# 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).

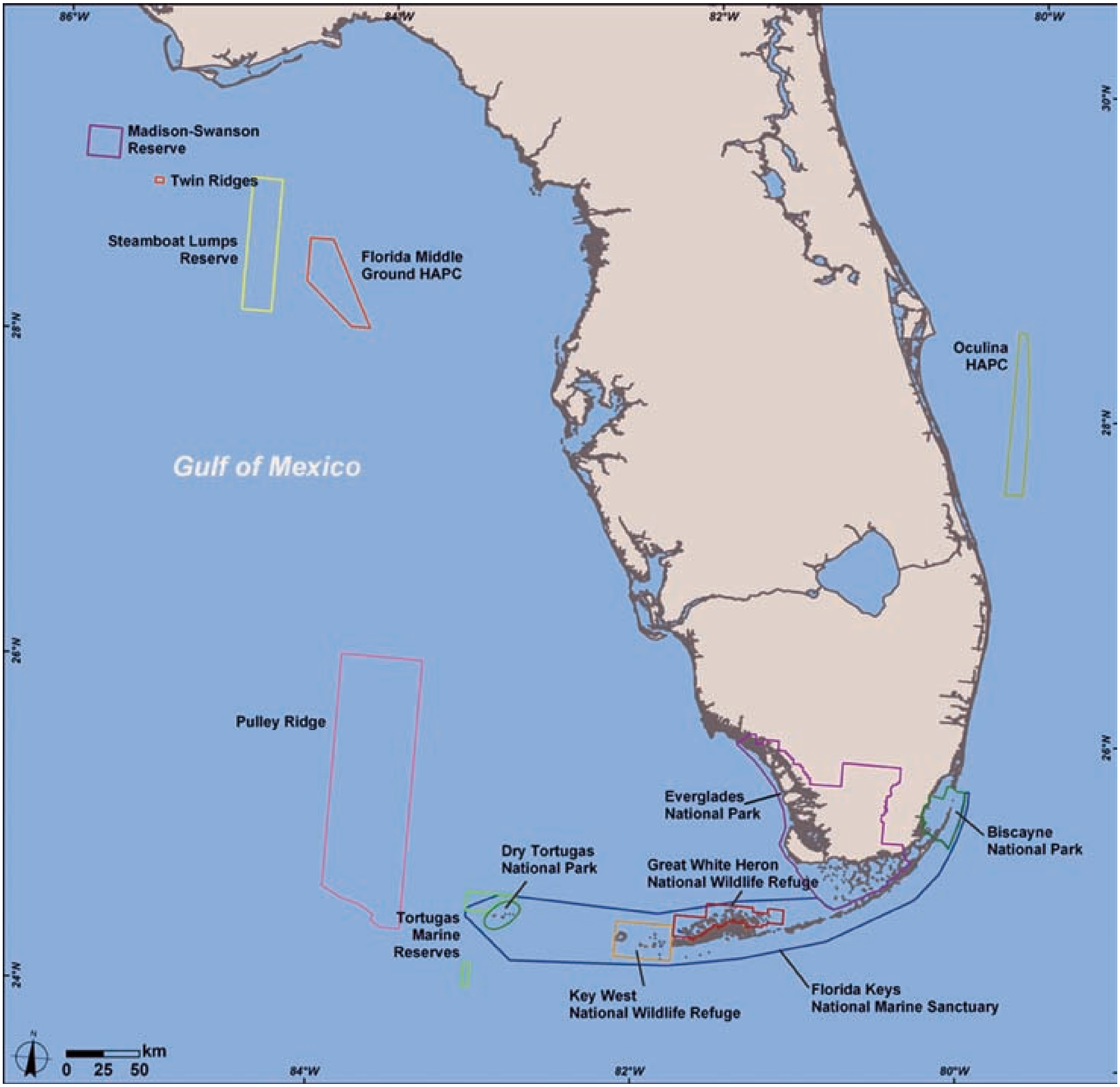


*Figure FL-1. Locator map for Florida. Map: A. Shapiro.*

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.<br><br>*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.<br><br>*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. | √ | | | |

# Jurisdiction-Wide Research Needs

Broad overarching research needs that apply to all jurisdictions (except where noted) are based on the discussion in Part I of this Plan and are presented below. Research needs that are specific to a jurisdiction are detailed under the sections entitled *Jurisdiction-Specific Research Needs*.

## *RESEARCH SUPPORTING MANAGEMENT*

### Fishing

| ALL JURISDICTIONS | FISHING |
|---|---|
| ***Management Objective*** | ***Research Need*** |
| Conserve and manage fisheries to prevent overfishing, rebuild stocks, and minimize destructive fishing. | Determine the population status of managed reef species using fishery dependent and independent programs. |
| | Determine the level of fishing pressure and the distribution of effort for subsistence, recreational, and commercial fisheries, and the impact of these activities on fisheries resources and coral reef habitats. |
| | Determine the effects of habitat degradation and loss of coral on fish community structure and stability. |
| | Determine the effects of various fisheries (gear and techniques) on coral reef ecosystems, including physical impacts on habitat, trophic effects, and incidental catch; and identify alternatives to minimize impacts. |
| | Determine the effectiveness of fishery management actions, including size limits and seasonal closures. |
| | Determine the current status and locations of reef fish spawning aggregations. |
| | Characterize fish movements and habitat utilization patterns of different life stages to assist in the identification of essential fish habitat. |
| | Characterize the life histories of important fish species and their movement patterns within and among different habitats. |
| | Characterize recruitment patterns for commercially and ecologically important species. |
| | Quantify fish community structure including size, diversity, and abundance among reefs and across multiple habitat types. |

## Pollution

| ALL JURISDICTIONS | POLLUTION |
|---|---|
| ***Management Objective*** | ***Research Need*** |
| Reduce the impacts of pollutants on coral reef ecosystems by improving the understanding of their effects. | Ascertain pollutant loads, their primary sources, flow rates, and transport pathways, and net flow rate (flux) to coral reef communities. |
| | Determine atmospheric deposition rates and concentrations of pollutants on coral reefs. |
| | Identify the component(s) in air samples from dust sources (e.g., Africa and Gobi Desert) and downwind sites that are toxic to coral reef organisms. |
| | Identify target concentration loading rates and develop bioindicators for pollutants to detect organismal and ecosystem stress at sublethal levels. |
| | Develop and test indicators for land-based pollutants and prioritize their use in environmental and injury assessments. |
| | Identify, evaluate, and track anthropogenic activity through the use of biogeochemical and biological tracers, and indicator organisms. |
| | Investigate algal community dynamics in response to pollutant level changes to determine their utility as an indicator of future changes in coral reefs. |
| | Investigate microbial organisms as indicators of nutrient, sediment, and chemical pollutants in coral reef ecosystems. |
| | Integrate current biological monitoring techniques with water quality monitoring data to assess potential affects of water quality on various habitat types and associated organisms. |
| Improve water quality by reducing land-based pollutant inputs and impacts on coral reef ecosystems. | Quantify, characterize, and prioritize the land-based sources of pollution that need to be addressed based on identified impacts to coral reefs and develop strategies to eliminate, reduce, and mitigate these impacts. |
| | Evaluate changes in water quality to determine the success of management actions to reduce sediment, nutrient, and chemical pollutants and other factors that degrade water quality. |

## Coastal Uses

| ALL JURISDICTIONS | COASTAL USES |
|---|---|
| ***Management Objective*** | ***Research Need*** |
| Reduce the impacts from recreational use, industry, coastal development, and maritime vessels on coral reef ecosystems. | Quantify and characterize, both spatially and temporally, threats from commercial and recreational non-extractive activities and the impact of these activities on coral reef ecosystems, and develop strategies to eliminate, reduce, and/or mitigate these impacts. |
| | Develop scientific criteria to determine the carrying capacity of the reef ecosystem, and determine the level of recreational use (e.g., diving, snorkeling, and boating) that specific areas can support. |
| | Design and conduct demonstration projects to evaluate science-based management options for improving shoreline stability, while maintaining coral reef ecosystem functions. |
| | Identify and apply biological indicators toward quantification and characterization of impacts associated with coastal uses. |
| | Develop new technologies, construction practices, and management measures to eliminate, reduce, and/or mitigate impacts from coastal uses. |
| | Conduct research to better understand the economic and social factors of the human dimension and their impact on coral reef ecosystems. |
| | Quantify and track vessel discharges, spills, and anchor damage, and their impacts on coral reef ecosystems; and recommend mitigation measures. |
| Protect, conserve, and enhance the recovery of protected, threatened, and other key species.<br><br>*Research needs related to acroporids are for the Atlantic Ocean only.* | Acroporids |
| | Identify the historical and current distribution of acroporids, compile this into a GIS database, and analyze spatial changes and relationships with physical, environmental, and anthropogenic factors. |
| | Assess (region-wide) the abundance and condition of acroporids incorporating colony size and counts per unit area of the different life stages (i.e., colonies, fragments, and new recruits). |
| | Evaluate the efficacy of measures to reduce anthropogenic stressors (including sedimentation, pollution, eutrophication, climate change, overfishing, and ship groundings) in enhancing recovery of existing populations of acroporids and promoting sexual recruitment. |
| | Evaluate the effects of storms and other natural stressors (e.g., coral predators) on the destruction and recovery of coral populations, and determine how anthropogenic disturbances may affect these natural processes. |
| | Evaluate the costs and benefits of various acroporid restoration strategies at promoting recovery of degraded populations, including efforts to reseed areas with larvae, optimal reattachment methods for fragments, and strategies to treat colonies affected by disease, predators, and other natural stressors. |
| | Identify microbial communities associated with diseased and healthy acroporid colonies; identify how these microbial communities change spatially, temporally, and under varying environmental conditions; and determine relationships between these communities and the health and mortality of colonies. |
| | Characterize the genetic structure and conduct demographic modeling of acroporid populations to predict population response to future disturbances and stresses encompassing a range of spatial and temporal scales. |

| ALL JURISDICTIONS | COASTAL USES |
|---|---|
| ***Management Objective*** | ***Research Need*** |
| Manage coral reef ecosystems and their uses in a holistic manner. | Assess the extent and condition of deep-water hermatypic coral reef ecosystems and their importance as essential fish habitat. |
| | Expand ecological and taxonomic understanding of functionally important, but understudied, coral reef ecosystem groups, such as sponges, octocorals, mollusks, polychaetes, crustaceans, echinoderms, tunicates, seagrasses, algae, and microbial diversity. |

## Invasive Species

| ALL JURISDICTIONS | INVASIVE SPECIES |
|---|---|
| ***Management Objective*** | ***Research Need*** |
| Minimize the introduction and spread of alien species. | Identify possible vectors and pathways of alien introductions and develop prevention measures, where applicable. |
| | Determine the threat and impact of hull fouling and ballast water as mechanisms for introducing and dispersing invasive species. |
| Control or eradicate invasive species that have the potential to cause damage to coral reef ecosystems. | Quantify the presence and evaluate the impact of invasive species on coral reef ecosystems. |
| | Establish protocols for early detection and eradication of invasive species. |
| | Develop methods to mitigate impacts of invasive species on coral reef ecosystems and evaluate the efficacy of these methods. |
| | Develop and evaluate methods to monitor, contain, and sterilize ballast water to prevent introduction of invasive species to coral reef ecosystems. |

## Climate Change

| ALL JURISDICTIONS | CLIMATE CHANGE |
|---|---|
| ***Management Objective*** | ***Research Need*** |
| Minimize the effects of climate change on coral reef ecosystems. | Bleaching of Coral Reef Organisms |
| | Assess the spatial and temporal scales of bleaching of coral reef organisms during identified bleaching events. |
| | Quantify the relationships between severity of bleaching events and mortality including factors that exacerbate bleaching impacts or confer resistance and resilience. |
| | Quantify the socioeconomic impacts of coral bleaching events on user groups and the economy and investigate user group perceptions of coral bleaching events. |
| | Identify factors and their thresholds that cause coral bleaching (including physical parameters, environmental factors, and anthropogenic stressors) and investigate interactions between factors and the severity of bleaching events and the ability of corals to recover from bleaching. |
| | Identify the potential for coral reefs to adapt to future bleaching events through changes in clades of zooxanthellae in individual species and shifts in taxonomic composition of symbiotic organisms. |
| | Develop early warning systems for coral reef bleaching based on known or predicted relationships with environmental factors (e.g., temperature and light) and catastrophic pollution events (e.g., oil spills and toxic discharges). |
| | Develop models to predict long-term impacts to coral reef ecosystems from coral bleaching events and climate change incorporating relationships with environmental and anthropogenic stressors. |
| | Calcification |
| | Investigate variations in rates of coral calcification among species, temporally and spatially, and within different life stages, and how those variations may affect survivorship. |
| | Investigate how differing levels of atmospheric $CO_2$ will affect ocean pH, carbonate saturation state, and coral calcification and growth rates. |
| | Quantify the effects of temperature, pH, and aragonite saturation state on calcification, reproduction, and recruitment. |
| | Measure biogenic $CaCO_3$ production, seawater chemistry, $CaCO_3$ dissolution and accumulation, bioerosion, and off-shelf export of $CaCO_3$ to improve the accounting of coral reef carbonate budgets and predict how reef accretion may change in the future. |
| | Determine how variations in calcification rates affect associated organisms, food web dynamics, carbon and nutrient cycling, and ecosystem services. |
| | Examine how reduced saturation states of $CaCO_3$ affect rates of bioerosion. |
| | Waves |
| | Determine the relationships among wave energy, coral reef damage, and factors that increase or minimize damage to reefs and coastal communities. |
| Mitigate the impacts from climate change on coral reef ecosystems. | Determine the effectiveness of management strategies to reduce anthropogenic stressors in mitigating the severity of bleaching. |
| | Evaluate available tools and develop new tools to quantify and mitigate the impacts of climate change on coral reef ecosystems. |
| Predict the future composition and condition of coral reefs under various climate change scenarios | Quantify organism and ecosystem responses to climate change and determine their relationships with stressors and pertinent physical, biological, and chemical parameters. |
| | Examine the impacts of past climate fluctuations on coral community structure. |
| | Develop tools to detect and describe decadal changes in relation to natural and anthropogenic disturbances. |

## Extreme Events

| ALL JURISDICTIONS | EXTREME EVENTS |
|---|---|
| ***Management Objective*** | ***Research Need*** |
| Identify and reduce the incidence of disease in coral reef ecosystems. | Determine temporal and spatial variations in disease prevalence among reef-building coral species across habitats, depths, and varying distances from land and their relationships with environmental factors and anthropogenic stressors. |
| | Quantify the rates and extent of partial and whole colony mortality from diseases, the effect of partial mortality on individual colonies (e.g., effect on reproduction and growth), and long-term impacts on affected coral reef ecosystems. |
| | In the event of a major die-off of corals resulting from disease, quantify the ecological and socioeconomic impacts. |
| | Identify external sources of pathogens (e.g., human sewage and dust) and disease vectors and quantify their distribution and abundance. |
| | Determine the distribution, abundance, and impact of diseases affecting other ecologically important benthic coral reef invertebrates (e.g., sponges and urchins) and fishes. |
| | Identify factors that increase the prevalence and impact of diseases (e.g., toxins, pollutants, sedimentation, temperature, and biotic agents), including factors and processes that increase the virulence of pathogens, increase host susceptibility and/or reduce resistance, and contribute to the transmission and spread of diseases. |
| | Identify and characterize the etiology of key coral diseases, including identification of biotic and abiotic causes. |
| | Characterize microbial communities associated with corals and coral mucus; the variations among species, seasons, and locations; identify factors that cause variations in microflora; and characterize the consequences of these changes to the host (e.g., shift from a symbiotic association to a disease-causing state). |
| | Develop standardized nomenclature, diagnostic characteristics, standardized field and laboratory methodologies, and rapid response protocols to enhance the comparability of data, improve capacity to respond to disease outbreaks and report on findings, and to identify viable management responses. |
| | Develop early warning systems for disease outbreaks based on known or predicted relationships of coral reefs with environmental factors (e.g., temperature and hurricanes) and catastrophic pollution events (e.g., oil spill and toxic discharge). |
| | Develop models to forecast long-term effects of disease on population dynamics, community structure, and ecosystem function incorporating information on biotic agents, environmental factors, and anthropogenic stressors known or predicted to affect disease prevalence and incidence. |
| | Characterize healthy and diseased corals on a cellular and physiological level (e.g., histological changes, immunological responses, and production of stress proteins). |
| | Develop tools to reduce the prevalence of diseases, mitigate their impacts, and treat affected corals. |

### TECHNOLOGY SUPPORTING RESEARCH & MANAGEMENT

## Marine Protected Areas

| ALL JURISDICTIONS | MARINE PROTECTED AREAS |
|---|---|
| ***Management Objective*** | ***Research Need*** |
| Evaluate and improve the effectiveness of MPAs as a management tool. | Develop site-selection criteria for MPAs to assist in the conservation of coral reef ecosystems and management of commercially important fishery species, taking into account:<br>o Species diversity, trophic structure, and abundance of economically or ecologically important species.<br>o Habitat utilization patterns of different life stages.<br>o Larval recruitment, dispersal, and connectivity (including sources and sinks).<br>o Connectivity between habitat types (including seagrass beds, mangroves, and other associated communities), spawning aggregations, and nursery areas.<br>o Environmental factors and anthropogenic stressors. |
| | Develop models to predict changes to coral reef resources that may occur under different zoning schemes, taking into account ways to conserve and possibly enhance marine resources. |
| | Evaluate the effectiveness of MPAs, including no-take reserves and other marine zoning schemes, taking into account:<br>o Abundance of ecologically and economically important species.<br>o Spillover of fishery species into adjacent habitats.<br>o Improvements in the condition of the sessile benthic community and abundance of mobile invertebrates.<br>o Cascading effects on non-target species. |
| | Develop useful indicators (biophysical and socioeconomic) of management effectiveness. |
| | Determine the socioeconomic and ecological costs and benefits of MPAs as a management tool, including relationships between levels of compliance and achieved benefits. |

## Habitat Restoration

| ALL JURISDICTIONS | HABITAT RESTORATION |
|---|---|
| ***Management Objective*** | ***Research Need*** |
| Restore injured and degraded coral reef habitat. | Identify and test new coral reef restoration strategies, including transplantation and attachment techniques; optimal fragment size, shape, and orientation; ability to withstand high-energy events; and use of environmentally-friendly exotic materials. |
| | Determine the effectiveness of efforts to collect and settle coral larvae as a restoration tool. |
| | Design and evaluate techniques to control or eradicate organisms that may inhibit recovery of damaged or degraded habitats. |
| | Evaluate the effectiveness of current strategies to restore degraded reefs (e.g., culturing corals in a laboratory, transplanting fragments, and creating coral nurseries), taking into account the ability to maintain genetic variability, mitigate source(s) of the damage, maintain the historical distribution of the species within that habitat, and restore habitat function. |
| | Evaluate effectiveness of restoration techniques for associated habitats, including mangroves, seagrass beds, sandy beaches, and riparian habitats. |
| | Determine the impacts of exotic materials (e.g., iron, cement, rubber, and fiberglass) on recruitment efficiency, biodiversity, and community structure. |
| | Evaluate the ecological recovery of restored areas. |
| | Evaluate the effectiveness of restocking ecologically important species (e.g., *Diadema* and herbivorous fishes), and the costs and benefits of restocking using species raised in captivity versus wild populations. |