National Park Service
U.S. Department of the Interior

Natural Resource Stewardship and Science

Natural Resource Condition Assessment

Biscayne National Park

Natural Resource Report NPS/BISC/NRR—2022/2252

ON THIS PAGE
Angler and guide sight-fish for bonefish (Albula vulpes) on the seagrass covered flats of Biscayne Bay
Photo by J. Luo

ON THE COVER
Elkhorn coral (Acropora palmata) at Ball Buoy reef
Photo by D. Bryan

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February 2022

U.S. Department of the Interior
National Park Service
Natural Resource Stewardship and Science
Fort Collins, Colorado

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Please cite this publication as:

Bryan, D. R., J. Luo, and J. S. Ault. 2022. Natural resource condition assessment: Biscayne National Park. Natural Resource Report NPS/BISC/NRR—2022/2252. National Park Service, Fort Collins, Colorado. https://doi.org/10.36967/nrr-2289813.

NPS 169/178451, February 2022

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Executive Summary

Biscayne National Park (BISC) encompasses a unique tropical marine ecosystem directly adjacent to one the nation's largest metropolitan areas. Each year, roughly half a million people visit the park and its resources are integral to south Florida's multibillion-dollar fisheries and tourism industry. The park can be divided into four prominent natural environments: (1) mangrove shorelines, the longest stretch in southeastern Florida that provides a buffer to coastal development and important habitats for birds, juvenile fishes and macroinvertebrates; (2) Biscayne Bay, a shallow estuarine system with a historically rich and productive benthic community; (3) more than 40 limestone keys, including a rare relatively undisturbed tropical hardwood ecosystem; and, (4) extensive patch coral reef and platform coral reef system, which play a critical role in the function and dynamics of the larger south Florida marine ecosystem. This prolific range of natural resources are highly inter-connected, both within the confines of the park, and as part of the broader regional ecosystem.

In this NRCA, a selection of nine key natural resources vital to assessment of park's overall health have been identified; water quality, seagrasses, terrestrial vegetation, corals, marine invertebrates, reef fish/gamefish/sharks, sea turtles, marine mammals/American crocodiles, and birds. The condition and trend for each of these resources was evaluated using the best available science and the NPS structured resource assessment and reporting framework.

BISC is a tropical marine park with 95% of its total acreage covered in water. As such, the importance of water quality to the health of the ecosystem is unequivocal. Almost all of the natural resources discussed in this report either exist in, or depend on, the marine environment. Significant hydrological alterations in conjunction with an ever-increasing urban population have affected the quantity, quality and timing of freshwater inflows into BISC and added considerable stress to a finely balanced ecosystem. Salinity levels not meeting desired ecological conditions, high nutrient levels promoting phytoplankton and algal blooms have raised significant public concerns. While the presence of contaminants both in the water and within the animals living in the park is high, monitoring efforts are in place and the park continues to work with neighboring state and federal agencies and the public to improve the quality, quantity and timing of water entering the park.

Seagrass beds cover nearly 90% of benthos within BISC. Seagrass provides essential habitats for a wide range of marine species during critical life stages, plays a major role in nutrient cycling in the Biscayne Bay, and helps to stabilize marine sediments. Seagrass monitoring efforts suggest that the acreage of seagrass within the park and the species composition within the nearshore environment of the bay have been relatively stable. However, nutrient loading and persistent algal blooms have deleteriously affected areas adjacent to the park, warranting moderate concern for the nearshore seagrass community.

Although only 5% of BISC is land, this area contains a significant portion of the park's biodiversity and includes terrestrial habitats highly connected with the marine environment and critical for a host of marine species. Mangroves, which make up the largest proportion of terrestrial vegetation in BISC, provide habitat for a wide range of terrestrial and marine fauna. The coastal tropical hardwood hammock community includes many rare and unique tree species, at their most northern limit.

Reference conditions for the composition and extent of mangrove and tropical hardwood forests were established in 2013, but there has been no subsequent mapping. Invasive plant species are an ongoing threat; however, restoration projects and removal efforts have appeared to have kept exotic plants under control.

The vibrant coral reef ecosystem within BISC has experienced significant stony coral declines over the past 50 years, relatively consistent with those throughout the greater Caribbean. The regional rise in ocean temperatures appears to have increased the prevalence and intensity of coral beaching events. These bleaching events can lead to coral disease and eventual mortality. Coral condition within BISC warrants significant concern, as percent coverage is at historic lows and several federally threatened species are nearly extirpated from BISC. Although global warming and coral disease may be the greatest threats to BISC stony corals, physical damage from anchors and derelict lobster traps are also a significant stressor. Extreme weather events, such as hurricanes and severe cold weather events, have also resulted in substantial coral mortality.

Commercial fishing for Caribbean spiny lobster, pink shrimp and stone crab is authorized within BISC. While these economically-valuable crustaceans are important for commercial fisheries, they also provide tremendous support for recreational fishers and are key food web components of the regional coral reef ecosystem. The catches of juvenile pink shrimp used as food and as bait for the recreational fishery along with catch rates for commercial and recreational fisheries lobsters appear stable over the past two decades. However, it is unclear if these current harvest rates are sustainable and how they affect overall ecosystem health.

Scientific stock assessments have shown that in south Florida, more than 70% of the 35 species of the snapper-grouper complex are overfished. An updated review of six key species for this report strongly indicates that these reef fishery resources remain overfished and are experiencing unsustainable fishing rates. The diversity and abundance of fishes is a major draw to visitors who come to the park to recreationally fish, snorkel or dive. However, the poor condition of these valuable resources warrants significant concern and requires an urgent and effective management response and intervention. Unlike some other key resources whose primary stressors are far afield, local resource management actions such as implementation of minimum size limits, creation of no fishing areas, and/or adopting more stringent harvest regulations could be used by BISC and the State to ameliorate or reverse the downward trend of reef fish abundance and spawning biomass.

BISC also provides important foraging and natal habitats for many transient and resident marine reptile, bird, mammal and fish species. Loggerhead turtles nest on the seaward side of the keys, more than 10 shark species frequent the bay and reef waters, large mature migratory Atlantic tarpon pass through BISC in spring and fall, and resident populations of bottlenose dolphins, Florida manatees and American crocodiles use BISC waters and can be enjoyed by the public. The status and condition of most of these species' populations in BISC waters remains uncertain as robust, cost-effective, statistically-standardized monitoring programs are not in place. In general, there has been no significant trend detected for any of these species due to insufficient monitoring programs; but, the general lack of data and apparent negative population trends from proximal areas outside the park warrant moderate concern.

Biscayne Bay, including within BISC, has been designated an *Important Bird Area* by the Audubon Society because of its significant populations of protected species, large numbers of wading birds, and unique natural habitats available for avian feeding, migratory stopover, and nesting. Some monitoring projects have been performed for a limited number of species, but there is limited long-term reference data available. Counts of colonial nesting and shore birds suggests relatively stable numbers over the past 5 years, but there does appear to be a decrease in the species richness of birds visiting the park.

BISC continues to offer park visitors a "*rare combination of terrestrial, marine, and amphibious life in a tropical setting of great natural beauty"*, intrinsic natural resource qualities that were specified in the parks enabling legislation. However, many decades of excessive use and pressure from the rapidly growing regional human population has taken a toll on the quantity, quality and abundance of park's resources. Of the nine key natural resources specifically evaluated for this NRCA report, two had an overall condition status that warranted significant concern, five warranted moderate concern, and only two were in relatively good condition. None of these nine natural resources had a condition rating that was considered "improving". Combined, these status and trend assessments clearly highlight the critical and complicated situation facing effective resource management within the park, and further, underscore the urgent need for action to protect the sustainability and future of these precious natural resources and the experience and enjoyment they provide to park users.

Acknowledgments

This NRCA is based on an extensive foundation of research and monitoring that has taken place in BISC since its inception. In additional to all of the literature and reports used to develop the assessment, we also had significant input from local scientists with a vast knowledge of the key resources within the park. We would like to acknowledge the time, expertise and data provided by the following scientists that were instrumental in generating this NRCA; E. Alvear (BISC), A. Atkinson (SFCN), C. Avila (DERM), A. Bourque (BISC), J. Contillo (SEFC), A. Davis (SFCN), M. Feeley (SFCN), G. Gelgado (FWRI), N. Hammerschlag (UM), B. Lockwood (NPS), V. McDonough (BISC), K. Marks (FRRP), T. Matthews (FWRI), J. Miller (SFCN), A. Meylan (FWRI), S. Moneysmith (BISC), R. Muxo (SFCN), K. Neely (FWRI), K. Nimmo (DRTO), S. Pappas (Coastal Cleanup Corp), J. Patterson (SFCN), L. Richter (SFCN), S. Schopmeyer (UM-RSMAS), J. Serafy (SEFC), B. Shamblin (SFCN), S. Smith (UM-RSMAS), R. Waara (SFCN), K. Whelan (SFCN), and I. Zink (SEFC).

List of Commonly Used Acronyms

BISC: Biscayne National Park

CERP: Comprehensive Everglades Restoration Plan

CPUE: Catch per Unit Effort

DERM: Miami-Dade Department of Environmental Resource Management

DRTO: Dry Tortugas National Park

ESA: Endangered Species Act

FKNMS: Florida Keys National Marine Sanctuary

FRRP: Florida Reef Resilience Program

FWRI: Florida Fish and Wildlife Conservation Commission, Fish and Wildlife Research Institute

IBBEAM: Integrated Biscayne Bay Ecological Assessment and Monitoring

IUCN: International Union for Conservation of Nature

NOAA: National Oceanic and Atmospheric Administration

NPS: National Park Service

NRCA: Natural Resource Condition Assessment

SEFSC: National Marine Fisheries Service, Southeast Fisheries Science Center (NOAA)

SFCN-IM: South Florida and Caribbean Network Inventory and Monitoring (NPS)

UM-RSMAS: University of Miami, Rosenstiel School of Marine and Atmospheric Sciences

Chapter 1. NRCA Background Information

Natural Resource Condition Assessments (NRCAs) evaluate current conditions for a subset of natural resources and resource indicators in national park units, hereafter "parks." NRCAs also report on trends in resource condition (when possible), identify critical data gaps, and characterize a general level of confidence for study findings. The resources and indicators emphasized in a given project depend on the park's resource setting, status of resource stewardship planning and science in identifying high-priority indicators, and availability of data and expertise to assess current conditions for a variety of potential study resources and indicators.

> ***NRCAs Strive to Provide…***
>
> - *Credible condition reporting for a subset of important park natural resources and indicators*
> - *Useful condition summaries by broader resource categories or topics, and by park areas*

NRCAs represent a relatively new approach to assessing and reporting on park resource conditions. They are meant to complement—not replace—traditional issue-and threat-based resource assessments. As distinguishing characteristics, all NRCAs:

- Are multi-disciplinary in scope;[1]
- Employ hierarchical indicator frameworks;[2]
- Identify or develop reference conditions/values for comparison against current conditions;[3]
- Emphasize spatial evaluation of conditions and GIS (map) products; [4]
- Summarize key findings by park areas; and [5]
- Follow national NRCA guidelines and standards for study design and reporting products.

Although the primary objective of NRCAs is to report on current conditions relative to logical forms of reference conditions and values, NRCAs also report on trends, when appropriate (i.e., when the underlying data and methods support such reporting), as well as influences on resource conditions. These influences may include past activities or conditions that provide a helpful context for

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[1] The breadth of natural resources and number/type of indicators evaluated will vary by park.

[2] Frameworks help guide a multi-disciplinary selection of indicators and subsequent "roll up" and reporting of data for measures ⇨ conditions for indicators ⇨ condition summaries by broader topics and park areas

[3] NRCAs must consider ecologically-based reference conditions, must also consider applicable legal and regulatory standards, and can consider other management-specified condition objectives or targets; each study indicator can be evaluated against one or more types of logical reference conditions. Reference values can be expressed in qualitative to quantitative terms, as a single value or range of values; they represent desirable resource conditions or, alternatively, condition states that we wish to avoid or that require a follow-up response (e.g., ecological thresholds or management "triggers").

[4] As possible and appropriate, NRCAs describe condition gradients or differences across a park for important natural resources and study indicators through a set of GIS coverages and map products.

[5] In addition to reporting on indicator-level conditions, investigators are asked to take a bigger picture (more holistic) view and summarize overall findings and provide suggestions to managers on an area-by-area basis: 1) by park ecosystem/habitat types or watersheds, and 2) for other park areas as requested.

understanding current conditions, and/or present-day threats and stressors that are best interpreted at park, watershed, or landscape scales (though NRCAs do not report on condition status for land areas and natural resources beyond park boundaries). Intensive cause-and-effect analyses of threats and stressors, and development of detailed treatment options, are outside the scope of NRCAs.
Due to their modest funding, relatively quick timeframe for completion, and reliance on existing data and information, NRCAs are not intended to be exhaustive. Their methodology typically involves an informal synthesis of scientific data and information from multiple and diverse sources. Level of rigor and statistical repeatability will vary by resource or indicator, reflecting differences in existing data and knowledge bases across the varied study components.

The credibility of NRCA results is derived from the data, methods, and reference values used in the project work, which are designed to be appropriate for the stated purpose of the project, as well as adequately documented. For each study indicator for which current condition or trend is reported, we will identify critical data gaps and describe the level of confidence in at least qualitative terms. Involvement of park staff and National Park Service (NPS) subject-matter experts at critical points during the project timeline is also important. These staff will be asked to assist with the selection of study indicators; recommend data sets, methods, and reference conditions and values; and help provide a multi-disciplinary review of draft study findings and products.

NRCAs can yield new insights about current park resource conditions, but, in many cases, their greatest value may be the development of useful documentation regarding known or suspected resource conditions within parks. Reporting products can help park managers as they think about near-term workload priorities, frame data and study needs for important park resources, and communicate messages about current park resource conditions to various audiences. A successful NRCA delivers science-based information that is both credible and has practical uses for a variety of park decision making, planning, and partnership activities.

Important NRCA Success Factors

- *Obtaining good input from park staff and other NPS subject-matter experts at critical points in the project timeline*
- *Using study frameworks that accommodate meaningful condition reporting at multiple levels (measures ⇨ indicators ⇨ broader resource topics and park areas)*
- *Building credibility by clearly documenting the data and methods used, critical data gaps, and level of confidence for indicator-level condition findings*

However, it is important to note that NRCAs do not establish management targets for study indicators. That process must occur through park planning and management activities. What an NRCA can do is deliver science-based information that will assist park managers in their ongoing, long-term efforts to describe and quantify a park’s desired resource conditions and management targets. In the near term, NRCA findings assist strategic park resource planning[6] and help parks to report on government accountability measures.[7] In addition, although in-depth analysis of the effects of climate change on park natural resources is outside the scope of NRCAs, the condition analyses and data sets developed for NRCAs will be useful for park-level climate-change studies and planning efforts.

NRCAs also provide a useful complement to rigorous NPS science support programs, such as the NPS Natural Resources Inventory & Monitoring (I&M) Program.[8] For example, NRCAs can provide current condition estimates and help establish reference conditions, or baseline values, for some of a park's vital signs monitoring indicators. They can also draw upon non-NPS data to help evaluate current conditions for those same vital signs. In some cases, I&M data sets are incorporated into NRCA analyses and reporting products.

NRCA Reporting Products…

Provide a credible, snapshot-in-time evaluation for a subset of important park natural resources and indicators, to help park managers:

- *Direct limited staff and funding resources to park areas and natural resources that represent high need and/or high opportunity situations* ***(near-term operational planning and management)***
- *Improve understanding and quantification for desired conditions for the park's "fundamental" and "other important" natural resources and values* ***(longer-term strategic planning)***
- *Communicate succinct messages regarding current resource conditions to government program managers, to Congress, and to the general public* ***("resource condition status" reporting)***

Over the next several years, the NPS plans to fund an NRCA project for each of the approximately 270 parks served by the NPS I&M Program. For more information visit the NRCA Program website.

[6]An NRCA can be useful during the development of a park's Resource Stewardship Strategy (RSS) and can also be tailored to act as a post-RSS project.

[7] While accountability reporting measures are subject to change, the spatial and reference-based condition data provided by NRCAs will be useful for most forms of "resource condition status" reporting as may be required by the NPS, the Department of the Interior, or the Office of Management and Budget.

[8] The I&M program consists of 32 networks nationwide that are implementing "vital signs" monitoring in order to assess the condition of park ecosystems and develop a stronger scientific basis for stewardship and management of natural resources across the National Park System. "Vital signs" are a subset of physical, chemical, and biological elements and processes of park ecosystems that are selected to represent the overall health or condition of park resources, known or hypothesized effects of stressors, or elements that have important human values.

Chapter 2. Introduction and Resource Setting

2.1. Introduction

2.1.1. Enabling Legislation

Prior to the creation of Biscayne National Park, the Biscayne National Monument was established by an Act of Congress and signed into law by President Lyndon B. Johnson on October 18, 1968 (Public Law 90-606). The efforts to create the Monument were led by Representative Dante Fascell (R, Miami) to protect "*a rare combination of terrestrial, marine and amphibious life in a tropical setting of great natural beauty*". The Monument boundaries were expanded in 1974 (Public Law 93-477) and in 1980 was re-designated as Biscayne National Park (BISC, Public Law 96-287) by expanding the Park boundaries northward to the southern tip of Key Biscayne and including Boca Chita Key, Ragged Keys and Soldier Key, along with additional bay, shoal and coral reef waters. The enabling legislation establishing BISC mandated the Park to "*preserve and protect for the education, inspiration, recreation and enjoyment of present and future generations a rare combination of terrestrial, marine, and amphibious life in a tropical setting of great natural beauty*" (16 USC Sect. 410gg). At that time, Congress recognized "*the unique and special values*" of the resources within BISC, as well as the "*vulnerability of these resources to destruction or damage due to easy human access by water*" (House of Representatives Report 96-693). Congress therefore directed the NPS to "*manage this area in a positive and scientific way in order to protect the area's natural resource integrity*."

Commercial & Recreational Fishing

Section 4 of the Public Law 90-606, which established Biscayne National Monument, stipulated that the waters within the National Monument:

> *"… shall continue to be open to fishing in conformity with the laws of the State of Florida except as the Secretary [of the Interior], after consultation with appropriate officials of said State designates species for which, areas and times within which, and methods by which fishing is prohibited, limited or otherwise regulated in the interest of sound conservation or in order to achieve the purpose for which the National Monument is established."*

While BISC's enabling legislation states that fishing will continue in BISC waters in accordance with State regulations, park authorities are also mandated to manage its fishery resources according to NPS guidelines. Further, Congress dictated that, with respect to lands donated after June 28, 1980, "*…the waters within the park shall continue to be open to fishing in conformity with the laws of the State of Florida*" (16 USC Sect. 410gg-2).

These legislative directives to BISC management can be divided amongst two regions: (1) the area comprising the original Monument boundaries, in which fishing regulations must follow State regulations, with the caveat that the Secretary of the Interior may enforce additional regulations as deemed necessary; and, (2) the National Park expansion area, in which fishing regulations conform with those of the State of Florida. Historically, the National Park Service (NPS) – BISC has followed State of Florida fishing regulations within the entirety of BISC; however proposed Fishery

Management (2014) and General Management Plans (2015) offer additional management alternatives to ensure protection of the park's fishery, coral reef and other natural resources.

Other important laws, projects, and international recognitions
BISC natural resource management is mandated to follow federal laws such as the Clean Air Act (1970), Clean Water Act (1972), Marine Mammal Protection Act (1972), Endangered Species Act (1973), and the Magnuson-Stevens Fishery Conservation and Management Act (1976, subsequent amendments). On March 21, 2000, the National Park Service (NPS) designated the units of the national parks system where personal watercraft can be operated, BISC was not listed and therefore personnel watercraft may not operate within park boundaries. In 2015, the National Oceanic and Atmospheric Administration (NOAA) selected Biscayne Bay as a *Habitat Focus Area* due to the growing concerns that regional deterioration of water quality may result in damage and loss of seagrass cover.

There are several easements still on the books. Miami-Dade County operates two county parks and marinas within BISC boundaries (i.e., Black Point and Homestead Bayfront). Both of the park's channel easements extend to or towards the Intercostal Waterway with specified dimensions of 31,000 ft in length and 150 ft wide. Florida Power and Light (FPL) Company holds two other easements, one is for Turkey Point Channel, and the other one is east of the Military Channel. There are six channel easements in the park that consist of 150 ft wide navigation channels in the submerged lands in Biscayne Bay. Three are in use: Turkey Point Oil Barge Channel, Goulds and Black Creek Canals and Homestead Bayfront Park. The other three easements are undeveloped.

Fowey Rocks lighthouse located inside BISC on coral reef (Photo by David Bryan)

2.1.2. Geographic Setting

Park Boundaries
Biscayne National Park (BISC) is roughly 22 miles long and 14 miles wide. The northern boundary of BISC is just south of Key Biscayne, and the southern boundary runs east-west through Broad

Creek north of Key Largo from the eastern boundary at the 10 fathom (60ft) depth contour at the edge of the barrier reef to the mangrove fringed western edge extending a few hundred meters inland from Biscayne Bay (Figure 2.1). BISC is principally a marine park with 95% of its area (173,900 acres or 270.3 square miles) underwater. The northern Park boundary is just south of Key Biscayne and Bill Baggs/Cape Florida State Park. The southern Park boundary extends through Broad Creek, just north of Key Largo and into Card Sound. The western Park boundary is the coastal land margin delineated by mangrove forests and coastal marshlands bisected by water management canals. From the Florida coastline the Park extends eastward across Biscayne Bay, numerous barrier islands (Keys), out across thousands of patch reefs out to the 60-foot depth contour along the Florida barrier reef tract.

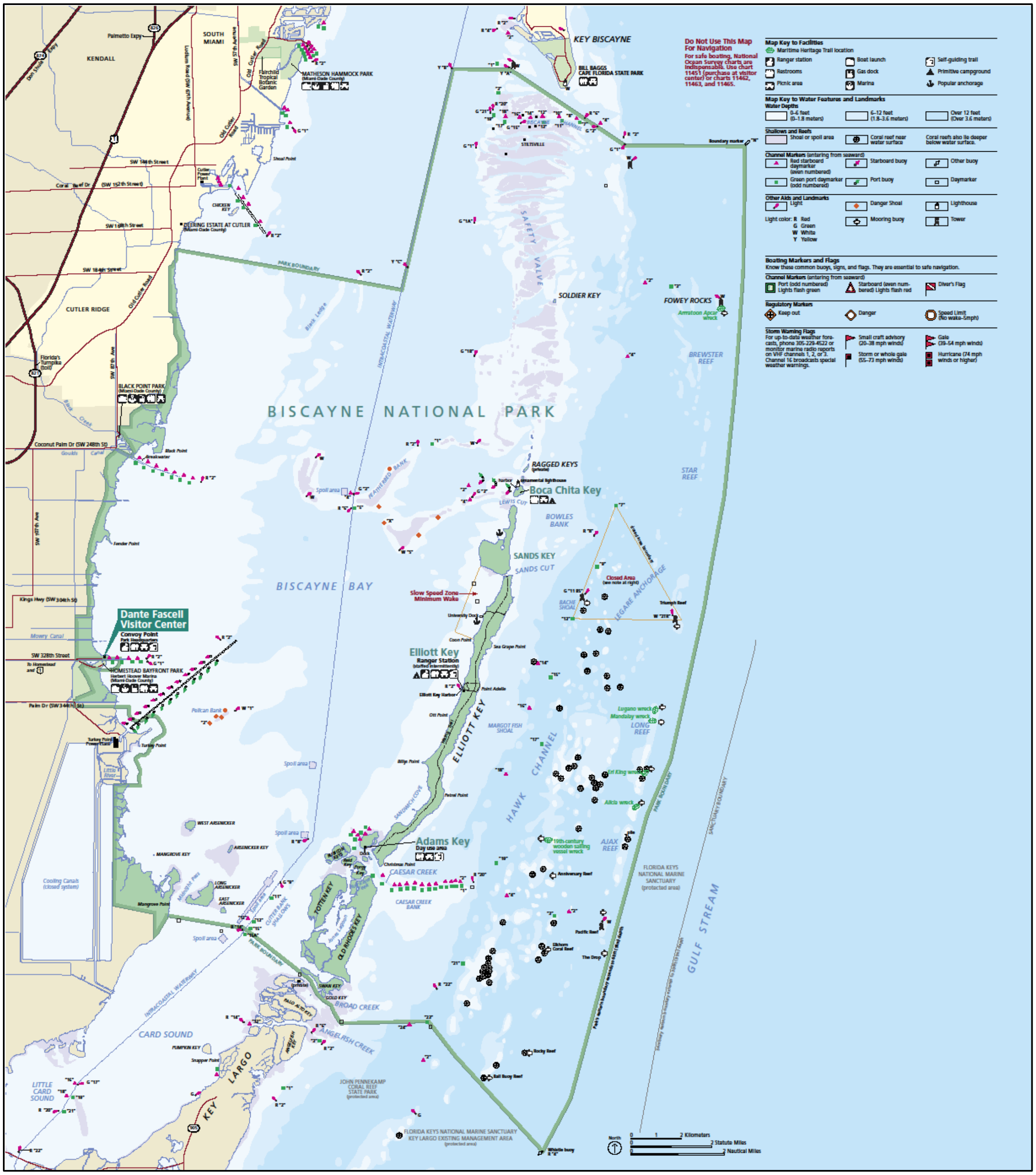


Figure 2.1. Map of Biscayne National Park (BISC) relative to the Florida Keys coral reef ecosystem. Map provided by Biscayne National Park (http://npmaps.com/wp-content/uploads/biscayne-map.jpg).

<u>The Regional Florida Keys Coral Reef Ecosystem</u>

The Florida Keys coral reef extends 400 km southwest along an island archipelago from Key Biscayne near Miami to the Dry Tortugas region west of Key West. The coral reef ecosystem is managed by different government agencies with specific spatial jurisdictions. Fisheries are managed by the Florida Fish and Wildlife Conservation Commission and two federal fishery management councils (U.S. South Atlantic and Gulf of Mexico). Fishing regulations can also apply in the Florida Keys National Marine Sanctuary (FKNMS) under NOAA (Department of Commerce); in three national Parks (Biscayne, Everglades, Dry Tortugas) and four National Fish and Wildlife Refuges (Department of Interior); and in John Pennekamp Coral Reef State Park (Florida Department of Environmental Protection).

Biogeography

Biscayne National Park (BISC) is a unique tropical marine environment of national significance, renowned for its productive coral reef ecosystem, diverse natural resources, important fishing opportunities, and spectacular scenic beauty (Ault et al., 2001). Of the 172,971 acres (270.3 sq. miles) encompassed by BISC, 95 % is water. It is located south and east of the densely populated urban environment of Miami (Miami-Dade County) in southeastern Florida. With the exception of the developed western park boundary, BISC is surrounded by state and federally managed waters. The FKNMS runs along the outer eastern boundary, and the FKNMS and Pennekamp State Park abut the southern boundary. Biscayne Bay Aquatic Preserve encompasses the waters to the north. Through water movement and animal migrations, the natural resources in BISC are highly connected to the broader regional coral reef ecosystem which also includes Everglades and Dry Tortugas National Parks.

Climate-weather, air and water temperature, rainfall, and tropical storms

BISC experiences a subtropical maritime climate, shaped by its latitude at 25° N, less than 2 degrees north of the Tropic of Cancer and proximity to the Gulf Stream, with moderate temperatures and two seasons: the summer wet season (May–October), marked by numerous convective thunderstorms and occasional tropical storms and hurricanes; and, the winter dry season (November–April) which features infrequent, fast-moving, dry cold fronts. Annual rainfall in south Florida is approximately 130 cm, but can vary dramatically among any particular micro-region (Duever et al., 1994). Temperatures during the wet season (June–October) range from 28°C to 34°C; but during the dry season, between late November and April, temperatures average around 21°C, with some very occasional days with temperatures less than 10°C. BISC water temperature range from about 22°C in the winter to 30°C in the summer. Offshore water temperatures on the reef tract are usually about 2 degrees warmer in winter and a degree or two cooler in the summer compared to inshore waters as a result of the Gulf Stream (Figure 2.2).

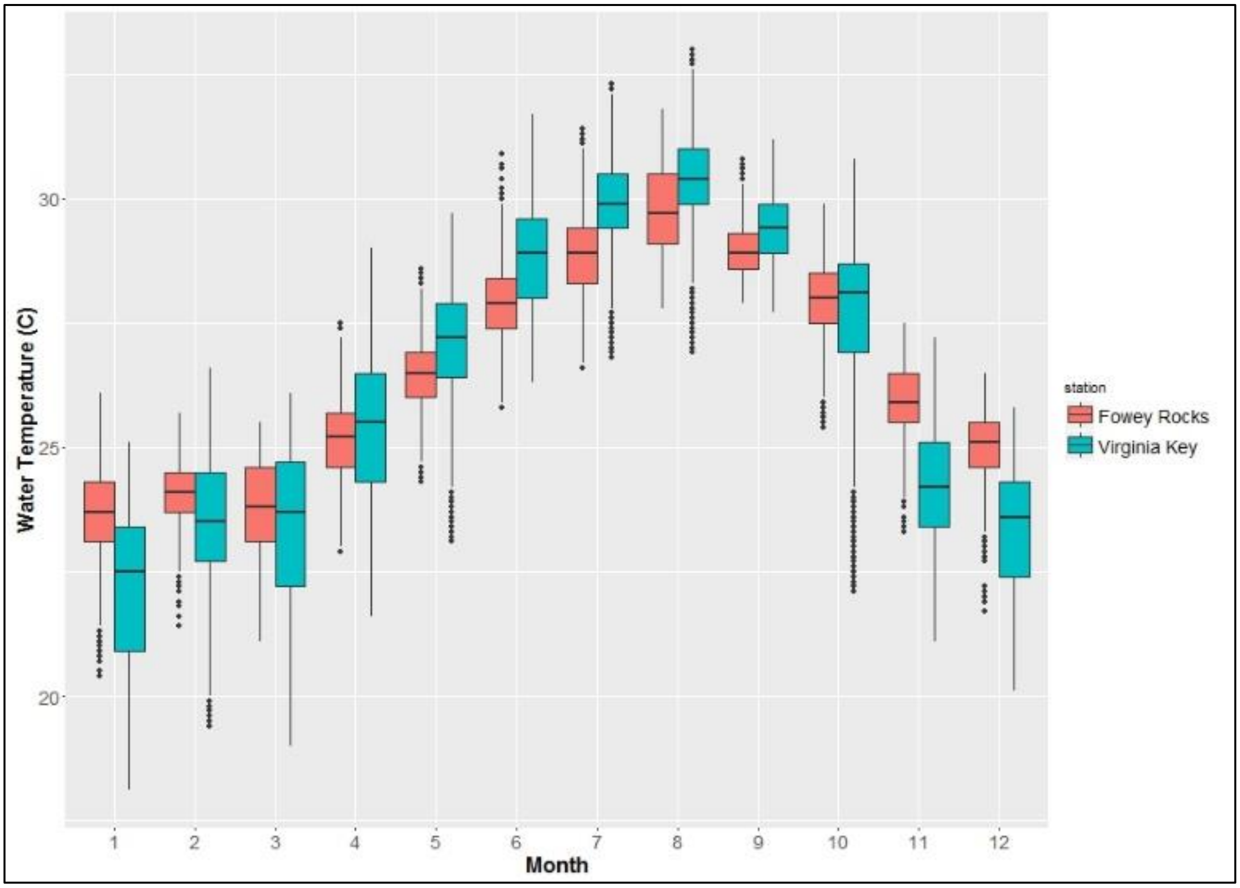


Figure 2.2. Box and whisker plots of monthly average water temperatures during 2013–2014 from Fowey Rocks (reef tract) and Virginia Key (northern part of Biscayne Bay). (Data from the National Data Buoy Center (https://www.ndbc.noaa.gov/)).

2.1.3. Park Visitation

Each year around 500,000 persons visit BISC. Visitation rates are fairly consistent year round, with a moderate peak from May to August (Figure 2.3). Park visitors typically enjoy BISC's marine environment through the use of private or chartered boats (Ault et al., 2008a; Ault et al., 2017). There is no 'gate' *per se* though which recreational visitors are required to pass. However, the origins of boating trips can be divided into three types of departure locations: (1) public marinas/boat ramps within park boundaries (i.e., Homestead Bayfront, Black Point): (2) public marinas/boat ramps located just outside park boundaries (i.e., Matheson Hammock Marina, Dinner Key, Crandon); or, (3) private residence or yacht club marinas or boat docks. Estimates of visitor use were derived from trailer counts at marina parking lots extrapolated to the total number of boaters seen during aerial surveys within the entire Park (Ault et al., 2008a). In addition to day-use park visitors, typically 5,000–10,000 overnight campers per year also use BISC.

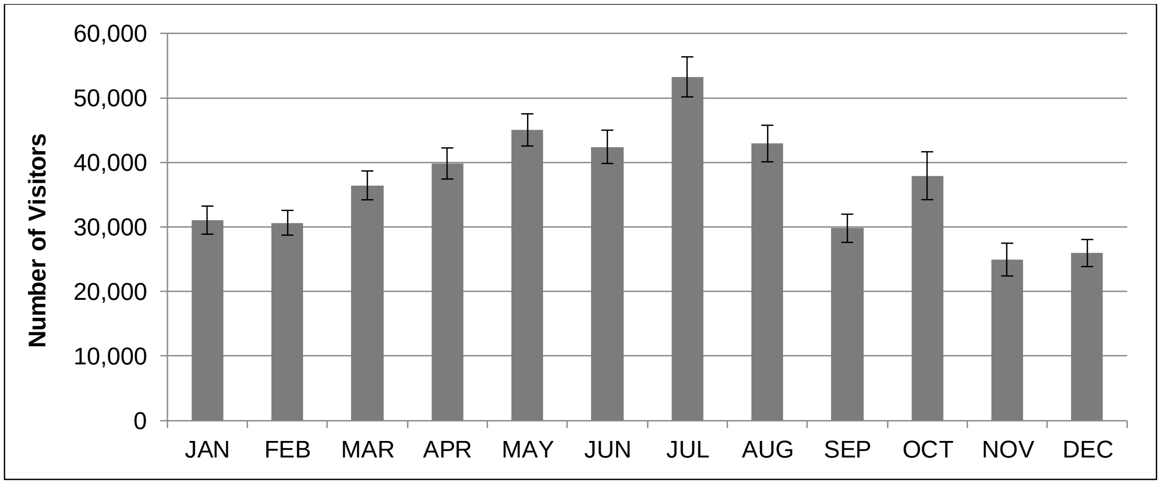


Figure 2.3. Average monthly BISC visitation from 1979–2015. (Data from NPS Visitor Use Statistics (https://irma.nps.gov/STATS/Reports/Park/BISC)).

Several small but valuable commercial fisheries operate within park boundaries, along with a relatively large charter fishing fleet. Similar to many recreational visitors, these commercial operations depend heavily on the health/condition of BISC's natural and fisheries resources. The park does not collect data on commercial usage, but there are several secondary data sources available to estimate their magnitude. Commercial fisheries statistics collected by the State and Federal agencies indicate that currently more than $10 million dollars of fish and crustaceans are landed each year in the Miami reporting area (Figure 2.4).

Roughly 20% of the mapped coral reef and 60% of the seagrass habitats beds in the Miami reporting area are within BISC boundaries. Important commercial species such as spiny lobster, shrimp, fish and crabs are found in these habitats. Shallow-water charter fishing with professional guides is also an extremely popular and lucrative activity within BISC (Ault 2008; Mill et al., 2010). Anglers interested in world-class sight fly- and conventional fishing for bonefish, tarpon and permit frequent the shallow water 'flats' throughout the park (Ault et al., 2008b; Larkin et al., 2010). In 2015, there were about 80 charter boat licenses registered in Miami-Dade county, and another 70 in nearby Key Largo. The professional fishing guides from these reporting areas have easy access to BISC, and it is likely that a significant proportion of their annual fishing trips are operated within the park boundaries.

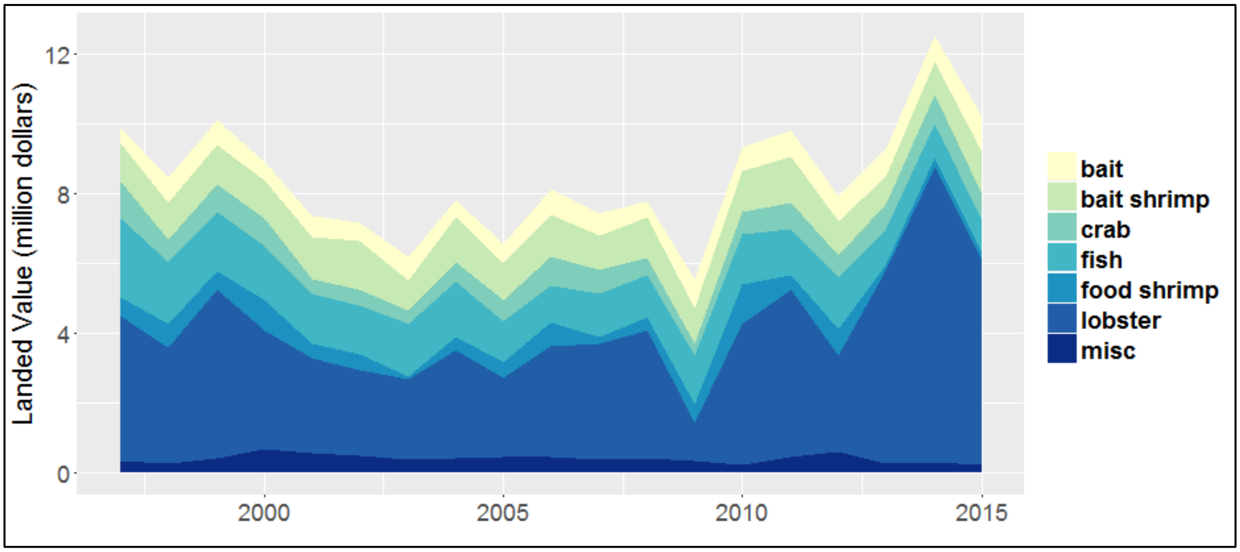


Figure 2.4. Value (millions of dollars) of landed commercial species or species group during 1997 to 2015 from the Miami reporting area (744). (Data from Florida Fish and Wildlife Conservation Commission, https://publictemp.myfwc.com/FWRI/PFDM/).

2.2. Physical and Natural Resources

2.2.1. Coastal Hydrology and Hydrodynamics

Biscayne Bay, Card Sound, and Barnes Sound make up a system of connected shallow lagoons on the southeastern coast of Florida. This lagoonal system is connected to the Atlantic Ocean to the east and is bordered by mangrove shorelines and the city of Miami to the west. In the past, freshwater freely entered the western edge of the bay through overland surface (rivers, streams, tidal creeks) flows via shallow sloughs ("transverse glades") oriented southeast in the Miami Limestone, and groundwater (springs, seeps) flows from the eastern Everglades. A network of drainage canals completed during the second half of the 20th century greatly altered the distribution of freshwater within the watershed, and therefore also the quantity, quality, and timing of freshwater discharges to Biscayne Bay (Larsen et al.,1995; Stalker et al., 2009). The canal system was originally put in place to provide drainage, but was subsequently enhanced to serve the additional functions of flood and salinity-intrusion control. Because of the naturally flat topography of adjacent wetlands and the shallow phreatic (free surface) aquifer, the management of the hydrologic system was constrained to a very narrow water table range and a small soil water storage capacity. These constraints necessitated alterations in the quantity, quality, and temporal distribution of freshwater runoff to the Bay, which became more pulsed with larger peak discharges in the wet season. During the dry season, less freshwater reached Biscayne Bay because of the reduced terrestrial storage and lowered groundwater levels (Larsen et al., 1995).

In the present system, salinity variations in Biscayne Bay result primarily from canal discharges through gated control structures managed to meet the municipal water supply, agricultural, and flood control objectives. Additional, but smaller freshwater exchanges in the Bay are driven by overland runoff, rainfall, and evaporation. Along with the creation of the canals, profound changes in groundwater seepage to the Bay occurred over the past several decades. The groundwater seeps into the canals and is released to tide to avoid flooding. The quantity of direct groundwater seepage out of Bay bottoms is now but a small fraction (less than 5%) of these canal flows (Wang et al., 2003). This quantity is a significant reduction from pre-drainage seepage because the groundwater table has been lowered resulting in smaller hydraulic gradients toward the coast. The circulation pattern of the Biscayne Bay is dominated by semidiurnal tidal flows which accounted by 87% of the observed variance (Wang et al., 2003) with the rest is from wind driving force. With tidal effects removed, the average current pattern consists of water entering the bay through the safety valve opening and exiting at ABC creeks in South, and via Rickenbacker to Government Cut at North (Wang et al., 2003). Historically, during the wet season, fairly sharp salinity gradients exist in coastal bays in which near-freshwater conditions found along the coastal shoreline progressively change to near-oceanic conditions at the barrier islands.

Biscayne Bay on a beautiful tranquil day with light winds (Photo from BISC)

Offshore of the barrier islands fringing the eastern side of Biscayne Bay, unique topographic and oceanographic conditions help sustain the highly productive coral reef ecosystem. The coastal marine environment exhibits relatively little topographic variation, although the sea floor abruptly plummets to depths of 1,500 m several kilometers seaward of the barrier reef tract. Oceanographic dynamics are influenced by the Loop Current in the southeastern Gulf of Mexico which merges with the Florida Current near the Dry Tortugas and then flows parallel to the barrier reef through the Straits of Florida towards Miami. This unique geophysical setting promotes dynamic oceanographic conditions comprised of intricate recirculating gyres and surface currents with some of the highest current speeds in the world. The seaward edge of the barrier reef tract is usually subjected to open tidal exchange from the Florida Straits with its warm, clear, low nutrient waters conducive to coral reef development. These conditions are periodically interspersed with pulses of nutrient-rich waters from locally intense upwelling events along certain deep reef margins where some of the most luxuriant coral habitats are found.

2.2.2. Ecological Units

Biscayne National Park can be divided into four unique, but prominent and highly inter-connected ecological units (or environments):

Mangrove and marshland shorelines

> Along the western boundary of BISC is >50 km of mangrove shoreline, the longest stretch of this habitat in southeastern Florida. This important habitat provides a critical buffer from the intensive proximal coastal development, and because of their complex root systems that extend into the bay, a vital habitat for

juvenile fishes, macroinvertebrates, and wading and diving birds. The principal species is red mangroves, but black and white mangroves are present as well.

Coastal Lagoon

Biscayne Bay is a shallow tropical lagoonal system averaging about 6 feet deep covered by sand, seagrass, sponges and gorgonians. At one time (circa, < 1920), the Bay was actually an estuary with substantially greater freshwater inputs and lower average salinities over a broader portion of the bay. Numerous nearshore and coral reef juvenile and adult fishes and macroinvertebrates utilize the bay for either a portion or throughout their life cycle. A keystone species of the bay is the pink shrimp.

Barrier Islands or Keys

The eastern Bay is ringed by a long chain of limestone keys (English Cays, or barriers islands). These Keys are fringed by mangroves with hardwood forests on their interiors. These keys harbor a plethora of rare and threatened species including: Sargents cherry palm; semaphore prickly pear cactus; and the Schaus swallowtail. They also provide nesting habitats for migrating mature loggerhead turtles and several species of song birds.

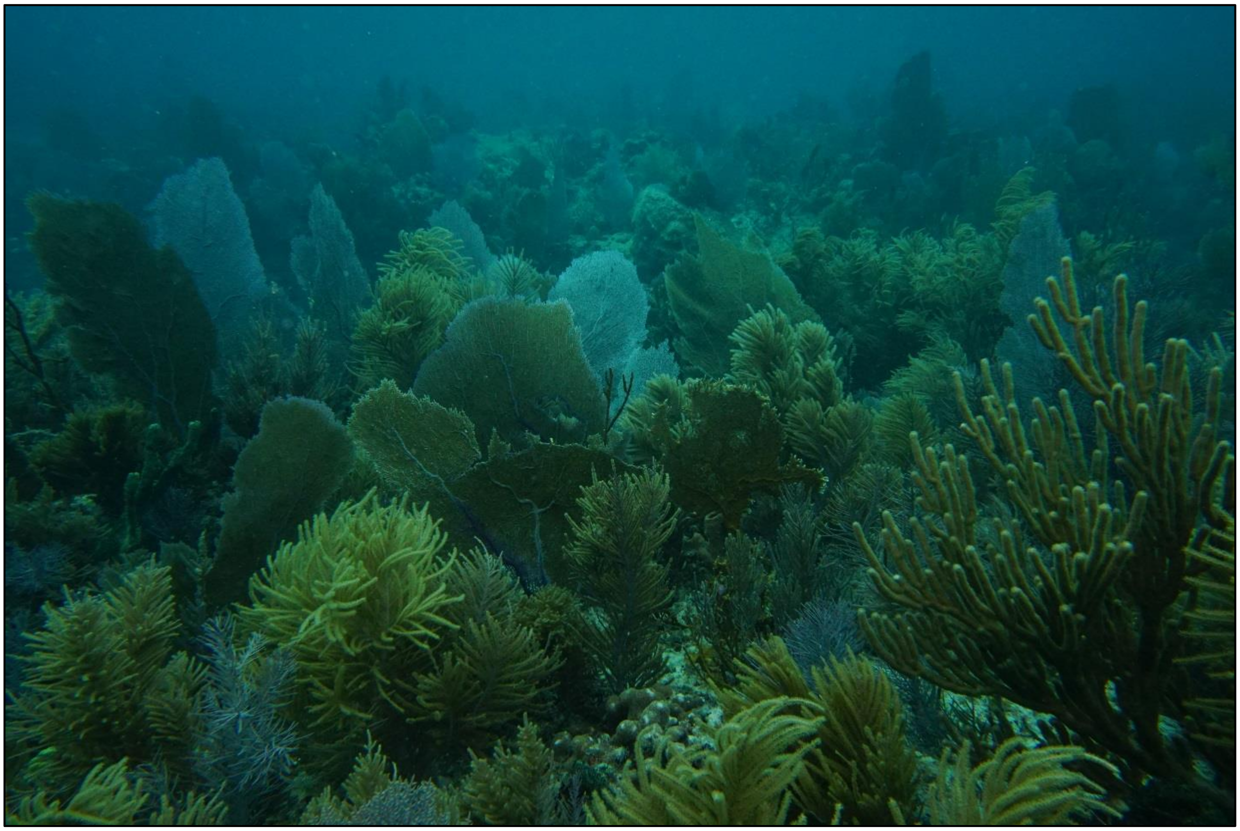
Coral Reefs

East of the keys out to about 6 km lie the diverse and highly productive coral reef ecosystem. Within BISC boundaries, are perhaps thousands of small patch reefs just east of Hawk Channel; and, offshore of these are the northernmost extent of the Florida Coral Reef Tract, home to numerous hard and soft coral species, seafans, and hundreds of tropical reef fishes.

Benthic habitats exhibit a distinct cross-shelf pattern through the four environments. Fringing mangrove habitats occur on the land-sea edge of coastal bays and around barrier islands. Coastal bays have three main benthic habitat types: seagrass beds, bare unconsolidated substrates, and oolitic limestone hardbottoms populated with sponges and octocorals. Seaward of the barrier islands, benthic habitat types include stony coral patch reefs and barrier reefs, sponge-gorgonian covered hardbottoms, seagrass beds, and carbonate sands.

2.2.3. Resource Descriptions

The park's unique location at the intersection of tropical and subtropical climates has allowed for a tremendous diversity of organisms to thrive in a highly productive marine and terrestrial ecosystem. These habitats include roughly 4,825 acres of largely undeveloped mangrove shoreline, over 40 uninhabited limestone islands and tropical hardwoods forests, 150,000 acres of submerged vegetation included seagrass and macroalgae, 4,000 individual patch reefs, and the northernmost extent of the Florida Reef Tract. It is among the top ten parks with the most endangered species within its boundaries (16) and at least 173 species occurring in BISC can be found on a list of federal or state protected species (FDEP). The park is within the NOAA designated Essential Fish Habitat (EFH) for spiny lobster, snappers, groupers, and the seaward waters are in the EFH for corals. All of BISC is within the NOAA-designated Habitat Areas of Particular Concern (HAPC) for spiny lobster, snapper, and grouper. The park also is part of the HAPC for penaeid shrimp HAPC in Biscayne Bay.



A variety of soft corals (Gorgonians) covering a shallow water reef in the park. (Photo by David Bryan)

BISC is an extremely important component in the south Florida coral reef ecosystem. BISC and the Florida Keys coral reef ecosystem support more than 500 fish species, including 389 that are reef-associated), and thousands of invertebrates, including corals, sponges, shrimps, crabs, and lobsters. Species in the snapper-grouper complex utilize a mosaic of cross-shelf habitats and oceanographic features over their life spans (Ault and Luo, 1998; Lindeman et al., 2000). Most adults spawn on the barrier reefs and sometimes form large spawning aggregations (Domeier and Colin, 1997). The Dry Tortugas region, in particular, contains numerous known spawning aggregation sites (Schmidt et al., 1999). Pelagic eggs and developing larvae are transported from spawning sites along the barrier reef tract by a combination of seasonal wind-driven currents and unique animal behaviors to eventually settle as early juveniles in a variety of inshore benthic habitats (Lee et al., 1994; Ault et al., 1999b). Some of the most important nursery habitats are located in the coastal bays and near barrier islands (Lindeman et al., 2000; Ault et al., 2001). As individuals develop from juveniles to adults, ontogenetic habitat utilization patterns generally shift from coastal bays to offshore reef environments making BISC a critical crossroads in support of regional ecosystem productivity.

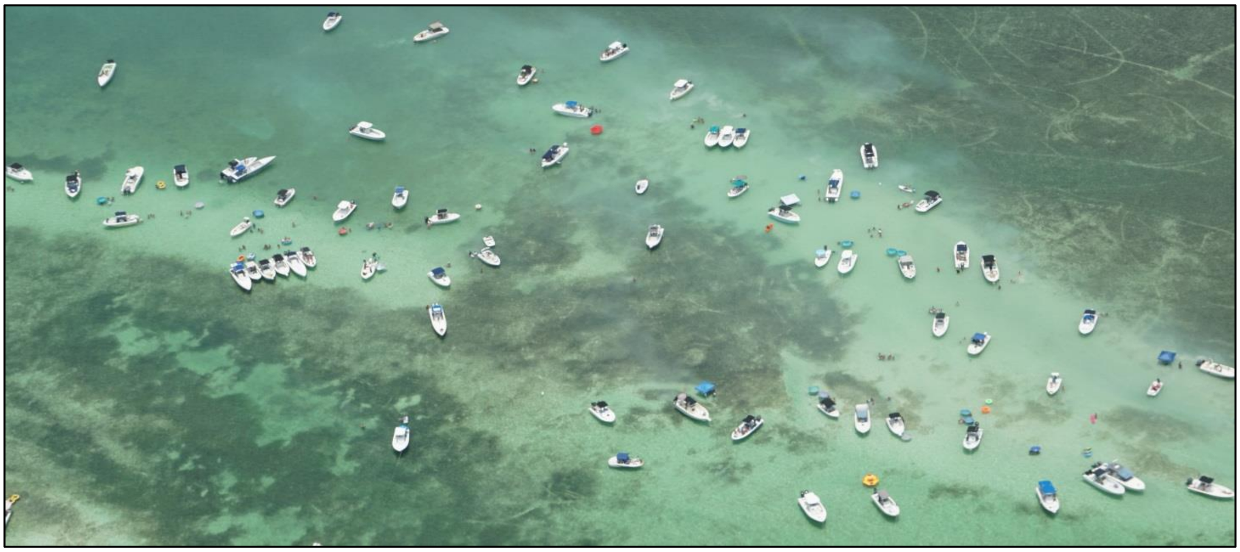
BISC is also home to a number of resident populations of threatened and endangered species. These include marine mammals like bottlenose dolphins, where the BISC is an important foraging site, and the Florida manatee. At least ten species of sharks have been reported within the park, including the great hammerhead listed as endangered by the IUCN, and the tiger shark, which is threatened. The seaward shores of the keys within BISC provide beaches for nesting loggerhead sea turtles and the occasional green turtle, while the keys proper support one of the last remaining tropical hardwood forests in south Florida. Dozens of migratory birds, and close to 100 resident bird species including numerous nesting birds, depend on BISC for their survival.

Boca Chita Key (Photo from BISC)

2.2.4. Overview of Resource Issues

The high connectivity amongst ecosystems within BISC and the regional ecosystem means that stressor(s) in one particular area can inadvertently affect resources throughout the park. Resource threats to the park can generally be divided into two categories: (1) near field; and (2) far field. Near-field threats are typically stressors that park management may have some or direct control over because they occur within park boundaries, and these can likely be mitigated with focused actions. For example, visitor usage such as boating or fishing can over-stress the natural resources by removing too many fish or physically damaging habitats. Protective or restorative actions like evaluating potential spatial management options, limiting access to shallow or sensitive waters, or effecting size or bag limits to catches may reduce negative impacts. Both near and far field threats often overlap, complicating effective management strategies.

On the other hand, far field threats are those stressors originating outside of park boundaries, but influence resource dynamics within the park. These can create great challenges to managing local park resources. Because of BISC's predominately marine environment and the high connectivity with resources and environments throughout the greater south Florida ecosystem, and in fact, northern Caribbean Sea, there are a number of potential far field threats that may affect the park. A large majority of mobile animals found within the park, can move or migrate 10s to 100s of km away from park boundaries at some times over their life cycle. Additionally, physical conditions such as air and water quality (e.g., rising air and water temperatures) within BISC may be influenced by inputs or sources that are managed or controlled by other agencies, states or countries. Therefore, there may be a considerable number of critical stressors that park management may have no direct control over, but require management collaborations with partner agencies to mitigate these effects within BISC.



Typical weekend boating scene near a popular spot in BISC. (Photo by David Bryan)

The principal threats to BISC natural resources are:

- Regional human population growth, coastal development, water management and pollution
- Overfishing (recreational and commercial)
- Exotic species
- Marine debris
- Climate changes and sea level rise

Population growth, coastal development, water management and pollution
Although BISC has a very thin buffer along its western boundary, continued rapid human population growth and development of Miami's waterfront will continue to directly and indirectly affect natural resource dynamics in the park. Currently, Miami-Dade is the seventh most populous county in the nation. Over the years, intensive urban development, drainage modifications and water management practices have modified or eliminated much of these flows to the bay, altering water quantity, quality, timing and location of delivery (Wang et al., 2003; Stabenau et al., 2015).

Continued and forecasted development within the surrounding watershed (e.g., increasing regional human population size by 75% by 2050 as proposed by Miami-Dade County) will undoubtedly increase runoff and contaminants (e.g., pesticides, herbicides, pharmaceuticals, antifouling agents, nutrients, etc.) that will make their way into the Bay.

From the late 1940–1960s, the Army Corps of Engineers and the South Florida Water Management District constructed an elaborate network of canals that drained wetlands for agriculture and human habitation, reduced seasonal flooding in urban areas, and provided freshwater for human use. Water management was a major factor in promoting regional human population growth. In addition, the canal network that detrimentally impacted the Everglades also severely impacted coastal marine ecosystems by altering the distribution of freshwater within the watershed and the quantity, quality, timing, and spatial locations of freshwater discharges to coastal bays. The Comprehensive Everglades Restoration Plan (CERP) is a 30-yr project aimed at correcting some of these adverse environmental effects and restoring the terrestrial everglades ecosystem while meeting the anticipated human water needs for the next 50 yrs. One CERP project, Biscayne Bay Coastal Wetlands, aims to restore freshwater flow to the bay's coastal wetlands. Because of the interactive effects on ecosystem dynamics, only time will tell us about its efficacy for BISC resources.

Overfishing

BISC is located proximal to one of the largest metropolitan areas in the United States. This means that the park waters have experienced significant visitation and use over time, and this is only expected to increase over the next few decades. Currently, more than a half-million visitors frequent the park each year, most of whom come solely to fish. Concomitantly, the Keys ecosystem and BISC fisheries are currently at a very high level of stress. More than 70% of species in the snapper-grouper complex are below the population level considered sustainable by state, federal and international fishery management standards (Ault et al. 1998, 2005a, 2009, 2018). Some populations are less than 1% of their historical abundance. The reef fishery exhibits classic "serial overfishing" in which the largest, most desirable, and vulnerable species are depleted by fishing. Fishing, combined with other stressors, has contributed to substantial changes in fish community structure and dynamics.

As Miami's and southern Florida's human populations continue to grow, there will be more pressure exerted on these natural resources. In addition to rapidly escalating recreational fishing pressures, park waters are also frequented by a commercial fishing fleet, largely targeting invertebrates such as pink shrimp, stone crabs, and lobsters, as well as a lucrative charter fishing industry. Most of the recreational and commercially important reef fish species within the Park waters are no longer as common, or even available, as in the past heydays.

Exotic species

In Florida, the terrestrial environment has been under constant threat from invasive plant (e.g., Australian pine, seaside mahoe, Melaleuca) and animal (e.g., Burmese pythons, green iguanas, cane toads etc.) species, and these have required diligent removal programs. In the marine environment, newly invasive lionfish have the potential to alter ecosystem dynamics through profound changes in food webs.

Marine debris

Marine debris has become a ubiquitous global problem with numerous negative effects on the natural resources (Kühn et al., 2015; Rochman et al., 2016). After decades of use, the park's reefs are being increasingly affected by the presence of debris directly related to recreational and commercial fishing. The prevalence of debris through the park has affected visitor's enjoyment and, more importantly, has led to increasing impacts, injuries and deaths to corals and other stationary benthic organisms, birds, sea turtles, and other species. In addition to the debris found underwater, the beaches along Elliott Key are constantly accumulating trash which negatively affects the diverse group of organisms that depend on this habitat.

Osprey (*Pandion haliaetus*) nest in BISC with variety of marine debris (Photo by Judd Patterson)

Climate changes and sea level rise

Climate change and attendant sea level rise will reportedly have profound effects on virtually every ecosystem on our planet; however, south Florida may be one of the most severely affected areas in the U.S. In BISC, some changes have already begun to stress natural resources. The coral reef ecosystem is perhaps the park's focal resource. However, increases in summer ocean temperatures have contributed to significant coral bleaching, and associated diseases and coral mortality. Within BISC, declines in coral cover over the past 30 years heightens concerns about long-term effects of climate changes, and rising sea levels may threaten low lying keys in BISC and the organisms they support.

A gray angelfish (*Pomacanthus arcuatus*), a common species found throughout the coral reef ecosystem. (Photo by David Bryan)

2.3. Resource Stewardship

Resource stewardship is the ethic that defines the approach to resource management in the National Park Service.

> *"The national parks of the United States stand as a singular achievement of the nation. From the establishment of Yellowstone as the first national park in 1872, the National Park System has grown to include 397 national parks, historical sites, urban recreation areas, national monuments, wild and scenic rivers, and national trails, with more than 279 million visits each year. The character and importance of this precious heritage lies at the heart of the American experience, and stewardship of the national parks is an enduring responsibility shared by all Americans" (NPSABSC 2012).*

Biscayne National Park's coral reef, keys, estuarine bay and mangrove coast is a significant and integral portion of the South Florida ecosystem within the wider Caribbean community where diverse, temperate and tropical species mingle. Visitors enjoy opportunities for a multitude of recreational activities near one the country's major metropolitan centers and find inspiration in Biscayne's tranquility, solitude, scenic vistas, underwater environment and diverse sounds of nature. The park encompasses a large portion of the northernmost extent of the Florida Reef Tract and preserves unique marine habitat and nursery environments that sustain diverse and abundant native fishery resources enjoyed by many. It preserves a largely undisturbed gene pool of tropical and subtropical flora. BISC provides a rare opportunity to experience largely undeveloped Florida Keys with forest and shoreline vegetation and wildlife surrounded by clear tropical waters and fresh sea breezes. BISC preserves unique marine habitat and nursery environments that sustain diverse and abundant native fishery resources. The park's submerged and terrestrial resources represent a sequence of rich history encompassing early settlement, agricultural and maritime activities, development of the islands, and the melding of diverse cultures. The park offers outstanding opportunities for education and scientific research because of the diversity and complexity and interrelatedness of its natural and cultural resources.

Busy afternoon at Elliott Key (Photo by Kara Wall)

2.3.1. Management Directive and Planning Guidance

BISC has a two instruments for a phased management strategy of directives and planning guidance: (1) General Management Plan (GMP); and, (2) Fisheries Management Plan (FMP).

General Management Plan

Since the last GMP was completed and implemented in 1983, much has changed concerning natural resources and their management within BISC. The human population near the park has greatly increased, visitation has greatly increased, and use patterns and activities have changed. At the same time, extensive scientific research has enhanced the park's understanding of their resources, dynamics, resource threats and visitor use. These changes have implications for how resources are managed and protected, how visitors access and use the park, and how NPS manages its operation.

The 2015 GMP defined the desired resource conditions and visitor experiences to be achieved in BISC. It provided a framework for NPS managers to use when making decisions about how to best protect national park resources, how to provide a diverse range of visitor experience opportunities, how to manage visitor use, and what kinds of facilities, if any, to develop in the park. It also ensured that the foundation for decision making has been developed in consultation with interested stakeholders and adopted by NPS leadership after an analysis of the benefits, impacts and economic alternative courses of action.

A key component proposed in the GMP was a marine reserve zone where extractive uses (fishing) would be prohibited. The intent of management was to allow for a portion of the park's resources in the coral reef ecosystem to recover, and to offer visitors a high-quality experience associated with experiencing a “healthy” coral reef ecosystem. Ultimately, the marine reserve zone proved to be a very contentious and controversial issue. As of 2019, the park has not yet implemented the marine reserve zone that was a part of the selected alternative of the GMP.

Fishery Management Plan

BISC’s Fishery Management Plan was the result of a cooperative effort between Biscayne National Park and the Florida Fish and Wildlife Conservation Commission (FWC), consistent with the Park’s enabling legislation. The FMP presented a range of candidate alternatives and identified a preferred alternative which would guide fishery management strategy and decisions-making in BISC for the next decade. Both commercial and recreational fishing occur with Park boundaries and pose impacts to the longer-term sustainability of the park’s fisheries resources. A coherent and forward-looking FMP was considered fundamental to guide sustainable use of BISC’s fishery-related resources. The park and the FWC have worked cooperatively on this FMP under a Memorandum of Understanding (MOU) which stated that a marine reserve zone would be considered a last resort option for fisheries management; the MOU acknowledged that while a marine reserve zone was an alternative for other management purposes under GMP, the FMP would focus on less-restrictive measures first. As of 2019, BISC and FWC were working collaboratively to implement new proposed fishing regulations in the park.

2.3.2. Status of Supporting Science

In 2008, the South Florida/Caribbean Network Vital Signs Monitoring Plan identified high priority vital signs for BISC in conference with more than 100 local natural resource experts (Table 2-1, Patterson et al. 2008). Among the vital signs identified, several monitoring plans have been put in place. Water quality including both the measurement of salinity in response to CERP and nutrient levels have been monitored by multiple agencies including BISC. New invasive species are monitored along “corridors of invasion” by SFCN and the Exotic Plant Management Team treats as many acres as feasible. Marine benthic communities throughout the park have been monitored by a variety of agencies including park staff. In the coral reef ecosystems, percent cover of major taxonomic groups (i.e., stony corals, algae, gorgonians, sponges), coral species diversity, community structure, rugosity, recruitment, disease mortality, algal community structure, episodic events (bleaching and mortality) are all monitored. Within Biscayne Bay, seagrass and other SAV community composition, cover and habitat quality of seagrass and other SAV habitat are monitored. Marine fish taxa and communities in the coral reef ecosystem have been monitored since 1979 to estimate size-structured abundance and track rends in sustainability status through time. BISC has conducted a fishery dependent creel survey of recreational anglers and lobster fishers providing a separate account of the status of fisheries related resources. Since 2009, the number of colonial nesting birds has been monitored monthly at six islands. Sea turtle nesting areas along Elliott Key have been monitored during the nesting period to obtain nest location, number of eggs and hatching success. Terrestrial vegetation types along the Keys are monitored, with legacy plots to track changes in the tree community.

Table 2-1. Natural resource vital signs identified for the South Florida and Caribbean Network, including BISC (Reprinted from Patterson et al., 2008). Original table caption: Vital signs for the South Florida/Caribbean I&M Network. Vitals signs for which the network will develop protocols and implement monitoring using funding from the vital signs or water quality monitoring programs are indicated by [+ symbol]. The remaining vital signs will be monitored by a network park, another NPS program, or by another federal or state agency using other funding [◊]. The network will collaborate with these other monitoring efforts.

Vital Signs Category	Vital Sign	Example Measures	Parks where Implemented						
			BICY	BISC	BUIS	DRTO	EVER	SARI	VIIS
Air & Climate	Air quality – Deposition	Wet/dry deposition of anions, cations	–	–	–	–	◊	–	◊
	Air quality – Mercury	Mercury deposition	–	–	–	–	◊	–	–
Geology & Soils	Coastal Geomorphology	Soil elevation change	+	+	+	–	+	+	+
Water	Surface Water Hydrology	Water stage, flow, timing, and duration, freshwater discharge to estuaries, rainfall	◊	◊	+	◊	◊	+	◊
	Estuarine salinity patterns	Conductivity patterns in bays	–	◊	–	–	◊	–	–
	Water Chemistry	DO, pH, temperature, conductivity, organic carbon	◊	◊	◊	◊	◊	◊	◊
	Nutrient Dynamics	Nitrogen, Phosphorous	◊	◊	◊	◊	◊	◊	◊
	Periphyton (Freshwater)	Community composition and structure	+	–	–	–	◊	–	–
	Phytoplankton (Marine)	Location, size, duration, type of algal bloom events	–	◊	–	–	◊	–	–
Biological Integrity	Invasive/Exotic Plants	Species detected at common invasion points	+	+	+	+	+	◊	◊
	Invasive/Exotic Animals	Invasive fish species in canals and invasion points	+	◊	◊	◊	+	◊	◊
	Marine Benthic Communities	Coral % live cover, seagrass density, species diversity, community structure, disease incidence	–	+	+	+	◊	+	+

Table 2-1 (continued). Natural resource vital signs identified for the South Florida and Caribbean Network, including BISC (Reprinted from Patterson et al., 2008). Original table caption: Vital signs for the South Florida/Caribbean I&M Network. Vitals signs for which the network will develop protocols and implement monitoring using funding from the vital signs or water quality monitoring programs are indicated by [+ symbol]. The remaining vital signs will be monitored by a network park, another NPS program, or by another federal or state agency using other funding [◊]. The network will collaborate with these other monitoring efforts.

Vital Signs Category	Vital Sign	Example Measures	Parks where Implemented						
			BICY	BISC	BUIS	DRTO	EVER	SARI	VIIS
Biological Integrity (continued)	Mangrove-Marsh Ecotone	Community composition and structure	+	+	–	+	+	+	+
	Wetland Ecotones and Community Structure	Wet prairie-forest ecotones change	◊	◊	–	–	◊	–	–
	Forest Ecotones and Community Structure	Community composition & structure	+	+	+	+	+	+	+
	Marine Exploited Invertebrates	Lobster spatial/temporal distribution, abundance/density, size structure	–	+	+	+	+	+	+
	Aquatic Invertebrates In wet prairies & marshes	Community composition, abundance (density, relative abundance), MBI	+	–	–	–	–	–	–
	Marine Fish Communities	Fish community composition, abundance, diversity	–	+	+	+	◊	+	+
	Focal Fish Species	Goliath Grouper, Sharks, Spotted Sea trout, Snook relative abundance, distribution, size structure	–	◊	◊	◊	◊	◊	◊
	Freshwater fish and large macro-Invertebrates	Community composition, abundance (density and relative abundance), size structure	+	–	–	–	◊	–	–

Table 2-1 (continued). Natural resource vital signs identified for the South Florida and Caribbean Network, including BISC (Reprinted from Patterson et al., 2008). Original table caption: Vital signs for the South Florida/Caribbean I&M Network. Vitals signs for which the network will develop protocols and implement monitoring using funding from the vital signs or water quality monitoring programs are indicated by [+ symbol]. The remaining vital signs will be monitored by a network park, another NPS program, or by another federal or state agency using other funding [◊]. The network will collaborate with these other monitoring efforts.

Vital Signs Category	**Vital Sign**	**Example Measures**	**Parks where Implemented**						
			BICY	**BISC**	**BUIS**	**DRTO**	**EVER**	**SARI**	**VIIS**
Biological Integrity (continued)	American Alligator	Density, sex, and age ratio	◊	–	–	–	◊	–	–
	Amphibians	distribution, community composition	+	–	–	–	+	–	+
	Colonial Nesting Birds	Location, size of colonies by species, fledging success	◊	+	◊	◊	◊	◊	◊
	Marine Invertebrates – Rare Threatened, Endangered	Species dependent (*Acropora* sp., *Diadema*, *Antipathes* sp.)	–	+	+	+	–	+	+
	Sea Turtles	Nest counts and distribution, eqq counts/nest, hatching success	–	◊	◊	◊	◊	–	◊
	American Crocodile	Abundance, nests/region, size	–	◊	–	–	◊	–	–
	Protected Marine mammals	Distribution, abundance, size, condition (manatees, dolphins)	◊	◊	–	–	◊	–	–
	Florida panther	Abundance, distribution, recruitment, mortality	◊	–	–	–	◊	–	–
	Sawfish	Distribution, relative abundance, recruitment	–	◊	–	–	◊	–	–
Human use Landscapes (Ecosystem Pattern and Processes)	Visitor Use	Distribution and abundance of visitors	◊	◊	◊	◊	◊	◊	◊

Table 2-1 (continued). Natural resource vital signs identified for the South Florida and Caribbean Network, including BISC (Reprinted from Patterson et al., 2008). Original table caption: Vital signs for the South Florida/Caribbean I&M Network. Vitals signs for which the network will develop protocols and implement monitoring using funding from the vital signs or water quality monitoring programs are indicated by [+ symbol]. The remaining vital signs will be monitored by a network park, another NPS program, or by another federal or state agency using other funding [◊]. The network will collaborate with these other monitoring efforts.

Vital Signs Category	**Vital Sign**	**Example Measures**	**Parks where Implemented**						
			BICY	**BISC**	**BUIS**	**DRTO**	**EVER**	**SARI**	**VIIS**
Human use Landscapes (Ecosystem Pattern and Processes) (continued)	Fire Return Interval	Fire location, size, time since last bum	◊	–	–	–	◊	–	–
	Vegetation Communities Extent & Distribution	Extent, distribution, shape, orientation of vegetation community types using remote sensing	+	+	+	+	◊	+	+
	Benthic Communities Extent & Distribution	Extent and distribution of benthic community types using remote sensing	–	+	+	+	+	+	+
	Land Use Change	Land use change, permitting/zoning changes	+	+	–	–	+	+	+

Chapter 3. Study Scoping and Design

3.1. Preliminary Scoping

On January 20, 2016, an initial meeting was held at BISC headquarters between the investigators and the Chief of Resource Management and relevant Program Managers to make formal introductions, and to discuss rationale for creation of a draft of priority resources for the park. The meeting also marked the beginning of data scoping and the initial evaluation of resource condition status. The need for consistency with other reports created by or with BISC and NPS staff was also discussed. These reports include: the SFCN Inventory and Monitoring Program publications;2015 Integrated Biscayne Bay Ecological Assessment and Monitoring (IBBEAM); BISC Site Characterization;, the 2014 System Status Report and 2014 System-wide Ecological Indicator Report for Everglades Restoration. Data collection for this report concluded in 2017 and newer reports and data may exist.

Thus, the goal of this NRCA is to build off these previous efforts by consolidating a vast amount of research into a single document that is easy to access, and to integrate additional data where possible. In doing so, we worked closely with BISC and SFCN staff to gather and assimilate information on key natural resources. Intimate involvement with BISC and SFCN marine fish and benthic resource monitoring programs allowed multiple filed days and direct interaction with key staff biologists, collecting critical new data and discussing the scope and intent of this NRCA. On October 17, 2016, an NRCA update meeting was held at the University of Miami RSMAS with attendees representing the full spectrum of leadership, scientists, and managers from BISC and Dry Tortugas National Park (DRTO), as well as SFCN (Appendix A). At that meeting, a provisional list of focal resources, all known data sources, and possible assessment metrics for evaluating status and trends was discussed.

3.2. Study Design

3.2.1. Indicator Framework, Focal Study Resources and Indicators

A hierarchal approach for summarizing resource status across BISC was used. Focal resources were first identified (i.e., sea turtles, reef fish, seagrass) and a list of condition metrics were generated from which to evaluate their status and trends. Chapter four of this report includes individual sections for each focal resource that contain a single condition status. The focal resources were grouped into broader ecological attributes that were given a condition status (Table 3.1). Finally, the overall park status was created by combining the ecological attribute conditions. This hierarchal design allowed for data from a wide range of sources to be incorporated and scored. The high level of interconnectivity among focal resources allowed for the larger synthesis of all resources within BISC.

3.2.2. Reporting Areas

The mainland mangrove shorelines, coastal bays, barrier islands, and coral reefs within BISC embody the key ecological components of a functional tropical marine ecosystem, all within the single Park unit. In this environment, nursery, juvenile and adult habitats are available for a huge and diverse range of resident and migratory marine fish, bird, mammal, and reptile species. Amongst these diverse ecological units, there are strong interconnected ecological linkages, as many organisms move throughout the ecosystem and are dependent on several to all of them for their existence.

Table 3.1. Ecological attributes, focal resources and indicators, dates of assessment and major references or program used to measure the status and trends of natural resources within BISC.

Ecological Attributes	Focal Resource	Indicators and Measures Criteria
Chemical / Physical	Water Quality	Salinity
	Water Quality	Phytoplankton blooms
	Water Quality	CHLA measurements
	Water Quality	Presence of contaminants
Biological – Plants	Seagrass Communities	Acreage
	Seagrass Communities	Species composition
	Seagrass Communities	Percent coverage
	Mangrove and Hardwood Forests	Acreage (mangroves and hardwood forests)
	Mangrove and Hardwood Forests	Hardwood forest community structure
	Mangrove and Hardwood Forests	Invasive species
Biological – Marine Invertebrates	Hard Corals	Percent coverage
	Hard Corals	Bleaching prevalence
	Hard Corals	Mortality
	Hard Corals	Abundance of threatened species
	Hard Corals	Seawater temperature
	Spiny Lobster, Pink Shrimp, Queen Conch and Long-spined Sea Urchin	Recreational CPUE (lobster)
	Spiny Lobster, Pink Shrimp, Queen Conch and Long-spined Sea Urchin	Commercial landings
	Spiny Lobster, Pink Shrimp, Queen Conch and Long-spined Sea Urchin	Bait shrimp CPUE
	Spiny Lobster, Pink Shrimp, Queen Conch and Long-spined Sea Urchin	Shrimp density
	Spiny Lobster, Pink Shrimp, Queen Conch and Long-spined Sea Urchin	Conch density and presence of aggregations
	Spiny Lobster, Pink Shrimp, Queen Conch and Long-spined Sea Urchin	Urchin density
Biological – Marine Vertebrates	Reef Fish, Gamefish and Sharks	Average length of key species (recreational fishery)
	Reef Fish, Gamefish and Sharks	Average length of key species (fishery independent survey)
	Reef Fish, Gamefish and Sharks	Density of exploited species
	Sea Turtles	Number of loggerhead nests
	Sea Turtles	Predation rate

Table 3.1 (continued). Ecological attributes, focal resources and indicators, dates of assessment and major references or program used to measure the status and trends of natural resources within BISC.

Ecological Attributes	Focal Resource	Indicators and Measures Criteria
Biological – Marine Vertebrates (continued)	Sea Turtles	Hatch success rate
	Sea Turtles	Nesting success rate
	Sea Turtles	Distance of nest from high tide
	Sea Turtles	Strandings
	Bottlenose Dolphins, Florida Manatees, America Crocodiles	Population size dolphins
	Bottlenose Dolphins, Florida Manatees, America Crocodiles	Population Size manatees
	Bottlenose Dolphins, Florida Manatees, America Crocodiles	Growth rate (crocodiles)
	Bottlenose Dolphins, Florida Manatees, America Crocodiles	Hatchling survival (crocodiles)
Biological – Terrestrial Vertebrates	Birds	Shorebird survey counts
	Birds	Shorebird species richness
	Birds	Annual peak count of colonial nesting birds
	Birds	Annual nesting index (colonial nesting birds)
	Birds	Changing in timing of peak nest counts
	Birds	White crowned pigeon counts
	Birds	Species richness (Christmas Bird Count)

Blue land crab in BISC (Photo by Judd Patterson)

3.2.3. General Approach and Methods

Focal natural resources could have multiple metrics by which its status could be evaluated. A range of synthesized information from resource monitoring, by NPS or partner agencies, and key published scientific research was used to determine the status and trends of focal resources. When available, existing reference conditions or desired conservation states were used to estimate each metric for a focal resource. When unavailable, discussions with local experts where used to determine a reference condition. To facilitate a meaningful, non-technical discussion, each metric was summarized by a status/trend/confidence icon using the scheme outlined below in Table 3.2. The color of the icon indicates condition, the arrow indicates trend, and the outline indicates the degree of confidence in the assessment. Icons that summarize undetermined conditions have no color, and resources that have not been monitored long enough to discern trends have icons with no arrow (see Table 3.3 for an example).

The aggregation of indicators for each metric within a focal resource was conducted using guidance from national State of the Park guidance. To determine the combined condition, each red symbol was assigned zero points, each yellow symbol was assigned 50 points, and each green symbol 100 points. Open (uncolored) circles were omitted from the calculation. Once the average was calculated, the scale in Table 3.4 was used to determine the resulting condition. The trend was determined by subtracting the total number of down arrows from the total number of up arrows. If the result was 3 or greater, the overall trend was up. If the result was −3 or lower, the overall trend was down. If the result was between 2 and −2, the overall trend was unchanged. Sideways trend arrows and cases where trend was unknown were omitted from this calculation. In some cases, equal weighting was not applied for aggregation purposes when individual metrics were determined to be more important than others. Documentation of where and why this was done is provided in each Chapter 4 section.

Table 3.2. Indicator symbols used to indicate condition, trend, and confidence in the assessment.

Condition Status		Trend in Condition		Confidence in Assessment	
	Resource is in Good Condition		Condition is Improving		High
	Resource warrants Moderate Concern		Condition is Unchanging		Medium
	Resource warrants Significant Concern		Condition is Deteriorating		Low

Table 3.3. Example indicator symbols and descriptions of how to interpret them in WCS tables.

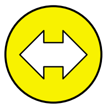
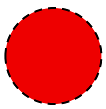
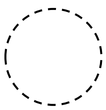
Symbol Example	Description of Symbol
	Resource is in good condition; its condition is improving; high confidence in the assessment.
	Condition of resource warrants moderate concern; condition is unchanging; medium confidence in the assessment.
	Condition of resource warrants significant concern; trend in condition is unknown or not applicable; low confidence in the assessment.
	Current condition is unknown or indeterminate due to inadequate data, lack of reference value(s) for comparative purposes, and/or insufficient expert knowledge to reach a more specific condition determination; trend in condition is unknown or not applicable; low confidence in the assessment.

Table 3.4. Scale for aggregating condition scores for multiple metrics for a focal reference.

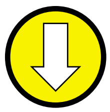
Score 0 to 33	Score 34 t0 66	Score 67 to 100
Red	Yellow	Green

Chapter 4. Natural Resource Conditions

4.1. Water Quality

Water quality condition in BISC including salinity, nutrients, and contaminants warrants moderate concern and the condition is deteriorating (Table 4.1.1). There is high confidence in this status based on several monitoring programs in place.

Table 4.1.1. Water quality condition status and trend.

Attribute	Condition & Trend	Interpretation
Salinity, Nutrients, and Contaminants		Nearshore salinity levels have not met desired conditions warranting moderate concern. High nutrient levels generating periodic phytoplankton and algae blooms inside and adjacent to the park are of significant concern. Contaminants found in the bay waters and animals is an ongoing concern. Overall, the bay has endured a number of human induced stressors and there is general concern that the health of the bay is at a tipping point.

4.1.1. Importance

More than 95% of the surface area of BISC is marine waters, and the park encompasses a large portion of Biscayne Bay (henceforth ‘the bay’), an area greatly influenced by human activities. The bay is a classic shallow water oligotrophic system with extensive seagrass beds. Historically, bay waters within BISC were more estuarine with relatively low salinity due to significant freshwater inputs through “transverse glades”.

The bay supports a tremendous diversity of marine fishes, invertebrates, birds, mammals and reptiles, and is principal nursery ground for many species found throughout the park. Hydrological changes in conjunction with rapidly increasing urban population have altered the quantity, quality and timing of freshwater inputs and changed the bay. The bay’s water quality may also affect the health of the reefs as tidal flux results in high connectivity between the two systems.

4.1.2. Stressors

Over the past 50 years, there has been both an increase in nutrient loading, and a transition to a more marine (higher salinity) environment in the bay. This transition has occurred in conjunction with reductions in freshwater flows to the bay, and intense pulses of freshwater followed by long periods of no inputs, in contrast to more constant flows in the past. These changes have disrupted the finely balanced ecosystem and have had a deleterious impact on organisms throughout the bay.

In recent years, the bay has experienced general higher salinity along with episodic hypersalinity events (>35 practical salinity units (psu)) in the nearshore environment that have affected the distribution and health of submerged aquatic vegetation and the associated fish species (Serafy et al., 1997; Lirman and Cropper, 2003; Lirman et al., 2008; Santos et al., 2011). Higher levels of nutrients from various sources have resulted in three major algal blooms. In 2005/06, a cyanobacteria bloom in southern Biscayne Bay impacted corals, sponges, seagrasses, lobster, fish, and shrimp. A macroalgal bloom (*Anadyomene stellata* and *Anadyomene* sp.) just north of the BISC boundary on the western edge of Biscayne Bay reduced seagrass coverage (Collado-Vides et al., 2013). In 2013, a diatom bloom in central Biscayne Bay marked the first open water algae bloom since monitoring began and is cause for great concern. In addition to higher salinity and increased nutrients, a variety of contaminants from the mainland have entered the bay with often negative consequences (Litz et al., 2007; Carriger and Rand, 2008; Mitsova et al., 2011).

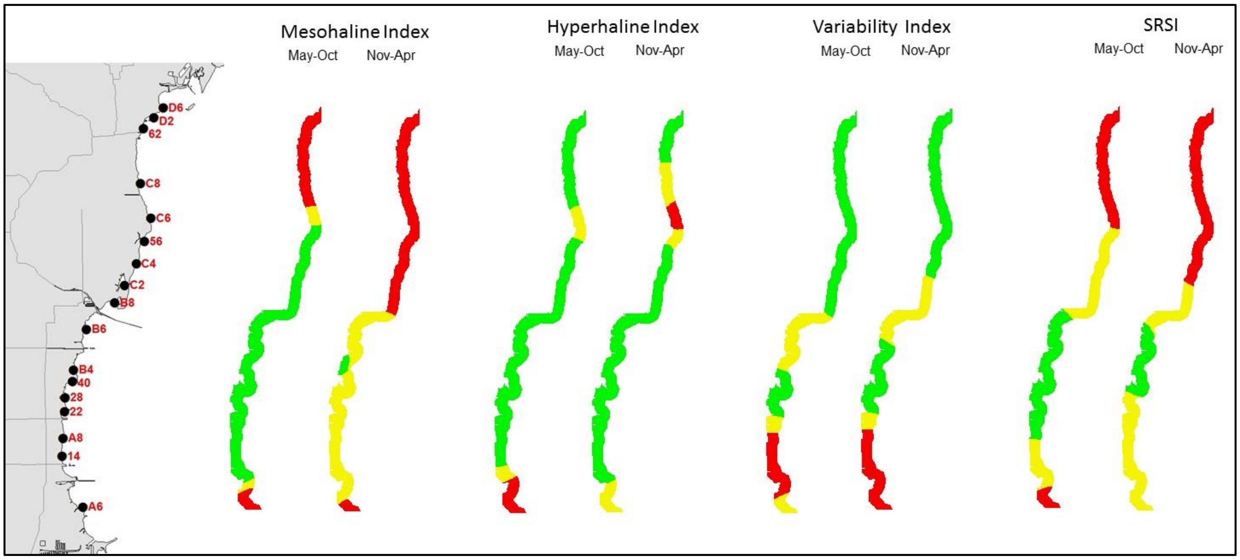
4.1.3. Monitoring Programs

The quality of the water in the bay is paramount to the health and survival of natural resources in the park. As such, there is significant effort in monitoring salinity and nutrient levels throughout the bay. The most detailed information on nearshore surface salinity in the bay is collected through the Integrated Biscayne Bay Ecological Assessment and Monitoring program (IBBEAM). The nearshore by salinity is affected by a number of factors including the extent of the Biscayne aquifer which was recently evaluated by the United States Geological Survey (USGS). Nutrient levels, associated Chlorophyll A (CHLA) concentrations and phytoplankton blooms for the bay are summarized in the Systems-wide Indicators for Everglades Restoration Report, the 2014 Systems Status Report and reports from Florida International University (FIU) and the National Park Service (NPS). In addition to these reports, there has been extensive scientific research involving the effects of salinity and nutrients on the bay that can be used to help understand the status and condition of water quality.

4.1.4. Salinity

<u>The Integrated Biscayne Bay Ecological Assessment and Monitoring program (IBBEAM)</u>
The Comprehensive Everglades Restoration Plan (CERP), which was authorized by Congress in 2000, is a plan to restore, preserve, and protect the south Florida ecosystem. Within this plan, includes a goal to improve the spatial distribution of freshwater into the bay. The establishment of a salinity regime that maintains healthy benthic habitats in Biscayne Bay is a prerequisite to successful estuarine restoration as identified by CERP and NPS. The goal of IBBEAM is to collect and analyze data from the western shoreline of the bay to track and gauge the efficiency of CERP. The program manages a salinity monitoring network with measurement targets that include: frequency and duration of mesohaline conditions (salinity between 5–18 psu), frequency and duration of hypersalinity events (>40 psu) and the frequency of high variation in salinity (days with range > 5 psu). These indices are combined to calculate a salinity regime suitability index (IBBEAM, 2015). Each of these indices is compared with a reference site in Florida Bay that has the approximate conditions that would be associated with restored flow to Biscayne Bay and a biological community representative of the target communities for the Biscayne Bay shoreline.

In the 2015 IBBEAM Report, the mesohaline index revealed that only a few sampled areas were optimal in terms of the preferred water quality restoration characteristics for CERP. Hypersalinity, which is a major ecological concern, did not occur every year in Biscayne Bay; however, the condition was reported in four of 11 years (IBBEAM, 2015). These events are more likely to occur during the end of the dry season when evapotranspiration rates are high, precipitation rates are low and canal discharge rates (which are positively correlated with precipitation) are also low (Lohmann et al., 2012). Salinity variability differed both spatially and seasonally, with some stations close to canals experiencing significant fluctuations. A composite of these measurements was used to generate a salinity regime suitability index (SRSI) which indicated poor salinity habitat suitability at the northern and most southern extremes of the project domain during the dry season (November through April) and greater suitability (around and south of Black Point) during the wet season (May through October) (IBBEAM, 2015). In relation to conditions recorded at the Florida Bay reference site, salinity environments of western Biscayne Bay are not adequate to support the target biological communities. As of 2014, “the IBBEAM results continue to indicate that Biscayne Bay's nearshore environment does not constitute the consistent, expansive mesohaline habitat that CERP seeks to re-establish.” (Figure 4.1.1) (IBBEAM, 2015).



	Red	Yellow	Green
Mesohaline Index	Min = Lowest value in matrix	50%	Max = Mean seasonal value at DJ*
Hypersaline Index	Max = Highest value in matrix	50%	Min = Mean seasonal value at DJ*
Variability Index	Max = Highest value in matrix	50%	Min = Mean seasonal value at DJ*
SRSI	Min = Lowest value in matrix	50%	Max = Mean seasonal value at DJ*

Red = Not Suitable
Yellow = Adequate
Green = Optimal

**DJ =Downstream Joe Bay, 25.21665 N and -80.55563W, chosen reference site, data provided by J. Lorenz (The Coastal Wetlands Monitoring and Assessment Project, Florida Audubon Tavernier Science Center, unpublished data)*

Figure 4.1.1. Simplified color scheme for IBBEAM salinity index and map of Salinity indices from IBBEAM as averages from 2004–2014. May–October (wet season), November–April (dry season). (Reprinted from IBBEAM, 2015).

Biscayne aquifer and saltwater intrusion

In conjunction with increased salinity in nearshore waters, salt water intrusion into the Biscayne aquifer has continued to encroach along the base of the aquifer (Prinos et al., 2014). Currently about 1,200 km^2 of the aquifer has been encroached by saltwater. Between 1995 and 2011, 24.1 km^2 of additional intrusion was mapped and measured (Prinos et al., 2014). Numerous freshwater springs both onshore and offshore in the bay that were once described by early residents and visitors appear to have been significantly reduced (Munroe and Gilpin, 1930; Parks, 1987). Today, models indicate a freshwater input ratio of canal/precipitation/ groundwater of 37%:53%:10% in the wet season and 40%:55%:5% in the dry season (Stalker et al., 2009). Prior to the development of south Florida, water levels were sufficiently high to maintain freshwater in the Biscayne aquifer close to the coast creating a natural barrier preventing saltwater intrusion (Parker, 1945). In addition, the creation of canals without lining have allowed saltwater to creep through the porous limestone into the aquifer during the dry season when freshwater levels are lower. The continued encroachment of saltwater into the aquifer is of concern and underscores the issues involving freshwater inputs and salinity in the nearshore environment of the bay.

4.1.5. Nutrients

System-wide Indicators for Everglades Restoration 2014

The 2014 System-wide Indicators for Everglades Restoration Report, a digest of system-wide ecological indicators for the south Florida ecosystem, includes a phytoplankton blooms indicator that reflects the overall water quality condition in Biscayne Bay (Brandt et al., 2014). Chlorophyll a (CHLA) concentrations which indicate algal biomass can be used as reference conditions (Boyer et al., 2009). In Brandt et al. (2014), data from 1989–2014 are used to establish a median concentration from which current conditions can be measured. In 2014, the authors reported that unprecedented algal bloom and increasing phytoplankton blooms over 20 years suggest water quality in Biscayne Bay in systematically degrading and appears to be near a tipping point with macroalgae replacing seagrass (Figure 4.1.2).

> *"If this tipping point is surpassed it will be far more costly to restore Biscayne Bay than it is to protect and improve water quality now. Thus, future restoration decision should in the near-term focus on improving water quality in Biscayne Bay and at an absolute minimum stop the degradation of water quality. Any restoration project with the potential to degrade water quality in Biscayne Bay should be carefully evaluated to ensure that water quality degradation is not an unwanted byproduct of the project."* (Brandt et al., 2014)

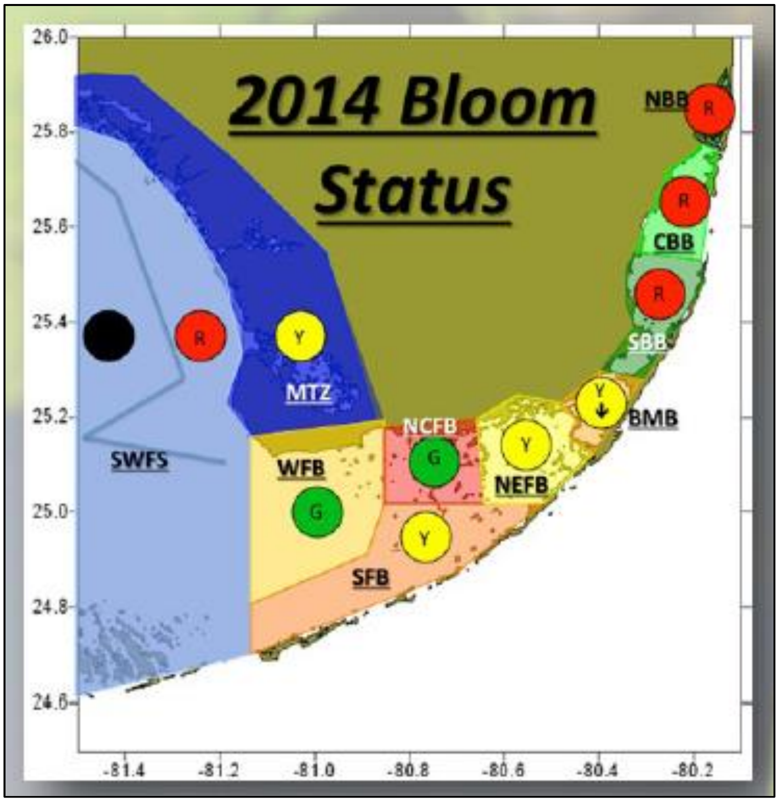


Figure 4.1.2. 2014 phytoplankton bloom status for south Florida including Biscayne Bay (reprinted from Brandt et al., 2014 System-wide Indicators for Everglades Restoration).

<u>2014 Systems Status Report</u>

This report, which cover the water-year periods 2009–2012, includes information from the Biscayne Bay Water Quality Monitoring Program, a cooperation between Miami-Dade County and the Miami Dade County and the South Florida Water Management District. In 2012, the State of Florida established numeric nutrient criteria for total phosphorous (TP), total nitrogen (TN) and CHLA for nine indicator regions within Biscayne Bay (Figure 4.1.3 and Table 4.1.2). Compliance with criteria is based on a single exceedance of the annual geometric mean in a three year period (Table 1). While TP and TN fell well below the criteria, the majority of CHLA values fell slightly above or below the criteria signifying concern (Table 4.1.3).

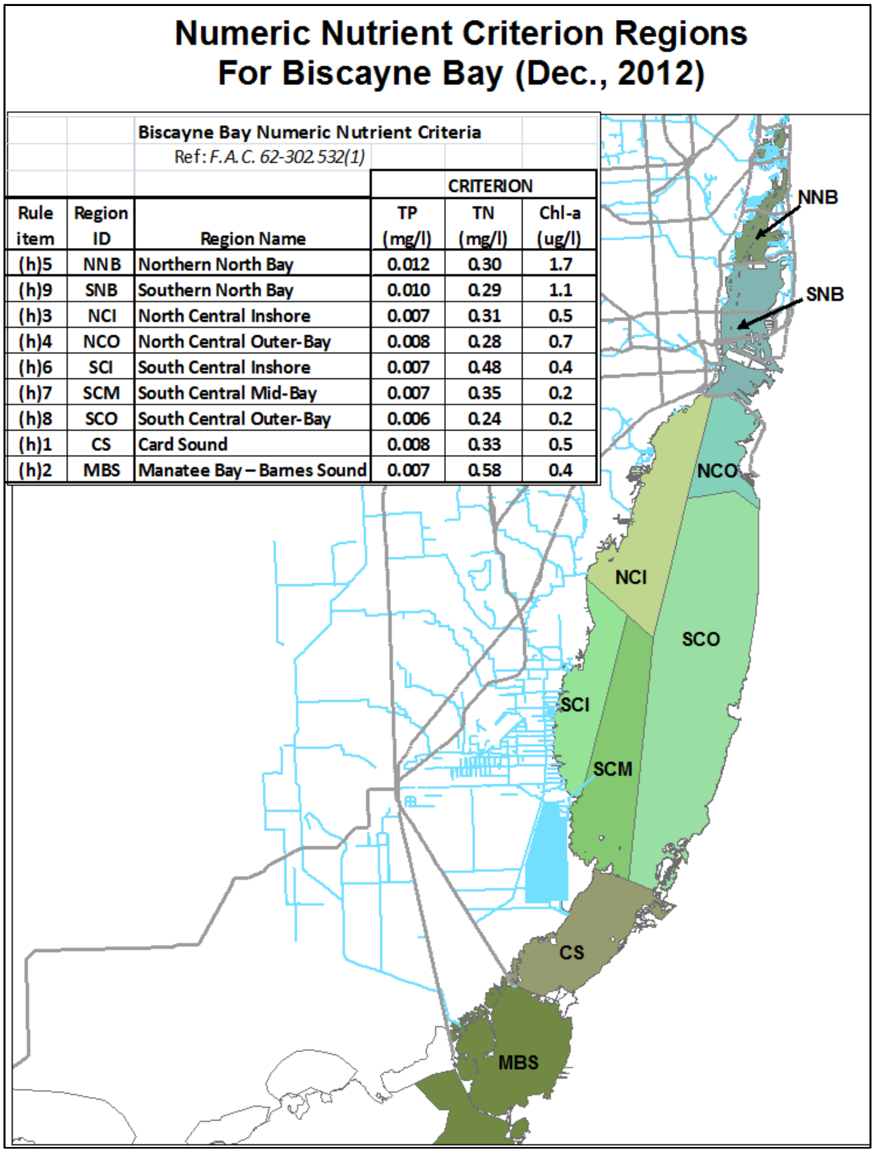


Figure 4.1.3. State of Florida numeric nutrient criteria (62-302.532(h) Florida Administrative Code), 2012. (Reprinted from Systems Status Report, 2014). The tabular data shown in the figure above can also be seen in Table 4.1.2

Table 4.1.2. A table showing the tabular data displayed in Figure 4.1.3 above. This is a more accessible version for people that depend on special screen reding software designed for people with visual and certain cognitive impairments (per NPS policy related to Section 508 of the Rehabilitation Act).

Rule Item	Region ID	Region Name	Criterion		
			TP (mg/l)	**TL (mg/l)**	**Chl-a (mg/l)**
(h)5	NNB	Northern North Bay	0.012	0.30	1.7
(h)9	SNB	Sothern North Bay	0.010	0.29	1.1
(h)3	NCI	North Central Inshore	0.007	0.31	0.5

Table 4.1.2 (continued). A table showing the tabular data displayed in Figure 4.1.3 above. This is a more accessible version for people that depend on special screen reding software designed for people with visual and certain cognitive impairments (per NPS policy related to Section 508 of the Rehabilitation Act).

Rule Item	Region ID	Region Name	Criterion		
			TP (mg/l)	TL (mg/l)	Chl-a (mg/l)
(h)4	NCO	North Central Outer-Bay	0.008	0.28	0.7
(h)6	SCI	South Central Inshore	0.007	0.48	0.4
(h)7	SCM	South Central Mid-Bay	0.007	0.35	0.2
(h)8	SCO	South Central Outer-Bay	0.006	0.24	0.2
(h)1	CS	Card Sound	0.008	0.33	0.5
(h)2	MBS	Manatee Bay -Bames Sound	0.007	0.58	0.4

Table 4.1.3. CHLA concentrations in 9 Biscayne Bay regions from 2009–2012 with shading indicating compliance with State of Florida standards. (System Status Report, 2014).

Region ID	Region Name	Criterion	AGM for Chlorphyll-a Concentration (ug/l)			
			2009	2010	2011	2012
MBS	Manatee Bay - Barnes Sound	0.4	0.51 [a]	0.66 [a]	0.66 [a]	0.70 [a]
CS	Card Sound	0.5	0.31 [b]	0.47 [b]	0.34 [b]	0.38 [b]
SCI	South Central Inshore	0.4	0.31 [b]	0.49 [b]	0.47 [a]	0.46 [a]
SCM	South Central Mid-Bay	0.2	0.22 [a]	0.35 [a]	0.31 [a]	0.28 [a]
SCO	South Central Outer Bay	0.2	0.26 [a]	0.35 [a]	0.25 [a]	0.24 [a]
NCI	North Central Inshore	0.5	0.53 [a]	0.51 [a]	0.42 [a]	0.46 [b]
NCO	North Central Outer-Bay	0.7	0.47 [b]	0.68 [b]	0.51 [b]	0.48 [b]
SNB	Southern North Bay	1.1	0.73 [b]	0.87 [b]	0.85 [b]	0.88 [b]
NNB	Northern North Bay	1.7	1.36 [b]	1.74 [b]	1.61 [b]	1.65 [b]

[a] Region is not compliant with Numeric Nutrient Criteria Standard (also shaded in light orange).

[b] Region is compliant with Numeric Nutrient Criteria Standard (also shaded in light green).

FIU Monitoring and 2011 NPS Report

FIU scientists monitored 39 fixed stations within the park (1991–2008) and authored a 2011 report on the ecological impacts on Biscayne Bay and Biscayne National Park from the proposed south Miami-Dade County development (Briceño et al., 2011). Their findings suggested regional differences in water quality throughout Biscayne Bay. In the regions that are encompassed by BISC, as shown in Figure 4.1.3, the north-central bay had intermediate CHLA, TP, inorganic nitrogen and turbidity, the south-central bay had the lowest CHLA, turbidity, and highest inorganic nitrogen concentrations; and the south Bay had the highest total nitrogen TN, total organic nitrogen (TON) and total organic carbon (Briceño et al., 2011).

4.1.6. Contaminants

Surface water

The water quality in BISC is highly influenced by land use patterns in a watershed comprised of both a densely populated urban center and a concentrated agricultural center (Caccia and Boyer, 2005). Contaminant monitoring in Biscayne Bay has focused on current and legacy pesticides as well as on metals and other industrial pollutants. In 2009–2011, the SFCN in collaboration with the USGS assessed baseline levels of emerging pollutants of concern and wastewater contaminants that enter the nearshore waters of BISC. Water sampling, sediment and fish samples have been collected and a baseline aquatic contamination and endocrine status for a resident fish species of BISC has been established (Bargar et al., 2017)

Between 1995 and 1996, NOAA performed extensive testing throughout Biscayne Bay investigating the toxicity of sediments and chemical contamination (Long et al., 1999). The results suggested that both the degree and spatial extent of chemical contamination and toxicity in the bay were similar to or less than those observed in many other areas in the U.S. The authors found that chemical contamination and toxicity levels were comparable to the national averages calculated by NOAA from previous surveys conducted in a similar manner (Long et al., 1999). However, more recent studies of terrigenous pollutants in Biscayne Bay have raised greater concern. Carriger and Rand (2008) revealed a potential hazard for insecticides affecting organisms in the southern portion of the bay. Mitsova et al. (2011) found polycyclic aromatic hydrocarbons (PAHs) in the sediments of canals entering BISC likely from stormwater runoff. Litz et al. (2007) detected persistent organic pollutants (POPs) and polychlorinated biphenyl (PCB) congeners in bottlenose dolphins in the bay.

4.1.7. Offshore Water Quality

Water quality offshore of the keys in BISC can have a significant effect on the health of the coral reefs. Increased levels of nutrients can lead to higher growth rates of competing macroalgae (Fabricius, 2005), increase the severity of coral diseases (Bruno et al., 2003) resulting in coral mortality (Smith et al., 2006). The US Environmental Protection Agency funds a water quality monitoring project throughout the Florida Keys National Marine Sanctuary (FKNMS) as part of a larger water quality protection program. Briceño and Boyer (2014) indicated that the offshore waters of BISC have similar water quality to the upper Florida Keys. Dissolved nutrients (total phosphorus and nitrogen), CHLA and turbidity, measurements are below EPA thresholds indicating healthy water quality in reef areas. Surface turbidity which can be an indicator of increased nutrients has remained stable from 1995–2014 (Figure 4.1.4). Other measurements of water quality also have shown minor changes during this same period in the offshore waters of BISC (Briceño and Boyer, 2014).

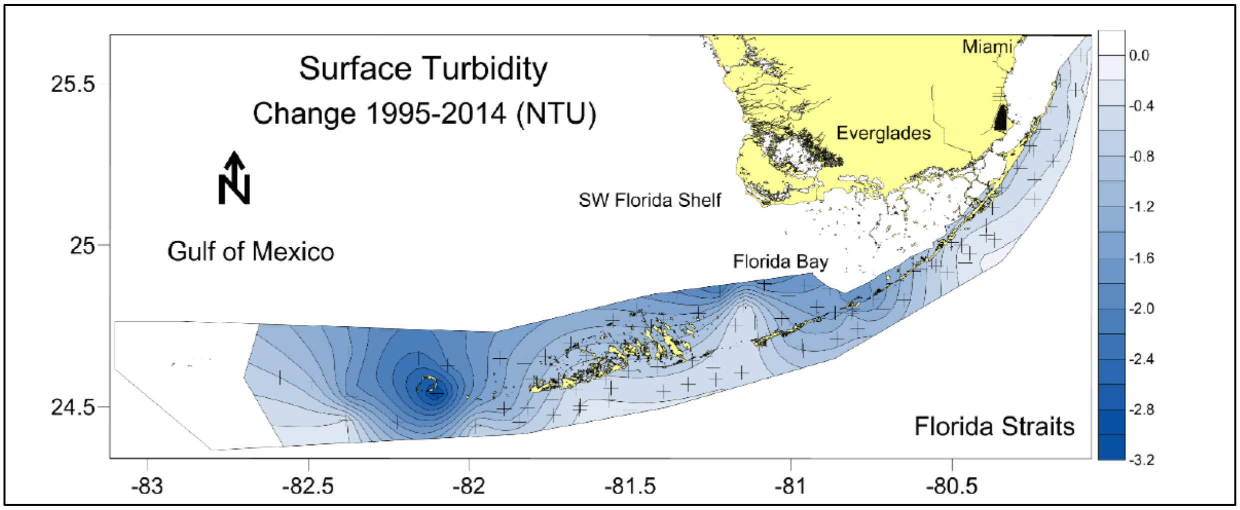


Figure 4.1.4. Total change in turbidity in surface waters for 20 year period calculated from significant trends ($p<0.10$). (Reprinted from Briceño and Boyer, 2014).

4.1.8. Conclusion

The bay and offshore waters of BISC offer an exceptional opportunity for visitors to escape the urban bustle and enjoy nature. Although the park's waters continue to provide a safe place to swim and harvest seafood, several changes in the water quality have had an effect on the finely balanced ecosystem (Table 4.1.4). Nearshore surface salinity and variability is higher than the desired state and has not met the restoration criteria of CERP. Saltwater intrusion into the Biscayne Aquifer has continued, exasperating the issue of high surface water salinity. Higher than desired levels of nutrients and CHLA have been recorded along with algae blooms within Biscayne Bay. Offshore waters remain below EPA targets and a similar to other regions in the Florida Keys. A variety of contaminates have entered the bay and there is some uncertainty as to their effect of wildlife. Biscayne Bay is under a tremendous strain due to its proximity to high density urban area in the north and large agricultural regions in the south. The bay conditions seem to be on a tipping point which warrants moderate concern.

Table 4.1.4. Conditions and trends of water quality metrics in BISC for years ranging from 2012–2015.

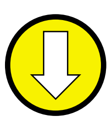
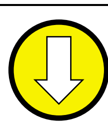
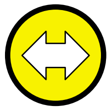
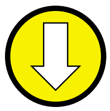
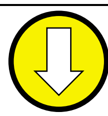
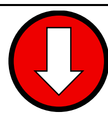
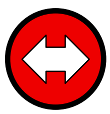
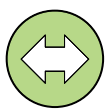
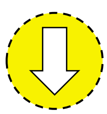
Criteria	Condition & Trend	Rationale	Reference Condition
Nearshore mesohaline conditions		Few sampled areas were optimal in terms of the preferred water quality restoration characteristics for CERP	Proportion of salinity observations ≥5 and <18 psu as compared to Florida Bay reference station (IBBEAM, 2015)
Nearshore hypersalinity events		Does not currently occur every year but was recorded in four of the last 12 years (2003–2015).	Proportion of salinity observations > 40 psu as compared to Florida Bay reference station (IBBEAM, 2015)

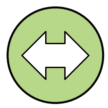
Table 4.1.4 (continued). Conditions and trends of water quality metrics in BISC for years ranging from 2012–2015.

Criteria	Condition & Trend	Rationale	Reference Condition
Nearshore salinity variability		The magnitude of salinity variability differed both spatially and seasonally. Some stations close to the canals experienced significant fluctuations, but there was no overall trend.	Proportion of days where salinity range is > 5 psu as compared to Florida Bay reference station (IBBEAM, 2015)
Salinity regime suitability index		Salinity environments are presently (as of 2015) not adequate to support the target biological communities.	Combination of mesohaline, hypersalinity and variability indices as compared to Florida Bay reference station (IBBEAM, 2015)
Area of saltwater intrusion of Biscayne aquifer		Between 1995 and 2011, 24.1 km^2 of saltwater intrusion was measured.	No new saltwater encroachment into Biscayne aquifer
Phytoplankton blooms in Bay		Unprecedented and increasing algal bloom in the bay	No blooms
CHLA measurements in bay		In 2012, 4 out of 9 regions of Biscayne Bay are non-compliant with numeric CHLA criteria	Florida State numeric nutrient criteria (Figure 4.1.3)
Offshore nutrients		As reported in 2014, offshore nutrients have been stable and are below EPA targets.	CHLA <= 0.35 µg l^{-1} as per EPA strategic targets for reef sites
Presence of contaminants		Testing in 1990s showed few contaminants but studies from 2008–2011 suggest that there may be problems.	Levels below national standards

4.2. Seagrass

Seagrass beds within BISC are in good condition and appear to be relatively stable despite declines on the periphery of park (Table 4.2.1).

Table 4.2.1. Seagrass condition status and trend.

Attribute	Condition & Trend	Interpretation
Biscayne Bay Seagrasses		Seagrass beds constitute a vast majority (90%) of benthic habitat within BISC. Acreage and species composition appear to be stable, though dramatic declines on the periphery of the park warrants moderate concern for the nearshore seagrass community.

4.2.1. Importance

The seagrass beds throughout BISC are highly productive and a key biological component of a healthy marine ecosystem. They provide essential habitat for a wide range of marine species, play a major role in nutrient cycling in Biscayne Bay, and provide stabilization of marine sediments. A benthic habitat map derived from aerial photography and satellite imagery from 2009 indicates that BISC contains 54,430 ha of continuous seagrass and 5,385 ha of discontinuous seagrass habitat (Davis, 2013) (Figure 4.2.1). The most common species of sea grass in the bay is turtle grass (*Thalassia testudinum*) followed by manatee grass (*Syringodium filiforme*), which is more common in northern sections of the bay, and shoal grass (*Halodule wrightii*) found closer to shore. The sea grass beds are also interspersed with a variety of calcareous green macroaglae along with sponges and small corals in some areas (Lirman et al., 2003). These areas provide critical habitat for over 200 species of juvenile and adult fish many of which are highly important for recreational fisheries (J. Ault unpublished data). Pink shrimp (*Farfantepenaeus duorarum*) and spiny lobster (*Panulirus argus*), which are the two most important commercial fisheries in BISC, depend on healthy seagrass beds throughout their life cycles. They are also important food and/or habitat for federally listed species found in the park such as green sea turtles (*Chelonia mydas*), Florida manatees (*Trichechus manatus latirostris*), and smalltooth sawfish (*Pristis pectinata*) (Bjorndal, 1980; Bengtson, 1983; Simpfendorfer and Wiley, 2004).

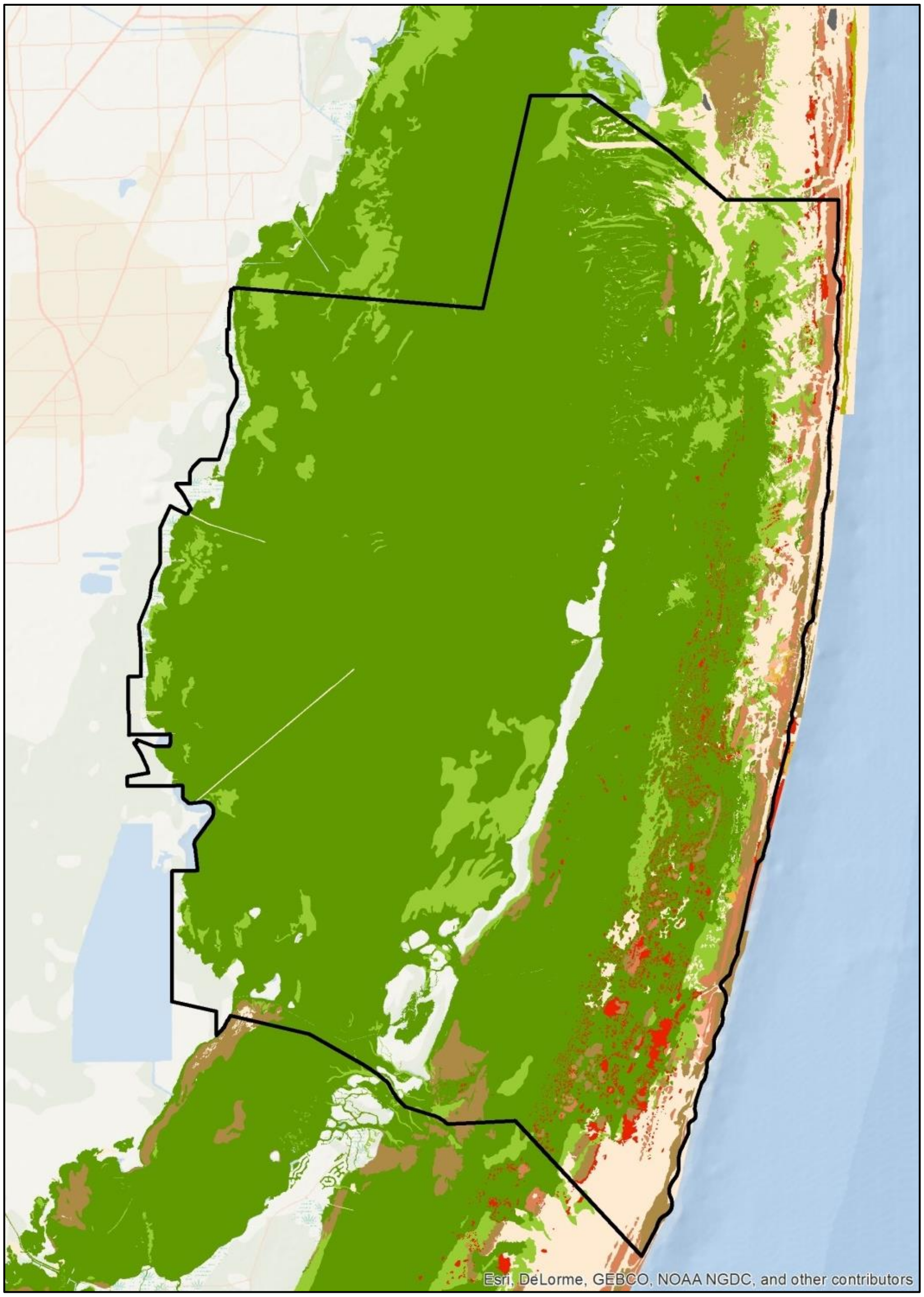


Figure 4.2.1. Benthic habitat map of BISC. Dark green represents continuous submerged aquatic vegetation (SAV) and lighter green represents discontinuous SAV. Biscayne Bay portion of map is from 2005 surveys and offshore portion is from 2009 (Davis 2013).

4.2.2. Stressors

The composition of seagrasses throughout the park is heavily influenced by salinity (Lirman and Cropper, 2003) and is therefore also a good indicator of water quality (Lirman et al., 2008). Alternations in the hydrology of Biscayne Bay as result of CERP are expected to result in changes in the composition and distribution of seagrasses in the Bay. As more freshwater is introduced into the bay to replicate a more historic pattern, the nearshore salinity is expected to decline and there is the potential for an increase in nutrient levels. The health of the seagrass is dependent on nutrient levels which are influenced by land use patterns throughout the watershed (Caccia and Boyer 2005). Historically, overall nutrient levels in the bay were low and fairly consistent but during the last decade several major algae blooms likely caused by increased nutrients levels have negatively impacted the seagrass beds. In 2005/06 a large cyanobacteria bloom in the southern areas of the Bay including Barnes Sound and Card Sound, just south of BISC boundary resulted in a major seagrass die-off. In 2013 a diatom bloom in the central portion of the bay was the first recorded open water bloom the Bay, signifying potential change. Since 2005 a growing *Anadyomene* spp. (macroalgae) bloom just north of the BISC boundary on the western edge of Biscayne Bay has stressed seagrass beds, resulting in decreased acreage (Collado-Vides et al., 2013). Faster growing macroalgae generally outcompete seagrass when nutrient levels increase, potentially changing the benthic community in Biscayne Bay (Duarte, 1995). A comparison of aerial photography from 1938–2009 of BISC suggests that seagrass beds have become more fragmented near the shoreline with slight declines in total acreage (Santos et al., 2016). In addition, physical disturbances such as boat groundings that occur within BISC can cause long term damage to seagrass beds and the soils in which they grow (Bourque et al., 2015).

Bottlenose dolphin (*Tursiops truncatus*) in shallow seagrass beds in BISC (Photo by Joe Contillo)

Due to the importance of the seagrass communities in Biscayne Bay, several monitoring programs are in place. The composition and extent of seagrass has been monitored by the Fish and Wildlife Research Institute (FWRI) and the Miami–Dade County Department of Environmental Resource

Management (DERM) as part of a broader program mapping and monitoring seagrasses throughout the state of Florida (Blair et al., 2015). Nearshore seagrass communities are monitored bi-annually as part of IBBEAM by scientists from UM-RSMAS. This program is a continuation of the USGS-NOAA joint south Florida fish and invertebrate assessment network that was run from 2005 until 2011.

4.2.3. Florida Seagrass Integrated Mapping and Monitoring Program

Digitized aerial photography from 1992 and 2004–5 was used to compare the extent of seagrass in the Biscayne region that includes North Biscayne Bay, Card Sound, Barnes Sound and other areas outside park boundaries (Lirman et al., 2016). In Biscayne Bay proper, an area encompassing the bay portion of BISC, there were an estimated 48,868 ha of seagrass in 2005, as compared to 46,502 ha in 1992. This represents a 5% increase in coverage. In addition to the seagrass beds within Biscayne Bay, 42,455 ha of seagrass were mapped east of Elliott Key in the coral reef environment in 1992 (Lirman et al., 2016).

The Fisheries Habitat Assessment Program of FWRI conducted monitoring twice a year from 2005 through 2009 at randomly selected sampling points. Staff at DERM sampled 100 probabilistic randomly chosen sites and 12 nonrandom fixed sites each June. Overall, species composition has been stable and a comparison of monitoring data from 2005 and 2007 showed few differences. However, there were substantial differences in seagrass species composition among the regions of Biscayne Bay. Turtle grass dominated beds in Card Sound and southern Biscayne Bay, while in northern Biscayne Bay seagrass beds were more diverse, with manatee grass occurring most frequently. Between 2005 and 2015, there has been a persistent algae bloom (*Anadyomene* spp.*)* in the northern part of Biscayne Bay that has negatively affected the seagrass community. Currently the bloom does not extend into park waters though it is a threat. The overall status of the seagrass in the Biscayne Bay region is moderate with some stable and negative trends (Table 4.2.2). Most of the declines are occurring in regions outside of the park but are still of concern due to their proximity and connectivity with park waters. Nutrient loading from the watershed, algae blooms, changing hydrologic regimes, and boating all add stress to the vast seagrass beds of BISC.

Table 4.2.2. Status and trends of seagrasses in the Biscayne Region (Reprinted from Lirman et al., 2016).

Status and stressors	**Status**	**Trend**	**Assessment, causes**
Seagrass cover and species	Yellow	Regional declines	Losses in North Bay and Barnes Sound; *Anadyomene* bloom in north central bay
Water clarity	Yellow	Regional declines	Phytoplankton blooms
Natural events	Green	Sporadic	Tropical cyclones
Macroalgal blooms	Yellow	Subsiding	Central bay; caused seagrass loss in recent years
Propeller scarring	Yellow	Localized	Near high-use areas

4.2.4. Biscayne Bay Ecological Assessment and Monitoring (IBBEAM)

Studies of the flora and fauna of Biscayne Bay extend back into the 1970s associated with licensing of the Florida Power and Light Turkey Point Nuclear Generating Station, and then had another intense period of activity in the 1990s (Ault et al., 2001). Recently, macrofauna (i.e., pink shrimp, etc.), mangrove fishes, and submerged aquatic vegetation (SAV, macroalgae and seagrasses), have been monitored under funding from CERP using two sampling protocols: (1) SAV sites are co-sampled with other epifauna twice a year as auxiliary covariates to the faunal (principally pink shrimp) sampling schedule; and, (2) randomly allocated sites spaced geographically north-south within 500 m of the western shoreline during the wet season (IBBEAM, 2015). The distribution and abundance of shoal and turtle grasses are also estimated along the western shoreline out to 500 m. Temporal trajectories of shoal and turtle grass abundance (above-sediment-surface occurrence and cover) showed high seasonal fluctuations (with peaks in abundance during the wet season). The 2010 cold snap impacted shoal and turtle grasses, resulting in a decline in abundance and a shrinking of the habitat suitability (proportion of domain with high cover) for both species. Abundance and suitability recovered within a year for turtle grass and two years for shoal grass. Both seagrass species appear to be on a slight declining trend initiated in 2012 in nearshore habitats (< 100 m from shore) but seem to follow a stable trajectory offshore (100–500 m from western shoreline) (Figure 4.2.2). Habitat suitability models incorporating 2008–2014 data reflect shoal grass affinity for low salinities and shallow depth, but opposite salinity and depth affinities by turtle grass. Current models suggest that increased mesohaline conditions, a desired target of CERP, will increase seagrass abundance and support co-dominance by shoal grass and turtle grass (IBBEAM, 2015).

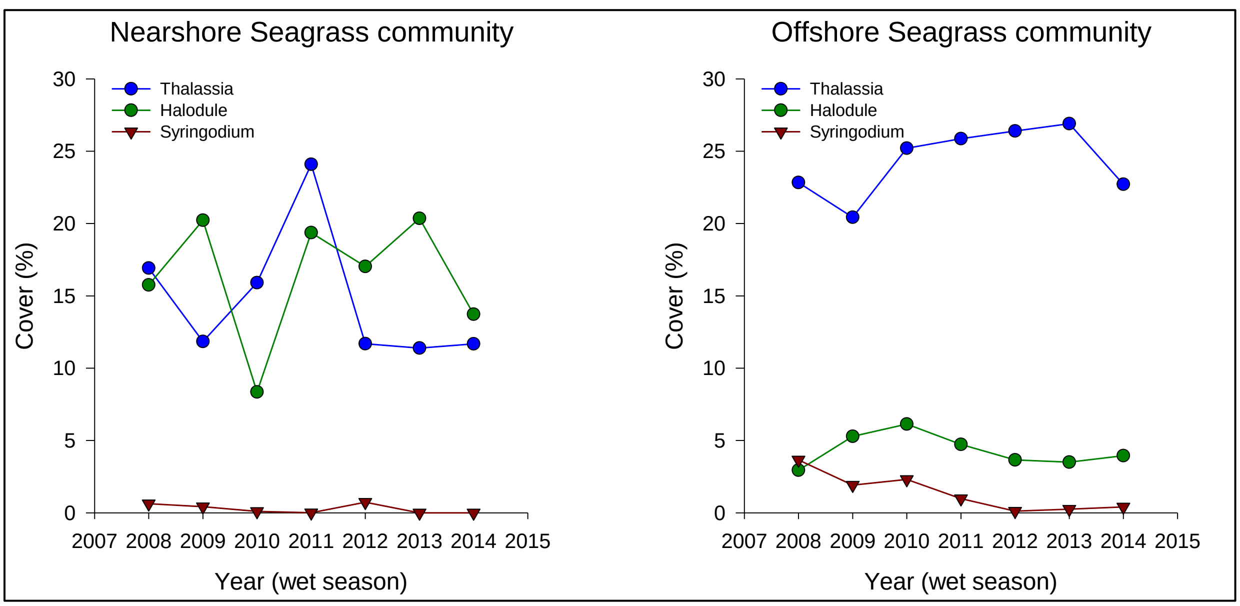
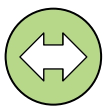
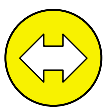
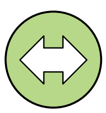
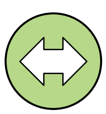


Figure 4.2.2. Percent cover of the three dominant seagrass species in western Biscayne Bay since the start of SAV monitoring program in 2008. The data presented were collected from nearshore (< 100 m from shore, left panel) and offshore (100–500 m from shore, right panel) habitats during the wet season in the region between Matheson Hammock and Turkey Point (Reprinted from IBBEAM, 2015).

4.2.5. Conclusion

Seagrass beds cover roughly 90% of benthic habitats within BISC. This extensive and highly productive ecosystem is critical to the ecological function of the park and the health of seagrass is of utmost importance. The overall extent of seagrass beds in BISC has slightly increased between 1992 and 2005 and species composition within the park appears to be stable (Table 4.2.3). However, nutrient loading and persistent algae blooms threaten areas adjacent to the park within the bay. Along the western shoreline of BISC, changes in nutrient levels and salinity can dramatically affect seagrass composition, which warrants moderate concern for these areas within the park. Throughout the rest of the bay and on the ocean side of Elliott Key there has been minimal monitoring of seagrass condition, but aerial photography suggests that those communities are healthy.

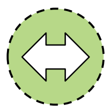
Table 4.2.3. Conditions and trends of seagrass in BISC.

Criteria	Condition & Trend	Rationale	Reference Condition
Acreage		Seagrass acreage in Biscayne Bay seems stable and slightly increased between 1992 and 2005. It has been over 10 years since another survey was conducted	1992 acreage estimates from aerial photography
Nearshore composition (Florida Seagrass Integrated Mapping and Monitoring Program)		Turtle grass remains the dominant species in Biscayne Bay and the composition appears stable. However, areas directly adjacent to the park have experienced significant decline warranting moderate concern.	2005 frequency of occurrence
Percent coverage nearshore (IBBEAM)		Percent coverage of three dominant species (turtle grass, shoal grass, and manatee grass) have remained stable since 2008.	Stable coverage with species compositions in accordance with hydrological regime.
Percent coverage offshore (IBBEAM)		Percent coverage of three dominant species (turtle grass, shoal grass, and manatee grass) has remained stable since 2008.	Stable coverage with species compositions in accordance with hydrological regime.

4.3. Terrestrial Vegetation

Terrestrial vegetation within BISC is in good condition and trend is unchanging. Reference conditions have been established, but subsequent mapping has not occurred which has contributed to a low confidence in the assessment (Table 4.3.1).

Table 4.3.1. Terrestrial vegetation condition status and trend.

Attribute	Condition & Trend	Interpretation
Mangroves, Hardwood Forests and Invasive Vegetation		Reference conditions for the composition and extent of mangrove and tropical hardwood forests were established in 2013. Subsequent mapping has not occurred. Forest monitoring plots indicate that normal succession is occurring following hurricane Andrew and earlier human disturbance. Invasive exotic plant monitoring and removal are continuing.

4.3.1. Importance

Only five percent of Biscayne National Park is comprised of land, yet these 8,600 hectares contain a significant portion of the park's biodiversity and include habitats which are not only highly connected with the marine environment but are critical for numerous marine species. Mangrove communities which make up the largest proportion of terrestrial vegetation in BISC can be found in several islands within the bay, along the western edge of Biscayne Bay and the shorelines of the keys (Whelan et al., 2013). They provide habitat for a wide range of terrestrial and marine fauna (Nagelkerken et al., 2008). Their root systems provide key habitat for numerous reef fish during their juvenile life phase (Serafy et al., 2003) and their canopy is used by nesting birds (Muxo et al., 2015). The coastal hardwood hammock community found on the keys includes many rare and unique Caribbean species of trees which are at their most northern limit. The park is currently home to five different "Champion Trees," the largest known representatives of their species growing in the United States. The 2004 inventory of vascular plants in BISC identified 454 taxa including 151 taxa previously undescribed from within the park. A vast majority of these plants, 322 (70.1%), are native, 108 (23.8%) are naturalized exotics, and 24 (5.3%) are known from the park only from cultivation (Bradley et al., 2004). During this survey, the rare semaphore cactus (*Consolea corallicola*) (see insert box) along with several other rare species were found, including the semi-parasitic mahogany mistletoe (*Phoradendron rubrum)* which is listed as endangered by the state of Florida, and the critically imperiled swampbush (*Pavonia paludicola), M*arsh's Dutchman's pipe *(Aristolochia pentandra)*, *Caesalpinia major*, red stopper (*Eugenia rhombea)*, Caribbean princewood (*Exostema caribaeum)*, lignum vitae (*Guajacum sanctum)*, Swartz's snoutbean (*Rhynchosia swartzii)* and pearlberry (*Vallesia antillana)*. (Bradley et al., 2004)

4.3.2. Stressors

Prior to the establishment of the Biscayne National Monument in 1968, the natural areas of BISC were heavily altered by homesteaders and developers. The environmentally sensitive hardwood hammocks on the keys were cleared and farmed and much of the western mangrove shoreline along Biscayne Bay was developed (Leynes and Cullison, 1998).Since the establishment of the National Monument in 1968, the condition of the keys has improved significantly and most areas have begun to return to a natural state. Along the western shoreline of BISC, development is prohibited within the park boundary, but urban areas directly adjacent to the park continue to grow adding stress to the thin line of protected habitat. Storm water runoff with associated pollutants and constant accumulation of trash debris alter the natural state of the mangrove forests and threaten their health. Invasive exotic species are an ongoing threat to terrestrial communities and can negatively affect forest composition and associated fauna. Of particular concern to offshore upland plant communities are Brazilian pepper (*Schinus terebinthifolia*), Seaside mahoe (*Thespesia populnea*), latherleaf (*Colubrina asiatica*), and sapodilla (*Manilkara zapota*), which can displace native vegetation and form near monotypic stands if untreated.

4.3.3. Monitoring Programs

The 2004 vascular plant inventory and the 2013 vegetation map provide a detailed baseline of species presence and the extent of various forest types. There is limited long-term monitoring of terrestrial vegetation within BISC. A series of forest monitoring plots established in 1995–1997 on Elliott Key, Old Rhodes Key, and Totten Key were revisited in 2010 providing an opportunity to understand forest succession in the park. The SFCN established an invasive exotic species monitoring protocol in 2013 (Shamblin et al., 2013) and ongoing restoration projects and exotic removals take place throughout the park in attempt to control the spread of invasive vegetation and restore native plant communities.

4.3.4. Vegetation Map

In 2013, SFCN in partnership with Florida International University published the first comprehensive vegetation map of BISC which provides a baseline of community extent (Figure 4.3.1) (Whelan et al., 2013). Mangrove and tropical hammock communities make up the vast majority of vegetation types in the park (Table 4.3.2). The mangrove shorelines along the western edge of Biscayne Bay represent the longest undeveloped mangrove coastline in the eastern US. Although the extent and composition type of the forest is known, there are no current plans to re-map the park to assess change. SFCN is developing a monitoring protocol that includes monitoring of mangrove forest plots within BISC, but these plots have yet to be established. SFCN is also monitoring mangrove soil elevations in BISC at two long term sites along the western mangrove shoreline in 2013 (Whelan, 2016). Changes in soil dynamics have can have far reaching impacts on the ecosystem especially as saltwater intrusion and rising sea levels continue to move westward. These changes may shift suitable areas where mangrove communities can thrive (Krauss et al., 2011).

Table 4.3.2. Area (ha) of major vegetation types found within BISC (Data from Whelan et al., 2013).

Vegetation Type	Mainland	Keys
Mangrove	1,359	941
Hammock	0	722

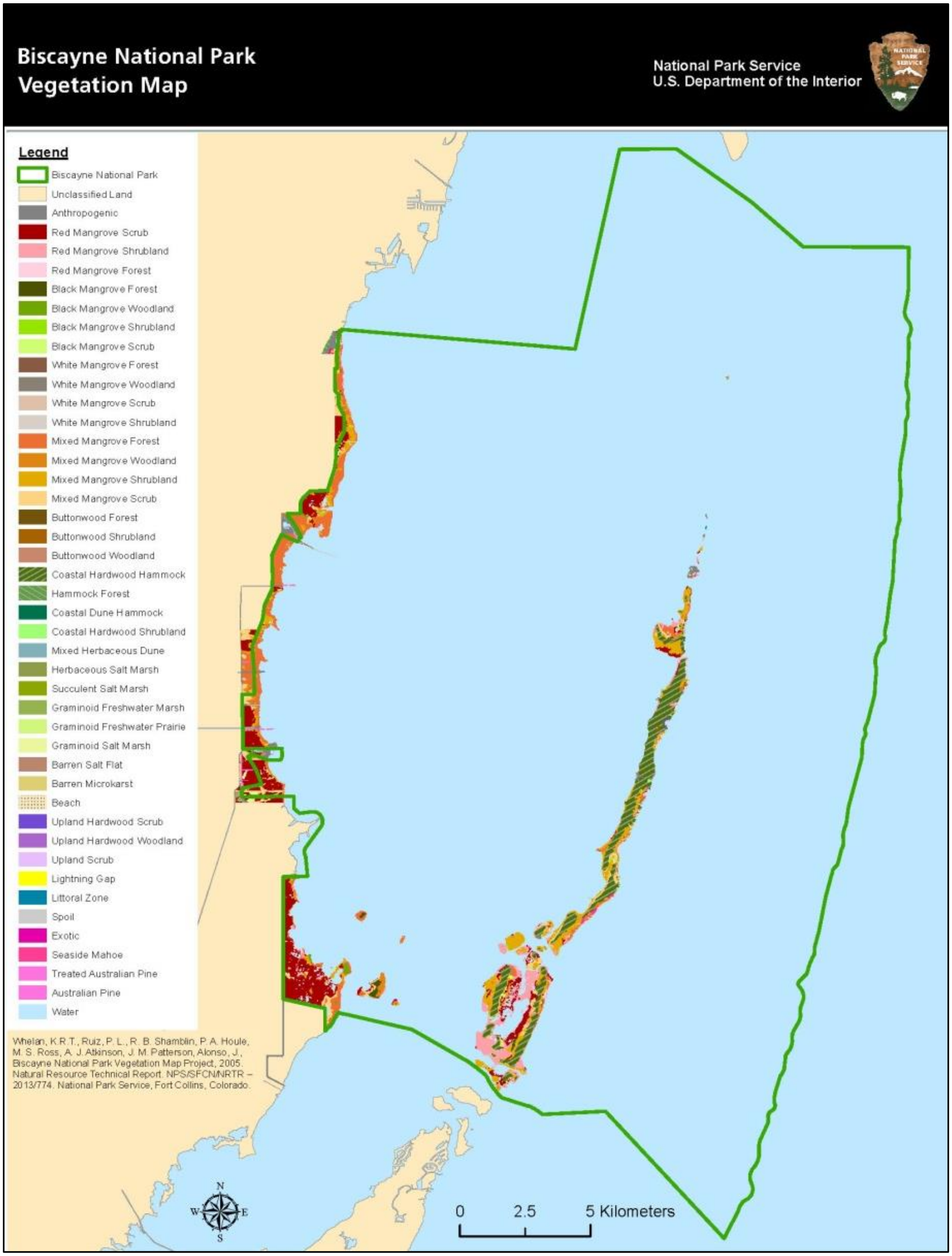


Figure 4.3.1. 2013 vegetation map of BISC (Reprinted from Whelan et al., 2013).

4.3.5. Forest Monitoring plots

Although mangroves make up a majority of the vegetation within BISC, the tropical hardwood forests located throughout the keys are an extremely important habitat and represent one of the last semi undisturbed hardwood hammocks in the Florida Keys. A series of plots were established in 1995–1997 to look at forest health and composition. On Elliott Key, plots were established inside and adjacent to an area cleared by developers before the islands were declared a national monument in 1968. The cleared area which has since been named the "Central Hiking Trail" and nicknamed 'Spite Highway' runs down the center of Elliott Key. The initial 1995–1997 surveys took place five years after Hurricane Andrew passed over the area, establishing a post-hurricane baseline.

After nearly fifty years since the area was cleared the forest within Spite Highway is reaching a relatively steady state where dense stands of hardwood pioneer species are thinning out and being replaced by longer-lived tree species and converging to a more mature, later successional community. Therefore, it appears that regeneration of these tropical hardwood hammocks from a clear-cut state to a more mature forest requires at least fifty years and possibly longer depending on other disturbance events such as hurricanes, sea level rise, etc. This rate of regeneration is consistent with other studies of tropical hardwood forests in south Florida (Ross et al., 2001).

Currently, recruitment counts are below that of mortality (Table 4.3.3). At this time the lower recruitment counts are not of immediate concern as a majority of species dying are the relatively shorter-lived hardwood pioneer species that would be expected to decline as a forest matures. Many of the species being recruited are part of the longer-lived later successional species. This process is indicative of succession where a disturbed forest is first colonized by short-lived pioneer species, gradually being replaced by hardwood pioneer species, and then finally converging upon the late successional climax community as dense stands of the pioneer hardwoods thin out and are replaced by the longer-lived late successional species (Ross et al., 2001).

SFCN is developing a protocol for monitoring forest vegetation in hammocks and will also continue to monitor a subset of these legacy plots.

Table 4.3.3. Elliott Key tree mortality and recruitment from 1997–2010 by succession type (Data provided by Brooke Shamblin, SFCN).

Scientific name	Common Name	Mort	Recruit	Succession
Bourreria succulenta	Bahama strongbark	14	4	early
Caesalpinia bonduc	Nickerbean	3	3	early
Carica papaya	Papaya	11	0	early
Genipa clusiifolia	Seven year apple	1	0	early
Cordia sebestena	Geiger tree	0	1	early
Eugenia foetida	Spanish stopper	218	148	early
Guapira discolor	Blolly	4	7	early
Guettarda elliptica	Hammock velvetseed	1	0	early

Table 4.3.3 (continued). Elliott Key tree mortality and recruitment from 1997–2010 by succession type (Data provided by Brooke Shamblin, SFCN).

Scientific name	Common Name	Mort	Recruit	Succession
Lysiloma latisliquum	Wild tamarind	21	2	early
Metopium toxiferum	Poisonwood	35	10	early
Pithecellobium guadalupense	Blackbead	115	41	early
Reynosia septentrionalis	Darling plum	9	1	early
Solanum erianthum	Potato tree	9	0	early
Swietenia mahogani	Mahogany	44	9	early
Zanthoxylum fagara	Wild lime	1	1	early
Colubrina asiatica	Latherleaf	0	1	early, exotic
Amyris elemifera	Torchwood	4	0	both
Coccoloba diversifolia	Pigeon plum	55	112	both
Conocarpus erectus	Buttonwood	1	0	both
Eugenia axillaris	White stopper	90	112	both
Ficus citrifolia	Short leaf fig	3	3	both
Pisonia aculeata	Devil's claws	0	2	both
Randia aculeata	White indigo berry	2	2	both
Simarouba glauca	Paradise tree	0	3	both
Manilkara zapota	Sapodilla	7	2	both, exotic
Ateramnus lucidus	Crabwood	4	17	late
Calyptranthes pallens	Pale lidflower	0	1	late
Canella winterana	Cinnamon bark	0	2	late
Chrysophyllum oliviforme	Satin leaf	0	4	late
Drypetes diversifolia	Milkbark	1	0	late
Exothea paniculata	Inkwood	1	0	late
Krugiodendron ferreum	Black ironwood	7	16	late
Sideroxylon foetidissimum	Mastic	4	6	late
Totals	**–**	**665**	**510**	**–**

4.3.6. Invasive Exotic Plants

Exotics plants such as Australian pine (*Casuarina* sp.), Brazilian pepper, Burma reed (*Neyraudia reynaudiana*), latherleaf, and seaside mahoe compete with native species, negatively affect native flora and fauna and alter ecosystems (Gordon 1998). An invasive exotic plant monitoring protocol has been established that looks for new exotic and invasive species in areas of likely invasion such as campgrounds, trails, and boat ramps (Shamblin et al., 2013) and each year the Exotic Plant Management Team, BISC staff, and/or a team of contractors search and treat areas within BISC for invasive plants (Figure 4.3.2). Since 2010, the total area searched annually for exotics has varied from 1.7 ha to 220.8 ha and during the first 5 years an average of 24% of the covered area was treated for exotics. In 2016, 220.8 ha were covered and only 7% were treated which is below the 2010–15 average (Figure 4.3.3).

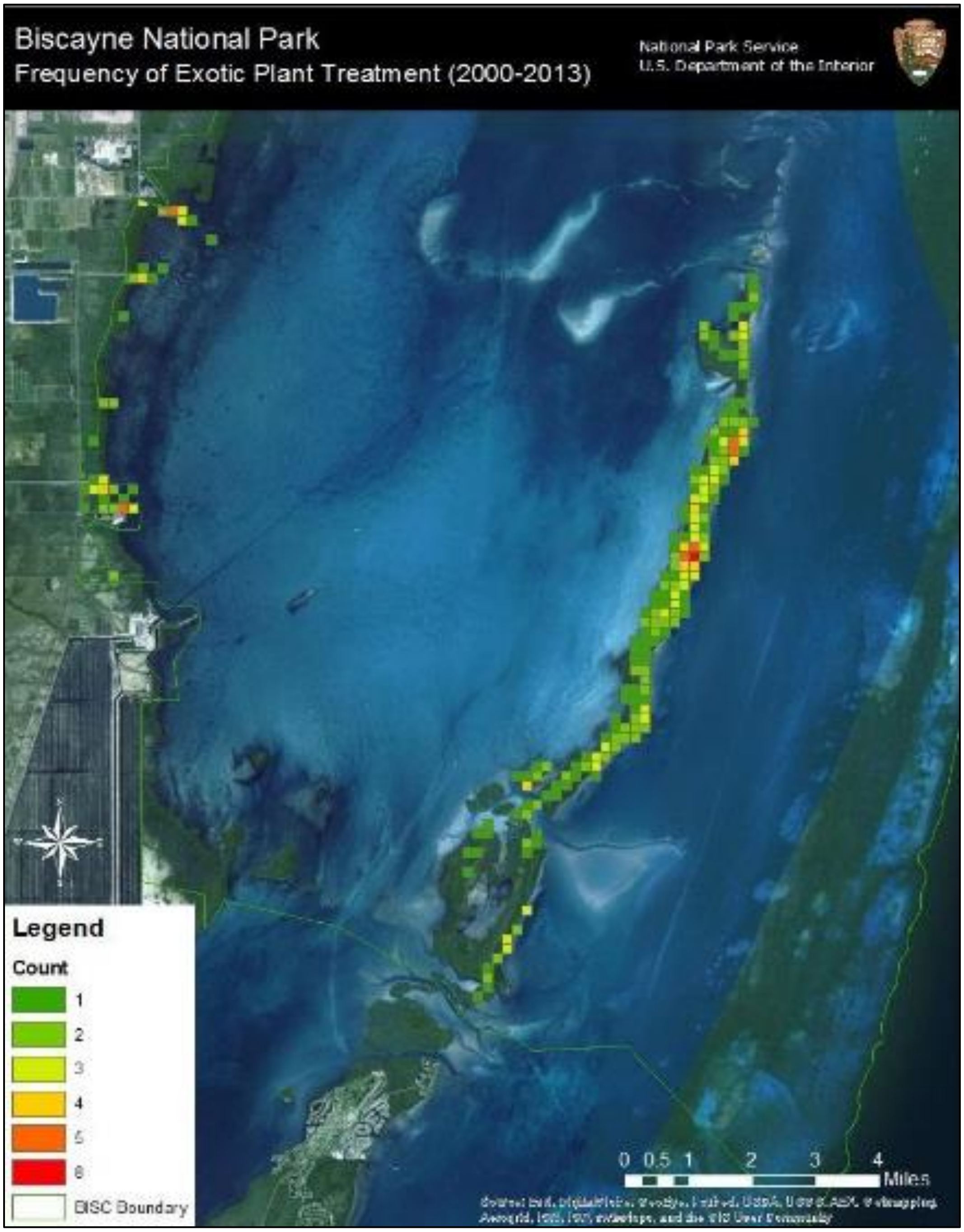


Figure 4.3.2. A visualization of the frequency of exotic plant treatment history for Biscayne National Park at a 250 meter scale. (Reprinted from Florida and Caribbean Exotic Plant Management Team: FY 2015 Annual Report, NPS. 87p).

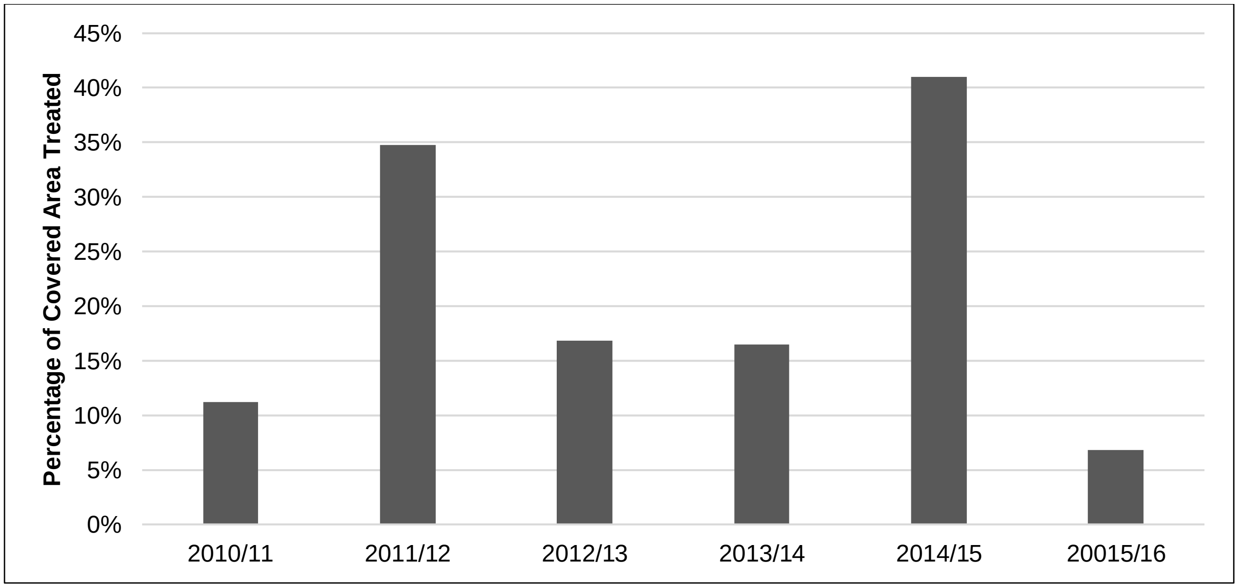


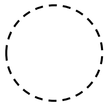
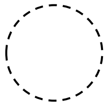
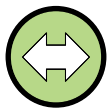
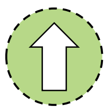
Figure 4.3.3. Percentage of covered area treated for exotics by year. (Data provided by Brian Lockwood, NPS).

Several restoration projects focused on the removal of invasive species and re-establishment of native plants have been conducted within or directly adjacent BISC. In 2013, NPS in partnership with the Tropical Audubon Society, Palmetto Bay Village Center, South Florida Water Management District, Fairchild Tropical Botanic Gardens and the U.S. Fish and Wildlife Service restored 370 acres of wetlands and associated uplands in BISC. There have also been restoration projects on Spoil Island and Princeton Island along with Schaus swallowtail (*Heraclides aristodemus ponceanus*) habitat enhancement on Elliott and Adams Key (see insert) and mitigation at the Florida City Canal.

4.3.7. Conclusion

The coastal mangrove forests and tropical hardwood hammocks within BISC are some of the last communities of their types to remain in south Florida. They contain and support a high diversity of organisms and are key to the functional ecology of the park (Odum et al., 1982). A detailed vegetation map completed in 2013 has provided a baseline for vegetation extent from which to compare future surveys. The mainland plant communities consist mainly of mangrove forest at the coast which gives way to the shorter red mangrove scrub habitat. Many of the lower lying offshore islands consist of mangrove scrub and mangrove shrublands. Larger islands have a fringe of mangroves at the coast and tropical hardwood hammocks in the center of the islands where elevation is higher. Monitoring plots established on Elliott Key suggest healthy forest succession over the last 50 years (Table 4.3.4). Invasive plant species are an ongoing threat but restoration projects and removal efforts appeared to have kept exotic plants under control.

Table 4.3.4. Conditions and trends of terrestrial vegetation in BISC.

Criteria	Condition & Trend	Rationale	Reference Condition
Extent of mangrove coverage		No new mapping survey has been conducted since the establishment of the reference condition.	2013 vegetation map area (ha)
Extent of hardwood forest		No new mapping survey has been conducted since the establishment of the reference condition.	2013 vegetation map area (ha)
Hardwood community composition		Hardwood community appears to be following natural succession following clear over a half a century ago and 25 years after a major hurricane.	2010 legacy plot composition
Invasive species		In 2016, 7% of the covered area was treated, which is below the reference condition. There is considerable uncertainty, in whether this metric represents the overall area within the park affected by invasive species.	2010–2015 average percent of covered area treated (24%)

Semaphore Cactus

The rare semaphore cactus (Consolea corallicola) is found naturally in only two places on earth, and the larger population is within BISC. This population, believed to consist of between 500 and 1,000 plants, was originally discovered in 2001 during an inventory of plants within BISC (Bradley et al., 2004). The cacti are monitored semi-annually by BISC staff and appear to be in stable condition.

Semaphore cactus (Photo from BISC)

Schaus swallowtail

The Schaus swallowtail butterfly (Heraclides aristodemus ponceanus) was listed under the Endangered Species Act in 1976 as "Threatened" and then as "Endangered" in 1984. Between 1979 and 1981 small numbers of Schaus swallowtail were reported as widely distributed throughout suitable habitat in BISC (Loftus et al., 1982).

During a 2012 survey in BISC only 5 individuals were counted in comparison to 41 during the prior year's survey and as many as 1,400 individuals in 1997. This low count prompted the U.S. Fish and Wildlife Service to declare an emergency for this species, allowing the National Park Service to permit collection of individuals by the University of Florida (UF) for captive rearing and captive breeding projects. Since then, there has been a modest increase in their numbers.

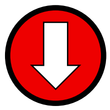
In addition to captive breeding and captive rearing with UF, the NPS also started a habitat enhancement project to increase the abundance of the butterfly's host plant and food source. At several restoration sites, exotic plants were removed and torchwood seedlings were planted.

Schaus swallowtail on Elliott Key (Photo by Holly Salvato)

4.4. Corals

The condition of stony corals in BISC is deteriorating and warrants significant concern. There is high confidence in this assessment due to several monitoring programs (Table 4.4.1).

Table 4.4.1. Corals condition status and trend.

Attribute	Condition & Trend	Interpretation
Stony Corals		Percent coverage of corals within BISC is at historic lows. Bleaching events and subsequent disease remain common and have increased the mortality of corals throughout the park. Several federally threatened species are close to being locally extinct.

4.4.1. Importance

The Biscayne National Park coral reef ecosystem encompasses much of the northern end of the Florida Reef Tract and is characterized by an extensive shallow water patch reef system and broad platform reef which provides protection from the high energy Straits of Florida (Figure 4.4.1). Within BISC there are thousands of patch reefs which have been built up by large massive stony corals over the last 6,000 years (Shinn et al., 1989; Brock et al., 2006). BISC is estimated to contain roughly 60% of all patch reefs found within the Florida Reef Tract (Brock et al., 2006). The offshore platform reef of BISC out to 20m depth provides an additional 4,000 ha of reef habitat that supports a tremendous diversity of marine organisms. Amongst the dozens of coral species found on the BISC reefs, six have been federally designated as threatened; boulder star coral (*Orbicella franksi*), elkhorn coral (*Acropora palmata*), lobed star coral (*Orbicella annularis*), mountainous star coral (*Orbicella faveolata*), rough cactus coral (*Mycetophyllia ferox*), and staghorn coral (*Acropora cervicornis*). Pillar coral (*Dendrogyra cylindrus*), which was also federally designated as a threaten species, became extinct within the park by 2019.

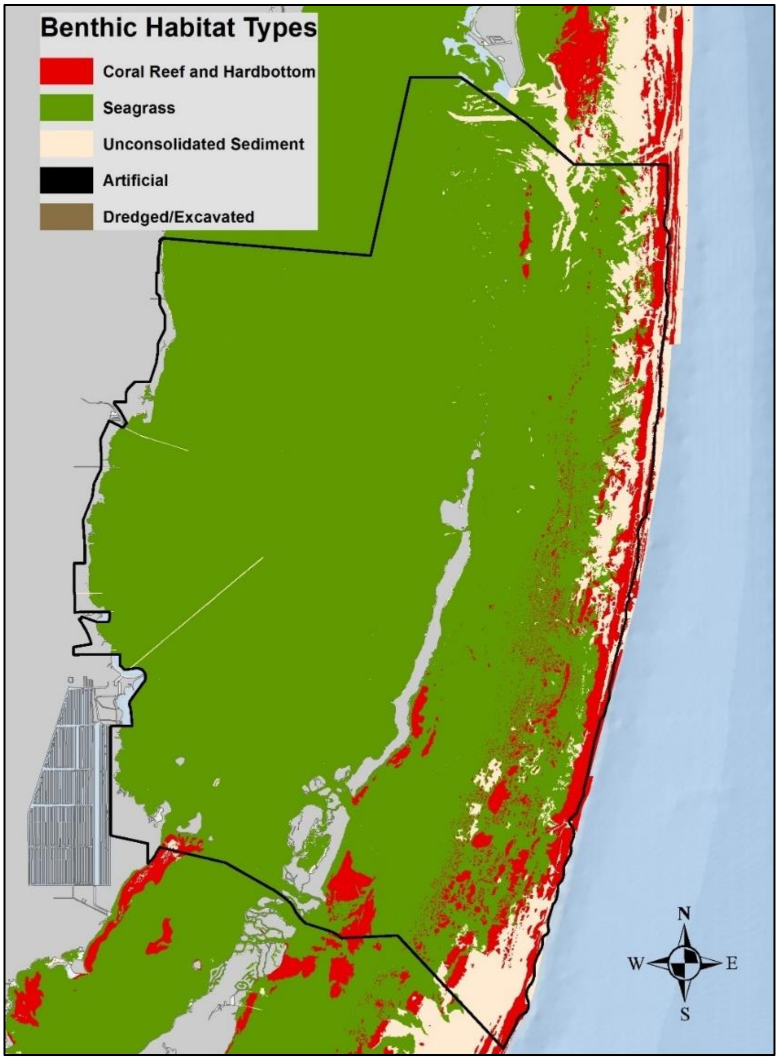


Figure 4.4.1. Map of benthic habitat types within BISC (black line) highlighting coral reef and hardbottom areas in red (Unified Florida Coral Reef Tract Map, FWC-FWRI).

Soft corals (gorgonians) dominate shallow water reef in BISC (Photo by David Bryan)

4.4.2. Stressors

The once vibrant coral reef ecosystem within BISC has experienced significant coral declines over the last 50 years consistent with those occurring throughout the greater Caribbean (Gardner et al., 2003; Jackson et al., 2014). Growth rates of a key reef building species, the lobed star coral, have been in decline in BISC since the 1950s when nutrients from sewage outfalls began to increase along with sedimentation from dredging and other development (Hudson et al., 1994). However, more recently, corals in BISC have experienced not only declining growth rates but also increased mortality and general decline in coral coverage. The rise of global ocean temperatures and frequency of coral bleaching and subsequent disease and mortality of corals have become more prevalent throughout the entire tropical Western Atlantic (Bruno et al., 2007; Heron et al., 2016). The south Florida stony corals have not been spared (Toth et al., 2014; Kuffner et al., 2015; Manzello, 2015); local reefs have not recovered from a major mortality event associated with the 1997/1998 El Niño and their decline has continued (Ruzicka, 2013; Precht, 2016). Corals in the park experienced severe bleaching in 2014 and 2015 and severe disease outbreaks in 2015 and 2016. Together, the warm water, bleaching and disease have resulted in considerable loss of live coral in the park. In January of 2010, a cold water anomaly also caused extensive mortality of corals throughout the Florida Reef Tract (Lirman et al., 2011; Colella et al., 2012). Recreational and commercial fishing within the park have also had a negative impact, as traps, anchors, and lines can cause significant physical damage to corals. During the first year of surveys at the 12 sites established by BISC to remove and categorize marine debris, park scientists documented 1,748 injuries and 457 mortalities of stationary reef organisms (stony corals, sponges, soft corals, fire corals, and zooanthids) as a result of contact with marine debris. Hook-and-line debris accounted for 50% of all documented injuries and 32% of all mortalities. Trap fishery debris accounted for 33% of all injuries and 52% of all mortalities.

Today the greatest stresses threatening coral reefs throughout the world are warming sea temperatures and chronic bleaching and disease, in combination with increasing anthropogenic impacts (Baker et al., 2008, Hoegh-Guldberg et al., 2007; Jackson et al., 2014). However, sea temperature rise and subsequent bleaching is predicted to be spatially variable (van Hooidonk et al., 2015) and corals have a range of stress tolerance. It is therefore important to look at the trends of corals within BISC against the broader background of decline to see if the reefs within the park are faring better or worse than other locations.

4.4.3. Monitoring Programs

In addition to ongoing coral research that takes place within BISC, there are several separate programs that monitor coral health. The SFCN has been monitoring two sites in BISC since 2004. Each year coral biologists associated with the Florida Reef Resilience Program (FRRP) survey between 20 and 30 randomly selected sites within BISC during the late summer/fall when bleaching is most likely to occur. Park biologists conduct surveys of benthic cover patterns at twelve sites using a point-intercept approach for a 25-point 1m^2 quadrat that is moved along a transect line. Surveys are conducted as staff are available, and typically occur every other year. The National Coral Reef Monitoring Program (NCRMP) also conducts coral demographic surveys at randomly selected sites every two years. Data from NCRMP have not been analyzed and thus are not included in the report, but new data will offer complementary information for future analysis. In addition to broad monitoring programs, the Florida Fish and Wildlife Research Institute (FWRI) in partnership with BISC, has been regularly monitoring known populations of two coral species listed in the Endangered Species Act (ESA) within the Park since 2011.

Erin Nassif (SFCN-IM) recording data during long term monitoring (Photo by David Bryan)

4.4.4. SFCN long-term monitoring sites

SFCN has been annually monitoring a series of randomized permanent 10-meter transects at two sites in BISC since 2004, Amanda's and Ball Buoy reefs. Each transect is filmed underwater by a diver with a digital camera. In the lab, the videos are broken into sequential still image "frames" and 10 dots are randomly placed upon each image and identified to major category. These categories include coral by species, algae (macroalgae, turf, or crustose coralline), gorgonians (sea fans, etc.), sponges, and substrate]. Other *in situ* collected field data have been gradually added to the protocol including coral disease type, number of lesions, area of disease mortality, disease prevalence, coral bleaching, site rugosity, and long-spined sea urchin (*Diadema antillarum*) density (Miller et al., 2017).

Since 2004, coral coverage at these sites has remained around 6% with a declining trend since a peak in 2013 (Figure 4.4.2). These coverage values are lower than historic data in BISC from 1977–1981, where coverage ranged from 8% to 28% at eight reefs (Dupont et al., 2008) and lower than 1994–96 value at Ball Buoy of 12.7% (Miller et al., 2000). Unlike the current SFCN monitoring program, in which transects were initially randomly chosen, earlier studies did not randomly choose locations of monitoring transects. There is the possibility that nonrandom 'haphazardly' selected transects may include a bias so it difficult to make direct comparisons to SFCN sites. Yet, this information still provides historic context of general coral coverage in the region. The two areas surveyed by the SFCN continue to be primarily covered with turf algae and gorgonians. While the percent cover of stony corals has declined, the overall species composition of corals has remained relatively similar from 2004–2014 at both sites. Some exceptions include a decrease in the relative abundance of the reef building *Orbicella* corals and elkhorn coral at Ball Buoy (Figure 4.4.3).

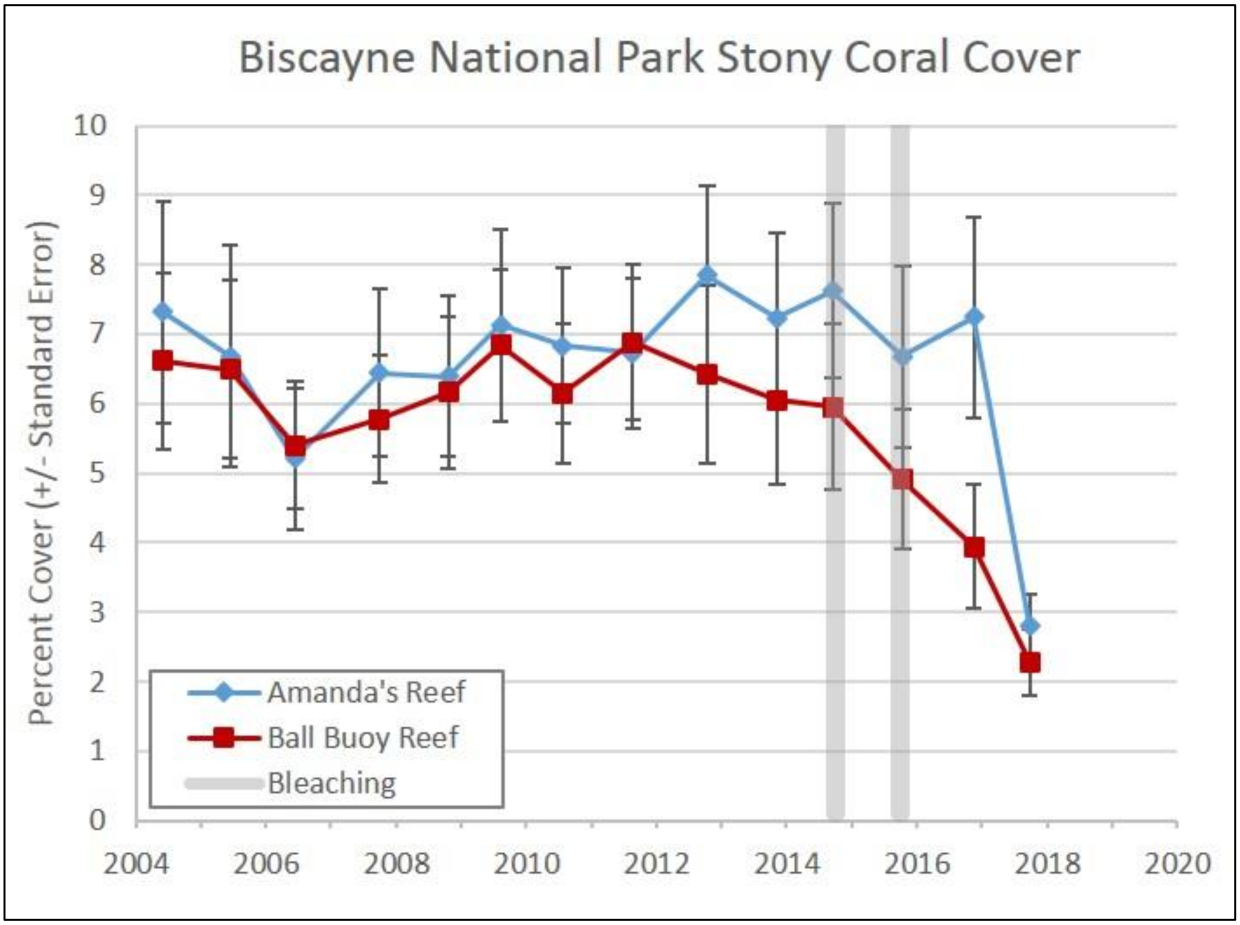


Figure 4.4.2. Percent coral coverage at Amanda's Reed and Ball Buoy from 2004–2017. Gray bars represent years of significant coral beaching that were then followed by a steep decline in coverage due to disease outbreaks in 2015 and 2016. (Provided by SFCN).

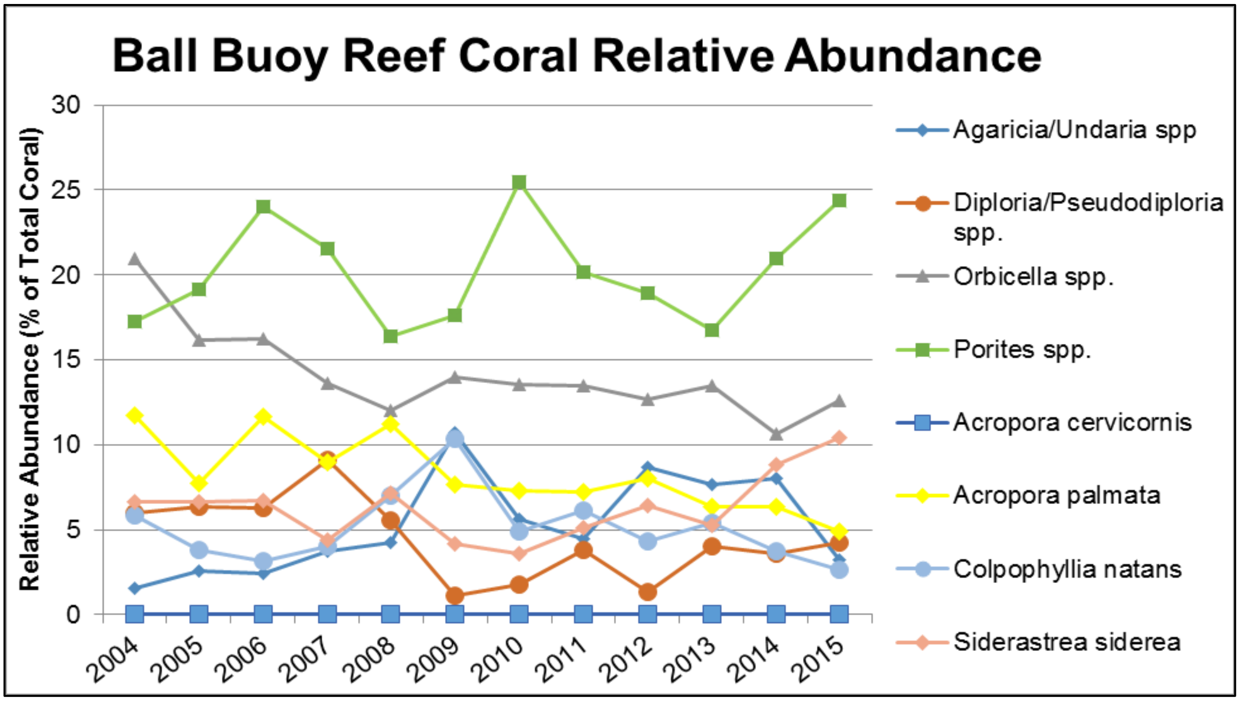


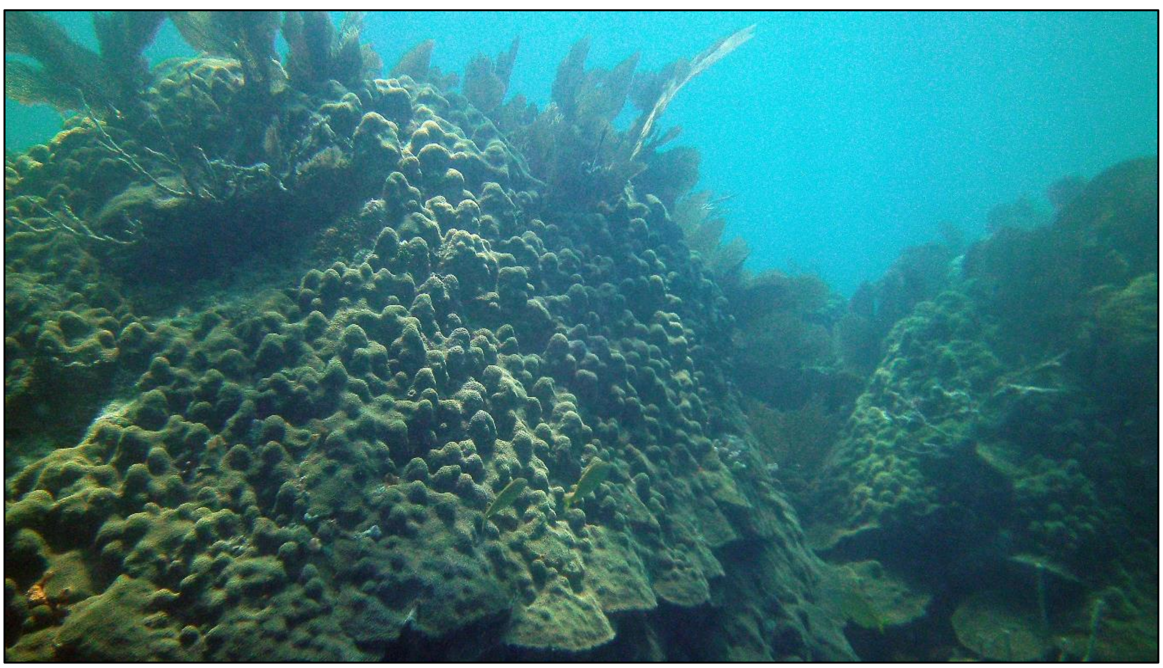
Figure 4.4.3. Relative abundance by year of the most common stony corals at Ball Buoy. (Provided by SFCN).

4.4.5. Florida Reef Resilience Program

The FRRP Disturbance Response Monitoring was developed for monitoring shallow coral reefs from the Florida Keys north to Martin County. FRRP consists of a probabilistic sampling design and a stony coral condition monitoring protocol implemented during the annual period of peak thermal stress. Each year since 2005, survey teams from federal, state, and local government agencies, universities and non-governmental organizations cooperate to complete surveys across the Florida Reef Tract within a six to eight week period. Each year between 20 and 30 sites are randomly selected within BISC. At each site, two $10m^2$ transects are conducted. All corals within the site are identified and measured, and signs of bleaching, disease and recent mortality are recorded.

In the FRRP, bleaching prevalence is measured as the number of colonies that exhibit signs of either partial or total bleaching. “Mild” bleaching is considered a prevalence of < 20%, “moderate” is 21–50% and “severe” is >50%. The prevalence of bleaching from 2005–2013 in BISC was typically lower than 20% and similar to the Florida Keys average in each reef zone in which the survey is divided (inshore, mid-channel, offshore patch reef and forereef) (Figure 4.4.4). However, in 2014 and 2015, bleaching prevalence was high in BISC (between 20–60% amongst reef zones) indicating moderate to severe conditions. The prevalence of bleaching in BISC was also above the Florida Keys average. Bleaching events are typically followed by an increase in disease and then mortality (Miller et al, 2009). The percentage of corals with disease present was stable from 2005 to 2013, at around 0.2%. But in 2015 and 2016, following the large bleaching events of 2014–2015, presence of disease rose by 3 times to 0.6% in 2015 and by 5 times to 1.1% in 2016 (Figure 4.4.5). Natural mortality rates of corals can vary significantly amongst species, locations and during different life stages with juvenile and post settlement mortality rates often greater than 25% (Smith, 1992; Bythell,et al., 1993). Despite its importance, there has been little work on coral demographics (i.e. growth rates and mortality) thus the interpretation of monitoring results is difficult and no standard baseline for a healthy community has been established. However, the presence of recent (typically < 2 months) and old (macroalgae has begun to grow on coral structure) mortality has been recorded during FRRP and can be used to look at trends over time and to track the effects of bleaching and disease. During normal years, the percent of recent mortality in BISC has been between below 1% but in 2015 it rose to 2% following bleaching and disease outbreaks (Figure 4.4.6). The percentage of old mortality present was high during the early years of the sampling program (2005–2007) which is a likely result of bleaching events in 2004 and 2005 (Figure 4.4.7) (Manzello et al., 2007). From 2008 until 2011, old mortality was fairly low but began to rise in 2012 which may be a delayed response to a cold water event in 2010 (Lirman et al., 2011; Colella et al., 2012).

There are a variety of techniques for measuring coral coverage which can depend on the field methods and types of data collected. In FRRP the total area of all live coral tissue within each transect can be used to estimate percent coverage of live coral. Percent coral coverage estimated from FRRP surveys in BISC is lower than in the Dry Tortugas and Florida Keys, and greater than the coverage north of the park and in Broward and Palm Beach counties (Figure 4.4.8). The average coverage from 2005 to 2016 has been 5.5% which is less than the fixed site survey conducted by SFCN because FRRP sites are randomly selected each year and can often include marginal reef habitat.



Boulder star coral (*Orbicella franksi*) at Alina's Reef in BISC (Photo from BISC)

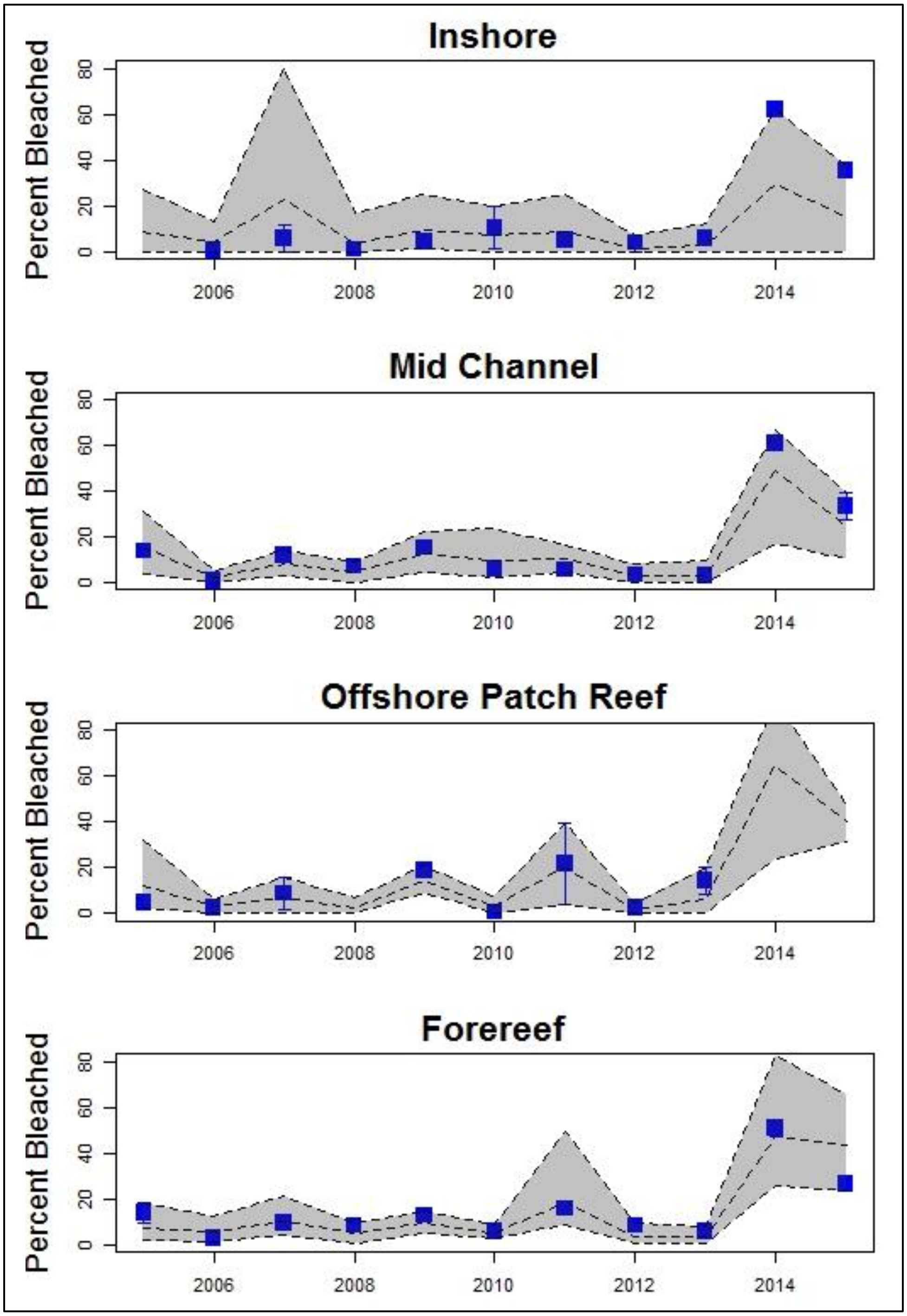


Figure 4.4.4. Percent of corals bleached in the four different reef zones surveyed by the Florida Reef Resilience Program in BISC (blue squares). Gray shading indicates minimum and maximum values and centered dashed line represents the mean for other regions with similar zones throughout south Florida. (Data provided by FRRP).

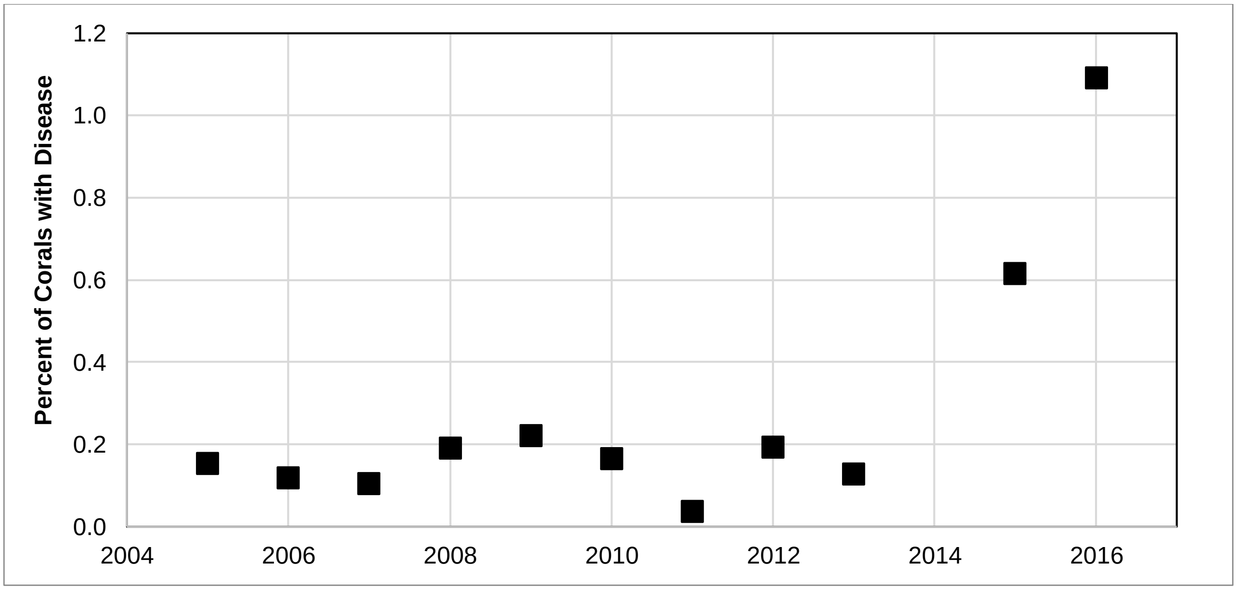


Figure 4.4.5. Percent of corals with disease present from 2005–2016 during Florida Reef Resilience Program surveys. (Data provided by FRRP).

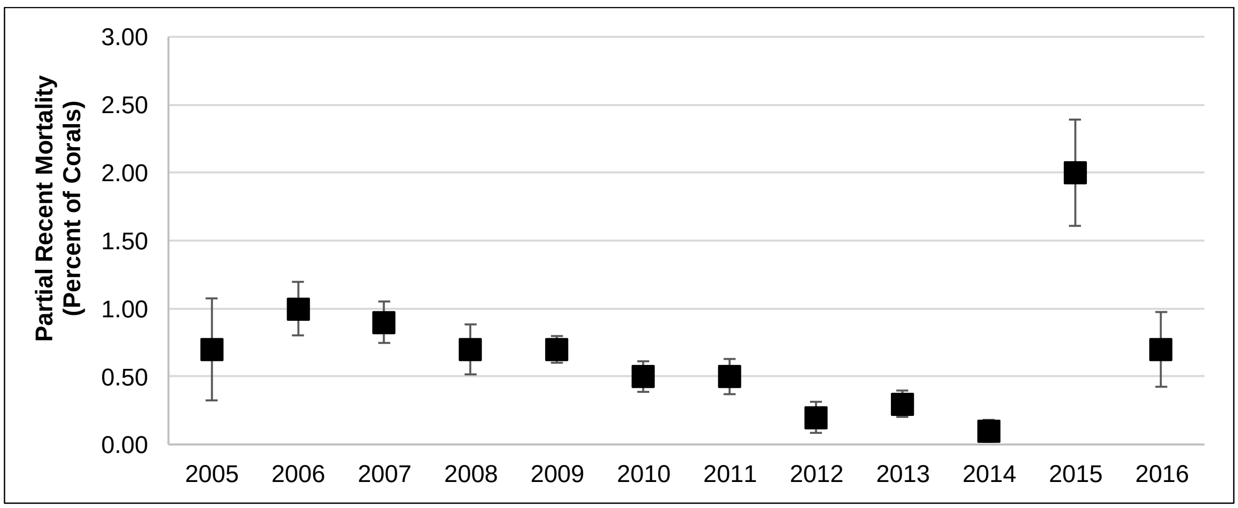


Figure 4.4.6. Percentage of coral area showing partial recent mortality from 2005–2016 (Data provided by FRRP).

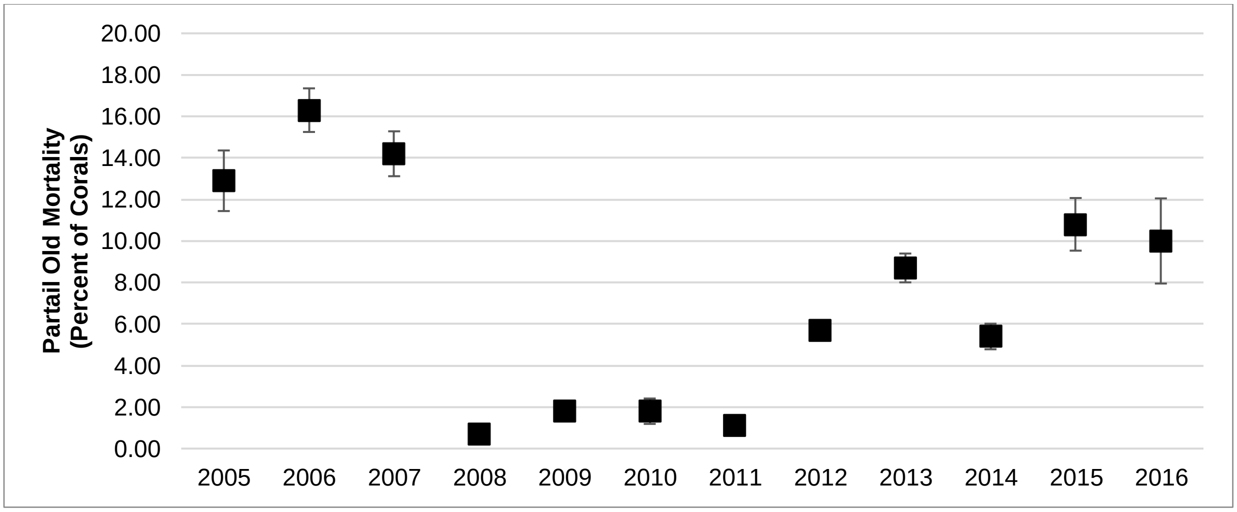


Figure 4.4.7. Percentage of coral area showing partial old mortality from 2005–2016 (Data provided by FRRP).

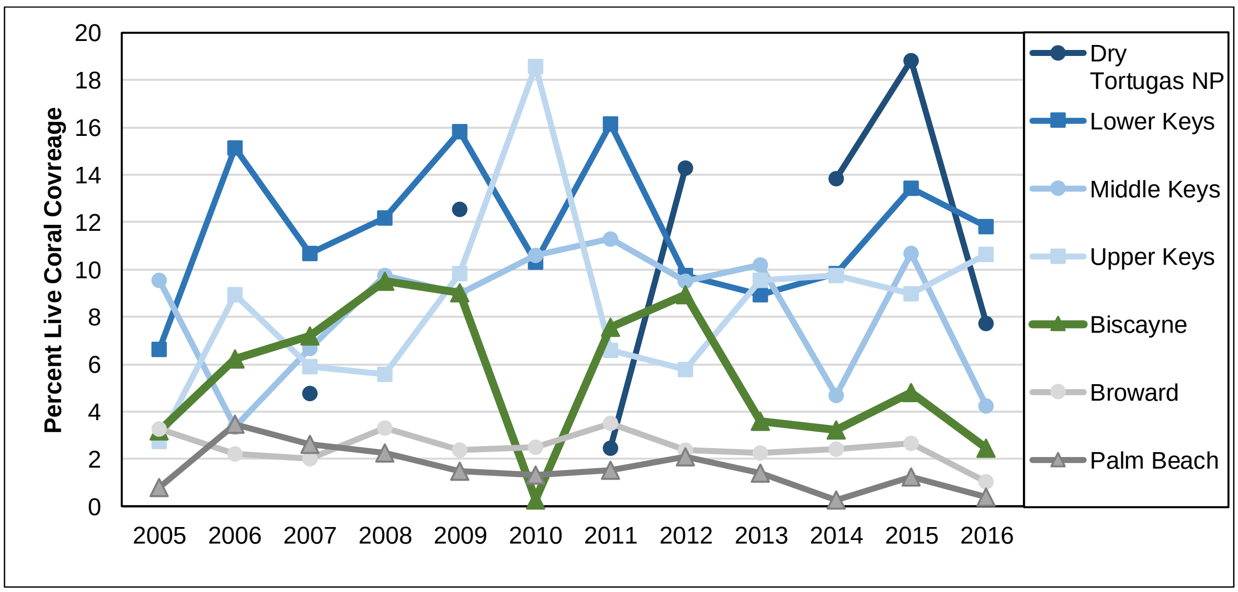


Figure 4.4.8. Percent coverage of all live scleractian (hard) corals from 2005–2016 during Florida Reef Resilience Program surveys. BISC is highlighted in green. (Data provided by FRRP).

4.4.6. BISC coral monitoring

BISC monitors corals at 12 sites throughout the park including patch reefs, deep continuous reefs and areas near shipwrecks. At each site divers run a 20m transect line and place a 1m^2 quadrat with 25 intercept points at every other meter of the transect line. Corals are identified to species, macroalgae to genus, soft corals to the lowest taxa possible (family or genus). Sites have been visited in 2011, 2012, 2015 and 2017. Coral cover is highly variable across the 12 sites with the most recent estimates from 2017 ranging from 0% to 19% (Figure 4.4.9).

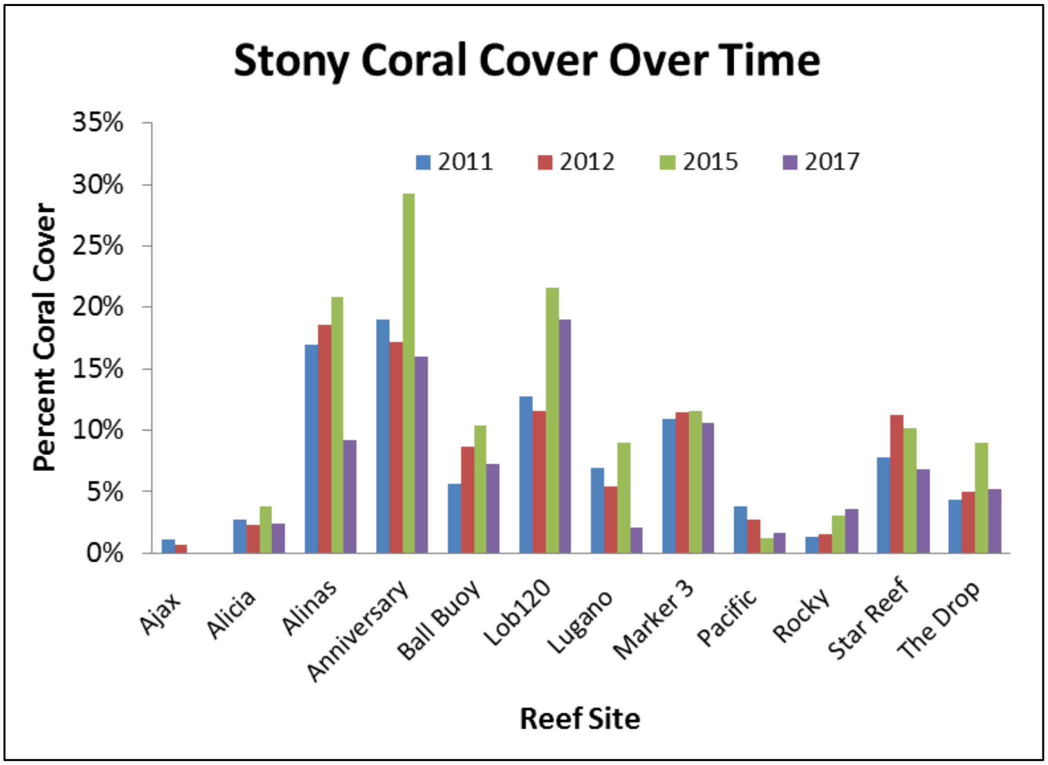


Figure 4.4.9. Stony coral percent cover among 12 permanent monitoring sites in BISC. (Provided by BISC).

4.4.7. Threatened species monitoring

FWRI in partnership with BISC, has been regularly monitoring known populations of two coral species federally listed as threatened within the park: pillar coral and elkhorn coral. Pillar coral has been the focus of a Keys-wide monitoring program to document the health and stressors affecting the species due to its status as a Florida Species of Special Concern and its recent 2014 ESA listing as threatened. Prior to its listing, the park had records of pillar coral at eight sites in the park representing northern, central and southern reefs. FWRI started routinely monitoring colonies at two sites in March 2014. Regular monitoring was conducted on a single colony of pillar coral at a site named Arch Reef and at twelve colonies at an area named Biscayne Pillars. The colonies at Biscayne Pillars underwent slow decline from 2014–2015 but in the beginning of 2016 there was an 82% loss of tissue due to disease and in 2017 no live coral was found. Two known colonies, the regularly monitored Arch Reef, and a colony at Arch Ledge which was observed periodically by NPS staff, died completely during 18 months in 2015/16. These losses represent the extinction of two likely distinct genotypes in a region with very low genetic diversity. As of March 2017, park staff revisited all know pillar coral sites and confirmed complete mortality of pillar coral at all sites. As a result of the catastrophic losses during the last two years, pillar coral is now locally extinct within the park. Due to the low regional genotypic diversity and disease vulnerability, five pillar coral fragments were harvested (under permit) from Biscayne Pillars by park staff and transferred to the Coral Disease and Health Consortium lab in an attempt to stop disease progression and preserve the genotype of this species. Three of the five fragments are still alive today.

Elkhorn coral, which has once a dominant species along the Florida reef tract (Shinn, 1989), has undergone significant loses during the last 30 years (Williams and Miller, 2012). The most common causes of tissue loss are due to bleaching, breakage, predation by snails and disease (Williams and Miller 2012). Two areas were identified within BISC that had elkhorn coral. During a four-year study period (2011–2015), there was 27% tissue loss at one site (Ball Buoy) and 96% tissue loss at the Marker 3 site. Prior to recent bleaching events at Marker 3, elkhorn coral had shown increased growth and number of colonies. Meanwhile at Ball Buoy, one of the last major stands of elkhorn coral in the Florida Keys, tissue loss has been slow and steady, with snail predation a major contributor (Miller, 2001; Karen Neely, FWRI, pers. comm. 2016). Recruitment of new elkhorn coral colonies is unlikely as the species is undergoing a dramatic decline throughout its entire range (Williams et al., 2008).

Elkhorn coral (*Acropora palmata*), at Ball Buoy in 2016 (Photo by David Bryan)

4.4.8. Sea water temperature

Rising ocean temperatures associated with global warming are one of the greatest threats to coral reef ecosystems (Baker et al., 2008; Hoegh-Guldberg et al., 2007; Hoegh-Guldberg and Bruno, 2010). Long term ocean temperatures have been rising in the Florida Keys (Kuffner et al., 2015; Manzello, 2015). SFCN has been recording water temperature at their coral monitoring sites since 2004. During this time period water temperatures during summer months were typically above the local bleaching threshold of 30.5°C. Previous work has shown that bleaching can began when corals experience four weeks of temperatures above their threshold and mortality can occur after eight weeks (Manzello et al., 2007; Eakin et al., 2010). In 2015 both Amanda's Reef and Ball Buoy had 50 days with temperatures greater than 30.5°C for the first time since data had been recorded (Figure 4.4.10).

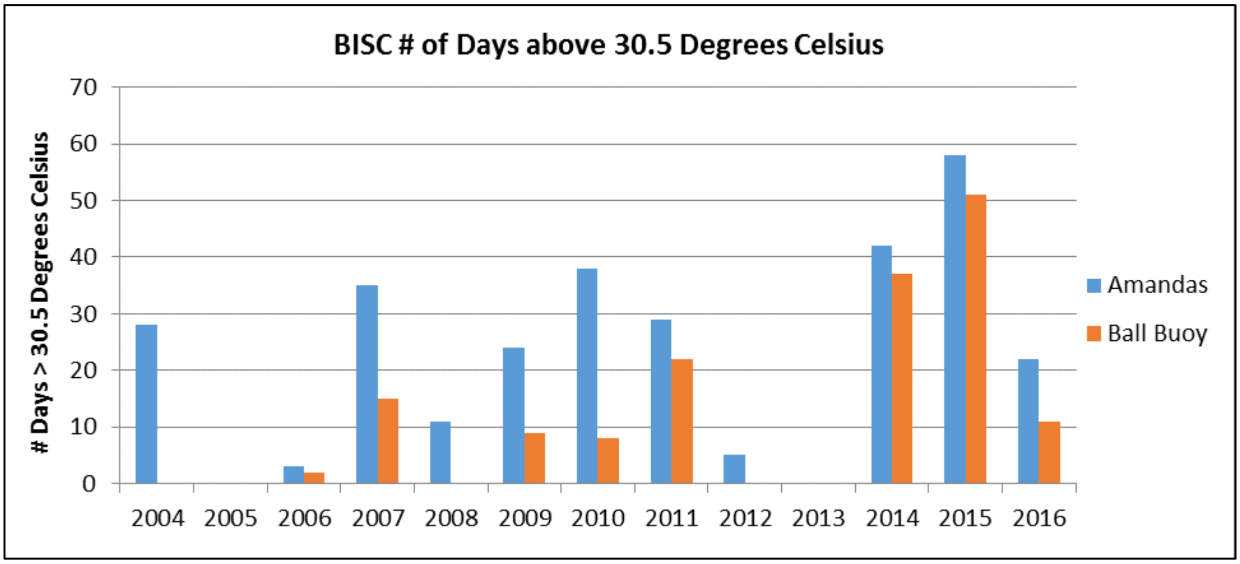
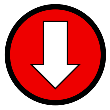
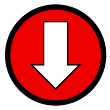
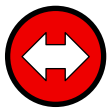
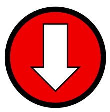
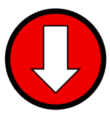


Figure 4.4.10. The number of days that water temperatures were above the south Florida coral bleaching threshold of 30.5°C at Amanda's Reef and Ball Buoy from 2004–2016. (Provided by SFCN).

4.4.9. Conclusion

The condition of corals throughout the park warrants significant concern (Table 4.4.2). Monitoring both at fixed sites and random sites throughout BISC suggests that coral coverage in the park has been at historically low percentages during the last 10 years and continues to suffer high levels of bleaching, disease, and subsequent mortality. One threatened species, pillar coral, is now locally extinct and there have been steep declines in the threatened elkhorn and *Orbicella* spp. corals throughout the park. Overall, the benthic community appears to be in transition from scleractinian hard corals to macroalgae, soft corals and sponges consistent with coral reef ecosystems throughout the Caribbean (Jackson et al., 2014). Tissue loss and mortality of corals within BISC is largely driven by far field threats such as global warming but activities such as anchoring and deploying traps have their effects and can be lessened through policies, regulations, and education (Davis, 1977; Medio et al. 1997; Dinsdale et al., 2004; Uhrin, 2016).

Table 4.4.2. Conditions and trends of corals in BISC.

Criteria	Condition & Trend	Rationale	Reference Condition
Percent coverage (long term sites)		Percent coverage of stony corals is at historic lows and is still declining	Increasing coverage by 10–30% to 1977–1981 levels
Bleaching prevalence		During 2014 and 2015, large scale bleaching events have affected the corals within BISC. Prevalence has been greater than 50% in several regions.	Low annual prevalence (<20%) and infrequent mass bleaching events (≤ every 5–10 years).
Mortality		Mortality rates are consistently above desired state	≤ 1% mortality
Threatened species abundance		Pillar coral is now locally extinct within the park. Elkhorn and *Orbcella* spp. corals have undergone a drastic decline.	A genetically viable population
Seawater temperature		During summer months water temperatures on Amanda's Reef exceed the bleaching threshold during 4 of the last 11 years with data. In 2014 and 2015 both monitored reefs had 35 days over bleaching threshold.	Reef temperatures exceed local bleaching threshold (30.5 C) for less than 4 weeks (28 days)

Staghorn Coral Nurseries and Outplanting

In south Florida and throughout the Caribbean, staghorn coral (Acropora cervicornis) has historically been a dominant builder of reef structure providing habitat for a wide variety of coral reef fish species. However, since the late 1970s, staghorn abundance has declined significantly throughout its range, causing grave concern.

In 2007, the University of Miami established an underwater coral nursery for staghorn coral with the goal of transplanting nursery-grown staghorn colonies onto reef sites to bridge spatial gaps in existing staghorn communities and to facilitate sexual reproduction. These new colonies can provide new recruits to reseed nearby reefs and promote the natural recovery of staghorn populations. Since inception, the project has developed efficient means to propagate coral fragments within in-situ coral nurseries. Two nurseries located within BISC presently (2016) hold 1,500 colonies/fragments from 33 genotypes.

In addition to growing corals within each nursery, over 3,500 individuals have been transplanted to 28 reefs within BISC. Since transplanting began in 2012, survivorship has been high (88.7%) and significant growth of colonies has been observed along with overall good condition.

The nurseries and outplant sites located within BISC play a key role by providing a physical connection between the Florida Keys and northern counties. Propagation and restoration activities within BISC may help recover a key marine resource that has declined significantly throughout the region. Staghorn corals contribute to a healthy reef ecosystem and provide a draw for tourism-related activities.

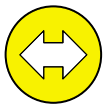
Information on program:

http://sharkresearch.rsmas.miami.edu/research/projects/coral-restoration

4.5. Selected Marine Invertebrates

The condition of Caribbean spiny lobster, pink shrimp, queen conch, and long-spined sea urchin is unchanging and warrants moderate concern (Table 4.5.1).

Table 4.5.1. Selected marine invertebrates condition status and trend.

Attribute	Condition & Trend	Interpretation
Caribbean Spiny Lobster, Pink Shrimp, Queen Conch and Long-spined Sea Urchin		Long-spined sea urchin and queen conch are at levels well below historic norms but appear to be stable. Lobster and shrimp catches appear to be stable but it is unclear if the current harvest rate is sustainable and if it affects ecosystem health.

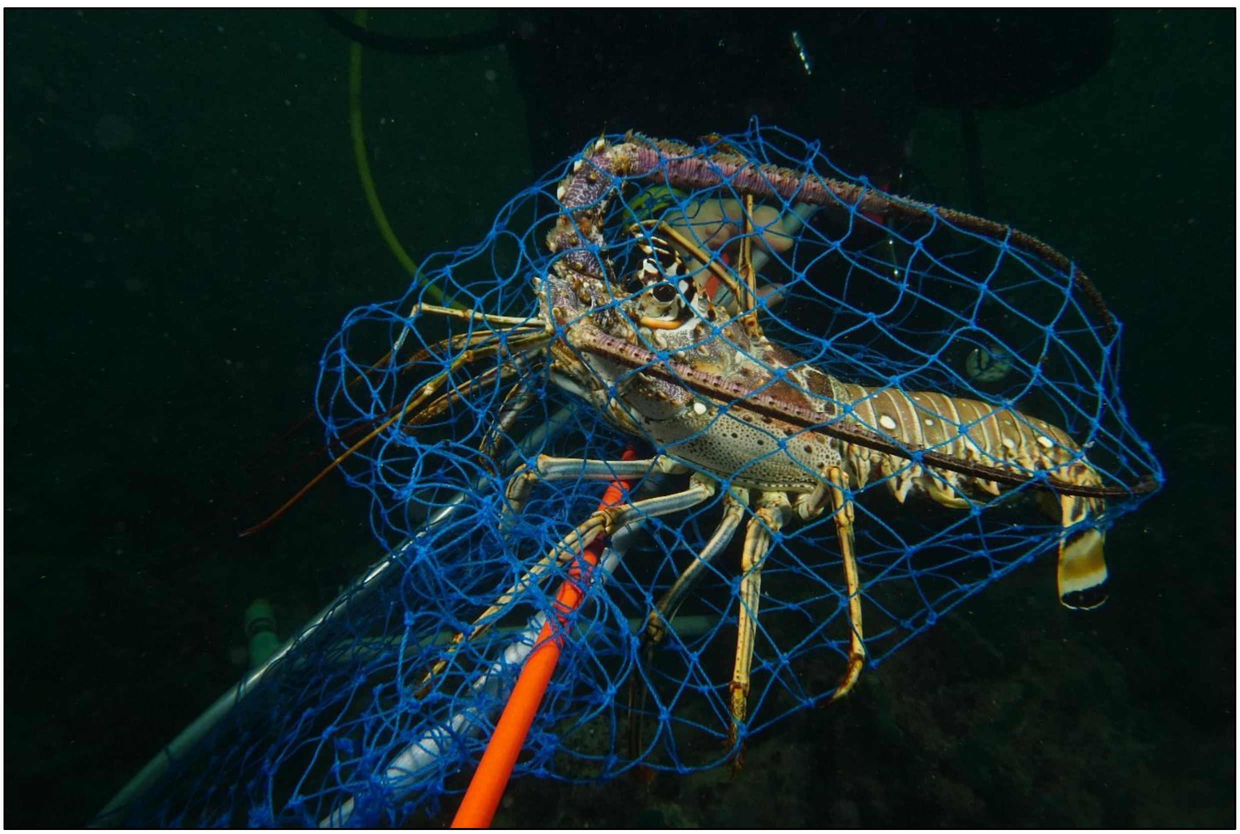
4.5.1. Importance

The two most valuable commercial fisheries within BISC both target crustaceans: Caribbean spiny lobster (*Panulirus argus*) and pink shrimp (*Farfantepenaeus duorarum*). Not only are these abundant crustaceans economically important for commercial fisheries, they also offer tremendous opportunities for recreational fishers. The spiny lobster recreational fishery alone draws thousands of visitors each year into park waters, particularly during the two-day mini season. To help protect the fishery, in 1979 the Florida State Legislature created the Biscayne Bay and Card Sound Lobster Sanctuary which prohibits commercial and recreational harvest throughout Biscayne Bay, including all bay waters of the park. Pink shrimp, which have historically been harvested by commercial fishermen for bait, now also support a commercial and growing recreational fishery for food. In addition to their economic value, both spiny lobster and pink shrimp are an integral component of the broader south Florida and Caribbean marine ecosystem. Queen conch (*Strombus gigas*) and long-spined sea urchin (*Diadema antillarum*) are two ecologically important invertebrates within BISC that have both seen precipitous population declines in the recent past. Queen conch have struggled to rebound despite protection from fishing and long-spined sea urchin have not recovered from a Caribbean-wide disease outbreak that occurred in 1983–1984. Each of these marine invertebrates fulfill a unique role in the tropical marine environment in BISC and their population status warrants concern.

The desired condition for the park is to have healthy populations of spiny lobster, pink shrimp, queen conch and long-spined sea urchins that resemble their natural unaltered state. Information for these invertebrates comes from various sources which determine the metrics that can be used to evaluate their status. Data from commercial fisheries can be used in lobster and shrimp fisheries to look at long-term trends. Likewise, data from the recreational lobster fishery also has a long time series and catch per unit effort estimates can be used as a relative index of abundance to assess potential population changes. Data from diver surveys can be used to compare the occurrence and density of conch and long-spined urchin to reference values.

4.5.2. Caribbean Spiny Lobster

The Caribbean spiny lobster is a benthic carnivore that preys upon a variety of small marine invertebrates besides scavenging the ocean floor for carrion. Juvenile and adult lobster are an important food source for a number of fish species found within BISC. In BISC, the recreational fishery alone attracts thousands of visitors each year with peak visitation during the two-day mini season, which is a precursor to the eight-month regular season. In BISC, the recreational lobster fishery is monitored with two fishery dependent surveys. The BISC creel survey records angler catch of finfish and crustaceans during select weekends throughout the year, with data going back to 1976. The BISC lobster mini season creel survey is focused on lobster catch only during the two-day mini season and dates back to 1987 (McDonough, 2012). In both surveys, the number and size of lobsters are recorded along with the number of anglers per boat and hours fished. Catch per unit of effort (CPUE) from the recreational fishery during the mini and regular season has been relatively stable since the early 1990s (Figure 4.5.1). Catch rates were a little higher in the 1990s during the regular season than more recently (2010–2015), but overall the recreational fishery data suggests a stable population.



Recreational diver captures a spiny lobster (Photo by David Bryan)

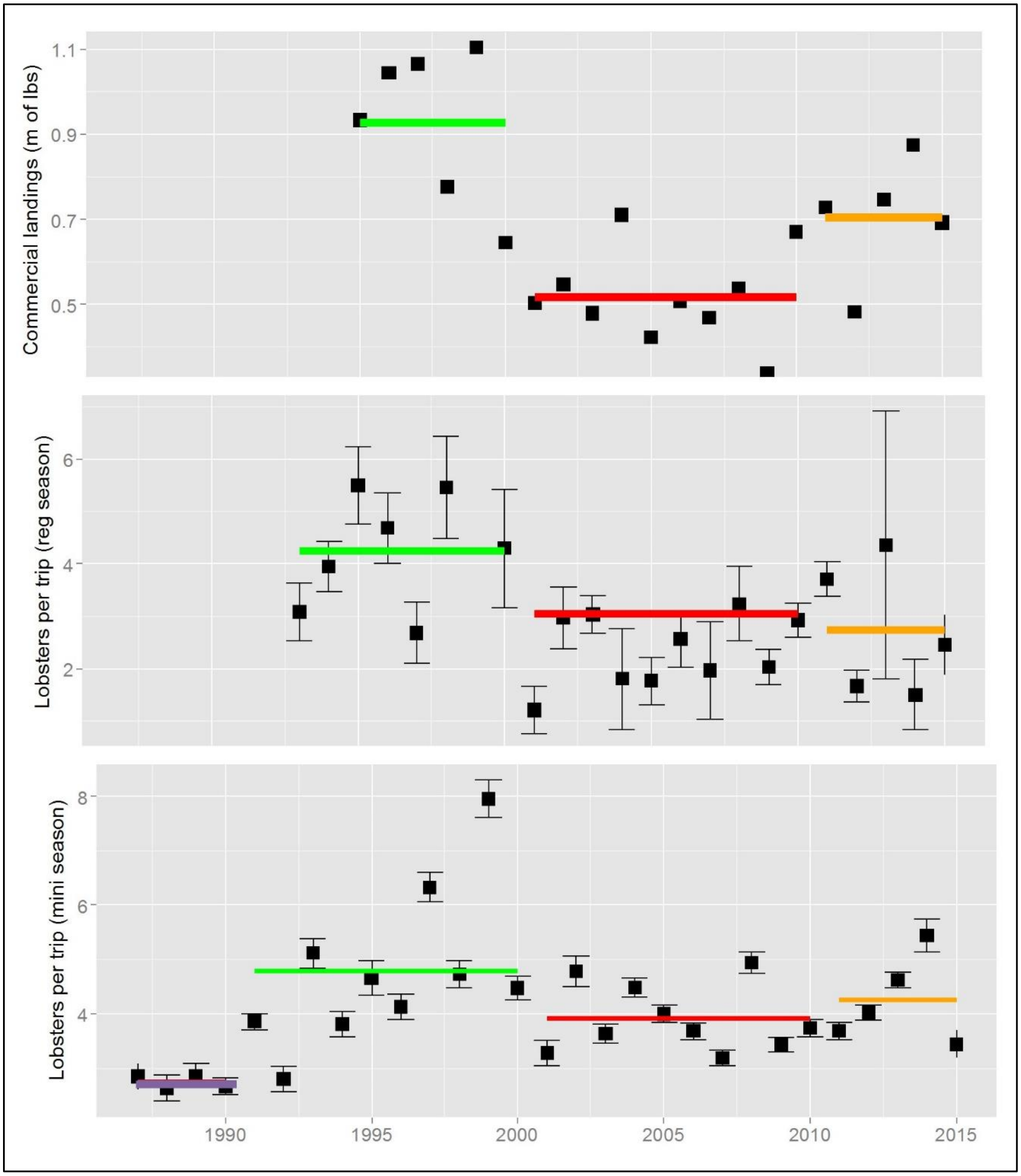


Figure 4.5.1. Fishery dependent time series of (a) total commercial lobster landings in Miami commercial fishing area 744), (b) number of lobsters per person trip during regular season when lobster is landed, (c) number of lobster per person trip during mini season. Error bars represent standard error. Horizontal lines represent decadal averages (purple= 1987–1990, green=1991–2000, red = 2001–2010, and orange= 2011–2015). (Data from FWC Commercial Landings Summary and BISC creel survey).

Despite its importance in BISC, the recreational fishery is only responsible for approximately 20% of total lobster mortality throughout Florida. This is roughly equivalent to the mortality estimated to be lost to trap discards (i.e., confinement of sub-legal lobster, ghost fishing, etc.) (Butler and Matthews, 2014; Tom Matthews, FWRI, pers. comm. 2016). The Florida commercial trap fishery has landed an annual average of 5.5 million lbs, with a dockside value of over 40 million dollars during 2011–2015. Roughly 13% of those landings have been made within the Miami commercial reporting area that encompasses BISC (Figure 4.5.2).

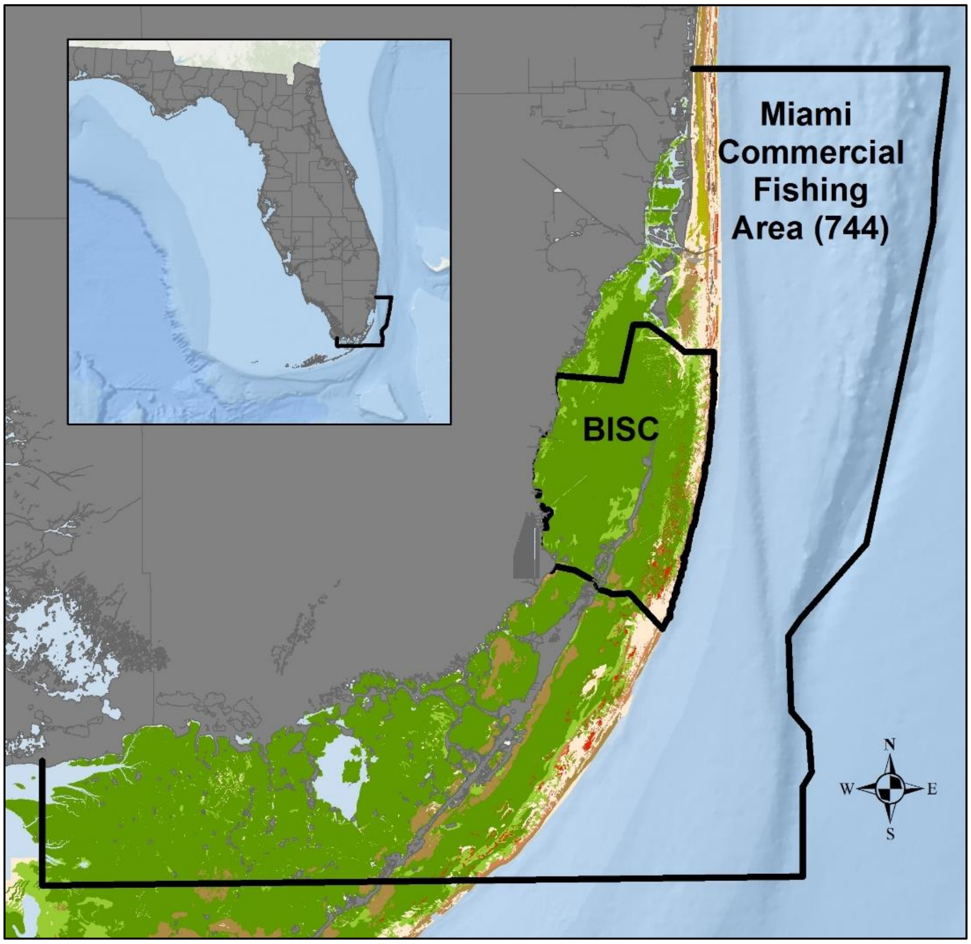


Figure 4.5.2. Miami commercial fishing area (744) and BISC boundary. 19% of mapped coral reef hardbottom in area 744 is found within BISC (Map the Unified Florida Coral Reef Tract Map, FWRI).

There are around 30 vessels that report commercial lobster fishing directly within BISC, but inconsistencies in the recorded geographical area of the catch often occur, so the exact amount of catch and effort within BISC is unclear. However, spiny lobster landings data for the Miami region (commercial reporting area 744) from commercial logbook and trip ticket information are available and they should share a similar trend as would catches made directly in BISC. Commercial spiny lobster landings, which declined during the 2000s, have recently increased (Figure 4.5.1). The interpretation of landings data alone is difficult. A decrease in landings could suggest a declining population or a stable population with fewer boats fishing. Likewise, the recent increase in landings may not represent population growth, but may instead be a result of increased fishing effort in response to the rise in price per pound caused by the demand and sale of live lobsters. However, the current landings in the Miami region, which are less than historic highs but greater than the low landings in the 2000s, suggest a relatively stable population.

Caribbean spiny lobster (*Panulirus argus*) (Photo by David Bryan)

4.5.3. Pink Shrimp

The pink shrimp is the most common shrimp found throughout Biscayne Bay (Figure 4.5.3). These shrimp are juveniles which have been transported on currents from the Dry Tortugas and settle on the shallow western boundary of Biscayne Bay (Ault et al., 1999a). As they mature, the shrimp move towards deeper water in the center of Biscayne Bay and then during strong winter fronts rise from the seagrass beds and migrate out of Biscayne Bay during the outgoing tide. Once past the keys, they sometimes ride southern currents down through Hawk Channel towards the Florida Keys. Here they may be swept into Florida Bay during incoming tides and possibly join the large pink shrimp migration to the Dry Tortugas region to spawn. Therefore, adult pink shrimp are not only an integral component of Biscayne Bay, but they are important food source throughout the south Florida reef ecosystem and provide key mechanism of energy transformation from nearshore waters to the reefs. As such, they are a keystone species for the health of the south Florida ecosystem.

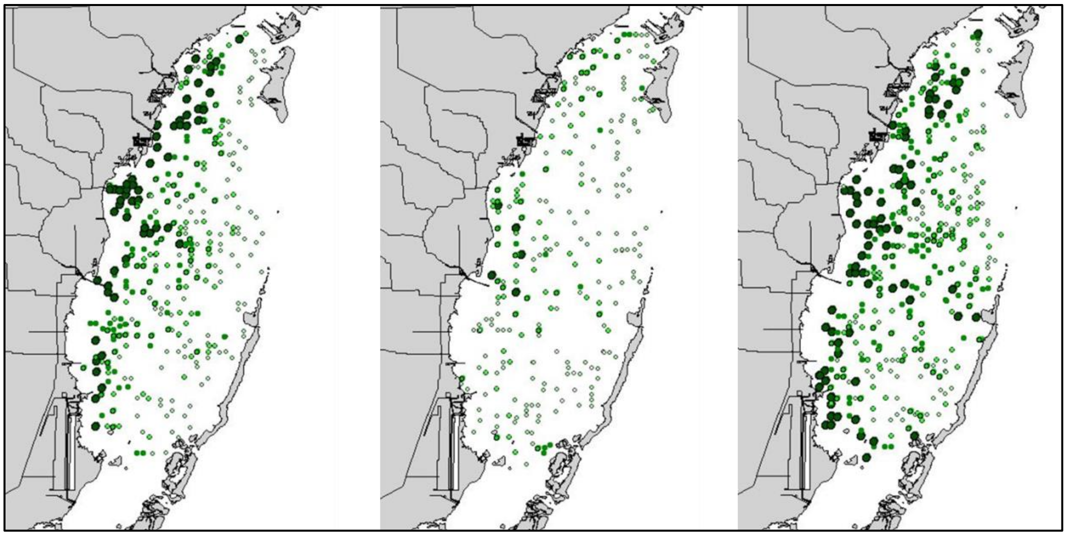


Figure 4.5.3. Pink shrimp seasonal density in the spring, summer and fall of 1999. Darker green represents greater density. (Provided by J. Ault unpublished).

Within BISC, the juvenile shrimp are the target of two productive commercial fisheries. They are caught in a bait fishery that uses a roller trawl in southern Biscayne Bay, and a food fishery that uses wing-net gear near channels in the middle and upper Biscayne Bay where the tidal flow is large. Johnson et al. (2012) reported a slight increase of CPUE since the early 1970s with peak CPUE in the late 1980s followed by a decline until 2005. Since 2005 there has been a slight increase in both bait and food shrimp CPUE in Miami (Figure 4.5.4). Similar to the lobster fishery data, fishery-dependent indices may not accurately represent the population status of pink shrimp in BISC. A standard unit of fishing effort to compare landings over many years is difficult to define and constrained by available data on the fishing fleet. Due to some shortcomings with the fishery-dependent data, there has been some effort to conduct fishery-independent surveys. Ault et al. (1999a) used a stratified random survey to estimate a baseline abundance of pink shrimp throughout Biscayne Bay with a very low coefficient of variance (4%). This survey could be repeated to see if the population size has changed with time. Pink shrimp density along the western nursery ground has been monitored since 2007 at 47 fixed sites. These data are collected semi-annually, during the dry and wet seasons, as and reported as part of the Integrated Biscayne Bay Ecosystem Monitoring and Assessment (IBBEAM) project. In recent years, pink shrimp densities have been below the running average (Figure 4.5.5).

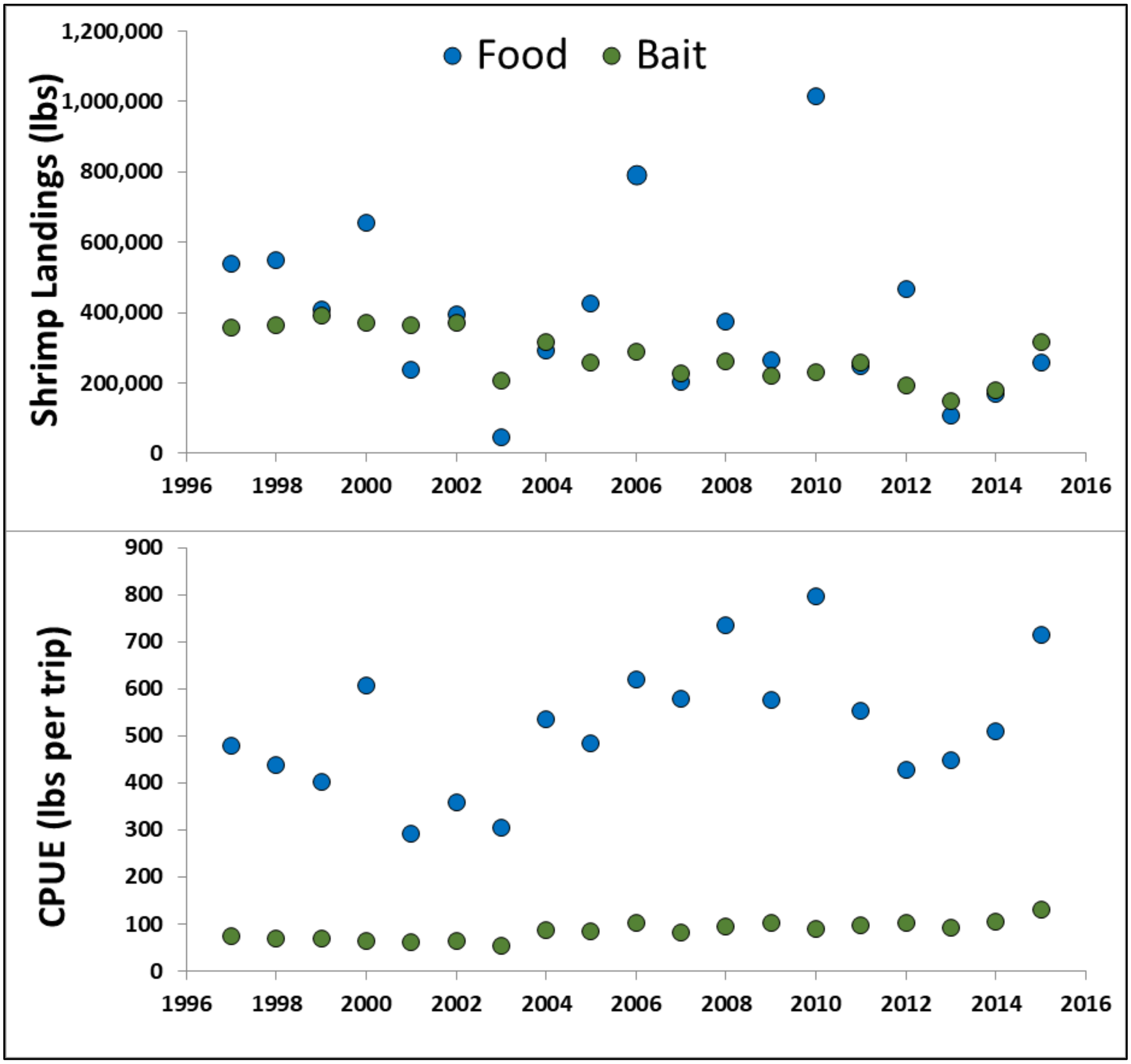


Figure 4.5.4. Pink Shrimp landings and catch per unit effort (CPUE) for the food and bait shrimp fisheries operating in the Miami commercial fishing area 744. (Data from https://public.myfwc.com/FWRI/PFDM/ReportCreator.aspx).

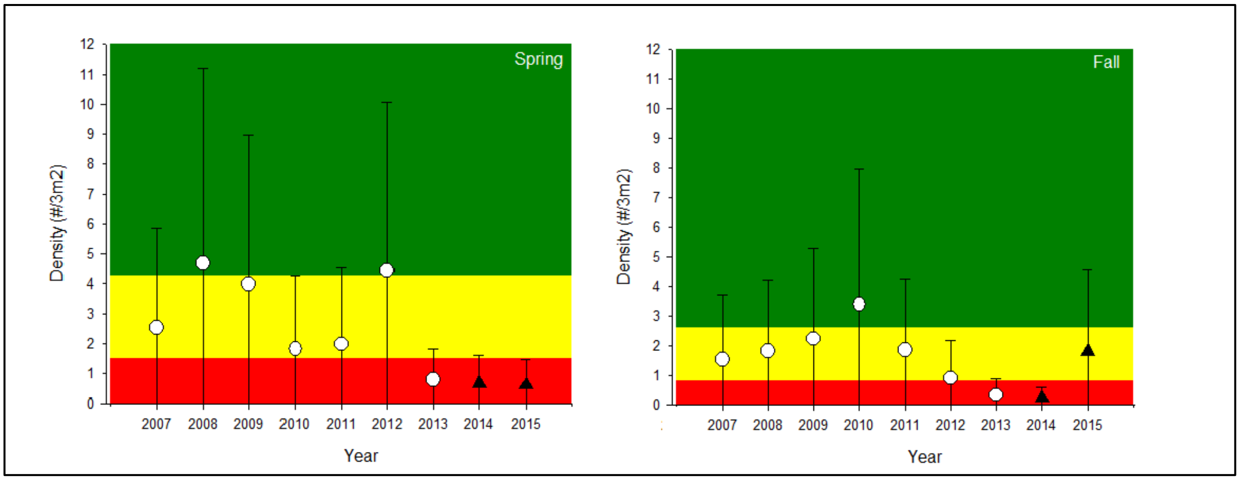


Figure 4.5.5. Stop-light pink shrimp status plots from IBBEAM. Spring or fall density for the years 2007 through 2013 are used to calculate the 25th and 75th percentiles used to demarcate the red (poor), yellow (neutral), and green (good) parts of the background. Pink shrimp status in 2014 and 2015 is evaluated against this background (Reprinted from IBBEAM, 2015).

4.5.4. Queen Conch

Queen conch, which once supported a modest recreational and commercial fishery in south Florida, continue to be an iconic item of Florida Keys culture (Glazer and Berg, 1994). Increased fishing pressure both for their shells and meat in the 1960s and 1970s led to a precipitous drop in their abundance. In response, the State of Florida enacted a ban on commercial harvest in 1975, followed by a total ban in 1985. Since the closure, there has been a substantial amount of research to examine the remaining queen conch populations in south Florida and to investigate means for their recovery (Glazer and Berg, 1994; NMFS, 2014). However, the focus has remained on the Florida Keys National Marine Sanctuary, while BISC has received very little attention for queen conch research and monitoring.

Adult queen conch can be found in a variety of habits in BISC including rubble, gravel, and low-relief hard bottom, though they are most commonly found in offshore stable sandy areas that have a high availability of macroalgae, their primary food source (Brownell and Stevely, 1981). The queen conch populations within BISC were unsustainably exploited in the past and it is unclear if any reproductively successful populations exist within the park. Characteristics of queen conch, such as their slow movement, long time to sexual maturity, tendency to form dense aggregations, and habitation of shallow waters make them especially susceptible to overfishing (Theile, 2005). Their gregarious nature, both as juveniles and adults, may still allow them to be illegally harvested, as their demand remains high in south Florida.

During the multi-agency reef fish visual census (RVC), divers record the presence and numbers of any conch within their 15m diameter cylinder. Data from 2003 to 2011 within BISC were examined to look for any possible breeding aggregations. There were 4 sites with greater than 200 conch per ha, suggesting possible aggregations, but these locations have not been surveyed (Lee Richter, SFCN, pers. comm. 2017).

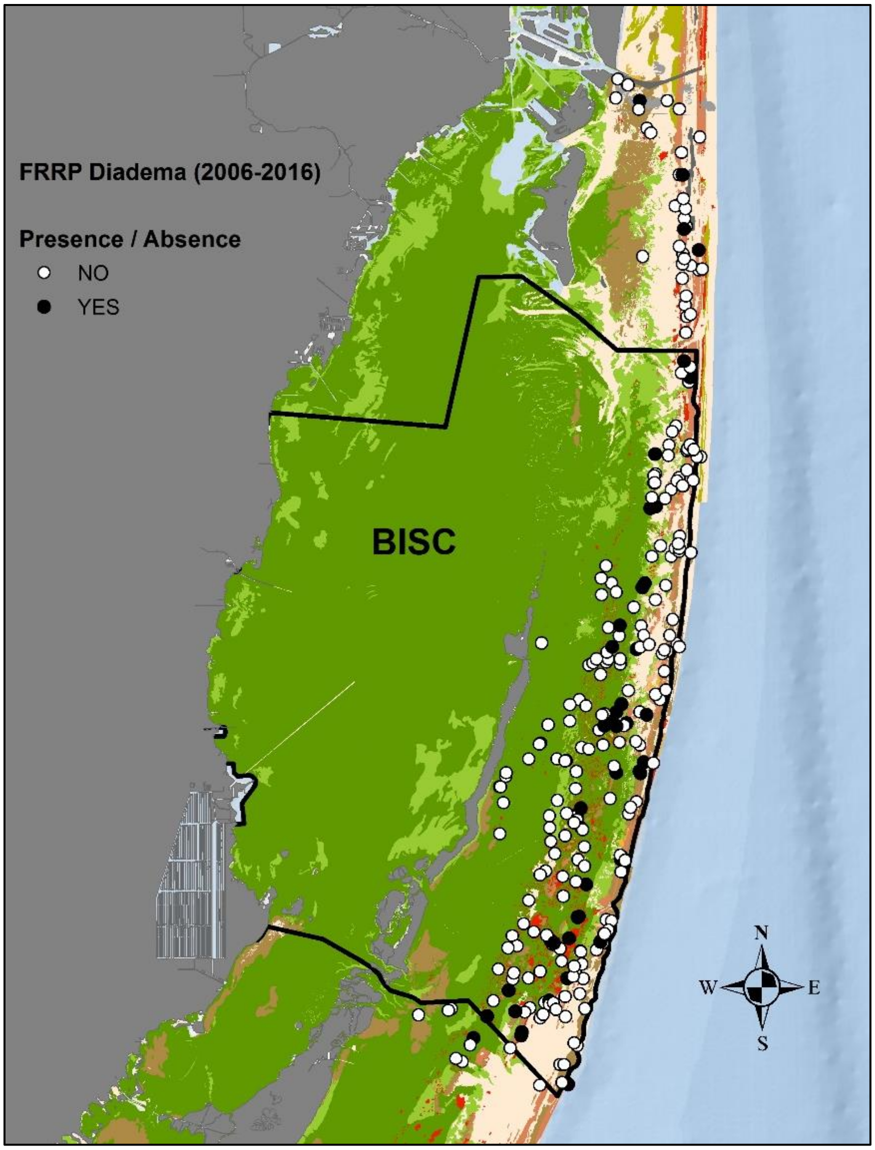
Queen conch (Photo from BISC)

In 2014, FWRI conducted a Florida Keys-wide survey of queen conch. A total of 37 back-reef sites were surveyed in BISC and 13 sites just outside the park at depths between 60 and 150 ft. Only four sites had queen conch present. Densities were low (13.5 conch per ha), with an estimated 95,613 conch living in BISC, most (99%) of which were juveniles. These findings suggest that BISC receives recruitment from upstream in the Florida Keys. However, sample size was low and it is still unclear if aggregations exist within the park (Glazer et al., 2014).

4.5.5. Long-spined sea urchin

In 1983 and 1984, a Caribbean-wide mass mortality event of long-spined sea urchin extended throughout South Florida (Lessios, 1988). Long-spined sea urchin were a major grazer within the coral reef ecosystem and the mass die-off has been attributed as one of several factors contributing to the decline of scleractinian corals and an increase in algae dominated reefs (Lessios, 1988).

Prior to the mass mortality event, the density and abundance of long-spined sea urchin varied greatly depending on reef location (Kissling et al., 2014). There is no historical data for BISC, but in the spur and groove habitat of the lower Florida Keys, densities averaged around 5 urchins per m^2 (Kissling et al., 2014). There has been a slow rate of recovery throughout Florida Keys (Chiappone et al., 2013), but densities are still an order of magnitude lower than estimates from before the die-off. The National Coral Reef Monitoring Program, FRRP and SFCN all record long-spined sea urchin presence within their coral sample sites. Data from FRRP suggest that the percent occurrence of long-spined urchins has been relatively stable, with a possible decrease since 2006 (Figure 4.5.6).



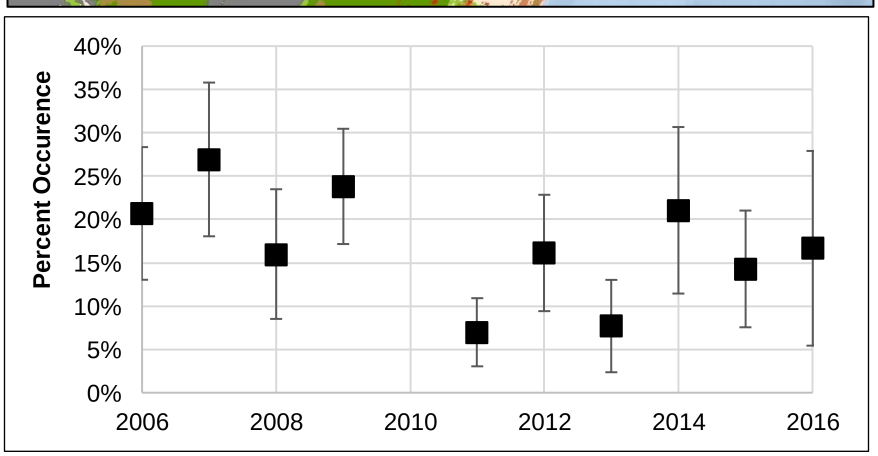


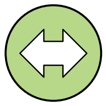
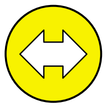
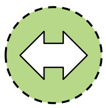
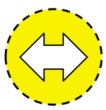
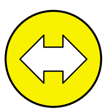
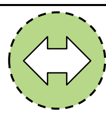
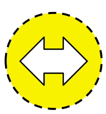
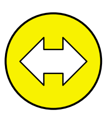
Figure 4.5.6. Location and percent occurrence of long-spined urchin (*Diadema antillarum*) in FRRP samples from 2006–2016 (Map data from Unified Florida Coral Reef Tract Map, FWC-FWRI and long-spined urchin data from FRRP).

4.5.6. Conclusion

Caribbean spiny lobster, pink shrimp, queen conch and long-spined sea urchins play an import role in the tropical marine environment and are key to a healthy ecosystem. Spiny lobster and shrimp also provide the greatest economic benefit for commercial fishers within BISC and contribute significantly to the value of the recreational fishery. Fishery-dependent data from the lobster and shrimp fisheries suggest that the populations of both species are stable. However, it is unclear what effects the current level of harvest has on the greater ecosystem and how the populations of lobster and shrimp compare to when they were not heavily exploited. Therefore, their condition status warrants moderate concern (Table 4.5.2). Queen conch and long-spined sea urchin occurrence and densities are well below historic values. Queen conch have been protected from human harvest for 30 years, yet no large breeding aggregation has been verified in BISC. Long-spined sea urchin have not recovered from the Caribbean wide disease outbreak that occurred in 1983 through 1984. Both of these species require moderate concern due to their low numbers.

Biscayne commercial shrimp trawler (Photo by David Bryan)

Table 4.5.2. Conditions and trends of selected marine invertebrates in BISC.

Criteria	Condition & Trend	Rationale	Reference Condition
Lobster catch per trip (mini season)		Average CPUE over the last twenty five years has remained relatively constant and is greater than during the late 1980s	Stable or increasing CPUE with rates similar to 1990s (5 lobsters per person per trip)
Lobster catch per trip (regular season)		Average CPUE over the last five years is markedly lower than the 1990s and has declined since the 2000s. However, sample sizes are very low and there is some uncertainty in values.	Stable or increasing CPUE with rates similar to 1990s (4 lobsters per person per trip)
Commercial lobster landings		Commercial landings over the last five years have increased since the 2000s, but are still less than in the 1990s.Without information on effort, it is unclear how to interpret this trend.	Stable or increasing landings.
Bait shrimp CPUE		The commercial bait shrimp fishery has a long history in Biscayne Bay. CPUE, as an index of relative abundance, shows apparent stable trends, though the ability to quantify effort is imprecise.	Stable CPUE
Shrimp density in drop net survey		Spring density in 2015 is below 25th percentile and is at a time series low. Fall density is at a time series average. There is significant error associated with estimates.	Seasonal densities from 2007–2013 are used as reference condition.
Density of juvenile Queen conch		Juvenile conch abundances suggest moderate recruitment.	Increasing densities of juvenile conch
Occurrence of Queen conch breeding aggregations		No breeding aggregations within BISC have been surveyed but RVC data suggests there may be possible locations.	Sites with adult densities >200 individuals per ha
Long-spined sea urchin density		Long-spined sea urchin densities are significantly lower than historical norms (pre 1983) but appear to be gradually increasing.	Pre-1983 densities

Lobster Sanctuary

In 1979 the Florida State Legislature established a lobster sanctuary in Biscayne Bay and Card Sound, including all bay waters within BISC. This area is off limits for commercial and recreational lobster fishing and has served as an important nursery for juvenile lobsters where they are associated with sponge flats, seagrass beds and exposed hardbottom structures.

As they mature these lobsters move out through the passes in the keys to the nearshore patch reefs and reef platform (David and Dodrill, 1980). From there they migrate north and south along the reef tract.

Currently no studies monitor the recruitment and survival of lobsters within Biscayne Bay, although the South Florida and Caribbean Inventory and Monitoring Network has developed a protocol for in-water, fishery-independent assessment of Caribbean spiny lobster, and hopes to implement this protocol in the near future in the South Florida and Caribbean parks that have this species.

In the 1960s and 70s juvenile lobsters were bycatch in the commercial shrimp industry and it is unclear if this is still the case. Nevertheless, Biscayne Bay, along with Florida Bay in Everglades National Park, function as key nursery for the south Florida lobster population, providing protection from direct harvest.

The Western Sambos marine reserve in the lower Florida Keys contains a greater density of larger and older lobsters than the surrounding area which has the beneficial effect of increasing egg production (Cox and Hunt, 2005; Maxwell et al., 2013).

Trap Debris

Trap debris from commercial lobster and stone crab fisheries present a continuous issue for Biscayne National Park. In the Florida Keys, an estimated 1 million traps and trap remnants are present (Uhrin et al., 2014) with more added each year.

On average commercial fishermen lose about 18% of the roughly 400,000 lobster traps that are put out each season (Matthews and Uhrin, 2009). During years with hurricanes this percentage can rise to over 60% (Lewis et al., 2009). These lost traps and associated trap line cause significant damage to the coral reefs (Chiappone et al., 2002; Chiappone et al., 2005; Lewis et al., 2009), entangle sea turtles, manatees and dolphins (Adimey et al., 2014) and can continue to confine and starve reef fish and lobsters (Hunt et al., 1986; Butler and Matthews, 2015).

A park program to remove and categorize benthic debris found that, by weight, over 50% of the debris initially found on 12 reefs sites was either intact traps or trap material, such as trap line and trap slats. During site revisits, as much as 82% of the weight of all re-accumulated debris (assessed quarterly) was related to the commercial trap fishery.

Since 2007, BISC has conducted annual derelict trap and debris removal projects in an effort to help restore reef areas affected by debris. Divers are towed along the park's reef tract and remove derelict traps and debris encountered during their search. Each year, the project focuses on a new reef area within the park.

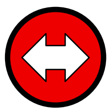
For the last five years, a rough average of 2.5 tons of debris have been removed annually. In 2016, 72 ghost traps (23 lobster, 49 stone crab), 4.9 miles of line, and 136 other pieces of debris ranging from trap pieces to boat parts to a truck tire to a tube sock were removed. Effort has been made to model marine debris hotspots to aid in the efficiency of removal programs (Martens and Huntington, 2012).

Ghost lobster trap at Ball Buoy reef in BISC (Photo by David Bryan)

4.6. Reef Fish, Gamefish and Sharks

The status of reef fish, gamefish, and sharks warrants significant concern and the condition is not improving. Overfishing of reef fish has been documented since at least 1999 and there is high confidence in the assessment of their status. Less is known about the status of gamefishes and sharks (Table 4.6.1).

Table 4.6.1. Reef fish, gamefish and sharks condition status and trend.

Attribute	Condition & Trend	Interpretation
Reef Fish, Gamefish and Sharks		Previous reports have shown that the average size in the exploited phase of the stock for 25 reef fishes in the snapper-grouper complex indicates that they have been overfished. An updated review of six key species for this report indicates that they are still overfished and currently experience overfishing. Overfishing has occurred since at least 1999, as density of these species has been relatively stable over time, but significantly less than for those observed in the Dry Tortugas region. There is scant information on the sustainability status of gamefishes (e.g., bonefish, permit and tarpon) or sharks within BISC.

4.6.1. Importance

The spectacular diversity of fishes within BISC is a major draw to visitors. The lush seagrass beds and sandy flats throughout Biscayne Bay are home to world renowned game fish such as tarpon, bonefish and permit. The patch reef system and offshore platform reef provide habitat to hundreds of species of reef fish and wide variety of shark species frequent the park. Recreational fishing and diving are the main visitor activities in BISC and participation in them brings millions of dollars into the south Florida economy. Many of the more popular species that are caught for personal consumption have been removed by anglers faster than they can reproduce, and the size and number of fish have declined significantly in the region. Historic accounts of bountiful numbers of fishes throughout Biscayne Bay and adjacent reef waters are no longer true. Since 2000, the NPS has worked cooperatively with the FWC on a park Fisheries Management Plan to address the condition of park fishery resources. As of 2019, the plan was being implemented and the cooperating agencies hoped to improve the condition of these resources through park-specific state regulations.

4.6.2. Stressors

Fish populations in south Florida have seen extensive declines over the last 50 years driven primarily by increased angler pressure (Ault et al., 1998, 2005a, 2009). Recreational fishing regulations for Florida reef fish that designed to conserve and improve fish stocks are typically established at the statewide level, and as a result of BISC's enabling legislation, state fishing regulations apply to the waters of BISC. BISC is directly adjacent to the large metropolitan area of Miami and its fish population has arguably the largest amount of fishing pressure in the state. Yet, despite this enormous fishing pressure, there are currently no additional regulatory protections within BISC to help maintain fish populations, although the park—as described in the Fishery Management Plan—is working with the State to develop park-specific State fishing regulations. Ault et al. (2007) analyzed seven important species in BISC and found that all were being unsustainably fished. They looked at potential benefits of a decrease in the number of fish anglers could keep (bag limit) and an increase in the minimum size at which they can be kept (size limit) and found that although an increase in the size limit could help, further restrictions such as a marine protected area were needed to ensure a sufficient number of reproductively viable fish are available to sustain those reef fish populations (Ault et al., 2007). In addition to the reef fish complex found within BISC, game fish such as tarpon (*Megalops atlanticus*), bonefish (*Albula vulpes*) and permit (*Trachinotus falcatus*) frequent the parks waters. Both tarpon and bonefish are protected from harvest in Florida waters and permit have several protective regulations throughout the state and in BISC. However, high fishing pressure coupled with catch and release mortality raises concern for the population status of these species (Cooke and Philipp, 2004; Edwards, 1998).

4.6.3. Reef Fish Monitoring and Assessment

<u>Monitoring</u>

There are two major surveys that have been conducted annually in BISC since the 1970s and that can be used to evaluate the status of reef fish within the Park: (1) the fishery-dependent BISC recreational angler creel survey; and, (2) the fishery-independent reef fish visual census (RVC).

The BISC creel survey (creel survey) has been conducted at local boat ramps and jetties since 1976. During the 1990s, surveys typically took place at Crandon Park Marina. More recently, surveys have been conducted either at Homestead Bayfront County Park, or on the water by Park law enforcement officials. Anglers volunteer to show their catch to Park staff who then identify the catch to species, count and measure what has been caught, and provide information about their fishing experience including where and how long they fished, and what they were targeting.

The multi-agency Reef-fish Visual Census (RVC, Brandt et al. 2009; Smith et al. 2011) fishery-independent monitoring of the Florida Keys began in 1979. RVC is a fishery-independent diver-based visual survey of the size-structured abundance of more than 300 species of exploited and non-target fish species. Abundance and size data for reef-fishes are collected by highly trained and experienced SCUBA divers using a standard, in situ, nondestructive monitoring method (Bohnsack and Bannerot, 1986; Brandt et al., 2009). A stationary diver collects reef-fish data while centered in a circular plot of 15 m diameter, chosen because extensive field experimentation by Bohnsack and Bannerot (1986) indicated this distance provided unbiased observations of small cryptic species as well as large species that avoided close approach to a diver. The larger economically and ecologically important snapper-grouper species are the focus of our survey design. Since 1999, the RVC has included around 100 sites per year within BISC (Figure 4.6.1). Unlike the creel survey with biases associated with fisheries-dependent data and varying sampling effort, the RVC's robust statistical design is repeatable year after year. Estimates of relative abundance (or density) from the RVC can be used to track changes in the population as well as make comparisons amongst regions. In addition, the abundance-at-length data can be used to calculate the average size in the exploitable phase to compare with data from the BISC creel survey to evaluate the status of key exploited species.

Estimation of relative index of population abundance, such as catch per unit effort (CPUE) is possible from the BISC creel survey data; however, the interpretation of CPUE trends may not accurately reflect changes in population abundance (Beverton and Holt, 1957; Hilborn and Walters, 1992). In addition, fundamental inconsistencies with BISC survey effort (location, day of week, time and number of surveys) along with uncertainty in the areas actually fished by anglers makes CPUE estimates highly problematic. Another good option was to evaluate the average size of exploited phase fish in the catch ($\bar{L}$), a metric which when used in conjunction with key life history demographic parameters provides a powerful method to determine the current fishing mortality rate, and thus, the sustainability status of a particular fisheries resource (Beverton and Holt, 1957; Ehrhardt and Ault 1992; Ault et al. 1998, 2005b, 2009, 2018). The average size method requires fewer assumptions than CPUE analysis and relies directly on observed data, instead of survey responses. Use of the average size of exploited phase fish ($\bar{L}$) has been shown to be robust to data-limited situations and can be a very good indicator of the health and status of a fish population (Ault et al., 2005a, 2009, 2014, 2018; Nadon et al. 2015). A comparison of current fishing mortality rate (F) to that at maximum sustainable yield (F_{msy}) can be used to assess stock status. For purposes of this report, we compared the average lengths associated with a F/F_{msy} ratio of 1 to $\bar{L}$. If $\bar{L}$ is greater than the average length at F_{msy}, then the stock is healthy, if lower, then the stock is overfished.

Red grouper *(Epinephelus morio)* with neon goby *(*Elacatinus *oceanops*) cleaner fish (Photo by David Bryan)

Figure 4.6.1. Reef fish visual census (RVC) sampling sites in BISC from 1999–2014 (n=1,659)(NMFS Southeast Fisheries Science Center).

BISC Creel survey

Some of the more sought-after reef fish species caught within BISC are yellowtail snapper (*Ocyurus chrysurus*), gray snapper (*Lutjanus griseus*), mutton snapper (*Lutjanus analis*), black grouper (*Mycteroperca bonaci*), red grouper (*Epinephelus morio*) and hogfish (*Lachnolaimus maximus).* Time series trends of the average size of these species in comparison to the average size throughout Florida suggests that the average size of fish landed in BISC is similar to elsewhere in the State of Florida (Figure 4.6.2). However, the fact that the average size of landed red grouper and mutton snapper are below the legal size limit for several years is of concern. In comparison with the rest of Florida, the percent of gray snapper, yellowtail snapper, hogfish and black grouper that are landed undersized is similar to Florida-wide averages, between 5 and 10% (Table 4.6.2). Yet almost a quarter of red grouper and mutton snapper landings are of undersized fish (Table 4.6.2). This suggests that traditional size limits for these species may provide inadequate protection. For much of the 2000s, gray snapper within BISC were smaller than gray snapper in the rest of Florida which may indicate the role of the park in providing juvenile habitat for gray snapper.

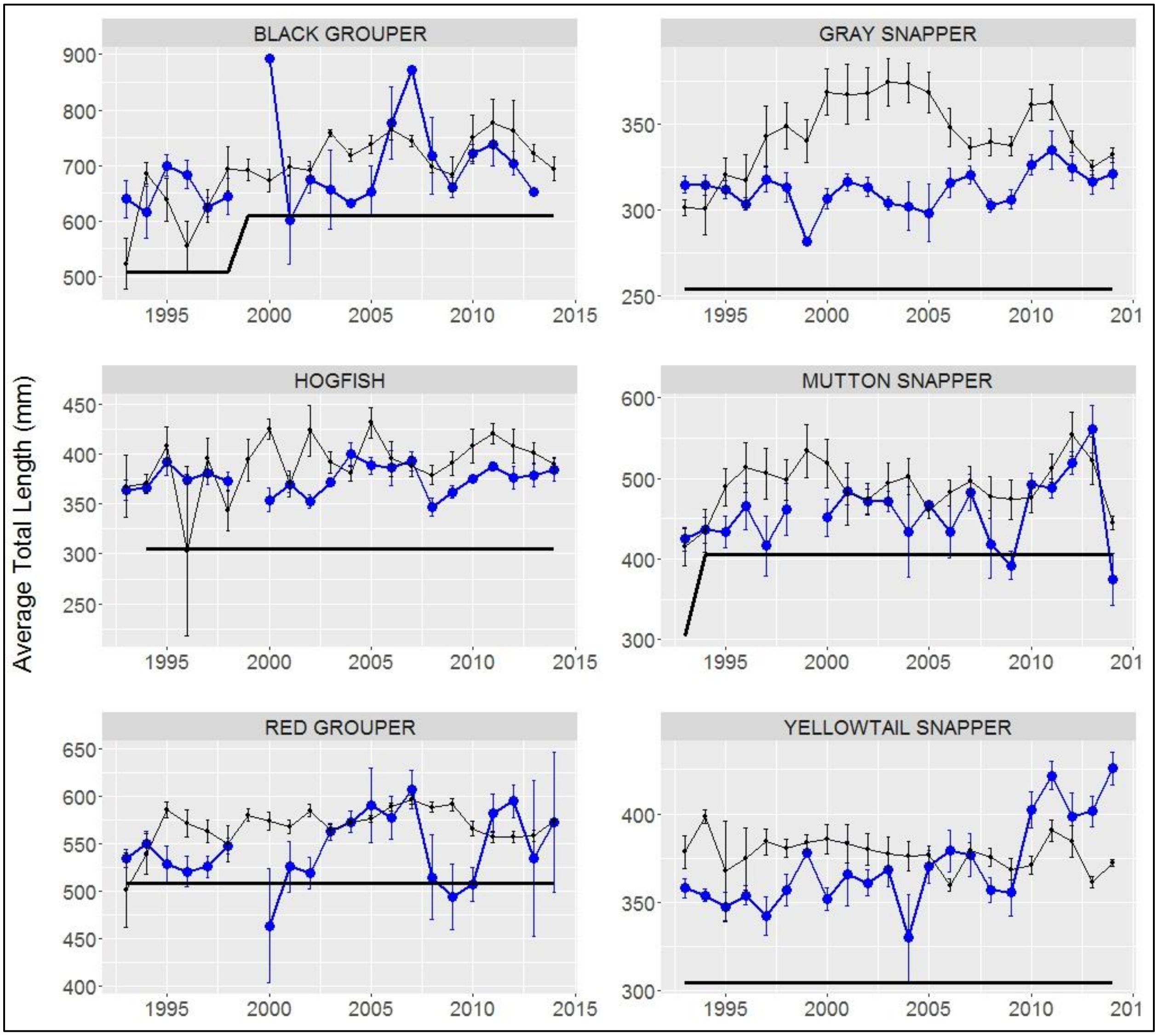


Figure 4.6.2. Average total length (mm) and standard error of key species measured in BISC creel (blue) and from the Marine Recreational Information Program (MRIP) throughout Florida (black) from 1993–2014. Solid black line indicates legal size limit (Florida Fish and Wildlife Conservation Commission).

Table 4.6.2. Percent of landed fish above the legal size limit between 2000–2014 from the Biscayne National Park creel survey and the Florida MRIP survey (NOAA Fisheries).

Common Name	BISC	Florida Wide
Black Grouper	86.8%	88.3%
Red Grouper	77.4%	86.9%
Hogfish	94.5%	97.8%
Gray Snapper	95.8%	97.9%
Mutton Snapper	71.5%	79.4%
Yellowtail Snapper	96.0%	97.0%

The average length of fish in the exploited phase (greater than legal size limit), $\bar{L}$ from the BISC creel (2010–2014) is similar to $\bar{L}$ for fish measured throughout south Florida in the Florida Marine Recreational Information Program (MRIP) survey and the RVC during the same time period (Figure 4.6.3.). For the six key species reanalyzed for this report each one had a $\bar{L}$ less than what would be expected if the population was being fished at a sustainable rate. This is cause for significant concern.

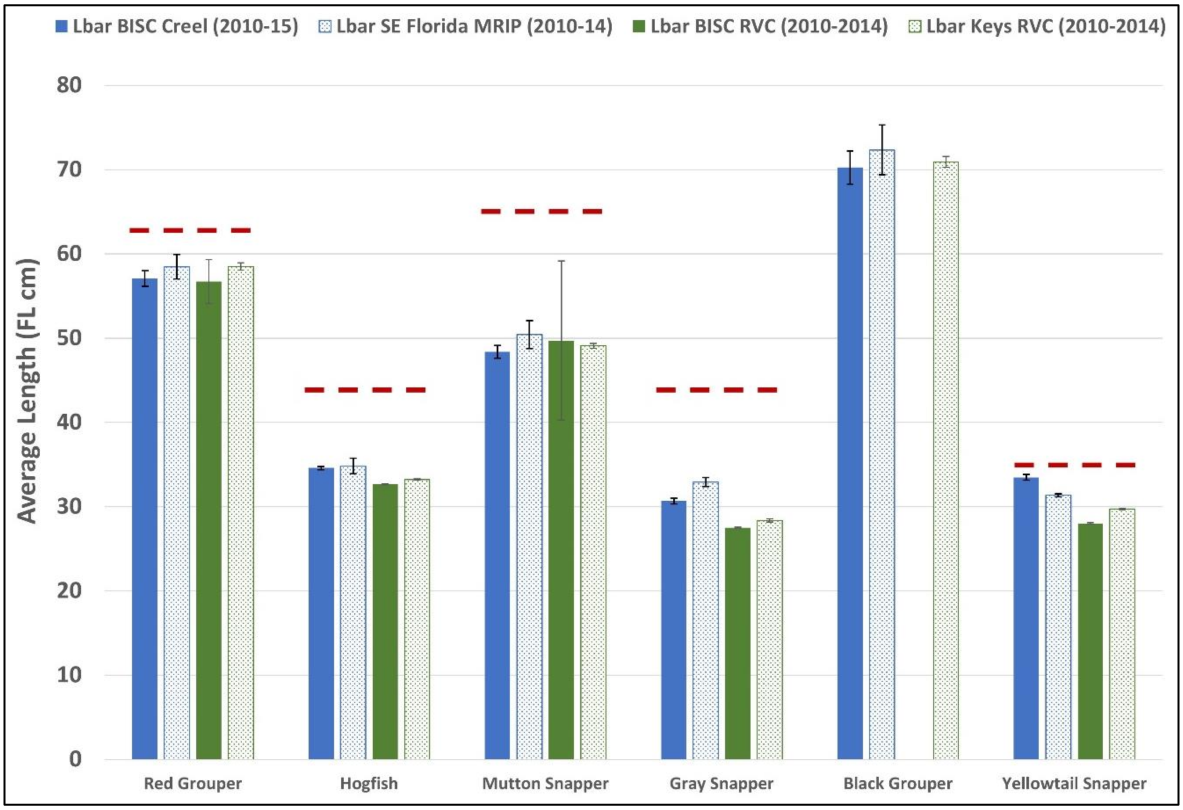


Figure 4.6.3. Average length (cm) of exploited phase ($\bar{L}$) key reef fish, estimated from Biscayne Creel, Florida Marine Recreational Information Program (MRIP), Biscayne RVC and Florida Keys RVC surveys. Bars represent standard error. Dashed red line indicates the expected $\bar{L}$ at MSY (From J. Ault unpublished). Black Grouper expected $\bar{L}$ is 94cm and not shown on chart.

<u>RVC</u>

The density of the key exploited species in BISC has remained relatively stable since 1999, suggesting no significant changes in the abundance of fish within the park during the last 2 decades (Figure 4.6.4). These fish were considered overfished in 1996 (Ault et al., 1998) and with no improvements observed, their status warrants moderate concern. In addition, the density of fishes in BISC is significantly lower than that of Dry Tortugas, where overall fishing pressure is lower and a large marine protected area has provided additional protection of fish species (Figure 4.6.4). As such, DRTO is used as a reference condition for density of exploited species. The average length of exploited phase fish ($\bar{L}$) measured during the RVC is similar to $\bar{L}$ from the fishery-dependent data and from RVC estimates from the rest of the Florida Keys (Figure 4.6.3.). The similarity of $\bar{L}$

between the two survey types adds additional strength to the assumption that the lengths represent the true population size structure and further indicate a problem with overfishing.

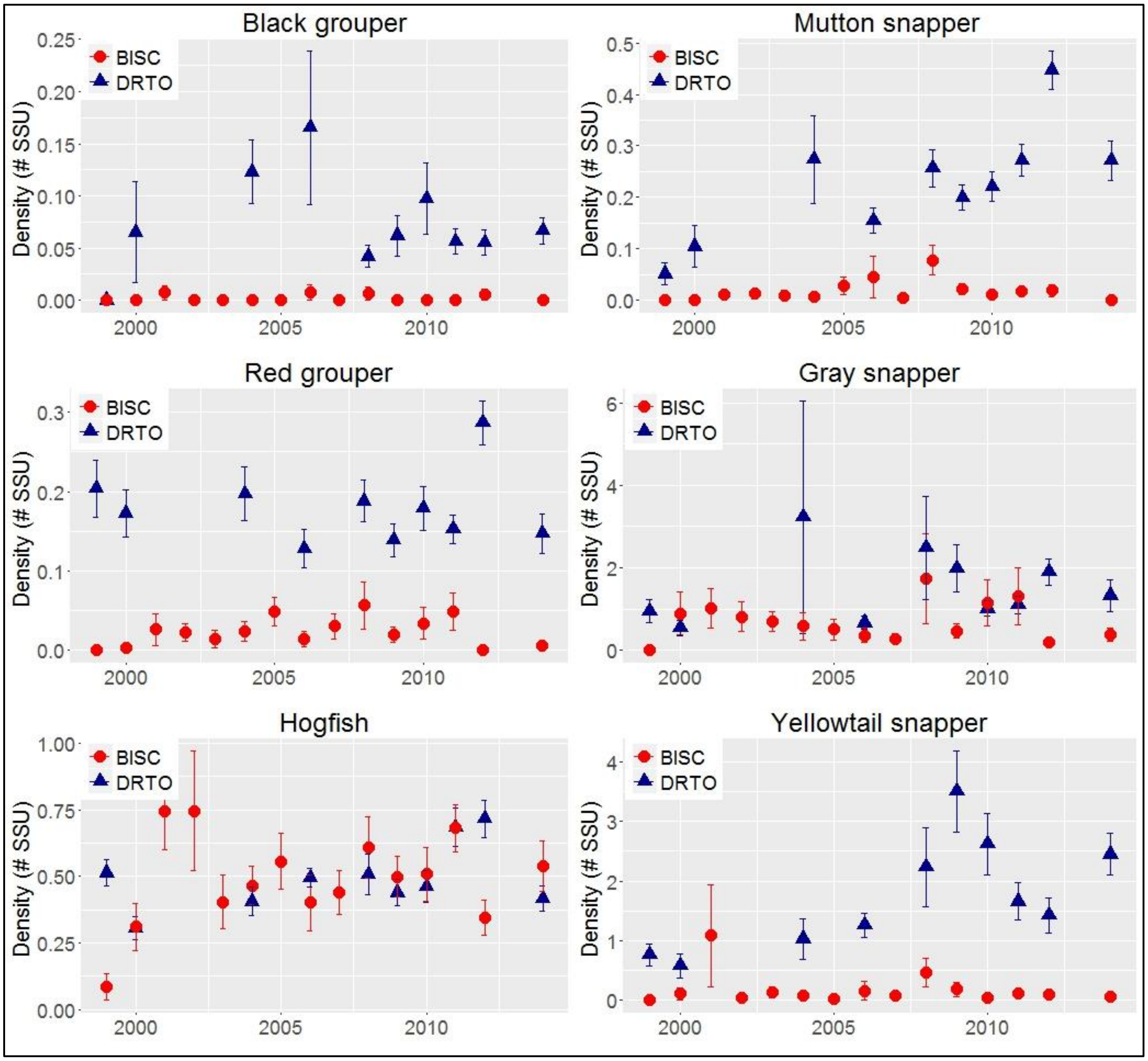


Figure 4.6.4. Mean density and standard error of key exploited species in BISC and DRTO from 1999–2014, estimated from reef fish visual census (RVC) data (NMFS Southeast Fisheries Science Center).

4.6.4. Gamefish

Gamefish with extraordinary fighting capabilities such as tarpon, bonefish and permit are a major draw for recreational fishermen to the waters of BISC contributing millions of dollars to the region. Each species has a unique life history that connects them to the productive waters of BISC. Juvenile tarpon, bonefish and permit all spend considerable time as juveniles in the mangrove shoreline, seagrass beds and sandy shorelines respectively in BISC (Adams et al. 2006; Ault et al., 2008c). As juveniles, these fish move throughout the bay to forage and start to venture towards the reefs. As they reach maturity, tarpon embark on an expansive migratory pathway that takes adults from BISC throughout the coastlines of the western Atlantic from Key West to the Chesapeake Bay (Luo and Ault, 2012). This migratory pathway also brings in thousands of tarpon during the winter and early spring to feed on shrimp, crabs and mullet runs (Luo and Ault, 2012). Bonefish tagged in BISC have been re-caught throughout the Florida Keys and a single fish was recovered near Andros Island in the Bahamas (Larkin et al., 2008). Permit, which are known to spawn on offshore reefs and artificial structures, may also partake in large movements as adults (Bryan et al., 2015). Despite their importance to local recreational fisheries, little is known about the population status of these species within BISC.

Atlantic tarpon *(Megalops atlanticus)*, the silver king cruising a reef at night (Photo by David Bryan)

Data from a variety of sources indicated that in 2010, the bonefish stock of south Florida, including BISC, was significantly reduced and likely bordering on an overfished status (Figure 4.6.5, Larkin, 2011). The stock status of tarpon is unknown and the last stock assessment for permit is from 1996. Tarpon are mostly protected from harvest in Florida with only a handful landed each year throughout the state when the angler is in pursuit of an International Game Fish Association (IFGA) record. .Permit are protected by a number of fishing regulations including a single fish bag limit, a 22-inch minimum fork limit and 3-month closed season. However, unintentional mortality from catch and release fisheries can be high causing reason for concern (Edwards, 1998; Cooke and Philipp, 2004). These species are vulnerable to negative impacts on the nearshore and seagrass habitat where they settle and grow as juveniles.

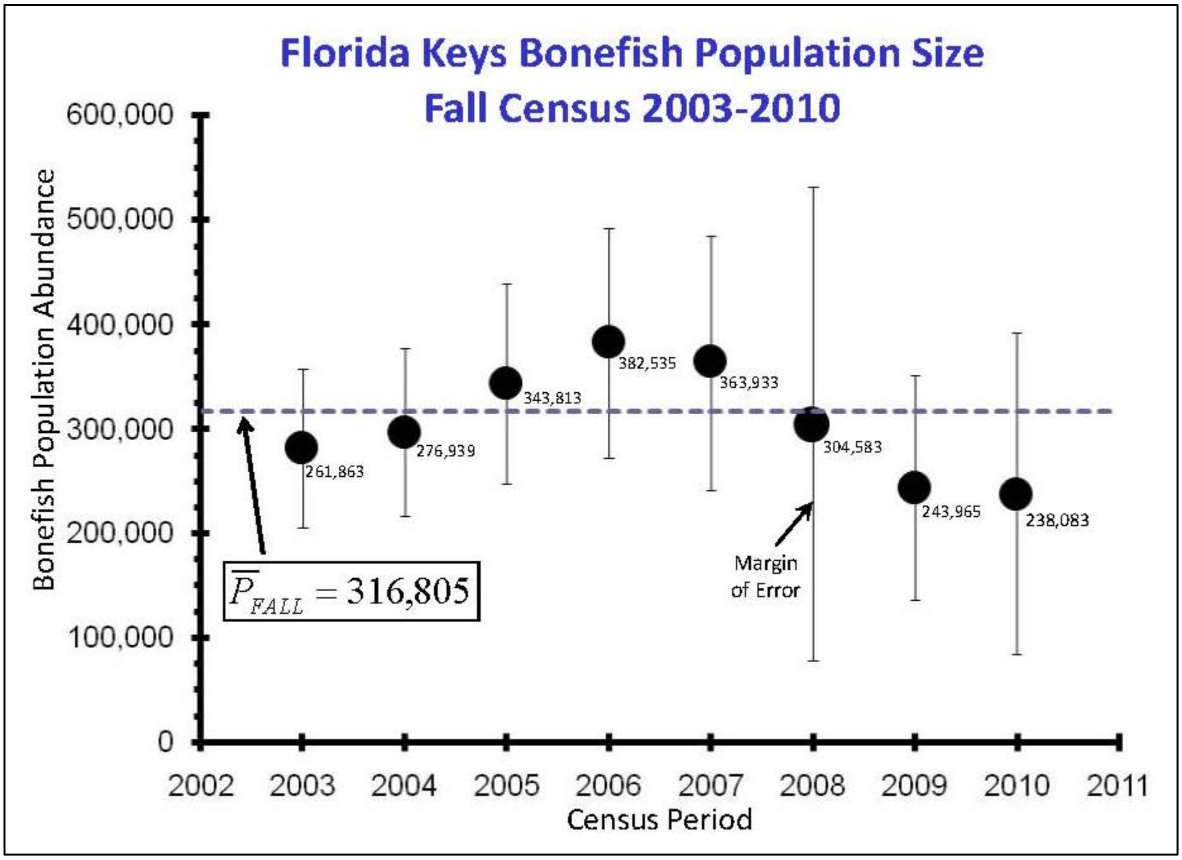


Figure 4.6.5. Florida Keys bonefish population size estimated from the fall census (Provided by J. Ault, unpublished data).

4.6.5. Sharks

As top predators, sharks have a major influence on the trophic structure of marine communities and changes in their abundance can have dramatic cascading effects on the ecosystem (Heithaus, et al., 2008: Baum and Worm, 2009). Abiotic conditions such as turbidity, salinity and temperate along with biotic conditions such as extent of mangroves can also affect the distribution and abundance of sharks within the park (Yates et al. 2015). Biscayne National Park including Biscayne Bay and the offshore reefs are home to a wide variety of shark species. Species present include; nurse sharks (*Ginglymostoma cirratum*), blacktip sharks (*Carcharhinus limbatus*), bull sharks (*Carcharhinus leucas*), great hammerhead (*Sphyrna mokarran*), lemon sharks (*Negaprion brevirostris*), tiger sharks (*Galeocerdo cuvier*), smalltooth sawfish (*Pristis pectinate*), bonnetheads (*Sphyrna tiburo*), Atlantic sharpnose sharks (*Rhizoprionodon terraenovae*) and blacknose sharks (*Carcharhinus acronotus*) (N. Hammershlag, University of Miami, pers. comm. 2016). Several of these species have experienced declines both throughout their range and locally, highlighting the importance of BISC for their population success (Heithaus et al., 2007; Ward-Paige et al., 2010).

Unpublished data from the University of Miami shark research lab suggests that this diverse group of sharks depend upon BISC for a variety of reasons. Nurse sharks, which are the most abundant shark in BISC can be found throughout the year and have been observed mating off the flats east of Broad

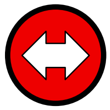
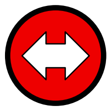
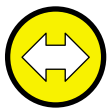
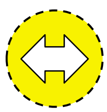
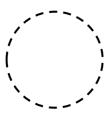
Key in the summer and subsequently pup within the park. Blacktip sharks are the second most abundant shark species in BISC and primarily visit the park to feed. They are in highest abundance during migrations in the winter and spring, but residents can be found throughout the year. Lemon sharks can also be found year-round in the park. Early life stage juveniles are found along the mangrove-seagrass fringe near the mainland and leeward key shorelines, while adults returning to their natal grounds within BISC to pup. They have recently become rare in comparison to historic data (the 2010 cold event may have been a contributing factor). Bull sharks are found feeding within the park year-round but have higher abundances during the winter. Tracking studies from 24 bull sharks suggest that they spend a majority of their time inside of south Florida National Parks including BISC (Hammerschlag et al., 2012; Graham et al., 2016). Great hammerhead sharks, which are listed as Endangered by the IUCN (Denham et al., 2007), are found feeding within the park year-round but have higher abundances during the spring. Tiger sharks, which have been listed as Threatened by the IUCN (Simpfendorfer, 2009), can also be found year-round; they are rare and are typically found as juveniles. Tiger sharks can influence the behavior of bottlenose dolphins, manatees, loggerhead and green sea turtles and cormorants (Heithaus et al., 2012). Little is known about the occurrence or distribution of the endangered smalltooth sawfish in BISC although it has been reported in the park. Bonnethead sharks frequent the shorelines and Altantic sharpnose sharks can be found in the deeper cuts in the safety valve region.

Commercial and recreational fishing for sharks is allowed within BISC in accordance with federal and state gear, size and bag limits. Three exceptions are hammerheads, tiger sharks and smalltooth sawfish that are protected within state waters throughout Florida. Yet even with fishing regulations in place, coastal sharks have declined in coral reef systems like the Great Barrier Reef (Robbins et al., 2006). As long-lived and slow growing animals, even moderate levels of fishing mortality can have detrimental effects on their population. Additional research is needed to assess the health of shark populations in BISC.

4.6.6. Conclusion

The density of six key species of reef fish in BISC has been stable from 1999–2014, however their density is significantly less than what is possible as shown by comparison with the Dry Tortugas and represents a fraction of what might be expected in a healthy ecosystem. The average size of these species is similar to other regions of Florida where they are considered overfished. Fishing regulations within the park have not provided any relief for red grouper and mutton snapper where nearly 25% of the catch is not legal. The reef fish community is comprised of hundreds of interconnected species, but these economically important fish are top predators and their loss can have a major impact on the ecosystem (Friedlander and DeMartini, 2002). Their low density and average size is of high concern (Table 4.6.3). It is expected that new park-specific state regulations in support of the FMP will be implemented by the FWC in early to mid-2020. These regulations, which will likely include actions such as increasing the minimum size, creating aggregate bag limits, establishing no-trawl and no-trap zones, and prohibiting spearfishing with air-supply, will be stricter than existing regulations in the park and in surrounding waters, and as such, they are expected to improve the condition of park fishery resources. Gamefish and sharks are likewise extremely important species found within the park, yet little is known of their condition. Additional monitoring is warranted.

Table 4.6.3. Conditions and trends of exploited reef fish, gamefish, and sharks in BISC.

Criteria	Condition & Trend	Rationale	Reference Condition
Average Length (key exploited species) from creel		All 6 key species have $\bar{L}$ values less than the desired state	$\bar{L}$ > estimated $\bar{L}$ for F_{msy}
Average Length (key exploited species) from RVC		All 6 key species have $\bar{L}$ values less than the desired state	$\bar{L}$ > estimated $\bar{L}$ for F_{msy}
Density of exploited species		The density of exploited species within BISC has remained stable since 1999. For most species, density estimates are significantly lower than Dry Tortugas.	Similar density to Dry Tortugas National Park and increase in density from 1999.
Gamefish stock status		A 2010 assessment of bonefish suggests the population was overfished. There is no current information on the stock status of tarpon or permit.	A sustainable population is desired but reference conditions for BISC have not been developed
Sharks		There is limited information on the status or trend of sharks within BISC	A desired state or reference condition has not been established

Invasive Lionfish

Indo-Pacific lionfishes (Pterois volitans and P. miles) are the first non-native marine fish species to become established in the western Atlantic (Schofield, 2009). Because lionfish are voracious predators, capable of consuming large quantities in short periods of time (Albins and Hixon, 2008), there is significant concern that the deleterious effect of lionfish predation on native reef fish populations and communities may threaten coral reef ecosystems throughout its introduced range.

In response to this concern, BISC supports a large lionfish removal program that has been in place since 2011, when lionfish were first becoming more abundant in south Florida (Ruttenburg et al., 2012). Trained scuba divers visit sites throughout the park to remove lionfish. Since 2011, an average of 791 lionfish per year have been removed, with an average of 4.7 fish per dive (Figure 4.6.6). Within BISC, lionfish CPUE remained relatively stable from 2011–2015 but there was a significant increase in 2016 (Figure 4.6.6). At the same time, the size structure of lionfish caught had shifted towards larger/older lionfish, until 2016 when smaller fish were once again being captured (Figure 4.6.7). This change in size structure can be interpreted as a maturation of the population since the initial recruitment with a potential new recruitment event in 2016 or may be the due to changes in the areas where divers have focused their removal efforts.

Lionfish populations in the Dry Tortugas and the Florida Keys appear to have stabilized as some combination of bio-controls and human intervention have prohibited further increases in abundance (D. Bryan et al., 2018). The 2016 uptick in CPUE in the park may represent a local population increase or an improvement in capture efficiency. Regardless, due to potentially catastrophic effects of this invasive species, it is imperative that the park continues to work on reducing their abundance within park boundaries.

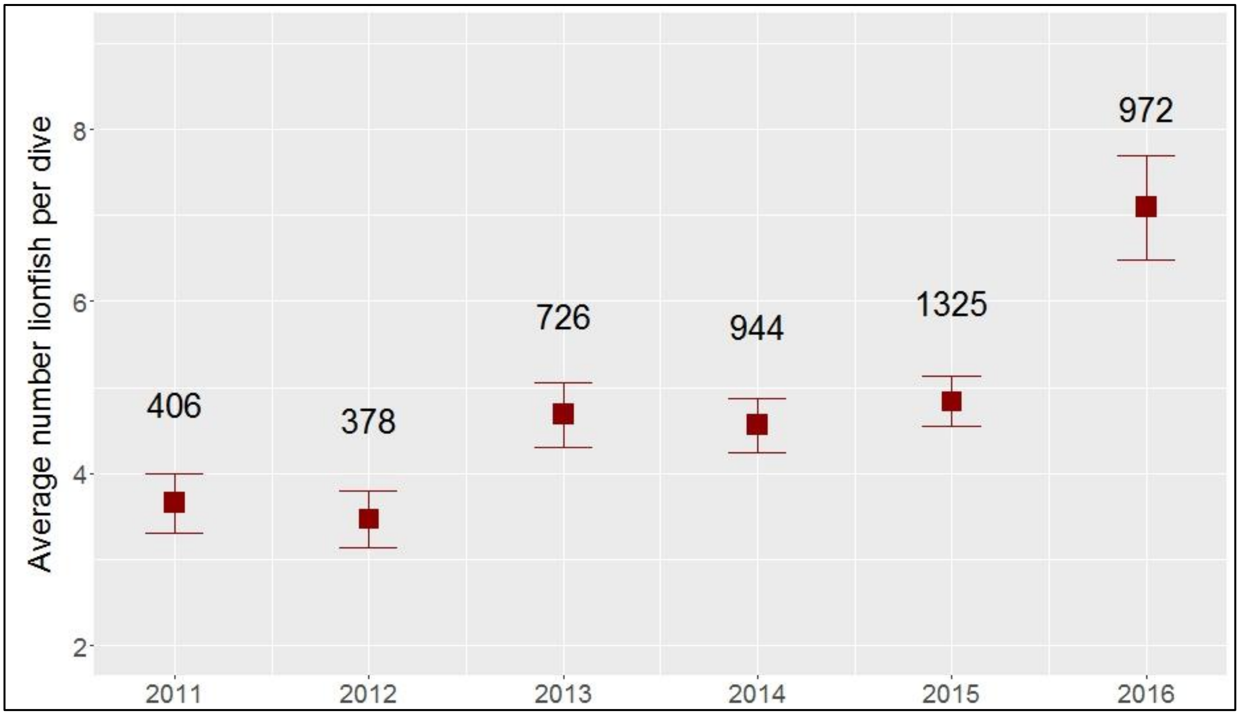


Figure 4.6.6. Average number of lionfish removed per dive (CPUE) in BISC from 2011–2016. Bars represent standard error and values are for total lionfish removed that year. (Data from BISC).

Lionfish (*Pterois volitans*) (Photo by David Bryan)

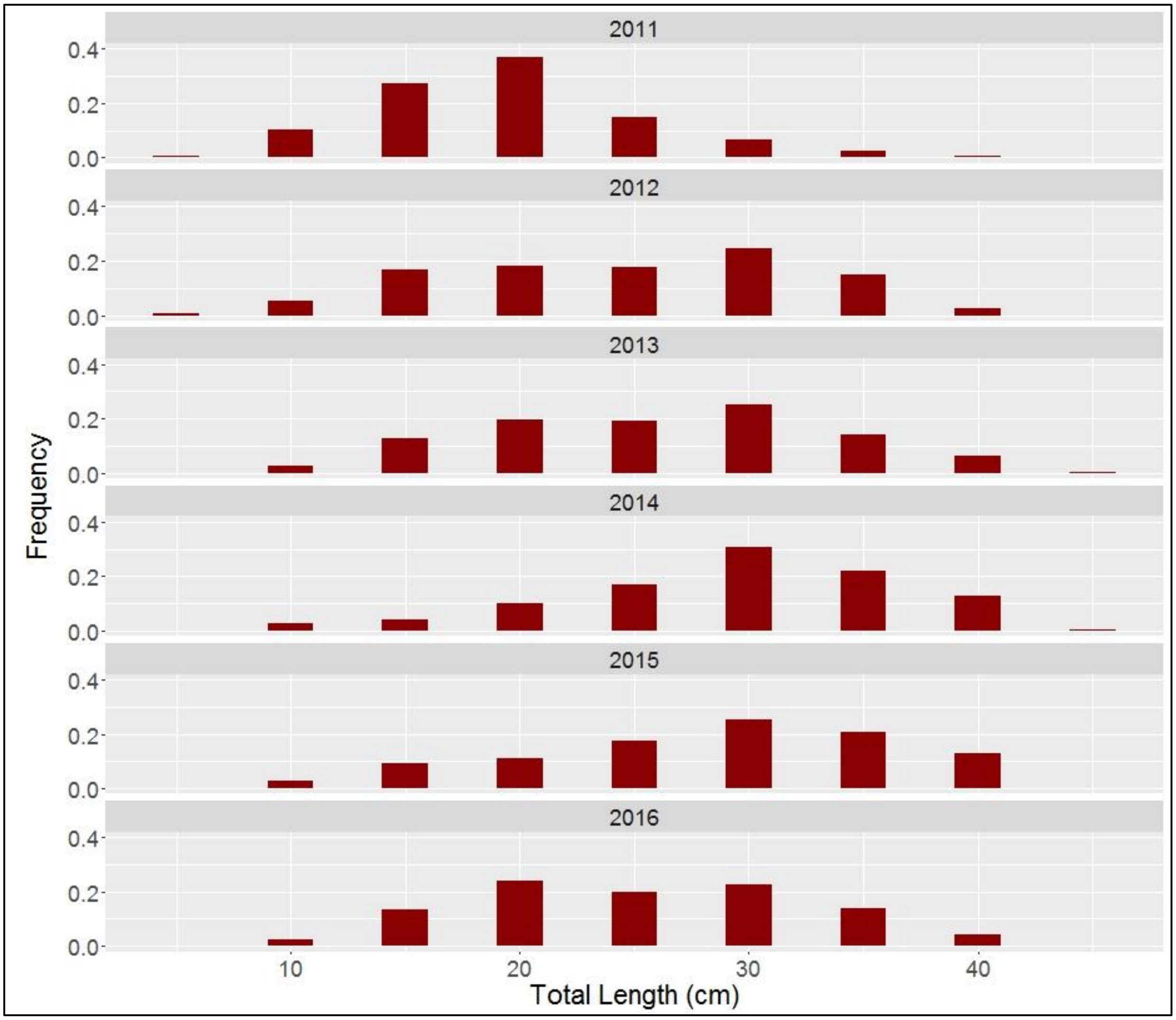
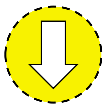


Figure 4.6.7. Length frequency of lionfish removed by BISC by year. (Data from BISC).

4.7. Sea Turtles

The condition of sea turtles warrants moderate concern and their condition is deteriorating. Varying sampling effort has resulted in low confidence in their assessment (Table 4.7.1).

Table 4.7.1. Sea turtles condition status and trend.

Attribute	Condition & Trend	Interpretation
Loggerhead Sea Turtles		Loggerhead use of BISC for nesting appears to be stable with around 10 nests per year. Although varying sampling effort through time leaves some uncertainty in detecting trends, the nesting success rate and the hatch success rate have been declining as nest inundations have become more common. However, predation rates have declined significantly.

4.7.1. Importance

Five species of sea turtles have been reported from the waters of BISC: loggerhead (*Caretta caretta*), green (*Chelonia mydas)*, hawksbill (*Eretmochelys imbricata*), leatherback (*Dermochelys coriacea*) and Kemp’s ridley (*Lepidochelys kempii*). Each of these turtles is listed under the Endangered Species Act as either threatened or endangered depending on the distinct population segment to which they belong. Loggerhead, green and hawksbill sea turtles are the most frequent visitors to BISC, where they spend time foraging, mating and nesting. They each have broad movement patterns which, although variable in spatial extent, typically result in individuals moving inside and outside of BISC during their life cycle. The rich marine environment within BISC is an important sea turtle foraging area. The windward beaches on Elliott Key are utilized as nesting habitat by primarily loggerhead turtles.

Loggerhead turtles are distributed worldwide in temperate, tropical, and sub-tropical waters of the Atlantic, Pacific, and Indian Oceans (Pearce, 2001). The loggerhead population nesting in the southeastern United States, predominately in Florida, is the second largest population in the world and accounts for about 35–40% of loggerheads nesting worldwide (Meylan et al., 1995; Pearce, 2001; NMFS & USFWS, 2008; Witherington et al., 2009). Their nesting season in Florida begins the end of April/early May and continues through August (Meylan et al., 1995).

Studies on nesting females have shown that the Florida population can be further divided into smaller sub-populations. Genetic research involving the analysis of mitochondrial DNA has identified four different loggerhead nesting subpopulations in the southeastern US: (1) the Northern subpopulation ranges from North Carolina through northeast Florida; (2) the Southern Florida subpopulation ranging from just north of Cape Canaveral on Florida’s east coast and extending around to Sarasota on Florida’s west coast; (3) the Dry Tortugas subpopulation; and (4) the Northwest Florida subpopulation occurring at Florida’s panhandle beaches (Encalada et al., 1998; Bowen et al., 2005; NMFS & USFWS, 2008; Shamblin et al., 2011). The loggerheads nesting on BISC are part of the large Southern Florida subpopulation.

4.7.2. Stressors

Sea turtles experience a wide variety of anthropogenic and natural threats throughout their complex life histories. Accumulation of large amounts of marine debris deteriorates the quality of sea turtle nesting habitat. Debris that accumulates on the beaches creates obstructions for nesting females, preventing them from finding suitable area to dig their nest. It also poses an entrapment hazard and obstructions to newly emerged sea turtle hatchlings attempting their journey to sea. Encounters with debris can increase the time taken to reach the sea, thereby increasing the hatchlings' risks of dehydration and predation (Triessnig et al., 2012). Furthermore, since a large majority of the debris is composed of plastic, there are concerns about plastic breaking down over time into microplastics that can be accidentally ingested by a variety of wildlife living and feeding in the sand and surf. A study of microplastics throughout southeastern NPS units found that there were, on average, 148 microplastic pieces per kilogram of sand on the oceanside beaches of Elliott Key (Whitmire et al., 2016). Within BISC, nesting loggerheads are also faced with nest predation, nest inundation and erosion/loss of sandy beaches. In the water, all turtles within BISC face risk of being struck by a boat due to high density of visitors, entanglement with fishing gear and marine debris, ingestion of marine debris, disease, and predation at sea both as juveniles and as adults.

4.7.3. Monitoring Programs

Data on sea turtle occurrence and use of BISC comes from two sources: 1) an annual nesting survey conducted by NPS staff and 2) stranding data that is reported to the Sea Turtle Stranding and Salvage Network. The sea turtle nesting beaches along Elliott Key have been monitored since 1991 with varying effort. Information on crawls (i.e., tracks and other signs left by a sea turtle interested in nesting on a beach), nests, number of eggs, predation and hatchling success are recorded when possible. Data on strandings, which include any sea turtle that has been found ashore or floating that is not able to return to the water or is unable to return to its natural habitat or behavior without assistance (dead or alive), has been collected since 1980. Stranding incidents are reported by NPS staff or park visitors.

Sea turtle tracks leading to Palm Cove nesting site in BISC (Photo from BISC)

4.7.4. Sea Turtle Nesting Surveys

Since 1991, sea turtle nesting surveys have been conducted along Elliott Key in BISC with varying degrees of effort. On average, 10 nests have been identified each year (Figure 4.7.1), and all of these have been loggerhead nests except for a single successful green turtle nest on Tannehill Beach during 2013. The sea turtle nesting survey is not a complete survey of all beaches in the park, so it is possible that additional nests from loggerhead, green, or hawksbill sea turtles occur on non-surveyed beaches.

Sea turtle nesting frequency in BISC has been relatively stable since surveys began in 1991 (Figure 4.7.1). However, survey effort has been considerably variable and the remote location of BISC beaches makes consistent nesting surveys difficult. Without consistent visitation rates through time, the number of nests and associated statistics are imprecise, and caution is warranted for the interpretation of these data. Despite this caveat, loggerhead nesting in BISC appears to generally follow a much broader Florida-wide trend which involved higher numbers during the 1990s with declining numbers of nests from 1999–2007 followed by a more recent increase (Figure 4.7.1). Predation rates of loggerhead nests in BISC were exceptionally high from 2001–07 with over 75% of nests experiencing total predation (Figure 4.7.2). Since then, efforts have been made to reduce the presence of raccoons, the main predators of sea turtle nests, on Elliott Key and to use screens to protect nests. This has resulted in a decline in predation rates. In 2014 and 2015, there were no signs of predation on loggerhead nests within BISC. Hatch success rate, the percent of hatchlings from nest with no or partial predation that were presumed to reach the Atlantic, has fluctuated over the years with no discernible trend (Figure 4.7.2).

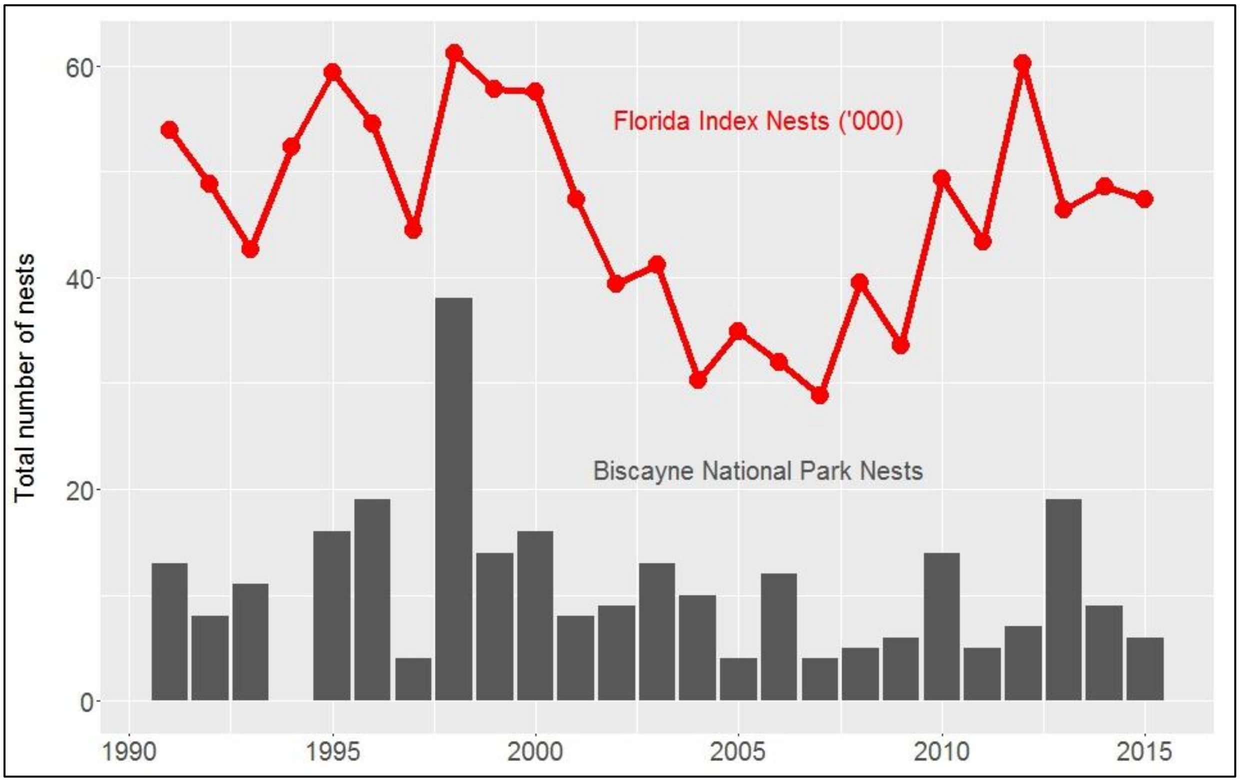


Figure 4.7.1. Total number of loggerhead nests surveyed in BISC (gray bars) and number of Florida index nests in thousands (‘000) since 1991. (Data from BISC and FWRI).

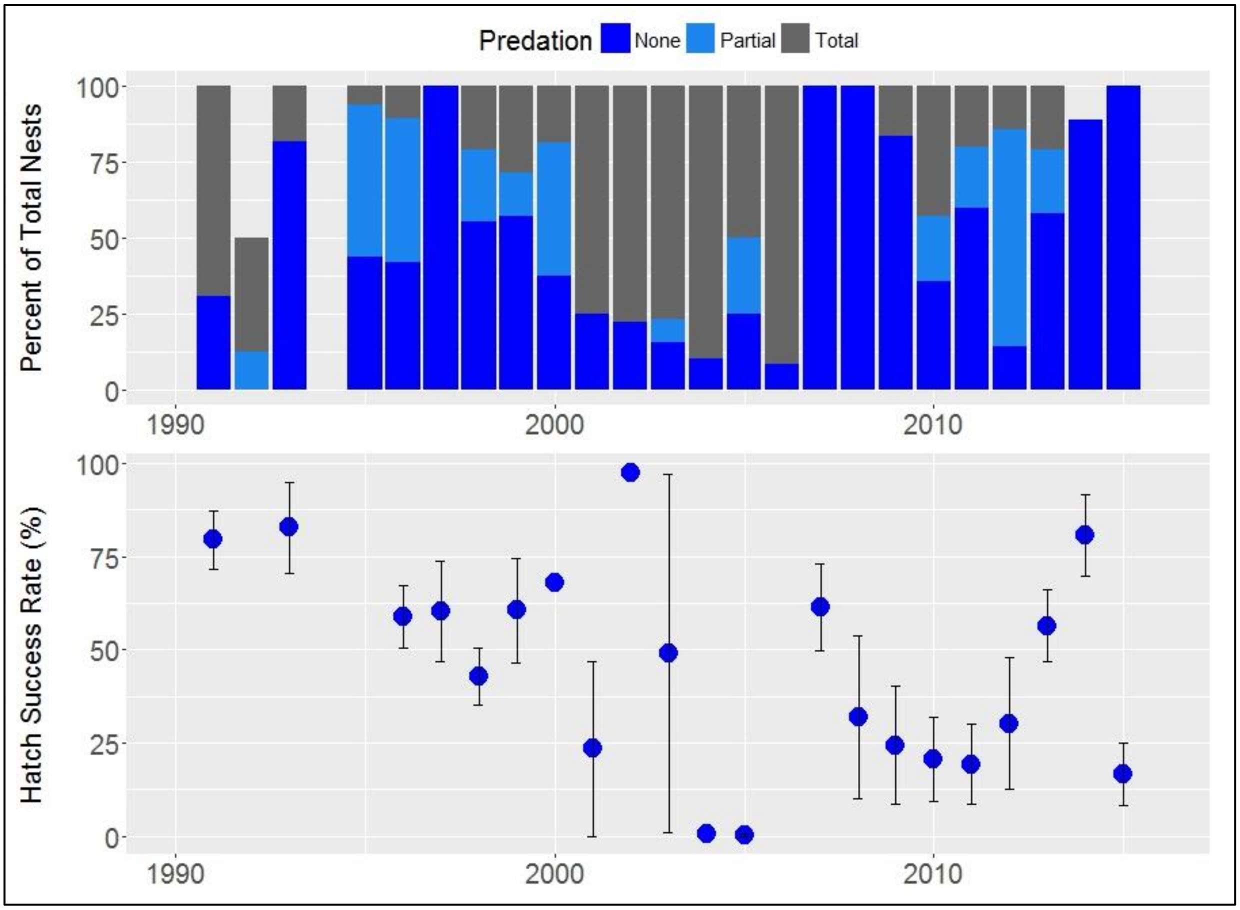


Figure 4.7.2. Percent of nests experiencing none, partial or total predation and the mean hatch success rate (# of hatchlings presumed to reach Atlantic / total eggs) of loggerhead turtles in Biscayne National Park from 1991–2015. Error bars represent standard error. (Data from BISC).

Two other related threats impacting loggerhead sea turtles are obstruction from nest sites by either marine debris or vegetation, and rising sea level. A false crawl occurs when a sea turtle abandons a nesting attempt. The nesting success rate is a measure of how many nests are made in comparison to attempts made. In BISC, this rate has varied over time but in four out of the last five years the rate has been significantly below the state average (Witherington et al., 2009), leading to a possible trend of decreased success rate in BISC (Figure 4.7.3). Turtles may abandon nesting attempts when they encounter obstructions such as vegetation or marine debris. In BISC, the distance from which nests are dug from high tide has been declining (Figure 4.7.4) possibly indicating that the width of beaches is decreasing. The reduction in beach area may reduce the opportunity for nesting sea turtles to find suitable nesting sites as they are more likely to run into vegetation and debris that has been washed further up the shoreline. In addition, higher tide levels with narrow beaches has increased the chance of nests being inundated during high tide events. From 2001–2007, an average of 6.5% of the total nests were inundated with water while from 2008–2016, 12.4% of total nest have been inundated.

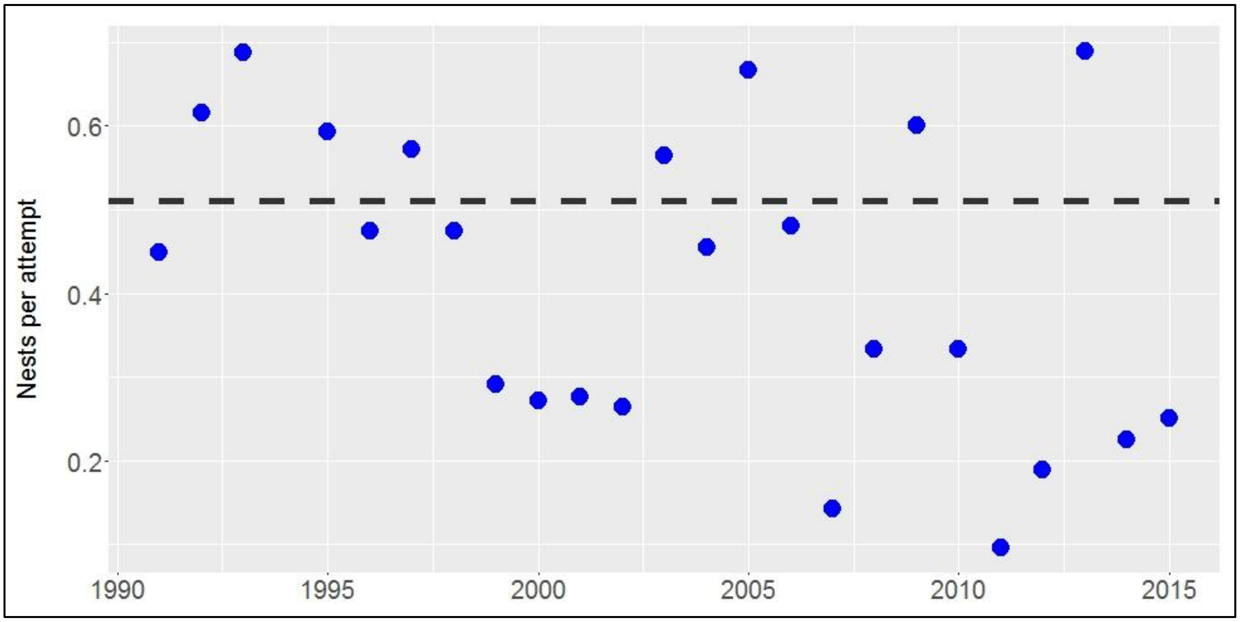


Figure 4.7.3. The number of nests per attempt by year for loggerhead turtles in BISC (Data from BISC). Dashed line represents Florida Index Beach average (Witherington et al., 2009).

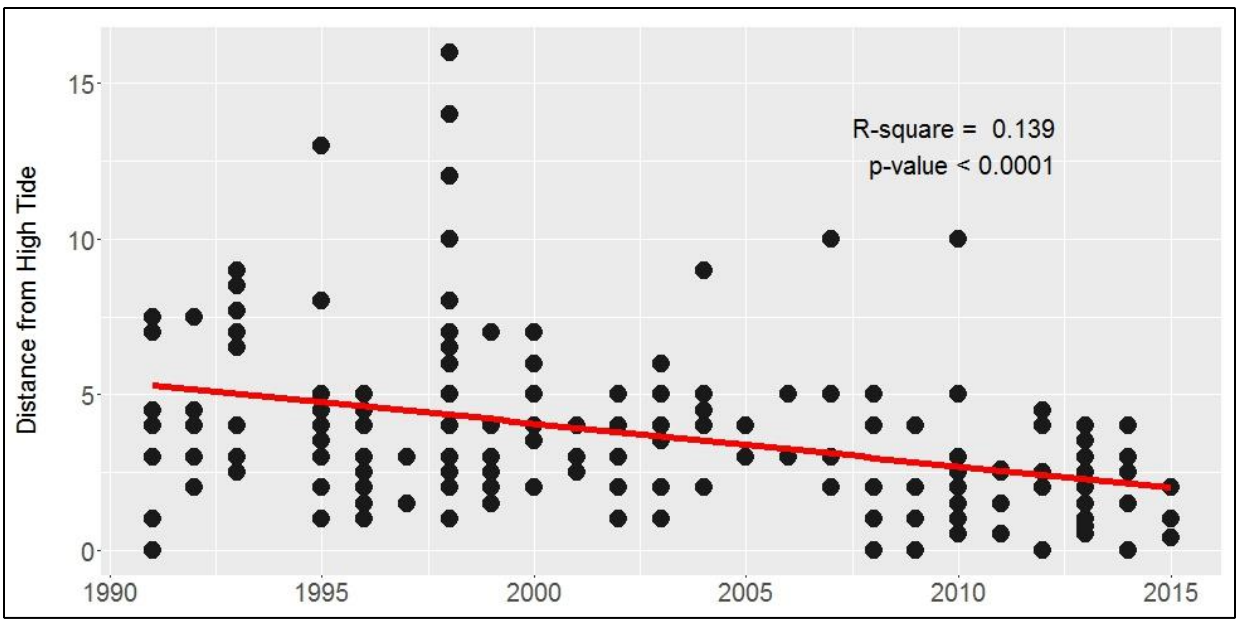


Figure 4.7.4. Nest distance from high tide in BISC from 1991–2015. Solid red line represents a linear regression with a significant negative slope. (Data from BISC).

4.7.5. Sea Turtle Strandings

The rich seagrass beds and vibrant coral reef ecosystem within BISC provides a tremendous source of food for foraging sea turtles. However, while in the park, they often face human threats, such as boats or fishing gear. Since 1980, 222 sea turtle standings have been reported from within BISC. A majority of these sea turtles (174) were dead when discovered. The main causes of strandings within

BISC were boat strikes (28%), the papilloma virus (16%) and fishery gear interactions (12%) (Van Doornik, 2015). Loggerhead and green turtles were the most affected (likely an artifact of these two species being the most abundant in the park) though hawksbill and Kemp's Ridley were also reported. Strandings have been randomly dispersed throughout the park both inside the bay and out on the reef tract. There appears to be an increase in reported strandings from 1979 until 2013 (Figure 4.7.5). Since boater usage of BISC has remained relatively stable over the last 10 years (Ault et al., 2017), this could be a sign of an increasing turtle population. However, it may also reflect an easier reporting system, widespread use of cell phones, and better public awareness to contact officials when a distressed or dead sea turtle is found.

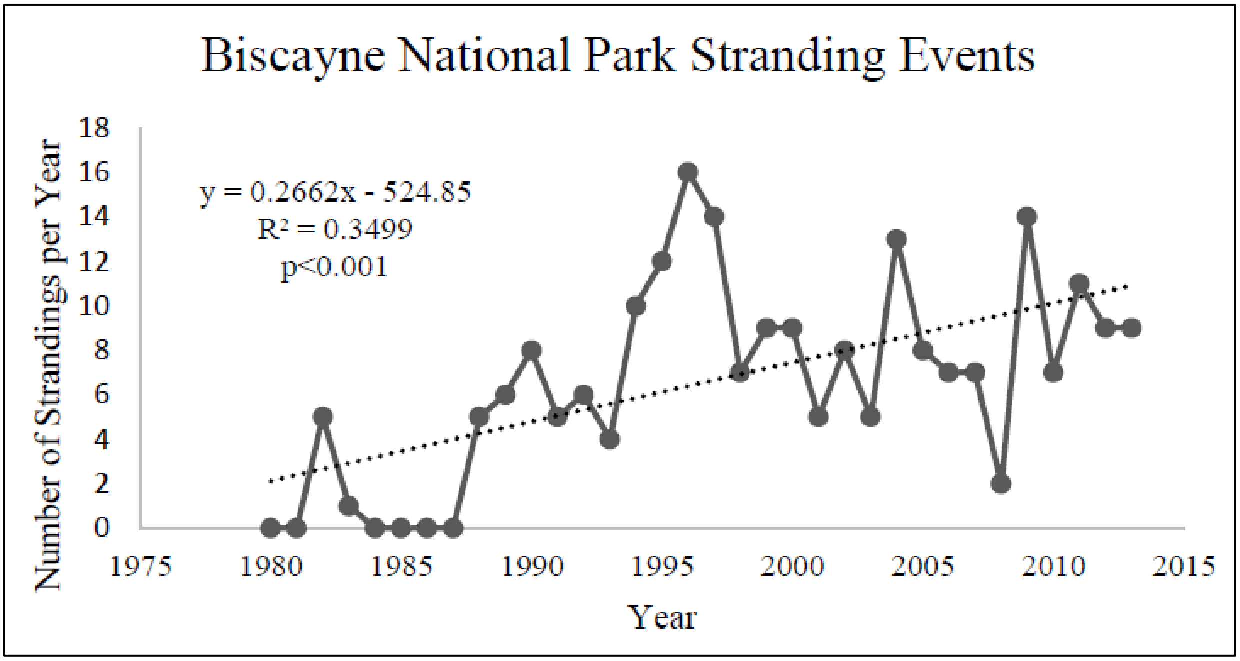


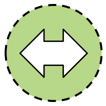
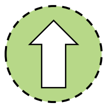
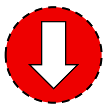
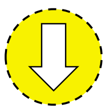
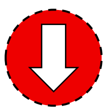
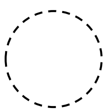
Figure 4.7.5. Reported sea turtle standings in BISC since 1979 (Reprinted from Van Doornik, 2015).

Hawksbill turtle *(Eretmochelys imbricata)* resting under coral head in BISC (Photo from BISC)

4.7.6. Conclusion

The loggerhead turtles that use BISC are part of one of the largest sub-populations of loggerheads in the world. Although 10 nests a year is a fraction of nests in comparison to other Florida beaches, the undeveloped shoreline in BISC is unique and an important site for a threatened species. The removal of marine debris from nesting beaches and reduction of raccoons on Elliott Key can help increase the nesting and hatchling success rate. Data from nesting surveys suggest moderate concern, but there is low confidence in the assessment due to changes in survey effort through time (Table 4.7.2). Reports of stranding incidents have increased in frequency within BISC, but this is difficult to interpret as visitor awareness and ease of communication have increased. There is little information available to determine the status of green and hawksbill sea turtles.

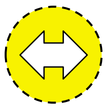
Table 4.7.2. Conditions and trends of sea turtles in BISC.

Criteria	Condition & Trend	Rationale	Reference Condition
Number of loggerhead nests		Loggerhead nests have been variable with no significant trend in numbers since 1991. Varying effort makes is hard to judge the condition with confidence.	1991–2000 average
Predation rate on loggerhead nests		The predation rate has declined significantly since the 2000s.	Predation rate below 25%
Loggerhead hatch success rate		During the last ten years, the hatching success rate had been below the reference condition for every year except 2014.	1991–2000 average (64%)
Loggerhead nesting success rate		The nesting success rate has been below the Florida State average for four of the last five years.	Florida Index Site Average (0.51)
Distance of nest from high tide		During the last five years (2011–2015) the average nest distance from high tide has been 2.0 m. This is significantly lower than reference condition.	1991–2001 average (4.6 m)
Strandings		The number of reported strandings has been increasing. This may indicate an increase in sea turtles visiting BISC, may be the result of better reporting, or that BISC has become more dangerous for sea turtles.	No more than 10 per year

4.8. Marine Mammals and American Crocodiles

The condition of marine mammals and American crocodiles is not changing and warrants moderate concern, but limited data on these species has resulted in low confidence in this assessment (Table 4.8.1).

Table 4.8.1. Marine mammals and American crocodiles condition status and trend.

Attribute	Condition & Trend	Interpretation
Bottlenose Dolphins, Florida Manatees and American Crocodiles		There is little long term data on bottlenose dolphins, Florida manatees or American crocodiles within BISC. Their abundances in BISC appear to be stable but at numbers much lower than anecdotal information from the turn of the century. These low numbers warrant moderate concern in their condition.

4.8.1. Importance

Bottlenose dolphins (*Tursiops truncatus*), Florida manatees (*Trichechus manatus latirostris*) and American crocodiles (*Crocodylus acutus*) are three large charismatic megafauna that are wildly popular with the general public and frequent the productive tropical marine environment of BISC. A resident population of around 100 bottlenose dolphins takes advantage of the multitudes of fish that can be found in the bay and mate and rear their offspring inside the park. The endangered Florida manatee is present in BISC throughout the year but during winter months, the local population swells as manatees migrate from the north to take advantage of the warmer waters and lush seagrass beds. There are roughly 2,000 American crocodiles in the continental US and BISC is an important part of their range. The threatened species has had a relatively long history of nesting success in the cooling canals at the Turkey Point Nuclear Generating Station but recent changes in the salinity in the canals may be a cause of concern.

Bottlenose dolphin (*Tursiops truncatus*) and calf in Biscayne Bay (Photo by Joe Contillo)

4.8.2. Bottlenose dolphins

Bottlenose dolphins are a top predator and beloved animal frequently observed in Biscayne Bay by visitors. Photo identification surveys conducted by SEFSC from the 1990s till 2007 suggest that there is a stable resident population of roughly 100 bottlenose dolphins throughout Biscayne Bay (Figure 4.8.1.). Residency patterns and genetic analyses provide strong evidence that Biscayne Bay dolphins should be managed as a separate biological stock from Florida Bay and other south Florida bottlenose dolphins (Litz et al., 2007, 2012). Furthermore, sightings records and genetic research also suggests northern and southern Biscayne Bay dolphins form two different social groups but with minor overlap (Litz et al., 2012). Within BISC, dolphins are typically sighted along the central and eastern sides of the bay where the water is deeper. The dolphins sighted within BISC are typically larger than those in the northern Biscayne Bay outside the park and have an average group size of five (J. Contillo SEFSC, unpublished data). While there has been significant work on understanding the residency patterns of bottlenose dolphins within Biscayne Bay, little is known about those that reside in offshore waters. A slight increase in sightings of new dolphins in the spring may be attributed to offshore dolphins temporarily visiting the bay. Opportunistic sampling efforts in offshore waters have found repeated sightings suggesting that there may be some area specific fidelity offshore as well (J. Contillo SEFSC, unpublished data).

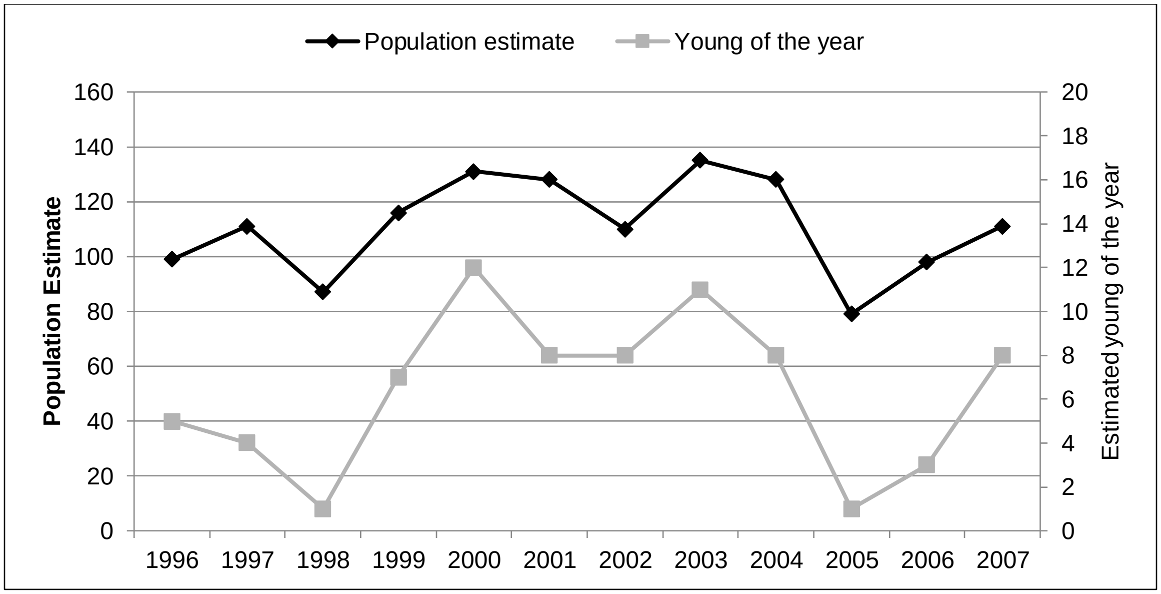


Figure 4.8.1. Bottlenose dolphin annual population estimates and number of young of the year in Biscayne Bay (Data provided by J. Contillo, SEFSC, unpublished).

From 1990–2007 the average number of young of the year dolphins in Biscayne Bay was estimated to be six (Figure 4.8.1). During the same time period, 11 dolphins were reported stranded in Biscayne Bay, six of which had human-induced mortalities, such as ingesting or entanglement with fishing gear. In addition to threats from marine debris, bottlenose dolphins can bio-accumulate toxins found in the marine environment. In the north part of Biscayne Bay, polychlorinated biphenyl (PCB) concentrations may place them at risk of reproduction failure and reduced immune function but those within southern BISC appear to have lower concentrations (Litz et al., 2007).

Bottlenose dolphin (*Tursiops truncatus*) feeding on mullet in Biscayne Bay (Photo by Joe Contillo)

4.8.3. Florida manatees

Just over 6,000 Florida manatees are estimated to inhabit Florida waters, over half of which reside on the east coast (Martin et al., 2015, FWC manatee synoptic survey). Statewide, manatee distribution is predominately influenced by feeding locations during warmer months and by warm water refugees in the winter. Manatees are vegetarians, feeding primarily on seagrass and therefore spend most of their time in shallow water. They often aggregate near canals and tributaries during winter months but are otherwise solitary. BISC is an important region for manatees as it serves as both a feeding location with large expansive seagrass beds as well as a winter refuge for local and central east Florida manatees (Deutsch et al., 2003). In the late 1800s in Biscayne Bay, manatees were "assiduously persecuted by all classes of people and killed in pure wantonness; it was yearly becoming scarcer and its extermination in a short time seemed inevitable." (Smith, 1896). At the time, a Miami citizen petitioned the Florida legislation and secured the passage of a law prohibited the killing of manatees except for scientific purposes (Smith, 1896).

Now, over one hundred years later, manatees are present year-round in BISC, with peaks in abundance during the winter when average temperatures in the bay are above their minimum thermoneutral limit of 20°C (Irvine 1983). Power plants and their associated thermal discharges that were built between the 1940s and early 1970s allowed manatees to expand their winter range northward (Reynolds and Wilcox, 1994; Laist and Reynolds, 2005). Today, 66% of the Atlantic manatee population relies on power plants for thermal refuge during the winter (Laist et al., 2013). As these power plants are retired, warm water springs and passive thermal basins will become more important for manatees (Laist and Reynolds, 2005) and more animals may migrate further south to BISC.

Aerial surveys conducted by DERM between 1988 and 1990 had a maximum daily count of 130 manatees during a winter survey and it was estimated that approximately 30 inhabit the area during the summer (Mayo and Markley, 1995). Manatees are more common in upper Biscayne Bay, with Miami River and the Little River being the most common sites of sighting (Miami Dade, 2009). In a 2003 survey, as many as 169 manatees were sighted on a single day and the average summer daily count is approximately 20 individuals (Miami Dade, 2009). Within BISC they were primarily located near Deering Bay, Black Creek, Convoy Pt, Mowry Canal, Turkey Point (Figure 4.8.2.). Recently there has been an increasing number aggregating around the southern extent of the cooling canal system at the Turkey Point Nuclear Generating Station (Figure 4.8.2).

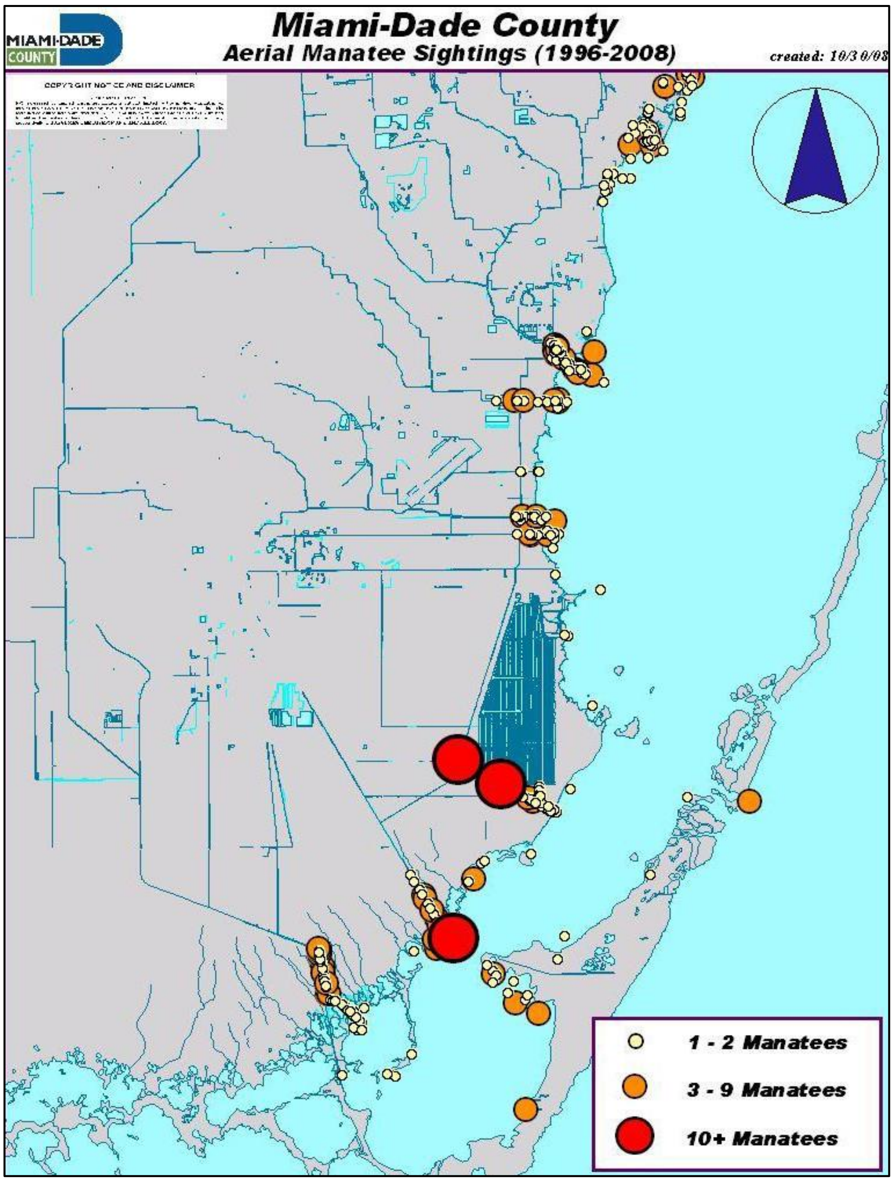


Figure 4.8.2. Composite of manatee aerial survey data, showing locations of manatee sightings and aggregations in all seasons. (Reprinted from Miami-Dade manatee protection plan data and information collection final report, July 2009).

There has been no change in the feeding patterns of manatees in the Biscayne region (1996–2008) and mating herds along with mothers and calves continue to be observed (Miami Dade, 2009). Tracking data suggest that BISC manatees are part of the east Florida subpopulation (Deutsch et al., 2003) whose status appears to be increasing (Figure 4.8.3).

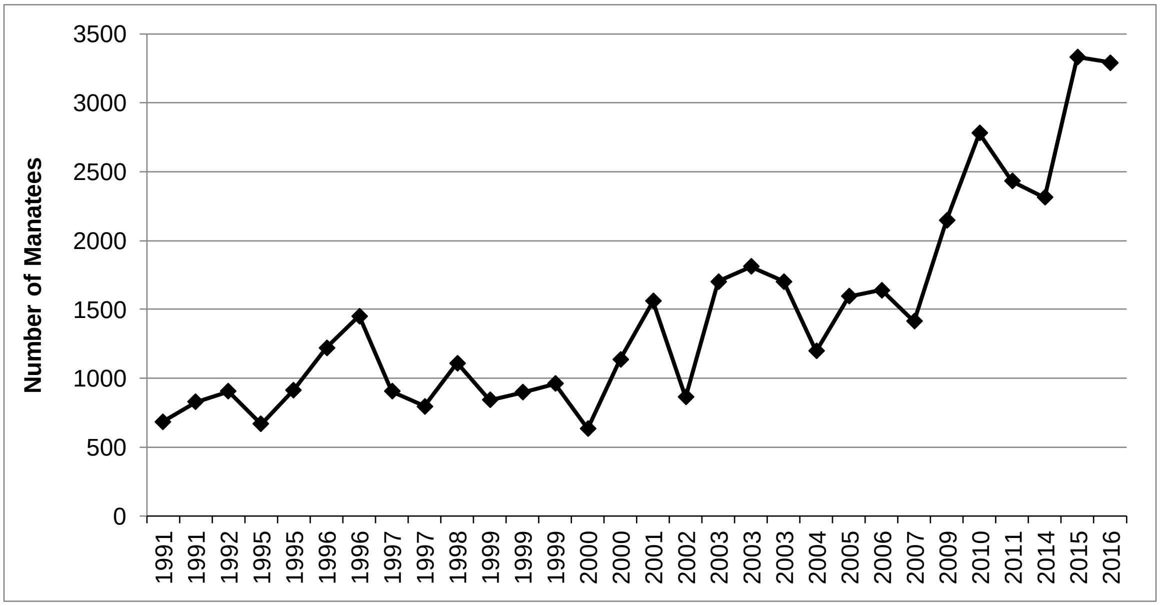


Figure 4.8.3. FWRI synoptic aerial surveys of manatees on the east coast of Florida. (Data from: http://myfwc.com/research/manatee/research/population-monitoring/synoptic-surveys/).

Mortality due to floodgate closure, which was once the leading cause of mortality in Miami-Dade, has declined since 1995 when the US Army Corps and the South Florida Water Management District began to retrofit gates with a pressure sensitive device. This device caused the gates to reopen if there is an obstruction, preventing manatees from being drowned and crushed to death. Vessel-related deaths have remained mostly stable around 2 per year from 1996 to 2009 (Miami Dade, 2009).

4.8.4. American crocodiles

An isolated population of threatened American crocodiles exists in south Florida spread out between three major nesting sites; Florida Bay, Northern Key Largo, and the cooling canals at the Florida Power and Light Company's Turkey Point Nuclear Generating Station (TP) (Cherkiss et al., 2011). There has been a relatively long history of nesting success (~35 years) at TP (Mazzotti et al., 2007) (Figure 4.8.4), but recent spikes in salinity may have negatively affected nesting success. The status of these crocodiles can be assessed in several ways. From 1996–2005, the number of adult crocodiles increased within the Biscayne Bay region (Figure 4.8.5) (Cherkiss et al., 2011). However, in a 2006 an assessment report based on thresholds later described in Mazzotti et al. (2009), American crocodiles in Biscayne were scored as a yellow, suggesting that restoration targets had not been met due to slow juvenile growth and lack of data to calculate survival (Mazzotti et al., 2008). In 2014, growth rates of crocodiles in Biscayne Bay (0.11 cm/day) also indicated that restoration targets had not been met (Mazzotti et al., 2014). Furthermore, in the 2014 System-wide Ecological Indicators

Report crocodiles in Biscayne were downgraded from yellow to red status indicating a combined shift from below to well below restoration targets for a suite of status metrics (Brandt et al., 2014).

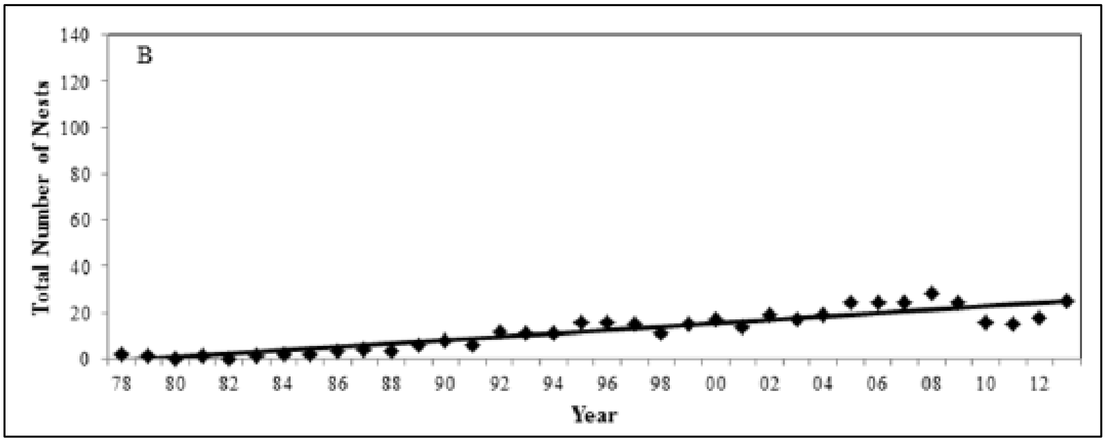


Figure 4.8.4. Summary of total number of American Crocodile nests found between 1978 and 2013 at Turkey Point Nuclear Generating Station ($R^2 = 0.8515$; $p < 0.0001$; nests = 430) (Graphs modified from Mazzotti et al., 2007 with addition of 2005–2013 data and analysis from 1978–2013). (Reprinted from 2014 System Wide Ecological Indicators Report).

American Crocodile (*Crocodylus acutus*) (Photo by Judd Patterson)

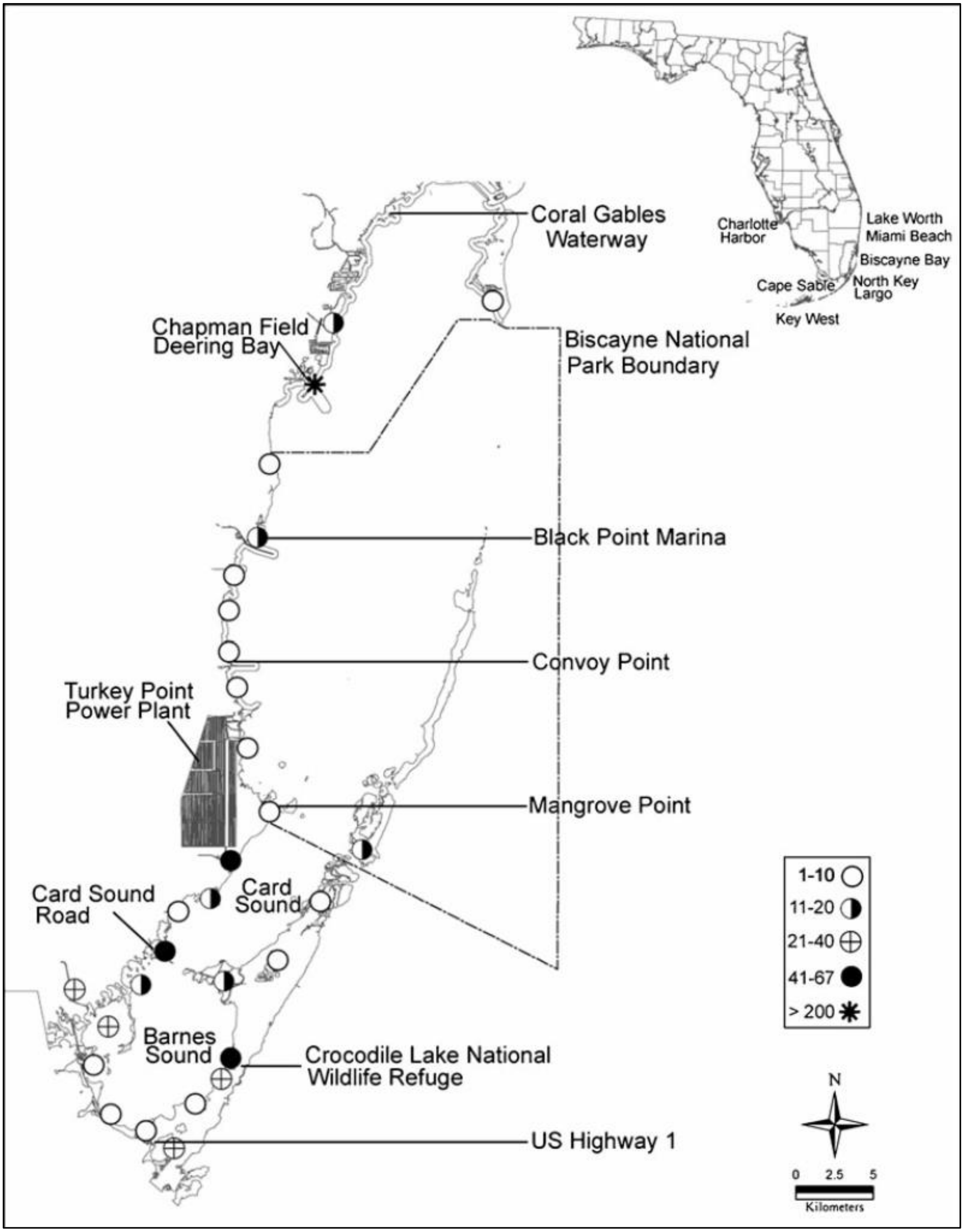
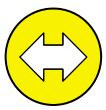
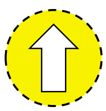
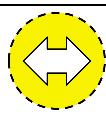
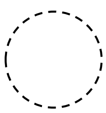


Figure 4.8.5. Distribution and total numbers of American crocodiles observed in BISC from 1996–2005. (Reprinted from Cherkiss et al., 2011).

4.8.5. Conclusion

Anecdotal information from early residents and visitors to Biscayne Bay in the late 1800s and early 1900s suggest that manatee and American crocodile populations were much larger than today. However, during the last few decades, manatees and American crocodiles appear to be increasing in numbers within the park. Both of these species, which were once considered endangered under the Endangered Species Act, have recently been reclassified as threatened. Yet, with population sizes in Florida in the thousands at best, their status still warrants concern (Table 4.8.2). The bottlenose dolphins of BISC are potentially their own stable sub-population but it is important that their numbers are monitored to detect any future trends.

Table 4.8.2. Conditions and trends of bottlenose dolphins, Florida manatees and American crocodiles in BISC.

Criteria	Condition & Trend	Rationale	Reference Condition
Bottlenose dolphin population size		The bottlenose dolphin population appeared steady from 1996–2007, new population estimates would confirm status.	Stable population size
Florida manatee population size		There was been an increase in max count per day from 1990 to 2003. More manatees may be utilizing BISC as power plants are decommissioned throughout the State	Increasing population size until species is delisted
American Crocodile growth rate		2014 growth rates reported at 0.11 cm/day (Mazzotti et al., 2014)	0.15 cm per day (Mazzotti et al., 2009)
American Crocodile Fall Monthly Survival For Hatchlings		Survival rate in BISC is unknown	85% (Mazzotti et al., 2009)

4.9. Birds

The condition of birds withing BISC is unchanging, but warrants moderate concern. Several monitoring programs are in place but the lack of long term references resulted in low confidence in their assessment (Table 4.9.1).

Table 4.9.1. Birds condition status and trend.

Attribute	Condition & Trend	Interpretation
Shorebirds, Colonial Nesting Birds, White-crowned Pigeons and Migratory Species		Shorebird counts and colonial bird nesting counts suggest stable numbers of key species over the last 5 years. However, species richness of shorebirds and all bird species appears to be declining. Several monitoring programs are in place, but there is limited long term reference information available.

4.9.1. Importance

Biscayne Bay, including BISC, has been designated an Important Bird Area by the Audubon Society for its significant populations of protected species, its large numbers of wading birds, and its natural habitats for avian feeding, migratory stopover, and nesting. Birds have an important ecological role and are a major draw for visitors. They are early responders to changes across the landscape—responding quickly in foraging and nesting patterns to both habitat degradation and to habitat improvement and restoration—which makes them excellent indicators of ecosystem health and integrity. A total of 233 species of birds have been identified within BISC (NPSpecies, accessed 2/5/2017). Of those birds, 12% are known to reproduce within the park, 44% are residents but not known to breed in BISC, 30% are migratory and 12% are vagrants (outside the species' usual range). Several surveys are conducted within BISC to monitor visitation and nesting of birds. Multiple shorebird counts timed with the winter migration are conducted along the keys when funding is available. Six colonial nesting bird sites have been monitored monthly with photographic flight surveys since 2009 by SFCN staff and two new colonies were added in 2016 (Muxo et al., 2015). In recent years, a white crowned pigeon (*Patagioenas leucocephala*) survey has been conducted on West and Long Arsenicker Key. Park staff also participate in an annual Audubon Christmas Bird Count within the park in which they record the presence and abundance of each species observed; this event has been held since 1979, making this the longest-running bird study in the park.

4.9.2. Shorebirds

Each year, tens of thousands of shorebirds winter in South Florida, where they feed on a variety of terrestrial and marine vertebrate and invertebrate species along the shallow coastline. Wintering shorebirds have been identified as ecological indicators for ecosystem health in South Florida (Ogden et al. 2014). In BISC, multiple shorebird-specific counts are conducted during the winter along a similar survey route that includes Convoy Point Jetty, Elliott Key Harbor, Boca Chita, and the main sea turtle nesting beaches on the ocean (eastern) side of Elliott Key. In 2016, an average of 620 birds were counted on a survey with an average of 7.5 different species observed (minimum = 6 and maximum =9). The most common species counted included: black-bellied plover (*Pluvialis* *squatarola*), semipalmated plover (*Charadrius semipalmatus*), ruddy turnstone (*Arenaria interpres*), sanderling (*Calidris alba*), least sandpiper (*Calidris minutilla*) and short-billed dowitcher (*Limnodromus griseus*) (Figure 4.9.1). The average number of individuals counted during surveys from the second week in December to the first week of March have varied from 2011 until the most recent survey in 2016. With only three data points and no reference condition, it is difficult to draw a conclusion about the status of shorebirds from these surveys, but continued monitoring would provide a baseline and allow for assessment of trends.

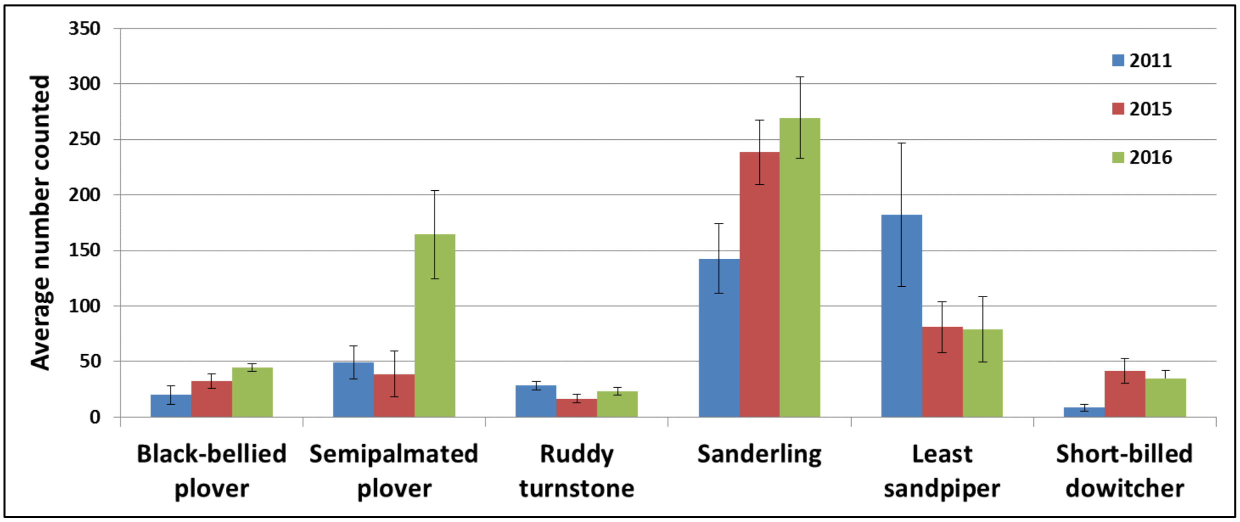


Figure 4.9.1. Average number and standard error of the most common shore birds counted during winter surveys in 2011, 2015 and 2016 (Data provided by Michelle Davis, Cape Florida Banding Station).

However, in addition to shorebird-specific counts, since 1979 there has been an annual Christmas Bird Count (CBC) that takes place in BISC. Participants, which include park staff and skilled birders, split up into teams to survey different areas of the park on a single day. Areas covered typically include the hardwood hammocks on Adams Key and Elliot Key, the harbor and beaches of Elliott Key, Pacific Light, the mainland shoreline and Visitor Center area, Boca Chita, and the Sands Key keyhole area. Data on the species observed and the numbers of birds representing each species are collected. During this count, a number of different shorebird species are encountered and recorded. During the 1980s, the average number of shorebird species observed during the CBC was 11.5 (Figure 4.9.2). Over the last 5 years, the average species richness of shorebirds during the CBC has declined to 8, which is similar to the shorebird survey species richness. This decline in species richness warrants moderate concern.

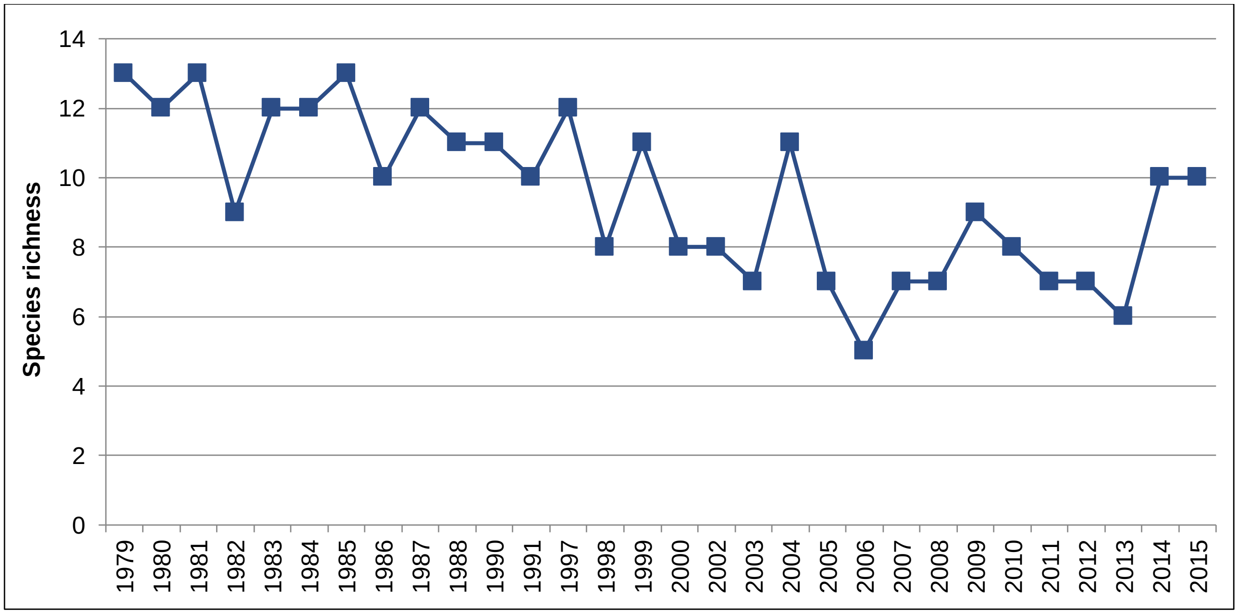


Figure 4.9.2. Species richness of shorebirds from Biscayne National Park annual Christmas Bird Count (Data from Audubon Christmas Bird Count, graph provided by Judd Patterson, SFCN).

4.9.3. Colonial Nesting Birds

Colonial nesting birds, such as great egrets (*Ardea alba*), great blue herons (*Ardea herodias*), great white herons (*Ardea herodias occidentalis*), white ibis (*Eudocimus albus*), roseate spoonbills (*Platalea ajaja)* and double-crested cormorants (*Phalacrocorax auritus*), are important as vital signs of the health of Biscayne National Park ecosystems. The presence of colonial nesting birds, the size and distribution of their nesting colonies, and the reproductive success of their nests indicate that the surrounding habitat is able to support these energy intensive activities. These birds must acquire large quantities of high quality food during the nesting season as they select mates, build nests, lay eggs, and rear chicks. Individual colonial nesting birds are vulnerable to entanglement in or choking from marine debris. Colonies are susceptible to human disturbance and predation pressure from both native species (e.g., raccoons) and exotic invasive species (e.g., pythons). Since most of the colonial nesting bird species in the park are piscivorous, they are vulnerable to declines in food supply from overfishing and other causes of fish decline. Thus, a decrease in nesting effort and nesting success, as well as local population declines, may indicate that the ecosystem is not functioning properly. Some of these colonial nesting species have already experienced statewide declines and are listed as species of special concern, threatened, or endangered.

SFCN has monitored six island colonies monthly since 2009, with photographic flight surveys and they recently added two more locations (Muxo et al., 2015; Figure 4.9.3). Average monthly nest counts along with total nest counts by species are calculated to evaluate trends in time. The major species surveyed include: double-crested cormorant, great blue heron, great egret, great white heron, roseate spoonbill and white ibis. Cormorants make up the vast majority of nests counted. Overall, although numbers of nests were slightly down in 2014/15 compared with the average of the previous four years, five of the six focal species peak nest counts and nesting indices fell within the range of variation seen in those years (Figures 4.9.4 and 4.9.5).

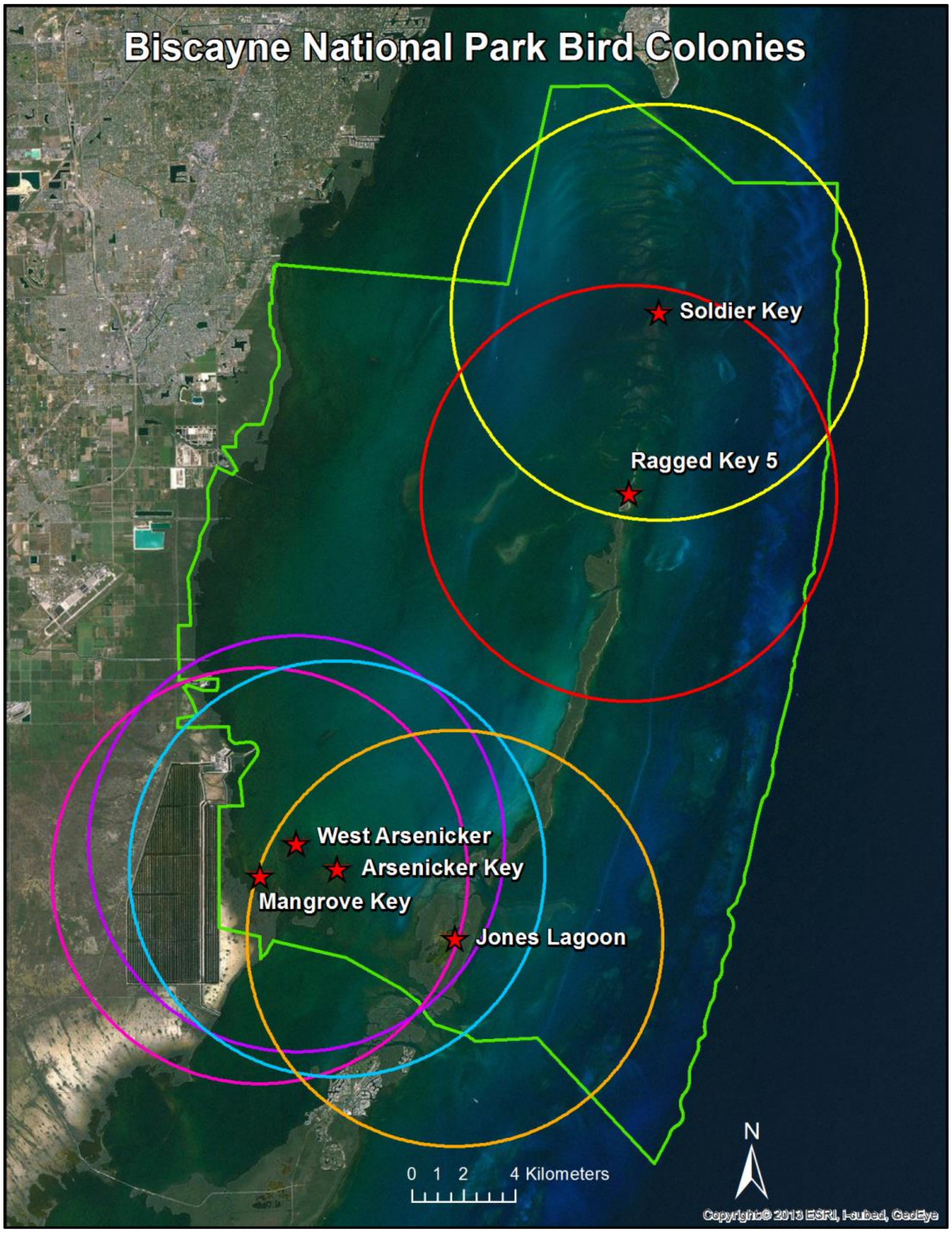


Figure 4.9.3. Location of colonial nesting bird locations surveyed by SFCN and 10 mile diameter foraging areas for each colony. (Figure provided by SFCN).

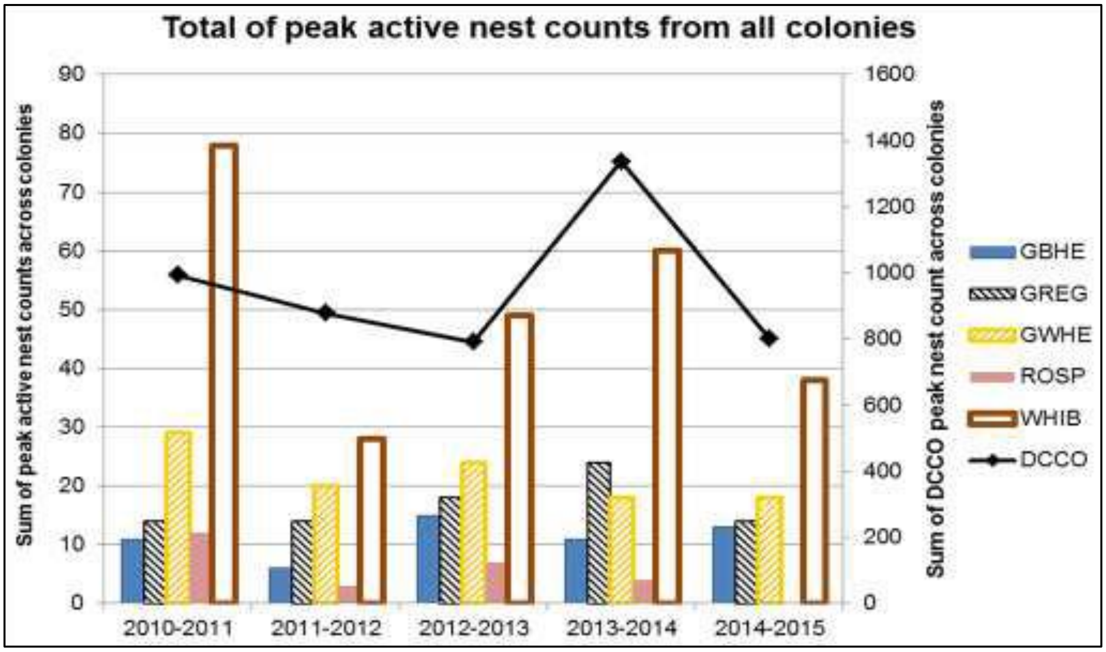


Figure 4.9.4. Total peak active nest counts for colonial birds in BISC. (Reprinted from Whelan and Muxo, 2016).

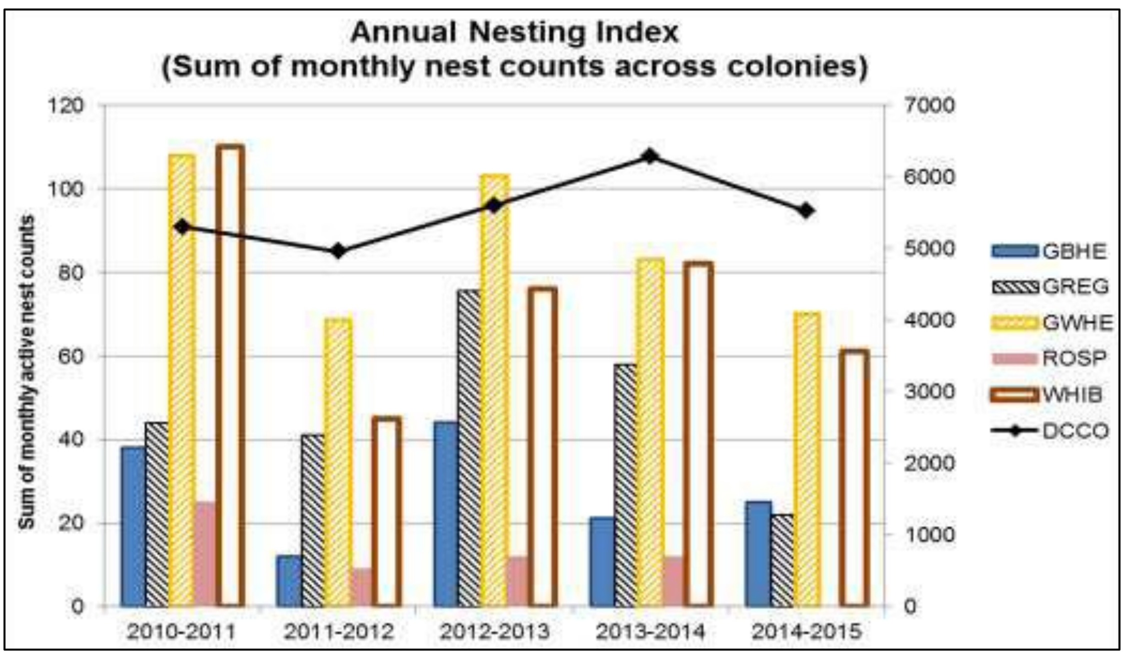


Figure 4.9.5. Annual nesting index for colonial birds in BISC. (Reprinted from Whelan and Muxo, 2016).

Great white herons are a color morph of great blue herons, a state listed species of special concern. This color morph can only be found in southern Florida and their colonies in BISC represent their northernmost nesting sites, making this color morph extremely popular amongst birders. Average monthly nesting of Great White Herons has been around 20 nests in BISC with a slight decline in 2015 (Figure 4.9.4).

The roseate spoonbill is another species of great interest, as they were not known to nest in BISC until SFCN discovered them doing so in 2009. Since then, several nests have typically been observed each year except 2015, when no nests were recorded. In nearby Florida Bay, the number of roseate spoonbills has increased during the last few years from a thirty year low in the mid-1980s.

4.9.4. White-crowned Pigeon

White-crowned pigeons are considered a vulnerable species with an estimated 7,500 to 10,000 pairs remaining in Florida (FWC, 2011). Throughout their range, they are experiencing significant habitat loss and their numbers are declining on several islands in the Caribbean (where they are sometimes consumed by humans) and the Florida Keys. They typically nest in colonies amongst the mangroves on small offshore islands and sometimes in the outer fringe of mangroves along the mainland, but they generally avoid areas with raccoons, which are a major nest predator. They often feed in tropical hardwood hammocks on islands and the mainland. The relatively undisturbed forests of BISC offer a perfect habitat for white-crowned pigeons. Counts of white-crowned pigeons returning (presumably from foraging elsewhere) to the mangrove-populated islands of West and Long Arsenicker Key (presumably where nesting occurs) have been conducted since 2014 (Figure 4.9.6). During this short time period, the maximum count of white-crowned pigeons during a survey has been 23 and 24 on each island, which represents a small percentage of the state-wide total estimates.

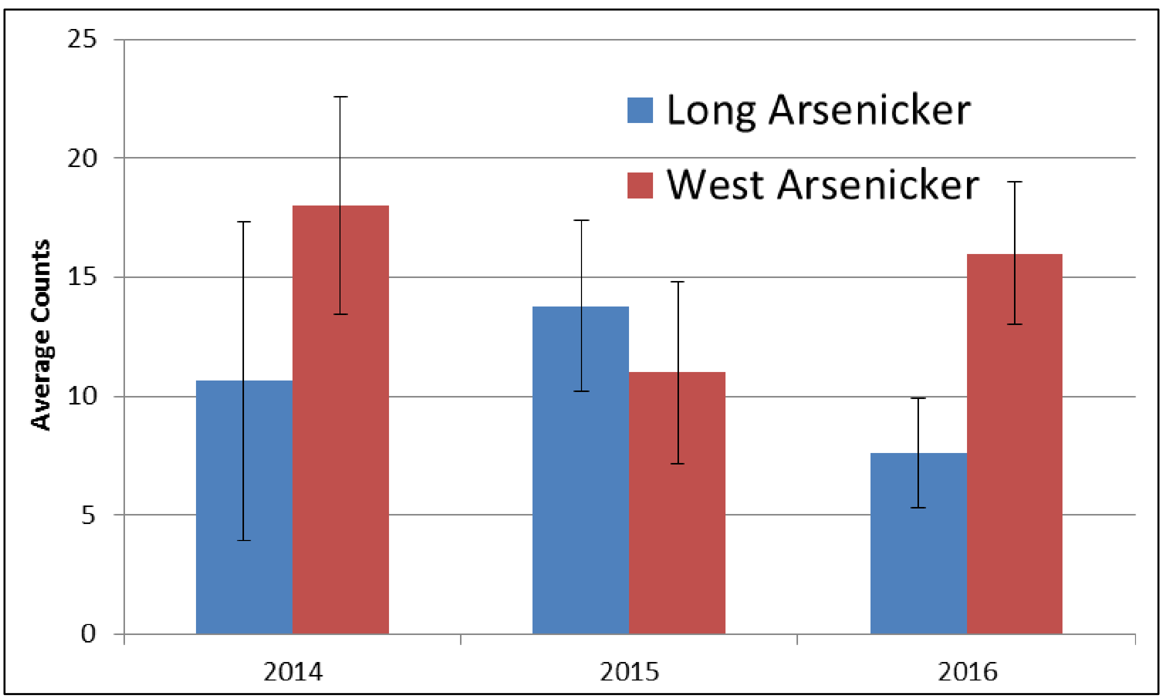


Figure 4.9.6. Average white crowned pigeon counts on Long and West Arsenicker Keys in BISC with standard error (Data from BISC).

White-crowned pigeon (*Patagioenas leucocephala*) (Photo by Judd Patterson)

4.9.5. Christmas Bird Count

Since 1979, an Audubon Christmas Bird Count (CBC) has been conducted in BISC. The amount of effort and skill level of observers has varied amongst the years, as this is largely a volunteer event, but the data still provide a useful long-term picture of bird diversity within the park on a single day (representing the winter season). Audubon CBC data from around the country has been used for hundreds of scientific papers (www.audubon.org). The BISC count first takes place along the entrance road and the Visitor Center parking lot and is then followed by participants loading into several boats to cover the bay and the keys. Between 1979 and 1981, participants in the annual CBC would identify over 90 species of birds within BISC. These numbers declined steadily into the late 2000s when between 40 and 50 species were counted (Figure 4.9.7). Species richness has increased slightly since 2007, with 62 species observed in 2015 and an average of 61.2 species observed during the last five years. However, species richness is still significantly lower than in the 1980s. The amount of effort and skill level of observers during the CBC can vary amongst years, but overall this trend of fewer species of birds within BISC during the winter warrants moderate concern.

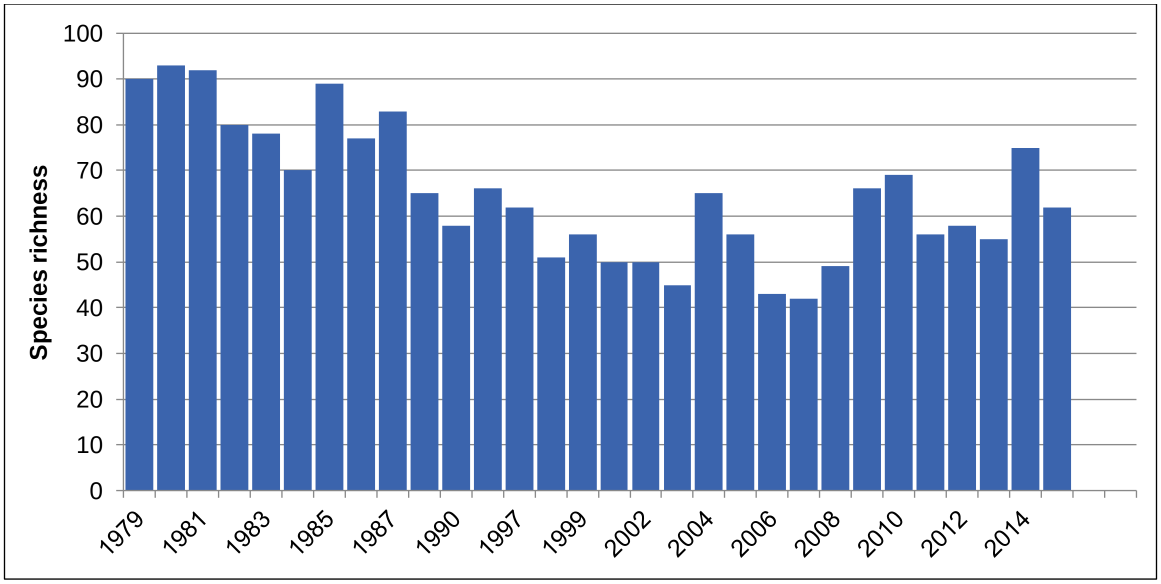


Figure 4.9.7. Species richness during Christmas Bird Counts in BISC since 1979 (Date from Audubon Christmas Bird Count, analysis performed by Judd Patterson SFCN).

4.9.6. Conclusion

A high diversity of birds utilize BISC's natural resources for foraging, nesting or as migratory refuge and as a result, birds are an integral component of the ecosystem. Wintering shorebirds have been identified as an ecological indicator for south Florida, but it appears that species richness within BISC is in decline (Table 4.9.2). Survey counts have been conducted, but no reference condition has been established. Colonial nesting birds have been monitored for seven years and there has been no major trends in their nesting. The white-crowned pigeon is a vulnerable species that is found in the park. Monitoring has recently been initiated to track their numbers over time. Data from the once-a-year CBC suggests that species richness has been declining, which warrants moderate concern (Table 4.9.2). An increase in avifauna monitoring efforts, and a continuation of ongoing surveys is necessary to ensure an adequate assessment of birds in the park.

Table 4.9.2. Conditions and trends of birds in BISC.

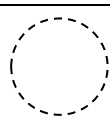
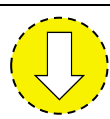
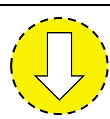
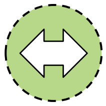
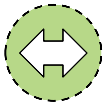
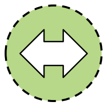
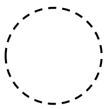
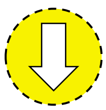
Criteria	Condition & Trend	Rationale	Reference Condition
Shorebird survey counts		Shorebird survey counts have a limited time series and no reference condition has been established	Reference condition has not been established for numbers of shorebirds desired.
Shorebird survey species richness		Average shorebird species richness in 2016 was 7.5. This is below historic richness values from the 1980s.	Maintenance of CBC 1980s average species richness (11)
Shorebird species richness CBC count		Species richness during the CBC has steadily declined since 1979.	Maintenance of 1980s species richness average (11)

Table 4.9.2 (continued). Conditions and trends of birds in BISC.

Criteria	Condition & Trend	Rationale	Reference Condition
Annual peak count of colonial nesting birds		Long term monitoring program is in place. No major trends over the last 7 years	Maintenance of current counts
Annual nesting index		Long term monitoring program is in place. No major trends over the last 7 years	Maintenance of current counts
Changing in timing of peak nest counts		Long term monitoring program is in place. No major trends over the last 7 years	Maintenance of current counts
White crowned pigeon counts		Limited time series and lack of reference condition preclude condition and trend status	Maintenance or increase of current counts
Species richness CBC		Average of last five years of 61.2 species is below reference condition.	1979–1981 average (91) species

Chapter 5. Discussion

5.1. Overall Condition

The natural resources of BISC are highly connected both within the park's ecosystem and to the wider south Florida and Caribbean environment. Birds, fish, turtles and marine mammals frequently move inside and outside of the park and are often part of larger populations whose health is determined by natural resource management decisions made at much larger scales. BISC is a marine park and the water that is found within the bay and on the reefs is important for these mobile species, but it is also critical to the health of benthic seagrass and coral communities. The quality of this water is also driven by decisions and actions made outside the park boundaries. BISC is located directly adjacent to a large metropolitan area which inadvertently has a great influence on the health of the ecosystem. Decades of pressure from the growing Miami population has taken its toll on the park's resources. Of the nine key resources evaluated for this report, two had an overall condition status that warranted significant concern, five warranted moderate concern and only two were in good condition (Table 5.1). No resource has a condition that is improving. Combined, these status and trend assessments highlight the complicated situation in resource management within the park and underscore the need for action.

Table 5.1. Overall conditions and trends for nine key resources in BISC.

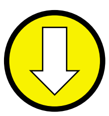
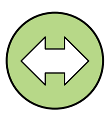
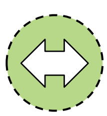
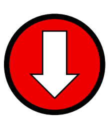
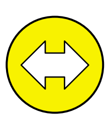
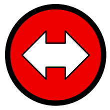
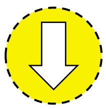
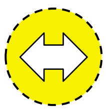
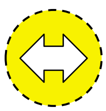
Attribute	Condition & Trend	Interpretation
Salinity, Nutrients, and Contaminants		Nearshore salinity levels have not met desired conditions warranting moderate concern. High nutrient levels coupled with phytoplankton and algae blooms inside and adjacent to the park are of significant concern. The presence of contaminants in the water and in animals living in the bay is an ongoing concern. Overall, the bay has endured a tremendous number of stressors for a finely balanced system and there is general concern that the health of the bay is at a tipping point.
Biscayne Bay Seagrasses		Seagrass beds constitute a vast majority (90%) of benthic habitat within BISC. Acreage and species composition appear to be stable, though dramatic declines on the periphery of the park warrants moderate concern for the nearshore seagrass community.
Mangroves, Hardwood Forests and Invasive Vegetation		Reference conditions for the composition and extent of mangrove and tropical hardwood forests were established in 2013. Subsequent mapping has not occurred. Forest monitoring plots indicate that normal succession is occurring following hurricane Andrew and earlier human disturbance. Invasive exotic plant monitoring and removal are continuing.
Stony Corals		Percent coverage of corals within BISC is at historic lows. Bleaching events and subsequent disease remain common and have increased the mortality of corals throughout the park. Several federally threatened species are close to being locally extinct.
Caribbean Spiny Lobster, Pink Shrimp, Queen Conch and Long-spined Sea Urchin		Long-spined sea urchin and queen conch are at levels well below historic norms but appear to be stable. Lobster and shrimp catches appear to be stable, but it is unclear if the current harvest rate is sustainable and if it affects ecosystem health.

Table 5.1 (continued). Overall conditions and trends for nine key resources in BISC.

Attribute	Condition & Trend	Interpretation
Reef Fish, Gamefish and Sharks		Previous reports have shown that the average size in the exploited phase of the stock for 25 reef fishes in the snapper-grouper complex indicates that they have been overfished. An updated review of six key species for this report shows that they are still overfished and currently experience overfishing. Overfishing has occurred before at least 1999 as densities of these species have been relatively stable but they are significantly less than those observed in the Dry Tortugas region for the same species There is little information on the status of gamefishes (e.g., bonefish, permit and tarpon) or sharks within BISC.
Loggerhead Sea Turtles		Loggerhead use of BISC for nesting appears to be stable with around 10 nests per year. Although varying sampling effort through time leaves some uncertainty in detecting trends, the nesting success rate and the hatch success rate have been declining as nest inundations have become more common. However, predation rates have declined significantly.
Bottlenose Dolphins, Florida Manatees and American Crocodiles		There is little long term data on bottlenose dolphins, Florida manatees or American crocodiles within BISC. Their abundances in BISC appear to be stable but at numbers much lower than anecdotal information from the turn of the century. These low numbers warrant moderate concern in their condition.
Shorebirds, Colonial Nesting Birds, White-crowned Pigeons and Migratory Species		Shorebird counts and colonial bird nesting counts suggest stable numbers of key species over the last 5 years. However, species richness of shorebirds and all bird species appears to be declining. Several monitoring programs are in place, but there is limited long term reference information available.

The timing, quantity, quality, and delivery of freshwater inputs into the bay establish the foundation for a healthy BISC ecosystem. Nearshore seagrass beds thrive on a delicate balance of nutrients and salinity. The beds proved habitat for invertebrates and juvenile fishes who in return provide a food source for predators such as birds, snappers and groupers, sharks, and dolphins. The seagrass beds are also important foraging ground for Florida manatees and sea turtles. If the quality of water entering the bay does not meet the criteria for healthy seagrasss community then the entire ecosystem is in jeopardy. The condition of water in the bay as measured by salinity, nutrient levels and contaminants warrants moderate concern and is declining (Table 5.2). This is beginning to have its effect on the health of seagrass beds (Table 5.2). Although they are still in good condition, they have begun to show signs of stress and there is considerable worry in the scientific community that they are approaching tipping point.

Outside of the bay on the coral reef, the major water quality concern is temperature which has been slowly rising. The condition of the coral reef systems warrants the greatest concern as bleaching, followed by disease and subsequent mortality has reduced the living coral reefs to a fraction of their size several decades ago (Table 5.2). It is important to note that this loss of corals is part of a much wider worldwide trend which has not spared BISC. Marine debris, that is primarily associated with commercial and recreational fishing, continues to cause physical harm to the remaining corals and other benthic invertebrates. Several removal programs are in place to help mitigate the constant flow of debris, yet it is time- and cost-prohibitive to keep up with the current rate of debris accumulation.

The proximity to a large city has not only indirectly affected natural resource conditions through degradation in water quality but direct human usage of the park and its natural resources has also had its effect. The coral reef fish community is overfished and has been experiencing overfishing since at least 1999 (Table 5.2). The size of fish landed within the park is cause for significant concern and the relative lack of abundance of many targeted species is also distressing. Hundreds of thousands of visitors enter the park each year, often with the intent to catch some fish, yet the fishing regulations in place are the same that an angler would find for a less populated region. This mispairing of regulations to usage has created a situation where anglers are no longer able to find the fish they desire. Commercial shrimp and lobster fishermen extract millions of dollars of seafood a year from the park with significant negative impacts (Table 5.2). Pink shrimp are the key prey item for a number of fish species and their removal by commercial fishing has a major impact on the food web in the park. The lobster fishery, which appears to be in good condition, requires the use of traps which are a major contributor to marine debris which itself is of major concern within the park.

Boca Chita Lighthouse (Photo by Judd Patterson)

Table 5.2. Indicator level conditions and trends for the ten key resources in BISC.

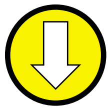
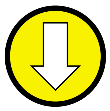
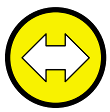
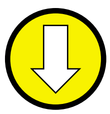
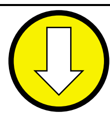
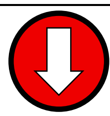
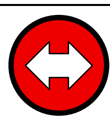
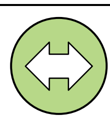
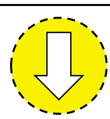
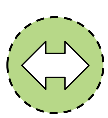
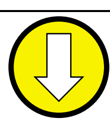
Criteria	Condition & Trend	Rationale	Reference Condition
Nearshore mesohaline conditions		Few sampled areas were optimal in terms of the preferred water quality restoration characteristics for CERP	Proportion of salinity observations ≥5 and <18 psu as compared to Florida Bay reference station (IBBEAM, 2016)
Nearshore hypersalinity events		Does not currently occur every year but was recorded in four of the last 12 years.	Proportion of salinity observations > 40 psu as compared to Florida Bay reference station (IBBEAM, 2016)
Nearshore salinity variability		The magnitude of salinity variability differed both spatially and seasonally. Some stations close to the canals experienced significant fluctuations, but there was no overall trend.	Proportion of days where salinity range is > 5 psu as compared to Florida Bay reference station (IBBEAM, 2016)
Salinity regime suitability index		Salinity environments are presently not adequate to support the target biological communities.	Combination of mesohaline, hypersalinity and variability indices as compared to Florida Bay reference station (IBBEAM, 2016)
Area of saltwater intrusion of Biscayne aquifer		Between 1995 and 2011, 24.1 km^2 of saltwater intrusion was measured.	No new saltwater encroachment into Biscayne aquifer
Phytoplankton blooms in Bay		Unprecedented and increasing algal bloom in the bay	No blooms
CHLA measurements in bay		4 out of 9 regions of Biscayne Bay are non-compliant with numeric CHLA criteria	Florida State numeric nutrient criteria (Figure 3)
Offshore nutrients		Offshore nutrients have been stable and are below EPA targets.	CHLA <= 0.35 $\mu g\ l^{-1}$ as per EPA strategic targets for reef sites
Presence of contaminants		Testing in 1990s showed few contaminants but recent studies suggest that there may be problems.	Levels below national standards
Groundwater contamination		No leakage of contaminants was discovered in the mid-2000s. This study is over ten years old leaving some uncertainty in knowledge of current status.	No migration of contaminants from Floridan Aquifer into Biscayne Aquifer
Overall Water Quality		–	–

Table 5.2 (continued). Indicator level conditions and trends for the ten key resources in BISC.

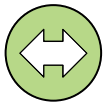
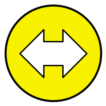
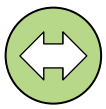
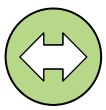
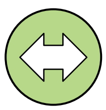
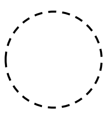
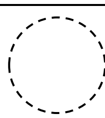
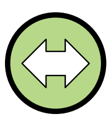
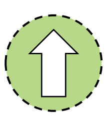
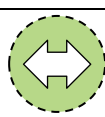
Criteria	Condition & Trend	Rationale	Reference Condition
Acreage		Seagrass acreage in Biscayne Bay seems stable and slightly increased between 1992 and 2005. It has been over 10 years since another survey was conducted	1992 acreage estimates from aerial photography
Nearshore composition (Florida Seagrass Integrated Mapping and Monitoring Program)		Turtle grass remains the dominant species in Biscayne Bay and the composition appears stable. However, areas directly adjacent to the park have experienced significant decline warranting moderate concern.	2005 frequency of occurrence
Percent coverage nearshore (IBBEAM)		Percent coverage of three dominant species (turtle grass, shoal grass, and manatee grass) have remained stable since 2008.	Stable coverage with species compositions in accordance with hydrological regime.
Percent coverage offshore (IBBEAM)		Percent coverage of three dominant species (turtle grass, shoal grass, and manatee grass) has remained stable since 2008.	Stable coverage with species compositions in accordance with hydrological regime.
Overall Biscayne Bay Seagrass		–	–
Extent of mangrove coverage		No new mapping survey has been conducted since the establishment of the reference condition.	2013 vegetation map area (ha)
Extent of hardwood forest		No new mapping survey has been conducted since the establishment of the reference condition.	2013 vegetation map area (ha)
Hardwood community composition		Hardwood community appears to be following natural succession following clear over a half a century ago and 20 years after a major hurricane.	2010 legacy plot composition
Invasive species		In 2016, 7% of the covered area was treated which is below the reference condition, but it is uncertain how well this metric represents the true are affected by invasive species.	2010–2015 average percent of covered area treated (24%)
Overall Terrestrial Vegetation		–	–

Table 5.2 (continued). Indicator level conditions and trends for the ten key resources in BISC.

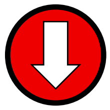
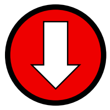
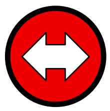
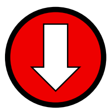
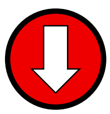
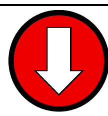
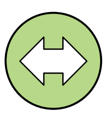
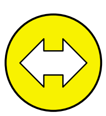
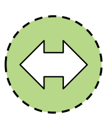
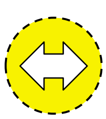
Criteria	Condition & Trend	Rationale	Reference Condition
Percent coverage (long term sites)		Percent coverage of stony corals is at historic lows and is still declining	Increasing coverage by 10–30% to 1977–1981 levels
Bleaching prevalence		During 2014 and 2015, large scale bleaching events have affected the corals within BISC. Prevalence has been greater than 50% in several regions.	Low annual prevalence (<20%) and infrequent mass bleaching events (≤ every 5–10 years).
Mortality		Mortality rates are consistently above desired state	≤ 1% mortality
Threatened species abundance		Pillar coral is now locally extinct within the park. Elkhorn and Orbcella sp. corals have undergone a drastic decline.	A genetically viable population
Seawater temperature		During summer months water temperatures on Amanda's Reef reef exceed the bleaching threshold during 4 of the last 11 years with data. In 2014 and 2015 both monitored reefs had 35 days over bleaching threshold.	Reef temperatures exceed local bleaching threshold (30.5 C) for less than 4 weeks (28 days)
Overall Corals		–	–
Lobster catch per trip (mini season)		Average CPUE over the last twenty five years has remained relatively constant and is greater than during the late 1980s	Stable or increasing CPUE with rates similar to 1990s (5 lobsters per person per trip)
Lobster catch per trip (regular season)		Average CPUE over the last five years is markedly lower than the 1990s and has declined since the 2000s. However, sample sizes are very low and there is some uncertainty in values.	Stable or increasing CPUE with rates similar to 1990s (4 lobsters per person per trip)
Commercial lobster landings		Commercial landings over the last five years have increased since the 2000s, but are still less than in the 1990s.Without information on effort, it is unclear how to interpret this trend.	Stable or increasing landings.
Bait shrimp CPUE		The commercial bait shrimp fishery has a long history in Biscayne Bay. CPUE, as an index of relative abundance, shows apparent stable trends, though the ability to quantify effort is imprecise.	Stable CPUE

Table 5.2 (continued). Indicator level conditions and trends for the ten key resources in BISC.

Criteria	Condition & Trend	Rationale	Reference Condition
Shrimp density in drop net survey		Spring density in 2015 is below 25th percentile and is at a time series low. Fall density is at a time series average. There is significant error associated with estimates.	Seasonal densities from 2007–2013 are used as reference condition.
Density of juvenile conch		Juvenile conch abundances suggest moderate recruitment.	Increasing densities of juvenile conch
Occurrence of breeding aggregations		No breeding aggregations within BISC have been surveyed but RVC data suggests there may be possible locations.	Sites with adult densities >200 individuals per ha
Long-spined sea urchin density		Long-spined sea urchin densities are significantly lower than historical norms (pre 1983) but appear to be gradually increasing.	Pre-1983 densities
Overall Selected Marine Invertebrates		–	–
Average Length (key exploited species) from creel		All 6 key species have $\bar{L}$ values less than the desired state	$\bar{L}$ > estimated $\bar{L}$ for F_{msy}
Average Length (key exploited species) from RVC		All 6 key species have $\bar{L}$ values less than the desired state	$\bar{L}$ > estimated $\bar{L}$ for F_{msy}
Density of exploited species		The density of exploited species within BISC has remained stable since 1999. For most species, density estimates are significantly lower than Dry Tortugas.	Similar density to Dry Tortugas National Park and increase in density from 1999.
Gamefish stock status		A 2010 assessment of bonefish suggests the population was overfished. There is no current information on the stock status of tarpon or permit.	A sustainable population is desired but reference conditions for BISC have not been developed
Sharks		There is limited information on the status or trend of sharks within BISC	A desired state or reference condition has not been established
Overall Reef Fish, Gamefish and Sharks		–	–

Table 5.2 (continued). Indicator level conditions and trends for the ten key resources in BISC.

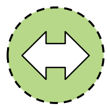
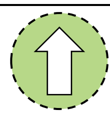
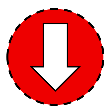
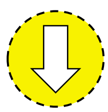
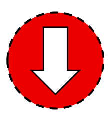
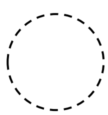
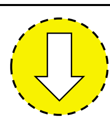
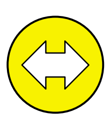
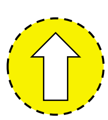
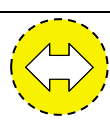
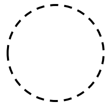
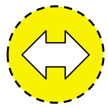
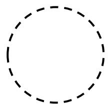
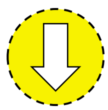
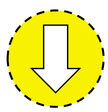
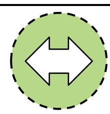
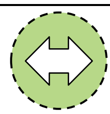
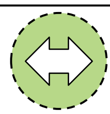
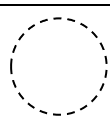
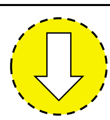
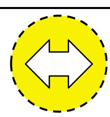
Criteria	Condition & Trend	Rationale	Reference Condition
Number of loggerhead nests		Loggerhead nests have been variable with no significant trend in numbers since 1991. Varying effort makes is hard to judge the condition with confidence.	1991–2000 average
Predation rate on loggerhead nests		The predation rate has declined significantly since the 2000s.	Predation rate below 25%
Loggerhead hatch success rate		During the last ten years the hatching success rate had been below the reference condition for every year except 2014.	1991–2000 average (64%)
Loggerhead nesting success rate		The nesting success rate has been below the Florida State average 4 of the last 5 years.	Florida Index Site Average (0.51)
Distance of nest from high tide		During the last 5 years (2011–2015) the average nest distance from high tide has been 2.0 m. This is significantly lower than reference condition.	1991–2001 average (4.6 m)
Strandings		The number of reported strandings has been increasing. This may indicate an increase in sea turtles visiting BISC, may be the result of better reporting, or that BISC has become more dangerous for sea turtles.	No more than 10 per year
Overall Sea Turtles		–	–
Bottlenose dolphin population size		The bottlenose dolphin population appeared steady from 1996–2007, new population estimates would confirm status.	Stable population size
Florida manatee population size		There was been an increase in max count per day from 1990 to 2003. More manatees may be utilizing BISC as power plants are decommissioned throughout the State	Increasing population size until species is delisted
American Crocodile growth rate		2014 growth rates reported at 0.11cm/day (Mazzotti et al., 2014)	0.15 cm per day (Mazzotti et al., 2009)

Table 5.2 (continued). Indicator level conditions and trends for the ten key resources in BISC.

Criteria	Condition & Trend	Rationale	Reference Condition
American Crocodile Fall Monthly Survival For Hatchlings		Survival rate in BISC is unknown	85% (Mazzotti et al., 2009)
Overall Marine Mammals and Crocodiles		–	–
Shorebird survey counts		Shorebird survey counts have a limited time series and no reference condition has been established	Reference condition has not been established for numbers of shorebirds desired.
Shorebird survey species richness		Average shorebird species richness in 2016 was 7.5. This is below historic richness values from the 1980s.	Maintenance of CBC 1980s average species richness (11)
Shorebird species richness CBC count		Species richness during the CBC has steadily declined since 1979.	Maintenance of 1980s species richness average (11)
Annual peak count of colonial nesting birds		Long term monitoring program is in place. No major trends over the last 7 years	Maintenance of current counts
Annual nesting index		Long term monitoring program is in place. No major trends over the last 7 years	Maintenance of current counts
Changing in timing of peak nest counts		Long term monitoring program is in place. No major trends over the last 7 years	Maintenance of current counts
White crowned pigeon counts		Limited time series and lack of reference condition preclude condition and trend status	Maintenance or increase of current counts
Species richness CBC		Average of last five years of 61.2 species is below reference condition.	1979–1981 average (91) species
Overall Birds		–	–

5.2. Data Availability

In order to make scientifically sound management decisions, robust sources of data are needed. In BISC there are already a number of well-developed programs in place providing the necessary data to track trends through time and to monitor the conditions of various resources. For example, a number of institutes and agencies have been collaborating for years to monitor the water quality throughout the bay. This multi-agency approach for data collection is imperative and should continue to be supported by the park.

Information for fishery dependent (creel survey) and fishery independent (RVC) show unequivocally that reef fish assemblages in the park are overfished and require urgent management actions to ensure their continued existence in the park. Likewise, a patchwork of coral monitoring programs all show the same dire situation for the coral reefs of BISC. Given the high importance of both of these resources, continued monitoring is essential, and it is beneficial to have more than one program so that cross validation can occur. However, it is important that when moving forward, monitoring programs are rigorously vetted to ensure that proper methods and survey designs are implemented to ensure that the data can be used to address management concerns. Furthermore, it is important to check for potential overlap and cost savings through partnerships.

Along with multiple programs established for monitoring water quality, corals and reef fish, there are individual programs that are in place to monitor sea turtles nesting, colonial nesting birds, shorebirds, marine debris, pink shrimp and nearshore seagrasses. Currently there is a healthy balance of monitoring programs shouldered by the park, SFCN and outside agencies, but it will be important to make sure that no group is burdened with excess monitoring programs, thereby reducing the quality of data collection.

Currently there is a lack of information on the health of seagrass beds to the east of the keys. This is not only an important resource but constitutes a large proportion of the acreage within the park. The SFCN has recently drafted a seagrass monitoring protocol and is initiating a monitoring program. The only information on the status of Caribbean spiny lobsters is from fishery dependent sources such as the recreational catch monitored during the regular and mini season and commercial landings. A fishery independent survey is desperately needed and the SFCN has also just completed a monitoring protocol and began testing sampling methods in 2017.

Despite all of the monitoring programs in place, there are still a few key resources for which a standardized data collection program does not exist. A NOAA-sponsored program to track bottlenose dolphins in Biscayne Bay ended in 2007 and since then there is little information on the status of the population. The Florida manatee population is monitored statewide but local counts are sparse. It may be possible for the park to work with other agencies to see if monitoring within the park can be accomplished.

Very little is known about the shark population in BISC despite their key role as an apex predator. Likewise, there is a paucity of information on the states of gamefish populations such as tarpon, bonefish, permit, snook, and sea trout. These species are also an integral component of a healthy ecosystem and draw thousands of visitors each year into the park boosting the local economy.

Monitoring programs for these species should be a high priority and there is considerable expertise available at the local institutes to help create the necessary programs.

Finally, there are a few resources that require mapping efforts to monitor changes in acreage. These include seagrass beds and terrestrial vegetation. A coordinated effort should be made at least every ten years to fund large scale mapping projects to supply this much needed information.

5.3. Recommendations

The location of BISC, directly adjacent to a major metropolitan area with little to no borders, provides incredible access for hundreds of thousands of visitors each year, but also presents a tremendous challenge for park natural resource managers. A majority of the natural resources highlighted in this condition assessment warrant a moderate concern, and in particular, the deleterious conditions of reef fish populations and stony corals warrant significant concern. Management action on several fronts is recommended:

- There is an ongoing opportunity for continued public outreach and education. Marine debris is partially a visitor usage issue which can be mitigated through public user education. A reduction in visitor-based pollution could go a long way in helping to clean up the park. The continuation and possible expansion of volunteer debris-removal programs, which not only serves as an excellent outreach tool but also helps assist park staff with clean-up, is strongly encouraged. Reducing the impacts of commercial fishing in the park is also encouraged. These impacts are manifested by loss of lobster traps and use of bottom-dragging trawls.
- Overfishing within the park is a very significant concern, yet visitors (recreational fishers) continue to illegally retain under-sized fish, fish out of season, and protected species. Fishing regulations within the State of Florida are somewhat complex, and it is important to provide park visitors with clear and up-to-date information. New fishing regulations would be more effectively implemented with a robust outreach including the Fishery Education Program, and the effectiveness could be evaluated by implementation of the Science Plan co-developed with the State of Florida.
- The mandated consent in the enabling legislation to allow commercial fishing within the boundaries of a National Park is rare, and it has its own impacts on resource quality and quantity. Both the shrimp trawl that provides “bait” to the burgeoning recreational fishery, and the intense spiny lobster fishery, both not only remove key species from the ecosystem, but also damage important benthic habitats throughout the park. Neither type of fishery is allowed to operate in either adjacent Dry Tortugas or Everglades National Parks. It is strongly recommended that further extensive analyses are conducted to evaluate the cost and benefits to the sustainability of park natural resources associated with these fisheries. The new state regulations in support of the park FMP are planned to increase the size and abundance of certain fish species within the park.
- BISC offers easy access to large numbers of recreational anglers in the State of Florida, yet fishing regulations specific to the park do not reflect this excessive strain. If reef fish stocks within the park are going to be rebuilt, significant additional resource management strategies and protections must be devised that balance visitor access, use, enjoyment, and adequate resource protection. These strategies and protections can be developed and implemented through collaborative on-going robust efforts with BISC’s many partners and stakeholder communities.

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Appendix A: Draft Agenda for NRCA Updates and Discussion: Dry Tortugas and Biscayne National Parks

Agenda

Draft Agenda

NRCA Updates & Discussion:

Dry Tortugas and Biscayne National Parks

When: Monday October 17, 2016
Time: 10:00 AM to 3:00 PM (Lunch and refreshments provided)
Location: CIMAS 3rd Floor Conference Room, Rosenstiel School of Marine Atmospheric Science, University of Miami, 4600 Rickenbacker Causeway, Miami, FL 33149
Call 305-546-3223 if lost!
Hosts: Jerry Ault and David Bryan, University of Miami

Time	Activity	Location
10 a.m. – 11 a. m.	**Introductions & NRCA Overview** Presenter: Jerry Ault Group Comments *Coffee*	CIMAS 3rd floor conf. room
11 a.m. – 12 p.m.	**Dry Tortugas: Focal Resources** Presenter: David Bryan Group Discussion	CIMAS 3rd floor conf. room
12 p.m. – 1 p.m.	**Lunch Break** *Provided*	SALT Restaurant @RSMAS
1 p.m. – 2 p.m.	**Biscayne: Focal Resources** Presenter: David Bryan Group Discussion	CIMAS 3rd floor conf. room
2 p.m. – 3 p.m.	**Wrap-up** **Linkages between NRCAs, RSS and Foundation documents** **Facilitator: Jerry Ault**	CIMAS 3rd floor conf. room

Attendees

Justin Unger, ENP/DRTO Deputy Superintendent
Brien Culhane, ENP/DRTO Chief, Planning and Compliance
Glenn Simpson, DRTO Park Manager
Elsa Alvear, BISC Chief of Resource Management
Dr. Vanessa McDonough, BISC Fishery Biologist & Program Manager
Tylan Dean, ENP/DRTO Branch Chief of Biological Resources
Meaghan Johnson, DRTO Fishery Biologist

Dr. Erik Stabenau, ENP Oceanographer
Dr. Mike Feeley, SFCN Marine Ecologist & Program Manager
Andrea Atkinson, SFCN Quantitative Ecologist
Judd Patterson, SFCN Data Manger
Dr. Jerry Ault, UM/RSMAS Professor and Chair, Department of Marine Ecosystems & Society
David Bryan, UM/RSMAS Senior Research Associate II
Molly Stevens, UM/RSMAS Ph.D. Candidate

Meeting Notes

Dry Tortugas National Park

- Seagrass
  - Do we know if there has been any change with time? What is the species composition; is it a monoculture? Is the seagrass community robust to negative impacts?
- Terrestrial vegetation
  - The seabird (sooty tern) surveys contain vegetation data that may be used to help asses condition of resource
  - The black mangroves were planted at DRTO and appear to be dying (red already gone), this vegetation has provided nesting habitat for frigate birds
  - Vegetation surveys could be more up-to-date/comprehensive
  - Loggerhead Key is migrating south; losing vegetation on north shore, but tremendous growth in the last few years elsewhere
    - Similar changes on Garden Key
    - Is there a natural succession?
      - Cycles of 100–200 years is reasonable (losing vegetation 100 years old)
      - Cycles of 10–20 years is unreasonable for natural succession
  - Bush Key & Long Key are now separated after TS Hermine
  - There have been constant land mass changes
  - Historical structures are being lost (i.e.,Boat House)
- Corals
  - FWRI Elkhorn/Pillar monitoring project includes coral measurements
    - Percent coverage
    - Mortality rates of individual colonies
    - Pillar coral has only a single genotype in DRTO, functionally extinct
      - There has been discussion about introducing another genotype to allow reproduction for that species
    - Some Elkhorn coral genotypes have been ‘rescued’ because it didn’t appear that they would survive the summer (BISC?)

    - Staghorn coral
        - Ongoing work to determine why some colonies are proliferating
        - USGS (Kim Yates) has been looking at high growth at Pulaski shoals
    - Coral monitoring programs
        - Currently many monitoring programs with different goals.
        - Long-term goals of percent coverage of specific sites vs percent coverage of the regions
        - Hybrid approach—high % sites have ecological importance; overall from random draw is a valuable metric
        - Compare high versus low density coral sites
    - *Acropora* coral nursery updates
        - 4000 corals have now been outplanted
        - Survivorship has declined from 95% to 80% survivorship (w/ recent bleaching)
- Marine invertebrates
    - *Diadema*
        - FRRP data has occurrence of *Diadema*
        - SFNC collects *Diadema* data in their coral surveys as well
    - Conch
        - Spawning aggregation definition? Area/number?
- Reef fish
    - Morning recreation vessel visitors
        - Recommended dashed line around this
        - There is a need for better data
        - Intermittent reporting by rangers
        - Boaters don’t always come in to get a permit
        - Need to have a person there to complete registration; self-registration is also merged in to capture that data better
        - Looking at this over the next 2 years to have a better sense of the reliability of the data
        - Was there a period where the ferry wasn’t operating?
        - Ferry use has been increasing (Sept. highest ever) possibly due to increased advertising
        - Instead of merging ferry/morning use dataset, keep them separate as they represent different things
        - Two Processing
            - Harbor log count (described above)

- Boater registration process is used to determine how users utilize the park
  - Sailing, fishing, location, etc.
- Not getting an accurate picture

- Mooring visual count by flag pole
  - Problem distinguishing bt recreational activities inside/outside the park

- Lionfish
  - Removal by UM interns from positive sites identified by RVC

- Sea Turtles
  - DRTO is in the 3rd year of turtle monitoring as a Florida Index Site (committed to 10 years of index beach protocol)
    - Should include hatching success w/ no predation as metric
    - 2016 data may have issues due to internship problems
  - There is no count number of adults; instead focus on monitoring nests. Kristen Hart with USGS has information on adult movements
  - Is there information on stock size?
  - Predation
    - Break this out by predator type
    - Quantify rat management program
- Seabirds
  - Only nesting sites in lower 48 for masked booby, magnificent frigates, and sooty terns. All should be included in NRCA.
  - Sooty tern monitoring might encompass frigate birds as well (check w Sonny Bass)
  - Value of Christmas bird count?
    - Need to explain its value
    - Partially funded by NPS, partially volunteer
      - Motives/perceived motives of volunteers?
      - Tends to be same volunteers w/ few newcomers
    - Dry Tortugas is the only count capturing masked booby, frigate, sooty tern, etc. etc.
  - Sooty tern nesting pairs
    - Anecdotal decline due to food availability (ask Sonny Bass)
      - Development of pink shrimping industry
      - Nesting in spring/summer months to nesting fall into winter
    - Frigate bird count
      - Use total numbers not counts per hour

            - Translates to a complete census because not nesting year round anywhere else
            - Same for masked boobies
            - Metric – Nesting habitat availability/quality (due to vegetation changes—which isn't necessarily a stressor in itself)
        - Laughing gull numbers
            - Ferry used to serve food at the dock did this increase laughing gull numbers?
            - When it moved into ferry, did gulls move to predation on sooty tern eggs?
            - Does not sound like there is any quantitative information available but Stuart Pimm or Sunny Bass may know something
    - Avian Research and Conservation Institute has bird tracking studies (Ken Meyer)
- Water Quality
    - What's being measured? What's an indicator?
        - USGS—Kim Yates
        - Nutrient loading, acidification, salinity
        - Derek Manzelo—ph, salinity, light meters—at least 2 years of data
        - NCRMP water quality information
        - There has been some interest in micro plastics
    - Eric Stabeneau is measuring water quality around Garden Key

Biscayne National Park

- Seagrass
- Mangrove & Hardwood Forest
    - Monitoring benchmarks as habitat shifts with climate change?
    - Can we look at balance between tropical hardwood hammock, mangrove, and sandy beach?
    - Could set a current 'baseline' for going forward
    - Are there historic photos of the extent of the beach along Elliott Key?
    - General consensus is that there is less beach today than in the past and this may have an effect on sea turtle nesting
    - What action lies behind the data and the collection?
    - Forest extent & forest composition are good metrics
    - Schaus Swallowtail should be a separate resource from terrestrial plants
        - Status symbol should be red w/out an arrow?
        - Only tropical hardwood location left that still has this species
        - Starting to see them again in Key Largo

        - May not be a good indicator of tropical hardwood bc it needs one species of tree within the hardwood habitat
        - Almost functionally extinct (not a good ecosystem indicator)
        - FSU is conducting the surveys
    - Avian surveys or insect surveys may be a better indicator of hardwood habitat
        - Haven't been doing these surveys
        - May just fall back on plants themselves as indicators
    - Indicators
        - Extent of habitat
        - Community composition
        - Invasive species
- Corals
    - Genetic rescue email strand will be forwarded to David
    - Fair to color BNP coral cover red?
        - Stabilized at ~5% which is better than declining
        - Historical levels? There was one paper that indicated a reference point of ~30% (Author – Japp? Dunstan? Hudson?)
            - Could just be specific sites with higher % coverage anyways
        - Could have no color to indicate that we don't know the baseline level
    - Important to make the connection between the health of corals and fish communities
- Lobster, shrimp, & conch
    - Shrimp baseline from Ault et al. 1999 in the Bay w/ 4% CV
    - Pink shrimp commercial harvest for recreational purposes
        - Largely unreported
        - Send graph of commercial landings w/ trend line to Elsa
    - Conch
        - Large amounts of illegal poaching (mostly anecdotal)
    - Lobster
        - FWC and SFCN are working on a joint monitoring protocol
        - Check with FWC for survey data
- Birds
    - Bill Baggs banding station data? Could compare vegetation map for Bill Baggs vs BISC to check for similarities
        - Migratory pass rates ; fall banding station

        - Warblers, thrushes
        - Not a good immediate indicator for the park
        - Indicator for how important the stop is for migratory birds
    - Christmas count within BISC may be useful data
- Water Quality
    - Contaminant report from USGS
- Marine Debris
    - Source could be used as another metric
        - Commercial vs recreational (trap line vs monofilament)
        - Inside vs outside the park
    - Marine reserve could greatly reduce the amount of trash being dumped on the reef

Discussion

- Value in the use of historic photos for long term reference (eg. fish pictures, habitat photos)
- Elasmobranch surveys?
    - Include sharks and rays in NRCA
    - N. Hammerschlag (U Miami) tracking data may be useful
- Mangrove fish composition monitoring
    - Encompasses w/in some surveys (IBBEAM?)
    - Need surveying on barrier islands
- Crocodile inclusion?
    - DRTO data on crocodile-human interactions?
        - Anecdotal reports—would need more detailed information to include in NRCA
    - BNP crocs had a long history of nesting success in cooling canals
        - Changes in water quality (salinity / algae blooms / temperature) there are reports that they are not healthy and nesting has declined
        - Skinny and stressed out (anecdotal evidence)
        - Will these crocodiles start dispersing into BNP?
        - How will the proposed phase out cooling canals over next 30 years effect crocodile distributions
    - CERP reports includes # crocodile nests
- Include Semaphore Cactus in report. Vanessa has data
- Include manatees?
- Have any focal resources been missed?

- Annual groundings data for each park
    - Seagrass, reef habitat
    - Management impacts
    - BNP ~100/year, DRTO very few
    - Groundings aren't as frequent as 10 years ago (depth finders, GPS help)
- Soundscape
    - Naval aerial activity around DRTO
    - Use report to leverage conversation?
    - BNP has both aerial and underwater sound pollution
    - Anecdotal visual disturbance of supersonic sounds to birds at DRTO
- Lightscape
    - NRCA has reports on soundscapes/night sky
    - Pursuing international dark sky sanctuary at DRTO
    - Unique because surrounding water creates less distortion of night sky
        - Lighthouse is not a threat to this
- Resource violations
    - Over limits, poaching?
    - Time series data?
    - CREEL survey includes column for violations
        - Undersized fish
        - Over bag limit
        - No license
    - Consensus is to not use as a management indicator or highlight in NRCA
        - BNP told to use it as a management indicator in the future
- Resource Stewardship Strategy component

NPS 169/178451, February 2022

National Park Service
U.S. Department of the Interior

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