National Park Service
U.S. Department of the Interior

Natural Resource Stewardship and Science

Natural Resource Condition Assessment

Dry Tortugas National Park

Natural Resource Report NPS/DRTO/NRR—2018/1791

ON THIS PAGE
Vibrant DRTO coral reef with schools of blue chromis (*Chromis cyanea*)
Photo by David Bryan

ON THE COVER
A DRTO goliath grouper (*Epinephelus itajara*) interested in a diver
Photo by David Bryan

Natural Resource Condition Assessment

Dry Tortugas National Park

Natural Resource Report NPS/DRTO/NRR—2018/1791

David R. Bryan and Jerald S. Ault

University of Miami, Rosenstiel School of Atmospheric and Marine Science
4600 Rickenbacker Causeway
Miami, FL 33149

October 2018

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

The National Park Service, Natural Resource Stewardship and Science office in Fort Collins, Colorado, publishes a range of reports that address natural resource topics. These reports are of interest and applicability to a broad audience in the National Park Service and others in natural resource management, including scientists, conservation and environmental constituencies, and the public.

The Natural Resource Report Series is used to disseminate comprehensive information and analysis about natural resources and related topics concerning lands managed by the National Park Service. The series supports the advancement of science, informed decision-making, and the achievement of the National Park Service mission. The series also provides a forum for presenting more lengthy results that may not be accepted by publications with page limitations.

All manuscripts in the series receive the appropriate level of peer review to ensure that the information is scientifically credible, technically accurate, appropriately written for the intended audience, and designed and published in a professional manner.

This report received informal peer review, which was provided by subject-matter experts who were not directly involved in the collection, analysis, or reporting of the data. The level and extent of peer review was based on the importance of report content or its potentially controversial or precedent-setting nature.

Please cite this publication as:

Bryan, D. R., and J. S. Ault. 2018. Natural resource condition assessment: Dry Tortugas National Park. Natural Resource Report NPS/DRTO/NRR—2018/1791. National Park Service, Fort Collins, Colorado.

NPS 364/149169, October 2018

Contents

Contents (continued)

Contents (continued)

Page

Figures

Figures (continued)

Figures (continued)

Page

Tables

Page

Tables (continued)

Page

Executive Summary

Dry Tortugas National Park (DRTO), located 100 km west of Key West, Florida, is perhaps the most remote marine National Park in the United States, offering visitors a rare opportunity to see and experience an intact and relatively pristine coral reef ecosystem. As a result of its remote location, DRTO typically hosts less than 80,000 visitors a year. Commercial fishing has been banned since 1935, when the Natural Monument was established. Recreational fishing is now restricted to the eastern half of the park, and the western half is a fully protected "no-take" research natural area. The combination of its remote location, low visitation and substantial fishing restrictions have largely preserved the integrity of the natural ecosystem that now provides an important refuge for more than 700 species of fishes, birds, mammals, plants, and hard and soft corals.

DRTO, and the surrounding Dry Tortugas region are located upstream at the southwestern most point of the highly connected Florida coral reef ecosystem. The Dry Tortugas region provides breeding habitat for a number of species and is important in delivering coral and fish recruits to the rest of the ecosystem. "Healthy" resource conditions in DRTO are not simply a concern for the park, but are also vital for the sustainability of the entire regional ecosystem.

This natural resource condition assessment (NRCA) has identified seven key natural resources vital to the park: seagrasses, terrestrial vegetation, corals, marine macroinvertebrates, reef fishes and sharks, sea turtles, and birds. Assessment of the condition and trend for each of these natural resources was guided by the best available science and the National Park Service (NPS) framework for structured resource assessment and reporting. The availability and quality of data for condition scores varied substantially amongst resources; overall, this NRCA analysis found this suite of natural resources to be in "moderate condition", with various trends observed.

Seagrasses form "beds" that are highly productive biologically, and comprise an essential component of a healthy marine ecosystem. Seagrasses provide essential habitats for a wide range of marine species and life stages, both as foraging and nursery grounds. In DRTO, seagrasses comprise about 14% of the mapped benthic substrate. Data suggest that their species compositions and densities have been relatively stable over the past 20 years, and that they are in good condition. More than half of the other key natural resources assessed here (e.g., marine macroinvertebrates, reef fishes, and turtles) depend directly upon the health of the seagrass community. Their continued "healthy" status provides a valuable foundation for a sustainable environment within the park.

Although DRTO is principally a marine park (99% water), the seven islands within the park boundaries provide unique habitats for nesting and migratory birds, as well as, pristine beaches for nesting sea turtles. About 50% of land area in DRTO is comprised of either sparsely vegetated or non-vegetated sand; and, the remaining area contains a highly-adapted plant community capable of surviving the harsh maritime conditions. Exotic plants, in particular the Australian pine, were previously a major threat to this community, but focused restoration and removal of non-native species during the 1990s eliminated almost all exotics. Currently, the terrestrial vegetative community appears to be in good condition. There is some concern that climate changes and sea level rise may negatively impact some species. There has been a gradual loss of park islands and vegetation through erosion, from eleven islands in 1829 to seven in 2018. The remaining seven islands have shorelines that are forecast to have moderate to high vulnerability to further erosion.

DRTO provides essential habitats for several hundred species of coral reef fishes. The extensive and luxuriant seagrass beds, soft coral forests and thousands of acres of patch contiguous stony coral reefs offers a wide range of habitats for fishes throughout their life cycles. The diverse reef fish community is not only integral to the dynamics and functioning of DRTO, but also provides key support to the multibillion dollar southern Florida region recreational and commercial fishing and diving industries. However, multispecies stock assessments of the DRTO exploited fish community suggests that many of the premier grouper and snapper species are overfished and experiencing fishing mortality rates greater than those required for sustainability. To ameliorate these conditions within DRTO, a no-take research natural area (RNA) was established in 2007 in the western half of the park. The RNA provides complete protection for reef fish by prohibiting any extraction. Scientific results from an on-going fishery-independent census of reef fish conducted throughout the park and Tortugas region has shown higher densities and larger sizes of key exploited reef fish species are found within the park as compared to the broader regional ecosystem where fishing continues. Continued protections within the park from extractive fishing pressures will help ensure sustainable conditions, and help to increase and preserve these populations in the broader regional ecosystem for years to come.

Another DRTO natural resource warranting significant concern are the stony corals. The Dry Tortugas region has historically contained some of the best coral reef habitats in the Florida coral reef tract. However, data from several independent and relatively long-term reefs monitoring programs indicate a significant loss of coral cover in the park over the past two decades. This is consistent with an apparent worldwide trend. Despite this reduction, DRTO still has some of the highest coral cover in the region. Unfortunately, sea water temperature, one of the root causes of coral mortality, is forecast to continue to increase independently of the park’s management jurisdiction. However, local and regional management efforts to mitigate the impacts of other stressors such as fishing, boating and visitor impacts will remain an important component of coral reef management.

The Caribbean spiny lobster support a large and economically-important commercial and recreational fishery in south Florida. Harvest of spiny lobster has been prohibited within the park since 1974, creating the most significant protected area in the region for the species. Currently, there is no specific monitoring program for spiny lobsters in the park, but because of its protected status, the lobster population condition has been considered good. Queen conch are also an ecologically important species, though through heavy exploitation, they have been effectively extirpated since the 1970s. They are now fully protected in Florida waters. Similar to spiny lobster, there is no monitoring program in place. Long-spined sea urchins were considered a major grazing species in the regional coral reef ecosystem prior to a widespread Caribbean die-off in 1984. Data from the various monitoring programs in the park suggest an increasing trend in abundance over time, but the population size is still substantially below historical levels.

DRTO's sandy beaches provide essential nesting grounds for loggerhead turtles, and represents the largest nesting area for green turtles in Monroe County. In recent years, nesting counts for both loggerhead and green turtles are at historic highs within in the park. The park is also an important foraging area for sea turtles. The condition of sea turtles is good and the standardized monitoring efforts in place have been recognized by the State of Florida.

DRTO is a critical stop-over location for an incredible diversity of migratory birds. The park also provides key habitats for 36 resident species, and encompasses the only large breeding colony for five species of seabirds in the lower 48 United States. Monitoring of birds within DRTO has been highly variable, but annual counts of sooty tern nests suggests a decline to historic lows. Counts of masked boobies are up from their initial discovery, but more recently the population has apparently declined. Magnificent frigate birds appears to be stable. Condition and trends for a number of bird species is unknown. A program of standardized monitoring of nesting birds is recommended to better understand the health of this important resource.

This NRCA revealed that overall, the natural resources of DRTO are in moderate condition. There was a positive trend in condition status for two resources, no overall trend for three resources and a negative trend for two resources. The partial recovery of reef fish populations, as a result of marine protected areas, highlights how park management actions can make a significant difference towards resource conditions. Likewise, the park's resolve to remove exotic vegetation as part of a conscious effort to protected sea turtle nesting sites, has led to considerable increases in their numbers. For resources with no trends, seagrass, terrestrial vegetation and macro-invertebrates, continued or additional monitoring is required to track their status and help determine if management action is warranted. Global warming and sea level rise are a major threat to several resources in DRTO and impose a tremendous challenge for park managers. The decline in terrestrial habitat, as a result of rising sea levels, has begun to effect the breeding colonies of birds and will eventually impact nesting sea turtles. Stony corals have declined precipitously due to warming oceans and their future is uncertain. Continued monitoring will inform park managers on how these resources are responding to a rapidly changing marine environment.

Acknowledgments

This NRCA is based on an extensive foundation of research and monitoring that has taken place in in DRTO 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 flowing scientists that was instrumental in generating this NRCA: E. Alvear (BISC), A. Atkinson (SFCN), A. Davis (SFCN), M. Feeley (SFCN), N. Hammerschlag (UM), M. Johnson (DRTO), B. Lockwood (NPS), K. Marks (FRRP), J. Miller (SFCN), A. Meylan (FWRI), R. Muxo (SFCN), K. Neely (FWRI), K. Nimmo (DRTO), J. Patterson (SFCN), L. Richter (SFCN), J. Sadle (NPS), B. Shamblin (SFCN), S. Smith (UM-RSMAS), R. Waara (SFCN), K. Whelan (SFCN), S. Wilson (FIU), and T. Ziegler (NPS).

List of Commonly Used Acronyms

BISC – Biscayne National Park

CPUE – Catch per Unit Effort

DRTO – Dry Tortugas National Park

ESA – Endangered Species Act

FKNMS – Florida Keys National Marine Sanctuary

FIU – Florida International University

FRRP – Florida Reef Resilience Program

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

NOAA – National Oceanic and Atmospheric Administration

NPS – National Park Service

RNA – Research National Area

SEFC – 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 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 Geographic Information System (GIS) products;[4]
- Summarize key findings by park areas;[5] and
- Follow national NRCA guidelines and standards for study design and reporting products.

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*

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

[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

The Dry Tortugas National Park (DRTO) lies at the western end of the Florida Straits, 113 km (70 miles) west of Key West. The relatively small park (269 km^2) is 99% water, and consists of seven small islands surrounded by an extensive coral reef ecosystem. DRTO is renowned for its cultural and natural resources, accentuated by its unique remote location and subsequent limited access. As the westernmost landmass along the Florida Reef tract, DRTO is an important stop-over for migratory birds, supporting the only nesting colony for five species in the lower 48 states and is a critical nesting habitat for loggerhead and green sea turtles. The coral reef ecosystem harbors a tremendous diversity of fishes and invertebrates including 9,214 ha of coral habitat and 3,723 ha of seagrasses. Due to its geographic location, the marine organisms found in DRTO provide a significant source of recruits to the entire south Florida ecosystem as larvae are carried downstream by the Florida Current (Lee and Williams 1999, Domeier 2004, Burton et al. 2005, Bryan et al. 2015).

Although coral reef communities have declined throughout the western Atlantic and are now mostly characterized by macroalgae and soft corals, the parks marine ecosystem includes some of the healthiest coral reef communities along the Florida Keys Reef Tract. The remote tropical waters of DRTO sustain some of the last known reefs with coral coverage greater than 20% in south Florida. These remaining coral communities along with extensive hardbottom areas colonized by sponges, soft corals and macroalgae and dense seagrass beds provide key habitat for hundreds of reef fish species.

The reef fish community of DRTO has been safeguarded from excessive levels of fishing as a result of its remoteness and a number of management actions such as the creation of marine protected areas. Snappers and groupers that are commonly overfished in Florida are more common and larger within the park (Ault et al. 2006, 2013).

2.1.1. Enabling Legislation

The Dry Tortugas name originates from a 1513 description by Ponce de Leon who called the area Las Tortugas due to the vast numbers of sea turtles he encountered. Over the next three hundred years, the strategic location of the park brought countless explorers and merchants through its waters. During the mid-19th century the United States established Fort Jefferson on Garden Key as a bastion during the civil war and later as a prison and then navy base. Since its discovery, the Dry Tortugas has been recolonized by sailors and early scientists as an area with remarkable natural resources; John Audubon and Louis Agassiz visited the island and in 1904 the Carnegie Institute established a world class marine biology laboratory on Loggerhead key. President Theodore Roosevelt designated the area as a wildlife refuge in 1908 to protect sea bird rookeries. Then in 1935, Franklin D Roosevelt designated the area as a National Monument under the Antiquities Act. The monument, which originally included 19,071 ha, was expanded in 1983 and redesignated a National Park on October 26, 1992 by an act of Congress. The Dry Tortugas National Park (DRTO) was established by the federal government to "*preserve and protect for the education, inspiration, and enjoyment of* *present and future generations nationally significant natural, historic scenic, marine, and scientific values in south Florida*" The enabling legislation stipulates that the park must be managed so as to protect, among other values, "*a pristine subtropical marine ecosystem, including an intact coral reef community*." The state of Florida retained the rights to the seabed and associated resources. In 2007, NPS and the state of Florida entered into a joint agreement or Memorandum of Understanding (MOU) to establish a Research Natural Area (RNA) within the DRTO. The RNA is 119 km^2 (46 mi^2), but its regulations exclude an area 1.85 km (1.15 mi) in diameter around Garden Key Lighthouse and the developed areas on Loggerhead Key.

<u>Other important laws</u>

The NPS Organic Act states that the National Park Service will "conserve the scenery and the natural and historic objects and the wildlife therein and to provide for the enjoyment of the same in such manner and by such means as will leave them unimpaired for the enjoyment of future generations." Natural resource management in DRTO is also driven by a variety of federal laws including the Lacey Act (1900), Migratory Bird Treaty Act (1918), the Clean Air Act (1970), the Clean Water Act (1972), the Marine Mammal Protection Act (1972) Endangered Species Act (1973), the Magnuson-Stevens Fishery Conservation and Management Act (1976) and subsequent amendments. Executive Order 13089 (Coral Reef Protection), signed by President Bill Clinton in 1998, helped fulfill the purpose of many of the above mentioned acts and other pertinent statutes , to preserve and protect the biodiversity, health, heritage, and social and economic value of U.S. coral reef ecosystems and the marine environment. Executive Order 13158, signed in 2000 by President Clinton, strengthened the management, protection, and conservation of existing marine protected areas (MPA) and established new and expanded existing MPAs. It also emphasized a comprehensive science based approach to the MPA system, and set guidelines for all federal agencies operating within MPAs.

Fort Jefferson cannon. (Photo by David Bryan).

2.1.2. Geographic Setting

The Dry Tortugas make up the western most component of the Florida Keys Reef Tract, the third largest barrier reef system in the world. The seven islands that lie within DRTO are located 113 km west of Key West and 175 km northwest of Havana, Cuba. The park is situated at the start of the Florida Straits where the Loop Current coming out of the Gulf of Mexico and the Caribbean Current up from the Yucatan, converge to form the Gulf Stream. This creates highly dynamic physical oceanography leading to increased productivity. The three limestone banks, that make up the park are comprised of Holocene corals and sand stacked upon an underlying Pleistocene reef (Shinn et al. 1977). These banks form a partial atoll creating an inner lagoon region in the park. DRTO encompasses 269 km^2 and its boundary is marked by a series of buoys located beyond the reef margins in about 22 m of water. DRTO is surrounded by the Florida Keys National Marine Sanctuary and its northwestern boundary abuts the large Tortugas North Ecological Reserve that includes the Tortugas western bank. Riley's Hump, which is part of the Tortugas South Ecological Reserve, is located roughly 11 km to the southwest of the park. Both of these prominent geological features are known for their abundance of commercially important reef fish that both reside and travel to them to spawn (Burton et al. 2005, Locascio and Burton 2016, Feeley et al. 2018).

The temperatures in DRTO vary little from the rest of the Florida Keys. The highest temperatures occur in July and August (32 °C) and the lowest temperatures during the winter rarely drop below 19 °C. The Florida Keys are the driest area in Florida and given its remote location from the mainland, DRTO is the driest region in the Keys. Precipitation averages 124 cm per year with most of the rain coming between May and October. Tropical storms and hurricanes which are more common in the Florida Keys than any other area in the North American can deliver excess amounts of rain during hurricane season that lasts from June to November with a peak in September.

Water temperatures in DRTO are typical to south Florida with winter bottom temperatures in the low 20s (°C) to summer temperatures in the upper 20s (°C) (Figure 2.1.1). Warm summer time temperatures are sometimes interrupted with cold water upwellings (e.g., 2016 data in Figure 2.1.1) that are likely caused by local eddies, but currently not well understood. Average summer and winter time temperatures have been increasing. In 2014 and 2015, summer time temperatures were above average causing coral bleaching and in 2016 winter temperatures were the highest recorded in the last decade (Figure 2.1.1).

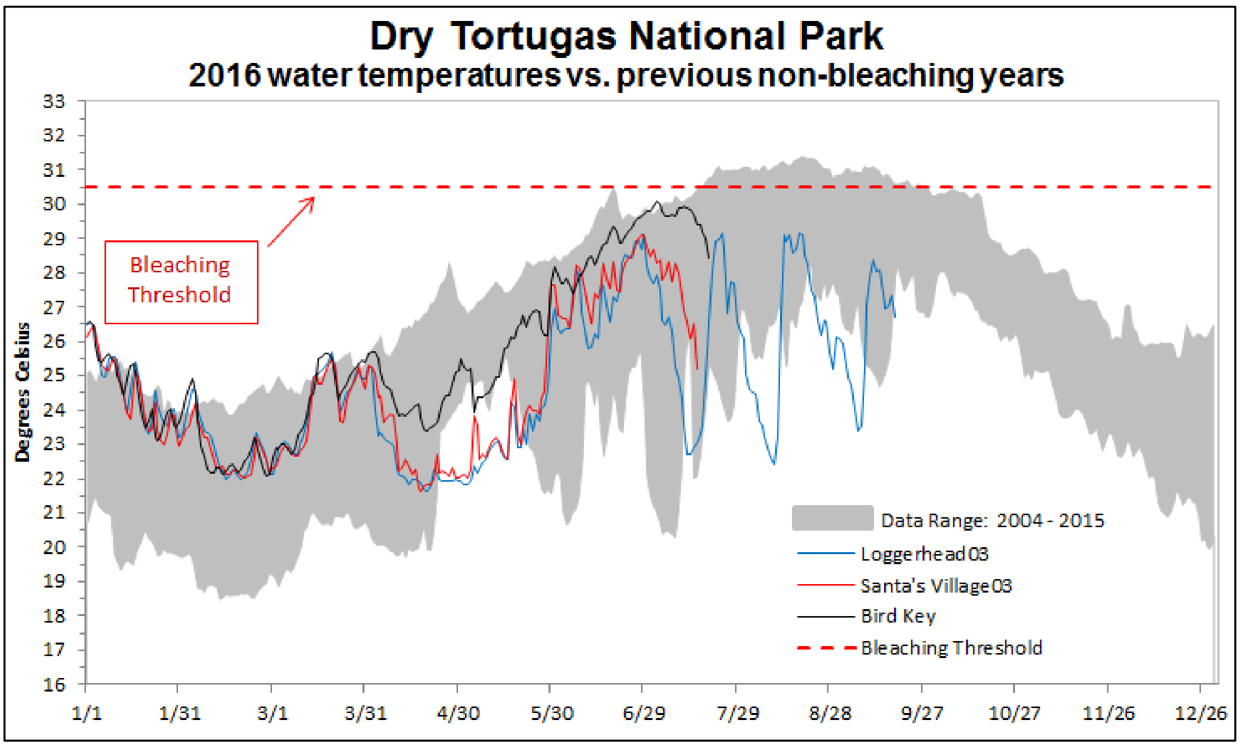


Figure 2.1.1. Annual range of water temperature at SFCN coral monitoring sites since 2004 with 2016 data highlighted. (Figure provided by SFCN).

2.1.3. Visitation Statistics

National Park Service regulations inside DRTO prohibit commercial fishing, but allow recreational fishing, boating, snorkeling, scuba-diving, and other recreational activities. During the last ten years, around 65,000 people visit the park each year (Figure 2.1.2). The majority of visitors arrive by the commercially operated fast ferry and just stay for the day, but roughly 10,000 visitors per year spend the night either on their own boat or camp at Fort Jefferson. Commercial fishermen also take advantage of the safe harbor, and several thousand vessel nights are recorded each year. Because DRTO is a marine park with no official entrance, the exact number of visitors that come by private boat is difficult to determine. Likewise, there is little information on the types of activities pursued by visitors. In the RNA, permitted aquatic activities include boating, swimming, snorkeling, scuba diving, research, and education, but exclude anchoring and recreational fishing. Mooring buoys are provided for snorkeling and scuba diving boat operations during the day.

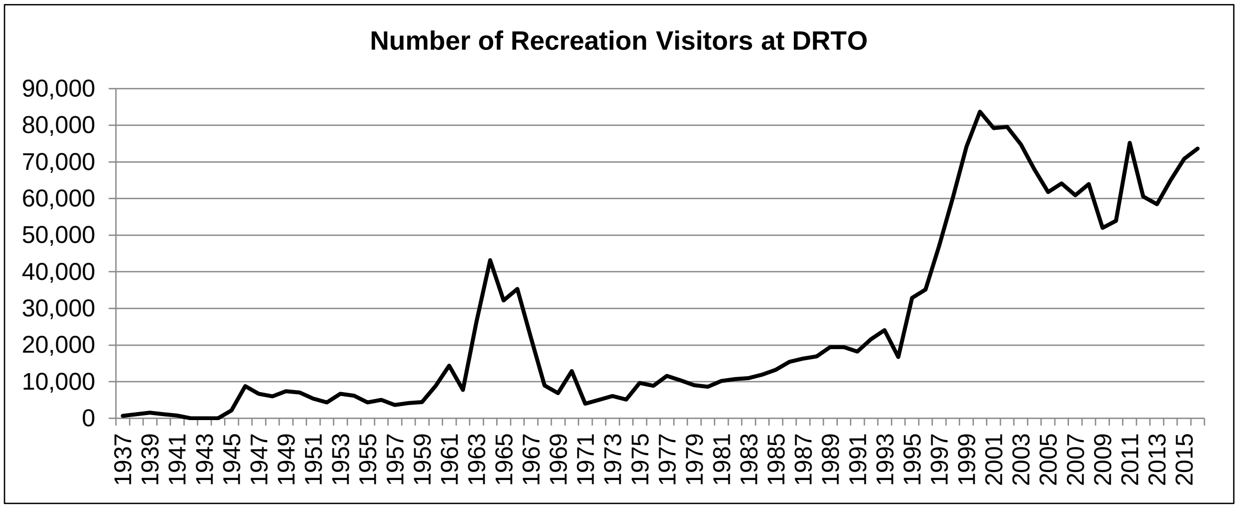


Figure 2.2.1. Number of annual recreational visitors to DRTO from 1937 until 2016. (Data from NPS stats).

The Yankee Freedom III, a fast boat ferry that services DRTO. (Photo by Judd Patterson).

2.2. Natural Resources

2.2.1. Resource Descriptions

The Dry Tortugas National Park lies at the southwestern most region of the Florida reef tract and is intricately connected with the entire south Florida ecosystem. Directly adjacent to the park are two other coral banks with depths less than 40m that together with DRTO comprise the Dry Tortugas region. Riley's Hump and the Western Bank are considerably deeper than DRTO. These coral banks are located directly adjacent to the Loop Current, which has a great influence on the transport of larvae from the Dry Tortugas region to the rest of south Florida (Lee and Williams 1999, Domeier 2004). As such, these banks are important spawning grounds for numerous economically important species, and also provide habitat for a large number of adult fish (Burton et al. 2005, Bryan et al. 2015). Within DRTO, there are large areas of coral reef habitat, extensive shallow water seagrass beds and shallow flats that are important juvenile fish habitat. Combined, the deep water habitat of the banks and the shallower park waters provide a wide range of habitat types that are critical for many species during their lives. Several species of fish make daily and seasonal migrations both into and out of the park to meet a variety of feeding and reproduction strategies. Overall, the Dry Tortugas regions represents roughly 30% of coral reef habitat in the Florida reef tract and includes a disproportionate number of large reproductively active reef fish.

<u>Seagrasses</u>

There are 3,700 ha of continuous and patchy seagrass beds throughout DRTO accounting for 14% of mapped habitat (Waara et al. 2011). This highly productive tropical reef biotope provides essential nursery habitat for a number of key fish species including grunts (Haemulidae), snappers (Lutjanidae), surgeonfishes (Acanthuridae), and parrotfishes (Sparidae) (Heck et al. 1989; Nagelkerken et al. 2000) as well as an important foraging ground for adult snappers, barracuda, sharks, and other predators (Torres et al. 2006, Luo et al. 2009, O'Toole et al. 2011). It also serves as an important habitat for the endangered green sea turtle in between nesting periods (Hart et al. 2013).

View from Loggerhead Key lighthouse. (Photo by Judd Patterson).

<u>Islands</u>

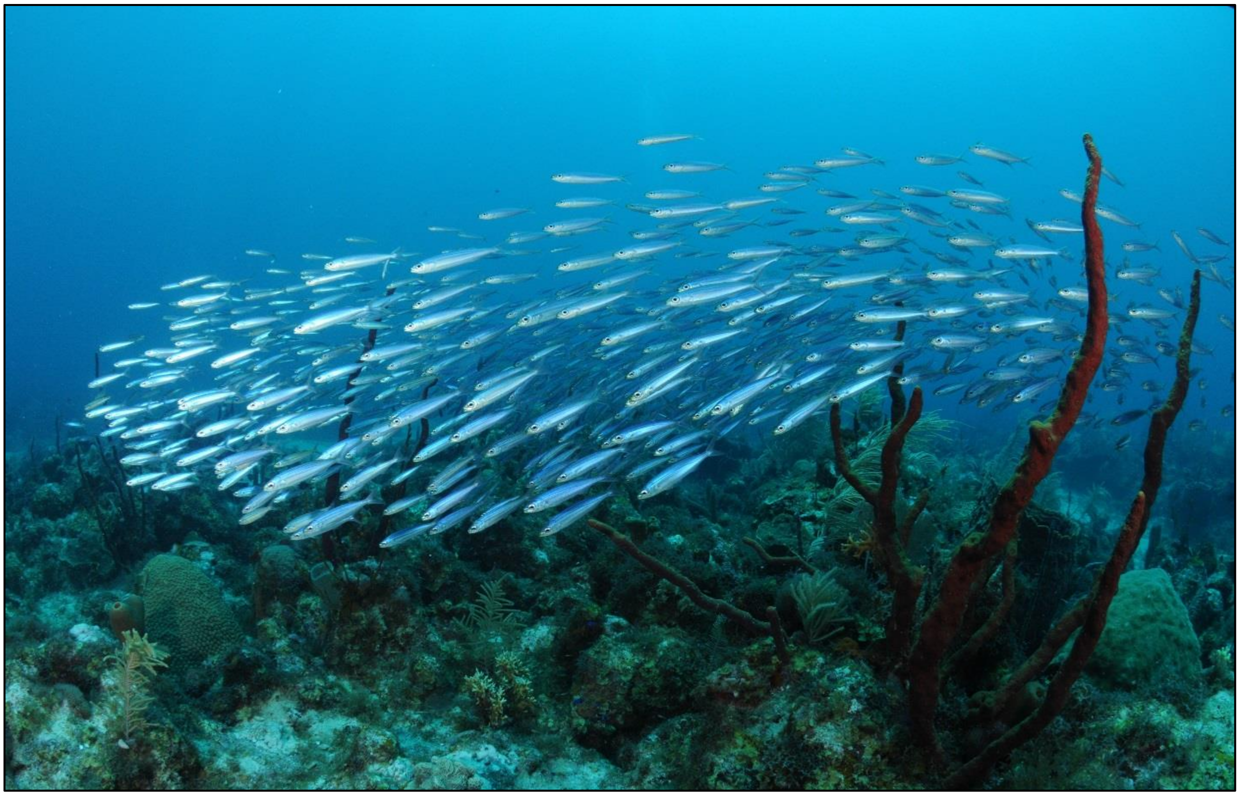
Although there is less than 40 ha of land within DRTO, the seven islands provide substrate for a dynamic and diverse vegetative community, which in return helps support an incredible diversity of nesting and migratory seabirds. DRTO supports the only large breeding colonies in the lower 48 states for sooty terns (*Sterna fuscata*), masked booby (*Sula dactylatra*), magnificent frigatebird (*Fregata magnificens*), brown noddy (*Anous stolidus*) and bridled tern (*Onychoprion anaethetus*).

The beaches in DRTO are a key nesting site for a distinct subpopulation of loggerhead turtles (*Caretta caretta*) and the main nesting site in Monroe County for the endangered green turtles (*Chelonia mydas*) with a nesting density nearly double of that recorded in the rest of Florida. DRTO was a historically important nesting site for both seabirds and sea turtles, but several species suffered tremendously during the colonization of the new world and intense fishing pressure in the early 20th century. Recently sea turtle nesting populations have been increasing in DRTO and are now at historic highs. Meanwhile, seabird nests has been increasing for some species while declining for others.

Seagrass beds just offshore of Fort Jefferson. (Photo by David Bryan).

Coral Reefs

Nearly 50% of the marine habitat in DRTO is comprised of coral reef substrate (Waara et al. 2011). These substrates are covered by a variety of sponges, soft corals, macroalgae, and hard corals including seven species listed as threatened under the federal Endangered Species Act: elkhorn coral (*Acropora palmate*), staghorn coral (*Acropora cervicornis*), pillar coral (*Dendrogyra cylindrus*), rough cactus coral (*Mycetophyllia ferox*), lobed star coral (*Orbicella annularis*), mountainous star coral (*Orbicella faveolata*), and boulder star coral (*Orbicella franksi*)). Although hard coral coverage has declined throughout DRTO, some reefs still harbor the highest percentage of coral coverage in the south Florida reef tract.



School of boga (*Haemulon vittatum*) swim over DRTO reef. (Photo by David Bryan).

Marine invertebrates

Caribbean spiny lobster (*Panulirus argus*), the most valuable commercial fishery within south Florida, have been protected from harvest within DRTO for over 40 years. This protection has allowed the local population to grow larger and faster and to produce more offspring per individual than lobster found elsewhere in the Florida Keys (Bertelsen and Matthews 2001, Maxwell et al. 2009). Given DRTO's geographic location upstream in the Florida current, larvae from this population of lobster likely provides enormous benefits for the rest of the State. Queen conch (*Lobatus gigas)* and the long-spined sea urchin (*Diadema antillarum*) are both functionally important invertebrates found on tropical reefs that can be found in DRTO. Their current population sizes are considerably less than in the past.

Reef fish and Sharks

Over 280 species of fish have been identified within DRTO (NPSpecies), including some of the most economically important species in the State of Florida. Both goliath grouper (*Epinphelus itajara*) and Nassau grouper (*Epinephelus striatus*), which have been listed as critically endangered and endangered, respectively, by the IUCN can be found within DRTO. The remote location of the park and relatively restrictive fishing regulations, including no commercial fishing, no spearfishing and the creation of a large no-take marine reserve, have resulted in a refuge for many exploited species. Along with the rest of the Tortugas region, DRTO supports the most healthy reef fish community in south Florida. Not only is this important for the park, but a number of fish species that thrive in DRTO have reproduction strategies that result in pelagic offspring that are swept downstream to settle in the rest of south Florida. This provides a constant recruitment of young fish into areas of the state that have high removal rates due to unsustainable fishing practices. DRTO includes 17.8% of the mapped coral reef habitat in south Florida, but for several exploited fish species over 30% of the adult population in south Florida live within the within the park boundaries. Without DRTO and the Dry Tortugas region, many reef fish populations in south Florida would likely suffer. Shark research in DRTO has focused on nurse sharks (*Ginglymostoma cirratum*) which travel to the park each year to breed, but several other species are known to frequent the waters. These include the endangered great hammerhead (*Sphyrna mokarran*) (IUCN), lemon sharks (*Negaprion brevirostris*), bull sharks (*Carcharhinus leucas*), Caribbean reef sharks (*Carcharhinus perezii*), blacktip shark (*Carcharhinus limbatus*), and tiger sharks (*Galeocerdo cuvier*).

Blacktip shark (*Carcharhinus limbatus*) cruises over diver in clear blue Dry Tortugas waters. (Photo by David Bryan).

2.2.2. Resource Issues Overview

Due to its relatively remote location and long history of no commercial fishing and limited recreational fishing, DRTO has fewer resource issues than other parks in south Florida including Everglades National Park and Biscayne National Park which are both close to the Miami metropolitan area (Bryan et al. 2018a). However, given the high connectivity between DRTO and the rest of the south Florida reef ecosystem, there are still some resource concerns.

Invasive species are an increasing threat at National Parks across the nation and both preventative and removal programs are taken very seriously by the NPS. Currently invasive plants are under control in DRTO, but they remain a persistent issue. Beyond exotics, a more crucial issue for terrestrial vegetation at DRTO is a concern that current changes in sea level are occurring at a pace that may be too fast for some species to adapt. The beaches at DRTO are dynamic and have historically waxed and waned through time although during the last two centuries there has been a gradual loss of islands from 11 in 1829 to seven in 2018. Rising sea levels and erosion from storm events has left the shorelines in DRTO vulnerable for continued losses. Erosion and the loss of nesting habitat is also of great concern for birds that nest at DRTO.

The effects of climate change are a major concern for the health of the stony corals throughout the park. Rising temperatures have increased the frequency of coral bleaching events leading to coral disease outbreaks and subsequent tissue loss or death of affected corals. DRTO still has some of the highest coral coverage in south Florida, but there have been significant declines in the areas where corals are monitored.

Reef fish that are exploited by commercial and recreational anglers have for the most part been experiencing localized overfishing in south Florida for several decades (Ault et al. 2018). Within DRTO and the Dry Tortugas region, spatial closures for commercial and recreational fisheries have provided protection unlike elsewhere in the region. However, despite this protection, the size structure of most exploited fish within the park still suggests issues with overfishing. Many of these species are long-lived and often travel inside and outside of park waters and among management areas within the park to forage or reproduce. Although fishing pressure in the area is lower than other parts of south Florida, these fish are still susceptible when outside of the restricted fishing areas. The extent of illegal poaching within DRTO is unknown but it may also contribute to overfishing issues.

Loggerhead and green turtles nesting numbers have been increasing at DRTO which hopefully indicates increases in population size. Due to the commercial fishing ban within the park, incidental catch in commercial fisheries and entanglement with marine debris (two major threats that sea turtles face) are not common. Instead the major threat within the park is the loss of nesting sites through erosion and loss of beaches.

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).*

The Dry Tortugas National Park is renowned for its marine resources which are an integral component of the south Florida ecosystem and the park has remained committed to preserving these resources since its inception. The most recent large action by DRTO was the establishment of the Research Natural Area (RNA), a 46 square mile area created to restore ecological integrity and capacity within the park by minimizing the effects of human activities (Figure 2.3.1.). The goal of establishing the DRTO RNA is to protect shallow water marine habitat, ensure species diversity, and enhance the productivity and sustainability of fish populations throughout the region. This is a no-take area that offers divers, snorkelers and researchers an opportunity to explore and study a large marine environment protected from human extraction. The NPS and the Florida Fish and Wildlife Conservation Commission (FWC) have been working together conduct research and to assesses the conservation efficacy of the RNA (Ziegler and Hunt 2012, Ziegler and Hunt 2015). Performance evaluation for the NRCA is based on six areas including the quantification of changes in abundance and size structure of exploited species within the RNA relative to adjacent areas and monitoring of species composition and abundance of the benthic community. Both are key metrics in this NRCA's assessment of the condition and trends of the entire park.

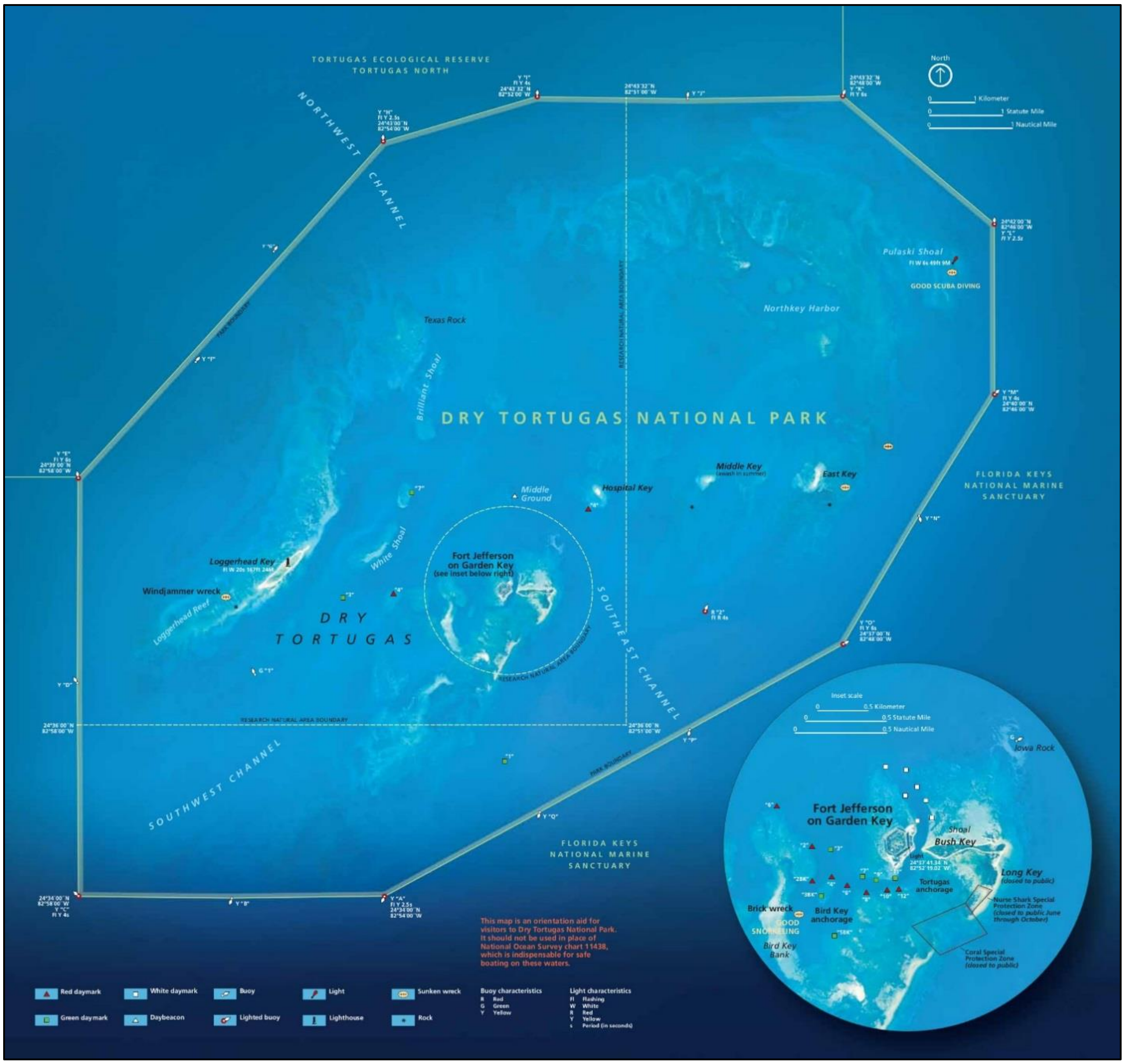


Figure 2.3.1. Dry Tortugas National Park. (Figure from NPS).

SFCN research vessel on calm day in DRTO. (Photo by Rob Waara).

2.3.1. Management Directive and Planning Guidance

The fundamental resources within DRTO, as defined by the 2017 DRTO Foundation Document, include the coral reef community and ecologically connected seagrass beds, the terrestrial islands and associated vegetation that provide habitat for nesting sea turtles and birds, the reef fish and shellfish that are a prominent part of the ecosystem, the military and maritime history resources and the outstanding recreational, research and education opportunities. An assessment of these resources within the document suggests that most have considerable planning needs. A resource stewardship strategy (RSS) was listed as a high priority for the park and was identified as a planning need for most resources. In order to guide these plans additional research and reports are required. The last Assessment of Natural Resources was published in 2012 (Jeffrey et al. 2012) and a 5 year report on the RNA was published in 2015 (Ziegler and Hunt 2015). This NRCA includes all of the natural resources highlighted in the Foundation Document and will help with future planning and management directives.

Inside Fort Jefferson, DRTO. (Photo by Judd Patterson).

2.3.2. Status of Supporting Science

In 2008, the South Florida/Caribbean Network Vital Signs Monitoring Plan identified high priority vital signs for DRTO in conference with more than 100 local natural resource experts (Table 2.3.1, Patterson et al. 2008). Among the vital signs identified, several long term monitoring programs are in place. Marine benthic communities are monitored by SFCN and FWC along with collaborative efforts through the Florida Reef Resilience Program (FRRP) and the National Coral Reef Monitoring Program (NCRMP). Marine fish have been monitored since 1999 through a multiagency collaboration (Brandt et al. 2009). Sea turtles nesting sites have been monitored for several years, but effort since 2014 has been standardized to meet FWC's index site standards. For these and other vital signs, example measures are provided for guidance and when available were used for this assessment.

In their 2012 Assessment of Natural Resource Conditions in and Adjacent to DRTO, Jeffrey et al. (2012) identified six resource categories, their park desired conditions, and recommended metrics for evaluating their status (Table 2.3.2). Coral reefs, seagrasses, reef fish, seaturtles and seabirds are all included in this NRCA. Overall, the amount and quality of data available for these key resources varies tremendously from corals where there are four long term monitoring programs in place to some species of nesting birds, sharks, lobsters and conch where there is no current monitoring. For some resources, mapping efforts and research projects have taken the place for monitoring and allowed for useful insight into the condition of several resources. When available, these data sources are included in this report.

Blue hamlets (*Hypoplectrus gemma*) can be found on reefs throughout DRTO. (Photo by David Bryan).

Table 2.3.1. Natural resource vital signs identified for the South Florida and Caribbean Network, including DRTO (Reprinted from Patterson et al. 2008).

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	–	+	+	+	◊	+	+
	Mangrove-Marsh Ecotone	Community composition and structure	+	+	–	+	+	+	+
	Wetland Ecotones and Community Structure	Wet prairie-forest ecotones change	◊	◊	–	–	◊	–	–

+ Vital signs for which the network will develop protocols and implement monitoring using funding from the vital signs or water quality monitoring programs. Vital signs also shown in bold text.

◊ 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 also shown with gray cell shading.

Table 2.3.1 (continued). Natural resource vital signs identified for the South Florida and Caribbean Network, including DRTO (Reprinted from Patterson et al. 2008).

Vital Signs Category	Vital Sign	Example Measures	Parks where Implemented						
			BICY	BISC	BUIS	DRTO	EVER	SARI	VIIS
Biological Integrity (continued)	**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	+	–	–	–	◊	–	–
	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, egg counts/nest, hatching success	–	◊	◊	◊	◊	–	◊
	American Crocodile	Abundance, nests/region, size	–	◊	–	–	◊	–	–

+ Vital signs for which the network will develop protocols and implement monitoring using funding from the vital signs or water quality monitoring programs. Vital signs also shown in bold text.

◊ 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 also shown with gray cell shading.

Table 2.3.1 (continued). Natural resource vital signs identified for the South Florida and Caribbean Network, including DRTO (Reprinted from Patterson et al. 2008).

Vital Signs Category	Vital Sign	Example Measures	Parks where Implemented						
			BICY	**BISC**	**BUIS**	**DRTO**	**EVER**	**SARI**	**VIIS**
Biological Integrity (continued)	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	◊	◊	◊	◊	◊	◊	◊
	Fire Return Interval	Fire location, size, time since last burn	◊	–	–	–	◊	–	–
	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	+	+	–	–	+	+	+

+ Vital signs for which the network will develop protocols and implement monitoring using funding from the vital signs or water quality monitoring programs. Vital signs also shown in bold text.

◊ 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 also shown with gray cell shading.

Table 2.3.2. Summary of ecological conditions of resource categories from 2012 Assessment of Natural Resource Conditions (Reprinted from Jeffrey et al. 2012).

Category	Water Quality	Coral Reef and Hardbottom		Seagrass and Algae		Reef Fishes	Sea Turtles	Seabirds
		Abiotic	Biotic	Abiotic	Biotic			
Proportion of stressors affecting resources	12%	59%	76%	41%	41%	47%	35%	41%
Proportion of stressors with good or fair information on effects	24%	59%	59%	12%	12%	29%	41%	12%
Park-desired condition	Intact and Pristine Marine Ecosystem (NPS 2005); for water quality	Intact and Pristine Marine Ecosystem (NPS 2005); undefined for coral reefs	Intact and Pristine Marine Ecosystem (NPS 2005); undefined for coral reefs	Intact and Pristine Marine Ecosystem (NPS 2005); undefined for seagrasses	Intact and Pristine Marine Ecosystem (NPS 2005); undefined for seagrass and algal beds	Intact and Pristine Marine Ecosystem (NPS 2005); undefined for reef fishes	Intact and Pristine Marine Ecosystem (NPS 2005); undefined for sea turtles	Intact and Pristine Marine Ecosystem (NPS 2005); undefined for seabirds
Recommended metrics to determine Park-desired condition	Dissolved oxygen, total nitrogen, turbidity	Spatial extant of reef and hardbottom communities	Coral cover; colony density; disease prevalence and incidence	Spatial extents of seagrass and algae habitats	Seagrass shoot density; Species composition; productivity indices	Species composition, abundance and size; presence commercially-important species (e.g., black and red grouper)	Aerial extent of nesting beaches; turtle sighting frequency; turtle nesting activity	Nesting activity; aerial extent of nesting habitat; seasonal and annual bird counts; abundance by life-stage
Overall condition	Good	Caution	Significant Concern	Inadequate Data	Inadequate Data	Caution	Significant Concern	Inadequate Data
Information score	1.00	0.59	0.59	0.20	0.22	0.56	0.58	0.20
Stressor extent score	0.09	0.47	0.56	0.55	0.60	0.51	0.38	0.34

Chapter 3. Study Scoping and Design

3.1. Preliminary Scoping

The authors of this NRCA have worked regularly with DRTO staff for a number of years on research projects and produced numerous reports (Ault et al. 2002, 2003, 2007, 2008; Jeffrey et al. 2012). This strong relationship with the park along with an intimate knowledge of the Dry Tortugas aided in the scoping portion of this report. At the start of this NRCA we contacted the fisheries and marine biologist at DRTO and had several phone conversations and email exchanges discussing the key resources from which to focus the report. We also had two in person meetings with staff at SFCN to discuss key resources and data sources for DRTO. During the first 10 months the first author (D. Bryan) worked with staff at DRTO and SFCN to gather information and data on key natural resources. In March 2016, the second author (J. Ault) participated in a three day Foundation Document workshop at the park and spoke with a number of park staff about the focal resources for the NRCA.

On October 17, 2016, a NRCA update and discussion meeting was held at the University of Miami with attendees from DRTO and Biscayne National Park as well as staff from SFCN (Appendix A). A list of focal resources was shared with a presentation on all known data sources and possible metrics for evaluating status and trends. The preliminary status of resources was discussed.

The goal of this NRCA is to integrate a wide range of scientific literature, reports and data sources into a single document that is easy to access.

3.2. Study Design

3.2.1. Indicator Framework, Focal Study Resources and Indicators

A hierarchal approach for summarizing resource status across DRTO 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 evaluated 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 3.2.1). 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 DRTO.

Table 3.2.1. Ecological attributes, focal resources and indicators used to measure the status and trends of natural resources within DRTO.

Ecological Attributes	Focal Resource	Indicators and Measures
Biological -Plants	Seagrass communities	• Acreage • Species composition • Percent coverage
	Terrestrial Vegetation	• Invasive species • Total acreage
Biological – Marine Invertebrates	Hard Corals	• Percent coverage • Bleaching prevalence • Mortality • Abundance of threatened species • Seawater temperature
	Spiny Lobster, Queen Conch and Long-spined Sea Urchin	• Lobster size and fecundity • Conch density and presence of aggregations • Urchin density
Biological – Marine Vertebrates	Reef Fish and Sharks	• Density • Relative abundance • Average length in exploited phase • Occurrence and density of sharks
	Sea Turtles	• Number of loggerhead and green nests • Percent of nest effected by erosion and inundation • Nesting success rate
Biological – Terrestrial Vertebrates	Birds	• Nesting counts • Christmas Bird Counts

Research divers offshore of Loggerhead Key during reef fish visual census. (Photo by David Bryan).

3.2.2. Reporting Areas

In 2007, the NPS and FWS established the DRTO RNA prohibiting fishing in roughly one third of the parks waters. Since its inception several research projects have been developed to evaluate the performance of the RNA. Several of these studies are included in this NRCA however, we considered the resources to be park wide and have determined their status at the park level.

3.2.3. General Approach and Methods

Multiple indicators were often used to evaluate the status and trends of each focal resource. Data from either NPS or partner agencies resources monitoring or independent scientific studies was used to compare indicators against baseline reference conditions when available. When reference conditions were not available, discussions with local experts were 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 in Table 3.2.2. 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).

Table 3.2.2. Indicator symbols used to indicate condition, trend, and confidence in the assessment.

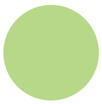
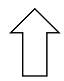
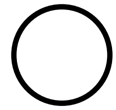
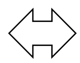
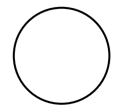
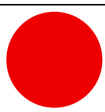
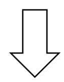
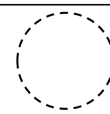
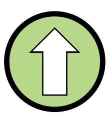
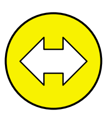
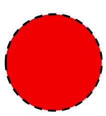
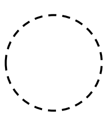
Condition Status		Trend in Condition		Confidence in Assessment	
Condition Icon	**Condition Icon Definition**	**Trend Icon**	**Trend Icon Definition**	**Confidence Icon**	**Confidence Icon Definition**
	Resource is in Good Condition		Condition is Improving		High
	Resource warrants Moderate Concern		Condition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

Table 3.2.3. 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.

The aggregation of indicators for each metric within a focal resource was conducted using 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 3.2.4. Scale for aggregating condition scores for multiple metrics for a focal reference.

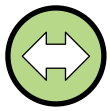
Score 0 to 33	Score 34 to 66	Score 67 to 100
Red	Yellow	Green

A cryptic spotted scorpionfish (*Scorpaena pumeri*) hiding on a DRTO reef. (Photo by David Bryan).

Chapter 4. Natural Resource Conditions

4.1. Seagrass

Table 4.1.1. Overall condition and trend of seagrass in DRTO.

Attribute	Condition & Trend	Interpretation
Seagrass		A baseline of acreage has recently been established and there appears to be no major change since 2010. Monitoring effort is in place suggest that there has been no major trend in species composition, density or elemental composition since 2011.

4.1.1. Importance

Continuous and patchy seagrass beds make up 14% or roughly 3,700 ha of the mapped habitat throughout DRTO (Waara et al. 2011; Figure 4.1.1). They are highly productive and a key biological component of a healthy marine ecosystem that provide essential habitat for a wide range of marine species. Seagrass communities play a major role in nutrient cycling, provide stabilization of marine sediments and are an important nursery ground for a large number of reef fish species (Nagelkerken et al. 2000). Seagrasses also serve as a major foraging area for grazing fish species which transfer energy up the food chain to the carnivorous reef fish that feed upon them (Jackson et al. 2001, Kirsch et al. 2002). In DRTO, seagrass beds are also an extremely important habitat for green sea turtles during their nesting period (Hart et al. 2013). These beds are comprised primarily of turtlegrass (*Thalassia testudinum*) but manateegrass (*Syringodium filiforme*) can be locally abundant.

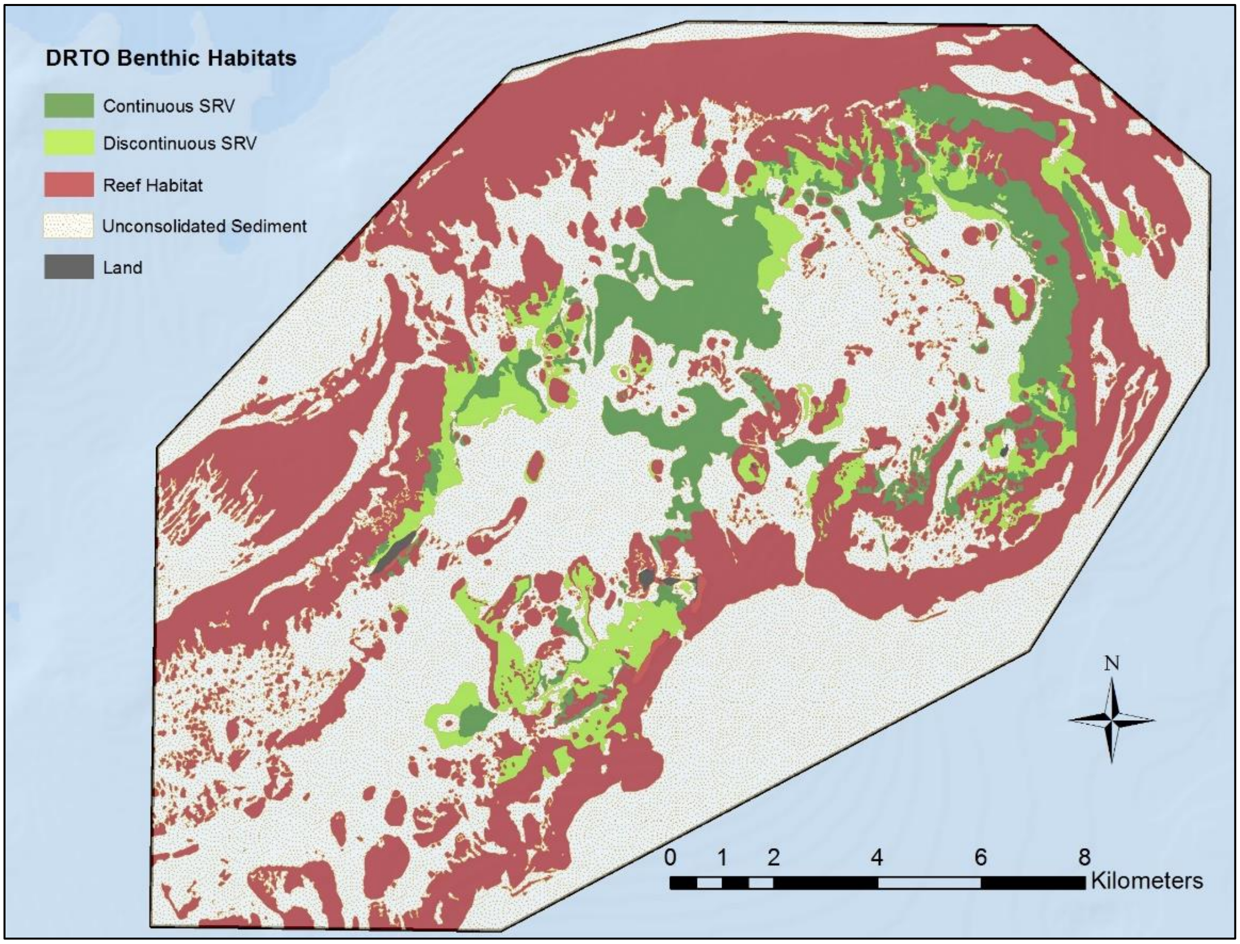


Figure 4.1.1. Continuous and patchy seagrass beds throughout Dry Tortugas National Park. (Data from SFCN).

4.1.2. Mapping and Monitoring

The health of DRTO seagrass beds can be measured in two ways: 1) changes in the extent or total coverage can be estimated through mapping, 2) density and species composition changes can be characterized with field monitoring measurements.

<u>Mapping</u>

In 2011, SFCN published a benthic habitat map for DRTO, where a total of 2,268 ha of continuous and 1,455 ha of patchy seagrass habitat was identified. This extent varied slightly from mapping efforts in 2008 as compared to 1998 but is mostly due to differences in map resolution and does not reflect a change in acreage (Waara et al. 2011). The Florida Seagrass Integrated Mapping and Monitoring program report (Carlson et al. 2015) provides information of the inventory mapping and monitoring programs and identifies emergent metrics of seagrass distribution, abundance and health. In the 2015 report, the authors suggest that overall seagrass cover in the Florida Keys including Dry Tortugas is probably stable, but significant changes in seagrass species composition continues in many locations in response to alterations in water quality (Table 4.1.2.).

Table 4.1.2. General status of seagrasses in the Florida Keys (including Dry Tortugas) in 2015 (Reprinted from Carlson et al., 2015).

Status and stressors	Status	Trend	Assessment, causes
Seagrass cover	Green	Stable	–
Water clarity	Yellow	Locally poor	Phytoplankton blooms
Natural events	Green	Sporadic	Tropical cyclones
Propeller scarring	Yellow	Localized	Near high-use areas

Monitoring

Researchers at Florida International University (FIU) established 17 permanent seagrass monitoring stations in 2011 to evaluate the long term ecological status and trends of seagrass community types in Dry Tortugas National Park. Stations were divided between shallow waters between 3 and 10 m depth and sites with depths greater than 10 m. Each July, seagrass, macroalgae, sponge and coral cover and abundance are assessed at 10 random locations along a 50 m transect at each stations. Seagrass is the dominant vegetation at each site and turtlegrass is the dominate species (Wilson and Fourgurean 2017). From 2011 until 2017, seagrass communities and their elemental composition have shown a slight downward trend, but the overall their condition is considered stable (Figure 4.1.2). Results indicated the seagrass beds of DRTO are very similar to the seagrass beds within the larger Florida Keys National Marine Sanctuary (FKNMS) (Fourqurean 2013). Continued changes in seagrass composition in the greater south Florida region (Carlson et al. 2015) warrant sustained monitoring in DRTO.

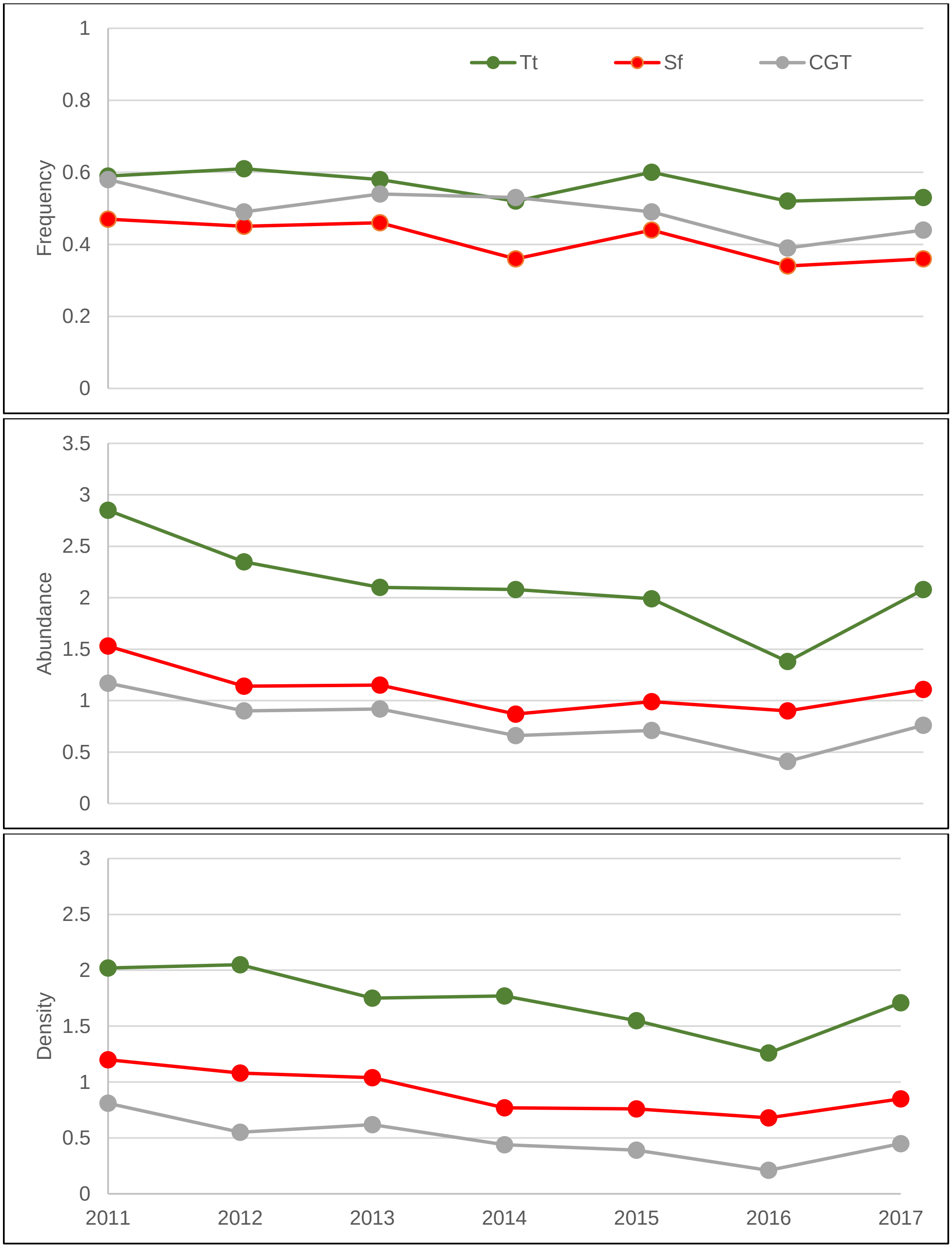
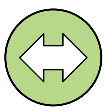
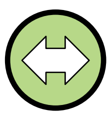
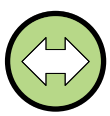


Figure 4.1.2. Mean frequency (number of quadrats present / total quadrats), abundance (sum of Braun-Blanquet scores divided by number of quadrats present), and density (sum of Braun-Blanquet scores divided by total quadrats) of *Thalassia testudinum* (green), *Syringodium filiforme* (red) and calcareous green macroalgae (CGT; gray) across all of our monitoring stations from 2011-2017. (Reprinted from Wilson and Fourqurean 2017).

4.1.3. Conclusion

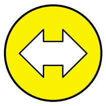
The vast seagrass beds throughout DRTO are an integral component of a healthy coral reef ecosystem. Baseline extent of the seagrass beds have been established in the SFCN's benthic habitat map and subsequent mapping efforts will allow for the detection of significant trends in coverage. The species composition, density, and elemental composition of seagrasses is monitored by FIU and results suggest that there has been no major change from 2011 until 2017. Meanwhile within the FKNMS, increased nutrient availability in the past 20 years has been altering the relative abundance and dominance of seagrasses and macroalgae. While these changes in the composition of submerged aquatic vegetation may not affect total acreage, it can affect the suitability of these areas for the organisms that depend on it. Where nutrients have been elevated for some time, long-term increases in phytoplankton populations have been observed, which increase light attenuation in the water column and thus harm seagrass beds (McGlathery 2001). It is important to continue to monitor the health of DRTO seagrasses as they provide several essential ecological functions.

Table 4.1.3. Condition and trends of seagrass in DRTO.

Criteria	**Condition & Trend**	**Rationale**	**Reference Condition**
Acreage		Seagrass acreage in DRTO appears to be stable.	2010 acreage estimated from benthic habitat report (Waara et al. 2011)
Species composition		Species composition has been stable from 2011-2017	Average from first three years of FIU sampling (2011-2013)
Percent coverage		Percent coverage of seagrass has been stable from 2011-2017	Average from first three years of FIU sampling (2011-2013)

4.2. Terrestrial Vegetation

Table 4.2.1. Overall condition and trend of terrestrial vegetation in DRTO.

Attribute	Condition & Trend	Interpretation
Terrestrial vegetation		The removal of exotic plants has been successful on Loggerhead Key but there is significant concern that rising sea level and shoreline erosion will reduce total acreage available to the native vegetative community. A comparison to the 2009 baseline map has not been made.

Helmet conch *(Cassis tuberosa)* grazing along the edge of seagrass bed in DRTO. (Photo by David Bryan).

4.2.1. Importance

The Dry Tortugas is a marine park, with very little terrestrial vegetation scattered amongst the seven islands. Nonetheless, this sparse vegetation is critical habitat for nesting seabirds and provides refuge and food for a large number of migratory bird species. The flora of Dry Tortugas, with the exception of Garden Key, represents a glimpse of coastal plant community succession largely isolated from human influence. The islands of the Dry Tortugas have historically been in a constant flux with changing sea levels and strong tropical storms rearranging shorelines and creating or destroying islands. A number of historical studies, that have produced maps of the vegetation at DRTO, show a highly adaptable plant community that is capable of surviving the sometimes harsh maritime conditions (Millspaugh 1907, Bowman 1918, Davis 1942, Schroeder 1971, Stoddart and Fosberg 1981). The most recent effort to map the plant community of DRTO was completed by the SFCN in 2009, and provides the most detailed map to date (Luciani et al. 2011). This work depicts a diverse range of vegetation, from the common dune communities found on each island, to the rare woodland community of mangroves on Long Key.

Because of the long and continual influence of humans, determining the native flora (e.g., native plant species that arrived at the site by natural means) with certainty is not possible. The Institute for Regional Conservation reports 216 plant species for the flora of DRTO, 91 of which are considered native to the site (Gann et al. 2001-2017). The remaining species reported for the site are either established non-native species, ruderal species and plant species that are or were cultivated at the site but do not become established.

4.2.2. Monitoring

There has been limited published monitoring of vegetation at DRTO. The most recent effort has been the creation of the vegetation map by the SFCN (Luciani et al. 2011). This map was derived from in-field polygon delineation that produced greater detail than commonly used photo interpretation of aerial imagery. A total of 41 mapping classes were identified within the 39.4 ha of land in the park. These mapping classes can be further grouped into 6 physiognomic classes (Table 4.2.2). Almost 50% of the land in DRTO is classified as either sparse to non-vegetative sandy areas. The dune associative communities are the main physiognomic classes pertaining to native communities which have significant cover on four of the seven islands. The vegetation communities as they are represented on these islands differ in distribution and commonality. Some classes are only found on one island, whereas, many can be found on more than one with differences in abundance and composition. This map provides a strong baseline from which to document and quantify changes in the vegetative community.

Table 4.2.2. Percentage of area covered by each physiognomic class (broken down by each individual island) and total area (ha) for each island and all the islands combined. (Reprinted from Luciani et al. 2011).

Class/Island	Bush	East	Garden	Hospital	Loggerhead	Long	Middle	All
Woodland	0%	0%	3.3%	0%	0%	11.5%	0%	1.1%
Shrubland	6.6%	0%	0.1%	0%	19.6%	1.5%	0%	11%
Scrub	0.2%	0%	0%	0%	0.2%	0.6%	0%	0.1%
Dune	54.6%	0.4%	12.9%	0%	38.4%	19.2%	0%	31.7%
Sparse	38%	99.6%	7.2%	100%	34.4%	67.2%	100%	34.8%
Non-Vegetative	0.6%	0%	76.5%	0%	7.4%	0%	0%	21.3%
Total Area (ha)	**6.4 ha**	**2.3 ha**	**9 ha**	**0.4 ha**	**19.8 ha**	**1.1 ha**	**0.4 ha**	**39.4 ha**

Ten transect lines were established on Loggerhead Key in 1994 to monitor the removal of Australian pines (*Casuarina equisetifolia*). These transects were revisited annual until 2001 (Pernas et al. 2001).

Sampling of a subset of these transects resumed in 2004, and overlapped with the vegetative mapping efforts by SFCN in 2009. Transects were most recently monitored in 2014, and are scheduled to be re-monitored in 2018. A comparison showed that the transect data does a good job at characterizing the vegetative community and also provides more detail about the relative abundance of individual species. As Loggerhead Key shifts over time, transects are extended into the newly formed portions of the island allowing characterization of plant colonization and plant community succession. So, just as future vegetation maps of the Dry Tortugas are necessary to document changes in vegetation communities, regular monitoring of established vegetation transects on Loggerhead Key is crucial to monitor plant community status and changes, individual species abundance, floristic diversity. In addition, transect monitoring provides a means of detecting exotic species infestations throughout the seldom visited interior of Loggerhead Key.

4.2.3. Coastal Erosion

The islands of the Dry Tortugas are highly dynamic with the passage of hurricanes and tropical storms dramatically shifting the location and size of the islands (Figure 4.2.1.). In 2018, there were seven islands in the DRTO compared with 11 in 1829 (Luciani et al. 2011). In addition to storms, rising sea levels, and a decline in the protective coral reefs has led to a significant concern for the long term stability of several remaining islands. In 2005, Pendleton et al. conducted a coastal vulnerability assessment of DRTO. They found that the majority of DRTO's shoreline had between moderate to high vulnerability, with East Key and Middle Key having the highest rates of shoreline erosion (Figure 4.2.2). The loss of island habitat is not only a concern for terrestrial vegetation, but it also has a significant impact on nesting sea turtles and breeding bird colonies.

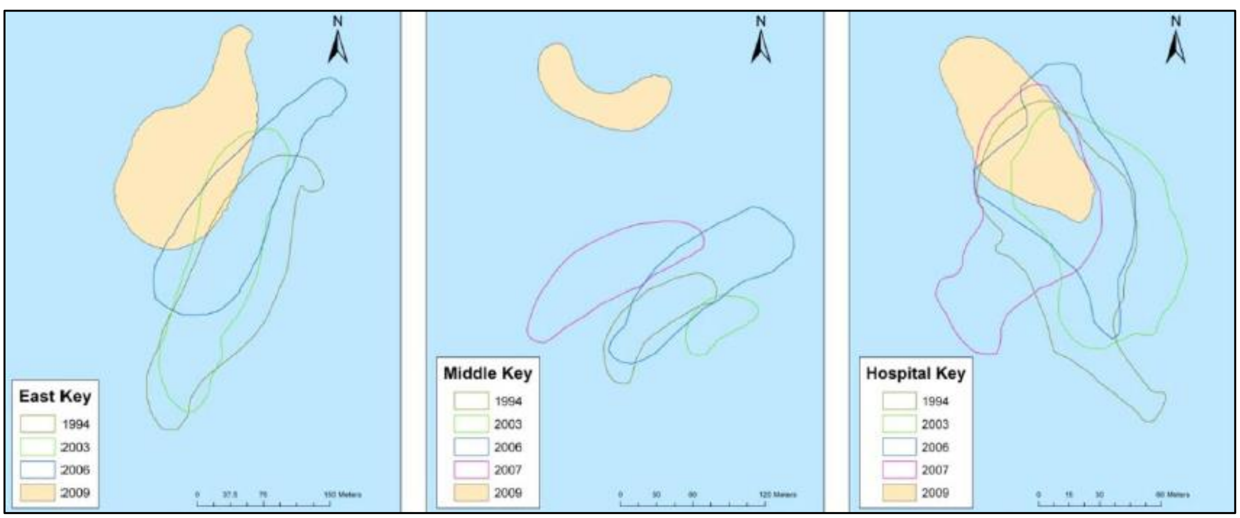


Figure 4.2.1. Historic shoreline changes for East Key, Middle Key, and Hospital Key. (Reprinted from Luciani et al. 2011).

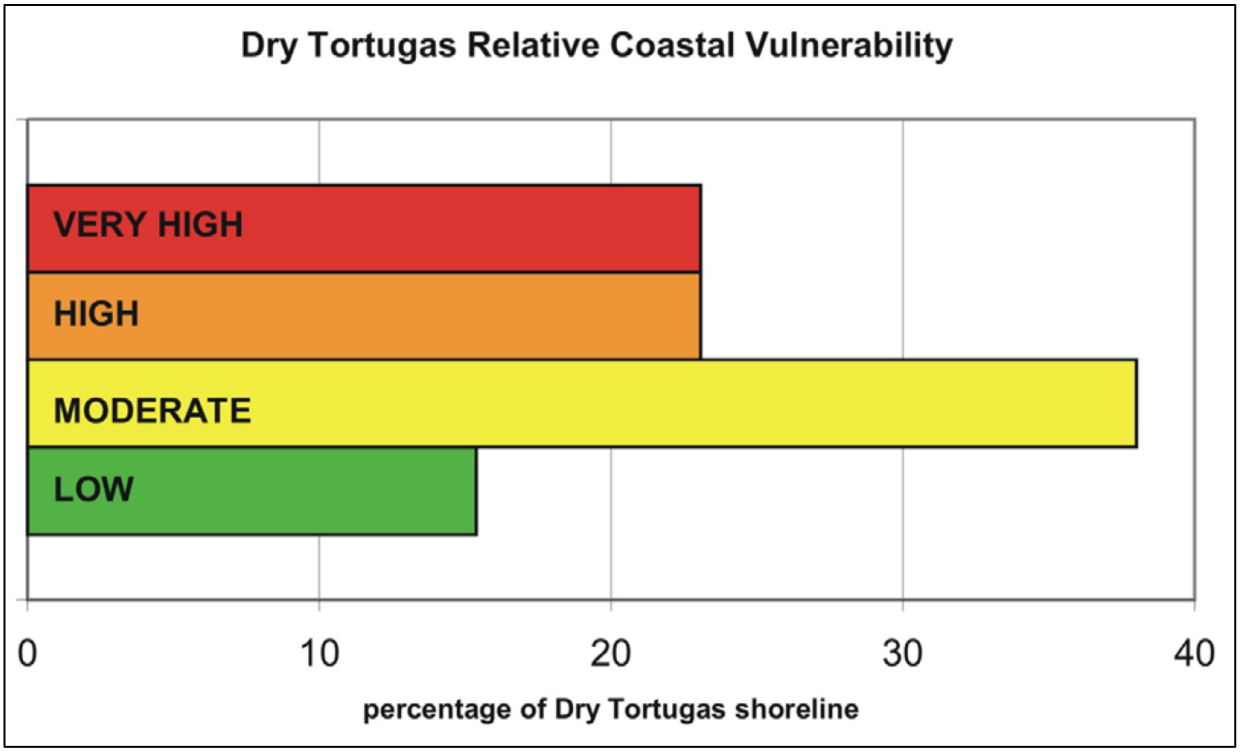


Figure 4.2.2. Percentage of DRTO shoreline in each coastal vulnerabilty index category. (Reprinted from Pendleton et al. 2005).

4.2.4. Exotic plants

Exotic vegetation is a major stressor that impacts the composition of native floral species at DRTO. Loggerhead Key and Garden Key have been subject to years of human impact, thus introduction of exotic vegetation has occurred more often. Although Garden Key has seen the highest number of introduced exotic species, the flora of Loggerhead Key was more heavily affected by the introduction of the Australian pine (*Casuarina equisetifolia)* and *Agave* spp. *Casuarina* was introduced around 1910 by the director of the Carnegie Institution (Stoddart and Fosberg 1981). The Australian pine spread throughout the entire island, creating a forest with an understory of *Agave* spp. The Australian pines and their associated root structure often disrupted sea turtles as they attempted to create nests on the island. Restoration efforts to remove the invasive community began in the 1990s, and by 2001 almost all of the Australian pines were removed (Pernas et al. 2001). False crawls of sea turtles have declined since their removal, yet remnant root balls still occasionally impact nesting sea turtles (Nimmo 2015).

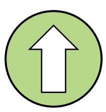
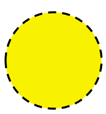
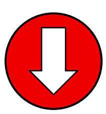
Crowfoot grass (*Dactyloctenium aegyptium*) has invaded nesting areas for brown noddy and sooty tern on Bush and Long Key. It is believed to have arrived from Garden Key. It is unclear what effect it has, if any, on nesting substrate or nest success. Vegetation management staff have made efforts over the past several years to control this species. Ongoing monitoring of natural areas for invasive species continues. This enables staff to efficiently detect and control invasive species like beach naupaka (*Scaevola taccada*), Australian pine and coconut (*Cocos nucifera*) before infestations become large and difficult to treat.

The flora of Dry Tortugas includes one species listed as critically imperiled in south Florida by the Institute for Regional Conservation. Big sandbur (*Cenchrus myosuroides*) is found in two small areas on Loggerhead Key. Park staff monitor the status of this species and provide guidance to management to avoid impacting occupied areas when carrying out park projects and activities.

4.2.5. Conclusions

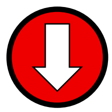
The vegetative community at DRTO is dynamic by design; species are able to cope with tropical storms and constantly shifting land masses along with limited dispersal connectivity. However, current conditions of change such as rising sea levels may be happening at a rate too fast for plants to keep up. The shorelines of several islands have high to very high vulnerability to coastal erosion which will have a major impact on the vegetative community and other wildlife that depends on the habitat. The 2009 vegetation map provides a reference point for which to compare future estimated of acreage and changes in the overall community. However, additional monitoring is needed to keep track of species specific changes on the islands. On a positive note, large swaths of exotic species have been removed from Loggerhead Key restoring the island to its native state. The benefits of this removal have been seen through a decrease of false crawls by sea turtles.

Table 4.2.3. Condition and tends of terrestrial vegetation in DRTO.

Criteria	**Condition & Trend**	**Rationale**	**Reference Condition**
Presence of exotic plants		The large removal of Australian pines from Loggerhead Key and the continued monitoring and removal of exotics throughout the park has dramatically reduced the number of exotic plants.	Minimal occurrence of exotics.
Total acreage of vegetation		No trend can be established but since 2009 there is moderate concern of loss of suitable habitat due to rising sea levels.	Baseline established from the 2009 Vegetative Report (Luciani et al. 2011).
Coastal Erosion		11 islands originally charted in DRTO have been reduced to seven. The remaining islands all have moderate to very high shoreline vulnerability.	Coastal Vulnerability Index (Pendleton et al. 2005)

4.3. Corals

Table 4.3.1. Overall condition and trend of stony corals in DRTO.

Attribute	Condition & Trend	Interpretation
Stony corals		Measurements from several monitoring projects indicate that there has been a decline of coral cover within DRTO. Coral cover at reefs within the park is still greater than other regions in south Florida but below a desired condition based on historical data. Coral diseases and bleaching events continue to negatively affect the coral community are of major concern.

4.3.1. Importance

Dry Tortugas National Park includes a diverse and productive coral reef ecosystem that occupies the southern and western most portion of the Florida Reef tract. The Dry Tortugas have been historically described as containing some of the most diverse marine fauna and complex pristine reef habitat in the Florida Keys. Approximately 45.9% of the marine habitat in the park is coral reef substrate (i.e., aggregate patch reefs, individual patch reefs, aggregate reef, spur and groove, pavement and reef rubble) (Waara et al. 2011; Figure 4.3.1). Certain areas in the Dry Tortugas are known to have relatively high percentage of coral cover in comparison to the region and research suggests that growth rates (calcification and linear extension) of corals in the Dry Tortugas are greater than other areas in the Florida Keys (Murdoch and Aronson 1999, Kuffner et al. 2013). However, coral reefs are extremely dynamic and over the last 100 years significant changes have occurred in DRTO (Davis, 1982). Extensive staghorn (*Acropora cervicornis*) reefs, which were historically prominent within DRTO, have been reduced drastically over the last half century (Davis 1982). Staghorn coral and the related elkhorn coral (*Acropora palmata*), which at the turn of the 19th century occupied a 44 ha swath on the Long Key reef crest and has since declined, are both listed as threatened under the Endangered Species Act (Davis 1982). Similar to coral reefs throughout the greater Caribbean (Gardner et al. 2003, Jackson et al. 2014), general coral coverage within DRTO has also declined (Ruzicka et al. 2010). The coral reefs of DRTO provide critical habitat for a tremendous diversity of reef fishes and invertebrates and the physical structure of the reefs themselves act as a barrier protecting the islands from storms and high wave energy.

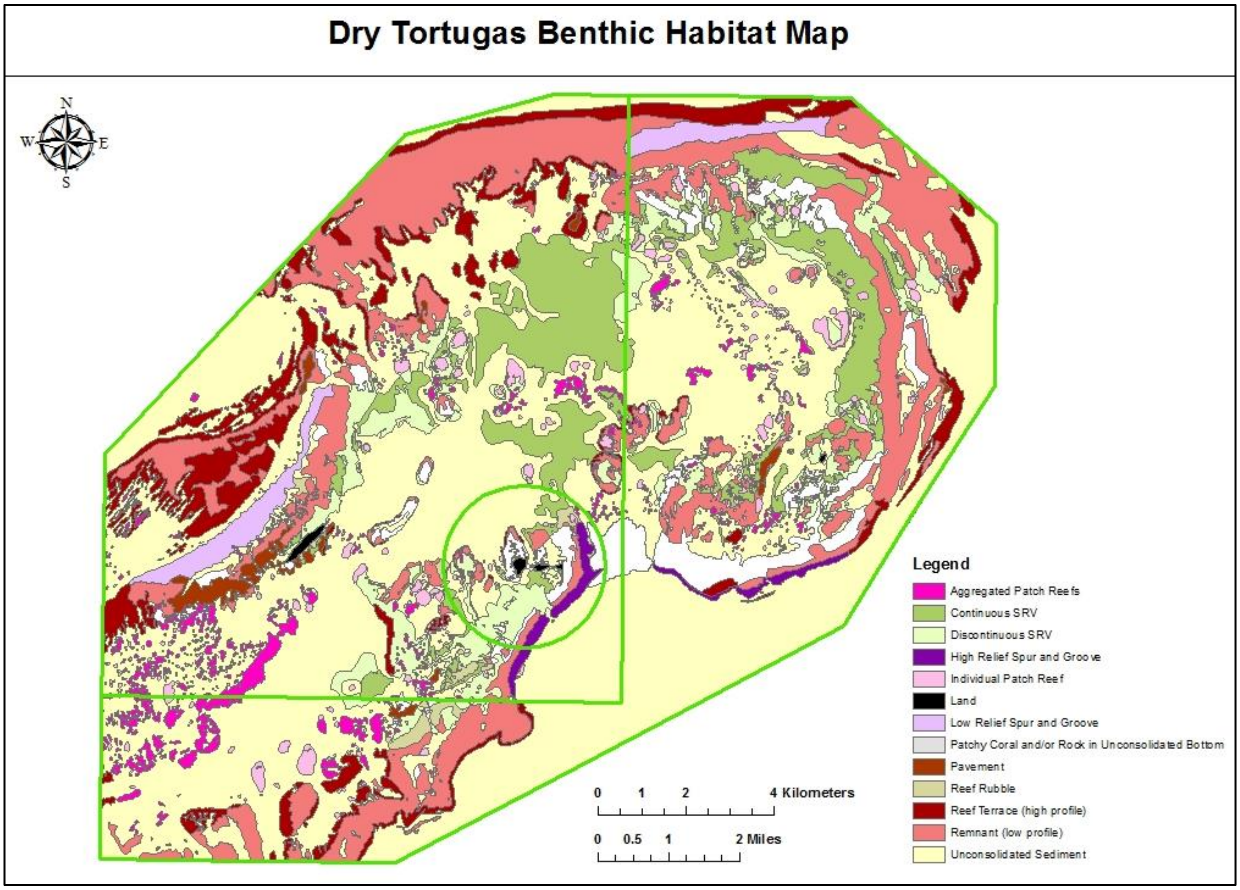


Figure 4.3.1. Benthic habitat map of the Dry Tortugas National Park. (Reprinted from Waara et al. 2011).

4.3.2. Stressors

Caribbean wide, rising ocean temperatures have increased the frequency of bleaching events and coral disease outbreaks leading to a rise in mortality (Bruno et al. 2007, Miller et al. 2009, Heron et al. 2016). Currently rising temperatures in combination with localized anthropogenic stressors are the greatest factors impacting coral reefs throughout the world (Hoegh-Guldberg et al. 2007, Baker et al. 2008, Jackson et al. 2014). South Florida stony corals have not been spared these stressors (Toth et al. 2014; Kuffner et al. 2015, Manzillo 2015). Local reefs have not recovered from a major die-off associated with the 1997/1998 El Nino (Ruzicka 2013), and unprecedented disease-related coral mortality has continued through 2015 (Precht et al. 2016). In the Dry Tortugas, less visitation and fishing regulations has reduced damage from anchors, derelict traps and fishing gear throughout the park. Anthropogenic impacts have been further reduced in the RNA, where anchoring is prohibited, and in several shallow water areas that are closed to boating to protect staghorn and elkhorn corals. Despite these protections, coral bleaching, disease, and mortality are still common.

4.3.3. Monitoring

There are several long term coral monitoring programs in DRTO with substantial overlap. The NPS South Florida/Caribbean Inventory and Monitoring Network (SFCN) and the Florida Fish and Wildlife Research Institute's (FWRI) Coral Reef Evaluation and Monitoring Program (CREMP) monitor several fixed sites throughout the park with similar methodologies. The Florida Reef Resilience Program (FFRP) and the NOAA National Coral Reef Monitoring Program (NCRMP) use similar methods to conduct a stratified random survey of corals and benthic coverage throughout the park. In addition to fixed station and random site selection monitoring programs, there are several projects focused on threatened species. FWRI has been monitoring the condition of elkhorn and pillar (*Dendrogyra cylindricus*) corals since 2013, and research scientists at the United States Geological Survey (USGS) and University of South Florida (USF) have conducted staghorn coral surveys in the park.

Fixed Station Sites

SFCN long-term monitoring sites

The SFCN has been annually monitoring the benthic community at a Bird Key site since 2004, and at two other sites within DRTO (Loggerhead Forest and Santa's Village) since 2012. At each site randomly selected permanent 10-meter transects are filmed with a digital camera. In the lab, the videos are divided into sequential still image "frames" and 10 points (per image) are randomly placed upon each image and identified to major category (Miller et al. 2017). These categories include coral by species, algae (macroalgae, turf, or crustose coralline), gorgonians (sea fans, etc.), sponges, and substrate. Other field data collected *in situ* have been gradually added to the protocol including coral disease (type, number of lesions, area of disease mortality, coral bleaching, site rugosity, and long-spined sea urchin (*Diadema antillarum*) density.

Stony coral coverage has declined slightly at all three sites but is still significantly higher than permanent sites within Biscayne National Park (BISC) where average coral coverage is around 6% (M. Feeley, SFCN, pers. comm. 2017). In 2016, the Loggerhead Forest site had an average stony coral coverage of 21.7% (Figure 4.3.2), which is extremely high for south Florida. However, there has been a 15% reduction in coral cover since the site was established in 2012. The cause of this decline can mostly be attributed to an increase in disease. In 2016, the prevalence of diseases was 9% and a white plague outbreak caused considerable mortality. Preliminary analyses indicated lesions were observed on five different species of coral, however the majority of lesions (93%) involved *Orbicella faveolata* and *O. franksi*; two species listed on the ESA's threatened list. At Santa's Village monitoring site coral coverage is near 15% and experienced a 7% prevalence of diseases in 2016. Bird Key, which has been monitored for longer, showed an initial decline in coral coverage from 2004-2010, but since has been relatively stable at 10%. Macro and turf algae have been dominant since 2004 at the Bird Key site (Figure 4.3.3) and continue to be the dominant benthic coverage at other sites.

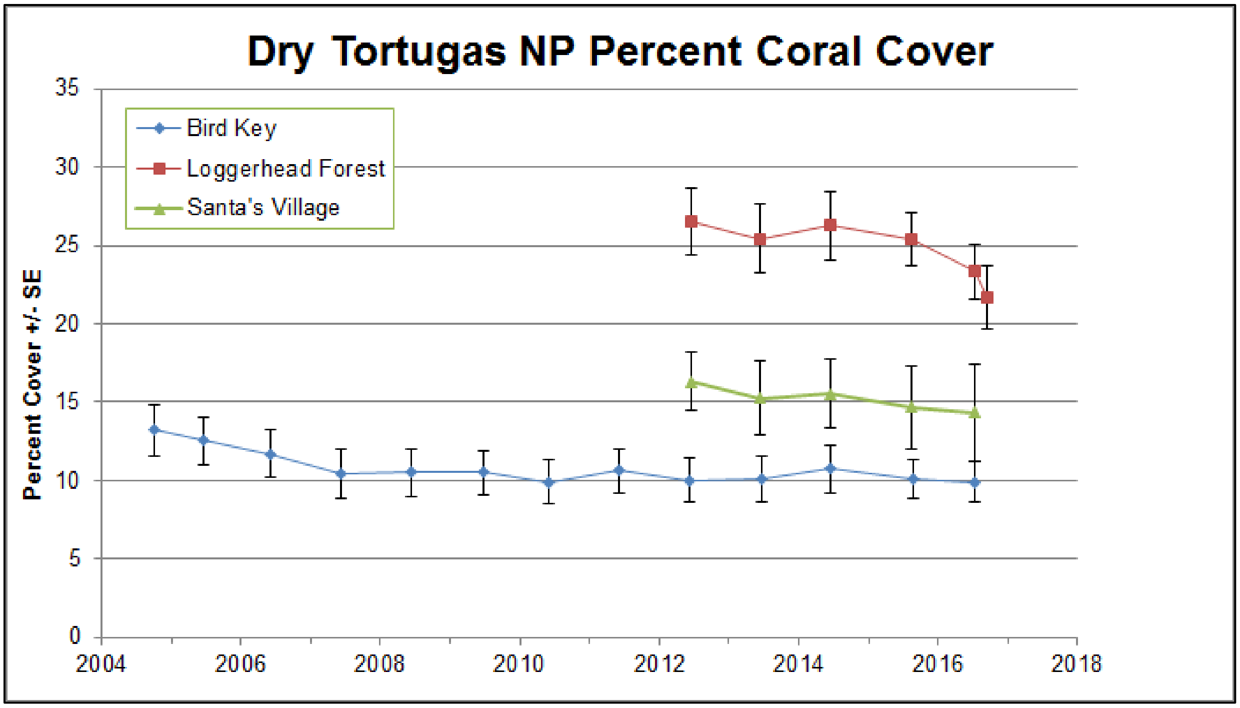


Figure 4.3.2. Times series of percent coral cover at SFCN's three permanent monitoring sites. (Figure provided by SFCN).

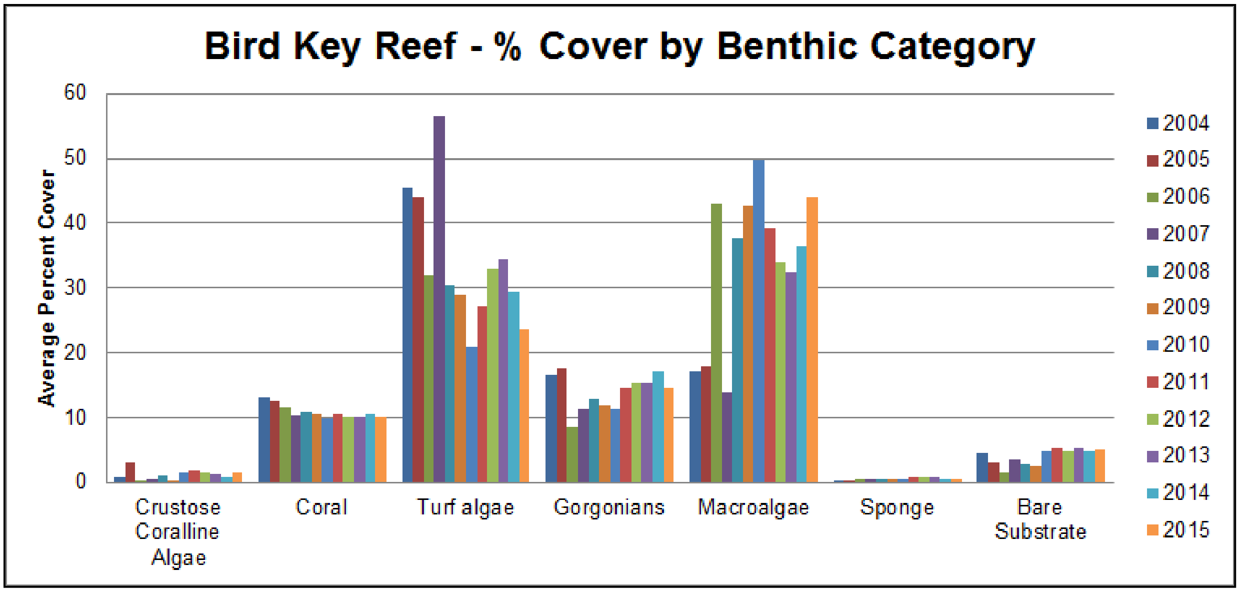


Figure 4.3.3. Percent coverage by benthic type at the Bird Key site monitored since 2004. (Figure provided by SFCN).

Corals can bleach under both extreme warm water events along with cumulative temperature stress (days above 30.5 °C) (Manzello et al. 2007). Research based on sea surface temperatures suggest that more than 40 days above 30.5 °C indicates a significant risk of bleaching (Manzello et al. 2007).

Temperature data collected from each of the SFCN sites in DRTO indicate that the 40 day 30.5 °C threshold has been exceeded twice (2014 and 2015) since monitoring began in 2008. (Figure 4.3.4).

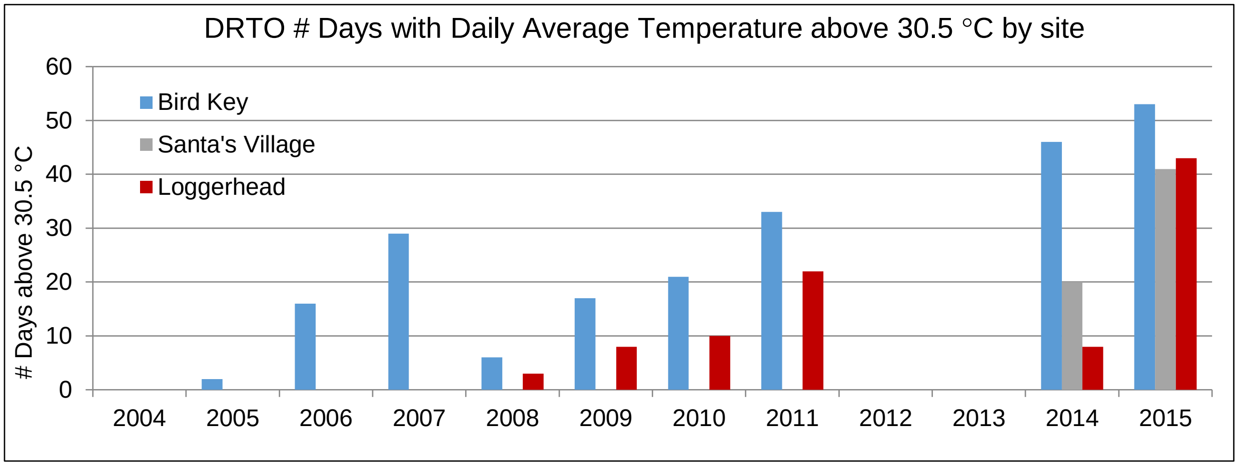
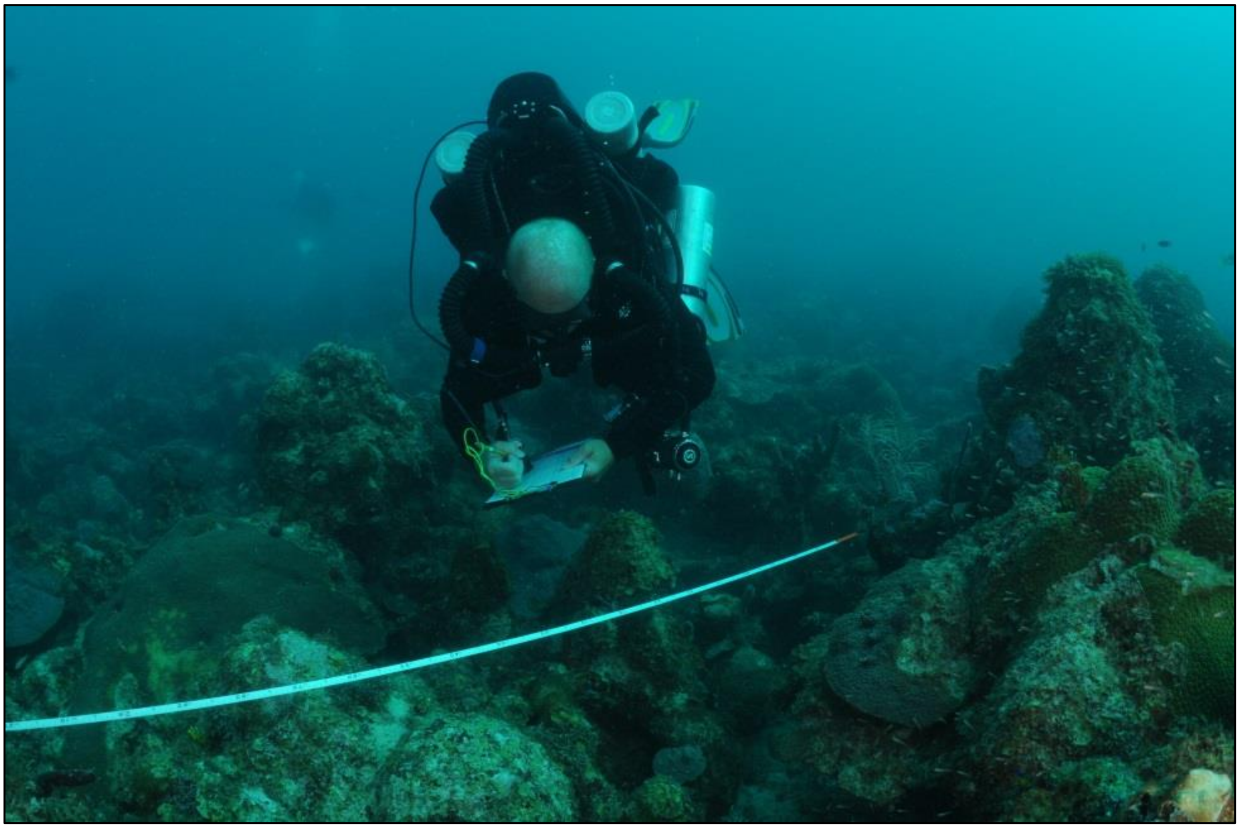


Figure 4.3.4. Number of days above the coral bleaching threshold (30.5 °C) recorded at Bird Key, Santa's Village and Loggerhead Forest reefs. (Figure provided by SFCN).



Rob Waara (SFCN) monitoring corals in DRTO. (Photo by David Bryan).

CREMP long term monitoring

In 1999, FWRI began monitoring three sites within DRTO. This monitoring effort was expanded in 2004 (5 additional sites) and again in 2007 when three new sites were added inside the Research Natural Area (RNA). These sites include six high-relief pinnacle reefs that support diverse assemblages of stony corals and octocorals, four shallow, monotypic stands of threatened acroporid corals (two *Acropora cervicornis* sites, one *A. prolifera* site, and one *A. palmata* site), and a sloping bank reef adjacent to Garden Key (Bird Key). At each site, permanently marked stations (22x2 m) were haphazardly selected at the commencement of monitoring. In 2011 the survey was modified to collect demographic data (density and size class information) and data on the prevalence of bleaching, disease, recruitment and other conditions that may affect coral condition.

At the three sites that have been monitored since 1999 (Bird Key, White Shoal and Black Rock), there has been a general trend in declining coral coverage and increasing macroalgae (Figure 4.3.5; Ruzicka et al. 2014). At the Bird Key site, which has the longest time history, coral coverage has declined from ~ 20% during the first three years of monitoring (1999-2001) to about 10% in 2012 (Figure 4.3.6). At both the long term and newer sites, the most concerning finding in the CREMP survey has been the increase of macroalgae noted since 2009 (Ruzicka et al. 2014). In 2009/10 macroalgae cover was 30.3% marking the first time macroalgae cover has exceed 15% in DRTO CREMP surveys and remained high (27.9%) in 2011/12 (Ruzicka et al. 2014). At CREMP monitoring sites in the Florida Keys annual macroalgal cover in the Florida Keys has averaged ~12% and has only exceeded 20% once since 1996 (Ruzicka et al. 2013). This increase in macroalgal coverage in DRTO has been primarily driven by *Dictyota* spp. Despite the overall macroalgal increase, coverage has been significantly lower at the shallower sites. At the shallower Palmata Patch site, *A. palmata* has increased from 1.8% following the hurricanes of 2004/05 to 7.7% in 2011 (Ruzicka et al. 2014).

Species richness of corals has been stable at 11 sites, including 7 that have been surveyed since 2004. In addition, the prevalence (percent of colonies affected) of coral disease has been between 2.4 and 5.5 % since 2007 with no apparent trend (Ruzicka et al. 2014). At two study sites octocorals have been increasing. The inclusion of demographic data beginning in 2011 will provide for an increased understanding of the coral reef benthic community moving forward. As of the writing of the NRCA, only 3 years of density and size data were available for hard and soft corals (octocorals) so it was premature to look at trends.

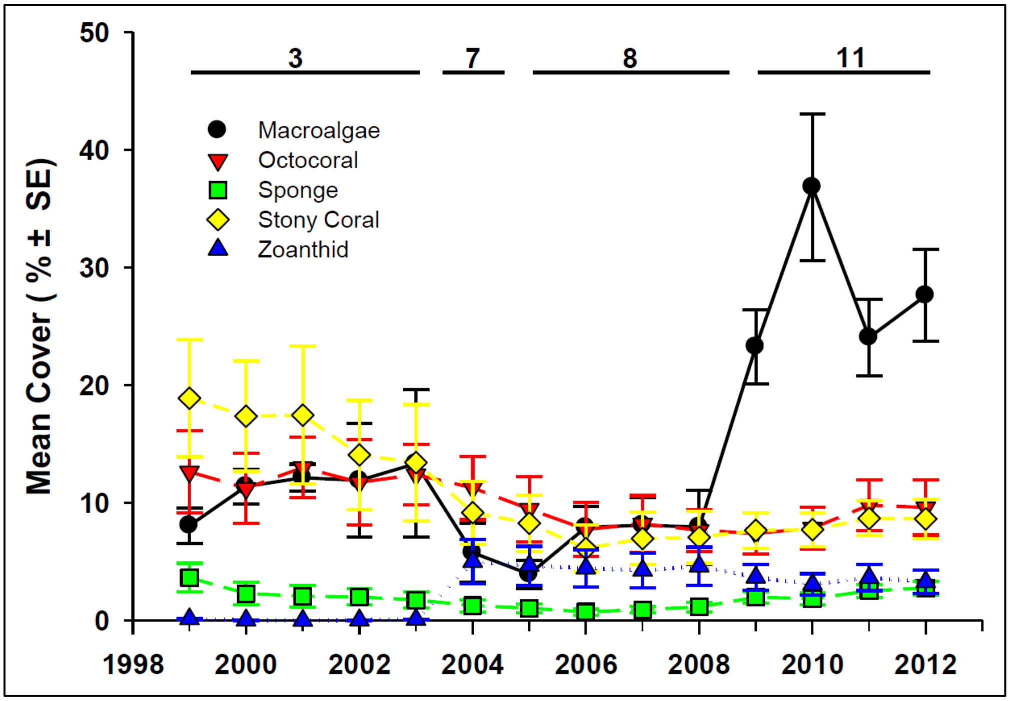


Figure 4.3.5. Annual percent cover of the five major benthic taxa recorded in CREMP image analysis pooled for all sites. Numbers above the graph indicate the number of sites sampled each year. (Reprinted from Ruzika et al. 2014).

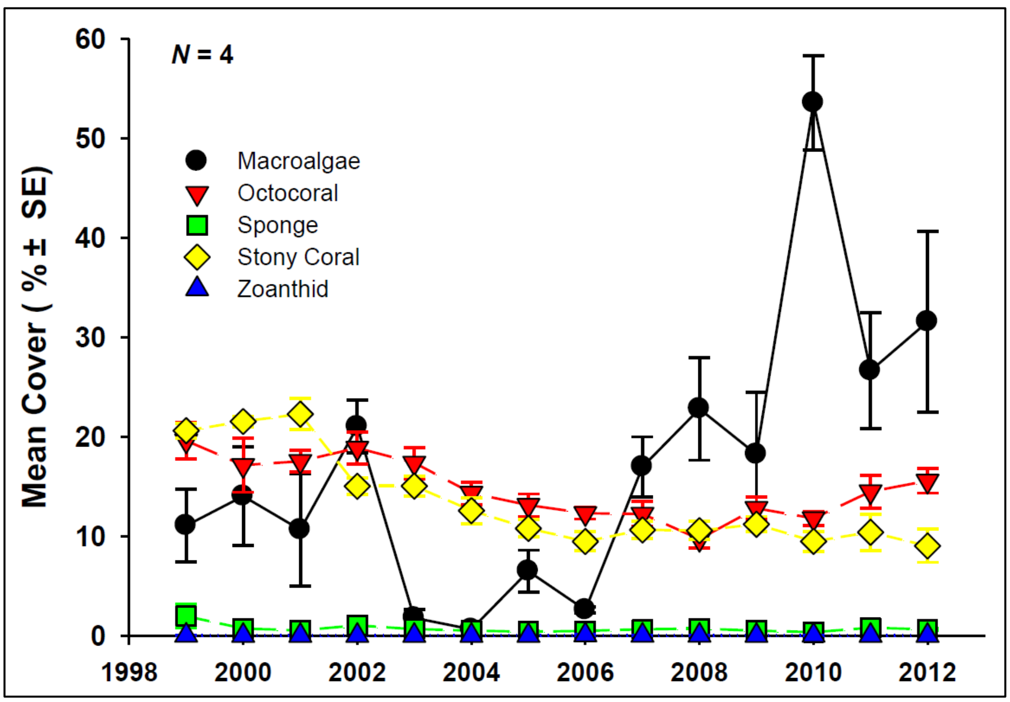


Figure 4.3.6. Mean annual percent cover at Bird Key Reef for the five major benthic taxa recorded in CREMP image analysis. A mixed model regression indicates a decreasing trend for stony corals ($p \leq 0.001$), an increasing trend for macroalgae ($p = 0.004$), and no trend for octocorals, sponges and zoanthids ($p > 0.05$), from 1999 to 2012. N = number of stations. (Reprinted from Ruzicka et al. 2014).

A red grouper keeps an eye on divers monitoring corals in DRTO. (Photo by David Bryan).

Random Sites

NCRMP

The NCRMP began collecting coral demographic data at randomly selected sites every 2 years in DRTO in 2014. This program is similar to the one used by the Submerged Coral Reef Ecological Monitoring (SCREAM) team which collected data in DRTO from 1999-2002 and from 2005-2006. A comprehensive time series of data from SCREAM and NCRMP is being developed but was not available at the time of this NRCA. In the future these data points will provide park wide context for the fixed station monitoring programs (SFCN and CREMP).

FRRP

The FRRP Disturbance Response Monitoring (DRM) program was developed for monitoring coral reefs from the Florida Keys to Martin County. The DRM 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. Since 2007, an average of 25 sites was randomly select within DRTO. At each site two $10m^2$ transects are conducted. All corals within the site are identified and measured, and signs of bleaching, disease and mortality are recorded. Annual estimates of the percentage of live coral in the DRTO region has ranged widely with no trend from 2.5 % in 2011, when only 5 sites surveyed to 18.8% in 2015. During years when more than 20 sites were surveyed percent coverage of live corals averages 12.1% which is similar to live coral coverage recorded in the lower Florida Keys (Figure 4.3.7).

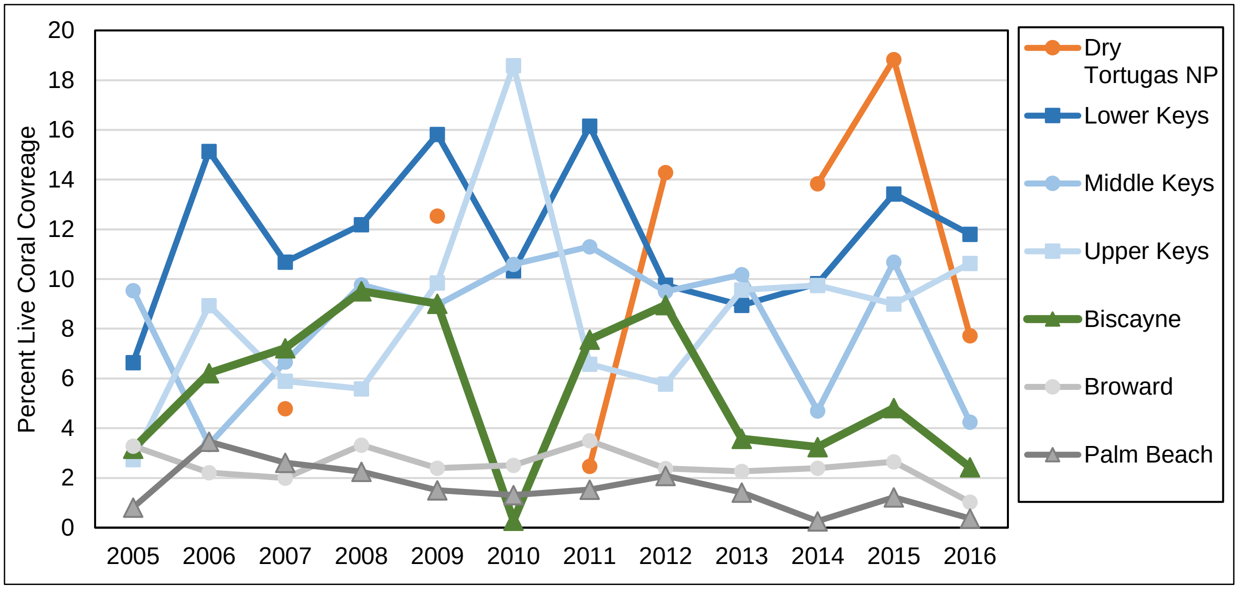


Figure 4.3.7. Percent coverage of all live scleractinian (hard) corals from 2005-2016 during Florida Reef Resilience Program surveys. DRTO is highlighted in orange. (Data provided by FRRP).

In the FRRP, bleaching prevalence is measured as the number of colonies with signs of either partial or total bleaching. A mild bleaching event is defined as prevalence of < 20%, moderate 21-50% and severe >50%. Estimates from the forereef areas of DRTO were compared to estimates for the forereef in other regions in south Florida and lagoon estimates from DRTO were compared to the mid channel reefs in the Florida Keys. In 2011, 2014, and 2015, bleaching prevalence was severe within the lagoon zone of DRTO and was greater than levels recorded in similar habitats throughout the Florida Keys (Figure 4.3.8). Bleaching prevalence on the forereef was moderate in 2011 and 2014, severe in 2015, which was similar to other forereef areas throughout the Florida Keys (Figure 4.3.8). Following the major bleaching events in 2014 and 2015, there was a white plague disease outbreak noted in 2016 with 1.5% of corals showing disease, more than 3 times greater than the average of 0.4% from 2007-2015 (Figure 4.3.9).

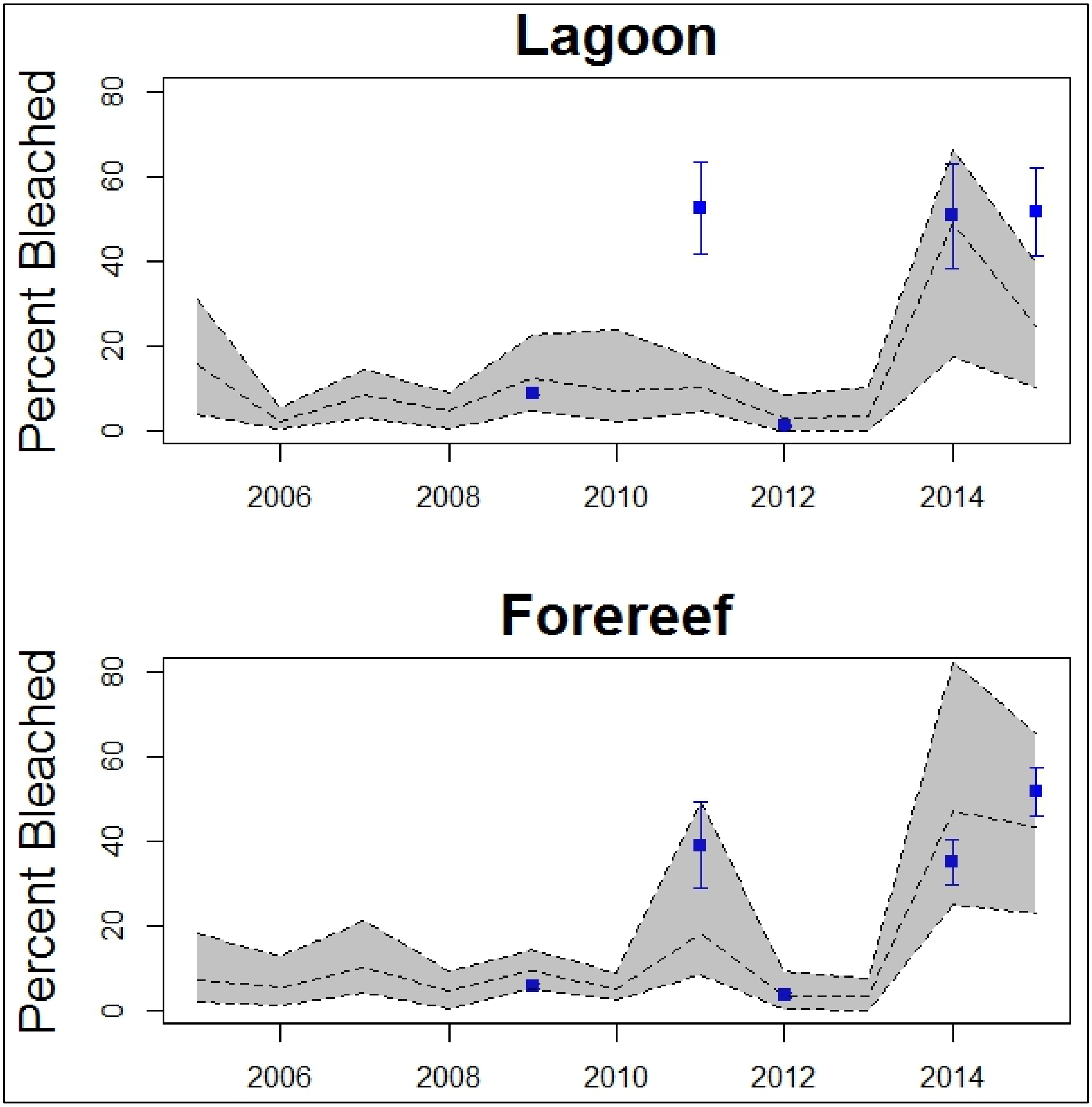


Figure 4.3.8. Percent of corals bleached in the two different reef zones surveyed by the Florida Reef Resilience Program in DRTO (blue squares). Gray shading indicates minimum and maximum values and centered dashed line represents the mean for other regions with similar zones throughout south Florida. (Data provided by FRRP).

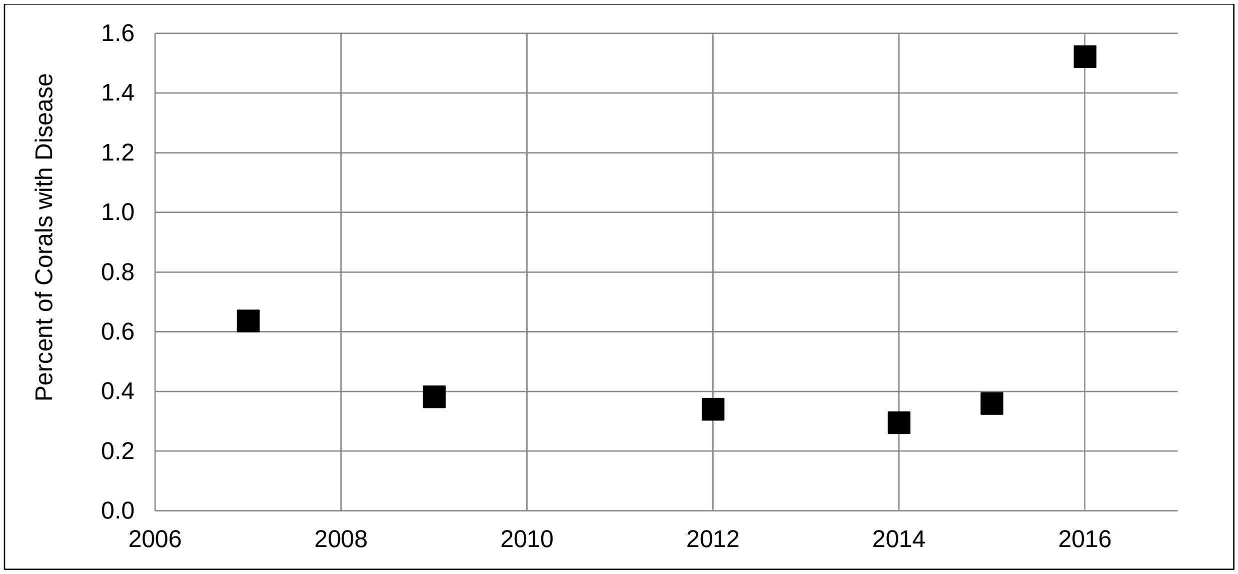


Figure 4.3.9. Percent of corals with disease from 2007-2016. Over 50% of the diseased corals in 2016 had white plague disease (Data provided by FRRP).

Boulder star coral (*Orbicella franksi*) on DRTO reef. (Photo by Rob Waara).

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 are 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. Recently mortality was below 1% from 2007 to 2012, but in 2014 it increased to 1.3 % and reached 3.3% in 2015 (Figure 4.3.10). Partial old mortality has fluctuated between 3.4 and 13.6% with no trend since 2007 (Figure 4.3.11).

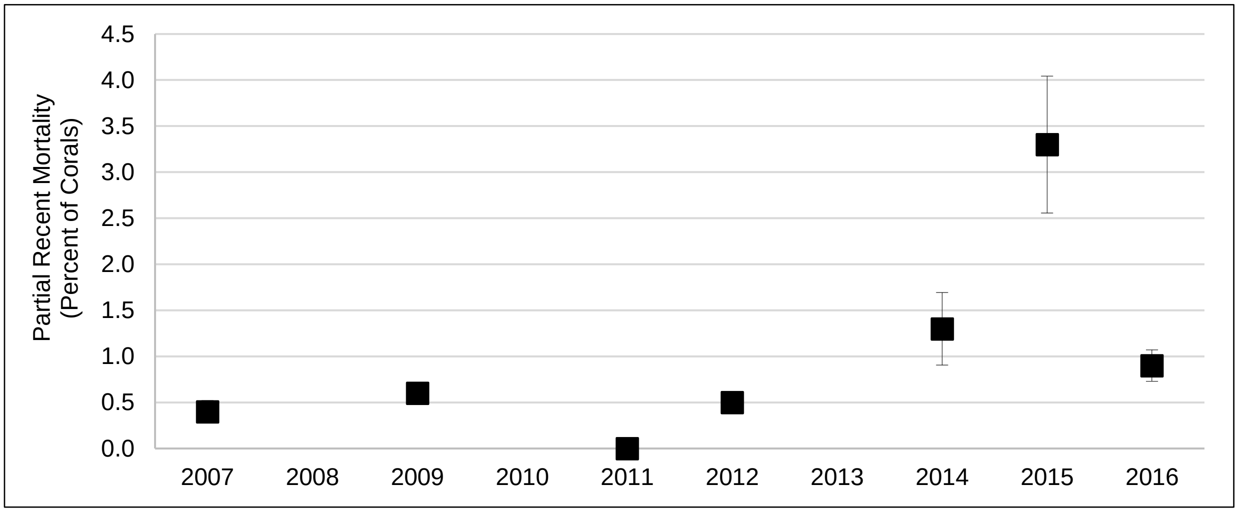


Figure 4.3.10. Percentage of coral area showing partial recent mortality from 2007-2016. (Data provided by FRRP).

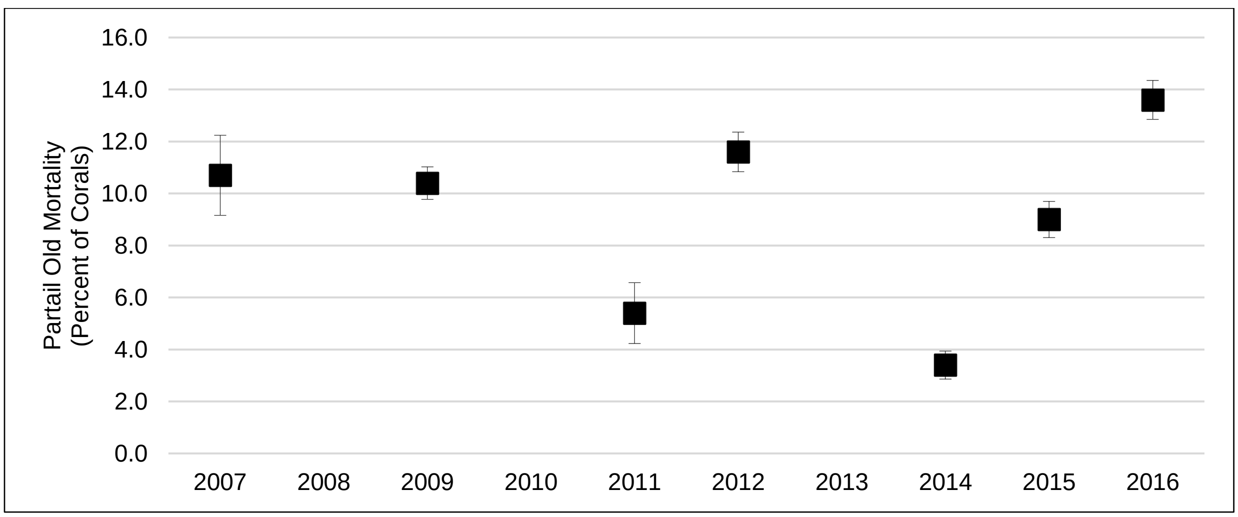


Figure 4.3.11. Percentage of coral area showing partial old mortality from 2007-2016. (Data provided by FRRP).

<u>ESA species monitoring (elkhorn coral and pillar coral)</u>

The Florida Fish and Wildlife Research Institute (FWRI) in partnership with DRTO staff, has been regularly monitoring populations of two ESA-listed coral species within the park: pillar coral and elkhorn coral. DRTO is home to a population of ten pillar corals colonies at a site called Magic Castles. These individual corals were initially monitored annually as part of the CREMP program, but since September 2013 they have been monitored three times a year. From 2010 until 2012, during annual CREMP monitoring, there was a combined 8% decrease in tissue area for all 9 colonies, but 2 colonies saw increases (Ruzika et al. 2014). Since 2013 the loss of pillar coral tissue within the park has been too small for the current methods to numerically detect. This is despite significant tissue loss at other sites along the Florida Reef Tract in 2013-2015. Small losses that have occurred are primarily due to white plague disease. A single colony has been chronically infected with white plague during all but one sampling period. These losses have been small relative to the total amount of pillar coral tissue at the site, but the colonies should continue to be monitored; white plague can become extremely virulent and kill a large colony in a few months. There is only one genotype of pillar coral present within Dry Tortugas National Park (FWRI). Due to the remoteness of the park and the short time pillar coral gametes have to fertilize after spawning, FWRI has concluded that pillar coral is functionally extinct within the park as it will not be able to create new offspring. FWRI has advised that DRTO considers participation in a genetic rescue to preserve the genotype for these colonies and to join a restoration program that has begun throughout the Florida Reef Tract for this species.

The only elkhorn colonies within DRTO are found within the Coral Special Protection Zone. These colonies have been part of a five-year monitoring project beginning in 2011 to determine condition, growth, and stressors affecting this species within the park. From 2011-2014, the amount of Elkhorn tissue at the site increased and the incidence white pox disease was low (<20%) except for an outbreak in September 2012. In 2014-2015, there was a 9% overall tissue mortality rate, with nearly 2/3 of colonies losing tissue. These losses were primarily from white pox disease within incidence greater than 20% in 5 of 8 surveys (FWRI).

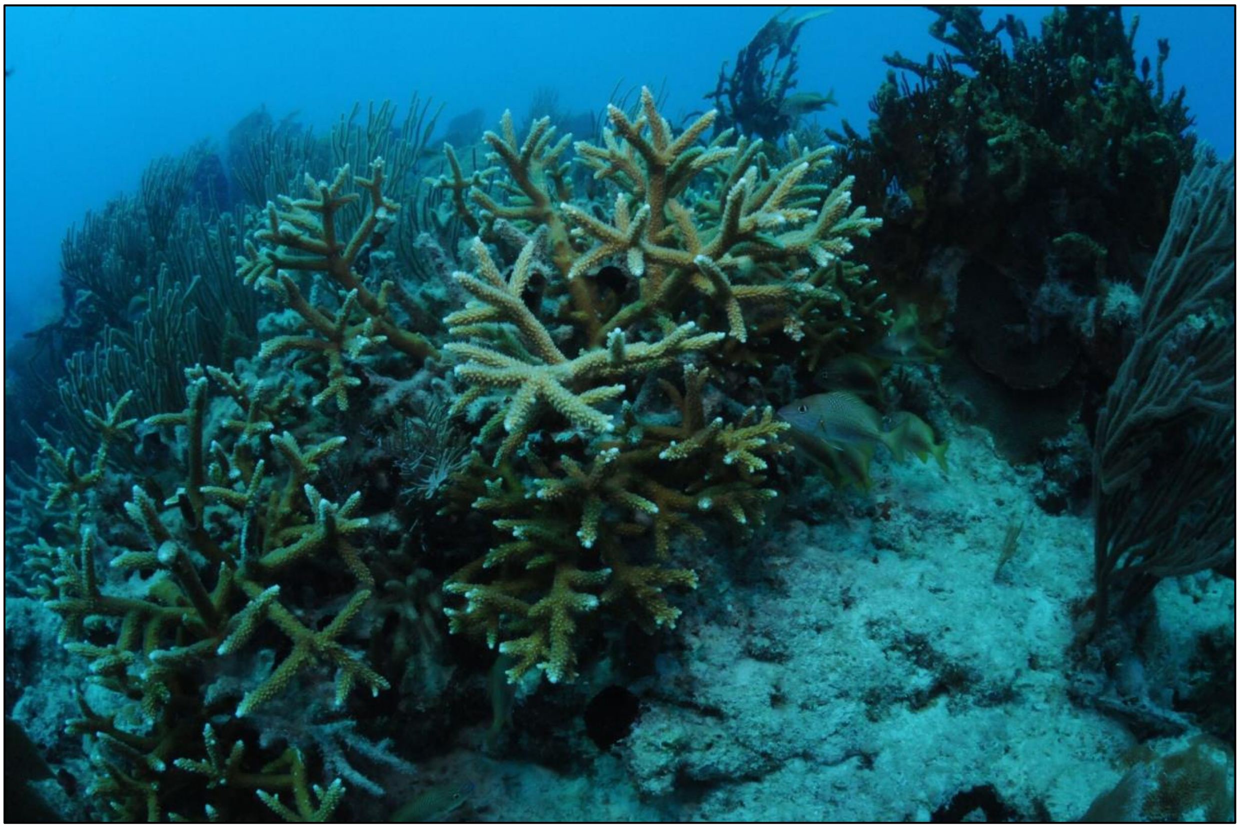
4.3.4. Staghorn Coral Nurseries and Outplanting

In south Florida and throughout the Caribbean, staghorn corals (*Acropora cervicornis*) have historically been a dominant builder of reef structure providing essential fish habitat for a wide variety of coral reef fish species. However, since the late 1970s, their abundance has declined significantly throughout their range causing grave concern. In 1976, there were 478 hectares of staghorn dominated reefs (55% of park coral reefs) in DRTO (Davis 1982). However a cold water event during the winter of 1976 and 1977 resulted in the mortality of an estimated 96% of the surveyed population (Davis 1982, Porter et al. 1982). Since then there has been slow recovery of staghorn in the park particularly near Pulaski Shoals (Lidz and Zawada 2013, Lizza 2015).

As part of a south Florida wide effort to grow and transplant staghorn colonies on to reef sites a nursery was established in 2010 approximately 1.5 miles southwest of Garden Key in DRTO. In June of 2015, 1,700 staghorn corals were outplanted to 2 reef sites within the Park. In September 2015, there was 95 percent survivorship of corals but bleaching was recorded at both outplant sites. Of the 504 corals monitored, 100% showed signs of bleaching. In 2016, up to 4,000 corals were outplanted and in 2017, over 1,000 more corals were outplanted.

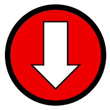
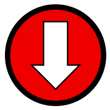
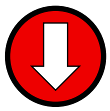
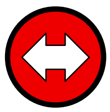
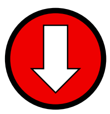
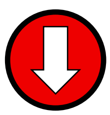
4.3.5. Conclusions

In terms of coral cover, the corals in DRTO appear to be in better condition than those in the rest of the Florida Keys. However, monitoring at both fixed and random sites throughout DRTO suggest that coral coverage in the park continues to decline. Macroalgae coverage has increased significantly since 2009 and is of moderate concern (Table 4.3.2). In 2014 and 2015, coral bleaching was severe in the park causing a noticeable spike in recent mortality in 2015 above the reference condition. Although not new (Brandt et al. 2012), outbreaks of coral disease are major concern in DRTO and the recent disease outbreak at Loggerhead occurred at an area with some of the most complex, most diverse, and highest coral cover in the park. There is little known about the long-term effects of coral disease on the gorgonian dominated hard bottom communities that are pervasive throughout the park but disease outbreaks on well-developed reefs are a clear problem.



Staghorn corals *(Acropora cervicornis)* growing on DRTO reef. (Photo by David Bryan)

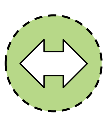
Table 4.3.2. Condition and tends of stony corals in DRTO.

Criteria	Condition & Trend	Rationale	Reference Condition
Percent coverage (SFCN long term sites)		Coral coverage has been steadily declining at all three monitoring sites since each was first monitored.	Increasing coral coverage to site specific baseline
Percent coverage (CREMP long term sites)		There has been a general trend of declining coral overage across all monitored sites.	Increasing coral coverage to site specific baseline
Bleaching prevalence (FRRP)		3 of the last 4 FRRP surveys have had bleaching prevalence greater than 20%.	Low annual prevalence (<20%) and infrequent mass bleaching events (≤ every 5-10 years).
Recent mortality (FRRP)		Recent mortality as measured by FRRP was greater than 1% in 2014 and 2015 and 0.9% (±0.17%) in 2016. These levels are greater than the reference condition.	≤ 1% mortality.
Pillar and Elkhorn coral		Both species have been affected by white plaque and white pox disease respectively, and suffered considerable tissue loss at sites monitored by FWRI.	A genetically viable population.
Seawater temperature		Exceeded bleaching threshold for more than 40 days in 2014, 2015 at Bird Key reef and in 2015 at Santa's Village and Loggerhead reefs.	Reef temperatures exceed bleaching threshold (30.5 °C) for less than 40 days (Manzello et al., 2007).

Orbicella coral with white plague disease. (Photo by Rob Waara).

4.4. Selected Marine Invertebrates

Table 4.4.1. Overall condition and trend of lobster, queen conch and long-spined sea urchin populations in DRTO.

Attribute	Condition & Trend	Interpretation
Lobster, queen conch and long-spined sea urchin populations		Caribbean spiny lobster have been protected within DRTO since 1974 and previous research has shown that their size and fecundity in the park is a sign of healthy population. Little is known about queen conch aggregations within the park but they are protected from harvest. Long-spined sea urchins have undergone Caribbean wide decline and their populations including those in DRTO are slowly rebounding.

4.4.1. Importance

The most valuable commercial fishery within the Florida Keys targets the Caribbean spiny lobster (*Panulirus argus*). Not only are these abundant crustaceans economically important for commercial fisheries, they also offer tremendous opportunities for recreational fishers throughout south Florida. In addition to their economic value, spiny lobster are an integral component of the broader south Florida and Caribbean marine ecosystem. In order to protect this valuable resource, commercial and recreational harvest of spiny lobster were prohibited within the Fort Jefferson National Monument in 1974, and this protection was expanded with the creation of the National Park in 1992 (Davis 1977). Along with the ecologically and economically important spiny lobster, queen conch (*Lobatus gigas*) and long-spined sea urchin (*Diadema antillarum*) are also ecologically important invertebrates that can be found throughout Dry Tortugas National Park (DRTO). Both of these species have seen their populations decline precipitously in the recent past (Stevely and Warner 1978, Lessios 1988). 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 1983/84 (Glazer and Berg 1994, Lessios 1988). Each of these marine invertebrates fulfill a unique role in the tropical marine environment in DRTO and their health is critical for a healthy functioning ecosystem.

4.4.2. Spiny lobster

The Caribbean spiny lobster is a benthic carnivore that preys upon a variety small marine invertebrates in addition to scavenging the ocean floor for carrion. Conversely, juvenile and adult lobster are an important food source for a number of fish species found within DRTO. The Dry Tortugas was established as a lobster sanctuary in 1974 and commercial and recreational harvest is prohibited. This protection has provided two major benefits for the DRTO marine ecosystem. For one, spiny lobsters in DRTO are larger, grow faster, mature at a larger size and on average have larger clutch sizes than those throughout the rest of the Florida Keys (Bertelsen and Matthews 2001, Maxwell et al. 2009). When Davis (1977) first began collecting data in an experimental close area in the park in the early 1970s the average carapace length was 101 mm (Figure 4.4.1). In the late 1990s the size distribution was very similar suggesting a stable population as a result of the protection (Figure 4.4.2.) (Bertelsen and Matthews 2001). During both these time eras, the lobster within the protected Dry Tortugas were much larger that found in the fishery (Figures 4.4.1. and 4.4.2).

The local south Florida lobster population, including the Dry Tortugas, is not completely self-sustaining, but it likely provides a significant proportion of its overall recruitment (Ehrhardt and Fitchett 2010, Kough et al. 2013). The lobsters within DRTO, are therefore not only important for the park but are also a significant benefactor to the overall health of the south Florida population. A well-designed statistical survey of the park’s lobster population conducted periodically would be beneficial to track any population and status changes that are currently unknown.

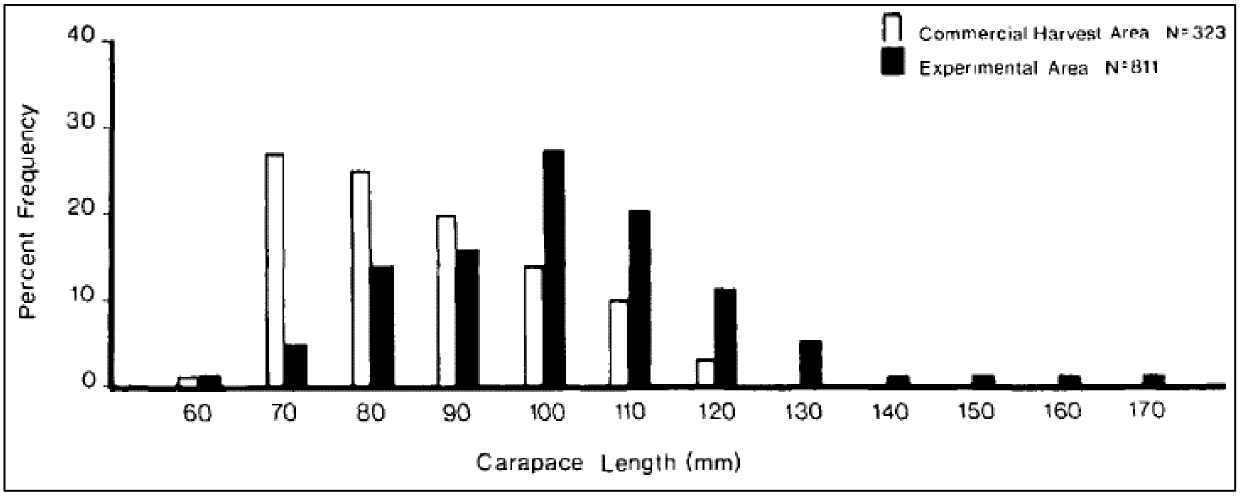


Figure 4.4.1. Size distribution of spiny lobsters in commercial harvest area in the Dry Tortugas and in experimental closed area from 1971-1973. (Reprinted from Davis 1977).

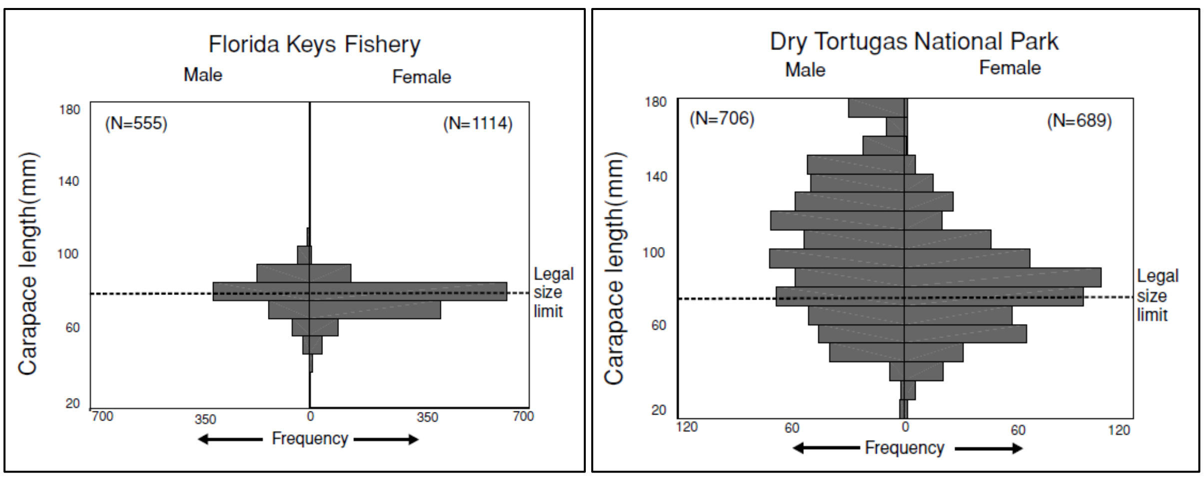


Figure 4.4.2. Size distributions of male and female lobster in the Florida Keys fishery and DRTO from 1996 to 1998. (Reprinted from Bertelsen and Matthews 2001).

The creation of the lobster sanctuary in DRTO was not only beneficial for the lobster population (Davis 1977, Cox and Hunt 2005), but it has also protected the coral reefs from destructive lobster traps and the associated debris left behind in the commercial fishery. 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 lines 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). The lack of trap debris in DRTO has been a positive byproduct in the creation of the lobster sanctuary.

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

4.4.3. Queen conch

Queen conch once supported a modest recreational and commercial fishery in south Florida and continues 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 70s 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, while DRTO has received very little attention for queen conch research and monitoring. A survey of queen conch within the Fort Jefferson National Monument by Bob Glazer (FWRI) in 1991 reveled at least two breeding aggregations and approximately 184,500 conch in the monument. However this value was noted as likely an overestimate and there has been limited survey effort since. If the aggregations still exist, larval recruits from the park may help supply the Florida Keys conch populations (Delgado et al. 2008).

Juvenile queen conch (*Lobatus gigas*) grazing in a seagrass bed. (Photo by Rob Waara).

4.4.4. Long-spined sea urchin

In 1983-84, 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 influencing the decline of scleractinian corals and increase in algae dominated reefs (Lessios 1988). Prior to the mass mortality event, density measurements of long-spined sea urchins ranged widely and were dependent on reef location (Kissling et al. 2014). There is no historical data for DRTO, but in the spur and groove habitat of the lower Florida keys densities ranged between 2 and 5 sea urchins per m^2 before the die-off (Kissling et al. 2014). In 2000, Chiappone et al. (2001) reported a mean densities of 0.3 to 0.5 sea urchins per m^2. Since then there has been a slow rate of recovery throughout the Florida Keys including DRTO (Chiappone et al. 2013).

Unlike spiny lobsters and queen conch, long-spined sea urchin densities have been tracked as part of several coral monitoring programs. The Florida Fish and Wildlife Research Institute's (FWRI) Coral Reef Evaluation and Monitoring Program (CREMP) has measured urchin density since 2004 (Ruzicka et al. 2014). Several transects are conducted at 11 sites throughout DRTO. Overall density has been slightly increasing (Figure 4.4.3). In 2012 the highest density was recorded at 0.17 +/- 0.06

(SE) urchins per m^2 (Ruzicka et al. 2014). However these average densities include several deeper sites where they are not likely common. At some of their shallower sites sea urchin densities have increased to 0.37 (+/- 0.37 SE) and 1.1 (+/- 0.50 SE) urchins per m^2.

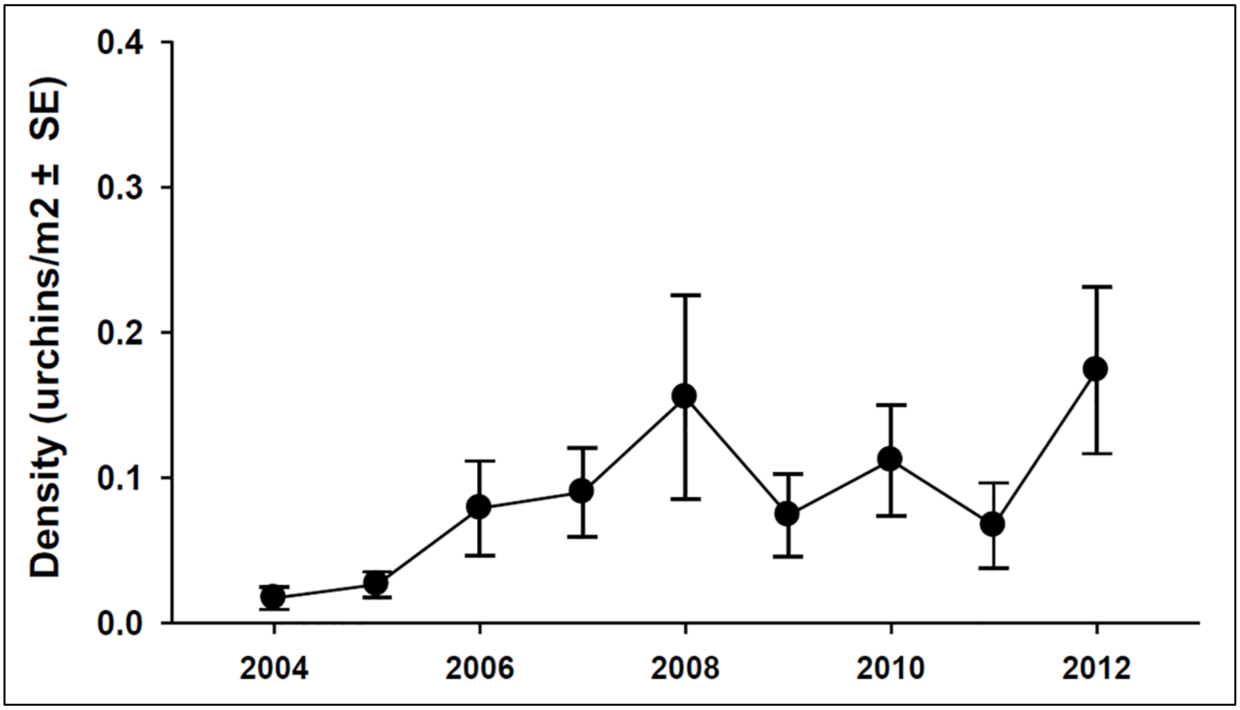
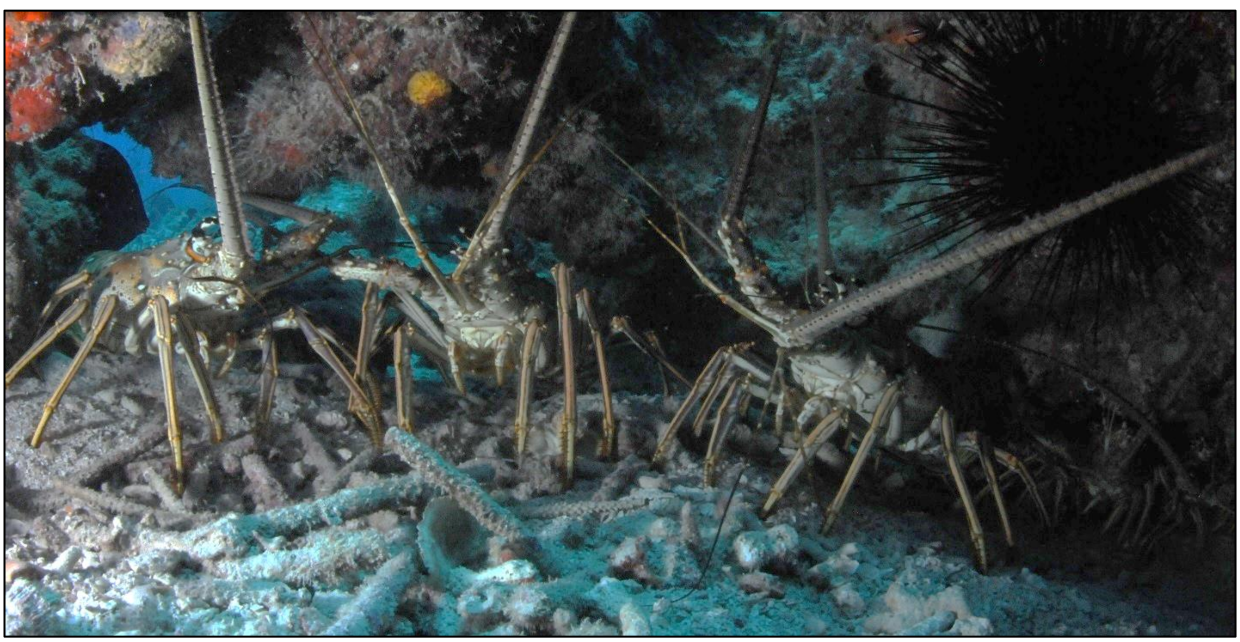


Figure 4.4.3. Mean density (urchins/m^2) ± SE of *Diadema antillarum* at seven sites in 2004, eight sites in 2005 through 2008, and 11 sites in 2009 through 2012. (Reprinted from Ruzika et al. 2014).



Lobster den with spiny urchin on DRTO patch reef. (Photo by David Bryan).

The National Coral Reef Monitoring Program (NCRMP), the Florida Reef Resilience Program (FRRP) and the South Florida and Caribbean Network Inventory and Monitoring (SFCN-IM) program all record long-spined sea urchin presence within their coral sample sites. Long-spined sea urchins have been present in roughly close to 50% of all FRRP transects since 2009 (Figure 4.4.4). This is significantly greater than BISC where they are consistently present in around 15% of FRRP transects but there does not appear to be an increasing trend. At the SFCN coral monitoring sites long-spined sea urchin density has ranged from 0.015 to 0.034 per m^2 since 2008; an order of magnitude lower than CREMP sites and with no sign of an increasing trend (Figure 4.4.5).

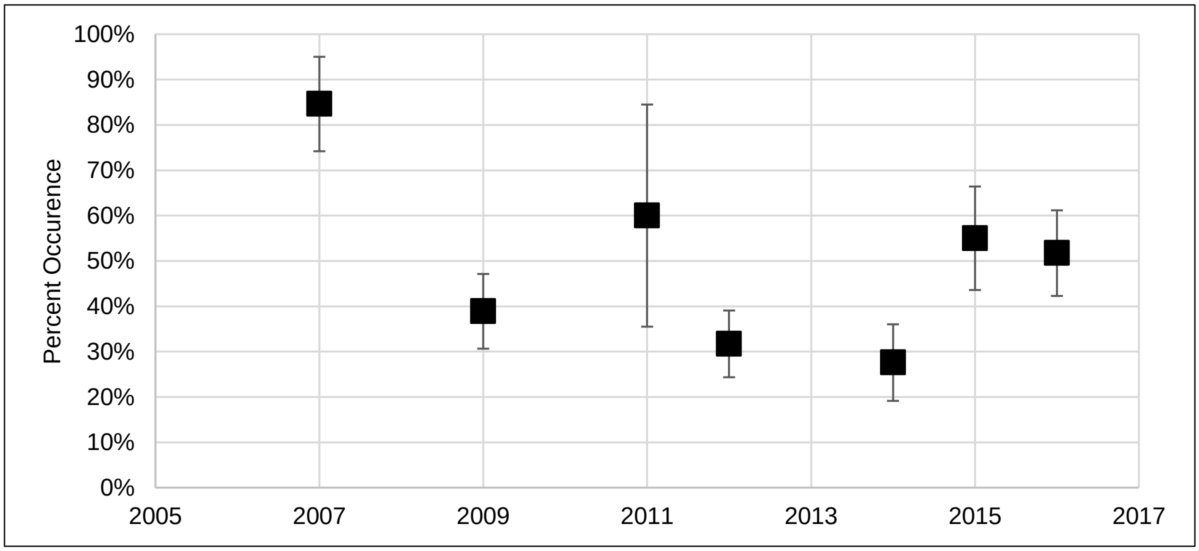


Figure 4.4.4. Percent occurrence of long-spined sea urchins on Florida Reef Resilience Program transects in Dry Tortugas National Park by year. Bars represent standard error. (Data from FRRP).

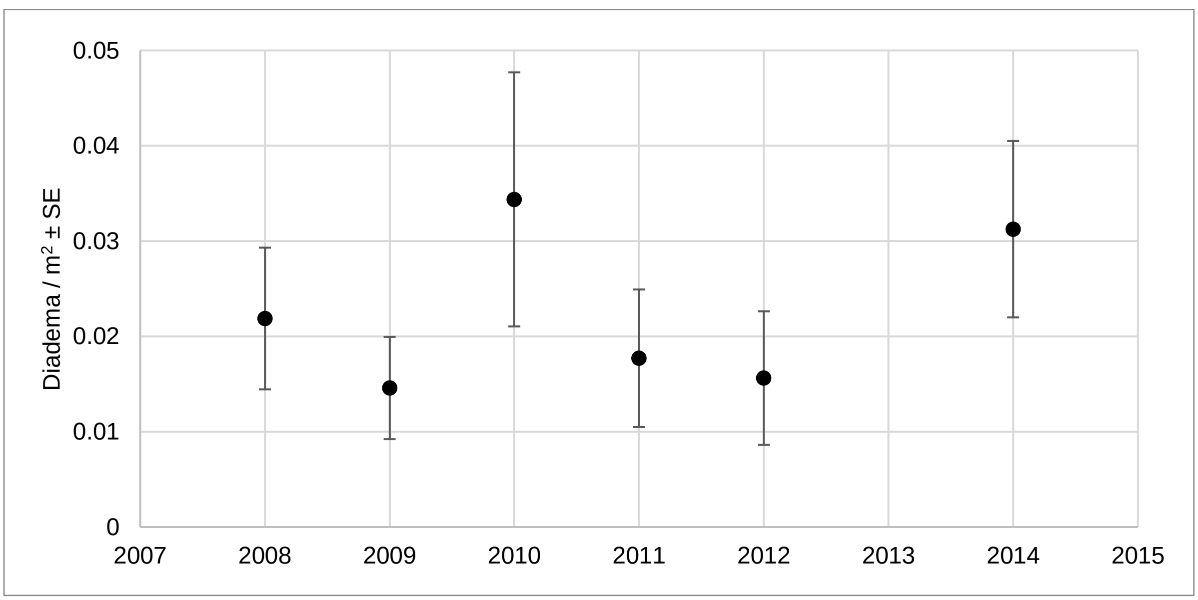
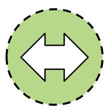
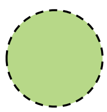
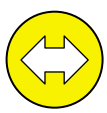


Figure 4.4.5. Long-spined sea urchin density measured during SFCN coral monitoring at 12 sites. (Figure provided by SFCN).

4.4.5. Conclusion

Caribbean spiny lobster, queen conch and long-spined sea urchin are ecologically important marine invertebrates that each play an important role in maintaining the health of the coral reef ecosystem. DRTO provides an important sanctuary for lobster which are heavily exploited throughout their range that has resulted in not only a healthy local population but likely contributes significant recruitment to the rest of the Florida Keys. Queen conch aggregations have been reported in DRTO in the past but limited survey effort has precluded an estimation of their status. The density of long-spined sea urchins is still significantly below historic levels in DRTO and although their density appears to be increasing in one monitoring program there is no trend associated with two others.

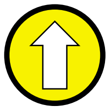
Table 4.4.2. Condition and trends of marine invertebrates in DRTO.

Criteria	Condition & Trend	Rationale	Reference Condition
Lobster size and fecundity		Lobsters are protected in DRTO and it is likely that their size and fecundity are similar to the 1990s baseline but there has been no recent study.	Size frequency and fecundity reported from late 1990s (Bertelson and Matthews 2001).
Occurrence of conch aggregations		Breeding aggregations have been reported in DRTO (1991) but there has been limited survey effort since. They are protected from harvest so their condition is expected to be good.	Sites with adult densities >200 individuals per ha.
Density of long-spined sea urchin		Urchin density is greater than anywhere else in south Florida, yet it is still below the desired state.	> 1 per m^2 in shallow water sites.

Divers swim down to monitor reef in DRTO (Photo by David Bryan).

4.5. Reef fish and sharks

Table 4.5.1. Overall condition and trend of reef fish and sharks in DRTO.

Attribute	Condition & Trend	Interpretation
Reef fish and sharks		Occupancy rates, density and the overall abundance of principal species from the snapper and grouper complex have been increasing in DRTO since 1999. Although the average size of exploited phase fish is larger for several species in comparison the rest of south Florida, they are still smaller than expected with a sustainable fishing mortality rate which warrants moderate concern.

4.5.1. Importance

Located 110 km west of Key West, the Dry Tortugas is one of most remote coral reef ecosystem in the continental United States. The Dry Tortugas region is comprised of three carbonate banks; the Dry Tortugas which includes DRTO, the Tortugas Bank, and Riley's Hump. Within DRTO, extensive seagrass beds, shallow water patch reefs and thousands of acres of continuous reefs offer a wide range of habitats for hundreds of species of reef fish throughout their life cycle. These fish are not only integral to the marine ecosystem but many are highly valuable and sought after species that support the south Florida economy. Since the National Monument was implemented in 1935, DRTO has been closed to commercial fishing. Recreational fishing which is limited to hook and line fishing has been prohibited in the Resource Natural Area (RNA) since 2007. These park specific protections, the geographic isolation of DRTO and several state and federal regulations in the area have helped preserve a number of the most vulnerable and commercially targeted species that reside in the park. This is crucial, as research has shown that not only are the local populations critical for the health of the park, but larvae spawned in the greater Tortugas region are transported down current throughout south Florida where they replenish local assemblages that face increasingly high fishing mortality (Domeier 2004, Burton et al. 2005, Bryan et al. 2015).

Goliath grouper (*Epinephelus itajara*) in DRTO. (Photo by David Bryan).

4.5.2. Stressors

The Florida reef tract including the Dry Tortugas is home to great diversity of reef fish; some are exploited by fishermen as game or for food, others are captured for the aquarium trade but the majority of species are not directly exploited by humans. The greatest threat is faced by those fish that are exploited by anglers. Populations of these species, such as snappers and groupers, have seen extensive declines in south Florida over the last 50 years driven primarily by increased fishing pressure (Ault et al. 1998, Ault et al. 2005). Even the Dry Tortugas, which is geographically removed from the preponderance of recreational anglers, is susceptible to overfishing (Ault et al. 2002). During the last 15 years, the establishment of several no take marine reserves has improved the health of many exploited fish stock in DRTO and in the Dry Tortugas region (Ault et al. 2006, 2013). Yet as fish stocks continue to decline elsewhere, there is consistent pressure to remove or reduce these marine reserves in the Dry Tortugas region.

4.5.3. Reef Fish Monitoring and Assessment

Since 1999, the reef fish visual census (RVC) has been used to estimate the size structured population abundance of exploited and non-target reef fish species in the Dry Tortugas (Ault et al. 2006, Smith et al. 2011). During the census, highly trained scientific divers are deployed at randomly selected sites throughout the park to identify, count and estimate the size of all fish within a standardized unit of time and space (Brandt et al. 2009). Indices of relative fish abundance and density can be generated and compared over time and amongst regions throughout the south Florida reef tract. Equally important, estimates of the average size at the exploited phase ($\bar{L}$) of fisheries targeted species can be used to estimate fishing mortality and to determine if individual species are being sustainably fished (Beverton and Holt 1957, Erhardt and Ault 1992).

Brightly colored male hogfish (*Lachnolaimus maximus*) swims along DRTO reef. (Photo by Rob Waara).

Two small groupers, a graysby (*Cephalopholis cruentata*) and a rockhind (*Epinephelus adscensionis*) hiding on reef. (Photo by David Bryan).

Due to a large sample size and optimally allocated stratified random sampling design, survey precision has been sufficient to detect statistically significant increases and decreases in population occupancy, density, and abundance within management zones for a suite of exploited and non-target species of the reef-fish community. Following previous publications, a select group of 'principal' species have been chosen as representatives of exploited fishes in DRTO and used for the assessment of the reef fish community in this report. These species include the red grouper (*Epinephelus morio*), black grouper (*Mycteroperca bonaci*), mutton snapper (*Lutjanus analis*), yellowtail snapper (*Ocyurus chrysurus*), gray snapper (*Lutjanus griseus*), and hogfish (*Lachnolaimus maximus*).

Ault et al. (2006) reported on intensive fishery-independent visual surveys conducted in the Dry Tortugas region in 1999, 2000, and 2004, before and after implementation of the Tortugas North Ecological Reserve (TNER) and the Tortugas South Ecological Reserve (TSER). They found beneficial effects of the reserve implementation based on the occupancy, abundance and size structure of exploited reef fish species. A study published by Ault et al. (2013) presented results from continued visual surveys conducted in the Dry Tortugas region during 2006-2011 (Smith et al. 2011), which included the period before and after implementation of the RNA in DRTO. Surveys detected significant changes in population occupancy, density, and abundance within management zones for a suite of exploited and non-target species. An increase in size, adult abundance, and occupancy rates were detected for several principal exploited species in protected areas. In addition, these protected areas harbored a disproportionately greater number of adult spawning fishes. In contrast, density and occupancy rates for aquaria and non-target reef fishes fluctuated above and below baseline levels in each management zone. Observed decreases in density of exploited species below baseline levels only occurred at the Tortugas Bank area that is open to all fishing. Their findings indicated that the No-Take Marine Reserves (NTMR) in the Dry Tortugas region, in conjunction with traditional fishery management control strategies, were helping to build sustainable fisheries while protecting the fundamental ecological dynamics of the Florida Keys coral-reef ecosystem.

Fishery independent, RVC surveys were conducted again in 2012 and 2014 in the Dry Tortugas region including DRTO and Ault et al. (2015) re-evaluated the status and trends of a suite of principal reef fish species. An increase in density compared to the 1999/00 baseline for exploited life stages of fishery species were detected in the TNER and in DRTO for a number of surveys and species including red grouper (Table 4.5.2; Figure 4.5.1). The authors also compared changes in density of principal species from 2006 in the RNA and recreational fished areas of DRTO. Densities of fishes had increased but there is no significant difference between the two areas (Ault et al. 2015).

Not only has there been a trend of increasing density of exploited fishes in DRTO since 1999, but when compared to other regions in south Florida, such as Biscayne National Park (BISC), DRTO typically has higher densities of yellowtail snapper, mutton snapper, red grouper and black grouper (Feeley et al. 2016; Figure 4.5.2). The average size of the exploited phase ($\bar{L}$) for hogfish, mutton snapper, gray snapper, and black grouper is slightly larger in DRTO than in BISC and other parts of the Florida Keys (Figure 4.5.3). But $\bar{L}$ for all six principal species is below the expected $\bar{L}$ when the fishing mortality rate is set for maximum sustainable yield (Figure 4.5.3). This low $\bar{L}$ from the DRTO RVC survey is similar to estimates from the recreational fishery (Figure 4.5.3) and highlights regional issues with overfishing that also affect DRTO.

Table 4.5.2. Number of post 1999-2000 baseline surveys that show a significant change in density. Includes 8 post baseline surveys and 4 categories of reef fishes: exploited, aquaria, non-target, and moratorium. The minimum change detection from baseline was based on a 95% CI. (Reprinted from Ault et al. 2015).

Category	Family	Species	Increase	Decrease
Exploited	Groupers	Red grouper	1	0
	Groupers	Black grouper	7	0
	Snappers	Mutton snapper	7	0
	Snappers	Yellowtail snapper	6	0
	Wrasses	Hogfish	4	0
	Wrasses	Total Detections, Exploited	25	0
Aquaria	Angelfishes	Blue angelfish	0	1
	Angelfishes	Gray angelfish	0	0
	Butterflyfishes	Foureye butterflyfish	0	2
	Butterflyfishes	Spotfin butterflyfish	1	3
	Seabasses	Butter hamlet	7	0
	Seabasses	Total Detections, Aquaria	8	6

Table 4.5.2 (continued). Number of post 1999-2000 baseline surveys that show a significant change in density. Includes 8 post baseline surveys and 4 categories of reef fishes: exploited, aquaria, non-target, and moratorium. The minimum change detection from baseline was based on a 95% CI. (Reprinted from Ault et al. 2015).

Category	Family	Species	Increase	Decrease
Non-Target	Damselfishes	Bicolor damselfish	3	0
	Damselfishes	Threespot damselfish	1	3
	Parrotfishes	Princess parrotfish	3	0
	Parrotfishes	Striped parrotfish	2	0
	Parrotfishes	Stoplight parrotfish	4	1
	Porgies	Saucereye porgy	3	0
	Seabasses	Harlequin bass	0	3
	Surgeonfishes	Ocean surgeon	1	1
	Surgeonfishes	Blue tang	2	0
	Wrasses	Yellowhead wrasse	8	0
	Wrasses	Puddingwife	0	1
	Wrasses	Total Detections, Non-target	27	9
Moratorium	Groupers	Goliath grouper	3	0
	Groupers	Total Detections, Moratorium	3	0

Tiny juvenile black grouper (*Mycteroperca bonaci*) hiding near the coal docks at Fort Jefferson, DRTO. (Photo by David Bryan).

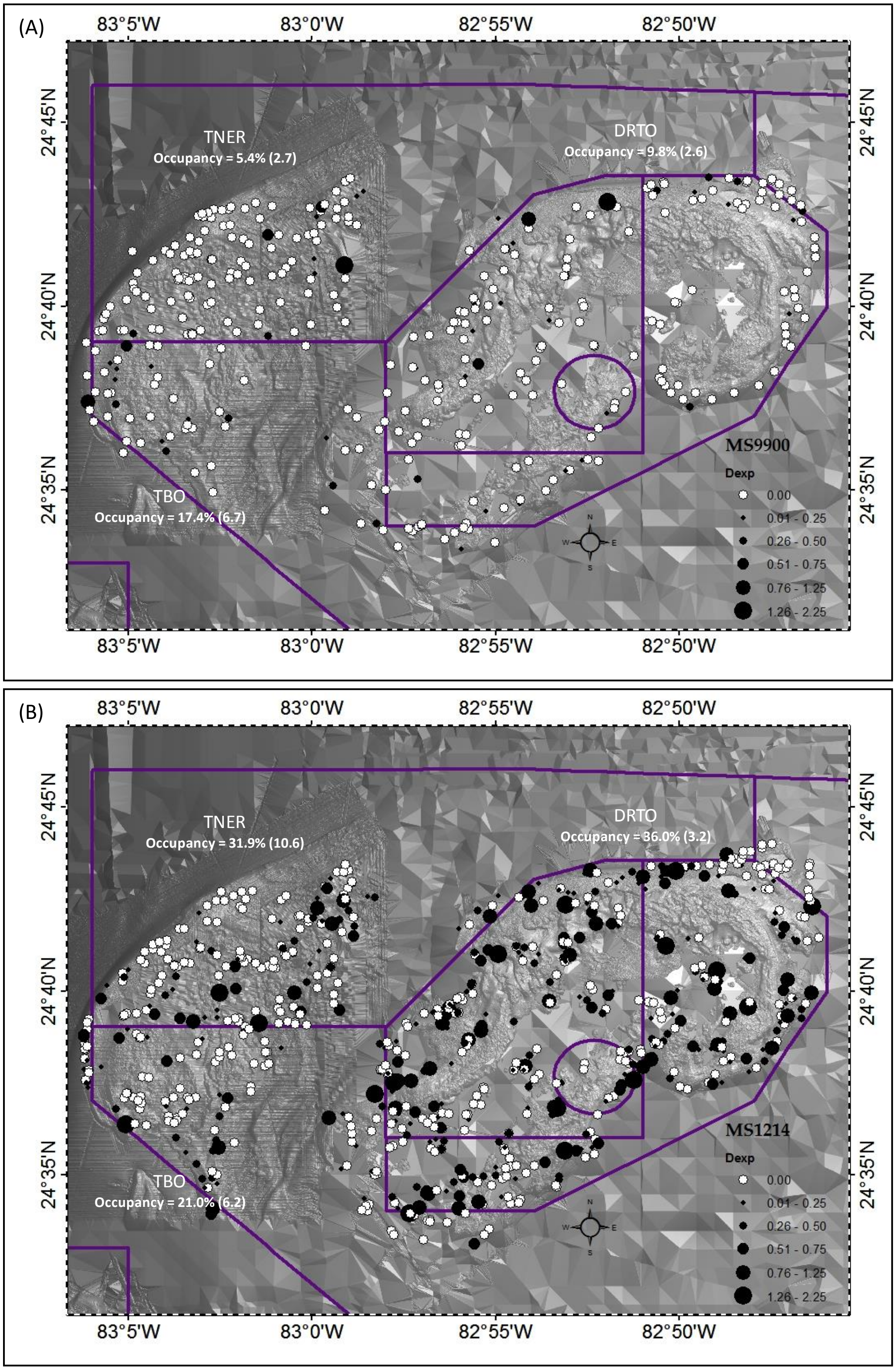


Figure 4.5.1. Spatial distribution of density for exploited life-stage red grouper (mean number of fish per secondary sample unit) from Tortugas region visual surveys conducted in (A) 1999-2000 and (B) 2012 and 2014. Each point is the average sample value within a primary sample unit. Also shown are mean occupancy rates (SE) for three principal management zones. (Reprinted from Ault et al. 2015).

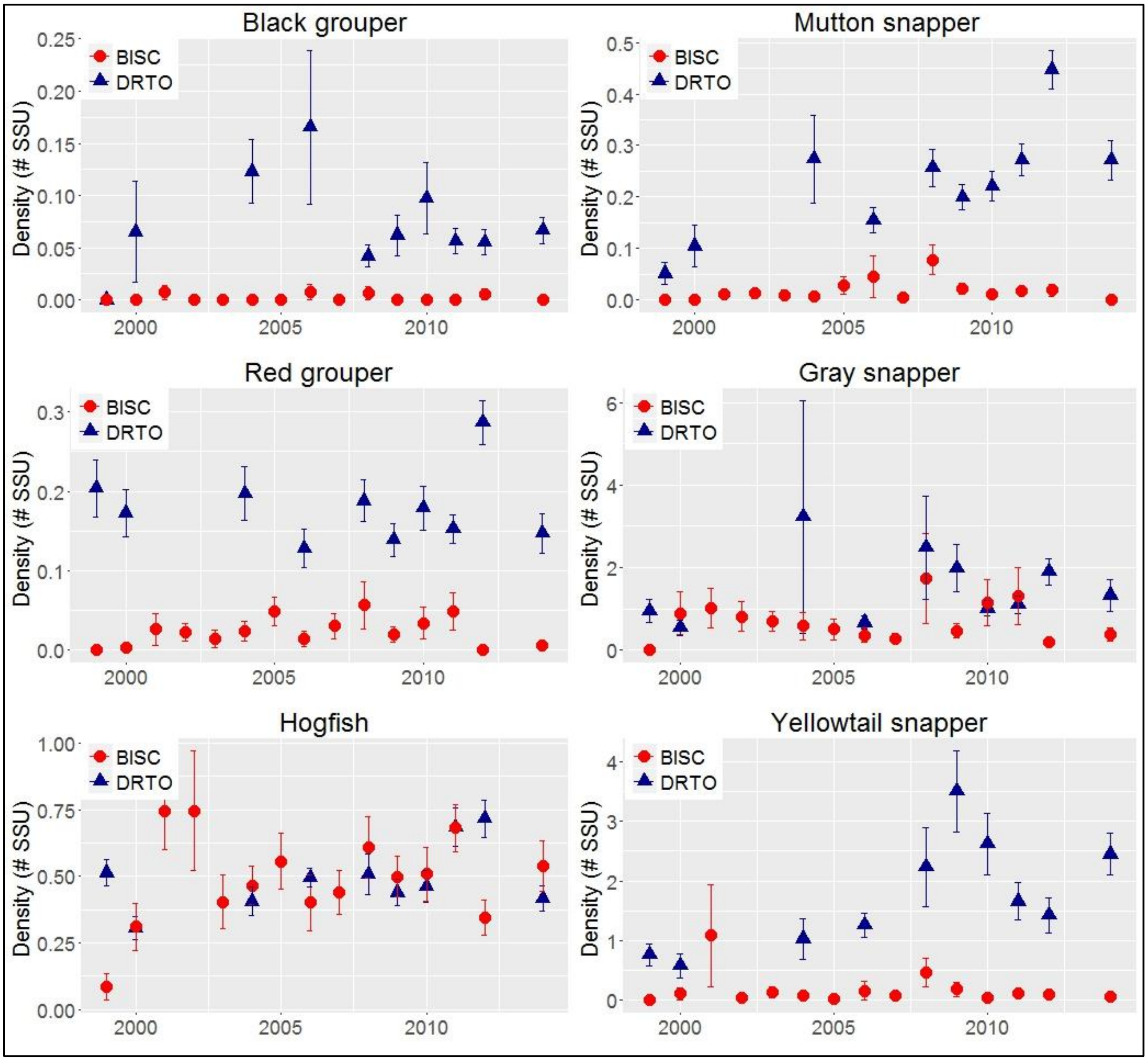


Figure 4.5.2. Density and standard error of key exploited species in BISC and DRTO from 1999-2014, estimated from reef fish visual census (RVC) data. (Reprinted from Feeley et al. 2016).

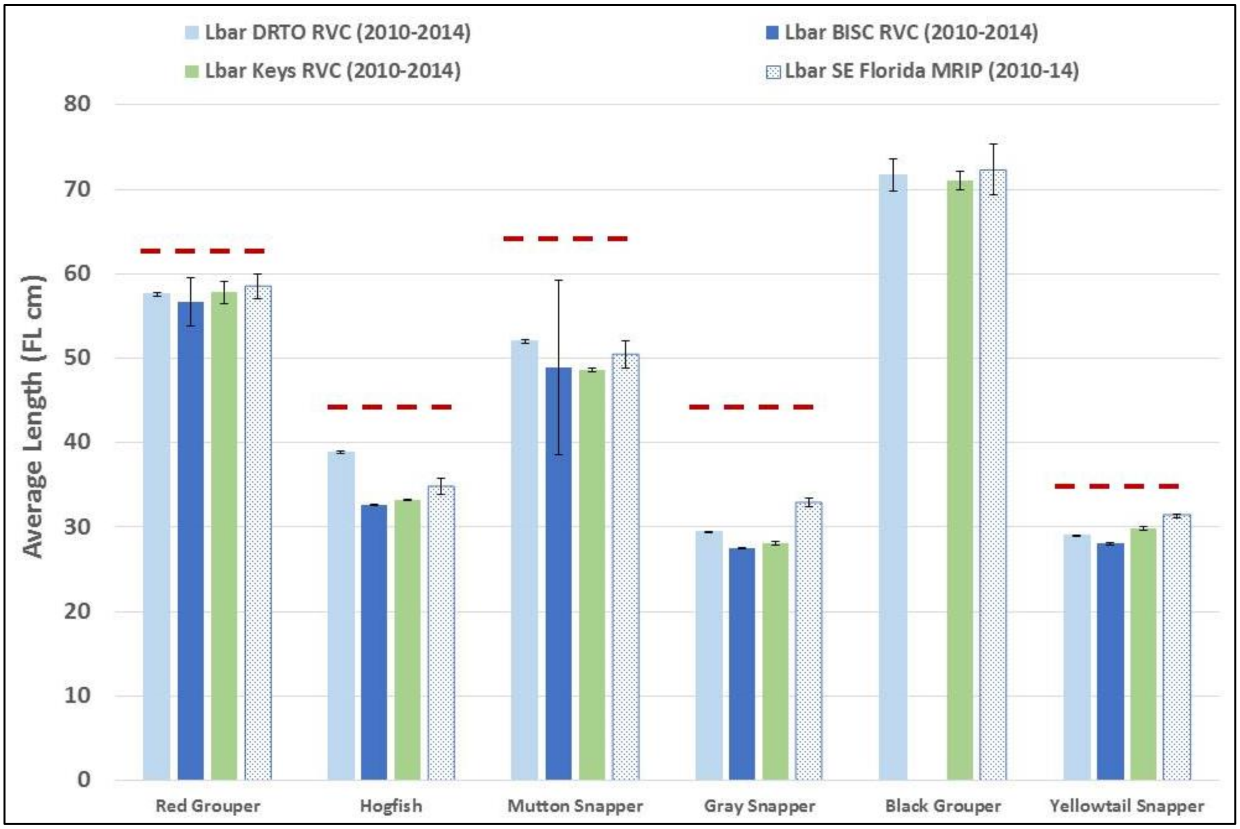


Figure 4.5.3. Average length (cm) of exploited phase ($\bar{L}$) key reef fish estimated from DRTO, BISC, the Florida Keys RVC surveys and the Florida Marine Recreational Information Program (MRIP). Bars represent standard error. Dashed red line indicates the expected $\bar{L}$ at MSY (from J. Ault unpublished). Black Grouper expected $\bar{L}$ is 94cm and not shown on chart.

Ault et al. (2015) evaluated the ecological role of the Dry Tortugas management zones in providing habitat for juvenile and adult life stages of the principal fishery species. While DRTO contains about 57% of the Dry Tortugas region survey area (live coral reef habitats, 0-33 m depth), the percentage of juvenile abundance in DRTO in 2012-2014 was similar to or greater than this percentage, ranging from 60 to 91% for the 5 species analyzed (Table 4.5.3). This is likely attributed to the wider range of depths and juvenile fish seagrass habitats found within DRTO as compared to relatively deeper Tortugas Bank (Lindeman et al. 2000, Ault et al. 2005). In 2012-2014, DRTO also contained 58-69% of adult spawners in the Tortugas region for all 5 species (Ault et al. 2015). For the combined Florida Keys-Dry Tortugas regions surveyed with RVC, DRTO contained 18% of the total survey area (mapped live coral habitats, 0-33 m depth), yet harbored a disproportionately larger percentage of the adult spawners for 4 of the 5 fishery species (Table 4.5.4, Table 4.5.5).

Table 4.5.3. Estimates of 2012-2014 total abundance (numbers) and the percentage of abundance among management zones for 5 exploited reef fish species that are the focus of management: Dry Tortugas region (domain area = 311 km^2), juveniles (i.e., immature). Dry Tortugas management zones are: TBO, Tortugas Bank Open; TNER, Tortugas North Ecological Reserve; and DRTO, Dry Tortugas National Park. The percentage shown below the area acronym is the proportion of reef area. (Reprinted from Ault et al. 2015).

		Percentage of Juvenile Abundance		
Species	**Total Juvenile Abundance (x 1,000)**	**TBO (18.5%)**	**TNER (25.0%)**	**DRTO (56.5%)**
Red Grouper	628.0	13.5	26.6	59.9
Black Grouper	232.3	1.1	9.0	89.9
Mutton Snapper	8.9	17.5	0.0	82.5
Yellowtail Snapper	6,958.4	8.6	19.1	72.3
Hogfish	26.1	6.0	3.2	90.8

Table 4.5.4. Estimates of 2012-2014 total abundance (numbers) and the percentage of abundance among management zones for 5 exploited reef fish species that are the focus of management: Dry Tortugas region, adults. Dry Tortugas management zones are: TBO, Tortugas Bank Open; TNER, Tortugas North Ecological Reserve; and DRTO, Dry Tortugas National Park. The percentage shown below the area acronym is the proportion of reef area. (Reprinted from Ault et al. 2015).

		Percentage of Adult Abundance		
Species	**Total Adult Abundance (x 1,000)**	**TBO (18.5%)**	**TNER (25.0%)**	**DRTO (56.5%)**
Red Grouper	478.5	12.3	29.2	58.4
Black Grouper	88.1	7.9	25.9	66.2
Mutton Snapper	567.9	13.2	27.9	58.8
Yellowtail Snapper	8,667.0	9.9	30.1	60.0
Hogfish	900.2	13.8	17.5	68.7

Table 4.5.5. Estimates of 2012-2014 total abundance (numbers) and the percentage of abundance among management zones for 5 exploited reef fish species that are the focus of management: Florida Keys-Dry Tortugas ecosystem (domain area = 311 + 676 km^2 = 987 km^2), adults. Dry Tortugas management zones are: TBO, Tortugas Bank Open; TNER, Tortugas North Ecological Reserve; and DRTO, Dry Tortugas National Park. Florida Keys management zones are: Keys Open-Use, open to fishing; and Keys NTMRs, no-take marine reserves. The percentage shown below the area acronym is the proportion of reef area. (Reprinted from Ault et al. 2015).

Species	Total Adult Abundance (x 1,000)	Percentage of Adult Abundance				
		TBO (5.8%)	TNER (7.9%)	DRTO (17.8%)	Keys Open-Use (65.5%)	Keys NTMRs (3.0%)
Red Grouper	626.8	9.4	22.3	44.6	22.3	1.3
Black Grouper	156.9	4.4	14.6	37.1	39.9	4.0
Mutton Snapper	1,409.7	5.3	11.2	23.7	56.8	2.9
Yellowtail Snapper	15,165.4	5.6	17.2	34.3	40.1	2.7
Hogfish	6,208.1	2.0	2.5	10.0	82.7	2.8

4.5.4. Sharks

The wide range of habitats and productive fish populations in DRTO support a diverse group of sharks. There has been no directed survey effort within DRTO but during the RVC, great hammerheads, lemon sharks, bull sharks, reef sharks, and nurse sharks have all been observed. Acoustic receivers located within DRTO have detected the migration of several shark species included six bull sharks that were tagged 500 km away in Jupiter, Florida (Feeley et al. 2012). Tiger sharks have not been observed during the RVC, but the University of Miami shark research lab tracked a pregnant female tiger shark from the Bahamas to DRTO (per comm. N. Hammershlag, University of Miami). DRTO is also an important breeding ground for nurse sharks. Adult males visit the area each year to mate with females which arrive in alternating years (Pratt and Carrier 2001). 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). DRTO offers a unique opportunity to study the role sharks play in a large marine protected area in the western Atlantic/ Caribbean and a baseline survey of their abundance within the park would be beneficial.

Nurse shark (*Ginglymostoma cirratum*) under a patch reef in DRTO. (Photo by David Bryan).

4.5.5. 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, DRTO has supported a lionfish removal project that has been in place since 2011. Trained divers visit areas in the park that are known to harbor lionfish and remove them. From 2010-2016 a relatively low number of lionfish were removed by NPS divers (annual max = 119 in 2011) however in 2017 over 600 lionfish were caught. Overall, lionfish densities in the Dry Tortugas region remain the lowest in south Florida (Figure 4.5.4) (Bryan et al., in review). This may be a result of greater numbers of both competitors and predators in the Dry Tortugas region when compared to other areas in south Florida (Bryan et al., in review).

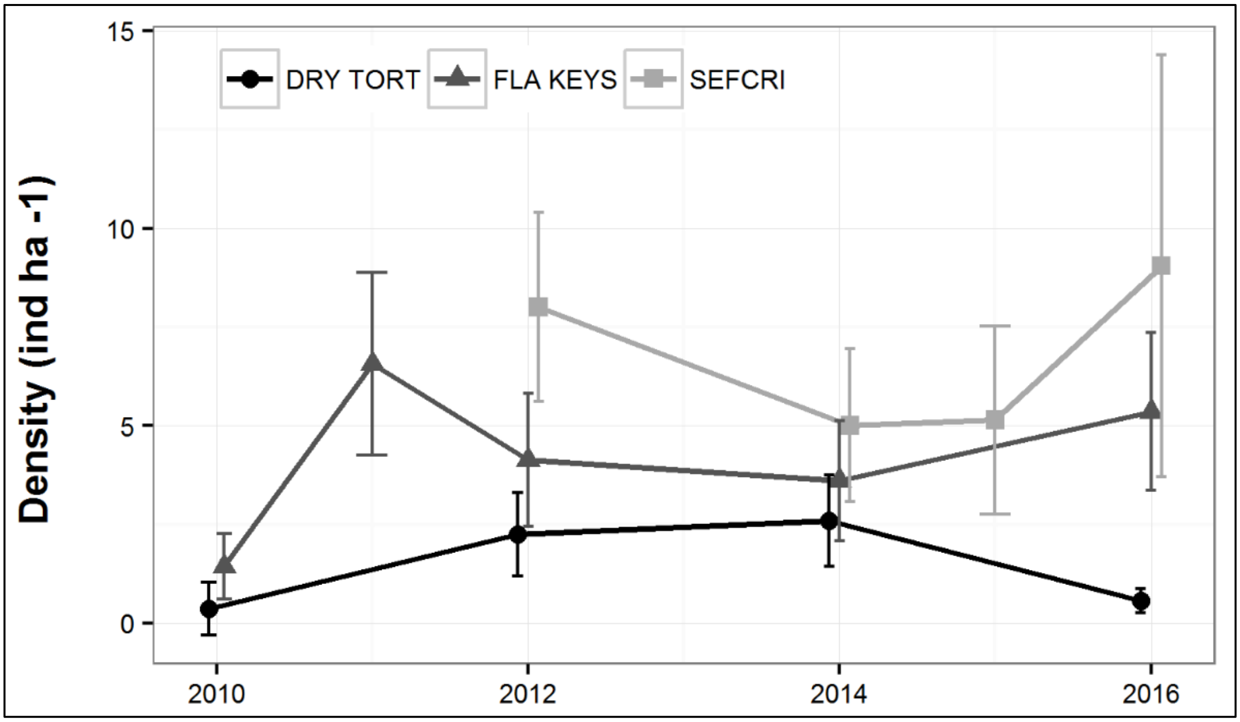


Figure 4.5.4. Density (individuals per ha) estimates of lionfish in the Dry Tortugas (Dry TORT), Florida Keys (FLA KEYS) and southeast Florida (SEFCRI) from the reef fish visual survey. (Reprinted from Bryan et al., in review).

Invasive red lionfish (*Pterois volitans*). (Photo by David Bryan).

4.5.6. Conclusions

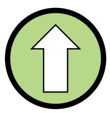
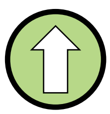
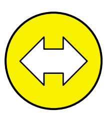
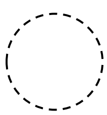
The RVC has enabled quantitative evaluation of changes in the assemblage of reef fish populations in the Dry Tortugas region from 1999-2014. Results show clear evidence that spatial control of fishing activities can improve the condition of exploited populations. Increases in density and abundance of fish above the minimum legal size of capture (i.e., exploited phase of the population) occurred for five principal fishery species (red grouper, black grouper, mutton and yellowtail snapper, and hogfish) in the TNER and within DRTO between the baseline years of 1999-2000 and 2014. Density increases were usually accompanied by increases in both the occupancy rate and the size of fishes in the exploited phase of the population (i.e., minimum legal size of capture to the maximum size).

Red grouper (*Epinephelus morio*) with neon cleaner goby. (Photo by David Bryan).

Within DRTO, the visual survey detected some increases in density and occurrence for principal fishery species before (2006) and after (2008-2014) implementation of the RNA; however, these increases occurred in the open-use and RNA zones with nearly equal frequency. From a broader fishing perspective, there were more and larger reef fish available for capture by recreational anglers in the DRTO open-use zone in 2014 as compared to 1999, prior to implementation of the TNER and DRTO RNA. Acoustic telemetry tagging studies found that the principal fishery species occasionally moved between the DRTO RNA and Open zones, both of which comprise a similar mix of reef habitat types and depths, as well as between the RNA in the northwest portion of DRTO and adjacent TNER and TSER (Farmer and Ault 2011, Feeley et al. 2012). These movement fluxes between zones, coupled with the fairly stringent controls on fishing in the DRTO Open zone, perhaps explain the lack of a clear NTMR effect for exploited species thus far post-establishment of the RNA in 2007.

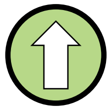
DRTO also contains a disproportionately greater number of adult spawning fishes of exploited species found in the region. Viewed from the larger perspective of the entire Florida coral reef ecosystem, the role of DRTO with respect to reef fish spawning stock is even more striking. Although DRTO accounts for about 18% of the total reef habitat area, it contains one-fourth to nearly one-half of the adult spawners for 4 of the 5 principal exploited species analyzed. These results, combined with studies of regional oceanography and larval transport (Domeier 2004, Burton et al. 2005, Bryan et al. 2015) indicate that the DRTO and the greater Dry Tortugas region are major source points of recruits to populations of principal reef fishery species in the Florida Keys (Table 4.5.6).

Table 4.5.6. Condition and trends of reef fish and sharks in DRTO.

Criteria	Condition & Trend	Rationale	Reference Condition
Density of principal species		5 out of 5 principal species had increase in density since baseline.	Increase from 1999 baseline.
Density/ relative abundance of principal species		DRTO has a higher percentage of the south Florida adult population than expected by area for 4 out 5 principal species.	Density of principal species greater than or equal to Florida Keys average.
Average length in the exploited phase of principal species		The $\bar{L}$ of principal species is slightly larger than estimates from the Florida Keys RVC for 4 out of 6 principal species but it is lower than $\bar{L}$ at F_{msy} which indicates that stocks are overfished.	$\bar{L}$ > estimated $\bar{L}$ for Fmsy.
Shark abundance		There is currently no program in place to monitor shark populations in DRTO.	No reference condition available.

4.6. Sea Turtles

Table 4.6.1. Overall condition and trend of loggerhead and green sea turtles in DRTO.

Attribute	Condition & Trend	Interpretation
Loggerhead and green sea turtles		The number of loggerhead and green turtle nests has been increasing and is at all-time highs since standardized monitoring began. The number of nests affected by erosion or inundation has been relatively stable since 1995. There has been no trend in nesting success rate of both loggerheads and green turtles since 1995.

4.6.1. Importance

The Dry Tortugas name originates from a 1513 description by Ponce de Leon who called the area *Las Tortugas* due to the vast numbers of sea turtles he encountered. In stark contrast, five hundred years later the five species of sea turtles that have been reported from the waters of DRTO (loggerhead (*Caretta caretta*), green (*Chelonia mydas*), hawksbill (*Eretmochelys imbricate*), leatherback (*Dermochelys coriacea*) and Kemp's ridley (*Lepidochelys kempii*) are all listed under the Endangered Species Act as either threatened or endangered depending on the distinct population segment that they belong. Currently the sandy beaches of DRTO provide the essential nesting grounds for the Dry Tortugas sub population of loggerhead turtles and the major nesting ground for green turtles in Monroe County. DRTO offers several unique undeveloped island locations surrounded by a healthy coral reef ecosystem for sea turtles to nest and forage. The availability of these beaches for loggerhead and green turtles is critical for their regional populations.

Green turtle hatchlings (Photo by Kayla Nimmo)

4.6.2. Stressors

Historically loggerhead and green sea turtles were prevalent throughout the Caribbean and were exploited for their eggs and meat. Workers and soldiers stationed at Fort Jefferson regularly harvested adult turtles and their eggs in the mid-1800s and the development of a market for turtle meat and eggs in Key West in the early 1900s caused an additional rise in demand along with a dramatic decline in sea turtles. In 1935, President Franklin Delano Roosevelt declared Fort Jefferson a National Monument, falling under the care and jurisdiction of the National Park Service, Department of the Interior. With the establishment of Fort Jefferson as a National Monument, sea turtles and their nests became protected within monument boundaries. However, poaching remained a significant problem (Budlong 1943). Turtle mortality increased once again during the 1950s, when the Dry Tortugas became the primary fishing area for the Key West-based pink shrimp (*Penaeus duorarum*) industry which indiscriminately caught sea turtles in their trawl nets. According to the 1990 National Research Council, incidental catch by shrimp-trawlers at the time resulted in more human-associated deaths in sea turtles than all other human activities combined (Magnuson et al. 1990). Since then several regulations have been put into place to reduce turtle bycatch and mortality estimates are 94% lower than in pre-regulation days (Finkbeiner et al. 2011). However, up to 98% of this mortality occurs in the southeast and Gulf of Mexico pink shrimp trawl fishery and there is concern that not all bycatch is reported (Finkbeiner et al. 2011).

Additional threats beyond incidental capture in commercial fisheries (bycatch), include the loss and or destruction of nesting beaches, entanglement in marine debris, and vessel strikes. Within DRTO there is no commercial fishing which protects sea turtles from incidental catch and also dramatically reduces the amount of marine debris in which they can become entangled. This refuge provided by the park is likely more significant for green sea turtles which spend more time within park waters as compared to loggerheads which often migrate as far away as the Bahamas to forage (Hart et al. 2013, 2015). The amount of vessel traffic in the park is generally lower than other areas in south Florida which lowers the risk of vessel strikes while the sea turtles are in DRTO. However, despite some relief while in the water, sea turtles still face multiple threats on the beaches.

Erosion and inundation of nests can be a major concern for a certain location, especially with rising sea levels associated with global warming (Hawkes et al. 2009). In 2015, nearly 10% of sea turtles nests were lost due to erosion, with an additional 14% over washed yet these percentages are normal (Figure 4.6.1). While the loss due to erosion is substantial, sea turtles have evolved a strategy to offset these natural events by laying large numbers of eggs and distributing their nests both spatially and temporally (NMFS and USFWS 2012). Thus, the total annual hatchling production is rarely affected by storm generated beach erosion and inundation (NMFS and USFWS 2012). In the past, sea turtles attempting to nest on Loggerhead Key were often disrupted by the invasive Australian Pines (*Casuarina equisetifolia*). Since their removal, false crawls have declined, but the remnants of the Australian Pines have continued to impact an average of 2.75 crawls per year (2009-2017).

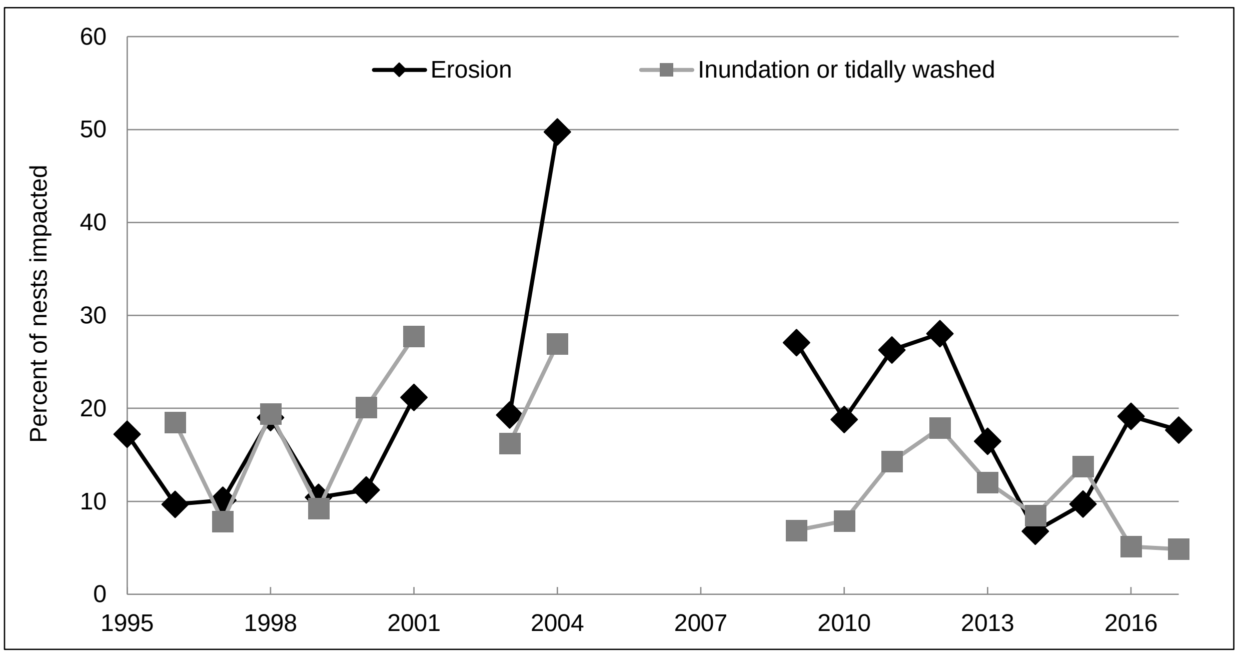


Figure 4.6.1. Percentage of sea turtle nests affected by erosion or inundation in the Dry Tortugas. (Data from K. Nimmo, DRTO).

Predation of sea turtle nests is another cause of concern. In DRTO, a major predator is the ghost crab (*Ocypode quadrata*) but recently non-native ants have been of concern. Despite concern with ant predation, the nesting success rate of both loggerhead and green turtles have remained stable in DRTO (Figure 4.6.2).

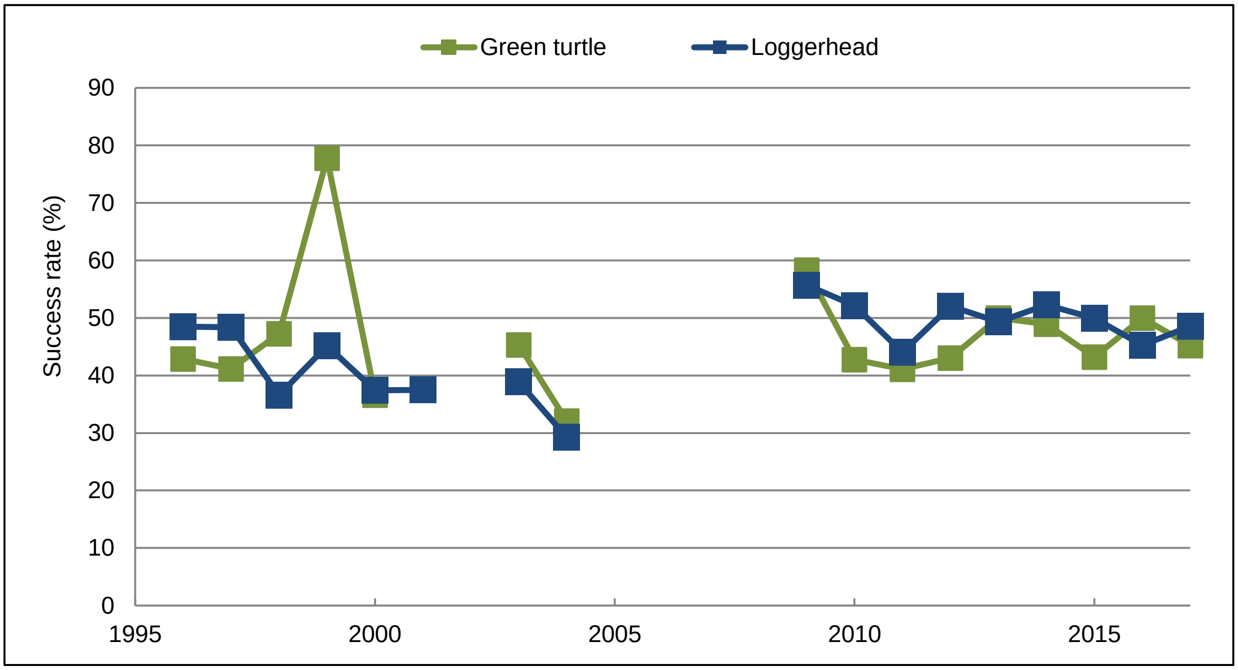


Figure 4.6.2. Nesting success rate of green and loggerhead sea turtles in Dry Tortugas National Park. (Data from K. Nimmo, DRTO).

4.6.3. Monitoring Effort

Information on the status of sea turtles in DRTO come primarily for nest surveys that have been conducted with varying levels of effort in DRTO since 1980. Until 1995 the survey effort ranged from a few days to months each year making interpretation difficult. Since 1995 a standardized survey has been conducted on the seven islands that make up the archipelago. Loggerhead and green sea turtles regularly nest in DRTO with East Key and Loggerhead Key typically accounting for 90% of their nesting sites. Leartherback nests are rare in DRTO, three nests were recorded in 2004 and one nest in 2013. DRTO staff and volunteers follow a standardized monitoring protocol that is compatible with the Florida Fish and Wildlife Conservation Commission (FWC) and other marine National Parks. In 2014 DRTO was included as part of a core set of index beaches that have been monitored throughout the State of Florida since 1979. The inclusion as an index beach is a testament to the consistency and quality of data that is collected by NPS staff and volunteers.

<u>Loggerhead turtles</u>

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 and USFWS 2008, Witherington et al. 2009). 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; (4) the Northwest Florida subpopulation occurring at Florida's panhandle beaches (Encalada et al. 1998, Bowen et al. 2005, NMFS and USFWS 2008, Shamblin et al. 2011).

The loggerhead turtles of Dry Tortugas are not only a distinct subpopulation but the National Marine Fisheries Service (NMFS) has distinguished the Dry Tortugas population of loggerheads as their own recovery unit (NMFS and USFWS 2012). Since sea turtles exhibit natal homing behavior, a decimated nesting population in one location may not be replenished by turtles from other areas (McClenachan et al. 2006). Therefore, it is vital to protect the sub-populations at DRTO and annual monitoring of this species is of high importance.

Loggerhead nesting season in Florida begins in the end of April/early May and continues through August (Meylan et al. 1995). During this time loggerhead turtles are seasonal residents of DRTO (Hart et al., 2010). After nesting the DRTO loggerhead turtles forage in the Gulf of Mexico and in the Bahamas (Hart et al. 2102, 2015). Since 2009, DRTO has accounted for between 41.5% and 71% of loggerhead sea turtle nesting in Monroe County despite representing between 11.1 and 17.2% of the sandy beachfront monitored (Nimmo 2015). This disproportionately high amount of the county-wide turtle nesting in comparison to area highlights the importance of DRTO for loggerhead turtles. In 2016 there were an estimated 122,706 loggerhead nests in the state of Florida, an all-time record since the inception of monitoring in 1979.

For the first two decades of state-wide monitoring, loggerhead turtle nesting remained fairly stable. A significant decrease in nests from 1999 to 2007 caused significant concern (Witherington et al. 2009), but numbers have begun to rebound since. Total nests and nest density (nests per km of beach) in DRTO follow a similar trend as statewide loggerheads (Figures 4.6.3 and 4.6.4). Recent years have had some of the highest number of loggerhead nests since standardized next surveys began in 1995.

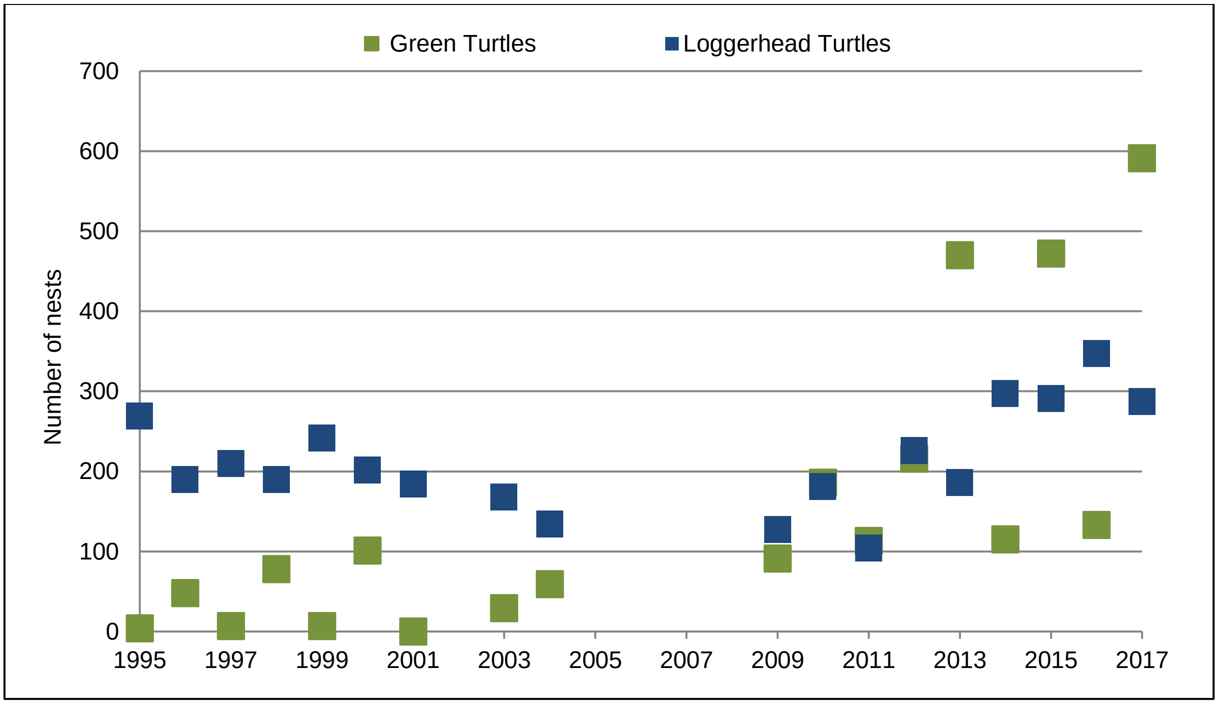


Figure 4.6.3. Number of loggerhead and green turtle nests in Dry Tortugas National Park since 1995. (Data from K. Nimmo, DRTO).

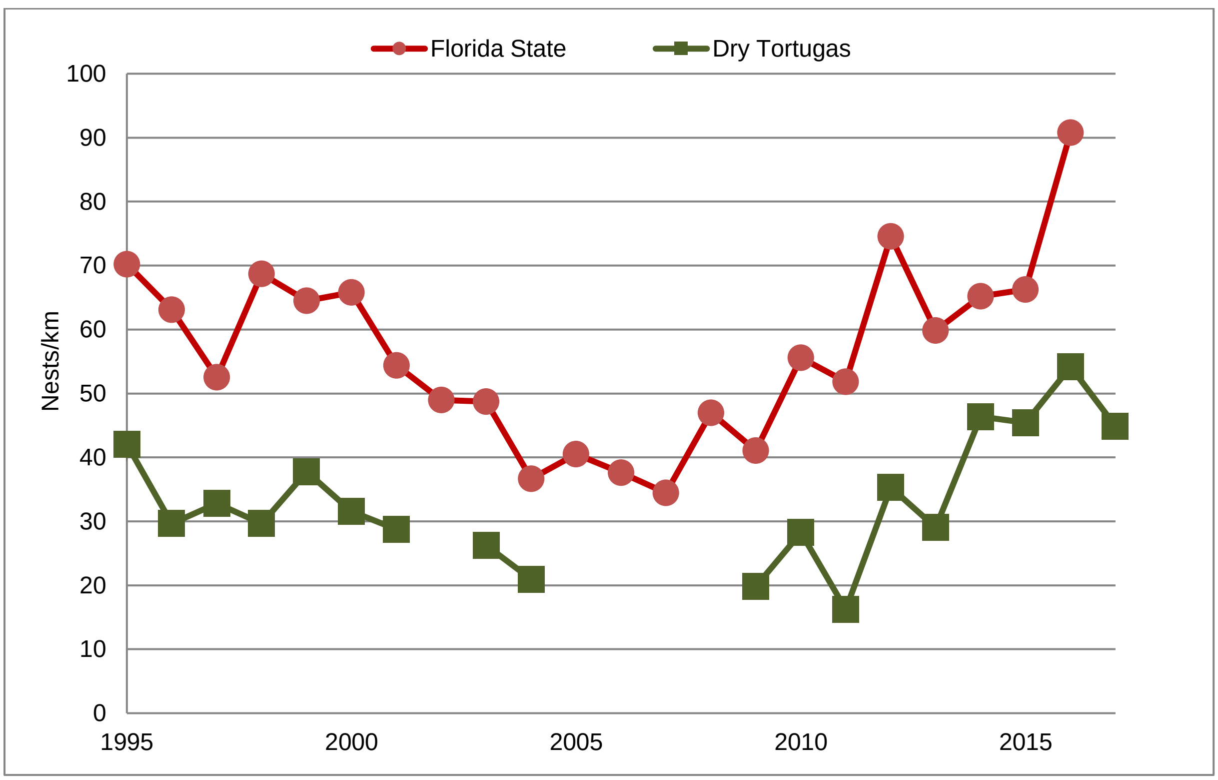


Figure 4.6.4. Loggerhead turtle nest density (nests/km) throughout Florida and in the Dry Tortugas. (Data from K. Nimmo, DRTO).

Green Sea Turtle

Florida's nesting population of green turtles is one of the largest remaining in the Caribbean Sea and western Atlantic Ocean (Ogren 1989, Meylan et al. 1995). Parsons (1962) considered the Dry Tortugas to have been a historically important rookery for green turtles but similar to loggerhead turtles, green turtles suffered greatly during the colonization of the new world and the fisheries established in the early 1900s. Similar to loggerhead turtles, green turtles exhibit natal homing behavior, which can be extremely detrimental to localized nesting areas if they are being over exploited. This behavior also emphasizes the importance in protecting their nesting habitat in DRTO to help the local population rebound. In addition to the importance of nesting beaches, green turtles use the marine waters of DRTO both during their inter-nesting period and throughout their foraging period (Hart et al. 2013). Healthy seagrass beds and shallow water habitat in DRTO are important for the growth rate of individuals and the recovery potential of the nesting stock (Kubis et al. 2009).

Green turtle nesting begins in June and continues through the end of September/early October (Meylan et al. 1995). Statewide 37,341 green turtle nests were documented in 2015 representing a record-high number of green turtle nests documented since the inception of state-wide monitoring in 1979. Since 2009, DRTO has accounted for between 83.7% and 96.4% of green turtle nesting in Monroe County (Nimmo 2015). Green sea turtle nesting has increased exponentially in DRTO since monitoring began (Figure 4.6.3 and 4.6.5). Many conservationists have declared the Florida population of green turtles as the fastest growing colony of this species in the world. Growth rates in Florida have even surpassed the celebrated increases in green turtle nesting documented by STC in Costa Rica, though the Tortuguero colony is still significantly larger than the population nesting in the U.S (Godfrey 2013). At DRTO, nesting density is double that recorded throughout the rest of Florida (Figure 4.6.5). Green turtles appear to have a 2 or sometimes 3 year cycle of high numbers of nests followed by a year of low nests which is especially pronounced in DRTO.

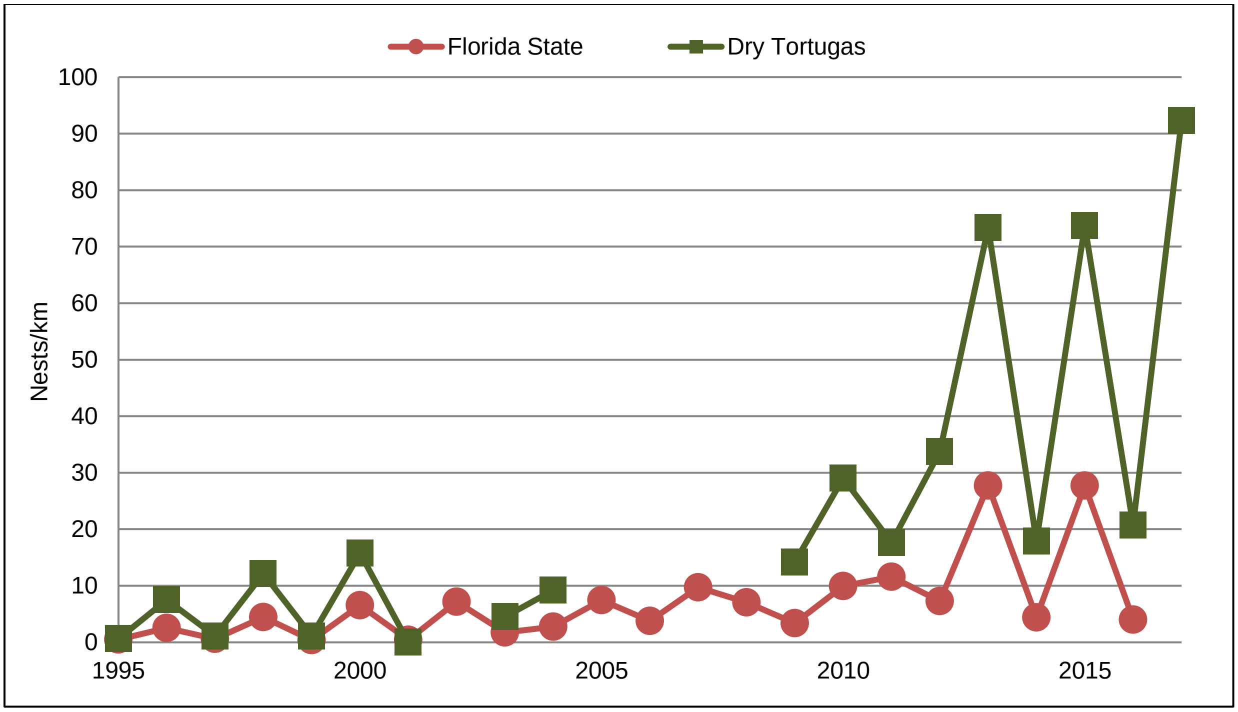


Figure 4.6.5. Green turtle nest density (nests/km) throughout Florida and in the Dry Tortugas. (Data from K. Nimmo, NPS- DRTO).

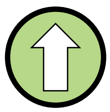
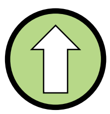
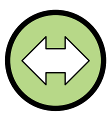
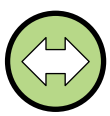
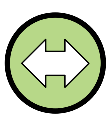
Leatherback, hawksbill and Kemp's ridley turtles

Unlike loggerhead and green turtles which nest annual on the beaches of DRTO, leatherback, hawksbill and Kemp ridley turtle nests are extremely rare. Although they are observed in the waters of DRTO, without information from nests it is difficult to determine their status within the park and if there has been any trends. However information on these turtles is collected when possible. In 2004, a leatherback nested three times on East Key. Unfortunately these nests were eroded during tropical storms. A little over ten years later another leatherback nest was found on Loggerhead Key in 2013. In 2013, ecologist Dr. Kristen Hart of USGS in Davie, FL first tagged a nesting hybrid hawksbill/loggerhead female on Loggerhead Key. Brian Shamblin's lab at University of Georgia confirmed the first tagged turtle to be ¼ hawksbill and ¾ loggerhead turtle. This turtle's mother was loggerhead, while the father was hawksbill. No previous hybridized turtles had been observed previously nesting within park waters. Since 2013, several more hybrid turtles have been observed nesting and subsequently tagged.

4.6.4. Conclusion

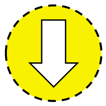
The number of loggerhead and green sea turtle nests has increased since lows in the late 2000s and are at near all-time highs since standardized monitoring began in 1995. This increase has followed a state wide trend yet the density of green turtles in DRTO has exceeded increases at other beaches throughout the State. The closure of East, Hospital, Bush, Middle and Long Keys during each nesting season since 2009 appear to be effective, although continual education and enforcement are required (Table 4.6.2). With the high rates of nesting on some of these keys, it is paramount to continue high levels of protection. Additional protection during nesting season may be required. Anchored vessels, especially the brightly lit commercial fishing vessels with underwater lights turned on, have been observed to disorient both hatchlings and nesting females. Hatchlings released on the beach were frequently observed to travel towards the brightest-lit boat in the vicinity, increasing potential for predation. Therefore, it is recommended that the park adopt a policy to restrict the use of underwater lights as well as bright deck lights. DRTO is a critical nesting area for loggerhead and green sea turtles and it is important to continue with monitoring and research to help understand the biology of these species.

Table 4.6.2. Condition and trends of loggerhead and green sea turtles in DRTO.

Criteria	Condition & Trend	Rationale	Reference Condition
Number of loggerhead nests		Loggerhead nests have increased since lows in the 2000s and are now at the highest number since standardized surveys began in 1995.	1995-2000 average.
Number of green sea turtle nests		Green nests have increased dramatically since standardized surveys began in 1995.	1995-2000 average.
Percent of nest effected by erosion or inundation		The number of nests effected by erosion or inundation has been relatively stable since 199. Erosion rates are similar to 1995-2000 average and inundation rates are lower.	1995-2000 average.
Loggerhead nesting success rate		There appears to be no trend in nesting success rate since 1995 but 2016 and 2017 rates were slightly above 1995-2000 average.	1995-2000 average.
Green sea turtle nesting success rate		There appears to be no trend in nesting success rate since 1995 but 2016 and 2017 rates were slightly above 1995-2000 average.	1995-2000 average.

4.7. Birds

Table 4.7.1. Overall condition and trend of seabirds in DRTO.

Attribute	Condition & Trend	Interpretation
Seabirds		Sooty tern nesting pairs have declined to near 100 year lows. Masked booby counts have increased since first sited, but a four year decline has raised moderate concern. Magnificent frigate bird counts have remained relatively stable. After an initially successful re-introduction roseate terns, nesting numbers have declined The status of brown noddies, least terns and bridled terns is unknown. There is significant concern regarding nesting habitat loss due to rising sea levels.

4.7.1. Importance

The Dry Tortugas provides both shelter and a strategic stopover for an amazing diversity of birds that pass through the region on their spring and fall migrations. Of the 292 species of birds that have been recorded in DRTO, 60% have been identified as migrants and 24% as vagrant (outside the species usual range). Northbound migrants arrive as early as mid-February while spring migration increases substantially during March and peaks during April through mid-May. During these months, the greatest number of birds can be observed during poor weather when many birds are forced by exhaustion to stop in the Tortugas for a chance to rest and forage (Harrington and Dinsmore 1975). In addition to these seasonal visitors there are 36 species of birds that are considered resident and 9 that breed within the park. The Dry Tortugas supports the only large breeding colonies for sooty terns (*Sterna fuscata*), masked booby (*Sula dactylatra*), magnificent frigatebird (*Fregata magnificens*), brown noddy (*Anous stolidus*) and bridled tern (*Onychoprion anaethetus*) in the lower 48 states.

Birds have an important ecological role in DRTO and are a major draw for visitors. They are also are excellent indicators of ecosystem health and integrity and are early responders to change across the landscape, responding quickly in foraging and nesting patterns to both habitat degradation and to habitat improvement and restoration. Early ornithologists noted the amazing number of resident and breeding birds in the Dry Tortugas in the 1800s but by the 1890s the numbers of gulls and terns had declined significantly as fishermen frequented the islands to collect eggs for consumption and for a commercial market in Key West (Scott 1890). The establishment of the National Monument in 1935 provided protection for the remaining birds. Since then nesting populations have fluctuated with natural changes in vegetation caused by hurricanes, shifting islands and available habitat and a variety of human influences. Monitoring has primarily focused on select species that nest on the islands. It is these birds that are most affected by the conditions in DRTO and that are used in this assessment.

4.7.2. Sooty terns

The sooty tern is a circumglobal species that can be found throughout the worlds tropical oceans. They are a highly migratory species spending their early years entirely at sea and return to land only to breed. In DRTO, Bush Key hosts the only breeding colony of sooty terns in the continental United States. Audubon was the first to mention sooty terns in the area in 1835 and since then numerous visiting ornithologists have reported on the sooty terns in the area. The colony has been under various forms of protection since overharvesting in the late 1800s and early 1900s reduced the number of breeding birds to 5,000 birds (Roberston 1964). Estimates of a normal adult Sooty Tern population in the Dry Tortugas range between 60-100,000 individuals (Robertson 1946, Rogers et al. 1996). In 2001, 40,000 breeding pairs were estimated to occupy Bush Key, but this number has been declining (Colochero et al. 2010) and in 2016 an estimated 16,000 pairs were present (Figure 4.7.1) (Cope 2016). Along with declining numbers there has been a shift in the start of the breeding season from June in the late 1800s to January today. This shift towards winter breeding coincides with the occurrence of avian predators such as herring gulls, peregrine falcons, cattle egrets and night herons wintering in DRTO (Colochero et al. 2010). Sooty terns which normally nest on the sand have shifted their habitat preference to areas with increased over hanging vegetation presumably to offer cover from predatory birds (Colochero et al. 2010). This dependency on vegetation comes at a cost as shoreline erosion, hurricanes and other large storms can alter the vegetation and possibly disrupt breeding success.

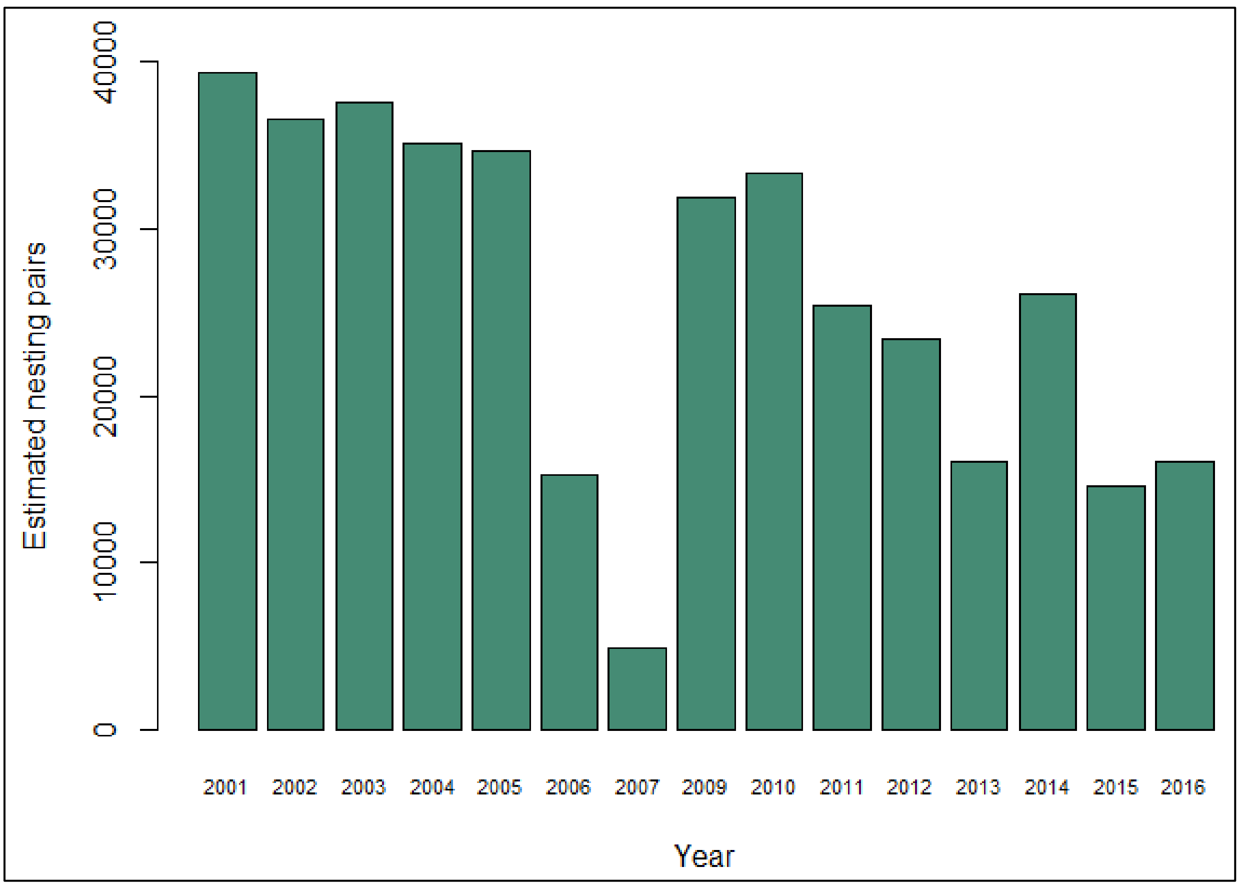


Figure 4.7.1. Estimated sooty tern nesting pairs in DRTO from 2001 to 2016. (Reprinted from Cope 2016).

4.7.3. Masked booby

The masked booby is a large gannet-like species with a pantropical oceanic distribution. They spend most of their time near breeding colonies and are known for diving into the ocean at high speeds for fish. They typically have small nesting colonies where they lay their eggs on the ground. The only known nesting area in the contiguous United States is at DRTO. The first report of nesting at DRTO was in 1984 when around 20 masked boobies where observed at DRTO (Clapp and Roberston 1986). They have been found nesting on Middle Key but more recently the colony has been reported on Hospital Key. Masked boobies which nest during the spring, are year-round residents of the park and are counted during the Audubon's Society's annual Christmas Bird Count (CBC). These counts have been conducted by staff and volunteer bird experts at DRTO since 2004. From 2004 until 2013 the numbers of masked boobies during the CBC steadily increased to 91 birds (Figure 4.7.2). In 2016 numbers had declined for the third consecutive year to 56. At the writing of this report, preliminary numbers from the 2017 CBC indicated another decline warranting moderate concern.

Masked booby on DRTO beach. (Photo by Judd Patterson).

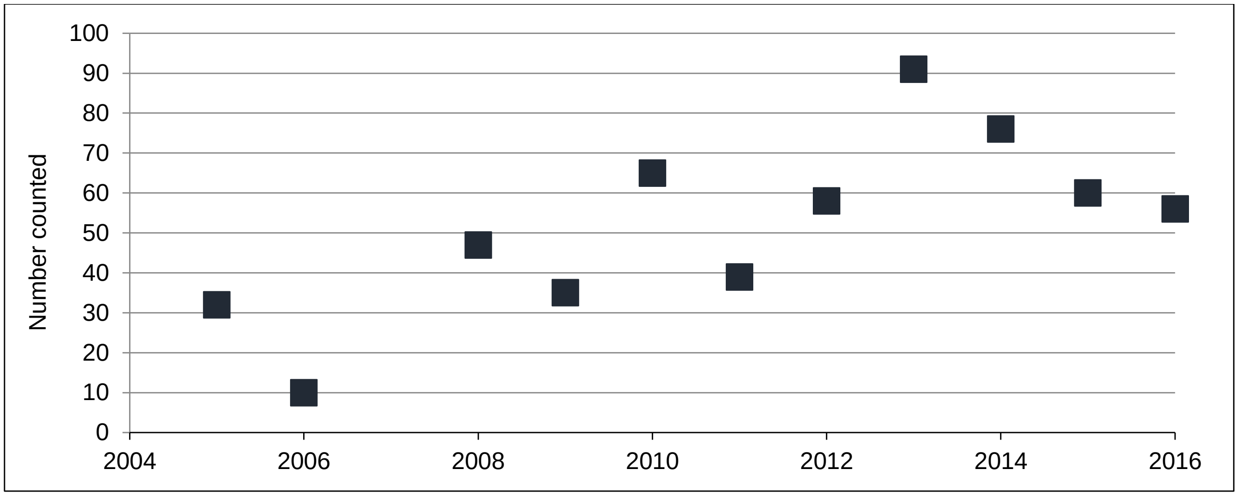


Figure 4.7.2. Number of masked boobies counted during the Audubon Society's annual Christmas Bird Count at the Dry Tortugas National Park from 2004 to 2016. Values are total birds counted. (Data from National Audubon Society).

4.7.4. Magnificent frigatebird

Magnificent frigatebirds are pantropical and can be found throughout the Caribbean with breeding colonies typically found on small islands. Roughly 50% of their colonies in the Caribbean have been extirpated and the only known breeding colony in the contiguous United States is found at DRTO. In 1988 a colony existed in the Marquesas Keys just west of Key West, FL, but the numbers had gradually declined since the first observation in 1969 and it is thought that remaining colony moved to DRTO (FWC 2003). They often forage near their nesting colonies but can make extensive trips thousands of km from their colony to visit other breeding sites or to forage (Weimerskirch et al. 2006). Frigatebirds found foraging in the Florida Keys have been tracked to Mexico and Cuba to reach breeding sites, while those that breed in DRTO typically remain in Florida (ARCI). Their nests are typically built on low vegetation (Diamond 1973) but in DRTO they nest in the black mangroves on the south end of Long Key. These mangroves were absent in the early 1900s but seemed to be present by the 1940s and were a lush forest by the 1970s which perhaps prompted the frigatebirds to move in initially. The hurricanes in 2005 battered these trees and they now persist in a much diminished state. There is concern that the remaining trees are vulnerable to a big storms and that if they are killed, the colony may be forced to relocate.

In September of 1949, Sprunt (1951) observed around 200 frigatebirds roasting and resting on Bush Key which at the time he noted was 'heavily grown'. In 1988, 40 pairs were observed at DRTO which built up to 75 pairs in 1991 (FWC 2003). Currently, the best information available on frigatebird usage comes from the annual CBC that is conducted during nesting season. Since 2004 the count has ranged from a high of 315 to a low of 85 with an average of 158 total frigatebirds counted (Figure 4.7.3). There has been no apparent trend in 10 years of counts and numbers are similar to those reported by Sprunt (1951) over a half a century ago.

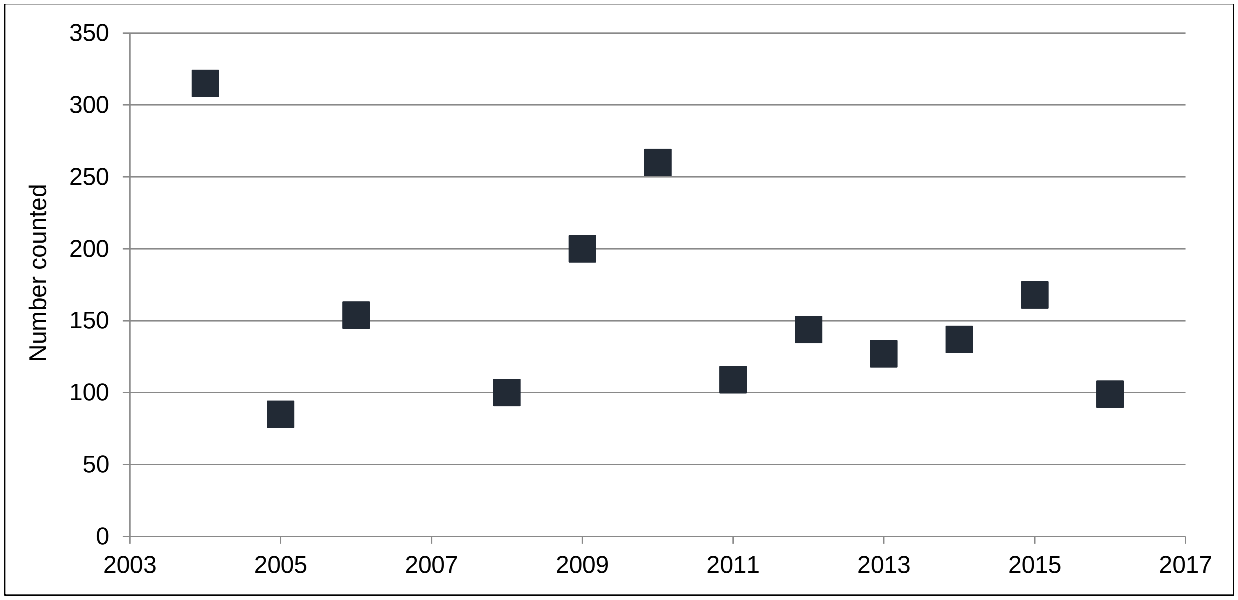


Figure 4.7.3. Number of magnificent frigatebirds counted during the Audubon Society's annual Christmas Bird Count at the Dry Tortugas National Park from 2004 to 2016. Values are total birds counted. (Data from National Audubon Society).

Magnificent frigatebirds riding an updraft in DRTO. (Photo by Judd Patterson).

4.7.5. Brown noddies

Since the 1900s, there have been several thousand brown noddies breeding in DRTO (Roberston 1964). These numbers declined to several hundred during the 1940s and 1950s but had rebounded by the 60s (Roberston 1964). In the 1980s, there were 2,000-3,000 brown noddies nesting at DRTO (Hensley and Hensley 1995). Satellite tracking data suggests that the home range of brown noddies during the nesting period is relatively small and mostly encompassed within the park and surrounding marine protected areas (Maxwell et al. 2016). However the sites where they are likely foraging are outside the park along the continental shelf and near the Loop Current (Maxwell et al. 2016). There has not been a recent update on brown noddie counts but anecdotal reports suggest that in the late 2000s 5,000-6,000 birds were present (Judd Patterson, SFCN, pers. comm. 2016) which could represents roughly 2,000-3,000 nests.

4.7.6. Roseate terns

The Dry Tortugas National Park was the former strong-hold of the roseate tern prior to the 1970s. The terns slowly abandoned the Dry Tortugas and settled on roof and ground sites in the Lower Keys. Pelican Shoal a small island located 5 miles south of Boca Chica Naval Air Station provided a nesting site for approximately 300 pairs of roseate terns. This area was designated as Critical Wildlife Area by the state of Florida through several hurricanes destroyed Pelican Shoal in 2005. Since then, the state and federally threatened roseate tern can only be found nesting in the Florida Keys on rooftops in Marathon.

Fortunately for the roseate terns not all of the storms effects were negative. The storm surge deposited a substantial amount of coral rubble on Long Key in DRTO which covered over existing vegetation and expanded an area of coral rubble already present. This newly created section of Long Key strongly resembled the former habitat of the now submerged Pelican Shoal. In an effort to recolonize the Dry Tortugas National Park with roseate terns, Ricardo Zambrano and Sharyn Hood with the Florida Fish and Wildlife Conservation Commission (FWC) and Sonny Bass with NPS deployed social attraction equipment at Long Key on April 12, 2006. A solar-powered compact disc player, amplifier, and water resistant speakers were placed next to forty plastic roseate tern decoys to broadcast roseate tern calls 24 hours a day. On July 11, 2006, FWC and the NPS discovered 33 nests on Long Key. On July 27, 2006, 42 adults and 16 chicks of differing ages were found. From 2006 until 2010, the number of nests remained above 27, but then in 2011 there was a decline to 12 nests (R. Zambrano, unpublished data). The number of rest have remained below 12 up until 2016 with the exception of a high of 43 in 2013 (R. Zambrano, unpublished data).

4.7.7. Least terns

Least terns have been listed as indicators for ecosystem health in the coastal and marine environments of South Florida as part of MARES (Ogden et al. 2014) and listed as threatened by the State of Florida (FWC 2011). Approximately 1000 least terns nested historically in the Dry Tortugas (Kushlan and White 1985) but since at least 2005 they have not nested at DRTO (Judd Patterson SFCN, pers. comm. 2016). Their breeding population appeared to be stable in the Florida Keys in 1987 at between 700-900 pairs (Hovis and Robson 1989). However the loss of natural beach habitats has almost entirely limited their nesting sites in southeastern Florida to rooftops (Zambrano et al. 1997). There has been no population viability analysis conducted for the Florida least tern population

(FWC 2011) but given their loss of habitat throughout the State, the Dry Tortugas may offer an important site for their recovery.

4.7.8. Bridled Tern

This species was first confirmed breeding in the Florida on Pelican Shoals off Boca Chica Key in 1987 (Hoffman et al. 1993) but it is unclear if they are still there. After the Roseate Tern success at DRTO, small coral “caves” were created on Long Key with coral rubble to see if Bridled Terns would start nesting in the park. It was successful and several nests were confirmed in 2012.

4.7.9. Nesting Habitat

The islands of DRTO are low lying and there is significant concern that sea level rise and shoreline erosion may continue to reduce the amount of nesting habitat available birds. Middle and Hospital Key, the preferred nesting sites of masked boobies, are seasonally awash and constantly moving. Brown noddies, roseate, least and bridled terns are found on islands with a little more elevation; but not much. The magnificent frigatebirds which prefer black mangroves for their nesting sites are also extremely vulnerable if the trees die due to flooding. The DRTO is dynamic system and these birds have managed to adapt in the past, but the current trend of rising sea level is not encouraging.

4.7.10. Conclusion

Since the overharvest of eggs during the late 1800s and early 1900s, the populations of breeding colonies have fluctuated significantly. Currently sooty tern nesting pairs are near 100 year lows. Masked boobies numbers are greater than when first discovered in 1984, but a four year decline is cause for concern along with increased vulnerability to rising sea levels and loss of nesting habitat. Magnificent frigate birds appear to have similar numbers as observed in 1951 and appear to be stable. The last estimates of brown noddies from the 1980s suggests that their population size at DRTO is similar to the early 1900s. Roseate terns, which appeared to have a successful re-introduction in 2006, have had very few nests in the last three years. The status of least and bridled terns is unknown (Table 4.7.2).

Table 4.7.2. Conditions and trends of birds at DRTO.

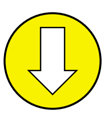
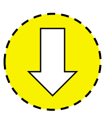
Criteria	Condition & Trend	Rationale	Reference Condition
Sooty Tern nesting pairs		At 16,000 breed pairs recorded in 2016, numbers of sooty terns near 100 year lows.	60,000-100,000 individuals.
Masked booby counts		The number of masked boobies has increased since the first observed nesting in DRTO, but a recent four year declined warrants moderate concern. There is also some uncertainty in setting a reference condition on a relatively recent addition to the park and the use of single annual count as a metric from which to measure their condition.	20 individuals.

Table 4.7.2 (continued). Conditions and trends of birds at DRTO.

Criteria	Condition & Trend	Rationale	Reference Condition
Magnificent frigatebird counts		Counts remain stable over the last 10 years.	200 individuals.
Brown noddies		Current status unknown.	2,000-3,000 nests.
Roseate terns		After an initially successful re-introduction, roseate tern nesting numbers have declined.	Occurrence of nests.
Least terns		Current status unknown.	Occurrence of nests.
Bridled terns		Current status unknown.	Occurrence of nests.
Overall nesting habitat		The historic loss of islands, sea level rise and the vulnerability of island shorelines to erosion is a significant concern for nesting habitat.	2009 Vegetation map

Chapter 5. Discussion

5.1. Overall Condition

The natural resources of DRTO are highly connected to the wider south Florida and Caribbean environment. Birds, fish and turtles that are key components of the park's marine ecosystem frequently move inside and outside of park boundaries (Farmer and Ault 2011, Hart et al. 2015, Maxwell et al. 2016). The overall health of these migratory species is often determined by natural resource management decisions made at much larger scales, but the remote location of DRTO has afforded them a partial refuge from anthropogenic stress that they encounter elsewhere during their movements. For the other less mobile resources (stony corals, seagrasses, marine invertebrates and terrestrial vegetation), regional stresses such as the quality and temperature of ocean water, that are outside of the park's control, can also have a major impact on their condition. The average condition status score of the seven resources assessed in this report was 64 (Tables 5.1, 5.2). This is just below the suggested NPS cut off for a good condition (66). Two resources had an increasing trend, two had a decreasing trend, and three had no trend. Based on these assignments and the NPS scoring protocols, the resources in DRTO are in moderate condition with no overall trend.

Table 5.1.1. Overall conditions and trends of natural resources within DRTO.

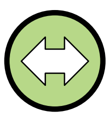
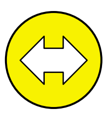
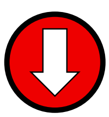
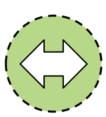
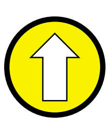
Attribute	Condition & Trend	Interpretation
Seagrass		A baseline of acreage has recently been established and there appears to be no major change since 2010. Monitoring effort is in place suggest that there has been no major trend in species composition, density or elemental composition since 2011.
Terrestrial vegetation		The removal of exotic plants has been successful on Loggerhead Key but there is moderate concern that rising sea level will reduce total acreage available to the native vegetative community. Continued shoreline erosion and future island loss is of significant concern. A comparison to the 2009 baseline map has not been made.
Stony corals		Measurements from several monitoring projects indicate that there has been a decline of coral cover within DRTO. Coral cover within the park is still greater than other regions in south Florida but below a desired condition based on historical data. Coral diseases and bleaching events continue to negatively affect the coral community are of major concern.
Lobster, queen conch and long-spined sea urchin populations		Lobster, conch and long-spined sea urchins are all protected species within DRTO. Lobster size and fecundity within the park have been shown in the past to represent a healthy population from which to compare other regions where they are heavily fished. Little is known about queen conch aggregations within the park but they are protected from harvest. Long-spined sea urchins have undergone Caribbean wide decline and their populations including those in DRTO are slowly rebounding.
Reef fish and sharks		Occupancy rates, density and the overall abundance of principal species from the snapper and grouper complex have been increasing in DRTO since 1999. Although the average size of exploited phase fish is larger for several species in comparison the rest of south Florida, they are still smaller than expected with a sustainable fishing mortality rate which warrants moderate concern.

Table 5.1 (continued). Overall conditions and trends of natural resources within DRTO.

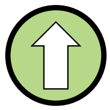
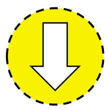
Attribute	Condition & Trend	Interpretation
Loggerhead and green sea turtles		The number of loggerhead and green turtle nests has been increasing and is at all-time highs since standardized monitoring began. The number of nests affected by erosion or inundation has been relatively stable since 1995. There has been no trend in nesting success rate of both loggerheads and green turtles since 1995.
Seabirds		Sooty tern nesting pairs have declined to near 100 year lows. Masked booby counts have increased since first sited, but a four year decline has raised moderate concern. Magnificent frigate bird counts have remained relatively stable. After and initially successful re-introduction roseate terns nesting numbers have declined The status of brown noddies, least terns and bridled terns is unknown. There is significant concern regarding nesting habitat loss due to rising sea levels.

Table 5.1.2. Indicator level conditions and trends for the seven key resources in DRTO.

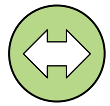
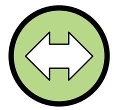
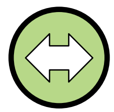
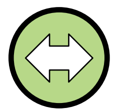
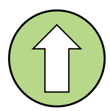
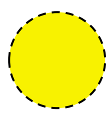
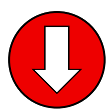
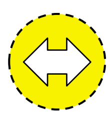
Resource	Criteria	Condition & Trend	Rationale	Reference Condition
Seagrass	Acreage		Seagrass acreage in DRTO appears to be stable.	2010 acreage estimated from benthic habitat report (Waara et al. 2011).
	Species composition		Species composition has been stable from 2011-2017	Average from first three years of FIU sampling (2011-2013).
	Percent coverage		Percent coverage of seagrass has been stable from 2011-2017	Average from first three years of FIU sampling (2011-2013).
	Overall condition and trend of seagrass		–	–
Terrestrial vegetation	Presence of exotic plants		The large removal of Australian Pines from Loggerhead Key and the continued monitoring and removal of exotics throughout the park has dramatically reduced the number of exotic plants.	Minimal occurrence of exotics.
	Total acreage		No trend can be established but since 2009 but there is moderate concern of loss of suitable habitat due to rising sea levels.	Baseline established from the 2009 Vegetative Report (Luciani et al. 2011).
	Coastal Erosion		11 islands originally charted in DRTO have been reduced to seven. The remaining islands all have moderate to very high shoreline vulnerability.	Coastal Vulnerability Index (Pendleton et al. 2005)
	Overall condition and trend of terrestrial vegetation		–	–

Table 5.1.2 (continued). Indicator level conditions and trends for the seven key resources in DRTO.

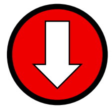
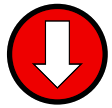
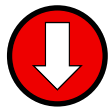
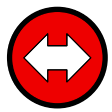
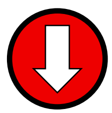
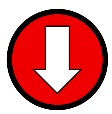
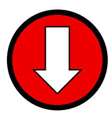
Resource	Criteria	Condition & Trend	Rationale	Reference Condition
Stony corals	Percent coverage (SFCN long term sites)		Coral coverage has been steadily declining at all three monitoring sites since each was first monitored.	Increasing coral coverage to site specific baseline
	Percent coverage (CREMP long term sites)		There has been a general trend of declining coral overage across all monitored sites.	Increasing coral coverage to site specific baseline.
	Bleaching prevalence (FRRP)		3 of the last 4 FRRP surveys have had bleaching prevalence greater than 20%.	Low annual prevalence (<20%) and infrequent mass bleaching events (≤ every 5-10 years).
	Recent mortality (FRRP)		Recent mortality as measured by FRRP was greater than 1% in 2014 and 2015 and 0.9% (±0.17%) in 2016. These levels are greater than the reference condition.	≤ 1% mortality.
	Pillar and elkhorn coral		Both species have been affected by white plaque and white pox disease respectively, and suffered considerable tissue loss at sites monitored by FWRI.	A genetically viable population.
	Seawater temperature		Exceeded bleaching threshold for more than 40 days in 2014, 2015 at Bird Key reef and in 2015 at Santa's Village and Loggerhead reefs.	Reef temperatures exceed bleaching threshold (30.5 °C) for less than 40 days (Manzello et al. 2007).
	Overall condition and trend of stony corals		–	–

Table 5.1.2 (continued). Indicator level conditions and trends for the seven key resources in DRTO.

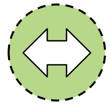
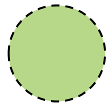
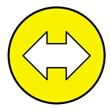
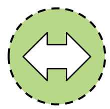
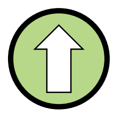
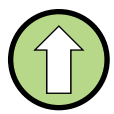
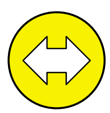
Resource	Criteria	Condition & Trend	Rationale	Reference Condition
Selected marine invertebrates	Lobster size and fecundity		Lobsters are protected in DRTO and it is likely that their size and fecundity are similar to the 1990s baseline but there has been no recent study.	Size frequency and fecundity reported from late 1990s (Bertelson and Matthews 2001).
	Occurrence of conch aggregations		Breeding aggregations have been reported in DRTO (1991) but there has been limited survey effort since. They are protected from harvest so their condition is expected to be good.	Sites with adult densities >200 individuals per ha.
	Density of long-spined sea urchin		Urchin density is greater than anywhere else in south Florida, yet it is still below the desired state.	> 1 per m^2 in shallow water sites.
	Overall condition and trend of selected marine invertebrates		–	–
Reef fish and sharks	Density of principal species		5 out of 5 principal species had increase in density since baseline.	Increase from 1999 baseline.
	Density/ relative abundance of principal species		DRTO has a higher percentage of the south Florida adult population than expected by area for 4 out 5 principal species.	Density of principal species greater than or equal to Florida Keys average.
	Average length in the exploited phase of principal species		The $\bar{L}$ of principal species is slightly larger than estimates from the Florida Keys RVC for 4 out of 6 principal species but it is lower than $\bar{L}$ at F_{msy} which indicates that stocks are overfished.	$\bar{L}$ > estimated $\bar{L}$ for Fmsy.

Table 5.1.2 (continued). Indicator level conditions and trends for the seven key resources in DRTO.

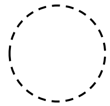
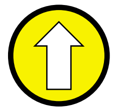
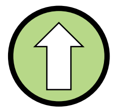
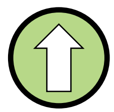
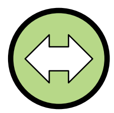
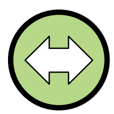
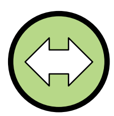
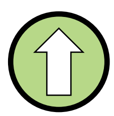
Resource	Criteria	Condition & Trend	Rationale	Reference Condition
Reef fish and sharks (continued)	Shark abundance		There is currently no program in place to monitor shark populations in DRTO	No reference condition available.
	Overall condition and trend of reef fish and sharks		**–**	**–**
Loggerhead and green sea turtles	Number of loggerhead nests		Loggerhead nests have increased since lows in the 2000s and are now at the highest number since standardized surveys began in 1995.	1995-2000 average.
	Number of green sea turtle nests		Green nests have increased dramatically since standardized surveys began in 1995.	1995-2000 average.
	Percent of nest effected by erosion or inundation		The number of nests effected by erosion or inundation has been relatively stable since 199. Erosion rates are similar to 1995-2000 average and inundation rates are lower.	1995-2000 average.
	Loggerhead nesting success rate		There appears to be no trend in nesting success rate since 1995 but 2016 and 2017 rates were slightly above 1995-2000 average.	1995-2000 average.
	Green sea turtle nesting success rate		There appears to be no trend in nesting success rate since 1995 but 2016 and 2017 rates were slightly above 1995-2000 average.	1995-2000 average.
	Overall condition and trend of loggerhead and green sea turtles		**–**	**–**

Table 5.1.2 (continued). Indicator level conditions and trends for the seven key resources in DRTO.

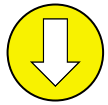
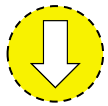
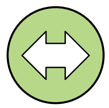
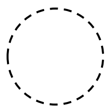
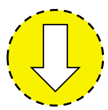
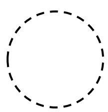
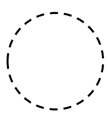
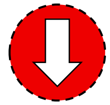
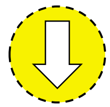
Resource	Criteria	Condition & Trend	Rationale	Reference Condition
Seabirds	Sooty Tern nesting pairs		At 16,000 breed pairs recorded in 2016, numbers of sooty terns near 100 year lows.	60,000-100,000 individuals.
	Masked booby counts		The number of masked boobies has increased since the first observed nesting in DRTO, but a recent four year declined warrants moderate concern. There is also some uncertainty in setting a reference condition on a relatively recent addition to the park and the use of single annual count as a metric from which to measure their condition.	20 individuals.
	Magnificent frigatebird counts		Counts remain stable over the last 10 years.	200 individuals.
	Brown noddies		Current status unknown.	2,000-3,000 nests.
	Roseate terns		After an initially successful re-introduction, roseate tern nesting numbers have declined.	Occurrence of nests.
	Least terns		Current status unknown.	Occurrence of nests.
	Bridled terns		Current status unknown.	Occurrence of nests.

Table 5.1.2 (continued). Indicator level conditions and trends for the seven key resources in DRTO.

Resource	Criteria	Condition & Trend	Rationale	Reference Condition
Seabirds (continued)	Overall nesting habitat		The historic loss of islands, sea level rise and the vulnerability of island shorelines to erosion is a significant concern for nesting habitat.	2009 Vegetation map.
	Overall condition and trend of seabirds		**–**	**–**

Although all of the resources assessed in this report are affected at some level by far field factors, DRTO management decisions are still important. Seagrass beds which are relatively undisturbed by human impacts in DRTO are healthy, proving a tremendously important nursery of foraging ground for a large number of species. Restoration efforts in the 1990s lead to the eradication of almost all of the invasive Australian pines on Loggerhead Key which was a significant concern to the health of the vegetative community and the animals which are dependent on it. Since then, periodic removals have kept the occurrence of exotic plants to a minimum. As a result of management practices, DRTO offers one of the few remaining places that several birds and sea turtles can find critically important nesting habitat unaffected by human development.

Commercial fishing is not allowed in the park and the impacts of recreational fishing are limited by the distance from Key West and the large amount of area off limits to fishing. These factors have mattered; the density of key reef fish species is greater in DRTO than anywhere else in the south Florida reef tract. However, the size structure of exploited species suggests that fishing mortality is still an issue and there is room for improvement. Neither commercial nor recreational lobster fishing has been allowed with DRTO since 1974 and the population of lobster residing within park boundaries have likely benefitted tremendously from this protection. Likewise there is no harvest of queen conch allowed within DRTO and although there has been no park-wide survey of their population, they are also likely to be doing well. Long-spined sea urchins which declined drastically throughout the Caribbean in the early 1980s have yet to make a significant come back in south Florida, but data from multiple coral monitoring programs in DRTO suggest a slow increase in their abundance.

Southern stingrays (*Dasyatis americana*) can be found in seagrass and sandy areas in DRTO. (Photo by Rob Waara).

The only resource within DRTO warranting significant concern are the stony corals. Rising sea level temperatures and increased frequencies of bleaching events have taken their toll. Although DRTO still has some of the highest coral coverage in south Florida, coverage has declined significantly over the last few decades. This decline is part of a worldwide trend and unfortunately the corals of DRTO have not been spared.

5.2. Data Availability

There is a long history of scientific research and discovery in the waters surrounding the Dry Tortugas. Louis and Alexander Agassiz mapped the islands and described the benthic communities during the late 1800s. In 1904, the first tropical marine lab in the western hemisphere, Carnegie's Tortugas Marine Laboratory, was established on Loggerhead Key. From 1878-1996 over 424 reports and papers were written about the resources within DRTO's boundaries (Schmidt and Pikula 1997). Since then, undoubtedly hundreds of more reports and articles have been written. This research is instrumental in understanding the complex ecosystem within DRTO's boundaries and can be incredibly valuable in establishing historic baselines from which to measure current conditions. However, there is a difference between scientific research and data that has been collected for monitoring purposes. Fortunately in the DRTO there has also been considerable effort in establishing long term monitoring programs for a number of key resources.

Detailed benthic habitat maps that show the extent of seagrass habitat have been created for DRTO providing an important baseline from which subsequent mapping data can be compared. FIU's Seagrass Ecosystem Research Lab has been monitoring several permanent sites in DRTO providing an important time series of species composition, density, and elemental tissue content of seagrasses. A terrestrial vegetation map has recently been completed and provides a baseline for future terrestrial mapping products. However, there is no standard monitoring program in place on land so there may be gaps in time where changes in the community are not detected. There has also been a comprehensive effort to map the marine benthic community which provides a baseline for the total acreage of different habitats and a foundation for the design of large surveys. In addition, multiple coral reef monitoring programs are in place in DRTO. SFCN, FWC, FRRP and the National Coral Reef Program all conduct annual or biannual monitoring of corals and associated benthic organisms throughout the park. Reports from SFCN and FWC are available and data from FRRP is available online. At the time of this report the National Coral Reef Programs benthic data was not yet available. Each monitoring programs has slight differences in protocols but there may be some opportunity for consolidation without lowering the quality of data provided for DRTO. Long-spined sea urchins are monitored during all of the above mentioned coral monitoring programs offering an additional benefit to these surveys. There are currently no monitoring programs in place for spiny lobsters or conch although SFCN has plans for lobster surveys in the near future.

Old coal dock pilings at Fort Jefferson. (Photo by David Bryan).

In 1999, the RVC was extended out to DRTO and the Dry Tortugas region. This collaborative multiagency survey has been the model for other reef fish monitoring programs in the tropical US jurisdictions and has provided both a wealth of information on the status and trends of reef fish within DRTO and in the surrounding areas. Biannual surveys are conducted due to budgetary constraints but annual surveys are recommended. Data from these surveys is available online along with periodic reports. There is no survey in place for sharks and there is a lack of data on their condition within the park.

Historically there has been some inconsistencies in sea turtle nesting monitoring effort at DRTO, but since 1995, there has been a standardized monitoring program in place. In 2014, DRTO was included as a Florida index site; a testament to the quality of data being collected. Up-to-date annual summaries of these data are available along with reports. The collection of sea bird nesting data in DRTO has a long history. Unfortunately all of these data are not readily available and there are some inconsistencies in methodology. Significant work has been done in reconstructing sooty tern nesting data and similar reconstructions would benefit the monitoring of other species.

5.3. Recommendations

The condition and trends of the natural resources in DRTO range from warranting a significant concern with a declining trend such as coral, to a good condition and increasing trend such as sea turtles. The remote location, which has limited modern human impacts, and key management actions that have restricted commercial and recreational fishing in most of the park's waters have been tremendously beneficial. One of the main stressor to the park, global warming, is outside the influence of park management. Because of the unique location of the park, the regulations already in place and the far-field characteristic of a major stressor causing the decline of several resources, our recommendations are mostly focused on the collection and dissemination of key monitoring data to help establish and track condition trends.

There are a number of long term monitoring programs that collect a variety of data on benthic organisms in the park including stony corals. Some of this data is available in a timely fashion while other data is not. We recommend that the park service asks all researchers to generate timely reports including the analysis on the conditions and trends of the benthic community. A better system for data sharing would also allow researches from separate programs to compare their results, ideally allowing for a comprehensive view of the benthic community. To date, a bulk of coral monitoring reports (including this one) have focused on coral coverage. This metric may not be the best for monitoring trends in the benthic community; especially with the already low coral coverage of today. We recommend that the park encourages collaborators to continue to think beyond coral coverage and develop other demographic metrics by which to evaluate changes in the benthic community.

Surveying of nesting birds has a long history at DRTO, but other than data on sooty terns most information from these surveys is not available. DRTO provides the only nesting site in the continental United States for five species of sea birds and it would be beneficial to have standardized nesting bird counts. The collection of this data should also include annual reports and/or access to the data to allow for timely tracking of trends. There has been no significant survey of lobster or conch in the park. Both species are protected so there is no essential need for frequent surveys, but an expansive initial survey could provide a much needed baseline with additional efforts every 4 or 5 years to monitor trends. Sharks are an apex predator that play a major role in managing the health of marine ecosystems. There has been no baseline survey of sharks within DRTO and we highly recommend that the park considers conducting one in the near future.

The condition and trend of stony corals in the park warrants significant concern. Unfortunately the decline of stony corals is part of a worldwide trend as a result of rising sea temperatures and outbreaks of coral diseases and local actions are limited. Probably the most important actions the park can take (in addition to their current management actions of shifting from anchoring to mooring buoys and educating park visitors to reduce diver and snorkeler damage and boating collision damage) is to continue to bring awareness to the general public of impacts of global warming though outreach and educational programs and push for funding into coral disease research. The average length of several key reef fish found in the park species suggest that fishing mortality is still higher than desired. Unlike other areas in south Florida, there is little information on the recreational fishery that takes place within the park and the surrounding waters. A better understanding of the catch and areas fished would help future management decisions as well as the enforcement of current regulations.

DRTO is a tremendously important refuge for both migratory and resident species and it is highly recommended that current management policies and protections remain in place.

Sunset over Loggerhead Key. (Photo by Judd Patterson).

Literature Cited

Adimey, N. M., C. A. Hudak, J. R. Powell, K. Bassos-Hull, A. Foley, N. A. Farmer, L. White, and K. Minch. 2014. Fishery gear interactions from stranded bottlenose dolphins, Florida manatees and sea turtles in Florida, USA. Marine Pollution Bulletin 81: 103–115.

Albins, M. A., and M. A. Hixon. 2008. Invasive Indo-Pacific lionfish *Pterois volitans* reduce recruitment of Atlantic coral-reef fishes. Marine Ecology Progress Series 367: 233-238.

Ault, J. S., J. A. Bohnsack, S. G. Smith, and J. Luo. 2005. Towards sustainable multispecies fisheries in the Florida, USA, coral reef ecosystem. Bulletin of Marine Science 76: 595-622.

Ault, J. S., S. G. Smith, J. A. Bohnsack, J. Luo, D. R. Bryan, and M. H. Stevens. 2018. Length-based risk analysis for assessing sustainability of data-limited tropical reef fisheries. ICES Journal of Marine Science.

Ault, J. S., S. G. Smith, J. A. Bohnsack, J. Luo, D. E. Harper, and D. B. McClellan. 2006. Building sustainable fisheries in Florida's coral reef ecosystem: positive signs in the Dry Tortugas. Bulletin of Marine Science 78: 633-654.

Ault, J. S., S. G. Smith, J. A. Bohnsack, J. Luo, N. Zurcher, D. B. McClellan, T. A. Ziegler, D. E. Hallac, M. Patterson, M. W. Feeley, B. I. Ruttenberg, J. Hunt, D. Kimball, and B. Causey. 2013. Assessing coral reef fish population and community changes in response to marine reserves in the Dry Tortugas, Florida, USA. Fisheries Research 144: 28-37.

Ault, J. S., S. G. Smith, J. A. Bohnsack, J. Luo, G. T. Kellison, D. E. Harper, and D. B. McClellan. 2008. Coral reef fish populations in Dry Tortugas National Park, 1999-2006: baseline assessment prior to implementation of the Research Natural Area. National Park Service and NOAA Fisheries.

Ault, J. S., S. G. Smith, D. R. Bryan, J. Blondeau, J. Luo, D.B. McClellan, J. Javech, and J. A. Bohnsack. 2015. Assessment of resource status and RNA marine reserve performance for the Dry Tortugas National Park reef fish community. National Park Service Task Agreement P06AC00040. University of Miami, FL 54pp.

Ault, J. S., S. G. Smith, E. C. Franklin, J. Luo, and J. A. Bohnsack. 2003. Sampling design analysis for coral reef fish stock assessment in Dry Tortugas National Park. Final Report, National Park Service Contract, (H5000000494-0012), p.87.

Ault, J. S., S. G. Smith, M. F. Larkin, and N. Zurcher. 2007. Inventory of Coastal Pelagic Fishes of Dry Tortugas National Park. Final Report 29pp.

Ault, J. S., S. G. Smith, G. A. Meester, J. Luo, J. A. Bohnsack, and S. L. Miller. 2002. Baseline multispecies coral reef fish stock assessment for the Dry Tortugas. NOAA Technical Memorandum NMFS-SEFSC-487. 117pp.

Avian Research and Conservation Institute (ARCI). http://arci-avianconservation.blogspot.com/ (Accessed 04/25/2017).

Baker, A. C., P. W. Glynn, and B. Riegl. 2008. Climate change and coral reef bleaching: An ecological assessment of long-term impacts, recovery trends and future outlook. Estuarine, Coastal and Shelf Science 80:435-471.

Baum, J. K., and B. Worm. 2009. Cascading top- down effects of changing oceanic predator abundances. Journal of Animal Ecology 78:699-714.

Bertelsen, R. D., and T. R. Matthews. 2001. Fecundity dynamics of female spiny lobster (*Panulirus argus*) in a south Florida fishery and Dry Tortugas National Park lobster sanctuary. Marine and Freshwater Research 52:1559-65.

Beverton, R. J. H., and S. J. Holt. 1957. On the dynamics of exploited fish populations. Fishery Investigations, Series II, Great Britain Ministry of Agriculture, Fisheries and Food 19.

Bowman, H.H.M. 1918. Botanical ecology of the Dry Tortugas. Papers Tortugas Laboratory 12:109-38.

Brandt, M. E., B. I. Ruttenberg, R. Waara, J. Miller, B. Witcher, A. J. Estep, and M. Patterson. 2012. Dynamics of an acute coral Disease outbreak associated with the macroalgae Dictyota spp. in Dry Tortugas National Park, Florida, USA. Bulletin of Marine Science 88:1035-1050.

Brandt, M. E., N. Zurcher, A. Acosta, J. S. Ault, J. A. Bohnsack, M. W. Feeley, D. E. Harper, J. H. Hunt, T. Kellison, D. B. McClellan, M. E. Patterson, and S. G. Smith. 2009. A cooperative multi-agency reef fish monitoring protocol for the Florida Keys coral reef ecosystem. Natural Resource Report NPS/SFCN/NRR -2009/150. National Park Service, Fort Collins, Colorado.

Bruno, J.F., E. R. Selig, K. S. Casey, C. A. Page, B. L. Willis, C. D. Harvell, H. Sweatman, and A. M. Melendy. 2007. Thermal stress and coral cover as drivers of coral disease outbreaks. PLoS Biol 5: e124. doi:10.1371/journal.pbio.0050124.

Bryan, D. R., J. Blondeau, A. Siana, and J. S. Ault. (*in review*). Regional differences in an established population of Indo-Pacific lionfish (*Pterois volitans* and *P. miles*) in south Florida. PLOSOne.

Bryan, D. R., J. Luo, J. S. Ault, D. B. McClellan, S. G. Smith, D. Snodgrass, and M. F. Larkin. 2015. Transport and connectivity modeling of larval permit from an observed spawning aggregation in the Dry Tortugas, Florida. Environmental Biology of Fishes 98:2263-2276.

Bryan, D. R., J. Luo, and J. S. Ault. 2018a. Natural resource condition assessment for Biscayne National Park. Natural Resource Report NPS/XXXX/NRR—20XX/XXX. National Park Service, Fort Collins, Colorado.

Burton, M. L., K. J. Brennan, R. C. Munoz, and R. O. Parker. 2005. Preliminary evidence of increased spawning aggregations of mutton snapper (*Lutjanus analis*) at Riley's hump two years after establishment of the Tortugas South Ecological Reserve. Fishery Bulletin 102:404-410.

Butler, C. B., and T. R. Matthews. 2015. Effects of ghost fishing lobster traps in the Florida Keys. ICES Journal of Marine Science 72:i185-i198.

Bythell, J. C., E. H. Gladfelter, and M. Bythell. 1993. Chronic and catastrophic natural mortality of three common Caribbean reef corals. Coral Reefs 12:143-152.

Carlson, P. R. Jr., L. A. Yarbro, and J. W. Fourqurean. 2015. Summary report for the Florida Keys National Marine Sanctuary, pp. 156-160, in L. Yarbro and P. R. Carlson, eds. Seagrass Integrated Mapping and Monitoring Report No. 1.1. Fish and Wildlife Research Institute Technical Report TR-17B, St. Petersburg, Florida, 207 p.

Chiappone, M., H. Dienes, D. W. Swanson, and S. L Miller. 2005. Impacts of lost fishing gear on coral reef sessile invertebrates in the Florida Keys National Marine Sanctuary. Biological Conservation 121:221–230.

Chiappone, M., S. Miller, D. Swanson, J. Ault, and S. Smith. 2001. Comparatively high densities of the long-spined sea urchin in the Dry Tortugas, Florida. Coral Reefs 20:137-138.

Chiappone, M., L. M. Rutten, S. L. Miller, and D. W. Swanson. 2013. Recent trends (1999–2011) in population density and size of the echinoid *Diadema antillarum* in the Florida Keys. Florida Scientist 76:23-35.

Chiappone, M. H., A. White, D. W. Swanson, and S. L. Miller. 2002. Occurrence and biological impacts of fishing gear and other marine debris in the Florida Keys. Marine Pollution Bulletin 44:597–604.

Clapp, R. B., and W. B. Robertson Jr. 1986. Nesting of the Masked Booby on the Dry Tortugas, Florida: the first record for the contiguous United States. Colonial Waterbirds 9:113-116.

Colchero, F., O. L. Bass Jr., R. Zambrano, and J. A. Gore. 2010. Clustered nesting and vegetation thresholds reduce egg predation in sooty terns. Waterbirds 33:169-178.

Cope, R. 2016. Disturbance and recovery of sooty tern nesting colony in Dry Tortugas National Park. M.S. Thesis, Nicholas School of the Environment of Duke University. 21 pp.

Cox, C., and J. H. Hunt. 2005. Change in size and abundance of Caribbean spiny lobsters *Panulirus argu*s in a marine reserve in the Florida Keys National Marine Sanctuary, USA. Marine Ecology Progress Series 294:227-239.

Davis, J. H. Jr. 1942. The ecology of the vegetation and topography of the Sand Keys of Florida. Papers Tortugas Laboratory 33:113-95.

Davis, G. E. 1977. Effects of recreational harvest on a spiny lobster, *Panulirus argus*, population. Bulletin of Marine Science 27:223-236.

Davis, G. E. 1982. A century of natural change in coral distribution at the Dry Tortugas: a comparison of reef maps from 1881 and 1976. Bulletin of Marine Science 32:608-623.

Delgado, G. A., R. A. Glazer, D. Hawtof, D. Aldana Aran da, L. A. Rodríguez-Gil, and A. de Jesús-Navarrete. 2008. Do queen conch (*Lobatus gigas*) larvae recruiting to the Florid a Keys originate from upstream sources? Evidence from plankton and drifter studies. Pages 29-41 in R. Grober-Dunsmore and B.D. Keller, eds. Caribbean connectivity: Implications for marine protected area management. Proceedings of a Special Symposium, 9-11 November 2006, 59th Annual Meeting of the Gulf and Caribbean Fisheries Institute, Belize City, Belize. Marine Sanctuaries Conservation Series ONMS-08-07. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, Office of National Marine Sanctuaries, Silver Spring, MD.

Diamond, A. W. 1973. Notes on the breeding biology and behavior of the Magnificent Frigatebird. The Condor 75:200-209.

Domeier, M.L. 2004. A potential larval recruitment pathway originating from a Florida marine protected area. Fisheries Oceanography 13:287-294.

Ehrhardt, N. M., and J. S. Ault. 1992. Analysis of two length-based mortality models applied to bounded catch length frequencies. Transactions of the American Fisheries Society 121:115-122.

Ehrhardt, N. M., and M. D. Fitchett. 2010. Dependence of recruitment on parent stock of the spiny lobster, *Panulirus argus*, in Florida. Fisheries Oceanography 19:434-447.

Farmer, N. A., and J. S. Ault. 2011. Grouper and snapper movements and habitat use in Dry Tortugas, Florida. Marine Ecology Progress Series 433:169-184.

Feeley, M. W., A. J. Atkinson, D. R. Bryan, J. A. Bohnsack and J. S. Ault. 2016. Monitoring and conservation of reef fish populations in south Florida National Parks. 13th Abstract Book International Coral Reef Symposium, Honolulu: 99.

Feeley, M. W., D. Morley, A. Acosta, P. Barbera, J. Hunt, T. Switzer, and M. Burton. 2018. Spawning migration movements of mutton snapper in Tortugas, Florida: Spatial dynamics within a marine reserve network. Fisheries Research 204: 209-223.

Feeley, M. W., D. Morley, A. Acosta, T. S. Switzer, N. A. Farmer and J. S. Ault. 2012. Spillover of select fish species in and near the Research Natural Area. Chapter 4 in Ziegler, T. A., and J. Hunt (eds), Implementing the Dry Tortugas National Park Research Natural Area Science Plan: The 5-Year Report. National Park Service and Florida Fish and Wildlife Conservation Commission Report. 80 p.

Feeley, M. W., D. Morley, A. Acosta, T. S. Switzer, and H. L Pratt. 2012. Regional connectivity of fishes within the Tortugas region of Florida. Chapter 3 in Ziegler, T. A., and J. Hunt (eds). Implementing the Dry Tortugas National Park Research Natural Area Science Plan: The 5-Year Report. National Park Service and Florida Fish and Wildlife Conservation Commission Report. 80 p.

Florida Fish and Wildlife Conservation Commission (FWC). 2003, January 6. Florida's breeding bird atlas: A collaborative study of Florida's birdlife. http://www.myfwc.com/bba/ (Accessed 04/25/2017).

Florida Fish and Wildlife Conservation Commission. 2011. Least Tern Biological Status Review Report. Florida Fish and Wildlife Conservation Commission, Tallahassee, FL 13pp. http://myfwc.com/media/2273337/Least-Tern-BSR.pdf (Accessed 4.25.17).

Fourqurean, J. 2013. Dry Tortugas Park seagrass communities assessment project: establishing long-term seagrass monitoring sites. NPS Investigators Annual Report.

Gann G. D., C. G. Stocking, and Collaborators. 2001-2017. Floristic Inventory of South Florida Database Online. The Institute for Regional Conservation. Delray Beach, Florida.

Gardner, T. A., I. M. Côté, J. A. Gill, A. Grant, and A. R. Watkinson. 2003. Long-term region-wide declines in Caribbean corals. Science 301:958-960.

Glazer, R. A., and C. J. Berg, Jr. 1994. Queen conch research in Florida: an overview pp. 79-96 In R.S. Appeldoorn and B. Rodriguez (eds.) Queen conch biology fisheries, and mariculture. Fundación Científica Los Roques, Caracas, Venezuela, 356 pp.

Gordon, D. R. 1998. Effects of invasive, non- indigenous plant species on ecosystem processes: lessons from Florida. Ecological Applications 8:975-989.

Harrington, B. A., and J. J. Dinsmore. 1975. Mortality of transient Cattle Egrets at Dry Tortugas, Florida. Bird-Banding 46:7-14.

Hart, K. M., D.G. Zawada, I. Fujisaki, and B.H. Lidz. 2013 Habitat use of breeding green turtles *Chelonia mydas* tagged in Dry Tortugas National Park: Making use of local and regional MPAs. Biological Conservation 161:142-154.

Hart, K. M., A. R. Sartain, and I. Fujisaki. 2015. Bahamas connection: residence areas selected by breeding female loggerheads tagged in Dry Tortugas National Park, USA. Animal Biotelemetry 3:3.

Heck Jr, K. L., and M. P. Weinstein. 1989. Feeding habits of juvenile reef fishes associated with Panamanian seagrass meadows. Bulletin of Marine Science 45:629-636.

Heron, S. F., J. A. Maynard, R. van Hooidonk, and C. M. Eakin. 2016. Warming trends and bleaching stress of the world's coral reefs 1985-2012. Scientific Reports, 6:38402: DOI: 10.1038/srep38402.

Heithaus, M. R., A. Frid, A. J. Wirsing, and B. Worm. 2008. Predicting ecological consequences of marine top predator declines. Trends in Ecology and Evolution 23:202-210.

Hoegh-Guldberg, O., P. J, Mumby, A. J. Hooten, R. S. Steneck, P. Greenfield, E. Gomez, C. D. Harvell, P. F. Sale, A. J. Edwards, K. Caldeira and N. Knowlton. 2007. Coral reefs under rapid climate change and ocean acidification. Science 318:1737-1742.

Hovis, J. A., and M. S. Robson. 1989. Breeding status and distribution of the Least Tern in the Florida Keys. Florida. Field Naturalist 17:61-66.

Hunt, J. H., W. G. Lyons, and F. S. Kennedy, Jr. 1986. Effects of exposure and confinement on spiny lobsters, *Panulirus argus*, used as attractants in the Florida trap fishery. Fishery Bulletin 84:69–76.

Jackson, J. B. C., M. Donovan, K. Cramer and V. Lam (eds). 2014. Status and trends of Caribbean coral reefs 1970–2012. Global Coral Reef Monitoring Network, International Union for the Conservation of Nature Global Marine and Polar Program, Washington, DC

Jackson, E. L., A. A. Rowden, M. J. Attrill, S. J. Bossey, and M. B. Jones. 2001. The importance of seagrass beds as a habitat for fishery species. Oceanography and Marine Biology 39:269-304.

Jeffrey, C. F. G., S. D. Hile, C. Addison, J. S. Ault, C. Currin, D. Field, N. Fogarty, J. Luo, V. McDonough, D. Morrison, G. Piniak, V. Ransibrahmanakul, S. G. Smith, and S. Viehman. 2012. Assessment of natural resource conditions in and adjacent to Dry Tortugas National Park. Natural Resource Report NPS/DRTO/NRR 2012/558. National Park Service, Fort Collins, Colorado.

Kirsch, K. D., J. F. Valentine, and K. L. Heck Jr. 2002. Parrotfish grazing on turtlegrass *Thalassia testudinum*: evidence for the importance of seagrass consumption in food web dynamics of the Florida Keys National Marine Sanctuary. Marine Ecology Progress Series 227:71-85.

Kissling, D. L., W. F. Precht, S. L. Miller, M. Chiappone. 2014 Historical reconstruction of population density of the echinoid *Diadema antillarum* on Florida Keys shallow bank-barrier reefs. Bulletin of Marine Science 90:665-679.

Kough A. S., C. B. Paris, and M. J. Butler IV. 2013. Larval connectivity and the international management of fisheries. PLoS ONE 8(6): e64970. doi:10.1371/journal.pone.0064970

Kuffner, I. B., T. D. Hickey, and J. M. Morrison. 2013. Calcification rates of the massive coral *Siderastrea siderea* and crustose coralline algae along the Florida Keys (USA) outer reef tract. Coral Reefs, 32:987-997.

Kuffner, I. B., B. H. Lidz, J. H. Hudson, and J. S. Anderson. 2015. A century of ocean warming on Florida Keys coral reefs: historic in situ observations. Estuaries and Coasts 38:1085-1096.

Lake, J. C., and M. R. Leishman. 2004. Invasion success of exotic plants in natural ecosystems: the role of disturbance, plant attributes and freedom from herbivores. Biological Conservation 117:215-226.

Lee, T. N., and E. Williams. 1999. Mean distribution and seasonal variability of coastal currents and temperature in the Florida Keys with implications for larval recruitment. Bulletin of Marine Science 64:35–56.

Lessios, H. A. 1988. Mass mortality of *Diadema antillarum* in the Caribbean: What have we learned? Annual Review of Ecology and Systematics 19:371-393.

Lidz, B. H., and D. G. Zawada. 2013. Possible Return of *Acropora cervicornis* at Pulaski Shoal, Dry Tortugas National Park, Florida. Journal of Coastal Research 29:256–271.

Lindeman, K. C., R. Pugliese, G. T. Waugh, and J. S. Ault. 2000. Developmental pathways within a multispecies reef fishery: management applications for essential fish habitats and protected areas. Bulletin of Marine Science 66:929-956.

Lizza, K. 2015. Historical and current population patterns of the staghorn coral (*Acropora cervicornis*) in Dry Tortugas National Park. Graduate Thesis, University of South Florida.

Locascio, J. V., and M. L. Burton. 2016. A passive acoustic survey of fish sound production at Riley's Hump within Tortugas South Ecological Reserve: implications regarding spawning and habitat use. Fishery Bulletin 114:103-117.

Luciani, J. M., K. R. T. Whelan, R. B. Shamblin, R. M. Vargas, and J. M. Patterson. 2011. Dry Tortugas National Park vegetation map, 2009. Natural Resource Technical Report NPS/SFCN/NRTR—2011/469. National Park Service, Fort Collins, Colorado.

Luo, J., J. E. Serafy, S. Sponaugle, P. B. Teare, and D. Kieckbusch. 2009. Movement of gray snapper *Lutjanus griseus* among subtropical seagrass, mangrove, and coral reef habitats. Marine Ecology Progress Series 380:255-269.

Manzello, D. P. 2015. Rapid Recent Warming of Coral Reefs in the Florida Keys. Sci. Rep. 5. 16762; doi: 10.1038/srep16762.

Manzello, D. P., R. Berkelmans, and J. C. Hendee. 2007. Coral bleaching indices and thresholds for the Florida reef tract, Bahamas, and St. Croix, US Virgin Islands. Marine Pollution Bulletin 54:1923-1931.

Maxwell, K. E., T. R. Matthews, R. D. Bertelsen, and C. D. Derby. 2009. Using age to evaluate reproduction in Caribbean spiny lobster, *Panulirus argus*, in the Florida Keys and Dry Tortugas, United States, New Zealand Journal of Marine and Freshwater Research 43:139-149.

Maxwell, S. M., M. G. Conners, N. B. Sisson, and T. W. Dawson. 2016. Potential Benefits and Shortcomings of Marine Protected Areas for Small Seabirds Revealed Using Miniature Tags. Frontiers in Marine Science, 3:264. doi: 10.3389/fmars.2016.00264.

McGlathery, K. J. 2001. Macroalgal blooms contribute to the decline of seagrass in nutrient-enriched coastal waters. Journal of Phycology 37:453-456.

Miller, J., E. Muller, C. Rogers, R. Waara, A. Atkinson, K. R. T Whelan, M. Patterson and B. Witcher. 2009. Coral disease following massive bleaching in 2005 causes 60% decline in coral cover on reefs in the US Virgin Islands. Coral Reefs 28:925-937.

Miller, J., C. Rogers, M. Feeley, A. Atkinson, A. Davis, M. Patterson, R. Waara, B. Witcher, J. Patterson, E. Muller. 2017. Coral reef monitoring protocol, v. 2.00. Natural Resource Report NPS/SFCN/NRR—2017/1464. National Park Service, Fort Collins, Colorado.

Millspaugh, C. F. 1907. Flora of the sand keys of Florida. Columbian Museum 118, no. (Bot. Ser. 2): 191-245.

Murdoch, T .J. T., and R. B. Aronson. 1999. Scale-dependent spatial variability of coral assemblages along the Florida Reef tract. Coral Reefs 18:341-351.

Nagelkerken, I., G. Van der Velde, M. W. Gorissen, G. J. Meijer, T. Van't Hof, and C. Den Hartog. 2000. Importance of mangroves, seagrass beds and the shallow coral reef as a nursery for important coral reef fishes, using a visual census technique. Estuarine, Coastal and Shelf Science 51:31-44.

National Marine Fisheries Service. 2014. Queen Conch, *Lobatus gigas* (Linnaeus 1758) Status Report. 104 pp.

Nimmo, K. 2015. Dry Tortugas National Park Sea Turtle Monitoring Program. 2015 Annual Report, Monroe County, Florida.

Ogden, J. C., J. D. Baldwin, O. L. Bass, J. A. Browder, M. I. Cook, P. C. Frederick, P. E. Frezza, R. A. Galvez, A. B. Hodgson, K. D. Meyer and L. D. Oberhofer. 2014. Waterbirds as indicators of ecosystem health in the coastal marine habitats of southern Florida: 1. Selection and justification for a suite of indicator species. Ecological Indicators 44:148-163.

O'Toole, A. C., A. J. Danylchuk, T. L. Goldberg, C. D. Suski, D. P. Philipp, E. Brooks, and S. J. Cooke. 2011. Spatial ecology and residency patterns of adult great barracuda (*Sphyraena barracuda*) in coastal waters of The Bahamas. Marine Biology 158:2227-2237.

Pendleton, E. A., E. R. Thieler, and S. J. Williams. 2005. Coastal vulnerability assessment of Dry Tortugas National Park to sea-level rise. United States Geological Survey, Open-File Report 2004-1416.

Pernas, T., B. Gamble and T. V. Armentano. 2001. Dry Tortugas National Park, Loggerhead Key exotic plant management and island restoration project. Wildland Weeds. Winter 2001:13-17.

Porter J. W., J. F. Battey, and G. J. Smith. 1982 Perturbation and change in coral reef communities. Proceedings of the National Academy of Sciences 79:1678-1681.

Pratt Jr, H. L., and J. C. Carrier. 2001. A review of elasmobranch reproductive behavior with a case study on the nurse shark, *Ginglymostoma cirratum*. In The behavior and sensory biology of elasmobranch fishes: an anthology in memory of Donald Richard Nelson (pp. 157-188). Springer Netherlands.

Precht, W. F., B. E. Gintert, M. L. Robbart, R. Fura, and R. van Woesik. 2016. Unprecedented disease-related coral mortality in southeastern Florida. Scientific Reports 6:1-11.

Robertson, W. B. 1964. The terns of the Dry Tortugas. Bulleting of the Florida State Museum. University of Florida, Gainesville. Volume 8, 98 pp.

Ruzicka, R. R., V. Brinkhuis, M. A. Colella, J. A. Kidney, J. M. Morrison, K. S. Lunz, G. Ward, K. A. Macaulay, J.W. Porter, and M. K. Meyers. 2010. Long-term monitoring of selected coral reefs in the Dry Tortugas National Park. 2009/2010 FWRI DTNP Final Report (F2760-08-10-A) 53 pp.

Ruzicka, R. R., M. A. Colella, J.W. Porter, J. M. Morrison, J. A. Kidney, V. Brinkhuis, K. S. Lunz, K. A. Macaulay, L. A. Bartlett, M. K. Meyers, and J. Colee. 2013. Temporal changes in benthic assemblages on Florida Keys reefs 11 years after the 1997/1998 El Niño. Marine Ecology Progress Series 489:125-141.

Ruzicka R., V. Brinkhuis, M. Colella, J. Kidney, C. Bradshaw, N. Sheridan, K. Lunz, J. Morrison, L. Bartlett, K. Macaulay, and K. Neely. 2014. Long-term Monitoring & Assessment of Selected Coral Reef Sites in the Dry Tortugas National Park. 2011-2012 Final Report. Fish & Wildlife Research Institute/Florida Fish & Wildlife Conservation Commission. Saint Petersburg, FL. 69 pp.

Schmidt, T. W., and L. Pikula. 1997. Scientific studies on Dry Tortugas National Park: an annotated bibliography. Atoll Research Bulletin, 449. pp 124.

Schofield, P. J. 2009. Geographic extent and chronology of the invasion of non-native lionfish (*Pterois volitans* [Linnaeus 1758] and *P. miles* [Bennett 1828]) in the Western North Atlantic and Caribbean Sea. Aquatic Invasions 4:473-479.

Schroeder, P. B., and J. H. Davis. 1971. Ecology vegetation and topography of the Dry Tortugas updated to 1970. Quarterly Journal of the Florida Academy of Science (Suppl 1):12-13.

Scott, W. E. D. 1890. On birds observed at the Dry Tortugas, Florida, during parts of March and April, 1890. The Auk 7:301-314.

Shinn, E. A., J. H. Hudson, R. B. Halley, and B. H. Lidz. 1977. Topographic control and accumulation rate of some Holocene coral reefs, south Florida and Dry Tortugas: Proceedings, 3rd International Coral Reef Symposium, v. 2, Geology, p. 1-7.

Smith, S. R. 1992. Patterns of coral recruitment and post-settlement mortality on Bermuda's reefs: comparisons to Caribbean and Pacific reefs. American Zoologist 32:663-673.

Smith, S. G., J. S. Ault, J. A. Bohnsack, D. E Harper, J. Luo, and D. B. McClellan. 2011. Multispecies survey design for assessing reef-fish stocks, spatially explicit management performance, and ecosystem condition. Fisheries Research 109:25-41.

Sprunt, A. Jr. 1951. Some observations on the fall migration at Dry Tortugas, Florida. The Auk 68:218-226.

Stevely, J. M., and R. E. Warner. 1978. The biology and utilization of the queen conch, *Lobatus gigas* L., in the Florida Keys and throughout its geographic range. Marine Resource Inventory. Monroe County Cooperative Extension Service.

Stoddart, D. R., and F. R. Fosberg. 1981. Topographic and floristic change, Dry Tortugas, Florida, 1904-1977. Atoll Research Bulletin 253:1-56.

Torres, L. G., M. R. Heithaus, and B. Delius. 2006. Influence of teleost abundance on the distribution and abundance of sharks in Florida Bay, USA. Hydrobiologia 569:449-455.

Toth, L. T., R. van Woesik, T. J. T. Murdoch, S. R. Smith, J. C. Ogden , W. F. Precht, and R. B Aronson. 2014. Do no-take reserves benefit Florida's corals? 14 years of change and stasis in the Florida Keys National Marine Sanctuary. Coral Reefs 33:565-577.

Waara, R. J., J. M. Patterson, A. J. Atkinson, and A. J. Estep. 2011. Development and policy applications of the 2010 benthic habitat map for Dry Tortugas National Park. Natural Resource Technical Report NPS/SFCN/NRTR—2011/474. National Park Service, Fort Collins, Colorado.

Weimerskirch, H., M. Le Corre, F. Marsac, C. Barbraud, O. Tostain, and O. Chastel. 2006. Postbreeding movements of frigatebirds tracked with satellite telemetry. The Condor 108:220-225.

Wilson, S. S., and J. W. Fourgurean. 2017. Investigators Annual Report, Dry Tortugas. Seagrass monitoring. Activity # DRTO-00032, Permit # DRTO-2014-SCI-0007

Zambrano, R., M. S. Robson, D. Y. Charnetzky, and H. T. Smith. 1997. Distribution and status of Least Tern nesting colonies in southeast Florida. Florida Field Naturalist 25:85-116.

Ziegler, T. A., and J. Hunt, eds. 2012. Implementing the Dry Tortugas National Park Research Natural Area Science Plan: The 5-Year Report 2012. South Florida Natural Resources Center, Everglades and Dry Tortugas National Parks, Homestead, FL, and the Florida Fish and Wildlife Conservation Commission, Tallahassee, FL. 63 pp.

Ziegler, T. A., and J. Hunt, eds. 2015. Assessing the Conservation Efficacy of the Dry Tortugas National Park Research Natural Area. South Florida Natural Resources Center, Everglades and Dry Tortugas National Parks, Homestead, FL, and the Florida Fish and Wildlife Conservation Commission, Tallahassee, FL. 11 pp.

Appendix: 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	Session	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 Elliot 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. 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 (e.g. 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 364/149169, October 2018

National Park Service
U.S. Department of the Interior

Natural Resource Stewardship and Science
1201 Oakridge Drive, Suite 150
Fort Collins, CO 80525