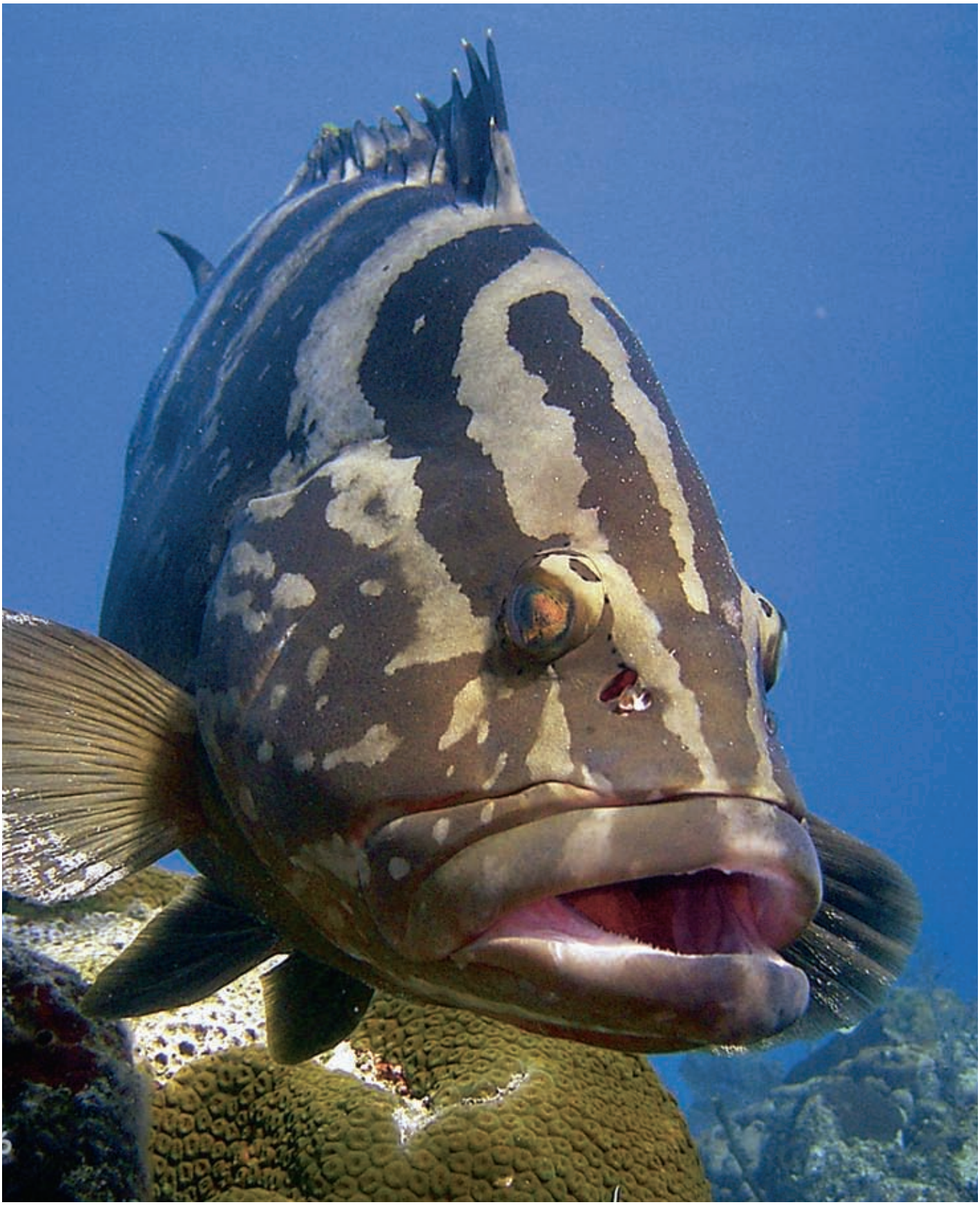
Jurisdiction-Specific Research Needs: Atlantic Ocean



Nassau grouper, Epinephelus striatus *(Cayman Islands, 2006). Photo credit: Diana Schmitt.*

FLORIDA

The Florida Section of this research plan is divided into three subsections: the Florida Keys, Southeast Florida, and the Eastern Gulf of Mexico (Figure FL-1).

Florida Keys

Coral reefs in the Florida Keys stretch south from Miami to Key West, and continue to the Dry Tortugas, covering over 220 miles of continuous shallow-water habitat. The flora and fauna existing in this region are heavily influenced by the warm tropical waters of the Gulf Stream current and the temperate waters of the Gulf of Mexico.

In the Florida Keys (Monroe County), reef based-recreation and tourism are a significant part of the economy. In 2001, a socioeconomic study showed that natural and artificial reefs in the Florida Keys contributed $490 million in sales, $139 million in income, and 10,000 jobs to the local economy over one year (Johns et al. 2001). Therefore, a decline in coral reef condition could have far reaching impacts on the economy of Monroe County.

The decline of coral reefs in the Florida Keys is well-documented. Public perception is strong that poor water quality is the primary reason for the decline, but the scientific evidence suggests that a combination of geography, multiple stressors acting synergistically, and natural factors explain the condition of the reefs.

Because coral reefs in Florida represent the northern extension of a rich Caribbean flora and fauna, they are subject to many of the same problems that have caused coral decline throughout the Caribbean. For example, both white band disease affecting the branching corals *Acropora palmata* (elkhorn coral) and *A cervicornis*. (staghorn coral), and an urchin disease have reshaped the condition of the offshore reefs in the Keys and the Caribbean. Coral bleaching has affected the Keys multiple times in the past 15 years. In 1997 and 1998, significant bleaching was observed during the El Niño Southern Oscillation (Causey 2001). Large numbers of corals are presumed to have been killed by this bleaching event.

Overfishing is also a significant problem in the Keys. Between 1965 and 1993, the commercial fishing fleet grew by 25%, and the recreational fleet increased by six fold (Ault et al. 1998). These trends are a consequence of a burgeoning south Florida population which brings increased fishing and all of the attendant problems associated with coastal development that can be detrimental to coral reefs.

Against this background of multiple stressors and other disturbances (e.g., hurricanes, ship groundings, and coral diseases), there are three pieces of good news: the recovery of urchins (the major algal grazers) appears to be occurring at some sites in the Dry Tortugas (Chiappone et al. 2001), which may reduce algal cover and help corals recover; the management plan for the Florida Keys National Marine Sanctuary includes 23 marine zones (known as Sanctuary Preservation Areas, Special-Use Areas, and Ecological Reserves) that provide "no-take" protection from fishing and other forms of extraction; and the Tortugas Ecological Reserve was created in 2001 to conserve deep-water reef resources and fish communities. While these "no-take" marine zones were established primarily to manage multiple user-groups rather than a fishery management tool, preliminary results suggest positive fishery benefits as well.[1]

Southeast Florida

The extensive reef system of southeast Florida is a northward continuation of the Florida reef tract extending approximately 150 km from Miami-Dade County, through Broward and Palm Beach Counties, to Martin County. There are generally three reef lines, running parallel to the shore and separated by sand deposits – one that nominally crests in 3 to 4 m of water depth (i.e., Inner Reef or the First Reef), another in 6 to 8 m (i.e., Middle Reef or the Second Reef), and one in 15 to 21 m depth (i.e., Outer Reef or the Third Reef). On the shoreward side of the Inner Reef, a series of hard ground ridges often occur.

The reef resources in southeast Florida have considerable economic value. In the four-county area (Monroe, Miami-Dade, Broward, and Palm Beach), users spent over 18.4 million person-days from June 2000 to May 2001 using natural reefs, with economic impacts of $2.7 billion in sales and $1.2 billion in local income (Johns et al. 2001).

In southeast Florida, there are a variety of natural and anthropogenic stressors impacting the coral reef ecosystems. Natural stressors that can effectively limit coral reef growth include frequent exposure to hurricanes, weather, extreme water temperatures (both hot and

1 Research needs identified for the Florida Keys are based on the Comprehensive Science Plan for the Florida Keys National Marine Sanctuary (NOAA 2002b).

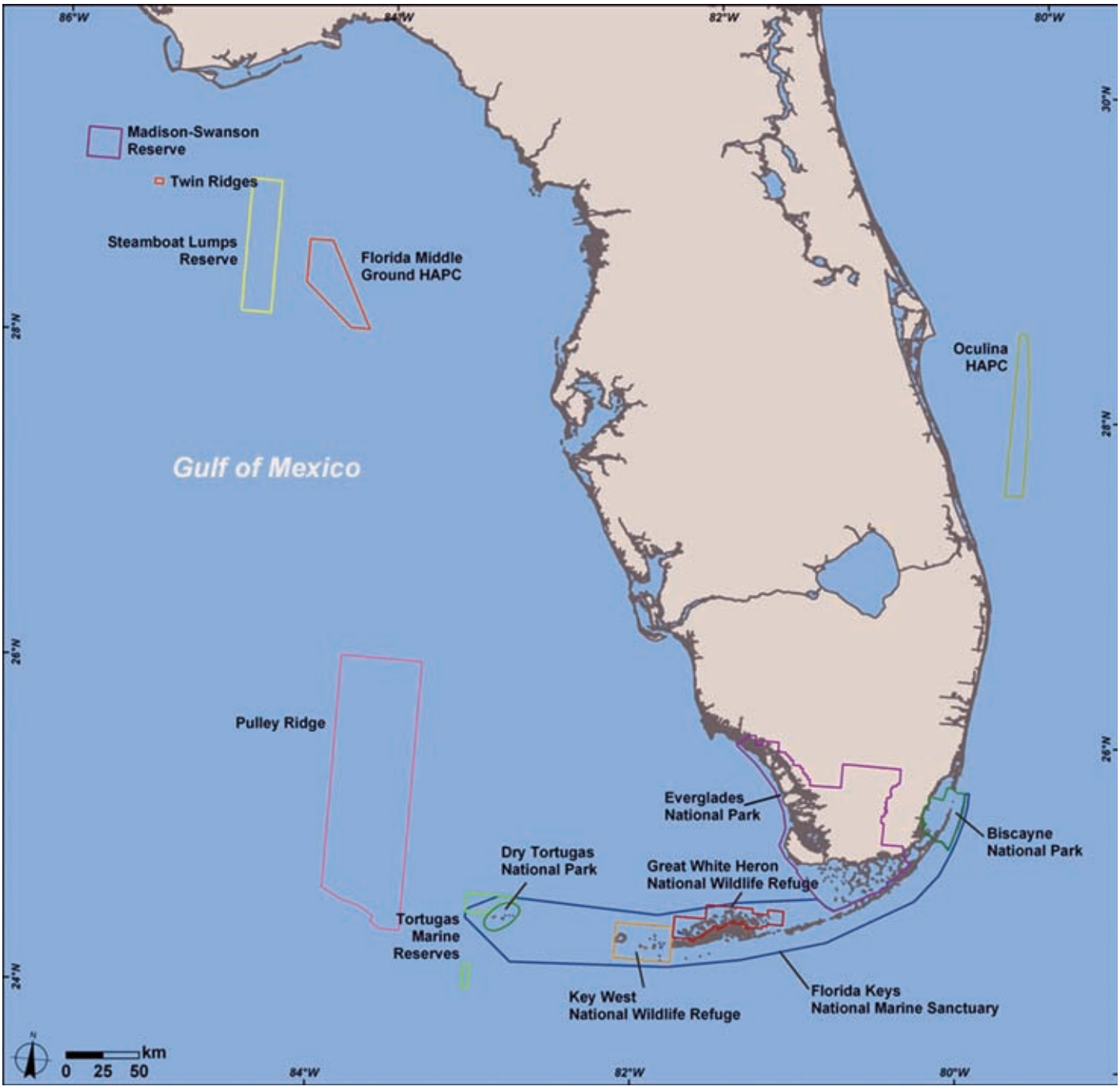


Figure FL-1. Locator map for Florida. Map: A. Shapiro.

cold), and deepwater upwelling. Potentially detrimental human activities include effects from offshore and onshore construction (e.g., pipelines, fiber optic cables, beach renourishment, channel dredging, and coastal development), large and small ship groundings, anchor and anchor chain damage, fishing, non-extractive recreational activities, and pollution from sewage and other land-based sources, including groundwater seepage, discharge from navigational inlets, and general runoff.

Coral diseases in southeast Florida are present across habitats and depth gradients. The main diseases observed in the region include black band disease, white band disease (mainly affecting ***A. cervicornis***), white plague, and octocoral aspergilliosis, although numerous other conditions also occur. Bleaching also affects corals in the region; however the scale and severity of these events are not well documented. Because mean live coral cover in Miami-Dade, Broward, Palm Beach, and Martin Counties is low, coral disease and coral bleaching-related mortality demand further attention.

Overfishing appears to be a major problem for snappers and groupers. During a four-year period (August 1998 to November 2002), 667 sites on the three reef tracts were censused for fishes. There was a surprising scarcity of legal size groupers (19) and snappers (198) over the entire survey area (Ferro 2005).

While coral reefs south of Miami enjoy various levels of Federal protection in the form of national parks, state parks, and national marine sanctuaries, there is only one established formal protected area north of Biscayne National Park, the Oculina Habitat Area of Particular Concern (HAPC). The Oculina HAPC, a 1029 km^2 area located off central Florida, is closed to bottom-associated fishing gear to protect the ivory tree coral, ***Oculina varicosa***, an azooxanthellate coral with a fragile branching structure (NOAA 2003b). Within the Oculina HAPC, a 92 nautical square mile (nm^2) area known as the Oculina Experimental Closed Area is also closed to the snapper and grouper fishery. It should be noted that the Oculina HAPC does not protect the more shallow-water reefs of Southeast Florida (Dade, Broward, Palm Beach, and Martin Counties).

Eastern Gulf of Mexico (West Florida Shelf)

The eastern Gulf of Mexico, or west Florida Shelf, has a broad continental shelf (140,000 km^2) dominated by sedimentary bottom types. The hard bottom habitat typically consists of ridge or ledge rock formations (Lyons and Collard 1974), which serve as essential fish habitat for both snappers and groupers. The coral reefs and live hard bottom habitats consist of warm-temperate species in the northern area and hardy Caribbean species in the southern area. The northern area comprises the Florida Middle Ground, Madison-Swanson Reserve, Steamboat Lumps Reserve, and Twin Ridges; the southern area consists of Pulley Ridge and the Dry Tortugas.[2]

Northern Area:

- The Florida Middle Ground is a 1,193 km^2 area in the northeastern Gulf of Mexico that represents the northernmost extent of hermatypic coral reefs in the United States.
- Madison-Swanson Reserve is a 394 km^2 area located south of Panama City, Florida and Steamboat Lumps Reserve is a 356 km^2 area located west of Tarpon Springs, Florida. Both Madison-Swanson and Steamboat Lumps Reserves lie at the margin of the continental shelf and slope in 60 to 140 m of water and are sites of spawning aggregations of gag (***Mycteroperca microlepis***) and other reef fish species (Koenig et al. 2000).
- Twin Ridges is an area adjacent to Madison-Swanson and Steamboat Lumps Reserves which is unprotected and used as a reference site to measure the impact of the reserves.

Southern Area:

- Pulley Ridge is a drowned barrier island approximately 100 km in length located off the southwest Florida Shelf at 60 to70 m in depth (Halley et al. 2003), and is believed to be the deepest hermatypic coral reef dependent on light off the continental U.S. (Halley et al. 2005). The ridge itself is 5 km wide with 10 m of relief. Coral cover in some sites may be as high as 60% (Jarrett et al. 2005). The fragile corals of Pulley Ridge remain at risk to bottom tending fishing gear and more habitat delineation is needed to assess the extent of coral habitat. As no coral bleaching events have been observed on Pulley Ridge to date, this area could serve as a control site for investigations of similar species in shallower waters which have experienced bleaching.

The major stressor in the eastern Gulf of Mexico is fishing pressure on grouper and snapper stocks and shrimp. The region has three prominent fisheries: the Penaeid shrimp, snapper and grouper, and a commercial sponge. Other important stressors are annual red tides or harmful algal blooms of phytoplankton that are toxic to many fish, birds, and marine animals that last from four to five months; pollutant loads from the Mississippi River and other rivers during spring runoff; occasional upwelling of cold, high nutrient water on the northern areas; positioning gas pipelines over the shelf that impact benthic organisms; ocean dumping; climate change; coastal development; and bottom tending commercial fishing gear. In 2005, extreme events heavily impacted the condition of benthic communities and fish stocks, including an extreme red tide and increased Mississippi River runoff from Hurricanes Katrina and Rita.

The coral reef ecosystems and spawning aggregations in the Gulf of Mexico have differing levels of protection. The Florida Middle Ground HAPC was designated in 1982 and encompasses most of the high-relief and live bottom habitat (Coleman et al. 2004). Although protected from coral harvest and bottom-associated fishing gear, this region's reef fish populations are fished using hook and

2 The Dry Tortugas are addressed in the Florida Keys section.

line. The level of commercial and recreational fishing pressure is unknown for this area and is a priority research need. Madison-Swanson and Steamboat Lumps Reserves were established in 2000 to protect gag and other fish spawning aggregations. These reserves were initially closed to all fishing (except highly migratory species) for a period of four years. These closures have since been extended to 2010 to evaluate the effectiveness of the reserves; however, surface trolling is now allowed for coastal pelagic and highly migratory species. Continued evaluation of the efficacy of the reserve determined through monitoring of reef fish abundance and distribution in and near the reserves remains a high priority as the species of interest are long-lived and late maturing. Enforcement of the fishing restrictions is complicated by the remoteness of the reserves and the level of illegal fishing is not being fully evaluated.

Research Needs

FLORIDA	FISHING	Florida All	Florida Keys Only	Southeast Florida Only	E. Gulf of Mexico 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.*	Produce habitat maps with adequate bathymetric and habitat resolution to manage and understand the region's nearshore and offshore reefs, hard bottom and soft bottom communities, estuaries, inlets, and the Intercoastal Waterway. Whenever possible, use existing maps to streamline new acquisition efforts.	√			
	Assess the distribution, abundance, and ecological role of aquarium trade species and the impacts associated with their extraction.	√			
	Characterize the trophic dynamics of the ecosystem relevant to key fisheries species.	√			
	Develop spatially explicit bioeconomic models for important commercial and recreational fisheries incorporating ecosystem attributes such as predator-prey relationships, habitat characteristics, environmental parameters, and fishing effort.	√			
	Experimentally examine the potential for enhancement of degraded inshore habitat and concomitant change in associated fauna.	√			
	Determine the levels of fishing pressure and associated impacts on deepwater hermatypic coral reef ecosystems.	√			
	Determine whether the source of recruits of commercially important groupers and snappers in the Upper Florida Keys are from localized spawning sites or elsewhere in Florida or the wider Caribbean.		√		

FLORIDA	FISHING	Florida All	Florida Keys Only	Southeast Florida Only	E. Gulf of Mexico Only
Management Objective	***Research Need***				
Protect, conserve, and enhance the recovery of protected, threatened, and other key species.	Queen Conch				
	Identify the specific toxins or pollutants that inhibit reproduction and/or recruitment, develop options to mitigate these factors, and determine the effectiveness of implemented management actions on conch recovery.		√	√	
	Evaluate the status and trends of conch populations (spatial distribution and abundance of different life stages) to determine whether management measures are helping to rebuild populations.		√	√	
	Identify reliable methods to assess conch population dynamics, including size, age, and reproductive structure.		√	√	
	Characterize habitat use patterns of different life stages of conch, and movement patterns between reproductive and feeding grounds.		√	√	
	Identify natural factors that contribute to the recovery of conch populations, including reproductive potential (e.g., optimal densities), recruitment, predator-prey relationships, and food sources.		√	√	
	Spiny Lobster				
	Assess the relationships between habitat types and quality, and abundance of different life history stages of lobsters.		√	√	
	Identify the natural factors affecting the population dynamics of lobsters, including recruitment, predator-prey relationships, and ontogenetic shift in habitats.		√	√	
	Determine whether the source of spiny lobsters recruitment in the Florida Keys is from adults spawning in the Florida Keys or elsewhere (e.g., Central or South America).		√		
	Assess the impacts of the recreational and commercial lobster fisheries on lobster populations and coral reef habitats.		√	√	
Evaluate and improve the effectiveness of MPAs as a fisheries management tool. *See Jurisdiction-Wide Section for additional research needs.*	Evaluate benefits of the Tortugas Ecological Reserve, including whether the reserve is: improving the quality of habitat and the recovery of fish stocks; helping replenish the fish stocks in the surrounding non-MPA areas; and supporting societal needs.		√		
	Determine the effect of management measures in the Oculina Experimental Closed Area and other southeast Florida MPAs on commercial and recreational fishery stocks.			√	
	Determine the effectiveness of Madison-Swanson and Steamboat Lumps Reserves in protecting gag and other fish spawning aggregations.				√
	Determine the level of commercial and recreational fishing pressure in the Florida Middle Grounds HAPC.				√
	Determine short- and long-term costs and benefits of marine zoning in the Florida Keys National Marine Sanctuary to displaced commercial fishers.		√		

FLORIDA	POLLUTION	Florida All	Florida Keys Only	Southeast Florida Only	E. Gulf of Mexico 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.*	Produce thematic maps for outlining habitat landscaping patterns for Miami-Dade, Broward, Palm Beach, and Martin Counties using existing laser airborne depth sounder mapping data.			√	
	Determine residence time of pollutants in specific areas.	√			
	Identify pollutant loads associated with episodic events (e.g., upwelling and major storms) and their impacts.	√			
	Identify sources and signals of sewage contamination by using appropriate tracers (e.g., stable isotopes as a signal in octocorals and macroalgal/*Lyncbya* tissue, and human enteroviruses).			√	
	Determine whether the rivers feeding into the Gulf, including Suwannee, Withlacoochee, Crystal, Homosassa, Chasshowitzka, Wiki Wachee, Anclote, Hillsboro, Alafia, Little Manatee, Manatee, Myaka, Peace, Fenholloway, and Caloosahatchee Rivers, are adding significant pollutants, nutrients, pesticides, and other contaminants to the Eastern Gulf of Mexico coral reef ecosystems.				√
	Determine the amount and flux of pollutants from: exiting ocean inlets, oceanic sources, and atmospheric sources to coastal waters and coral reef communities.			√	
	Determine the amount and flux of effluent and pollutants from wastewater outflow pipes and net flux to coral reef communities along the coast.			√	
	Quantify the amount and flux of pollution transported by groundwater to coastal waters and coral reef communities.			√	
	Develop a mass balance pollution budget for southeast Florida reefs from both point and nonpoint sources, including nutrients, carbon, and other pollutants. Identify the sources and quantify their relative and absolute contributions.			√	
	Identify and model impacts of freshwater discharges from the Everglades on coral reef ecosystems.			√	
	Understand the dynamics of water and waterborne chemicals as they move from source areas to the Eastern Gulf of Mexico and the Florida Keys reefs.	√			
	Assess the impact of shallow injection wells and stormwater on coral reef ecosystems.		√		
	Evaluate the impact of large-magnitude rainfall and water releases from Lake Okeechobee on nutrient and contaminant levels in the Eastern Gulf of Mexico on coral reef ecosystems.	√			

FLORIDA	POLLUTION	Florida All	Florida Keys Only	Southeast Florida Only	E. Gulf of Mexico Only
Management Objective	***Research Need***				
Improve water quality by reducing land-based pollutant inputs and impacts on coral reef ecosystems. *See Jurisdiction-Wide Section for additional research needs.*	Investigate effectiveness of real-time management of controlled runoff, including dams or other effluents, to reduce stress on coral reefs ecosystems during disease outbreaks, coral bleaching episodes, and spawning events.		√		
	Develop methods to improve water quality in Florida Keys canals.		√		
Improve the understanding of the economic benefits of improved water quality.	Conduct cost and benefit analyses of wastewater infrastructure upgrades and conservation land acquisition.	√			
	Determine how changes in water quality due to pollution may impact different economic uses, including potential fishery and habitat impacts.	√			

FLORIDA	COASTAL USES	Florida All	Florida Keys Only	Southeast Florida Only	E. Gulf of Mexico 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 impact of coastal development on seagrass and mangrove habitats and how changes in the quality of these habitats as a result of human uses affect the condition of the associated reef habitat.	√			
	Assess the impact of development on the Indian River Lagoon Estuary and associated tropical peripheral species.			√	
	Design and conduct demonstration projects to evaluate science-based management options for improving shoreline stability while maintaining coral reef ecosystem functions.	√			
	Evaluate ecological and socioeconomic costs and benefits of artificial reefs, including public perception and their effects on fish communities and neighboring coral reef environments.		√	√	
	Determine the appropriate structural configuration (considering ability to withstand hurricanes) and develop criteria (e.g., location, amount of light, and current) for creating a diverse fish and invertebrate community for artificial reefs.			√	
Balance resource use to minimize user conflicts, provide equitable uses, and ensure optimal benefits to present and future generations.	Perform geographic and sector use assessments for the various habitats.			√	
	Determine the socioeconomic costs and benefits of different management strategies on different user groups.		√	√	
	Determine decadal changes in recreational and commercial uses (e.g., scuba diving, snorkeling, boating) of coastal waters and their habitats, and the economic impact of these changes.		√	√	

FLORIDA	COASTAL USES	Florida All	Florida Keys Only	Southeast Florida Only	E. Gulf of Mexico Only
Management Objective	***Research Need***				
Protect, conserve, and enhance the recovery of protected, threatened, and other key species. *See Jurisdiction-Wide Section for additional research needs.*	Acroporids				
	Identify critical habitat for ***Acropora*** spp. in Florida, including the historical and current distribution of acroporid populations, and factors that affect their spatial extent.		√	√	
	Assess the abundance, population structure, and condition of Florida acroporids, including documenting threats affecting these species, relationships between coral condition/abundance and human impacts, and the potential for recovery under different management regimes.		√	√	
Restore injured and degraded coral reef habitat. *See Jurisdiction-Wide Section for additional research needs.*	Develop economic models relating various habitats to economic value to assist in quantifying costs of resource impacts associated with vessel groundings and other human impacts.	√			
	Evaluate the efficacy of current protocols used in seagrass and coral reef restoration efforts.	√			
Reduce impacts from and restore habitat damaged by vessel anchoring and groundings.	Determine the extent and impact of vessel groundings, anchoring, and anchor chains on coral reef and associated habitats, including the cumulative impacts of daily groundings of recreational vessels and the impacts surrounding designated large vessel anchorages, such as Port Everglades.		√	√	
	Evaluate the effectiveness of existing mooring buoys and channel markers in reducing the impact of anchoring, anchor chains, and groundings to coral reefs.		√	√	
	Characterize patterns of recovery in unrestored areas affected by anchorings and groundings, and compare to restored areas.		√		
Evaluate and improve the effectiveness of MPAs as a management tool. *See Jurisdiction-Wide Section for additional research needs.*	Conduct periodic assessments of stakeholder's knowledge, attitudes, and perceptions of the Florida Keys National Marine Sanctuary management strategies and regulations, and identify ways to improve public support.		√		
	Determine whether ***Oculina varicosa*** habitat will recover throughout the Oculina Experimental Closed Area without human intervention, and predict the time frame for significant recovery to occur.			√	
	Identify what and where the major habitat types are in the Oculina Experimental Closed Area, the Oculina Bank HAPC, and adjacent hardbottom areas.			√	
	Assess the effectiveness of special preservation areas and ecological reserves in resolving conflicts between extractive and non-extractive users of the Florida Keys National Marine Sanctuary.		√		

FLORIDA	INVASIVE SPECIES	Florida All	Florida Keys Only	Southeast Florida Only	E. Gulf of Mexico Only
Management Objective	***Research Need***				
Minimize the introduction and spread of alien species.	*See Jurisdiction-Wide Section for research needs.*	√			
Control or eradicate invasive species that have the potential to cause damage to coral reef ecosystems. *See Jurisdiction-Wide Section for additional research needs.*	Document the distribution, abundance, and population dynamics of non-native ornamental marine fish such as orbicular batfish, orange spine unicorn fish, raccoon butterfly fish, several varieties of tang and angelfish, and the lionfish.		√	√	
	Determine the distribution and abundance of the green mussel in the Eastern Gulf of Mexico and its current and potential impacts on the ecosystem.				√
	Identify potential methods to control/eradicate the green mussel without impacting native species or introducing alien species.				√
	Characterize the distribution and patterns of the spread of benthic invasive algae, such as *Caulerpa* and cyanobacteria.		√	√	
	Determine the distribution and abundance of *Tubastrea coccinea* and its impact on benthic communities.	√			

FLORIDA	CLIMATE CHANGE	Florida All	Florida Keys Only	Southeast Florida Only	E. Gulf of Mexico Only
Management Objective	***Research Need***				
Minimize the effects of climate change on coral reef ecosystems. *See Jurisdiction-Wide Section for additional research needs.*	Hindcast and forecast climatic trends for the region to determine what the potential impact of climate change was and will be on the region.		√	√	
	Identify potential environmental and anthropogenic factors that may influence the long term resilience of Florida's coral reef ecosystems to maximize benefits of reefs that are not susceptible to bleaching while seeking to improve the condition of those that are more likely to bleach.	√			
	Investigate differential impacts of coral bleaching between shallow and deeper hermatypic coral reefs, including the extent of bleaching and the relationships between coral bleaching impacts and environmental factors.	√			

FLORIDA	EXTREME EVENTS	Florida All	Florida Keys Only	Southeast Florida Only	E. Gulf of Mexico 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 prevalence, incidence, and impact of emerging diseases in deeper reef communities such as those off the Dry Tortugas.		√		
	Understand the etiology of diseases affecting ***Acropora*** spp. populations and identify potential pathogen sources.		√	√	
	Evaluate damselfish, butterflyfish, parrotfish, and invertebrate corallivores as potential vectors for coral diseases.		√		
Reduce impacts to and promote restoration of coral reef organisms affected by extreme events.	Characterize the impacts of hurricanes and other natural and anthropogenic disturbances on coral reefs, and identify restoration options for the affected ecosystems.	√			
Reduce the occurrence and intensity of harmful algal blooms.	Investigate factors that contribute to blooms of dinoflagellates (e.g., ***Karina*** spp.), cyanobacteria (e.g., ***Lyngbya*** spp.), and other phytoplankton, and benthic algal populations and their potential role in reef degradation.	√			

FLOWER GARDEN BANKS

The Flower Garden Banks National Marine Sanctuary (FGBNMS) consists of three geographically separate underwater features – the East and West Flower Garden Banks, and Stetson Bank (Figure FGB-1). The Sanctuary is located approximately 100 miles south of the Texas-Louisiana border in the northwestern Gulf of Mexico and contains some of the northernmost coral reefs on the continental shelf of North America. The coral reefs of the

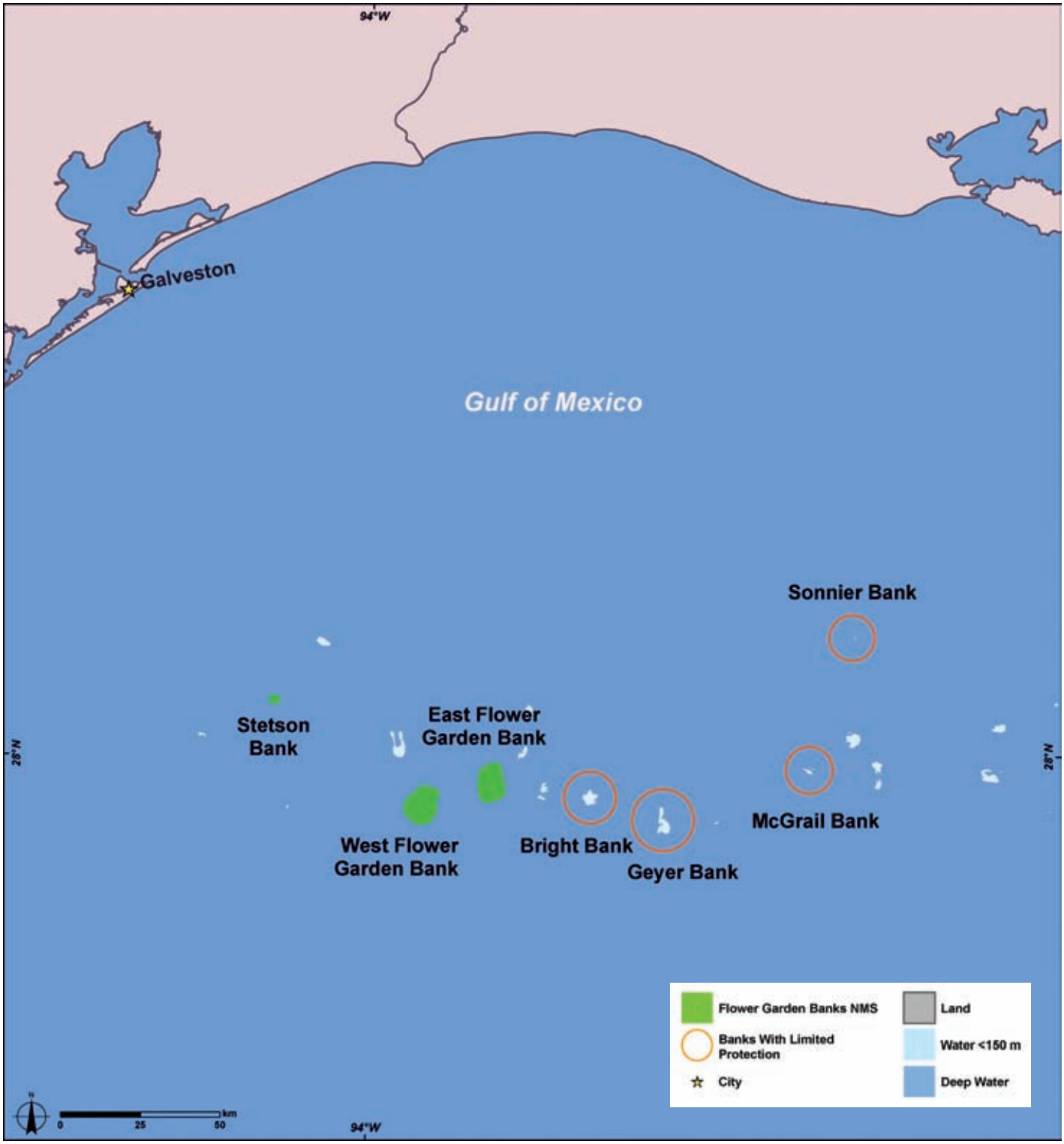


Figure FGB-1. Map showing the locations of the coral banks of the Gulf of Mexico. While some of the banks are protected by the provisions of the Flower Garden Banks National Marine Sanctuary, unprotected coral communities are present at Bright, Sonnier, Geyer, and McGrail Banks. These banks are part of the network of reefs and banks which are biologically and ecologically associated with the ecosystems of the sanctuary. Map: A. Shapiro. Source: Hickerson and Schmahl (2005).

East and West Flower Garden Banks are presently in good condition, compared to most other reef systems of the Caribbean and western Atlantic. Over 20 years of long-term coral reef monitoring at the East and West Flower Garden Banks indicates that the reefs have maintained approximately 50 to 70% coral coverage within the coral zone - an extraordinary coverage in a global climate of coral reef decline. The reefs are dominated by extremely large boulder corals (*Montastraea* spp., *Diploria strigosa*, and *Colpophyllia natans*). Branching corals are dominated by *Madracis mirabilis* fields in the deeper portions of the reefs. The coral cap ranges in depths from 17 to 49 m and covers an area of approximately 0.55 square miles (350 acres). Fish populations appear to be in good condition, although scuba divers encounter fishing debris and bycatch on a regular basis. This reef system appears to be thriving in spite of the fact that the FGBNMS is located in the middle of one of the most productive oil and gas fields in the world. Stetson Bank is a colorful, geologically exciting feature, dominated by sponges, several species of corals, and algae.

In addition to the FGBNMS, there are dozens of other reefs and banks in the northwestern Gulf of Mexico. The three banks within the Sanctuary are accessible to recreational scuba divers (within 130 ft depth), whereas the other reefs and banks are generally deeper. Coral reef communities are thriving on several of the other northwestern Gulf of Mexico features, including but not limited to McGrail Bank, Sonnier Bank, and Bright Bank. Evidence suggests that the coral reef communities of McGrail, Sonnier, and Bright Banks are biologically and ecologically linked to those found in the FGBNMS. These coral communities have historically been unprotected from threats other than those related to the oil and gas industry.

Due to the remote location of the banks, limited recreational activities occur (e.g., approximately 3,000 scuba divers per year visit FGBNMS). Hook and line fishing, both recreational and commercial, is allowed at the FGBNMS. However, the level of fishing pressure is not known, mainly due to the logistics of monitoring this activity at the site, and due to the manner in which commercial data is collected and managed.

The Gulf of Mexico Fisheries Management Council recently identified 13 reefs and banks in the northwestern Gulf of Mexico as HAPCs. While HAPC designation does not offer regulatory protections, a number of measures to regulate fishing gears and protect sensitive habitats were identified for these areas within specific fishery management plans. This includes prohibitions on bottom anchoring in coral reef areas; and prohibitions on trawling gear, bottom longlines, buoy gear, and fish traps in some areas.

Research Needs

FLOWER GARDEN BANKS	**FISHING**
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 status and trends of fish populations within FGBNMS and on other banks in the northwestern Gulf of Mexico.
	Assess temporal dynamics of coral reef fish trophic structure, including interactions with varying levels of fishing and other stresses.
	Assess larval fish dynamics in and around the FGBNMS.

FLOWER GARDEN BANKS	POLLUTION
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.*	Determine the sources, types, concentrations, and effects of pollutants on important coral reef species in the FGBNMS.
	Model the water circulation patterns of the northern Gulf of Mexico.
	Assess the potential impacts of oil and gas exploration and production on neighboring related coral reef communities.
	Assess the levels of toxins in commercially fished species within the FGBNMS.
	Assess the level of landborne and industry generated pollutants, including nutrients and hydrocarbon-associated contaminants in coral reef environments and in indicator organisms.

FLOWER GARDEN BANKS	COASTAL USES
Management Objective	***Research Need***
Reduce the impacts from recreational use, industry, development, and maritime vessels on coral reef ecosystems. *See Jurisdiction-Wide Section for additional research needs.*	Determine the annual number of violations of Sanctuary "no-anchoring" regulations by both commercial and recreational vessels, and evaluate their impact on the resource.
	Compare current bathymetric data to historical seismic and multibeam data to assess possible changes in bank topography due to natural processes or industry impacts.
	Evaluate the location and placement of artificial reefs proposed by the Texas Parks and Wildlife Department's Artificial Reef Program.
Balance resource use to minimize user conflicts, provide equitable uses, and ensure optimal benefits to present and future generations.	Assess the level of demand for recreational diving from commercial diving operators and private recreational boats, and the impacts of recreational diving on coral reef resources.
	Determine the effectiveness of mooring buoys in reducing physical impacts to coral reef resources.
Restore injured and degraded coral reef habitats. *See Jurisdiction-Wide Section for additional research needs.*	Determine the feasibility of deep water coral restoration.
Evaluate and improve the effectiveness of MPAs as a management tool.	*See Jurisdiction-Wide Section for research needs.*

FLOWER GARDEN BANKS	COASTAL USES
Management Objective	***Research Need***
Manage coral reef ecosystems and their uses in a holistic manner. *See Jurisdiction-Wide Section for additional research needs.*	Determine the level of vulnerability and exploitation of coral reef resources that are currently unprotected using deepwater survey techniques.

FLOWER GARDEN BANKS	INVASIVE SPECIES
Management Objective	***Research Need***
Control or eradicate invasive species that have the potential to cause damage to coral reef ecosystems. *See Jurisdiction-Wide Section for additional research needs.*	Identify and remove introduced species from natural coral reef areas (e.g., *Tubastrea coccinea*).
	Investigate growth rates and reproductive potential of identified invasive species on artificial structures and nearby natural hard bottom features.
	Determine whether nearby oil and gas platforms serve as "stepping stones" for the introduction of invasive species.

FLOWER GARDEN BANKS	CLIMATE CHANGE
Management Objective	***Research Need***
Minimize the effects of climate change on coral reef ecosystems. *See Jurisdiction-Wide Section for additional research needs.*	Characterize bleaching events (including the extent, impact, and causes) on deeper reef communities in the northwestern Gulf of Mexico, and identify factors that affect recovery/mortality.

FLOWER GARDEN BANKS	EXTREME EVENTS
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 of diseases and other direct sources of coral mortality (e.g., damselfish and parrotfish predation) on deeper reef communities in the northwestern Gulf of Mexico, including their impacts and relationships with known stressors.

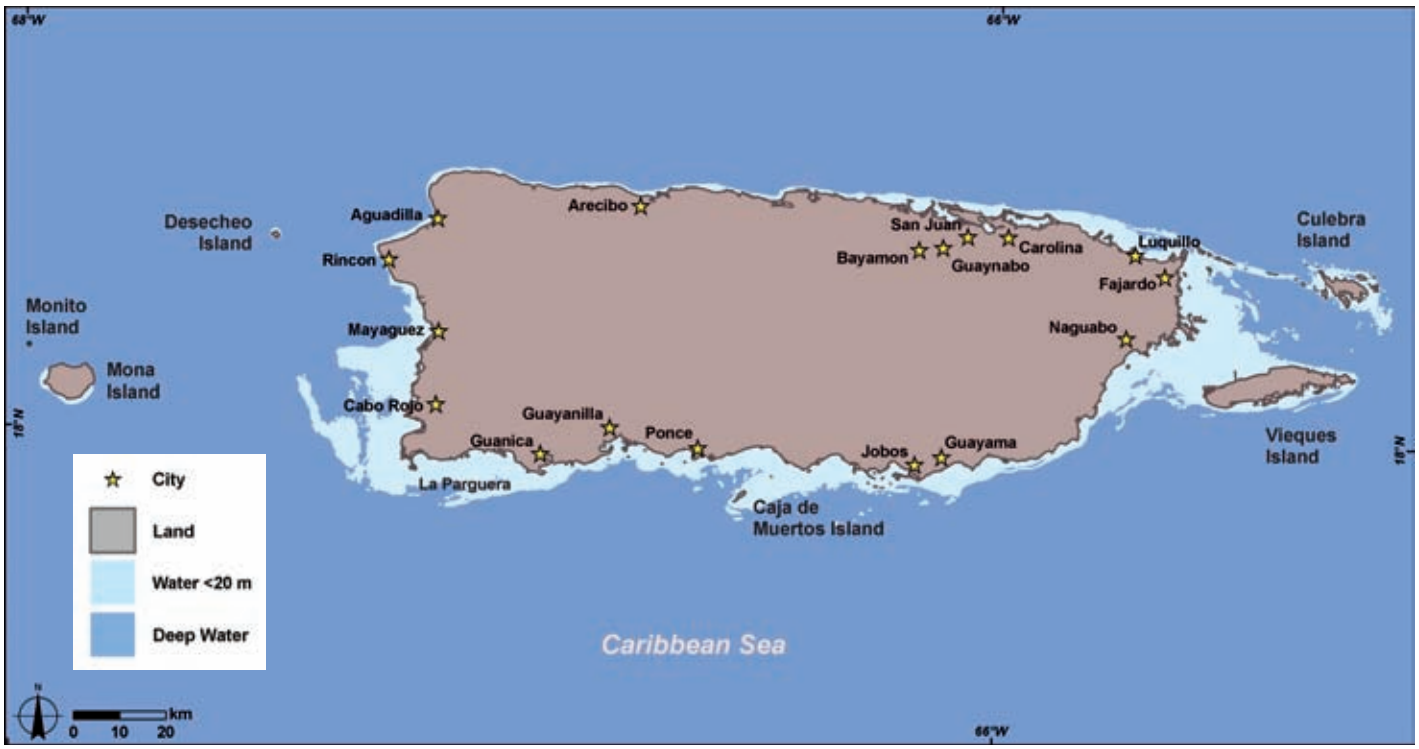


Figure PR-1. A map of Puerto Rico. (See Figure 4 for geographical context.) Map: A. Shapiro. Source: Garcia-Sais et al. (2005).

PUERTO RICO

The Commonwealth of Puerto Rico is a six island archipelago in the north-central Caribbean between the island of Hispaniola and the U.S. Virgin Islands. Puerto Rico has 3,370 km^2 of fringing coral reefs surrounding the island's east, south, and west coasts, as well as the two inhabited (Culebra and Vieques) and three uninhabited (Mona, Monito, Desecheo) small islands off Puerto Rico (Figure PR-1). Other parts of the shelf consist of hard ground areas, algal plains, and soft bottom communities with isolated coral colonies.

Reefs are characterized by a high diversity of corals (i.e., about 65 species of stony corals and 112 species of soft corals and gorgonians), although most nearshore locations have been badly degraded over the last 30 years. Most inshore reefs have a high cover of macroalgae with live coral cover ranging from 4 to 49% (mean 16%). While many offshore reefs are in better condition, these and other locations experienced massive losses of living coral cover during the 2005 bleaching event.

There are 242 reported reef fish species, many of which are targeted by commercial, recreational, and ornamental fisheries. Reef fish catches have plummeted during the last 20 years indicating classic signs of overfishing: reduced total landings, declining catch per unit effort, shifts to smaller fish, and recruitment failures (e.g., commercial fish landings fell by 69% between 1979 and 1990). In one study, reef fish density (individuals per 30 m^2) ranged from 93.2 near Desecheo Island to 12.6 near Caja de Muertos, with both reef fish density and species richness correlated with coral cover and rugosity. In 2003, 219,910 recreational anglers made over 1.1 million fishing trips in Puerto Rico. Most (56 to 64%) recreational fishing was from the shoreline, 35 to 40% was from private boats, and the rest (1 to 3%) were charter trips. In 2002, there were 1,163 active commercial fishers. Between 1995 and 2002, commercial fishers caught 1.6 million tons of fish per year, with 87% of the fishers targeting reef fish and invertebrates, including conch and lobster.

One of the major factors contributing to coral reef degradation is accelerated urban and industrial development on the coast combined with a lack of effective coastal zone management. Massive clearing of mangroves, dredging of rivers for sand and harbors, runoff from large-scale agricultural developments, deforestation in large watersheds, raw sewage disposal, and building of power plants have contributed to coral reef damage. Other major anthropogenic impacts include oil spills, anchoring of large cargo vessels, overfishing, uncontrolled recreational activities, eutrophication, and military bombing activities (at Vieques and Culebra Islands). Additionally,

anthropogenic factors are exacerbating the impacts from a number of natural stressors such as hurricanes, coral bleaching, and coral diseases.

The coastal zone is managed by the Puerto Rico Department of Natural and Environmental Resources, but the determination of consistency with the Coastal Zone Management Plan for Puerto Rico is the responsibility of the Puerto Rico Planning Board. The Environmental Quality Board monitors water quality, in part through its water quality certification program, and the Regulations and Permits Administration governs land use regulations. Development in the coastal zone that may result in impacts to water bodies, including wetlands, is also regulated by the U.S. Army Corps of Engineers. The Puerto Rico Department of Natural and Environmental Resources and the Caribbean Fishery Management Council share responsibility for managing 24 MPAs. In an effort to convert a collapsing fishery into a sustainable one, the Government of Puerto Rico has enacted new fishing regulations that require recreational fishing licenses, prohibit recreational spearfishing with scuba, eliminate beach seine nets, establish size limits and daily quotas on several species, require species-specific permits for high-value and sensitive species, and create MPAs around Mona, Monito, and Desecheo Islands, and the Condado Lagoon.[3]

3 Introductory material was taken, with slight modifications, from Kelty (2004).

Research Needs

PUERTO RICO	FISHING
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.*	Produce high resolution bathymetric and habitat maps to 200 m in depth.
	Evaluate the bioeconomic costs and benefits of current fishing regulations (i.e., size limits, closed areas, and closed seasons associated with spawning aggregations) and the effectiveness of these regulations.
	Assess the distribution, abundance, and ecological role of aquarium trade species and the impacts associated with their extraction.
	Identify areas that are essential as nursery grounds for exploited fisheries.
	Determine the economic value of commercial and recreational fisheries.
	Determine the level of engagement and dependence of communities on coral reef ecosystems and stakeholder attitudes, perceptions, and preferences regarding their utilization and identify methods to integrate fishery dependent information into the management process.
Protect, conserve, and enhance the recovery of protected, threatened, and other key species.	Queen Conch, Spiny Lobster, and Octopi
	Evaluate commercial, subsistence, and recreational fishing pressure on conch, lobster, and octopi and the adequacy of existing regulations.
	Characterize the population dynamics, habitat utilization, recruitment and ontogenetic movement patterns of conch, lobster, and octopi in key locations.

PUERTO RICO	FISHING
Management Objective	***Research Need***
Develop and support aquaculture projects that minimize impacts to coral reef ecosystems, fishery stocks, and existing fishing communities.	Evaluate the socioeconomic impacts of aquaculture projects on existing fishing communities.
	Determine the viability of restocking reef fish populations of commercial and recreational importance to aid in their recovery.
	Evaluate the impacts of new and existing aquaculture operations (especially offshore fish pens) with emphasis on the introduction of diseases, escapees, genetics, habitat impacts, and status as fish aggregating devices.

PUERTO RICO	POLLUTION
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.*	Develop internal circulation models for Puerto Rico to understand and predict the fate and effect of nutrients and other pollutants.
	Determine the impact of the Culebra municipal landfill to the eastern side of the Canal Luis Peña Natural Reserve.
	Determine the impacts of high-use marinas in areas with poor water circulation.
	Evaluate the effects of wastewater discharges from treatment plants and untreated sewage entering water bodies on adjacent coral reef ecosystems.
Improve water quality by reducing land-based pollutant inputs and impacts on coral reef ecosystems. *See Jurisdiction-Wide Section for additional research needs.*	Develop BMPs with relevance to tropical areas to reduce or eliminate the highest priority sources of pollution and evaluate the effectiveness of implemented measures (e.g., erosion and sediment control regulations).
	Evaluate the role of coastal wetlands in reducing contaminants before they are released into the marine environment.
	Evaluate water quality and its impacts on coral reef ecosystems in relation to changes in land and marine use in coastal areas.

PUERTO RICO	COASTAL USES
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.*	Design and conduct demonstration projects to evaluate science-based management options for improving shoreline stability while maintaining coral reef ecosystem functions.
	Determine the impact of onshore and offshore coastal development on coral reef ecosystems.

PUERTO RICO	COASTAL USES
Management Objective	***Research Need***
Balance resource use to minimize user conflicts, provide equitable uses, and ensure optimal benefits to present and future generations.	Conduct an economic valuation of coral reef ecosystems (including mangrove and seagrass habitats) in Puerto Rico.
Protect, conserve, and enhance the recovery of protected, threatened, and other key species. *See Jurisdiction-Wide Section for additional research needs.*	<u>Acroporids</u>
	Identify critical habitat for ***Acropora*** spp. in Puerto Rico, including the historical and current distribution of acroporid populations, and factors that affect their spatial extent.
	Identify the direct causes of mortality (e.g., disease, predation, and storms) to acroporids, the role of anthropogenic stressors in increasing their susceptibility or resistance to these factors, and benefits of existing and new management measures at mitigating threats and rebuilding acroporid populations.
	Evaluate the effectiveness of ***Acropora cervicornis*** nurseries as a restoration tool, including potential implications of translocation of these corals from the south coast to Culebra.
	<u>Sea Turtles</u>
	Determine the impact of continuing development around Culebra Island on green sea turtles and their habitat.
Reduce impacts from and restore habitat damaged by vessel anchoring and groundings.	Assess the extent and impact of damage caused by grounding, anchoring, or human trampling in coral reefs and associated habitats.
	Evaluate the effectiveness of restoration at the grounding sites of the ***Fortuna Reefer*** (Mona Island), ***Magara*** (Guayanilla), and other recent restoration efforts at promoting biological and ecological recovery.
Restore injured and degraded coral reef habitats. *See Jurisdiction-Wide Section for additional research needs.*	Develop recommendations for coral reef habitat restoration measures based on the quality of the habitat and the potential for success.
Evaluate and improve the effectiveness of MPAs as a management tool. *See Jurisdiction-Wide Section for additional research needs.*	Evaluate the effectiveness of existing management plans for natural reserves to determine whether strengthening of these plans is warranted.
	Determine if existing managed areas are facilitating the recovery of protected, threatened, and other key species, including conch, grouper, and lobster.

PUERTO RICO	INVASIVE SPECIES
Management Objective	***Research Need***
Minimize the introduction and spread of alien species.	*See Jurisdiction-Wide Section for research needs.*
Control or eradicate invasive species that have the potential to cause damage to coral reef ecosystems.	Determine the distribution and abundance of the paperbark tree and identify its impact on coastal wetlands.
	Determine the distribution and abundance of the green iguana and identify its impact on mangrove habitats and potential methods to control/eradicate it without introducing alien species.
	Determine the effect of Casarina Pine trees on nesting turtle populations around Mona Island, and the benefits of removal programs at improving the quality of coastal habitats.

PUERTO RICO	CLIMATE CHANGE
Management Objective	***Research Need***
Improve the capacity to forecast and respond to bleaching events. *See Jurisdiction-Wide Section for additional research needs.*	Develop and implement a rapid response protocol to characterize and manage future bleaching events.

PUERTO RICO	EXTREME EVENTS
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.*	Assess the differences in disease prevalence, incidence, and impacts between deeper and shallower reefs at nearshore and offshore locations, and their relationships with other environmental stressors.
Reduce impacts to and promote restoration of coral reef organisms affected by extreme events.	Develop a model to predict the potential impact of storms to coral reef habitats including factors such as spatial extent and degree of storm damage; storm strength, speed, and path; and benthic habitat characteristics.
	Identify the factors that need to be addressed to enhance the recovery of coral reefs following hurricane and storm damage.

U.S. VIRGIN ISLANDS

View of a bay from St. John, U.S. Virgin Islands.

The U.S. Virgin Islands (USVI) includes three main islands – St. Croix, St. Thomas, and St. John – and several smaller islands (Figure USVI-1). St. Thomas and St. John are geologically part of the Lesser Antilles and sit on the same shelf platform as Puerto Rico. The shelf platform ranges from 40 to 60 ft, with fringing, patch, and spur and groove reefs distributed patchily. Extensive coral reefs lie in water along the shelf edge in depths from 120 to 200 ft. These deeper reefs are dominated by plating forms of the *Agaricia* spp. and *Montastraea* spp. complexes, while corals in shallower water vary from columnar forms of *Montastraea* spp. to *Acropora* spp. to gorgonian dominated habitats. Maps of USVI benthic habitats (to 30 m) show that 61% of the 485 km^2 area is coral reefs and coral on hard bottom; 33% is predominantly seagrass beds, and 4% is sediment or rocky bottom.

St. Croix is part of the Greater Antilles and sits on a narrow, shallow shelf platform that drops off into the 4,000+ m deep Virgin Islands Trough. The shallow (46 to 60 ft) shelf edge is relatively close to shore in many places with classic back bay/lagoons to reef crest and fore reef habitats. The eastern and southern ends of the island are protected by a barrier reef system. Stocks and resources do not appear to move across the Puerto Rico Trench, whereas St. Thomas and St. John have fish populations more similar to Puerto Rico. Thus, St. Croix and St. Thomas/St. John are not considered a single management unit.

Many stresses affecting marine resources in the Caribbean may be causing degradation of USVI coral reef ecosystems. Over the past 40 years, living coral cover has decreased, while macroalgal cover has increased. Intensive fishing along with habitat degradation has been blamed for the loss of spawning aggregations and decreases in mean size and abundance of reef fish. Groupers and snappers are far less abundant now, while herbivorous fishes comprise a greater proportion of samples in traps and visual surveys than they did in the 1960s. Other damage to marine resources results from natural stresses such as hurricanes and coral diseases, as well as land-based pollution and other anthropogenic factors.

The jurisdiction over these coral resources is shared by several U.S. agencies and the Virgin Islands Government. In 2001, the Virgin Islands Coral Reef National Monument off St. John was established, and the Buck Island Reef National Monument off St. Croix was expanded. Both areas are managed by the National Park Service. In 2002, the St. Croix East End Marine Park, which is managed by the USVI Department of Planning and Natural Resources, was established as the first in a series of marine parks for the territory. These areas are designed to provide protection for important marine resources, including coral reef areas, thus allowing depleted populations of certain marine organisms (groupers, snappers, corals) to recover. Other managed areas in St. Thomas and St. John include: the Hind Bank Marine Conservation District (established in 1999) and Lang Bank designated by the Caribbean Fishery Management Council to protect spawning aggregations and coral habitats; the Grammanik Bank, established as a temporary seasonal closure area for 2005 (permanent regulations are pending); and the Cas Cay/Mangrove Lagoon and St. James Marine Reserves, established in 1994 to protect juvenile reef fish and associated habitat. In St. Croix, MPAs include the seasonal Mutton Snapper Spawning Area Closure, the seasonal Lang Bank Red Hind closure, and the Salt River Bay National Historical Park and Ecological Preserve. The latter was designated in 1995, but the regulations have yet to be signed.[4]

4 The sources for the introduction are Vasques (2005), Kelty (2004), and Jeffrey et al. (2005).

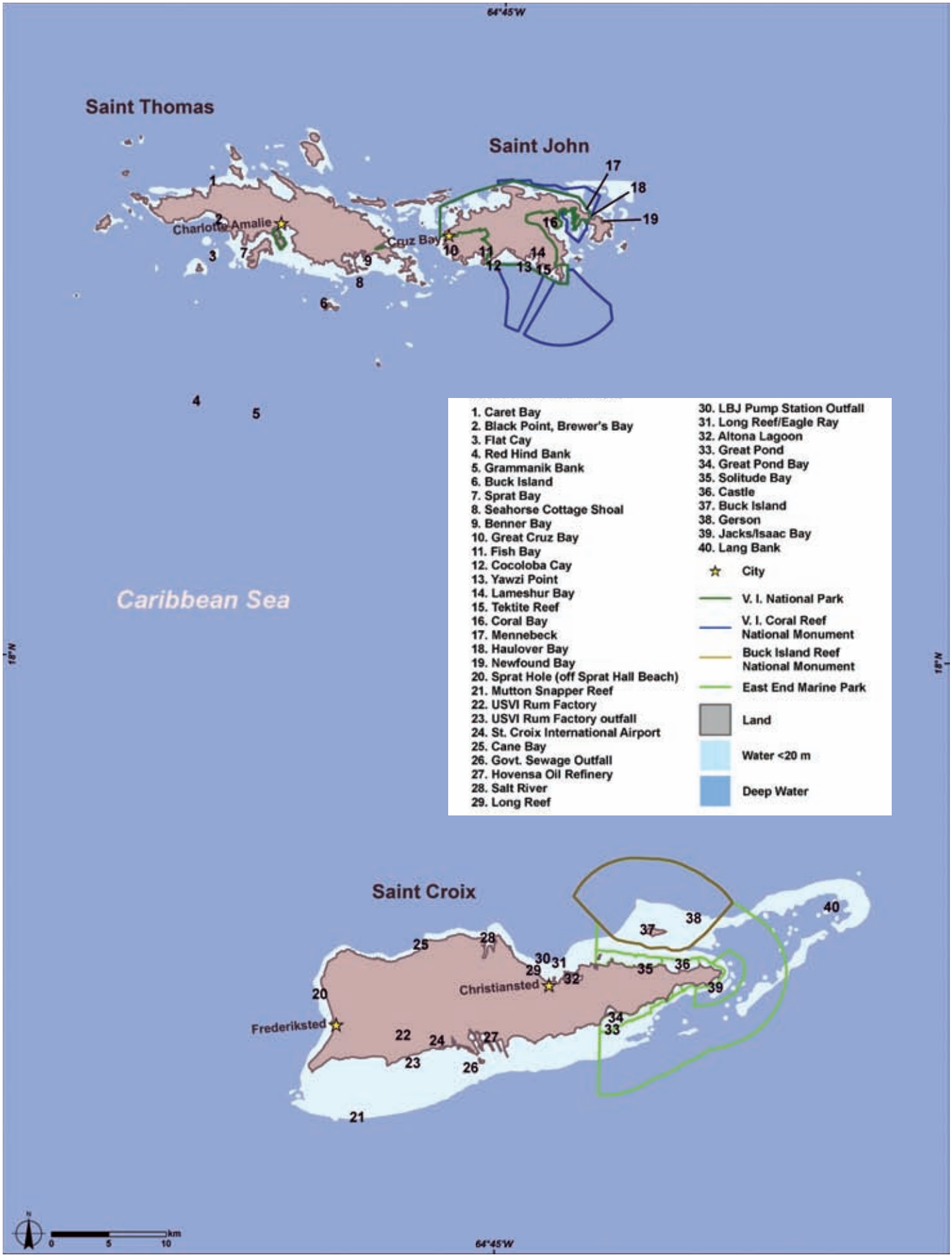


Figure USVI-1. A map of USVI showing managed areas, municipalities, and other locations of interest. (See Figure 4 for geographical context.) Map: A. Shapiro. Source: Jeffrey et al. (2005).

Research Needs

U.S. Virgin Islands	FISHING
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 impacts of fishing on spawning aggregations and monitor their recovery after regulations are enacted, especially at Grammanik Bank off St. Thomas.
	Assess the total catch and the value of local fisheries and the number of fishermen employed.
	Investigate the viability and effectiveness of enhancement programs (e.g., use of fishery aggregating devices to remove fishing pressure away from reefs) to mitigate fishing pressure on target organisms of commercial and recreational importance.
	Investigate expansion of pelagic fisheries within user groups affected by the establishment of MPAs, including benefits to coral reef ecosystems, socioeconomic implications, and other factors.
	Compare the population status of managed reef species in representative coral reef areas in St. Croix and St. Thomas, and identify environmental and anthropogenic factors that may explain differences in population dynamics of these species.
	Characterize fish assemblages on gorgonian dominated habitats and determine their importance as essential fish habitat.
Protect, conserve, and enhance the recovery of protected, threatened, and other key species.	Identify factors that promote or inhibit the recovery of key species and identify those factors which can be managed.
	Queen Conch, Spiny Lobster, Octopi
	Evaluate commercial, subsistence and recreational fishing pressure on conch, lobster, and octopi and the adequacy of existing regulations.
	Characterize the population dynamics, habitat utilization, recruitment patterns, and ontogenetic movement patterns of conch, lobster, and octopi in specific locations.
Evaluate and improve the effectiveness of MPAs as a fisheries management tool. *See Jurisdiction-Wide Section for additional research needs.*	Evaluate the level of enforcement and assess what effect increased enforcement would have on juvenile reef fish stocks and reef habitat.
	Quantify abundance and size structure of different life stages of commercially and ecologically important fish and invertebrate species, coral condition, and major reef processes (e.g., herbivory and recruitment) within and outside protected areas in Buck Island Reef National Monument, Virgin Islands Coral Reef National Monument, the St. Croix East End Marine Park, St. Thomas Marine Conservation District, Cas Cay/Mangrove Lagoon Marine Reserve, St. James Marine Reserve, and the Salt River Bay National Historical Park and Ecological Preserve.
	Determine whether user groups displaced by the establishment of MPAs have shifted to pelagic fish species.
	Evaluate the efficacy of the marine reserves in St. Thomas and determine if additional management measures are necessary.
	Determine if existing managed areas are facilitating the recovery of protected, threatened, and other key species including, conch, grouper, and lobster.
	Assess the costs and benefits of the Marine Conservation District on the commercial fishing community of St. Thomas.

U.S. Virgin Islands	FISHING
Management Objective	***Research Need***
Develop and support aquaculture projects that minimize impacts to coral reef ecosystems, fishery stocks, and existing fishing communities.	Determine the viability of restocking populations of commercially and recreationally important reef species to aid in their recovery.

U.S. Virgin Islands	POLLUTION
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 impacts of sewage and sedimentation associated with accelerated coastal development and assess temporal changes in the abundance of key organisms, such as macroalgae and corals.
	Quantify the impacts on coral reef ecosystems of effluents from Cruzan Rum Distillery and Hovensa Oil Refinery in St. Croix.
	Quantify the impacts of run-off or effluents from land fills, rum distilleries, and other industrial effluents on sensitive habitats (e.g., Mangrove Lagoon).
	Develop internal circulation models for USVI to understand and predict the fate and effect of nutrients and other pollutants.
	Investigate the effects of sewage and sedimentation on USVI coral reefs. Adapt the GIS-based sediment delivery model developed for St. John for application to St. Croix and St. Thomas and implement the model to predict effects of future coastal development.
Improve water quality by reducing land-based pollutant inputs and impacts on coral reef ecosystems. *See Jurisdiction-Wide Section for additional research needs.*	Develop BMPs to reduce or eliminate the highest priority sources of pollution and evaluate the effectiveness of implemented measures (e.g., erosion and sediment control regulations).
	Determine the effectiveness of upgrading regional primary sewage treatment facilities and monitor the long-term effects of upgrading on water quality and coral reef ecosystems.
	Evaluate the role of coastal wetlands in reducing contaminants before they are released into the marine environment.

U.S. Virgin Islands	COASTAL USES
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.*	Investigate the effects of oil pollution, cruise ship discharge, sedimentation (and resuspension), and other factors and assess whether they offset the benefits associated with designation of MPAs.
	Investigate the impacts of vessel traffic, including cruise ships, and the lack of designated anchorages on coral reef ecosystems in St. Thomas and St. Croix.
	Investigate changes in coastal land use and benthic habitat over time to determine whether and how increased development in certain areas has impacted coral reef ecosystems.
Balance resource use to minimize user conflicts, provide equitable uses, and ensure optimal benefits to present and future generations.	Examine coral reef-related recreation and tourism links to the economy and the environment.
	Determine the effectiveness of management efforts, such as the installation of mooring buoys in seagrass and reef areas and the elimination of fishing by assessing changes in seagrasses, macro and turf algae, and coral cover.
	Assess the costs and benefits of protective management tools (e.g., the installation of mooring buoys in seagrass and reef areas and the elimination of fishing) on the community.
Protect, conserve, and enhance the recovery of protected, threatened, and other key species. *See Jurisdiction-Wide Section for additional research needs.*	Acroporids
	Identify critical habitat for ***Acropora*** spp. in USVI, including the historical and current distribution of acroporid populations, and identify factors that contributed to the expansion/reduction in the spatial extent of these corals.
	Sea Turtles
	Determine the impact of rum distilleries and other anthropogenic impacts on sea turtles, their food sources (e.g., sponges and grasses), and their habitat.
Reduce the impacts from and restore habitat damaged by vessel anchoring and groundings.	Investigate the impacts of recreational vessel anchoring to benthic habitats to determine whether management measures, such as the installation of mooring buoys, are necessary.
	Assess the damage of large vessels (e.g., propeller damage) on the shallow water habitats of St. Thomas.
	Quantify the impacts of ferry and recreational vessel groundings.

U.S. Virgin Islands	COASTAL USES
Management Objective	***Research Need***
Restore injured and degraded coral reef habitat.	*See Jurisdiction-Wide Section for research needs.*
Manage coral reef ecosystems and their uses in a holistic manner. *See Jurisdiction-Wide Section for Additional Research Needs.*	Develop and evaluate ecosystem or trophic models for use in ecosystem management. Identify the connectivity of resources between eastern Puerto Rico and northern USVI, focusing on larval dispersal and movement of reef fish species that travel long distances to spawning aggregations (i.e., grouper and snapper).
	Identify the connectivity of resources between the British Virgin Islands and USVI to inform management practices that address the sharing of resources.
	Characterize interactions among reefs, mangroves, and seagrass beds and how deterioration of these contributes to changes in reef communities.
Evaluate and improve the effectiveness of MPAs as a management tool. *See Jurisdiction-Wide Section for additional research needs.*	Evaluate the ecological impacts of the de facto marine reserve (no transit zone) off the oil refinery in St. Croix.
	Conduct socioeconomic studies of recreational and commercial user groups affected by closures and restrictions in East End Marine Park.

U.S. Virgin Islands	INVASIVE SPECIES
Management Objective	***Research Need***
Minimize the introduction and spread of alien species.	*See Jurisdiction-Wide Section for research needs.*
Control or eradicate invasive species that have the potential to cause damage to coral reef ecosystems. *See Jurisdiction-Wide Section for additional research needs.*	Investigate the status of known invasive species within coastal waters of USVI, and establish a response network and protocol in the event of new invasive species introductions.

U.S. Virgin Islands	CLIMATE CHANGE
Management Objective	***Research Need***
Minimize the effects of climate change on coral reef ecosystems. *See Jurisdiction-Wide Section for additional research needs.*	Develop and implement a response plan to address bleaching events in the USVI.

U.S. Virgin Islands	EXTREME EVENTS
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.*	Determine the spatial and temporal distribution and abundance of the different coral diseases present in the USVI and their effects on affected corals and overall reef condition (e.g., species diversity and community composition).
	Examine coral community structure and impacts of disease and predation on coral reefs found in deeper areas such as Red Hind Bank Marine Conservation District.
	Inventory which diseases are present, their associated pathogens, and possible correlations with environmental factors such as temperature and nutrients.
	Assess the recovery of coral species impacted by disease (particularly acroporids).
Reduce impacts to and promote restoration of coral reef organisms affected by extreme events.	Examine the role of hurricanes in the decline of *Acropora* and how hurricanes influence patterns of recovery, including synergies with other stressors.
	Develop a model to predict the potential impact of storms to coral habitats including, factors such as spatial extent and degree of storm damage; storm strength, speed, and path; and benthic habitat characteristics.
	Identify anthropogenic factors that need to be addressed to enhance the recovery of reefs following hurricane and storm damage.
	Develop a system of coral mariculture farms as a strategy to maintain propagule sources through a wide geographic range and evaluate the value of these sources of corals for use in coral reef restoration projects in response to storms and ship groundings.

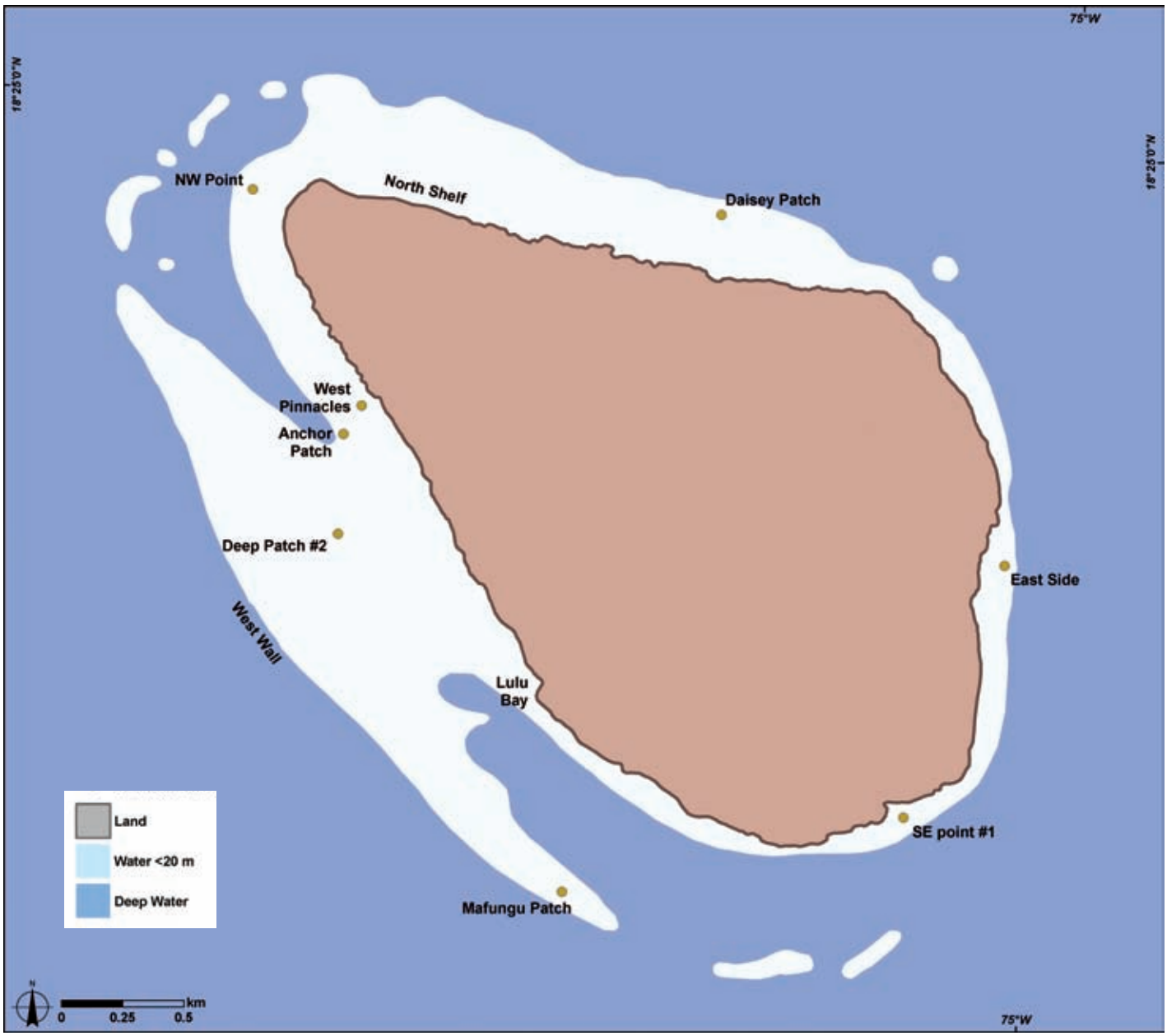


Figure NI-1. A map of Navassa Island. (See Figure 4 for geographical context.) Map: A. Shapiro. Source: Miller et al. (2005).

NAVASSA

Navassa Island is a small (5 km^2), uninhabited, oceanic island between Jamaica and Haiti (Figure NI-1). Navassa Island is under the jurisdiction of the FWS and has been managed as a component of the Caribbean Islands NWR since 1999. The dolomite island's cliffs plummet to about 25 m deep before a submarine terrace slopes out gradually. Thus, Navassa lacks typical Caribbean patterns of reef zonation and inshore and backreef habitats including mangroves, sandy beaches, and seagrass which are important in the life history of several reef fish groups. Small shoulders of shallow reef habitat (10 to 15 m) are found at the northwest point and Lulu Bay, but the primary reef habitats are reef walls formed by the cliffs and large boulders that have been dislodged from the cliffs. A 2002 survey documented 10 to 20% live coral cover in shallow habitats (10 to 20 m) and 46% live coral cover at the 25 to 30 m terrace; deeper reef slopes at shelves greater than 30 m farther offshore have not been well described. Dominant corals are *Montastrea* spp., *Agaricia* spp., *Porites porites*, and, at shallow sites, the elkhorn coral, *Acropora palmata.*

Because of its isolated and uninhabited status, Navassa has been presumed to provide a relatively pristine

example of an unimpacted reef that may serve as a valuable reference site for determining Caribbean coral reef structure and function. Land-based pollution and recreational uses are essentially absent. However, reefs on the east coast (and to a lesser extent, the southwest and west coasts) are exposed to persistent swells and seemingly regular storms and hurricanes. A fall 2004 NOAA/FWS research cruise documented storm damage to *A. palmata* colonies in the shallow shoulder of Lulu Bay. The same cruise documented relatively high prevalence of coral disease, despite the lack of land-based pollution and other anthropogenic stressors.

Fishing is the primary threat to Navassa's reefs. Subsistence fishing appears to have been ongoing since at least the 1970s and current activity by migrant Haitian fishers is substantial (but unquantified). A 2002 survey noted the virtual absence of large fish – the average total length was 4.6 cm and only 11 of 1,227 fish were longer than 24 cm. A less extensive survey in 2000 found that 92% of snapper and 23% of parrotfishes were longer than 40 cm. These results suggest that fishing impacts are substantial and rapidly increasing. Interviews with Haitian fishers in 2004 provided preliminary data on catch, frequency of fishing, and gear types. Large commercial foreign flagged fishing trawlers have been observed within NWR waters, which include a 12 mile area of open ocean around the island. The primary research priority in Navassa is the assessment of reef status and fishing activity and impact over time.[5]

5 Introductory material was taken, with slight modifications, from Miller et al. (2005).

Research Needs

NAVASSA	FISHING
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.*	Conduct capture-recapture studies to provide estimates of total population numbers of large resident species.
	Interview local fishers to provide anecdotal information in order to discern trends in catch effort and perhaps size shifts in target species.
	Collect size data for the most commonly taken species as they are landed in the nearest fishing villages in Haiti.
	Determine usage patterns of Navassa marine resources (i.e., catch and effort data for fishing activities).
	Determine what other fishery sectors (besides the Haitian subsistence sector) are active in Navassa and the impact they are having on the resource.
	Conduct a sociocultural assessment of Haitian communities from which primary fishing activity originates.
	Understand the relationship of declining fish assemblage and reef benthic community structure and condition.
	Develop a habitat map for the 12-mile radius around the island that is under Federal jurisdiction to identify essential fish habitat.

NAVASSA	POLLUTION
Management Objective	***Research Need***
Reduce the impacts of pollutants on coral reef ecosystems by improving the understanding of their effects.	Understand physical oceanic processes affecting Navassa water quality.

NAVASSA	COASTAL USES
Management Objective	***Research Need***
Not Applicable to Navassa. Aside from subsistence fishing, there are no coastal uses.	

NAVASSA	INVASIVE SPECIES
Management Objective	***Research Need***
Minimize the introduction and spread of alien species.	*See Jurisdiction-Wide Section for research needs.*

NAVASSA	CLIMATE CHANGE
Management Objective	***Research Need***
Minimize the effects of climate change on coral reef ecosystems.	Compare and contrast the prevalence of and impacts from bleaching events in Navassa with other U.S. jurisdictions, using Navassa as a reference site due to its low level anthropogenic impacts, other than fishing.

NAVASSA	EXTREME EVENTS
Management Objective	***Research Need***
Identify causes and consequences of diseases in coral reef ecosystems and mitigate their impacts.	*See Jurisdiction-Wide Section for research needs.*