse, and invasive species. Despite these stressors, Hawaii's coral reefs, especially those far from urban centers, remain in good to fair condition compared with other reefs around the world.

Coral reef ecosystems in the MHI are managed through MPAs with varying levels of protection. These include marine life conservation districts, fisheries management areas, a marine laboratory refuge, natural area reserves, NWRs, and the Hawaiian Islands Humpback National Marine Sanctuary. One of the most well known marine life conservation districts is Hanauma Bay, established in

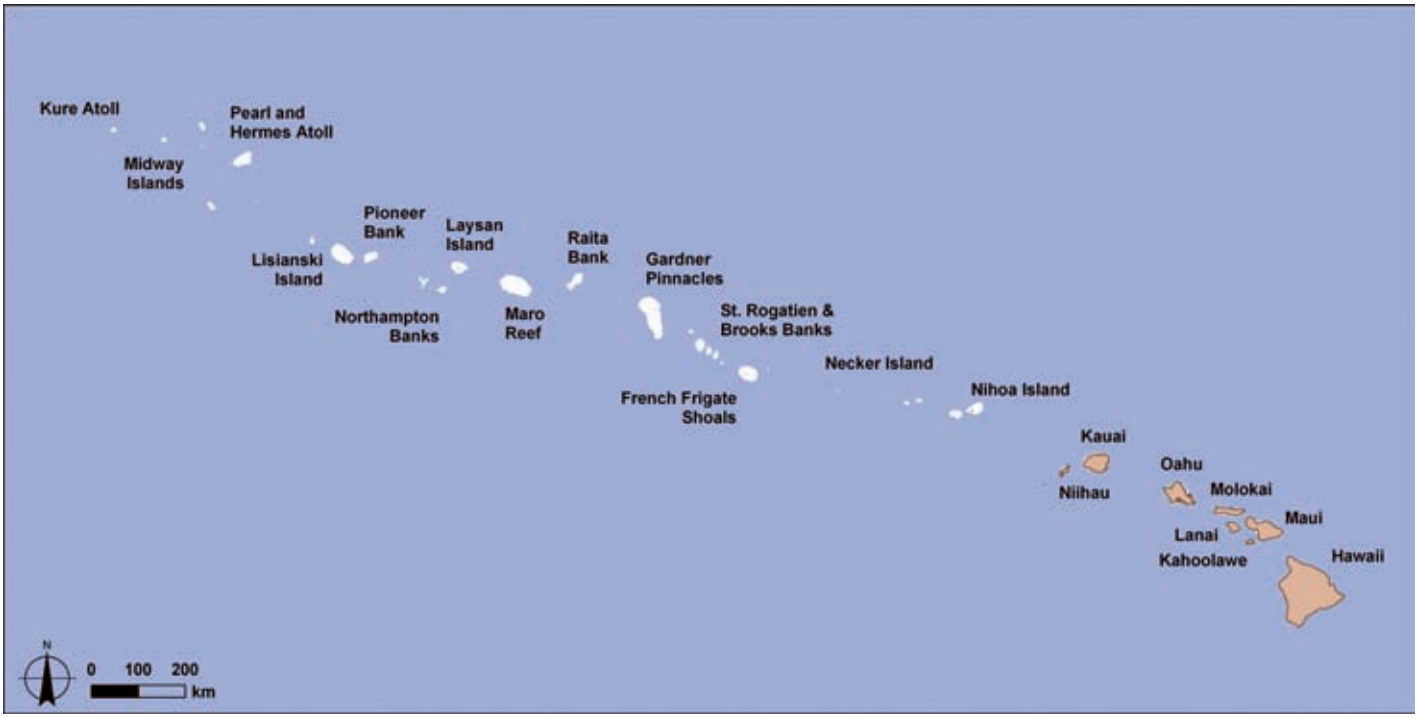

Figure HI-1. Locator map for the Hawaiian archipelago. (See Figure 5 for geographical context.) Map: A. Shapiro.

1967. Marine life conservation districts with strict no-take restrictions have been established at specific locations in Hawaii to help restore fish stocks and have met with some success. Even with all of these protections in place, Hawaii's coral reef MPAs are not as effective as they could be due to difficulties enforcing current regulations and laws, as well as recreational overuse of these MPAs by the tourism industry. [6]

6 Introductory material was taken, with slight modifications, from Gulko et al. (2002) and Friedlander et al. (2005a).

Research Needs

The research needs detailed below represent both MHI-specific research needs, and archipelago-wide research needs focused on identifying linkages between the NWHI and MHI. Understanding the linkages between the NWHI and MHI is critical because the knowledge gained can be applied to the management of the entire archipelago. NWHI-specific research needs are detailed in the next section.

Hawaiian Islands	FISHING	Hawaiian Archipelago	Main Hawaiian Islands Only
Management Objective	***Research Need***		
Conserve and manage fisheries to prevent overfishing, rebuild stocks, and minimize destructive fishing. *See Jurisdiction-Wide Section for additional research needs.*	Assess the ecological impacts of non-extractive activities conducted in coral reef ecosystems on managed fisheries species.		√
	Evaluate the potential of restocking ecologically important species (e.g., parrotfish, jacks, spiny lobster).		√
	Develop affordable ciguatera test kits that would allow a viable fishery for roi.		√
	Assess the ecological impact of aquarium collection on species of special concern, such as endemics, and develop scientific guidelines for aquarium fishery management.		√
Evaluate and improve the effectiveness of MPAs as a fisheries management tool. *See Jurisdiction-Wide Section for additional research needs.*	Evaluate the effectiveness of Hawaii's MPAs to determine how differing levels of protection improve catches of economically important coral reef resources and identify optimal MPA design under various scenarios.	√	
	Compare the benefits of fishery replenishment areas for the aquarium fishery in West Hawaii and determine additional management measure needed to rebuild stocks of species that have not rebounded within the fishery replenishment areas and surrounding fished areas.		√
Increase fishers' participation in fisheries management.	Document historical and cultural knowledge of Hawaiian coral reef resources and their ecology, as well as their historical trends in abundance size, distribution, and community composition.		√

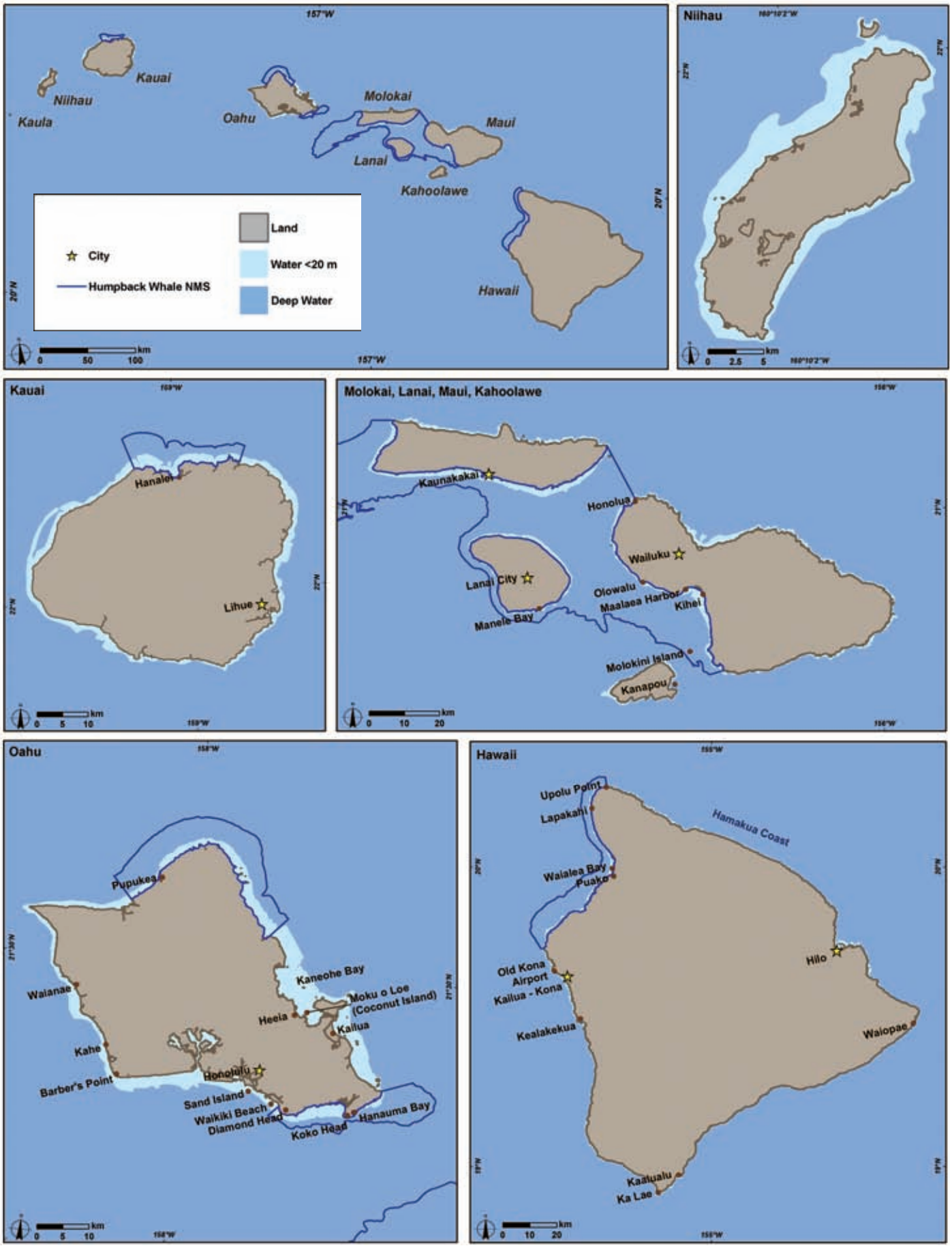

Figure HI-2. Locator map for the Main Hawaiian Islands. Map: A. Shapiro. Source: Friedlander et al. (2005a).

Hawaiian Islands	POLLUTION	Hawaiian Archipelago	Main Hawaiian Islands Only
Management Objective	***Research Need***		
Reduce the impacts of pollutants on coral reef ecosystems by improving the understanding of their effects. *See Jurisdiction-Wide Section for additional research needs.*	Quantify the individual and synergistic impacts of nutrients, chemicals, and pathogens from sewage on reef condition.		√
	Develop effective tools for tracking sewage-borne pollutants from cesspools and injection wells.		√
	Quantify nutrient, fertilizer, and sediment inputs from different sources (e.g., surface water, groundwater, injection wells, septic systems, and cesspools) and determine their impacts on coral reef ecosystems.		√
	Develop sediment transport models for critical reef areas.		√
Improve water quality by reducing land-based pollutant inputs and impacts on coral reef ecosystems. *See Jurisdiction-Wide Section for additional research needs.*	Develop low-cost tools to assess concentrations and loads of nearshore water pollutants that can be easily implemented by managers and volunteers.		√
	Develop protocols to evaluate the effectiveness of land-based pollution management methods.		√
	Create science-based guidelines for the evaluation, improvement, and/or development of permitting and regulatory tools for protecting coral reef ecosystems from pollution stress.		√
	Identify biological criteria for coral reefs that could be incorporated into state water quality standards.		√

Hawaiian Islands	COASTAL USES	Hawaiian Archipelago	Main Hawaiian Islands Only
Management Objective	***Research Need***		
Reduce the impacts from recreational use, industry, coastal development, and maritime vessels on coral reef ecosystems. *See Jurisdiction-Wide Section for additional research needs.*	Determine the ecosystem impacts of current and proposed non-extractive activities (e.g., snorkeling, wading, scuba diving, boating, and anchoring) and prioritize areas for protection based on their economic and ecological importance.		√
	Evaluate the effectiveness of current management efforts at reducing impacts from non-extractive activities.		√
	Identify BMPs that should be incorporated into relevant development permits to protect coral spawning and recruitment events, and determine their effectiveness.		√
	Examine the economic and legal factors contributing to destructive development and construction practices, and recommend economic incentives, regulatory changes, and BMPs to mitigate these impacts.		√
	Assess the loss of coral reef productivity and potential reef fish biomass as a result of large-scale harbor development, dredging projects, and beach replenishment activities.		√
	Evaluate Hawaii's artificial reef program. Provide scientifically-based recommendations for expanding the program if it is deemed effective and shown to have minimal impacts.		√
	Determine the extent of damage due to anchorage of large vessels.		√

Hawaiian Islands	COASTAL USES	Hawaiian Archipelago	Main Hawaiian Islands Only
Management Objective	***Research Need***		
Protect, conserve, and enhance the recovery of protected, threatened, and other key species.	Continue conducting research aimed at the protection, conservation, and recovery of protected species (i.e., marine mammals, sea turtles, and birds) that utilize coral reef ecosystems.	√	
Restore injured and degraded coral reef habitat. *See Jurisdiction-Wide Section for additional research needs.*	Develop coastal and beach restoration techniques (e.g., stream channels, beach replenishment, and harbor development) that minimize impacts on adjacent reefs.		√
Manage coral reef ecosystems and their uses in a holistic manner. *See Jurisdiction-Wide Section for additional research needs.*	Characterize and assess oceanographic factors that influence the distribution and abundance of biotic components of coral reef ecosystems.	√	
Evaluate and improve the effectiveness of MPAs as a management tool. *See Jurisdiction-Wide Section for additional research needs.*	Evaluate the effectiveness of Hawaii's MPAs to determine how differing levels of protection influence effectiveness and identify optimal MPA design under various scenarios.	√	
	Develop coupled ecosystem-hydrodynamic models to simulate and examine various management options.		√
	Assess population replenishment and connectivity among islands, banks, and associated coral reef ecosystems.	√	
	Improve hydrodynamic, ecosystem, and resource assessment models that capture the dynamics, structure, and function at appropriate temporal and spatial scales.	√	
	Identify indicator species (i.e., those which are indicative of the overall condition of the ecosystem) and keystone species (i.e., those of importance in structuring the composition of the ecosystem) for use as monitoring tools.	√	

Hawaiian Islands	INVASIVE SPECIES	Hawaiian Archipelago	Main Hawaiian Islands Only
Management Objective	***Research Need***		
Minimize the introduction and spread of alien species. *See Jurisdiction-Wide Section for additional research needs.*	Assess connectivity among islands and banks to determine the rate at which alien species spread between islands.	√	
	Assess the distribution of alien marine species in Hawaii, including reefs located outside of harbors.	√	
	Determine how invasive alga species are spreading (e.g., *A. spicifera* spreads via spores, and *H. musciformis* via fragments, but it is unknown if these and other invasive species spread only by these methods).		√
	Identify alternative methods for ballast water treatment for inter-island barges, vessels, and towed platform traffic.		√
Control or eradicate alien species that have the potential to cause damage to coral reef ecosystems. *See Jurisdiction-Wide Section for additional research needs.*	Develop protocols and tools to detect invasive species and assess their potential impacts.	√	
	Determine factors (including natural and anthropogenic stressors) that contribute to the success of alien species.	√	
	Develop and test approaches, including biological (e.g., native urchins, bacteria, and fungi) and mechanical tools, to remove and control alien species and restore damaged habitats.		√
	Quantify the effects of invasive algae on reef building corals, other invertebrates, and fishes, and identify taxa of particular concern.		√
	Determine why certain coral reefs or parts of reefs are affected by invasives more than similar reefs in the same area.		√
	Determine habitat and nest preferences of native blennies and gobies, and determine their interactions with non-native blennies and gobies.		√
	Determine the epidemiological and parasite vector relationships to enhance the understanding of interactions with native species.		√
	Determine the ecological interactions between established invasive species and native species (e.g., ta`ape and juvenile snappers), and their impacts on native populations.		√
	Evaluate socioeconomic impacts of established alien species problems.		√
	Determine the distribution, abundance, and impact of the snowflake coral, *Carijoa riisei*, on black coral populations and identify measures (including eradication techniques and potential restrictions on harvesting black coral) to conserve and sustainably manage the black coral fishery.		√
	Create a risk analysis of alien species introductions to facilitate appropriate management.		√

Hawaiian Islands	CLIMATE CHANGE	Hawaiian Archipelago	Main Hawaiian Islands Only
Management Objective	***Research Need***		
Minimize the effects of climate change on coral reef ecosystems. *See Jurisdiction-Wide Section for additional research needs.*	Assess the resistance and resilience of specific populations, locations, and habitats to episodic events (e.g., coral bleaching), emphasizing areas that may serve as sources of reproductive propagules.	√	
Improve the capacity to forecast and respond to bleaching events.	Develop a predicative capability to identify potential impacts of climate change.		√
	Develop response protocols to mitigate and reduce damage to coral reefs from stressors during bleaching events		√
	Assess the extent and severity of bleaching in Hawaiian waters.		√

Hawaiian Islands	EXTREME EVENTS	Hawaiian Archipelago	Main Hawaiian Islands Only
Management Objective	***Research Need***		
Identify causes and consequences of diseases in coral reef ecosystems and mitigate their impacts. *See Jurisdiction-Wide Section for additional research needs.*	Characterize the types, distribution, and prevalence of diseases in coral reef ecosystems at sites included in the Hawaii's monitoring program.		√
	Determine links between coral disease and anthropogenic stressors (including fishing effort and marine recreational activities).		√
	Develop protocols to assess community level changes through time following a coral disease outbreak.		√
Reduce impacts to and promote restoration of coral reef organisms affected by extreme events.	Develop models to predict how increasing storms (in both number and severity) may alter the structure and distribution of reefs in Hawaii.	√	

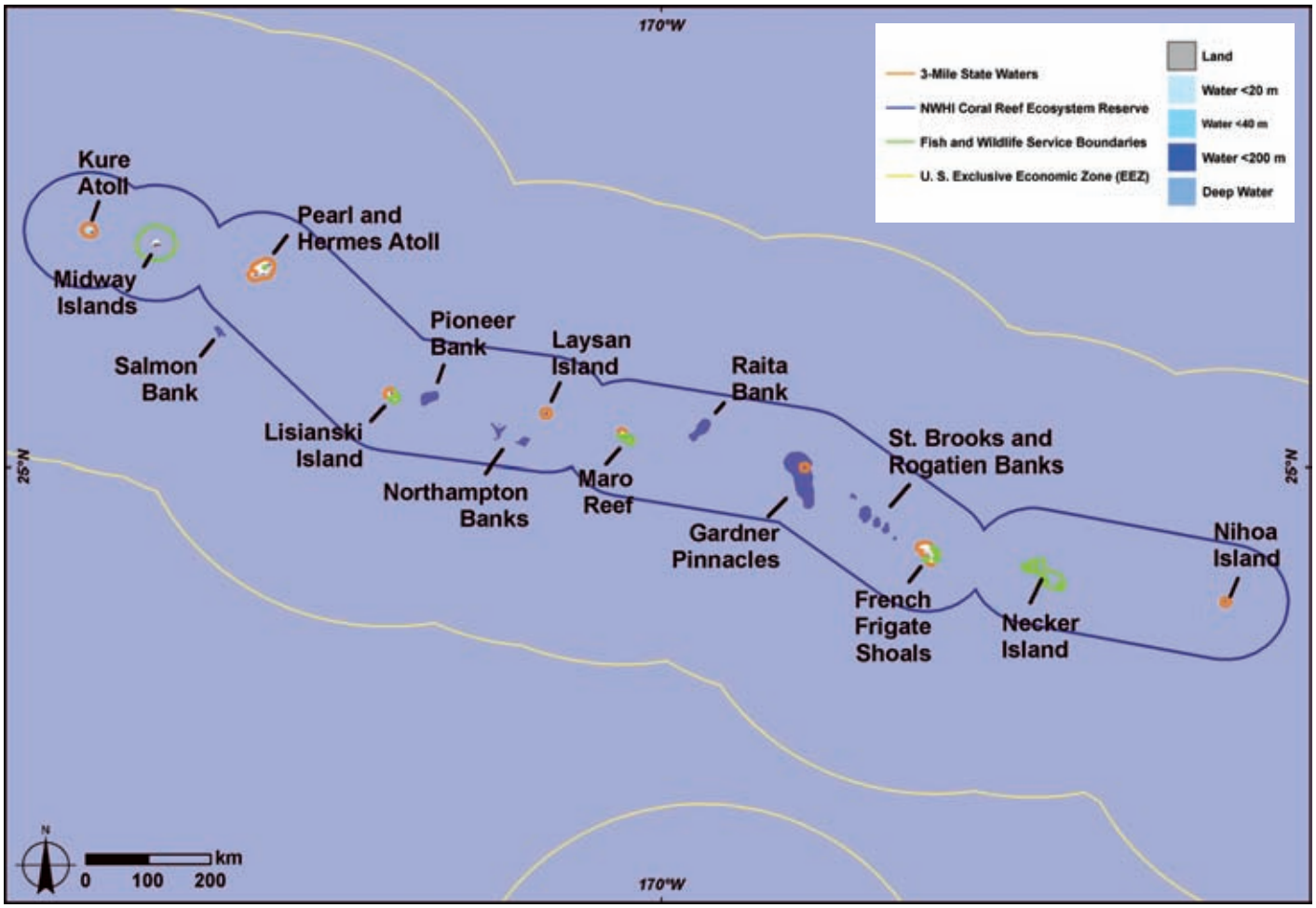

Figure HI-3. The Northwestern Hawaiian Islands, which extend across the north central Pacific, represent a vast, remote coral ecosystem that has been subjected to relatively minimal anthropogenic impacts. Map: A. Shapiro. Source: Friedlander et al. (2005b).

Northwestern Hawaiian Islands

MANAGEMENT GOAL

Maintain ecosystem integrity by implementing ecosystem-based management principles.

The NWHI consist of small islands, atolls, submerged banks, and reefs, and stretch for more than 2,000 km northwest of the high windward MHI (Figures HI-3 and HI-4). The majority of the islets and shoals remain uninhabited, although Midway, Kure, and Laysan Islands and French Frigate Shoals have all been occupied for extended periods over the last century by various government agencies.

With coral reefs around the world in decline, it is extremely rare to be able to examine a coral reef ecosystem that is relatively free of human influence and consisting of a wide range of healthy coral reef habitats. The remoteness and limited activities that have occurred in the NWHI have resulted in minimal anthropogenic impacts. The region represents one of the few large-scale, intact, predator-dominated reef ecosystems remaining in the world and offers an opportunity to examine what could occur if larger, more effective no-take marine reserves are established elsewhere. The high proportion of endemic species and unique mix of tropical and sub-tropical assemblages has identified the NWHI as a global biodiversity hotspot. The NWHI are critically important to a number of wide-ranging species such as seabirds, turtles, monk seals, and sharks. Strong ecological linkages are provided by these and a few other organisms for the transfer of energy and nutrients among ecosystems.

The nearly pristine condition of the NWHI allows scientists to understand how unaltered ecosystems are structured, how they function, and how they can most effectively be preserved. The NWHI provide an unparalleled opportunity to assess how a "natural" coral reef ecosystem functions in the absence of major human intervention. These reefs consist of discrete ecological subunits that can be used as replicates to examine large-scale ecological processes,

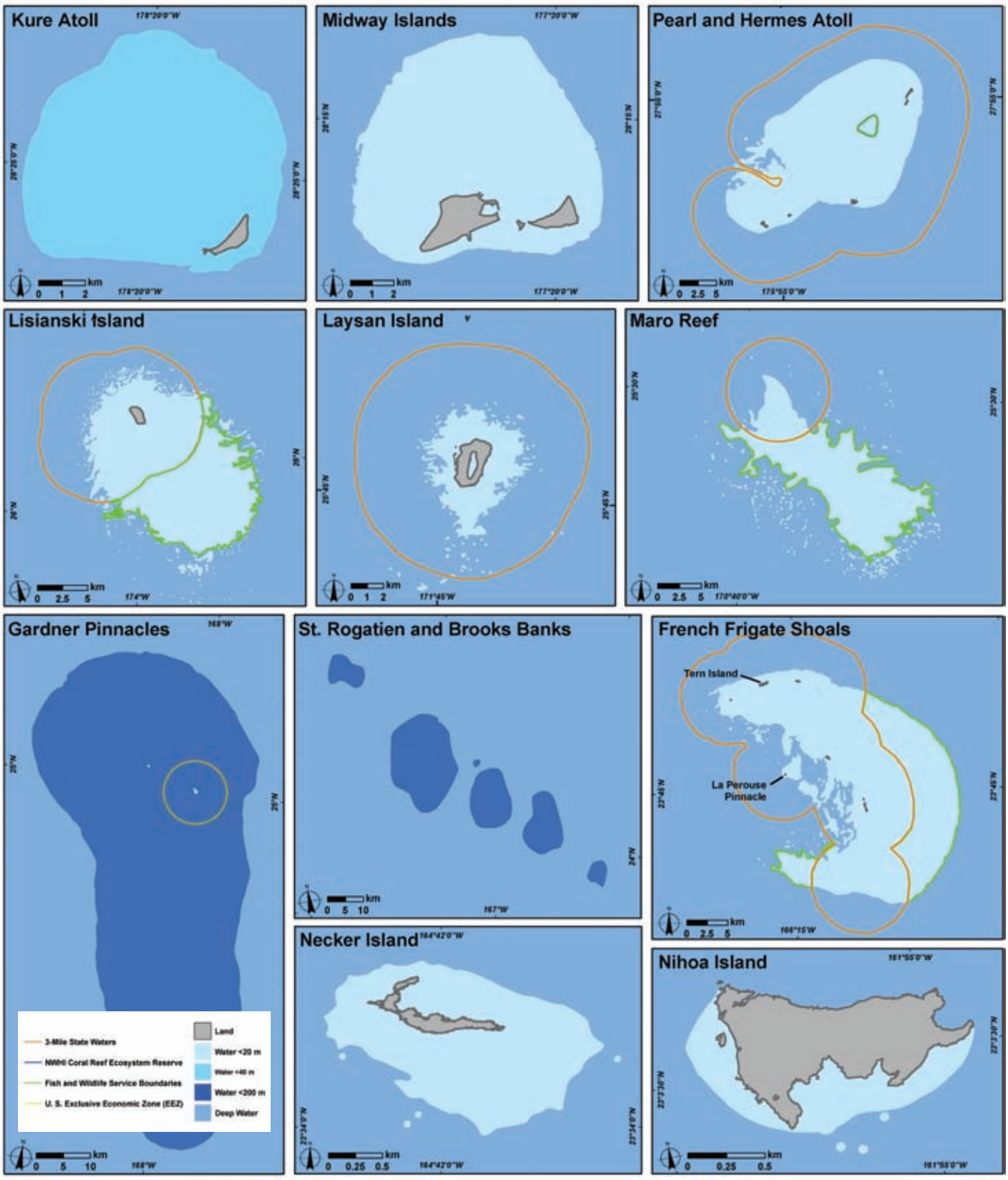

Figure HI-4. Locator map for the Northwestern Hawaiian Islands. Map: A. Shapiro. Source: Friedlander et al. (2005b).

while the scale of the existing fisheries allows for adaptive management strategies that can address questions related to stock decline and recovery. The NWHI represent a baseline within which to understand natural fluctuations and measure the success of existing management regimes elsewhere. Lessons learned from the NWHI can be used to help develop more effective management strategies in the MHI and other ecosystems. The NWHI should not only be

conserved for their intrinsic value, but also for their value to hedge against fisheries collapses and as a model for ecosystem-based management.[7]

To preserve and protect the NWHI for future generations, President Bush signed a Proclamation on June 15, 2006 creating the Northwestern Hawaiian Islands Marine National Monument (Bush 2006). The national monument was created to preserve access for Native Hawaiian cultural activities; provide for carefully regulated educational and scientific activities; enhance visitation in a special area around Midway Island; prohibit unauthorized access to the monument; phase out commercial fishing over a five-year period; and ban other types of resource extraction and dumping of waste.

Research Needs

The research needs described herein are for light-dependent coral reef ecosystems in the NWHI. This section was jointly developed by a working group consisting of NWHI resource managers and affiliated researchers, including the State of Hawaii, FWS, NOAA's Pacific Islands Fisheries Science Center, NOAA's National Marine Sanctuary Program, and the University of Hawaii. As a result of a working group process, it was determined that the format of this section should differ from the other regional sections in this document. Because of the remote nature of the NWHI, many of the threats and stressors that typically impact coral reef ecosystems are not present (e.g., coastal uses). To account for this, the format of the plan was modified. Also, only management objectives with associated research needs are included in the plan. This resulted in the removal of two important management objectives that need mentioning: outreach activities and improving coordination and collaboration among agencies, institutions, and scientists. Outreach activities, while generally not considered to be research, are pivotal to the implementation and success of management actions. Improving coordination and collaboration between agencies, institutions, and individual scientists conducting research in the Hawaiian Archipelago is critical to the success of this research plan, but clearly not a research priority.[8]

7 Introductory material was taken, with slight modifications, from Friedlander et al. (2005b).

8 While this research plan focuses on the shallow coral reef ecosystems in the NWHI, connectivity with the deep coral ecosystems has been documented. This connectivity is acknowledged in this plan by supporting ongoing research in the deep coral ecosystems of the NWHI.

NWHI	An Ecosystem Approach[9]
Management Objective	***Research Need***
Characterize NWHI shallow coral reef ecosystems and function.	Map, characterize, and assess coral reefs and their associated habitats.
	Catalogue existing data sets, document current data collection programs, and assess the quality (e.g., statistical rigor) of these data/programs.
	Describe species diversity, trophic structure, and associated dynamics (including habitat linkages with other ecosystem components) of coral reef ecosystems.
	Characterize critical oceanographic factors that influence the distribution and abundance of biotic components of coral reef ecosystems.
	Assess population replenishment and connectivity among islands, banks, and associated coral reef ecosystems.
	Improve hydrodynamic, ecosystem, and resource assessment models that capture the dynamics, structure, and function at appropriate temporal and spatial scales.
	Develop decision support analysis tools that incorporate the complexity, dynamics, and uncertainty associated with NWHI processes to assist managers in resource decision making processes.
	Identify the distribution and occurrence of deepwater hermatypic coral reefs, including identification of the extent and distribution of these habitats at each island.

NWHI	An Ecosystem Approach[9]
Management Objective	***Research Need***
Understand human impacts, natural variability, and episodic events.	Evaluate and assess impacts (direct and indirect) of human activities (e.g., recreational fishing, subsistence, research, and ecotourism) on coral reef ecosystems.
	Understand the potential effects of coral disease on population dynamics, community structure, and ecosystem function.
	Assess resistance and resilience of specific populations and locations habitats to episodic events (e.g., coral bleaching), emphasizing areas that may serve as sources of reproductive propagules.
	Establish long-term monitoring programs that incorporate biotic and abiotic data to document and assess spatiotemporal changes in biota.
	Document and remediate hazardous waste that poses a threat to fish, wildlife, or their habitats.
Maintain and, where appropriate, restore natural shallow coral reef ecosystems.	Identify and implement effective restoration, recovery, and remediation strategies to address human impacts, including marine debris accumulations, ship groundings, and hazardous waste.
	Restore, where possible, anthropogenically degraded coral reef habitats that are important for sustaining vertebrate and invertebrate stocks.
Identify robust ecosystem-based management indicators that reflect trophic interactions, community composition, biodiversity, and other metrics of ecosystem status.	Identify robust metrics to assess coral reef ecosystems (e.g., biodiversity and other statistical measures of assemblage structure; biomass size spectra; and life history responses to keystone species such as apex predators) that are consistent with existing mandates.
	Identify indicator species (i.e., those which are indicative of the overall condition of the ecosystem) and keystone species (i.e., those of importance in structuring the composition of the ecosystem) for use as monitoring tools.
Evaluate the effectiveness of MPAs as a management tool.	Assess the effectiveness of MPAs in conserving ecologically important species and their habitats.
	Evaluate the costs and benefits of MPAs, including compensation or assistance programs for those displaced from these areas.
	Assess the connectivity among MPAs within the NWHI and between adjacent ecosystems (e.g., Johnston Atoll).
Reduce the threat of alien species to shallow coral reef ecosystems in the NWHI.	Characterize biological and ecological requirements of specific alien species and develop effective prevention and eradication methods.
	Conduct research to support the detection, removal, and control of alien species in coral reef ecosystems in the NWHI.
Protect, conserve, and enhance recovery of protected, threatened, and other key species.	Characterize the role of protected species (i.e., marine mammals, sea turtles, and birds) in coral reef ecosystems and the threats impacting these species, and develop measures to enhance their conservation.

9 As a result of a working group process, it was determined that an ecosystem-based approach would be more appropriate for the NWHI than a threat-based approach. Because of the remote nature of the NWHI, many of the threats and stressors that typically impact coral reef ecosystems are not present.