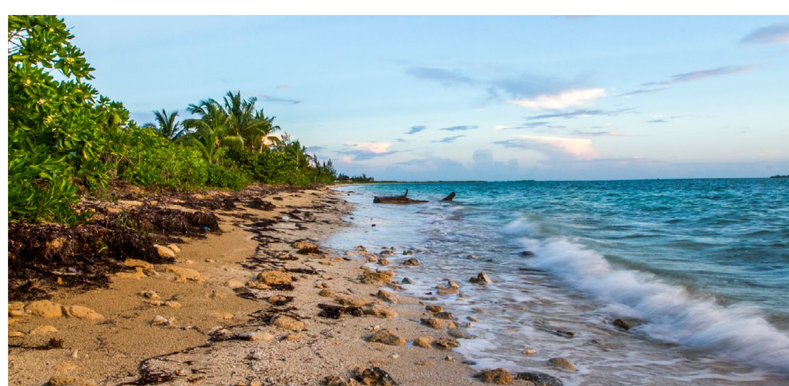
Expanding The Bahamas Marine Protected Area Network to Protect 20% of the Marine and Coastal Environment by 2020: A Gap Analysis



Bahamas Protected: Sea the Future

A goby peeks out from a Christmas Tree Worm, photographed underwater in the Exuma Cays Land and Sea Park, Bahamas
The Nature Conservancy works closely with partners such as the Bahamas National Trust and the Government of The Bahamas to protect the marine habitat of the Exuma Cays and achieve the goal for the long term protection of national parks through the Caribbean Challenge Initiative. © Jeff Yonover

A report prepared by The Nature Conservancy under the Bahamas Protected Project
August 21, 2017

Prepared by the Bahamas Protected project science team:
John E. Knowles[1], Alison L. Green[1], Craig Dahlgren[2], Frederick Arnett[1], Lindy Knowles[2]
[1]The Nature Conservancy, [2]Bahamas National Trust

Bahamas Protected is a three-year initiative to effectively manage and expand the Bahamian marine protected areas (MPA) network. It aims to support the Government of The Bahamas in meeting its commitment to the Caribbean Challenge Initiative (CCI); a regional agenda where 11 Caribbean countries committed to protect 20% of the marine and coastal habitat by 2020. CCI countries have also pledged to provide sustainable financing for effective management of MPAs.

Bahamas Protected is a joint effort between The Nature Conservancy, Bahamas National Trust, Bahamas Reef Environment Educational Foundation and multiple national stakeholders, with major funding from the international philanthropic organization, Oceans 5.

The Nature Conservancy

BAHAMAS NATIONAL TRUST

Bahamas Reef Environment Educational Foundation

Table of Contents

"No one who achieves success does so without the help of others. The wise and confident acknowledge this help with gratitude."

— **Alfred North Whitehead**

Acknowledgements

Aerial view of Exuma Cays in and among the Exuma Cays Land and Sea Park, The Bahamas. © Jeff Yonover

Acknowledgements

The first step in the design of a new set of marine protected areas for the project titled, *Bahamas Protected: Realizing the 2020 Goal to Effectively Manage and Expand Bahamian Marine Protected Areas* was led by a team comprised of scientists and conservation practitioners from The Nature Conservancy (John Knowles, Alison Green, Frederick Arnett) and Bahamas National Trust (Craig Dahlgren and Lindy Knowles), with expertise in marine protected area (MPA) network design, geographic information systems (GIS) and spatial analysis, and biophysical characteristics of The Bahamas.

This team wishes to express gratitude to the cadre of project team members, consultants and subject matter experts who supported this work including: Marcia Musgrove, Shenique Albury-Smith, Steve Schill, Vera Agostini, Nicholas Wolf, Krista Sherman, Alastair Harborne, Samuel González Delgado, Edward Game, Pete Mumby, Hugh Possingham, Diane Claridge, Sarah Wise, Sophie Butler, Ebonesse Bain, Jewel Thompson, Daniel Brumbaugh and Sharrah Moss-Hackett.

Special thanks to our partners and other key stakeholders from many organisations who engaged constructively through workshops, providing data, feedback and other support throughout this process. These organisations include:

- Antiquities, Monuments & Museums Corporation
- Bahamas Environment, Science & Technology (BEST) Commission
- Bahamas Marine Mammal Research Organization
- Bahamas National Geographic Information Systems (BNGIS) Centre
- Bahamas National Trust
- Bahamas Reef Environment Educational Foundation
- Bonefish & Tarpon Trust
- Cape Eleuthera Institute
- Clifton Heritage Authority
- Department of Marine Resources
- Florida International University
- Forestry Unit
- Friends of the Environment
- Global Environment Facility Small Grants Program
- Island Conservation
- Ministry of The Environment & Housing
- New Providence Community Center
- Ocean Crest Alliance
- Office of The Prime Minister
- Perry Institute of Marine Sciences
- SEV Consulting Group
- Sustainable Tourism Unit, Ministry of Tourism
- The National Audubon Society
- The Natural Capital Project
- The Nature Conservancy
- Young Marine Explorers

All project partners are deeply grateful to Oceans 5, the Lyda Hill Foundation (through the Mapping Ocean Wealth Project) and the China Global Conservation Fund of The Nature Conservancy for their commitment to The Bahamas. This work underpins the country's national conservation commitments related to the Convention on Biological Diversity, the United Nations Framework Convention on Climate Change and the Caribbean Challenge Initiative. Your generous donations are making a real difference not only in conserving some of the Caribbean's most important ocean habitat, but also in protecting critical marine resources for the people of The Bahamas for generations to come. Thank you!

Summary

Feather Duster Worm, photographed underwater in the Exuma Cays Land and Sea Park, The Bahamas. © Jeff Yonover

Summary

Marine protected areas (MPAs) can be effective tools for conservation if they are well designed and managed. The Bahamas National Protected Area System (BNPAS) currently protects approximately 10% of the country's entire marine environment and 34% of the terrestrial environment. Under the Aichi Biodiversity Targets, The Bahamas has agreed to protect 10% of its coastal and marine areas by 2020. The Bahamas has also committed to effectively conserve and manage at least 20% of its marine and coastal environment by 2020 under the Caribbean Challenge Initiative (CCI).

The *Bahamas Protected* science team (the team) conducted a national marine gap analysis to assist the government in reaching its 2020 CCI goal by identifying priority areas for establishing new MPAs. This analysis builds upon the work completed during two previous national gap analyses (Thurlow and Palmer 2007; Moss and Moultrie 2014), but it differs from these analyses in the following ways:

- Expands the objectives beyond biodiversity protection to include climate change and socioeconomics (e.g. to support Bahamian livelihoods);
- Specifies a planning area that aligns with multiple national planning processes;
- Uses the latest science to apply biophysical, socioeconomic, and governance principles for the design of the marine protected area (MPA) network;
- Incorporates new and refined spatial data layers; and
- Uses innovative scientific approaches to maximise the benefits of the MPA network, so that protected areas can adapt to climate change, enhance coral reef fisheries and benefit local communities.

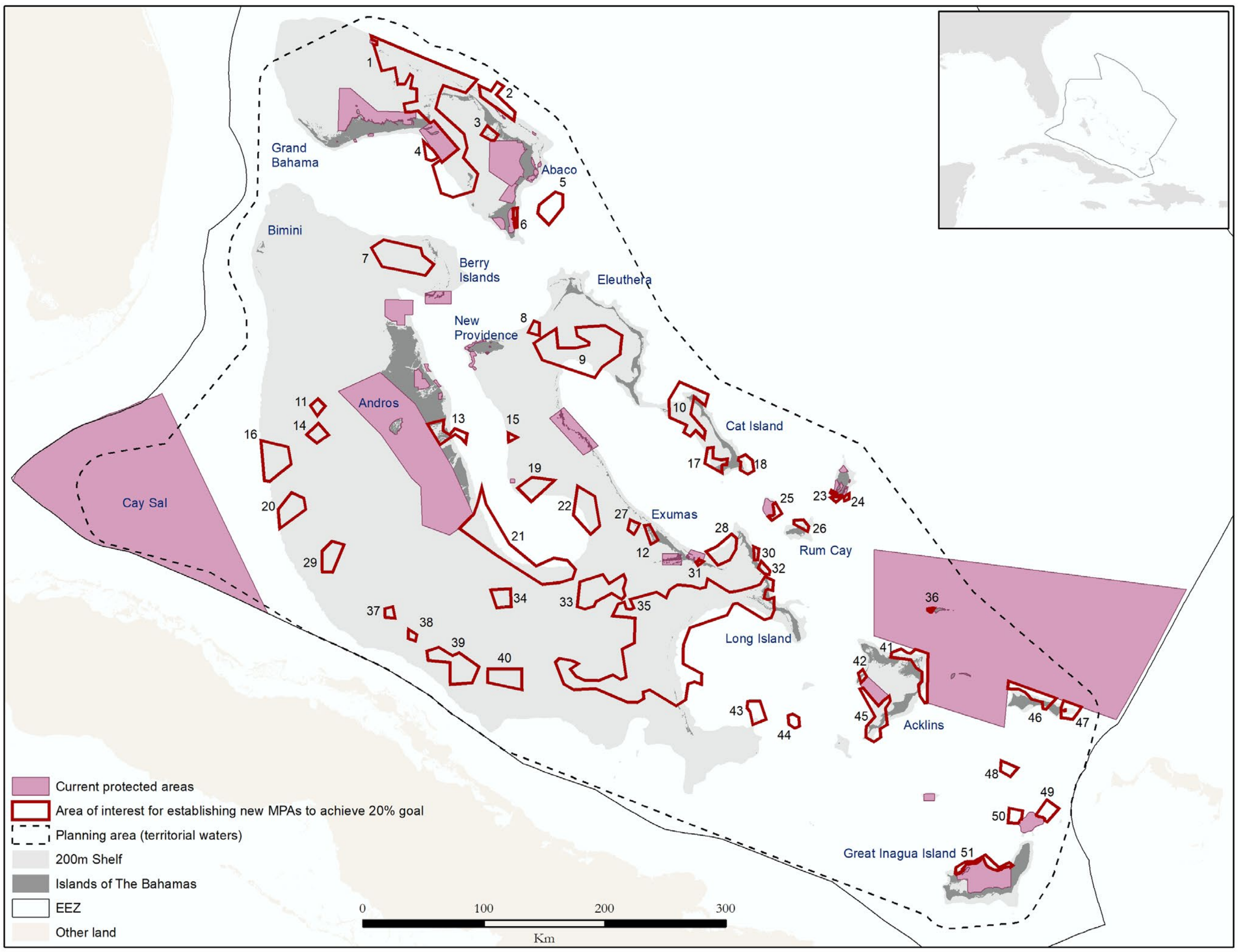
This work engaged approximately 40 local and international scientists and field practitioners from more than 26 organizations through three national workshops. Strategic advice was also obtained from the National Implementation Support Partnership (NISP).

Based on the information received, this marine gap analysis sought to do the following:

- Expand the objectives of the Master Plan for The Bahamas National Protected Area System: 1) By 2020, bearing in mind the impacts of climate change, identify and protect diverse marine ecosystems and critically important species; and 2) By 2020, protected areas (marine and terrestrial) will contribute to maintaining and improving Bahamian livelihoods by maximising the benefits and minimising the costs for local communities and stakeholders.
- Design MPAs zoned to include different levels of protection, with highly protected areas incorporated when and where possible after considering both the socio-economic and biophysical dynamics within The Bahamas.
- Use the territorial waters of The Bahamas as the planning area (the archipelagic baseline plus a 12 nm buffer), which provides the best option both ecologically and politically.
- Develop 44 socio-economic and governance principles that a) maximize the benefits of the MPA network and minimize the costs for local communities and other stakeholders; and b) aligns the network with local legal, political, and institutional requirements.
- Apply 18 biophysical principles that incorporate key biological and physical processes into the MPA network design.
- Use two cutting-edge scientific studies that account for coral-reef fisheries and climate change (bleaching risk from thermal stress).
- Use a total of 37 conservation features that represent shallow and deep-water habitats in critical, special, and unique areas; and incorporates aspects of ecological connectivity, climate change, fisheries, human population, existing protected areas, and other impacts.

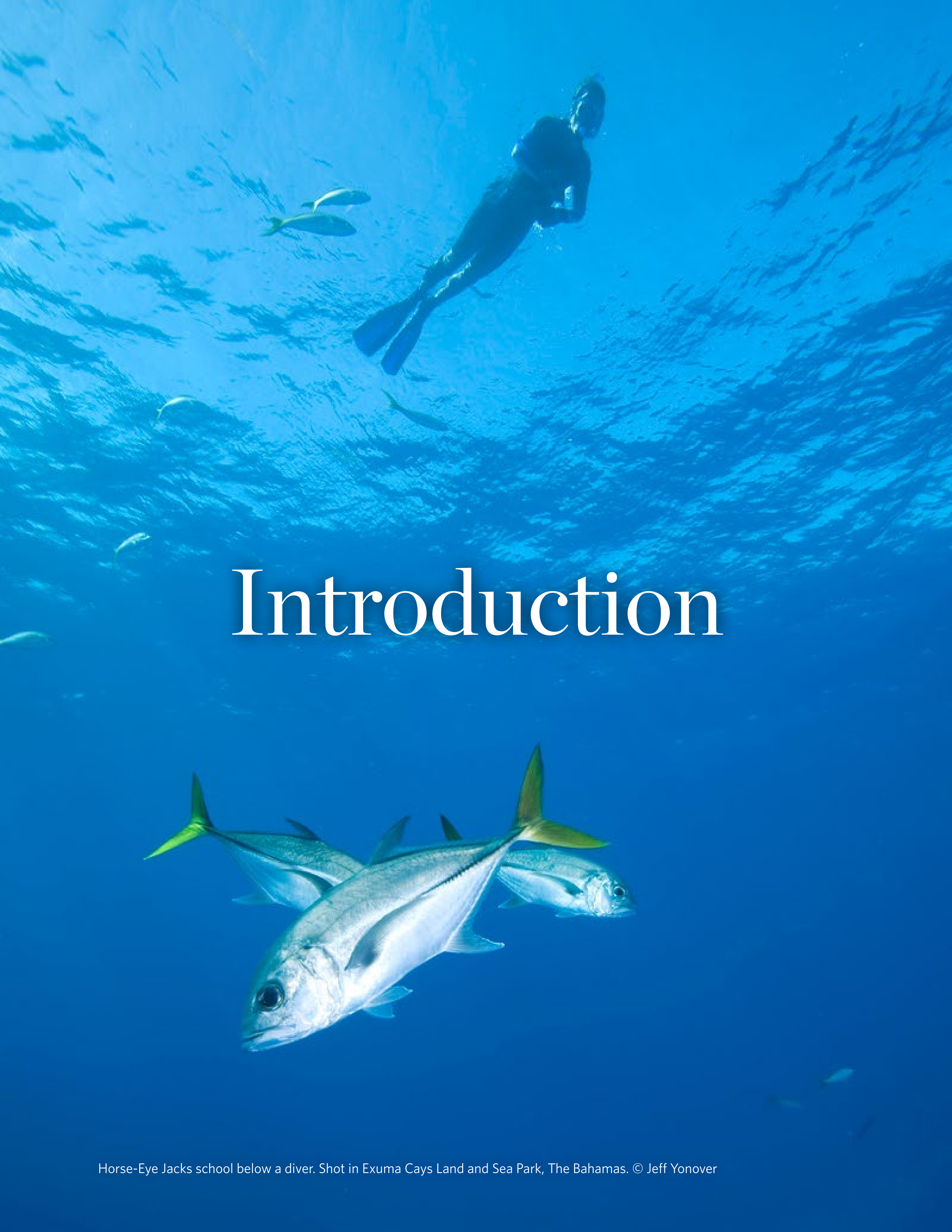
This marine gap analysis provides a range of priority areas, which represent more than 10% (or more than 28,035 km²) of the territorial waters of The Bahamas. Of the highest priority sites, 51 "areas of interest" (AOI) were delineated. The Bahamas Protected partners (The Nature Conservancy, Bahamas National Trust, and Bahamas Reef Environment Educational Foundation), the NISP and other stakeholders should consider these sites as focal areas when establishing new MPAs. These AOI represent 8% of the planning area (approximately 23,133 km²). They include locations in each geographic stratum that encompass a diversity of high-priority conservation features. (See map below.)

The Bahamas can now use these AOI along with the design principles, local knowledge, and stakeholder input, to identify, develop, and propose legal boundaries for new MPAs to achieve the goals and objectives of the BNPAS.



The Bahamas National Protected Area System and Areas of Interest Map

Introduction



Horse-Eye Jacks school below a diver. Shot in Exuma Cays Land and Sea Park, The Bahamas. © Jeff Yonover

Introduction

EXPANDING THE BAHAMIAN MARINE PROTECTED AREA NETWORK

The Bahamas has one of the largest marine territories of any country in the Caribbean covering approximately 237,584 sq. miles (382,354.38 kilometers). The marine and coastal resources of The Bahamas—its coral reefs, beaches, fisheries, and mangroves— help define its people and culture, support marine biodiversity, and provide critically important ecosystem services like food security and coastal protection for the roughly 377,000 people who live there. Additionally, these resources serve as an essential economic engine, supporting jobs, income, and overall economic prosperity for Bahamians. In 2014, travel and tourism contributed a total of BSD 3.7 million to the country's gross domestic product (GDP). This investment in the economy represents 43.6% of the total GDP for The Bahamas (World Travel & Tourism Council 2015).

The marine and coastal resources of the country are facing increasing threats, particularly from unsustainable fishing, coastal development, invasive species, and pollution. Changes in climate and ocean chemistry also pose serious threats to the long term sustainability of these resources (Moultrie 2012).

In 2008, the Caribbean Challenge Initiative (CCI[1]) was launched to provide greater leadership to chart a new course for protecting and sustainably managing the marine and coastal environment across the Caribbean. The Bahamas was one of two governments that initially agreed to participate in the CCI, committing to effectively manage at least 20% of their near shore and marine environment by the year 2020 (the 20-by-20 goal). It hopes to achieve this target by expanding The Bahamas National Protected Area System (BNPAS: Moultrie 2012).

Even before committing to the CCI, The Bahamas recognized the importance of safeguarding its marine environment through the creation of MPAs. The Exuma Cays Land and Sea Park, declared in 1958, is the oldest and one of the most successful MPAs in the Caribbean (see Brumbaugh 2014).

Since the 1950s, The Bahamas has been steadily expanding its protected area system. In 1992, The Bahamas formalized its commitment to conserving biodiversity through a system of protected areas by signing on to the Convention on Biological Diversity (CBD) (Moultrie 2012). In 2015, the Government of The Bahamas announced the designation of five new national parks on San Salvador, 14 new MPAs, and the expansion of three existing MPAs in the Bahamian archipelago. These declarations increased The Bahamas' existing MPA network by more than 11 million acres, or approximately 8% of the country's entire marine area[2]. Nearly 10% of its marine shelf (<200m depth) fall within a designated protected area (Fig. 1).

Before the 2015 declarations, stakeholders developed national targets for several habitat types and some critical, special, and unique areas (also called conservation features) during the 2014 gap analysis (Moss and Moultrie 2014). A version of these features is also listed in the Master Plan for The Bahamas National Protected Area System (Moultrie 2012). Fig. 2 compares the current MPA coverage of The Bahamas with targets previously established. Not all conservation features that were used in this analysis are a direct match to those used in the past (e.g. types of coral reefs).

Although The Bahamas has made progress in meeting or exceeding the area coverage goal for many marine conservation features, there are approximately 20 features that fall short of nationally set targets. Below is a short discussion on selected features which illustrates the gaps between the current protection levels and the national targets established in 2014:

- Less than 20% of all fish spawning aggregations are under protection. This disparity suggests there is a

[1] http://www.caribbeanchallengeinitiative.org/

[2] Percentage of the EEZ excluding land.

huge gap between the existing level of protection and national targets. Actively protecting fish spawning aggregations through the establishment of marine protected areas and the enforcement of fisheries regulations will ensure that biodiversity, fisheries livelihoods and cultural norms persist for future generations.

- Fifty percent (50%) of tidal creeks in The Bahamas are currently protected. However, progress to-date falls short of the national target, which is to protect 100% of these habitats.
- The Bahamas has the most expansive seagrass beds in the Caribbean. Seagrass provides important feeding and nursery habitats for many marine species and plays a significant role in regulating climate change in the ocean. Only 8% of this habitat falls within current protected areas.
- Coral reefs are one of the most diverse marine habitats in the archipelago. Forereefs, which support the largest biomass of fish, are under immense fishing pressure. Protecting corals that are more resilient to the impacts of climate change is important for biodiversity, sustaining livelihoods and preserving Bahamian culture. There are no national targets for forereefs or patch reefs. However, approximately 7% of forereef habitat and 30% of patch reefs fall under the current protected area system.
- Mangroves are critical nursery habitats that contribute significantly to the abundance and diversity of fish species throughout The Bahamas. Although they exceed the national target most of the nation's mangroves are located in the Andros Westside National Park. Further measures should be taken to protect mangroves in other locations to address ecological concerns related to connectivity, replication and representation of this habitat across the protected area system.

Eleuthera, Cat Island, Long Island and the Western Great Bahama Bank have no existing marine protection. The inclusion of these areas is critical to the design and expansion of the protected area network. These additions will help to address ecological concerns related to connectivity, replication and representation of biological features across the system.

Fig. 3 shows additional conservation features that fall under the current BNPAS. These features do not have nationally set goals, but were included in the analysis. Many of the nationally set goals apply to specific types of habitats or to species. Several of these were grouped in Fig. 4 (e.g. overall coral reef extent, seabird colonies, etc.) illustrative purposes.

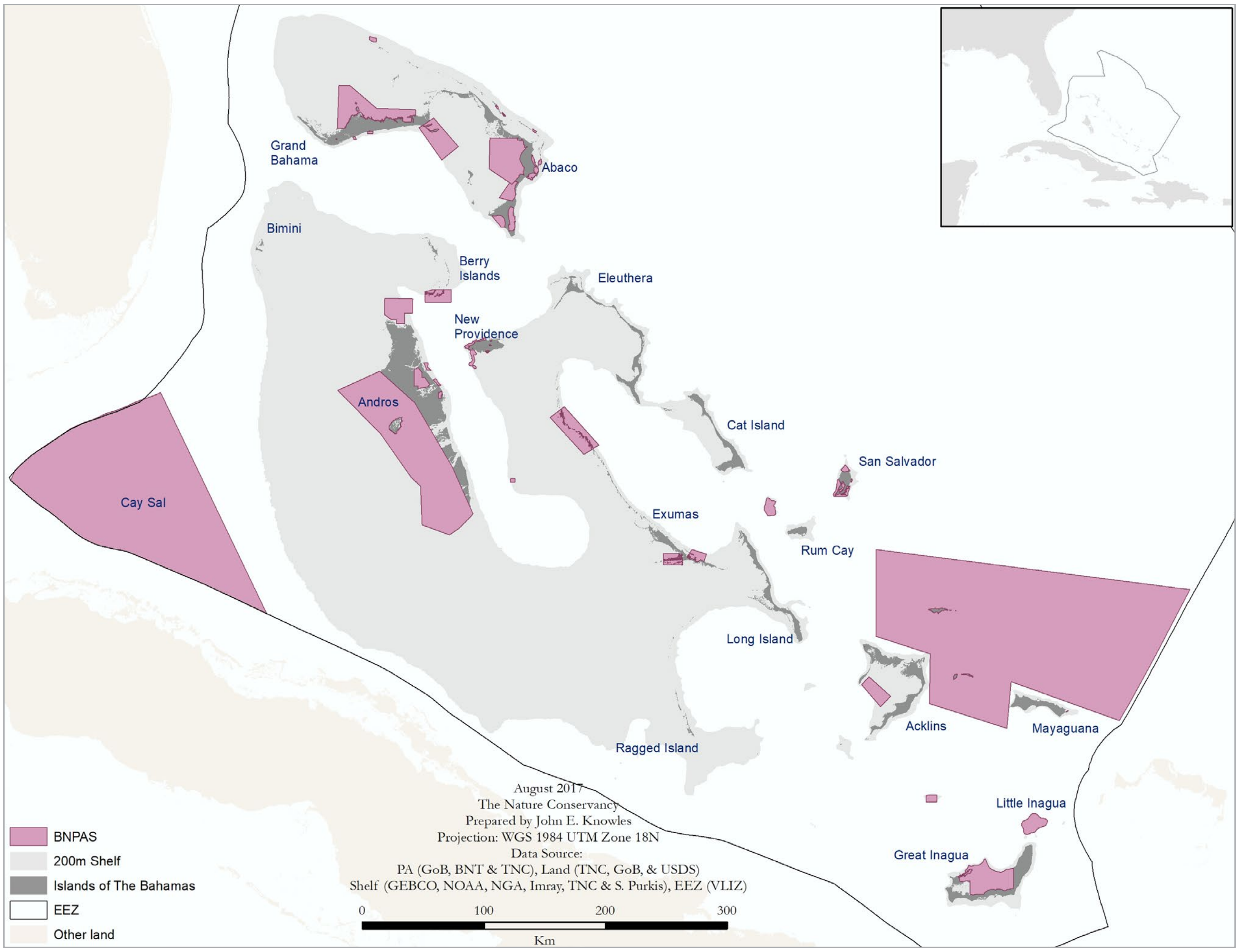


Figure 1. The Bahamas National Protected Area System

A NATIONAL MARINE GAP ANALYSIS

A MPA network can be an effective tool to protect biodiversity (i.e. ecosystems and species) and ecological processes that in many cases provide important goods and services for humans. To perform a gap analysis is to identify biodiversity and essential ecosystem goods and services not adequately protected.

Two national gap analyses have been conducted previously in The Bahamas (Thurlow and Palmer 2007; Moss and Moultrie 2014). Here, the results of a third analysis identifies gaps in the existing BNPAS that are priority areas for establishing new MPAs to realize the 20-by-20 goal. This third iteration of the gap analysis differs from the previous national gap analyses in the following ways:

- Has a marine focus only;
- Expands objectives beyond biodiversity protection to address climate change impacts and socioeconomic factors (e.g. to support Bahamian livelihoods);
- Has a different planning area that aligns with other national planning processes;
- Uses the latest science to develop biophysical, socioeconomic, and governance design principles to guide the planning process;
- Developed, modified and/or acquired new spatial data layers that support the design principles in the gap analysis; and
- Uses innovative scientific approaches to model and map coral reef fisheries and climate change (thermal stress).

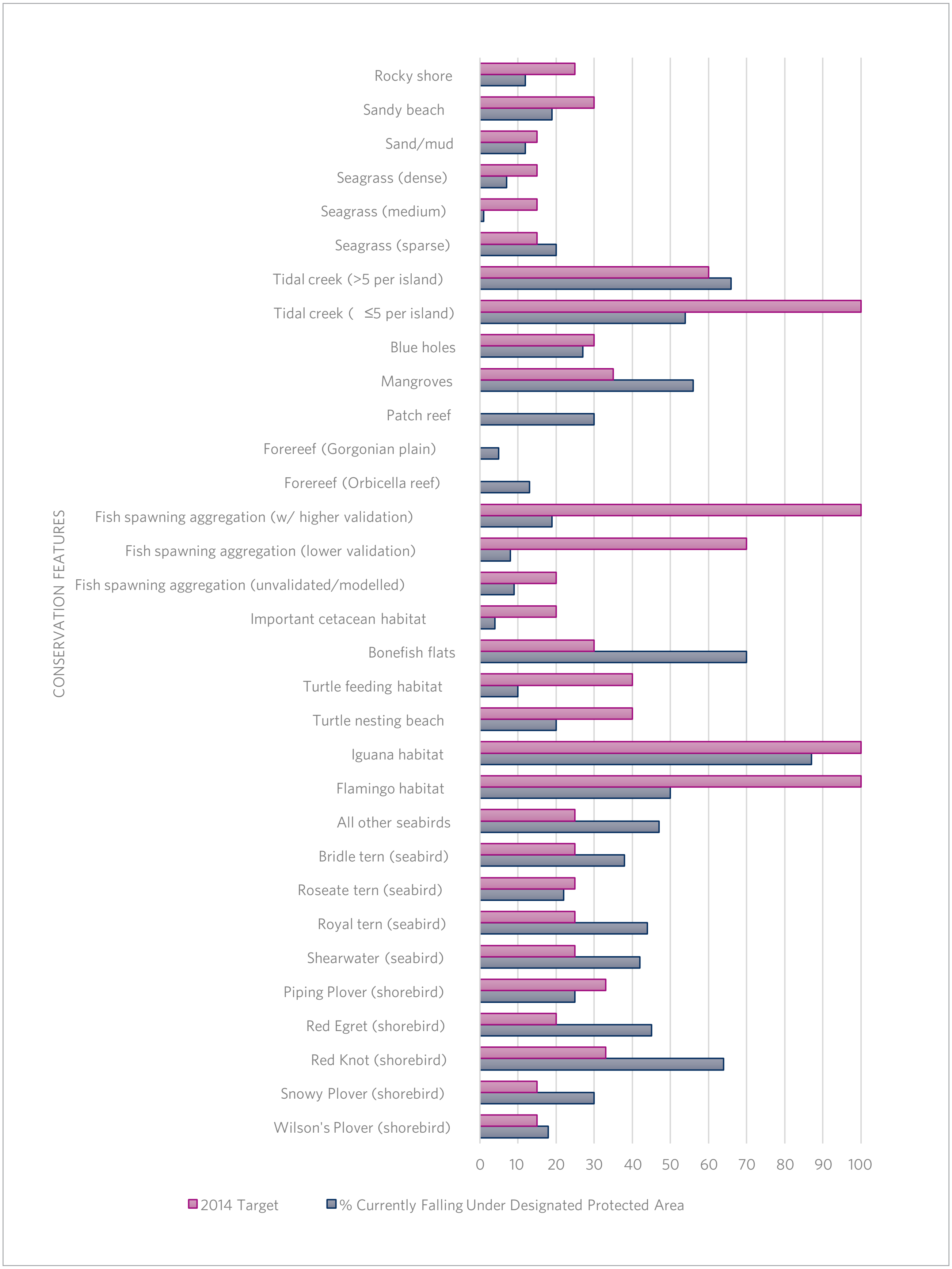


Figure 2. Comparison of previously set targets with percentage of conservation features currently falling under the BNPAS.

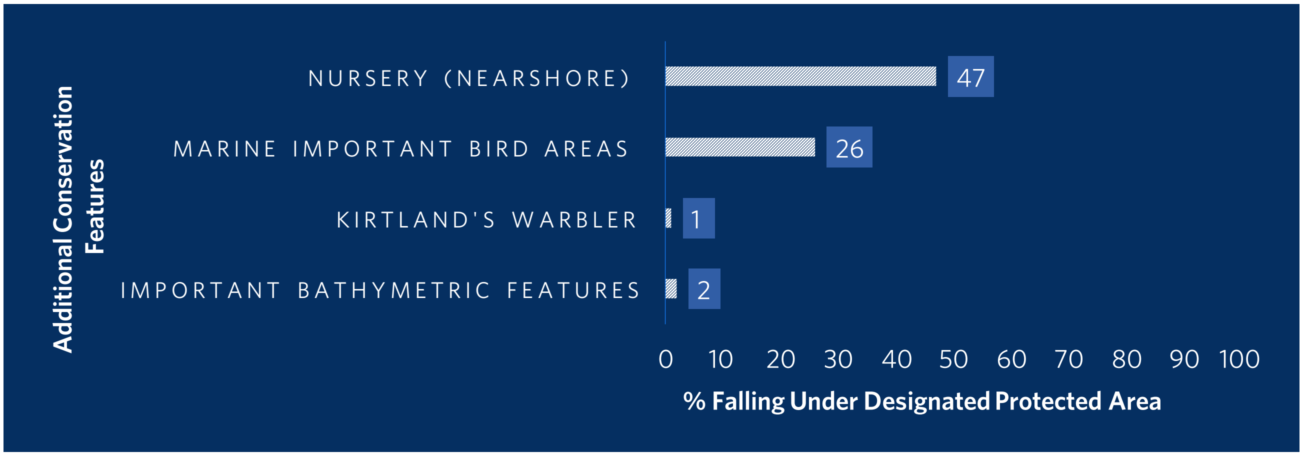


Figure 3. Percent of conservation features that fall under the BNPAS, which don't have nationally set goals, but which were included in the analysis.

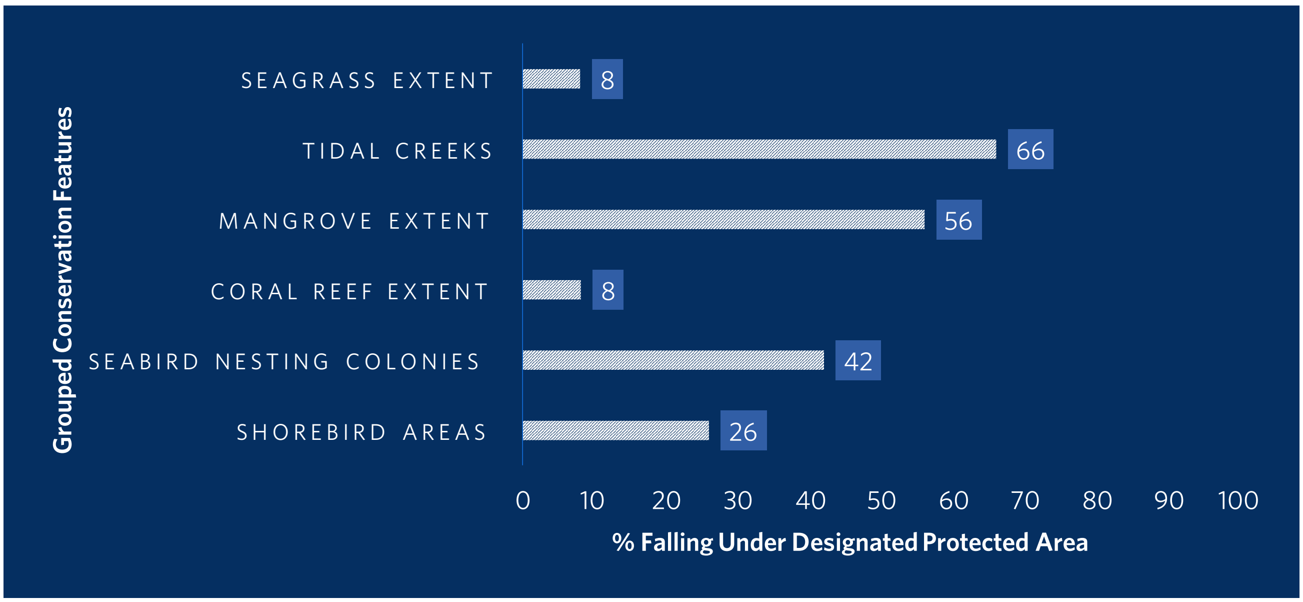


Figure 4. Percentage of grouped conservation features currently falling under the BNPAS. "Seagrass extent" is composed of the dense, medium, and sparse seagrass conservation features. "Tidal creeks" represents all tidal creeks in The Bahamas. The mangrove conservation feature is not split in any way, so it represents itself. "Coral reef extent" is composed of the patch reef, Orbicella reef, and gorgonian plain conservation features. "Seabird nesting colonies" is composed of all species of seabirds. "Shorebird areas" is composed of sightings of all shorebird species.

Methods & Results

Threespot Damselfish, photographed underwater in the Exuma Cays Land and Sea Park, The Bahamas. © Jeff Yonover

Methods & Results

OVERVIEW OF THE SCIENTIFIC PROCESS AND STAKEHOLDER INPUT

The team that led the marine gap analysis included scientific experts and practitioners from The Nature Conservancy (John Knowles, Alison Green, and Frederick Arnett) and the Bahamas National Trust (Lindy Knowles and Craig Dahlgren), with expertise in MPA network design, GIS and spatial analysis, and marine ecology and biology of The Bahamas.

The team conducted the scientific design process by:

1. Expanding the objectives beyond biodiversity protection to include climate change and socioeconomics (e.g. to support Bahamian livelihoods);
2. Specifying a planning area that also aligns with multiple national planning processes and defining the types of zones to consider in the analysis;
3. Using the latest science to apply biophysical, socioeconomic, and governance principles for the MPA network design;
4. Incorporating new and refined spatial data layers (Table 4);
5. Using innovative scientific approaches to maximise the benefits of the MPA network, so that protected areas can adapt to climate change, enhance coral reef fisheries, and benefit local communities; and
6. Identifying priority areas for establishing new MPAs.

To do this, the team worked with approximately 40 local and international scientists and field practitioners representing more than 26 organizations through three national workshops (as described in Table 1) and sought strategic advice from the National Implementation Support Partnership.

Table 1. National stakeholder workshops in Nassau, New Providence, their timing and outputs.

WORKSHOP	OUTPUTS
Inception Workshop for *Realizing The 2020 Goal: Advancing the Expansion and Effective Management of the Marine Protected Area System in The Bahamas* (February 3-4, 2016)	Input and advice from key stakeholders regarding the major goals and objectives of the marine gap analysis and the latest science for MPA network design.
Ecological Gap Analysis Workshop (September 13–14, 2016: Green et al. 2017b)	A shared understanding by key stakeholders of the scientific process to be used in the gap analysis and progress since the Inception Workshop. Input and advice from scientific experts and practitioners to improve the scientific design process regarding: objectives, planning area, types of zones, biophysical, socioeconomic and governance design principles, new and innovative science, and spatial data layers to be used in the analysis.
Gap Analysis Update Workshop (March 28th, 2017) (Moss 2017)	A shared understanding of progress made to date, and further input received from key stakeholders regarding developing socio-economic and governance design principles; revised spatial data layers; initial results of the Marxan analysis; and next steps beyond the gap analysis to realize the 2020 goal to effectively manage and expand marine protected areas in the Bahamas.

The following is a description of the methods and results from the scientific design process.

DEFINING NETWORK OBJECTIVES, PLANNING AREA AND TYPES OF ZONES

Prior to the Ecological Gap Analysis Workshop (Table 1), the Bahamas Protected science team sought strategic advice from the NISP regarding the:

- Overarching objectives of the BNPAS;
- Planning area to be used in the marine gap analysis; and
- Types of MPAs or zones to be considered in the expansion of the BNPAS.

Based on this advice (Green et al. 2017b), the team used the following objectives, planning area, and types of zones for the gap analysis.

Objectives

In the previous ecological gap analyses (e.g. Moultrie 2012), the overarching goals of the BNPAS were as follows: ensure that ecosystem services are kept intact; be responsible stewards of unique biodiversity; sustain livelihoods; ensure quality of life and the beauty of the islands; and contribute to global targets.

In order to achieve these goals, The Bahamas should have well defined objectives regarding key issues such as biodiversity protection, natural resource management, and climate change adaptation. These objectives should be SMART (specific, measurable, attainable, resourced, and time bound). Thus, the objectives were revised and then presented to the NISP for their consideration.

After much deliberation, the NISP agreed to the following objectives for the analysis and the BNPAS:

- By 2020, bearing in mind the impacts of climate change, identify and protect diverse marine ecosystems and critically important species; and
- By 2020, protected areas (marine and terrestrial) will contribute to maintaining and improving Bahamian livelihoods by maximising the benefits and minimising the costs of protected areas for local communities and stakeholders.

Planning Area

When setting national goals and targets, it is important that countries determine and agree upon how they will be specifically achieved. In the case of the Aichi Biodiversity Targets and the CCI, countries were given the autonomy to determine how best to measure their own progress. Although national discussions have been ongoing for some time in The Bahamas, no determination had been made about how to measure progress toward achieving the goals of the CCI. In the absence of national consensus, the NISP was asked to provide guidance on the planning area that should be used for national reporting purposes and this gap analysis.

Three planning area options were presented to the NISP: the entire EEZ; the marine shelf (<200 m); and the NISP 12 nm buffer around land. After a thorough review of each option, the NISP proposed a fourth option: the archipelagic baseline plus a 12 nm buffer, otherwise known as the territorial waters of the Bahamas.

The NISP recommended the territorial waters as the planning area (i.e. the archipelagic baseline plus a 12 nm buffer shown in Fig. 5) because it provides the best option both ecologically and politically. This planning area integrates and recognizes the archipelagic nature of The Bahamas; it incorporates most of the <200-meter-deep marine shelf and some deeper habitats (most activities occur within this area) and it aligns with other national planning processes (i.e. this area is accepted by the UNCLOS and has been adopted by coastal zone management efforts).

Types of Zones

MPA networks can be effective tools for natural resource management when well designed and effectively managed. Based on the latest science and best practices, an important component of a well-designed MPA network is the existence of various levels of protection or protected areas with different objectives, with some more stringent than others in terms of resource extraction and access. Protected areas with the highest levels of protection in the marine environment are no-take areas (NTAs), which are often called marine reserves or replenishment zones. NTAs provide the most ecological benefits in terms of increased biodiversity, greater fish density and overall biomass, and increased reproductive potential of many species within their boundaries (Fig. 6)—especially

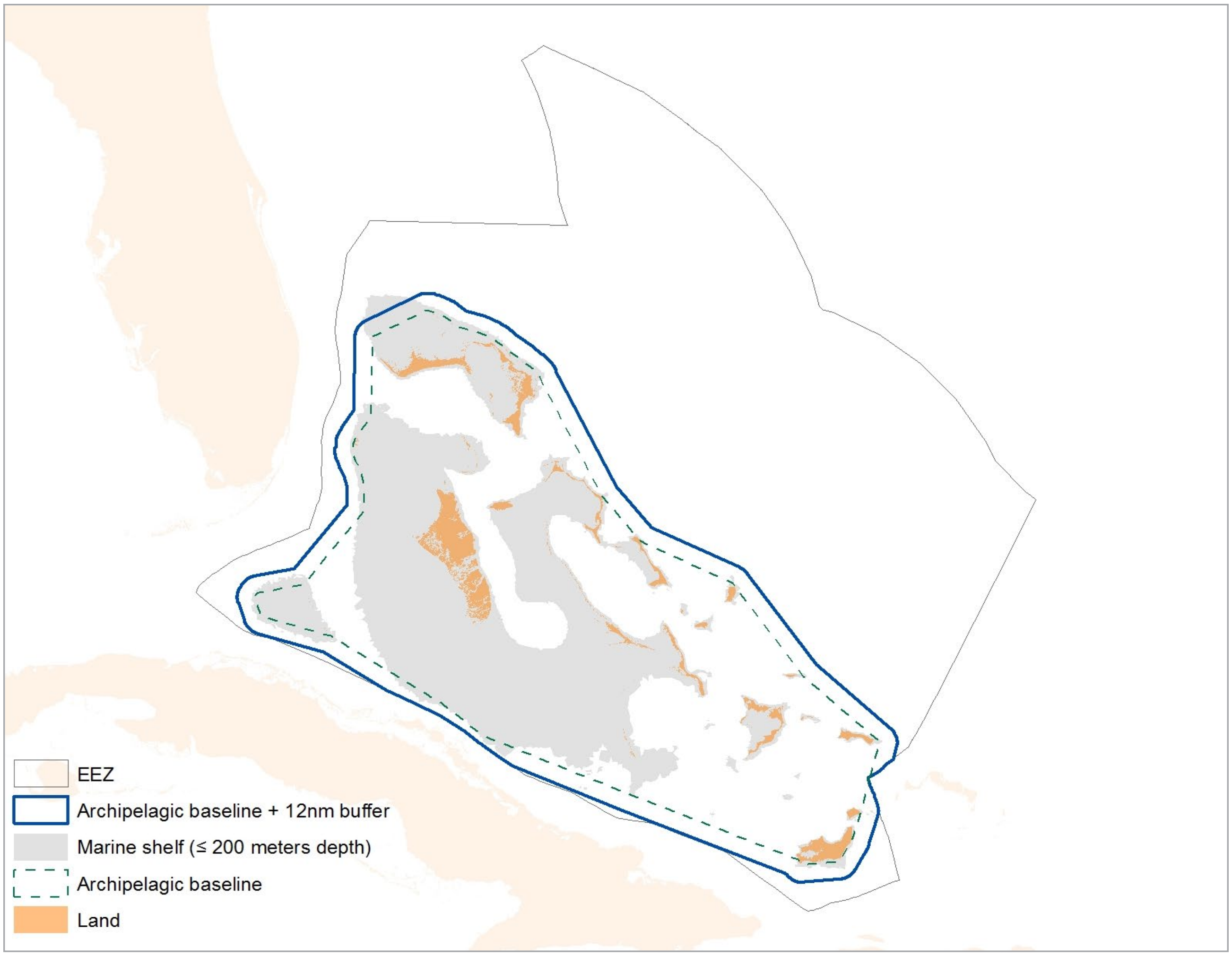


Figure 5. Planning area for the marine gap analysis: the territorial waters of The Bahamas (archipelagic baseline plus a 12-nm buffer).

those of commercial importance (Lester et al. 2009). Beyond their boundaries, NTAs can enhance fisheries' productivity through the export of eggs, larvae, and adults (Halpern et al. 2010; Harrison et al. 2012; Almany et al. 2013).

It was recommended to the NISP that different levels of protection should be used to meet the 20% goal under the CCI. This approach could be applied differently in shallow-water habitats (on the marine shelf <200 meters) and deep-water habitats (>200 meters deep) where:

- 20% of shallow-water habitats should be in highly protected NTAs; and
- 20% of deep-water habitats (>200-meter depth) should be within MPAs with different levels of resource protection (high, intermediate, and low).

However, the NISP selected an alternative option, which was used to guide the analysis: "Achieve the goal of 20% by employing MPAs which are zoned to include different levels of protection. Highly protected areas would be included where possible [in the future] considering both the socio-economic and biophysical dynamics within The Bahamas".

DESIGN PRINCIPLES

Design principles are guidelines that provide scientific advice on how to create a MPA network so that it will achieve its objectives. Two types of design principles were developed for The Bahamas: biophysical principles and socioeconomic and governance principles.

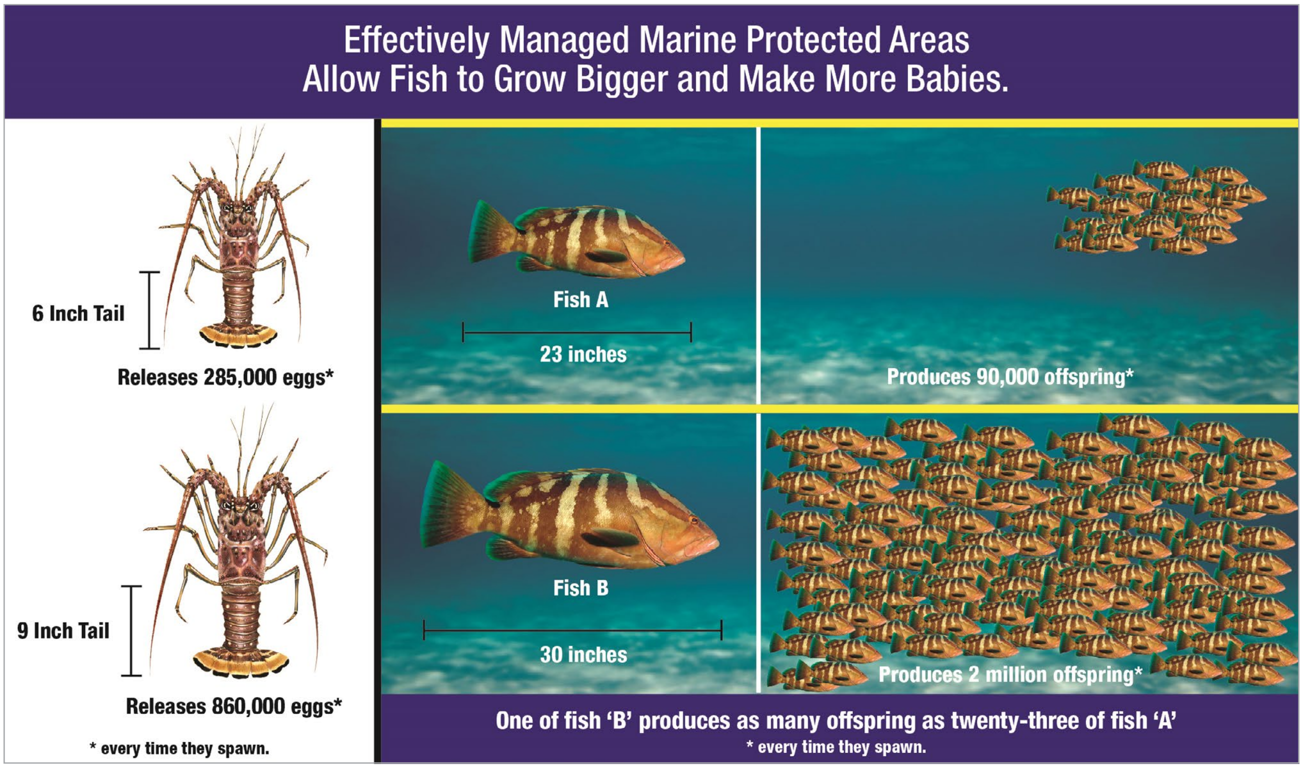


Figure 6. Some of the benefits of Marine Protected Areas

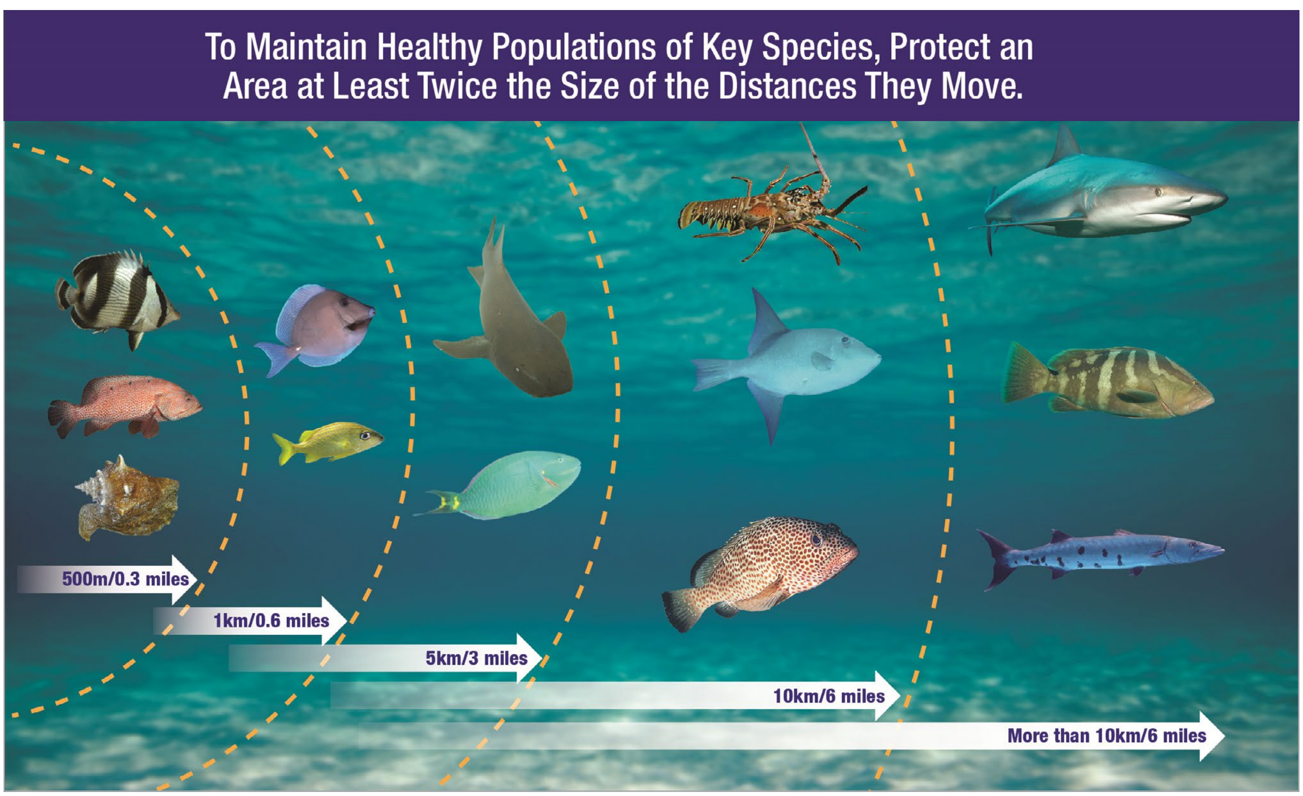


Figure 7. Illustrates the importance of the size of Marine Protected Areas to marine organisms.

Biophysical Design Principles

Biophysical design principles aim to achieve biological objectives by taking key biological and physical processes into account.

Recent reviews provide a scientific basis for designing MPA networks that improve fisheries management, biodiversity conservation, and climate-change adaptation in tropical marine ecosystems worldwide (Abesamis et al. 2014; Green et al. 2014a,b). Most of these design principles relate specifically to NTAs, because they provide the greatest ecological benefits. These principles can also be applied to other types of MPAs, although they are likely to be less effective in achieving the objectives of a protected area.

The science team took the following steps to develop biophysical design principles for The Bahamas:

- Referenced and modified design principles that were originally developed for coral-reef ecosystems worldwide (Abesamis et al. 2014; Green et al. 2014a,b) to suit the unique biological and physical environment in The Bahamas;
- Presented the draft principles at the Ecological Gap Analysis Workshop (September 13–14th, 2016: Green et al. 2017b) for review and input from workshop participants; and
- Finalized the principles with input from workshop participants (Table 2).

Table 2. Biophysical principles for designing a MPA network for The Bahamas. More information regarding the scientific rationale, explanatory notes and research priorities for each principle is available in Green et al. (2017b). Where focal species include key fisheries species, functional groups that are important for maintaining ecological resilience to local and global threats, and rare and threatened species.

CATEGORY	BIOPHYSICAL DESIGN PRINCIPLE
Habitat Representation	Represent at least 20% of each major habitat type in NTAs.
Risk Spreading	Protect examples of each major habitat type within at least three widely separated NTAs in each island/island group.
Protecting Critical, Special and Unique Areas	Protect critical areas responsible for supporting the life history of focal fisheries species in permanent or seasonal NTAs.
	Protect special or unique areas for biodiversity protection (e.g. important habitats for endemic, rare and threatened species; particularly healthy areas; and areas with high habitat or species diversity) in NTAs.
Incorporating connectivity: movement of adults and juveniles	Consider movement patterns of focal species when determining the size of NTAs.
	Use compact shapes for NTAs rather than elongated ones.
	Include entire ecological units in NTAs.
	Protect habitats used by focal species throughout their lives in NTAs, and ensure NTAs are located to allow for the movement of focal species among protected habitats.
Incorporating connectivity: larval dispersal	Spread the risk within island/banks rather than between them (see "Risk Spreading" above).
	Space NTAs <50 km apart.
	Isolated populations (separated by >100km) should be afforded greater protection.

CATEGORY	BIOPHYSICAL DESIGN PRINCIPLE
Allowing Time for Recovery	NTAs should be in place permanently.
	Short term or periodically harvested NTAs should only be used in addition to, not instead of, permanent NTAs.
Adapting to Changes in Climate and Ocean Chemistry	Protect refugia in NTAs where habitats and species are likely to be more resistant or resilient to climate and ocean change.
	Spread the risk (see "Risk Spreading" above) and add a climate change buffer by increasing percent representation of major habitat types (see "Habitat Representation" above).
Minimizing and Avoiding Local Threats	Avoid placing NTAs where ecosystems have been, or are more likely to be, degraded by local threats that can't be managed effectively.
	Prioritize placing NTAs where there are, or are more likely to be, healthy ecosystems and low levels of threats.
Integration within Broader Management Frameworks	Integrate networks of NTAs within broader planning and management regimes.

Socio-economic and Governance Design Principles

Socio-economic and governance (SEG) principles are aimed at designing and managing the MPA network for The Bahamas in ways that will:

- Maximize benefits and minimize costs to local communities and other stakeholders; and
- Align the network with local legal, political, and institutional requirements.

To develop SEG design principles for The Bahamas the team took the following steps:

- Refined the draft principles by reviewing and modifying those that were previously used for MPA network design processes in other countries including Australia (Fernandes et al. 2005), Papua New Guinea (Green et al. 2009), Belize (S. Cruz and J. Robinson pers. comm.), Indonesia (Wilson et al. 2011, Mangubhai et al. 2015), Palau (Victor et al. 2015), and the Coral Triangle (CTI-CFF 2012).
- Presented the draft principles to attendees at the Ecological Gap Analysis Workshop (September 13–14th, 2016) for feedback. Participants were asked to review and adapt the principles based on four thematic areas: general guiding principles and multiple use of marine areas; livelihoods; community and cultural interests; and governance (see Green et al. 2017b).
- Contracted a social scientist to continue working with key national and community-based stakeholders to further refine and develop the SEG principles for The Bahamas (Table 3).

Table 3. Socioeconomic and governance principles for designing and managing a MPA network for The Bahamas. More information regarding the scientific rationale, explanatory notes, and research priorities for each principle is available in Wise (2017).

CATEGORY	SOCIOECONOMIC AND GOVERNANCE DESIGN PRINCIPLE
General Guidelines	
General Guidelines	Base decisions on the best available science (ecological and socio-economic) and local knowledge.
	Commit to a trans-disciplinary approach from the initial phase of project.
	Use a consultative process which includes local communities in the decision-making process through open, balanced and transparent participation.
	Account for inter-island cultural differences as well as differences between community groups.
	Engage and support collaboration and co-management across sectors and community groups.
	Protect critical, special, unique, and culturally important areas: • Protect areas with cultural and social value (e.g. shipwrecks, areas with culturally and economically valuable plants and animals). • Support additional research to address gap in data and knowledge regarding features to protect and their location.
	Engage in responsible waste management and implement mitigation measures.
Promoting Equity in Risk Sharing	
Ensuring Sustainable Use of Natural Resources and Associated Livelihoods	Ensure effective management of natural resources (including protection where appropriate) that local communities identify as important to their livelihoods and cultural heritage.
	Protect economic multiplicity due to seasonal livelihood patterns (e.g. fishing, tourism and farming) whenever possible.
	Support and promote market diversity within fisheries e.g. develop alternative (and abundant) species for market, such as lion fish.

CATEGORY	SOCIOECONOMIC AND GOVERNANCE DESIGN PRINCIPLE
Minimizing Conflict	
Reducing Potential Conflicts	Allow for current and future multiple uses, including: • Sustainable commercial and subsistence fishing; • Tourism; • Management of invasive species; • Recreation; and • Education and research.
	Minimize conflicts by considering existing and future patterns of population trends and resource use to reduce conflicts among resource users by: • Separating incompatible uses in different zones e.g. extractive vs non-extractive uses; • Accommodating compatible uses within zones e.g. research and educational activities in no take areas; and • Avoiding the placement of protected areas near existing and planned mining, oil and gas industries, shipping lanes and infrastructure (ports, wharves, channels).
	Address the land-sea interface, by considering significant threats to near-shore habitats (e.g. from land development and run off) that provide critical habitat for valuable species (e.g. land crab).
Considering Costs and Benefits	
Considering Costs and Benefits	Ensure the costs and benefits of protected areas are shared equitably within and among communities, irrespective of gender, race, or interest groups or generations, through the diversification of livelihoods and the development of economic alternatives.
Considering Tradeoffs of Threats and Opportunities	Consider the costs and benefits of placing protected areas near major towns and cities (e.g. increased opportunities for enforcement, research and alternative incomes vs. increased use, pollution and loss of habitat with coastal development).
Ensuring Social, Ecological and Economic Sustainability	
Protecting Ecosystem Services	Prioritize areas for management where appropriate protection is important for providing ecosystem goods and services (e.g. for food security and coastal protection).
Ensuring Sustainable Use of Natural Resources and Associated Livelihoods	Support sustainable subsistence fisheries for local communities to improve food security and support livelihoods.
	Manage natural resources with local communities to support their livelihoods by prohibiting unsustainable and destructive practices.
	Work closely with local community members to improve enforcement of existing regulations.
	Maximize opportunities for diverse incomes for local communities from sustainable uses by: • Engaging with communities to develop relevant, appropriate, and sustainable livelihoods. • Supporting the development of alternative economic markets and market institutions.
Maintaining and Improving Quality of Life	Identify and address gaps in basic human needs (water, food, shelter, healthcare, education, etc.) when selecting protected area locations.

CATEGORY	SOCIOECONOMIC AND GOVERNANCE DESIGN PRINCIPLE
Facilitating Effective Governance and Management	
Facilitating Effective Governance and Management	Foster political will and leadership at the highest level.
	Develop strong ties with local on-the-ground contacts from the community.
	Operate the protected area system with clear, appropriate and effective institutional arrangements and coordination mechanisms.
	Integrate protected areas within broader management regimes (e.g. integrated coastal management, ecosystem-based management) to address threats.
	Recognize and address the transboundary nature of some important natural, social, and economic resources.
Recognizing and Integrating Existing Management Arrangements	Document existing management arrangements.
	Maximize placement of protected areas in locations that complement and include present and future management and tenure arrangements including: • Existing or proposed zoning plans, management plans, or other related management strategies for marine areas by federal, state, or local government authorities. • Ensure that all land use planning agencies (i.e. Ministry of Works, Dept. of Land & Survey and the Office of the Prime Minister) are included in the protected area planning process.
	Create training programs for enforcement agents and local government.
Considering Social and Cultural Values	
Respecting Local Culture, Ownership, Knowledge and Traditional Practices	Ensure that cultural values, traditional knowledge (local wisdom) and sustainable management practices are considered throughout the project planning, design, and decision-making processes.
	Recognize and respect land ownership, traditional resource use and access, and cultural claims.
	Provide opportunities for communities and other stakeholders to identify special or unique areas for protection (e.g. places of biological, cultural, aesthetic, historic, physical, social, or scientific value) and prioritize placement of areas (e.g. important fishing areas) to minimize impacts to livelihoods.
Sharing Perspectives and Capacity	Share knowledge and communicate the benefit of protected areas through education and capacity building programs among stakeholders.
Facilitating Effective Governance and Management	
Integrating Levels of Co-management	Integrate opportunities for co-management with local communities, other stakeholders, and across relevant government agencies.
Prioritizing Areas Where Conservation and Management are More Likely to be Successful	Prioritize sites for protected areas where: • Local communities support protected areas; • Community and science based prioritization efforts overlap; • Good collaboration and opportunities for co-management exist between local communities and authorities.

CATEGORY	SOCIOECONOMIC AND GOVERNANCE DESIGN PRINCIPLE
Prioritising Adaptability	
Adapting to Climate Change	Prioritize areas for protection where human communities are likely to be more resilient to climate change impacts.
Adapting to Social-economic Change	Prioritize areas for protection where human communities are likely to be more resilient to socio-economic impacts.
Adapting to Changes in Social and Environmental Conditions	Support the capacity to flexibly adapt to changing social, ecological, and economic conditions for the life, culture, and livelihoods of Bahamians.
Improving Compliance and Enforcement	
Improving Compliance and Enforcement	Encourage compliance and commitment to the protected area network by fostering public understanding and acceptance across all levels.
	Facilitate enforcement by having protected areas that have simple shapes and clear boundaries or follow natural boundaries (i.e. creeks, coastline).
	Augment existing enforcement with co-management strategies.
Facilitating Cooperation	Support cooperation through clarity in mandates, roles, and functions of management authorities.
Building Capacity	Actively strengthen deficits in capacity to ensure sufficient resources, skills and capacities.
Facilitating Accountability	Ensure protected area managers are accountable for management effectiveness. Develop an evaluation process to be executed by management staff at regular intervals.

ANALYSIS INPUTS

To systematically process the large amount of information required to identify the most suitable options for expanding the MPA network the team used a decision-support tool, Marxan (Ball and Possingham 2000). This tool was also used in the two-previous gap analyses to generate spatial priorities (Thurlow and Palmer 2007; Moss and Moultrie 2014). The following sections describe the key inputs to Marxan (the planning units, a geographic stratification, the conservation features and goals, and impacts to conservation features) and how the spatial prioritisation analysis was conducted.

Planning Units

Marxan helps to develop, compare and explore a vast number of suitable options for expanding the MPA network across the planning area. These options are a selection of smaller fundamental sections of the planning area, called planning units, which capture information on the habitats and the critical, special, and unique areas (also called conservation features) of The Bahamas.

The size of the planning unit should be at a scale appropriate for both the conservation features in the analysis and the size of the MPAs likely to be declared (Ball and Possingham 2000). A planning unit size of 500 hectares was selected based on the scale of certain conservation features (e.g. patch reef and bathymetric features: derived from LandSat images or coarser bathymetry data respectively), and the scale of the smallest MPAs in The Bahamas (some of which are just under 500 hectares in size). This size is also consistent with the planning units used in the previous analyses (Thurlow and Palmer 2007; Moss and Moultrie 2014).

Planning units can also come in a variety of shapes. A uniformed hexagon shape was used to reduce the edge-to-area ratio more than other shapes (e.g. squares or triangles). The resulting MPA network options, form a collection of hexagons that have a smaller boundary length in comparison to other shapes (Hales 2001). This is an important consideration because a smaller boundary length for the same area is slightly more efficient (achieving goals with minimum expense or effort), (Game and Grantham 2008).

The focus of this analysis is on coastal and marine areas. Therefore, none of the hexagonal planning units (59,895) are land locked (Fig. 8).

Geographic Stratification

A geographic stratification is a division applied to all conservation features which allows users to set and measure goals for each stratum. It also helps to ensure that the most suitable option for expanding the MPA network meets the biophysical principles of habitat representation and risk spreading. Therefore, results are not centred in one location (e.g. the southern Bahamas) (Table 2). Beyond the biophysical rationale, geographic stratification also helps to ensure that the costs and benefits of the MPA network are shared among communities on different islands/island groups (SEC Principles: Table 3).

The geographic stratification for The Bahamas is essentially a modified classification of the carbonate bank environment that was originally based on geomorphology, energy exposure, and bank size, with a latitudinal gradient as introduced by Sullivan Sealey et al. (2002). This original stratification appears to have been modified during the 2007 gap analysis, along with the inclusion of a nearshore-offshore division (Thurlow and Palmer 2007). Since most conservation features do not span both of these environments, it was considered

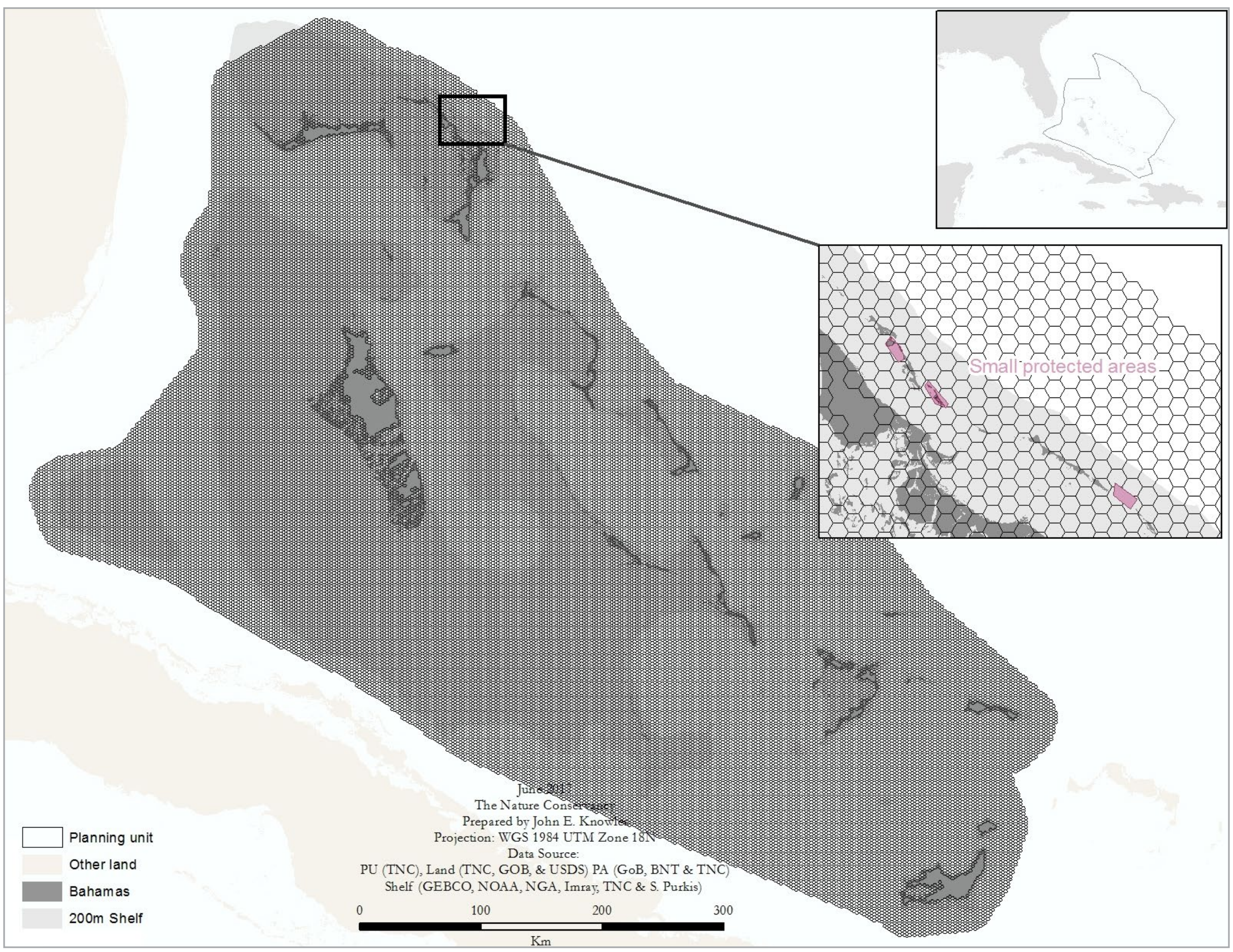


Figure 8. Map of planning units

unnecessary to retain this division. The stratification was further refined using expert knowledge to group areas around The Bahamas with similar biophysical environments for a total of 15 strata (Fig. 9).

Conservation Features

Conservation features represent the spatial distribution of the biological and ecological characteristics under consideration (e.g. major habitat types and critical, special, and unique areas). The conservation features used in the analysis were identified by starting with those used in the last gap analysis (Moss and Moultrie 2014), and adding additional features where spatial data layers were available in The Nature Conservancy's spatial database or provided by scientific experts. This list of conservation features was then reviewed with workshop participants (Table 1, Acknowledgements), and was refined or added to, based on their input and the input from other data providers.

The final list of 37 conservation features used in the spatial analysis is provided in Table 4, along with a summary of how they compare to those used in previous analyses. These conservation features primarily include major habitat types (e.g. coral reefs, mangroves, and seagrasses) and critical, special, and unique areas (e.g. breeding or feeding areas for focal species). Maps of the spatial data layers used for each conservation feature are provided in Appendix 3.

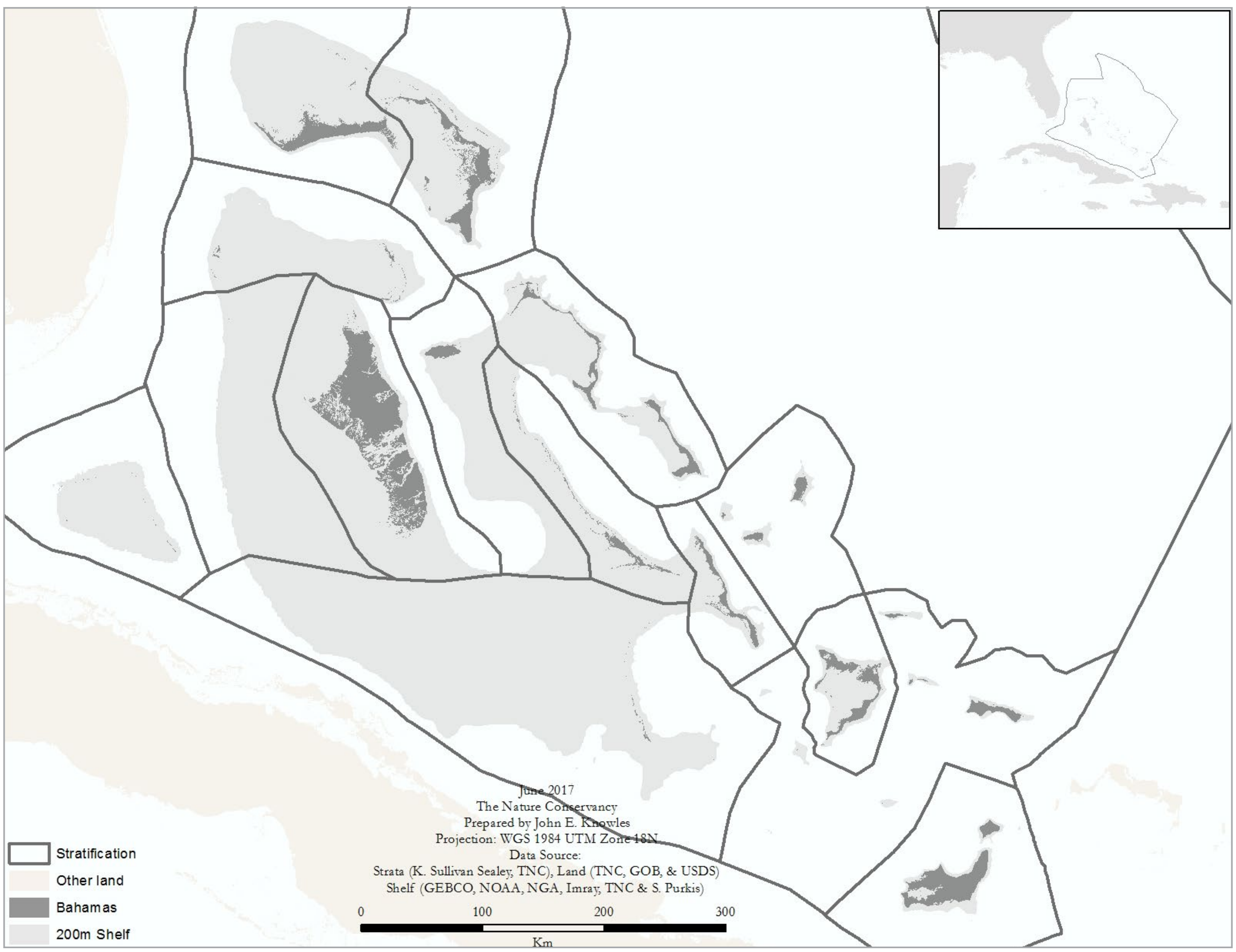


Figure 9. Fifteen (15) Geographic strata within the planning area

Table 4. Conservation features by category used in the marine gap analysis, and how they compare with those used by Moss and Moultrie (2014) as to whether they are the [S]ame, completely [N]ew or modified in some way ([U]pdated or [C]ombined). The last column contains the goals by conservation features in percent in three different bins (<30% goal; 30 – 60% goal; >60% goal) used in the analysis.

CATEGORY	CONSERVATION FEATURES	GOAL
Shallow and deepwater benthic habitats	1. Forereef — *Orbicella* reef (higher survival) [N]	30 - 60
	2. Forereef — *Orbicella* reef (better at adaptation) [N]	<30
	3. Forereef — gorgonian plain [N]	<30
	4. Patch reef [S]	30 - 60
	5. Mangroves [U]	30 - 60
	6. Seagrasses [S]	<30
	7. Sand/mud [C]	<30
	8. Important deep and shallow water bathymetric features [N]	<30
Subtidal/Intertidal habitats	9. Sandy beach [S]	30 - 60
	10. Rocky shore [S]	30 - 60
	11. Tidal creeks [U]	30 - 60
Critical, special and unique areas	12. Kirtland's warbler [N]	30 - 60
	13. Royal tern (seabird) [S]	<30
	14. Roseate tern (seabird) [S]	<30
	15. Bridle tern (seabird) [S]	<30
	16. Shearwater (seabirds) [U]	30 - 60
	17. All other seabirds [S]	<30
	18. Wilson's Plover (shorebird) [U]	<30
	19. Snowy Plover (shorebird) [U]	30 - 60
	20. Red Knot (shorebird) [U]	30 - 60
	21. Red Egret (shorebird) [U]	<30
	22. Piping Plover (shorebird) [U]	30 - 60
	23. Flamingo areas [U]	<30
	24. Marine important bird areas [U]	30 - 60
	25. Iguana habitat [S]	30 - 60
	26. Fish spawning aggregations (lower and higher degrees of validation) [U]	>60
	27. Fish spawning aggregation (not validated or modelled) [S]	30 - 60
	28. Turtle nesting beaches [U]	30 - 60
	29. Turtle feeding areas [S]	30 - 60
	30. Bonefish flats [N]	30 - 60
	31. General model of fish and crustacean nursery areas [S]	<30
	32. Cetacean areas [U]	<30
	33. Blue holes [U]	>60
Protection	34. Coral reef role in reducing coastal vulnerability near areas with relative higher human population density [N]	<30
	35. Mangrove role in reducing coastal vulnerability near areas with relative higher human population density [N]	<30
Fisheries	36. Standing stock of coral reef fisheries species [N]	<30
	37. Potential gain in standing stock of coral reef fisheries species [N]	<30

Goals

The numerical goals in Marxan attempt to approximate or frame the complex interactions of existing real-world goals, objectives, and guidelines related to expanding The Bahamas MPA Network. Examples of the real-world criteria include:

- The Government of The Bahamas commitment under the CCI to effectively conserve and manage at least 20% of the marine and coastal environment by 2020, which will be achieved through the expansion of the BNPAS.
- The Government of The Bahamas commitment to the Aichi Biodiversity Target of setting aside 10% of coastal and marine areas through networks of ecologically representative and efficiently managed protected areas by 2020.
- The biodiversity specific conservation goals identified in the Master Plan for The Bahamas National Protected Area System (Moultrie 2012).
- The biophysical and socioeconomic and governance design principles for MPA network design (Tables 2 and 3), particularly regarding the representation of at least 20% of each major habitat type in NTAs, protection of critical, special, and unique areas, protection of climate refugia, and protection of areas that provide important ecosystem goods and services to people (e.g. food security and coastal protection).
- The two new and expanded objectives for the BNPAS that include climate change and socioeconomics (e.g. to support Bahamian livelihoods)

For this analysis, the aim was to achieve as many of these as possible. However, there was a primary focus on finding the most suitable option for expanding the MPA network to reach the goal of protecting at least 20% of the marine and coastal environment by 2020. Since 10.3% (roughly 29,798 km^2) of the planning area is already within existing MPAs, this will require expanding the MPA network to include new MPAs that will cover an additional ≈10% (roughly 28,035 km^2).

To achieve this, the Marxan analysis must find suitable options representing the additional ≈10% of the marine and coastal environment based on goals set for individual conservation features. The team explored two ways to accomplish this.

First, set the same numerical goal for all conservation features, and then increase this number to investigate the most suitable options that meet both the goals set for the conservation features and represents 20% of the planning area.

Second, set variable goals for conservation features which establishes a distinction among the habitats and the critical, special, and unique areas and reflects the need to prioritize them for protection. While all conservation features are a high priority, it is useful to explore incorporating a range of priorities. To do this, the goals developed for each conservation feature in the 2014 gap analysis (Moss and Moultrie 2014) were used as a starting point. For more information see the Master Plan for The Bahamas National Protected Area System (Moultrie 2012). To optimize the Marxan analysis, these initial goals were added to and adjusted. A bin range of these goals for each conservation feature used in the analysis is listed in Table 4.

Impacts to Conservation Features

Local impacts (habitat destruction, unsustainable fishing practices, rapid tourism growth and unsustainable practices, invasive species and pollution) are degrading coastal and marine ecosystems in The Bahamas. These impacts decrease ecosystem health, productivity, and resilience to climate change, adversely affect many species, and severely undermine the long-term sustainability of marine resources and the ecosystem services they provide (Green et al. 2017b). Changes in climate and ocean chemistry pose serious threats globally to the long-term sustainability of resources, including those in The Bahamas (Moultrie 2012).

Several of the MPA network design principles recommend minimizing and avoiding local threats, and adapting to changes in climate and ocean chemistry (Tables 2 and 3) by:

- Prioritizing NTA locations where there are, or are more likely to be, healthy ecosystems and low impact levels;
- Avoiding placing NTAs where ecosystems have been, or are more likely to be, degraded by local impacts that can't be managed effectively; and
- Protecting refugia in NTAs where habitats and species are likely to be more resistant or resilient to climate and ocean change.

A MPA network that is less impacted may be more practical and more likely to be fully implemented (McDonnell et al. 2002). Many impacts were considered for inclusion in the analysis, and a final list was developed based on expert opinion and advice from workshop participants, other data providers, and stakeholders. The list was divided into local and global impacts. Values associated with these impacts are used as the cost layer in the Marxan analysis and their degree of impact varies across the planning area. For example, some areas are more costly than others to include in the MPA network because of the high impacts that affect those locations. (Fig. 10).

INNOVATIVE SCIENTIFIC MODELS WERE USED TO INCORPORATE FISHERIES AND CLIMATE CHANGE

Coral reef fisheries and climate change information is important to consider when expanding the MPA network in The Bahamas as they relate to key objectives of the BNPAS. Unfortunately, the spatial data layers required to account for these factors in the marine gap analysis were not available. Therefore, The Nature Conservancy commissioned two scientific studies that generated the information required to model and map coral reef fisheries (fishing intensity, current and potential standing stock) and climate change (thermal stress and bleaching risk) data. This process is described in more detail below.

Modelling and Mapping Fishing Intensity, and Current and Potential Standing Stock of Coral Reef Fish

Alastair Harborne (Florida International University) was contracted to model and map fishing intensity and the current and potential standing stock of coral reef fisheries in The Bahamas (Harborne 2017). Harborne's work was based on 335 fish surveys provided by three different sources. The results were limited to forereef habitats (*Orbicella*-dominated reefs and gorgonian plains) as this was the focus area of the survey data. However, forereefs represent the most fished habitat in The Bahamas; these habitats are also extensive, diverse, and support the largest biomass of fish.

Harborne modeled the fishing intensity of 165 selected sites by correlating the biomass of fished species in relation to 24 predictor variables, such as the size of nearby fish markets and temperature. The analysis demonstrated that fish stocks were affected not only by a range of biophysical gradients, but also the size of local markets. Using the resulting model, a metric of fishing intensity was calculated for every 4 ha forereef cell in The Bahamas (Fig. 11a). Estimates of fishing intensity were then used as a key data layer, along with 21 other potential environmental variables, to model the current standing stock of all species using the remaining 170 sites. The model demonstrated that standing stock decreased with increasing fishing pressure, but was also affected by biophysical factors (e.g. larval supply). For fishing intensity, the model was used to extrapolate estimates of current standing stock across the country to map fish biomass (Fig. 11b). Finally, the model of current standing stock was adjusted to represent a management scenario that reduced fishing pressure to zero (i.e. simulating the establishment of a NTA). The potential standing stock was then mapped across forereef habitats.

The resultant maps represent the first spatially explicit maps of fishing intensity and current and potential standing stock for The Bahamas. This information allowed practitioners to take coral reef fisheries into account for the first time within the analysis. Without it, it would have been impossible to guide the model towards sections of the forereef that are potentially more productive.

This approach should be refined in the future when zoning MPAs to identify the best locations for NTAs that will benefit coral-reef fisheries and biodiversity conservation. More specifically, NTAs should include areas where the populations of fisheries species are in the best condition (high standing stock) or likely to show the most benefits from protection. While other areas with high current or potential standing stock should remain open for fishing.

Having an understanding of these variables can assist with MPA network design by reducing conflicts (e.g. by avoiding placing NTAs in areas that have high fishing pressure), focusing attention on protecting either intact or highly exploited fish assemblages, and estimating the potential benefits of NTAs.

Modelling and Mapping Thermal Stress and Bleaching Risk

Nicholas Wolff, Climate Scientist with The Nature Conservancy, identified and mapped thermal stress regimes for coral reefs throughout The Bahamas (Wolff *unpubl. data*). This analysis is based on an approach developed by Mumby et al. (2011), which distinguishes and classifies reef locations according to

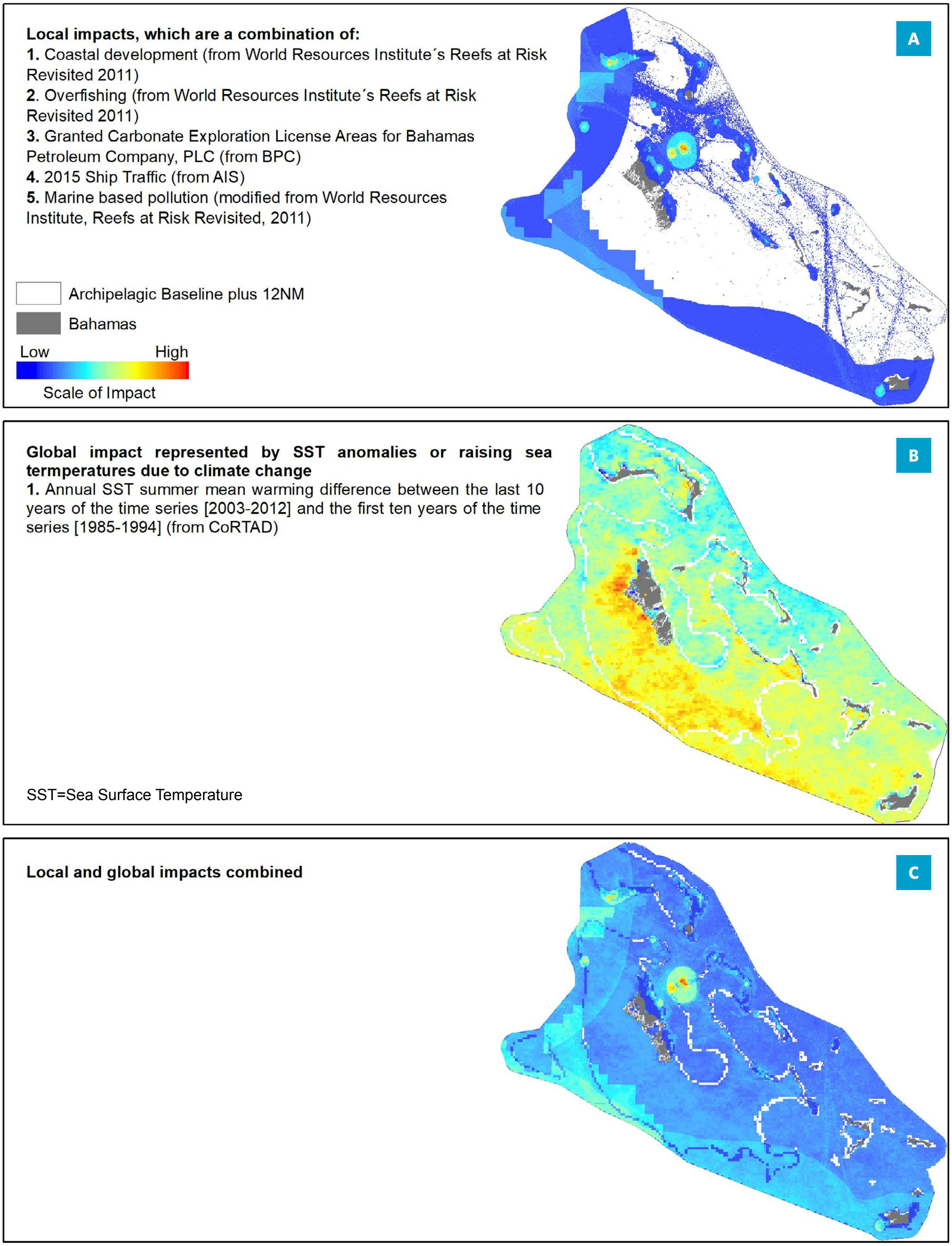


Figure 10. Spatial extent of impacts to conservation features: A) Local; B) Global; and C) Local and Global Combined

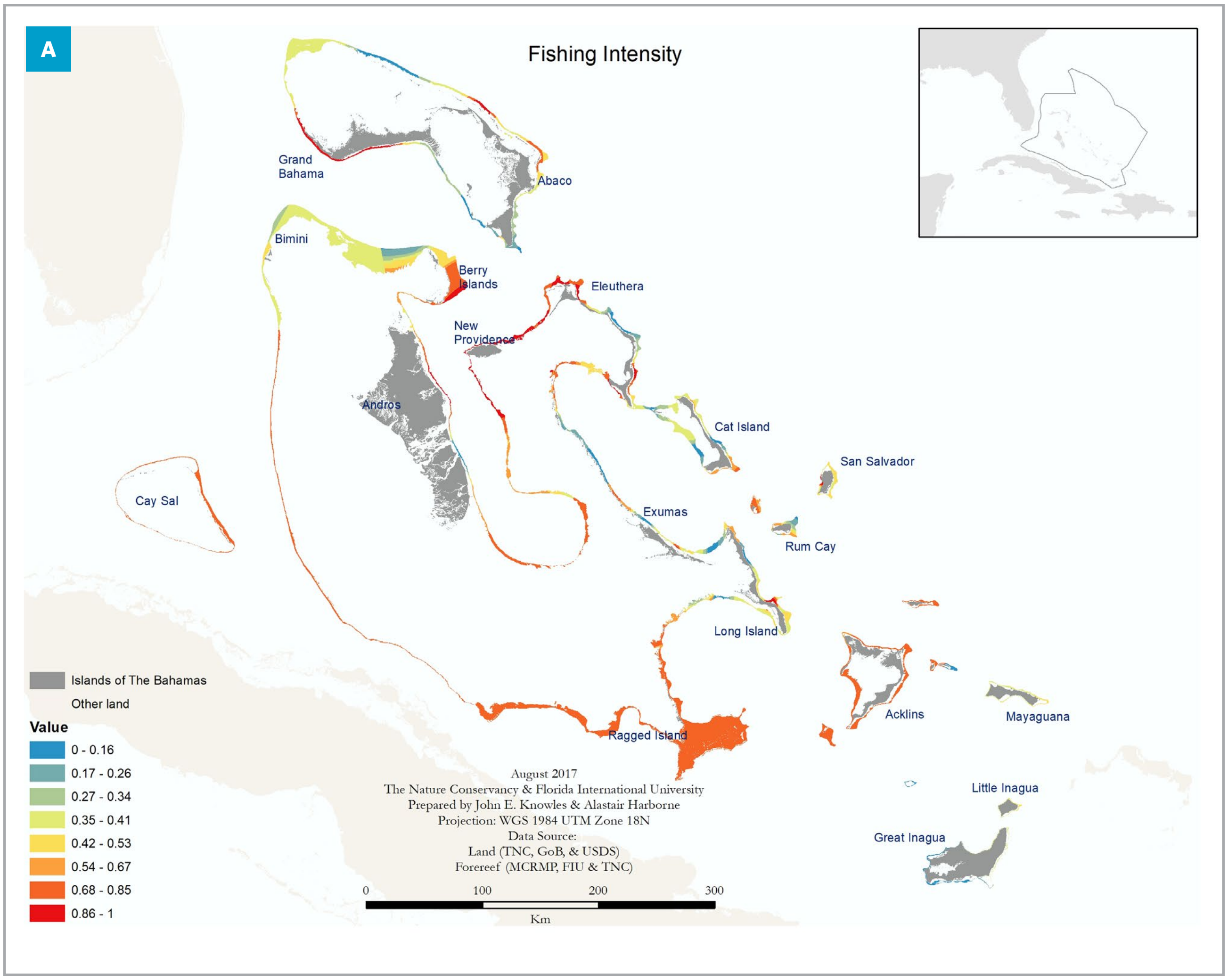


Figure 11. Maps of fishing intensity and predicted fish standing stocks in The Bahamas

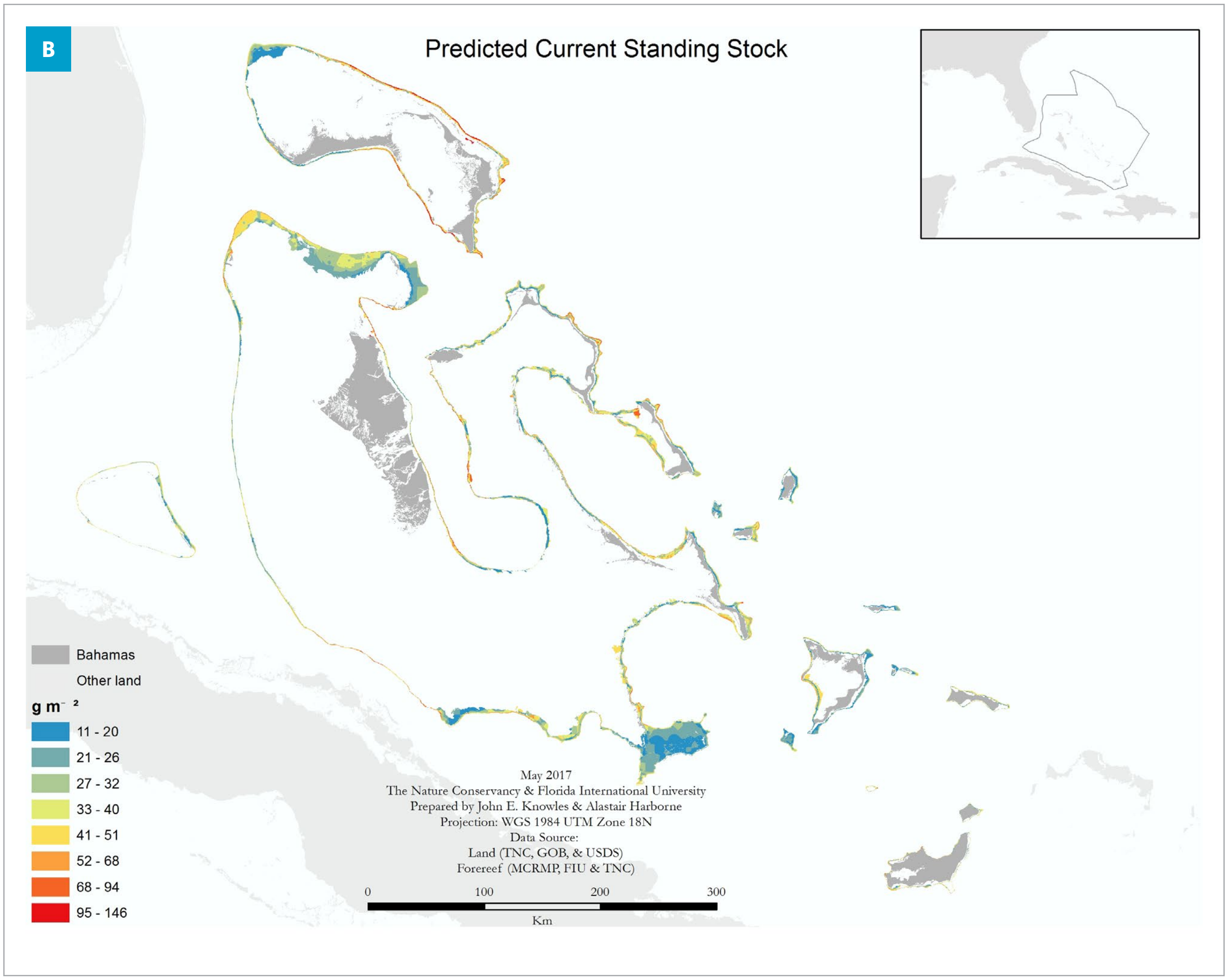


Figure 11. Maps of fishing intensity and predicted fish standing stocks in The Bahamas

their history (from satellite observations of sea surface temperature) of both chronic and acute thermal stress. This approach is based on empirical evidence and physiological theory that suggests that the ability of corals to acclimatize to warmer conditions depends on the levels of thermal stress they have already been exposed to.

Climate models indicate that all coral reefs in The Bahamas are likely to experience severe thermal stress in coming decades (Wolff et al. 2015). In fact, severe coral bleaching has already been observed throughout the country (e.g. in 2015: C. Dahlgren *pers. obs.*). However, Wolff's analysis suggests that some coral communities may be more likely to cope with future warming than others, because they are likely to experience less thermal stress and/or are more likely to acclimatize to the changing climate (Fig. 12). These coral communities that are more likely to cope with thermal stress are of high importance (Fig. 12) and should be prioritized for protection.

This gap analysis provides, for the first time, a unique opportunity to take climate-change modeling into account in The Bahamas. However, while the climate change models and maps are state-of-the art, they are experimentally new and exhibit some degree of uncertainty. Nevertheless, coral communities that are likely to be more resilient to the impacts of climate change (such as thermal stress: Fig. 12) were prioritized for protection.

The precautionary principle was used to identify and select resilient coral communities. All else being equal, coral communities (*Orbicella* reefs) were prioritized

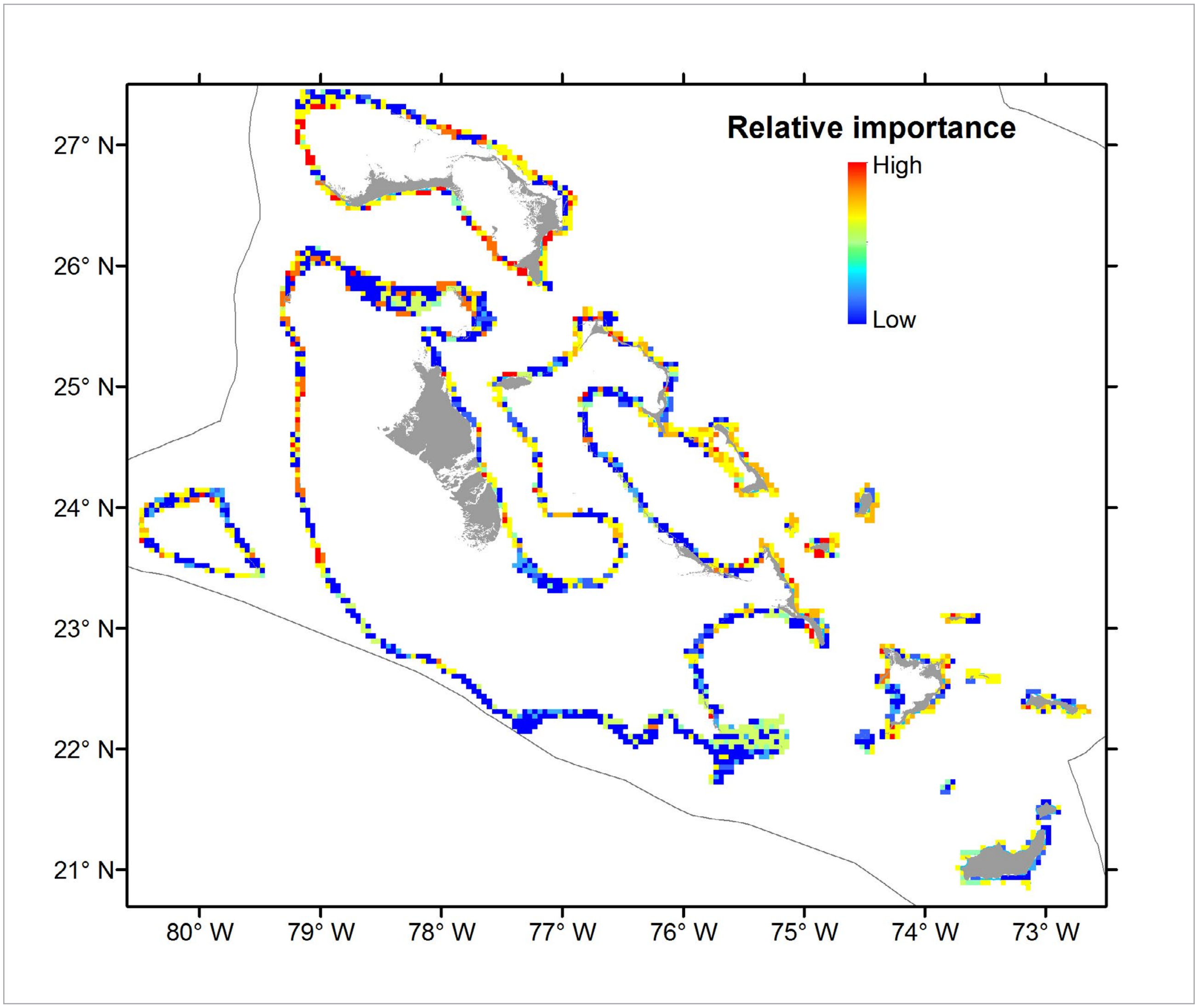


Figure 12. Relative importance of areas that should be protected. This map illustrates areas of high relative importance that are more likely to cope with thermal stress (Wolff *unpub. data*)

for protection if they appeared to have a better chance of coping with thermal stress (Fig. 12). The selection process was also guided by a risk-spreading factor. In other words, replicate examples of each major habitat were prioritized for protection in each island/island group (Table 2).

SPATIAL ANALYSIS AND RESULTS

For this analysis, the Protected Area Tool (PAT) in ArcGIS 10.1 was used to create the input text files (Schill and Raber, 2011) required by Marxan. PAT assisted with inputting the goals and extracting overlapping information from the planning units, the geographic stratification, conservation features, impacts, and existing MPAs.

Marxan was run multiple times while adjusting several key parameters to generate different scenarios of suitable options for expanding the MPA network. In general, this included running the analysis: a) using different goal settings (having equal versus variable goals for all conservation features); b) using different cost layers (P. 24, Impacts to Conservation Features); and c) including and excluding the existing MPA layer. Each scenario was run using 100 iterations and aimed to minimize the perimeter to area ratio of the most suitable option (i.e. preferring a spatially aggregated/clumped output versus a fragmented one). If targets were not met, slight modifications were made to parameters to ensure that the output met both the broader goal of covering 20% of the planning area and the individual goals of each conservation features.

Because each scenario was run using 100 iterations, Marxan generated 100 suitable options. Planning units that were selected most often (near 100 times) represent higher priority areas that should be considered when establishing new MPA. A single map was generated (Fig. 13) to demonstrate a ranking of priority areas. This map combines the results of two scenarios. One of the scenarios incorporated the layer of existing MPAs, while the other did not. The idea to exclude existing MPAs from the analysis provides an opportunity to examine the results of a scenario where The Bahamas has zero MPAs. By combining both of the scenarios, Marxan highlighted high priority areas outside of existing MPAs that would also be high priority areas if no MPAs existed at all. Both of these scenarios used variable goals for the conservation features, and both incorporated the local impacts represented in Fig. 10.

In Fig. 13, blue represents the highest priority areas (those that were selected most frequently in both scenarios) and covers approximately 5% of the planning area. Thus, if these blue priority areas were declared as MPAs, the government would increase its MPA coverage by 5%. Green and yellow represent the next highest priority areas, each enclosing 5% of the planning area. Therefore, these three priority areas combined represent 15% of the planning area. If they were all declared as MPAs, they would bring the national MPA coverage to approximately 25% of the planning area (which is more than 10% of the entire EEZ).

Finally, the analysis delineates 51 areas of interest (AOI), which include the highest priority areas identified by Marxan that the Bahamas Protected partners (The Nature Conservancy, Bahamas National Trust, and Bahamas Reef Environment Educational

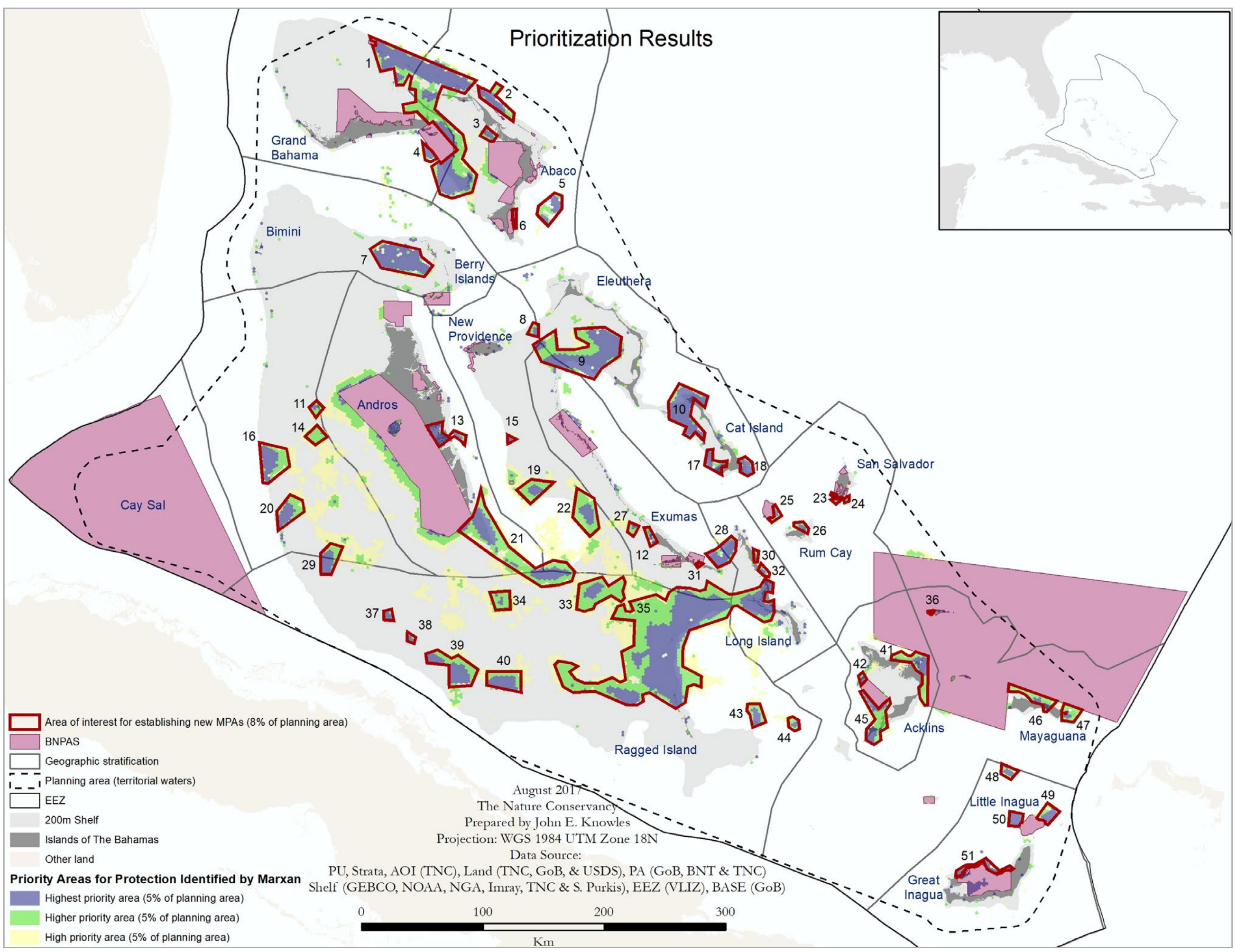


Figure 13. Areas of interests (AOI) for establishing new MPAs to expand The Bahamas MPA Network to protect 20% of the planning area by 2020. AOI were selected based on priority areas identify by Marxan

Foundation), the NISP and stakeholders can consider as focal areas for establishing new MPAs. These AOI represent 8% of the planning area. They were selected to include locations in each geographic stratum and encompass a diversity of high-priority conservation features. For more information, see Appendix 2 which provides a list of conservation features in each AOI.

Also included within this report (as Fig. 14) is a comparison of the results from the 2014 gap analysis and the 2008 gap. Figure 14 was originally produced in the 2014 GAP Report (Moss and Moultrie 2014).

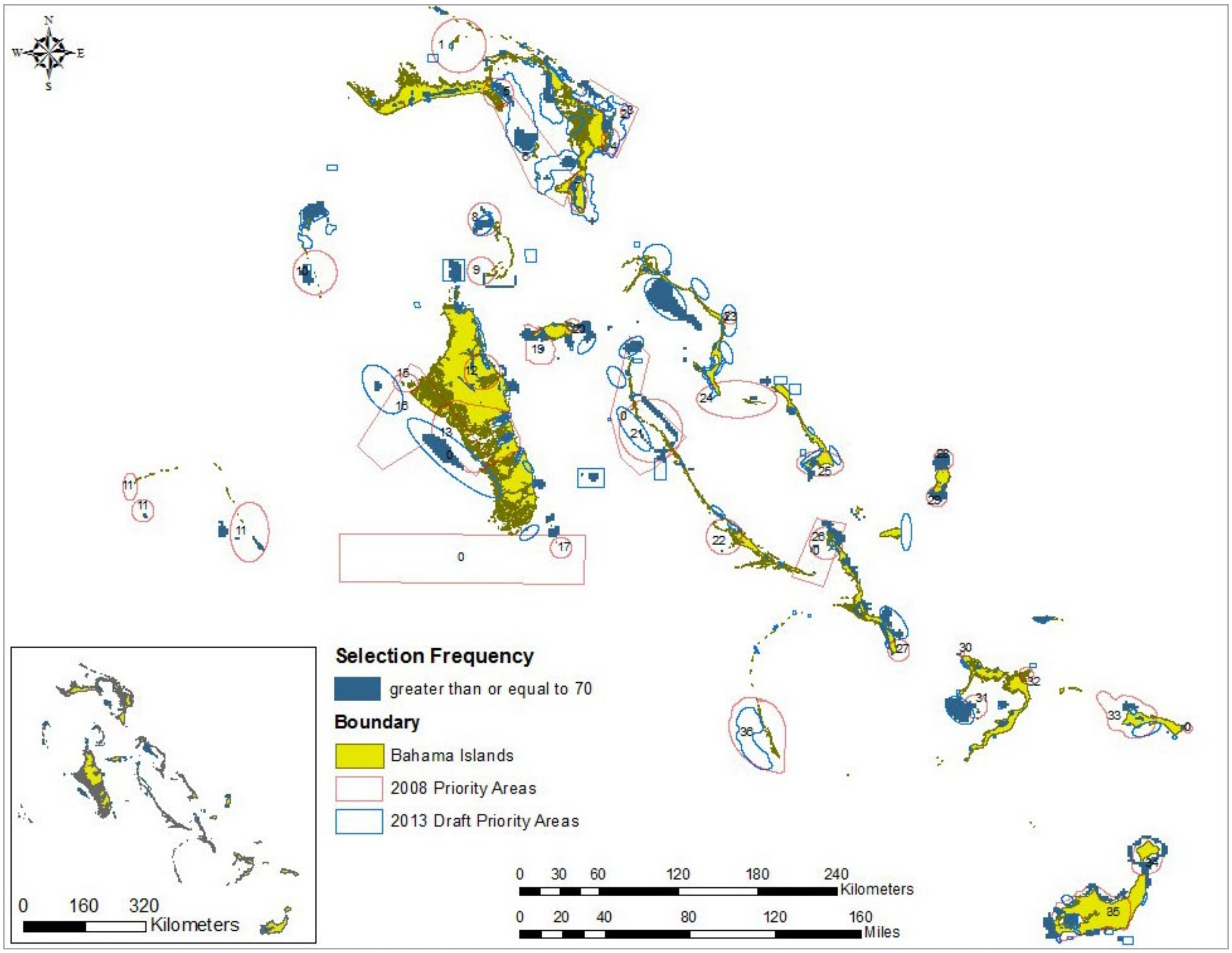


Figure 14. Map from the 2014 gap analysis report comparing 2008 priority areas to 2014 priority areas (Moss and Moultrie 2014)

Discussion

Red Mangrove displaying impressive arching root system. Shot in Exuma Cays Land and Sea Park, The Bahamas. © Jeff Yonover

Discussion

With The Bahamas poised to double its marine protection, the unique opportunity arose to develop and tailor explicit design principles and, to the extent possible, incorporate innovative scientific techniques into the planning process. The aim was to further enrich the discussion in The Bahamas regarding marine conservation and increase the likelihood that sufficient expansion and management occur.

Developing design principles during the early stages of the planning process influenced the type of spatial data collected and the delineation of the AOI. However, the use of these principles is critical to the steps in the planning process beyond the results of the gap analysis. For example, drafting the legal boundaries of individual MPAs and helping ensure effective management of the MPA network as a whole. It is likely that this is the first time in the insular Caribbean that explicit design principles have been developed and used for protected area network design.

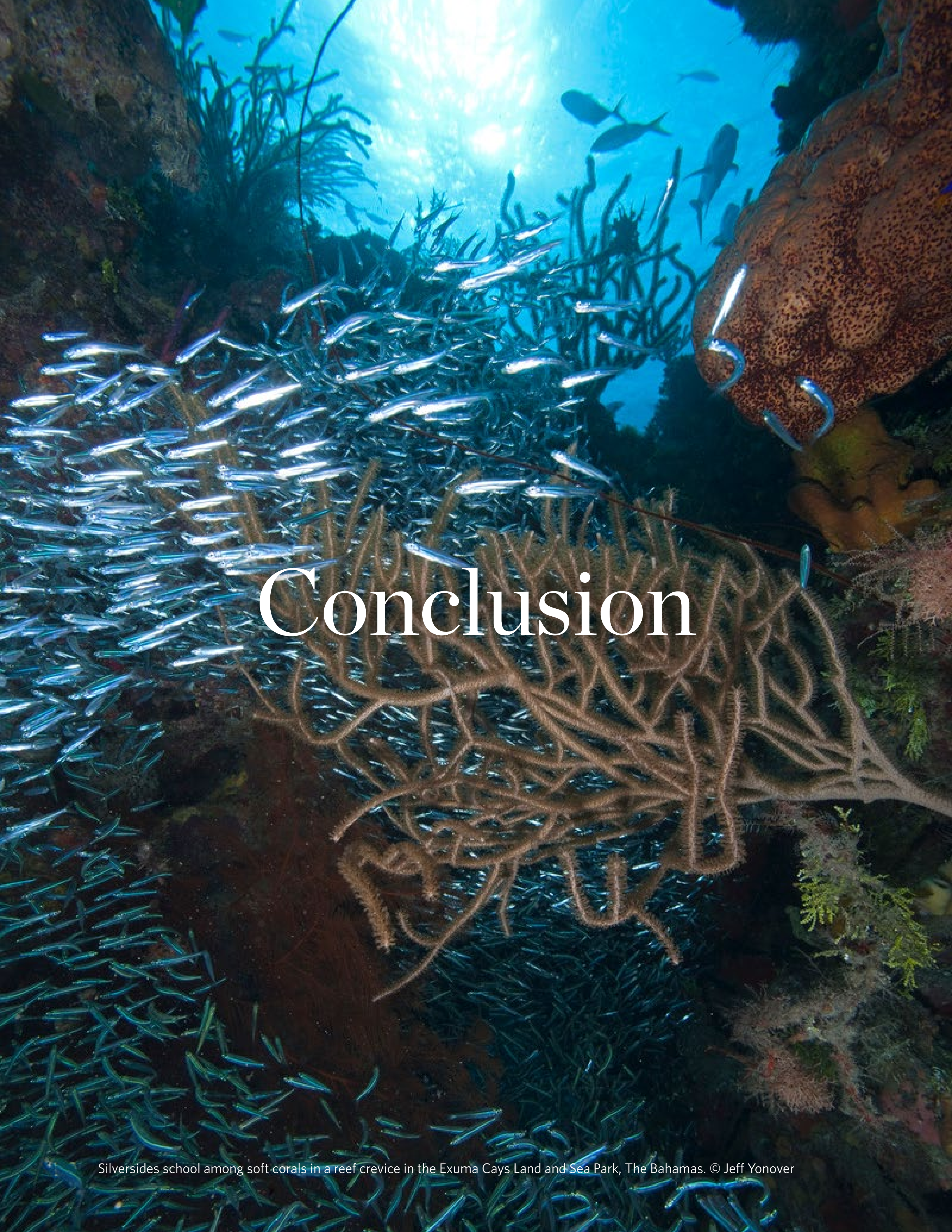
The biophysical design principles relate specifically to NTAs or replenishment zones, also known as highly protected areas in the Master Plan for The Bahamas National Protected Area System (Moultrie 2012). However, The Bahamas has less than 1% marine coverage of highly protected areas. Ideally, The Bahamas should have a greater percentage of NTAs along with non-spatial options for managing fisheries (such as catch limits, effort limits, temporal closures, and other controls such as gear restrictions and size limits) to ensure the preservation of economically and ecologically important fish species and biodiversity.

The SEG design principles help address the newly expanded objective of the MPA system, which is to contribute to maintaining and improving livelihoods. For example, the SEG principles call for the protection of ecosystem services to improve food security. Given such issues are critical for The Bahamas, it is important that the SEG design principles are strong and clearly articulated.

One means of incorporating critically important ecosystem services (e.g. food security and coastal protection) into the planning process is by setting targets for each conservation feature e.g. fish biomass, coral reefs and mangroves, etc. Although progress has been made in quantifying and mapping ecosystem services (Guerry 2015), more work is needed to better understand how goals set for ecosystem services can improve the suitable options for expanding the MPA network or zoning.

An understanding of this concept is important for The Bahamas as it advances national policies related to fisheries and sustainable development (FAO 2016; Natural Capital Project 2017). Fisheries, for example, certainly play a role in improving food security in the country. In this analysis, a focus on reef fisheries that are dependent on forereef habitats was chosen because these areas are the most fished habitat in The Bahamas and support the largest biomass of fish. However, the coral reef fisheries are not the only fisheries in the country. Spatially explicit information on other important fisheries, such as conch and lobster, should be obtained and incorporated into a future analysis that has a fisheries focus.

The amount of information on forereef habitat is unique to this analysis. Therefore, the results of this analysis include large sections of reef that have high survival rates, high fish biomass, and provide miles of shoreline protection to nearby coastal communities. This is likely the first analysis in the region to associate so many characteristics to corals or any conservation feature. It is understood that additional climate change and ecosystem service models for other conservation features would only serve to improve the results of this and future analyses.



Conclusion

Silversides school among soft corals in a reef crevice in the Exuma Cays Land and Sea Park, The Bahamas. © Jeff Yonover

Conclusion

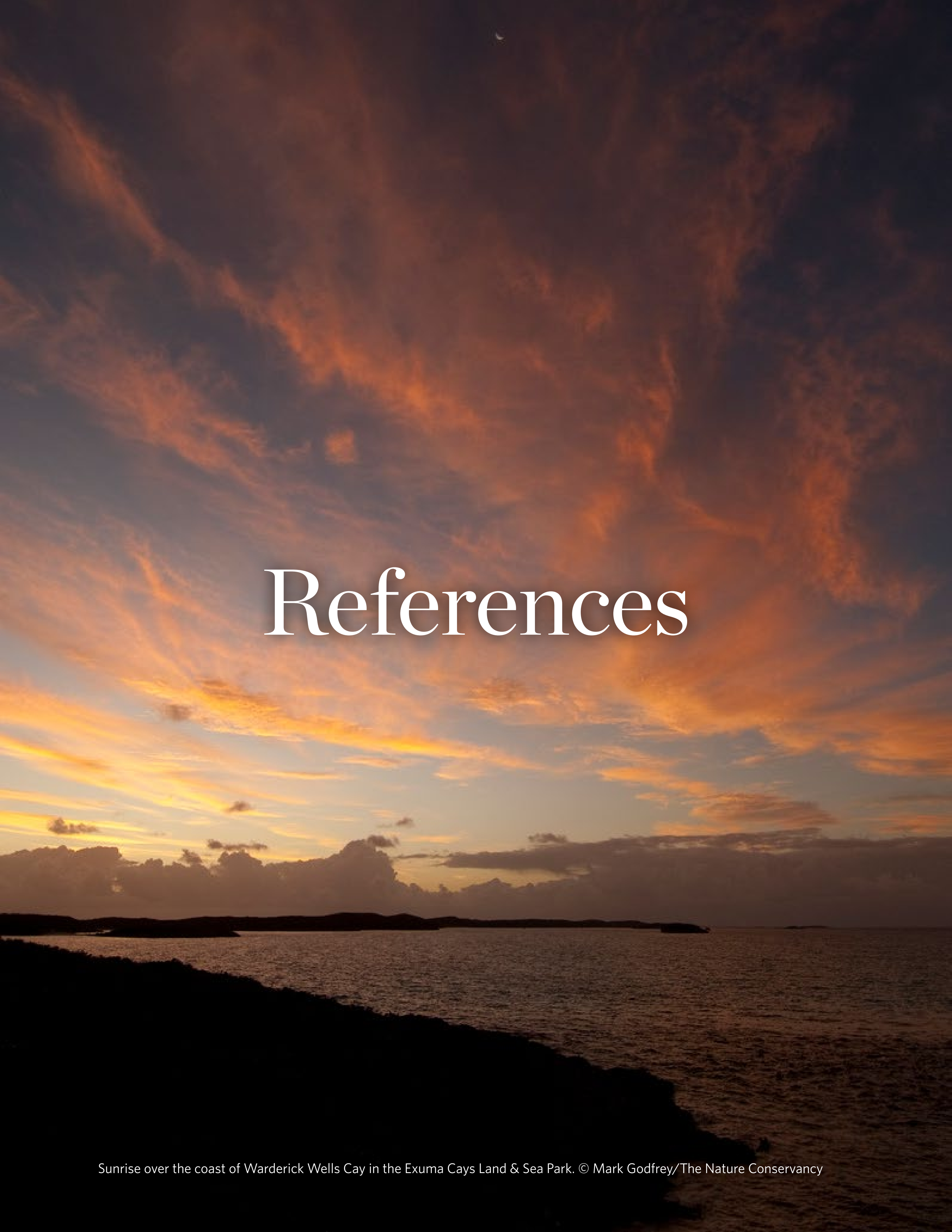
This document outlines the new and improved marine gap analysis for The Bahamas that will guide the expansion of its MPA network. To do this, the best available science was used to provide, for the first time:

- New and refined SMART objectives for the BNPAS that incorporate key issues such as fisheries and climate-change adaptation;
- A planning area that provides the best option for The Bahamas—both ecologically and politically—and which can be used to track progress toward the country's MPA goals;
- Biophysical and socioeconomic design principles to achieve the BNPAS objectives;
- New and updated spatial data layers for applying these principles;
- Innovative science that incorporates climate change and coral reef fisheries in the design; and
- A set of 51 areas of interest (AOI) that include the highest priority areas identified by Marxan that the Bahamas Protected partners (The Nature Conservancy, Bahamas National Trust, and Bahamas Reef Environment Educational Foundation), the NISP and stakeholders can consider as focal areas for establishing new MPAs.

The Bahamas can now use this information to work with stakeholders in each of the AOI, along with local knowledge and practices to develop and propose legal boundaries for new MPAs. It is hoped that this marine gap analysis provides valuable information and guidance that will facilitate the next steps to proposing and declaring new MPAs to meet The Bahamas' 20-by-20 and related sustainable development goals.

Red-Tipped Sea Goddess Nudibranch, photographed underwater in the Exuma Cays Land and Sea Park, The Bahamas. © Jeff Yonover

References



Sunrise over the coast of Warderick Wells Cay in the Exuma Cays Land & Sea Park. © Mark Godfrey/The Nature Conservancy

References

Abesamis, R.A., Green, A.L., Russ, G.R., Jadloc, C.R.L. 2014. The intrinsic vulnerability to fishing of coral reef fishes and their differential recovery in fishery closures. *Reviews in Fish Biology and Fisheries* 24(4):1033-1063.

Almany, G.R., Hamilton, R.J., Bode, M., Matawai, M., Potuku, T., Saenz-Agudelo, P., Planes, S., Berumen, M.L., Rhodes, K.L, Thorrold, S.R., Russ, G.R., Jones, G.P. 2013. Dispersal of grouper larvae drives local resource sharing in a coral reef fishery. *Current Biology* 23:626–630.

Ball, I.R. and H. P. Possingham. 2000. MARXAN (v1.8.2): Marine reserve design using spatially explicit annealing, a manual. Available online at http://courses.washington.edu/cfr590/software/Marxan1810/marxan_manual_1_8_2.pdf.

Brumbaugh, D. R. (ed.). 2014. *Guide to the Science of Marine Protected Areas in The Bahamas*. American Museum of Natural History, New York, NY, 16pp.

Burke L, Reytar K, Spalding M and Perry A. 2011. Reefs At Risk Revisited. Washington (USA): World Resources Institute. 130 pp. URL: http://www.wri.org/publication/reefs-risk-revisited.

Casey, Kenneth S.; Selig, Elizabeth R.; Zhang, Dexin; Saha, Korak; Krishnan, Ajay; and McMichael, Elizabeth. 2015. The Coral Reef Temperature Anomaly Database (CoRTAD) Version 5 - Global, 4 km Sea Surface Temperature and Related Thermal Stress Metrics for 1982-2012 (NCEI Accession 0126774). Version 1.1. NOAA National Centers for Environmental Information. Dataset. doi:10.7289/V5CZ3545 [Spring 2017]

Coral Triangle Initiative on Coral Reefs, Fisheries and Food Security (CTI-CFF). 2012. *Summary Report: Regional Exchange on Designing and Supporting National and Regional MPAs Systems in the Coral Triangle*. Denpasar, Indonesia March 26-30, 2012. US CTI Support Program Document No. 06B-USCTI-12.

FAO. 2016. Fisheries and Aquaculture in The Bahamas: A Review. Document prepared by Stacey Moutrie, Edison Deleveaux, Gregory Bethel, Yann Laurent, Vashti d'Shan Maycock, Sharrah Moss-Hackett, Raymon van Anrooy. Department of Marine Resources. Nassau, The Bahamas. 79pp.pi

Fernandes, L., Day, J., Lewis, A., Slegers, S., Kerrigan, B., Breen, D., Cameron, D., Jago, B., Hall, J., Lowe, D., Innes, J., Tanzer, J., Chadwick, V., Thompson, L., Gorman, K., Simmons, M., Barnett, B., Sampson, K., De'ath, G., Mapstone, B.D., Marsh, H., Possingham, H., Ball, I., Ward, T., Dobbs, K., Aumend, J., Slater, D., Stapleton, K. 2005. Establishing representative no-take areas in the Great Barrier Reef: large scale implementation of theory on Marine Protected Areas. *Conservation Biology* 19:1733-1744.

Game, E. T. and H. S. Grantham. 2008. Marxan User Manual: For Marxan version 1.8.10. University of Queensland, St. Lucia, Queensland, Australia, and Pacific Marine Analysis and Research Association, Vancouver, British Columbia, Canada.

Green, A., Smith, S.E., Lipsett-Moore, G., Groves, C., Peterson, N., Sheppard, S., Lokani, P., Hamilton, R., Almany, J., Aitsi, J., Bualia, L. 2009. Designing a resilient network of Marine Protected Areas for Kimbe Bay, Papua New Guinea. *Oryx* 43(4):488-498.

Green, A.L., Fernandes, L., Almany, G., Abesamis, R., McLeod, E., Aliño, P., White, A.T., Salm, R., Tanzer, J., Pressey, R.L. 2014a. Designing marine reserves for fisheries management, biodiversity conservation and climate change adaptation. *Coastal Management* 42:143–159.

Green, A.L., Maypa, A.P, Almany, G.R., Rhodes, K.L., Weeks, R., Abesamis, R.A., Gleason, M.G., Mumby, P.J., White, A.T. 2014b. Larval dispersal and movement patterns of coral reef fishes, and implications for marine reserve network design. *Biological Reviews* 90(4):1215-1247.

Green, A., Chollett, I., Suárez, A., Dahlgren, C., Cruz, S., Zepeda, C., Andino, J., Robinson, J., McField, M., Fulton, S., Giro, A., Reyes, H., Bezaury, J. 2017a. *Biophysical Principles for Designing a Network of Replenishment Zones for the Mesoamerican Reef System*. Technical report produced by The Nature Conservancy, Comunidad y Biodiversidad, A.C., Smithsonian Institution, Perry Institute for Marine Science, Centro de Estudios Marinos, Healthy Reefs Initiative and Universidad Autónoma de Baja California Sur, 59 pp.

Green, A.L., Knowles, J., Dahlgren, C., Arnett, F., Knowles, L., Albury-Smith, S. 2017b. *Bahamas Protected: Realizing the 2020 Goal to Effectively Manage and Expand Bahamian Marine Protected Areas*. A report prepared for the Ministry of the Environment for The Bahamas on the Ecological Gap Analysis Workshop held in Nassau, New Providence (September 13-14th, 2016).

Guerry A.D., S. Polasky, J. Lubchenco, R. Chaplin-Kramer, G.C. Daily, R. Griffin, M. Ruckelshaus, et al. 2015. Natural capital and ecosystem services informing decisions: from promise to practice. Proc. Natl. Acad. Sci., 112, pp. 7348-7355

Hales, T. Discrete Comput Geom. 2001. 25: 1. doi:10.1007/s004540010071

Halpern, B. S., Lester, S.E., Kellner, J.B. 2010. Spillover from marine reserves and the replenishment of fished stocks. *Environmental Conservation* 36:268–276.

Harrison, H. B., Williamson, D.H., Evans, R.D, Almany, G.R., Thorrold, S.R., Russ, G.R., Feldheim, K.A., van Herwerden, L., Planes, S., Srinivasan, M., Berumen, M.L, Jones, G P. 2012. Larval export from marine reserves and the recruitment benefits for fishes and fisheries. *Current Biology* 22:1023–1028.

Harborne, A. R. 2017. *Modelling and Mapping Fishing Pressure and the Current and Potential Standing Stock of Coral-reef Fishes in The Bahamas: Supporting Marine Reserve Design*. North Miami, USA: Florida International University.

Lester, S. E., Halpern, B.S., Grorud-Colvert, K., Lubchenco, J., Ruttenberg, B.I., Gaines, S.D., Airame, S., Warner, R.R. 2009. Biological effects within no-take marine reserves: A global synthesis. *Marine Ecology Progress Series* 384:33–46.

Natural Capital Project. 2017. A National Coastal Hazard and Social Vulnerability Analysis for The Bahamas. Seattle: Biodiversity and Ecosystem Services Program at the Inter-American Development Bank, 17 pp.

Mangubhai, S., Wilson, J.R., Rumetna, L., Maturbongs, Y., Purwanto. 2015. Explicitly incorporating socioeconomic criteria and data into marine protected area zoning. *Ocean & Coastal Management* 116: 523-529.

McDonnell, M. D., H. P. Possingham, I. R. Ball and E. A. Cousins. 2002. Mathematical methods for spatially cohesive reserve design. Environmental Modeling and Assessment 7: 107-114.

Moultrie, S. 2012. Master Plan for The Bahamas National Protected Area System. The Nature Conservancy, Northern Caribbean Office. Nassau, The Bahamas.

Moss, S. 2017. *Bahamas Protected: Realizing the 2020 Goal to Effectively Manage and Expand Bahamian MPAs*. A summary report prepared for the Nature Conservancy on the Gap Analysis Update Workshop held in Nassau, New Providence (March 28, 2017).

Moss, S., Moultrie, S. 2014. *Ecological Gap Analysis: GEF FSP Sustainable Network of MPAs – The Bahamas*. Nassau: BEST Commission, 60pp.

Mumby, P.J., Elliott, I.A., Eakin, C.M., Skirving, W., Paris, C.B., Edwards, H.J., Enriquez, S., Iglesias-Prieto, R., Cherubin, L.M., Stevens, J.R. 2011. Reserve design for uncertain responses of coral reefs to climate change. *Ecology Letters* 14:132-140.

Schill, S. and G. Raber. 2011. Protected Area Tools (PAT) for ArcGIS 10 (version 4.0) software http://www.gispatools.org. The Nature Conservancy, Arlington, Virginia.

Sullivan Sealey, K., B. Brunnick, S. Harzen, C. Luton, V. Nero and Lester Flowers. 2002. An Ecoregional Plan for the Bahamian Archipelago. Taras Oceanographic Foundation. Florida, USA. pp 683.

Thurlow, K.E., Palmer, M. 2007. The Bahamas Ecological Gap Analysis. The Nature Conservancy, Northern Caribbean Program, Nassau, The Bahamas.

Victor, S., Peterson, N., Green, A., Aulerio, M., Salm, R., Weeks, R. 2015. *Refining the Palau Protected Areas Network Design*. Report submitted to Ed Warner March 2015.

Watts, M.E, I.R. Ball, R.R. Stewart, C.J. Klein, K. Wilson, C. Steinback, R. Lourival, L. Kircher, H.P. Possingham. 2009. Marxan with Zones: software for optimal conservation based land- and sea-use zoning, Environmental Modeling & Software, doi:10.1016/j.envsoft. 2009.06.005.

Wilson, J., Darmawan, A., Subijanto. J., Green, A., Sheppard, S. 2011. *Scientific design of a resilient network of marine protected areas for the Lesser Sunda Ecoregion of the Coral Triangle*. Asia Pacific Marine Program. Report 2/11. 96 pp.

Wise, S. 2017 Socio-economic and governance principles for marine protected areas. A report to The Nature Conservancy, 51 pp.

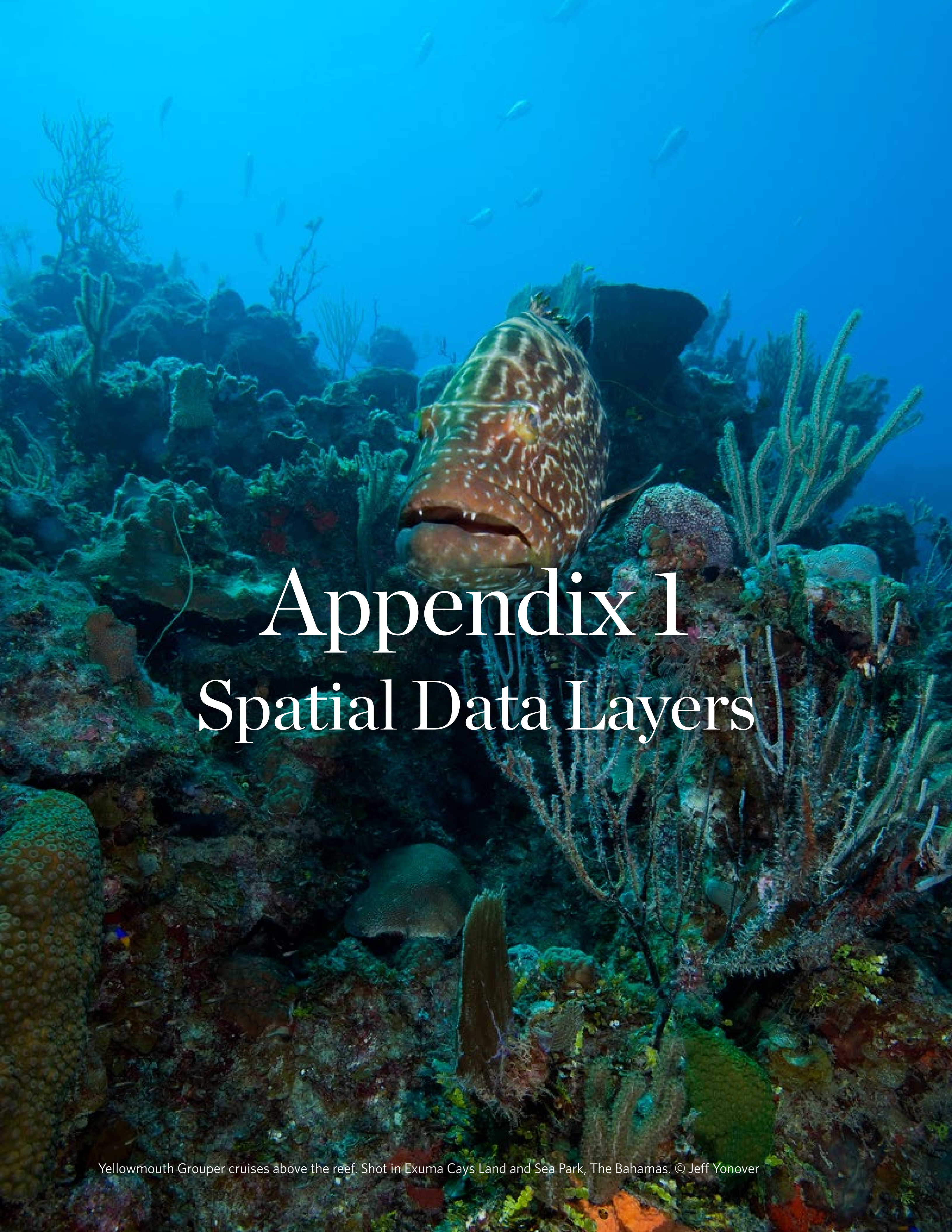
Wolff, N.H., Donner, S.D., Cao, L., Iglesias-Prieto R., Sale, P.F., Mumby, P.J. 2015. Global inequities between polluters and the polluted: climate change impacts on coral reefs. Global Change Biology 21:3982–3994.

Wolff, N. *unpubl. data* Incorporating bleaching risk into reserve design for The Bahamas.

World Travel & Tourism Council. 2015. Travel & Tourism Economic Impact 2015 Bahamas. http://www.caribbeanhotelandtourism.com/wp-content/uploads/data_center/destinations/Bahamas-WTTC-EconomicImpact2015.pdf

A pod of dolphins swims below the surface on a sandbank north of Bimini, The Bahamas. © Brent Durand

Appendix 1
Spatial Data Layers



Yellowmouth Grouper cruises above the reef. Shot in Exuma Cays Land and Sea Park, The Bahamas. © Jeff Yonover

Appendix 1 Spatial Data Layers

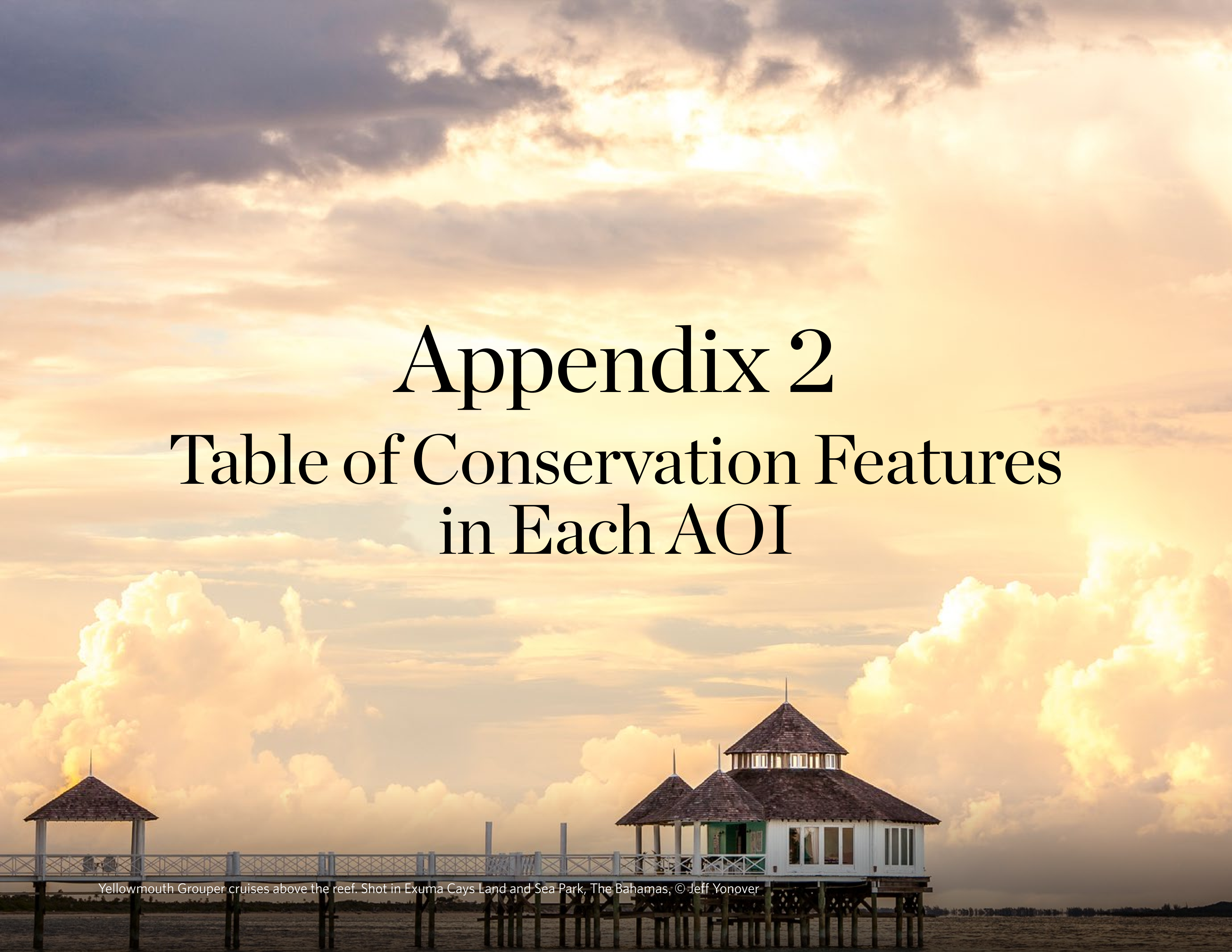
CONSERVATION FEATURES	DESCRIPTION
1. Forereef — *Orbicella* reef (higher survival)	Establishing the extent of reef areas within The Bahamas was accomplished by using the maps generated by the Millennium Coral Reef Mapping (MCRM) Project. This map has a thematically rich habitat classification scheme and forereef is represented by a combination of level 4 attributes (forereef; outer slope; Shelf hardground, relic; and Shelf slope). *Orbicella* reefs (the visually dominant coral complex) is major benthic habitat class of the forereef. The distribution of this habitat was predicted using a modelling approach based on environmental gradients (Harborne 2017). The higher survival classification was associated to certain sections of the *Orbicella* reef by overlaying the thermal stress regimes A (experiencing low acute, high chronic thermal stress) and C (experiencing low acute, low chronic thermal stress) (Wolff unpubl. data).
2. Forereef — *Orbicella* reef (better at adaptation)	Establishing the extent of reef areas within The Bahamas was accomplished by using the maps generated by the Millennium Coral Reef Mapping (MCRM) Project. This map has a thematically rich habitat classification scheme and forereef is represented by a combination of level 4 attributes (forereef; outer slope; Shelf hardground, relic; and Shelf slope). *Orbicella* reefs (the visually dominant coral complex) is major benthic habitat class of the forereef. The distribution of this habitat was predicted using a modelling approach based on environmental gradients (Harborne 2017). The better at adaptation classification was associated to certain sections of the *Orbicella* reef by overlaying the thermal stress regimes B (experiencing high acute, high chronic thermal stress) and D (experiencing high acute, low chronic thermal stress). It is important to point out that although forereefs in thermal stress regimes B and D will likely have high mortality, the corals that do survive may be well adapted to high stress conditions (Wolff *unpubl*. data).
3. Forereef — gorgonian plain	Bahamas was accomplished by using the maps generated by the Millennium Coral Reef Mapping (MCRM) Project. This map has a thematically rich habitat classification scheme and forereef is represented by a combination of level 4 attributes (forereef; outer slope; Shelf hardground, relic; and Shelf slope). The gorgonian plain is major benthic habitat class of the forereef. The distribution of this habitat was predicted using a modelling approach based on environmental gradients (Harborne 2017).
4. Patch reef	Establishing the extent of reef areas within The Bahamas was accomplished by using the maps generated by the Millennium Coral Reef Mapping (MCRM) Project. This map has a thematically rich habitat classification scheme and patch reef is represented by a combination of level 4 attributes (barrier reef pinnacle/patch; intertidal patch reef flat (faru); pinnacle; Shelf hardground, relic; and subtidal reef flat (thila) (shoal))
5. Mangroves	Represented by two classes, "Mangroves" and "Swash/Swamp Areas" from the topographic quadrangle maps produced by the Department of Lands and Surveys 1968-1975 which were scanned and digitized by The Nature Conservancy in 2007. This was modified for Andros Island by replacing the "Mangroves" and "Swash/Swamp Areas" classes of the topographic maps with three mangroves classes that were developed through the interpretation of Landsat imagery.
6. Seagrasses	The seagrass layer is mostly a product of a contract between The Nature Conservancy and The University of South Florida (USF). USF grad students used imagery analysis of Landsat 7 and limited ground truthing data to derive three classes of seagrass - sparse, medium and dense, which excluded Cay Sal. Cay Sal seagrass extent was added from work by Sam Purkis who classified seagrass (only sparse and dense) using WorldView-2 satellite imagery.

CONSERVATION FEATURES	DESCRIPTION
7. Sand/mud	The sand/mud class was a product of a contract between The Nature Conservancy and The University of South Florida to map benthic habitat. USF grad students used imagery analysis of Landsat 7 and limited ground truthing data to derive these classes. To maintain mutually exclusive classes, the Cay Sal portion was modified by erasing the extent of seagrass derived from WorldView-2 Satellite Imagery by Sam Purkis. The sand and mud class were combined due to low levels of confidence associated with the actual division between benthic sand and mud as pointed out by stakeholders.
8. Important deep and shallow water bathymetric features	In the absence of a consistently mapped national product for bathymetric substrates and depths, the bathymetric features were mapped in a participatory style with supplements from a bathymetric position index model. This layer represents features such as steep walls, seamounts, oceanic ridges and canyons.
9. Sandy beach	Digitized from the Department of Lands and Survey Topographic maps (1970) and Landsat 7 imagery interpretation (2000).
10. Rocky shore	Digitized from Department of Lands and Survey Topographic maps (1970) and Landsat 7 imagery interpretation (2000).
11. Tidal creeks	An initial dataset of tidal creeks was created from digitizing likely areas from Landsat 7 imagery. This file was edited by expert input by Kim Thurlow. This process was repeated, with successive edits from topo maps and expert input adding to the tidal creek shapefile until a final product was created. Tidal creeks were attributed by those that occur on islands with greater than 5 tidal creeks in total and those that exist on islands with 5 or less tidal creeks in total.
12. Kirtland's warbler	Location of Kirtland's warblers from quite a few years of surveys around The Bahamas by the Smithsonian Migratory Bird Center and The Nature Conservancy.
13. Royal tern (seabird)	Point location of breeding pair nesting colonies of the royal tern from Dr. Will Mackin's dataset.
14. Roseate tern (seabird)	Point location of breeding pair nesting colonies of the roseate tern from Dr. Will Mackin's dataset.
15. Bridle tern (seabird)	Point location of breeding pair nesting colonies of the bridle tern from Dr. Will Mackin's dataset.
16. Shearwater (seabirds)	Point location of defended nests of the Audubon's shearwater from Dr. Will Mackin's dataset.
17. All other seabirds	Point location of breeding pair nesting colonies for all other seabird species in Dr. Will Mackin's dataset.
18. Wilson's Plover (shorebird)	Point location of sightings of Wilson's plover from the National Audubon Society.
19. Snowy Plover (shorebird)	Point location of sightings of the snowy plover from the National Audubon Society.
20. Red Knot (shorebird)	Point location of sightings of the red knot from the National Audubon Society.
21. Red Egret (shorebird)	Point location of sightings of the red egret from the National Audubon Society.

CONSERVATION FEATURES	DESCRIPTION
22. Piping Plover (shorebird)	Point location of sightings of the piping plover from the National Audubon Society.
23. Flamingo areas	Point location of flamingo areas in The Bahamas
24. Marine important bird areas	Since 2004 the BirdLife Global Seabird Programme has been working with the BirdLife Partnership to identify IBAs for seabirds both on land and at-sea. This was shared with The Nature Conservancy.
25. Iguana habitat	Originally from the Terrestrial Vertebrates Management Strategy Report (2000) and verified for accuracy by the Bahamas National Trust.
26. Fish spawning aggregations (lower and higher degrees of validation)	Fish spawning aggregations with a lower and higher degree of validation are points that have been published in peer reviewed journals or are generally known by scientists to exist; or are points that have been documented by scientific divers as having spawning fish (respectively). Species included in this file range from unknown to group, snapper, mutton and bonefish. Originally created in 2007, this file was updated with the help of Craig Dahlgren, Bahamas National Trust and Bonefish & Tarpon Trust.
27. Fish spawning aggregation (not validated or modelled)	Fish spawning aggregations that are not validated come from fishermen or anecdotal sources. Species included in this classification range from unknown to group and bonefish. A modelled fish spawning aggregation site is predictive and was created to identify areas along the shelf with suitable geomorphic characteristicsis (i.e. promontory shape). Originally created in 2007, this file was updated with the help of Craig Dahlgren, Bahamas National Trust and Bonefish & Tarpon Trust.
28. Turtle nesting beaches	Nesting points were received from Alan Bolton, Karen Bjourndal and Stephen Connett. The points were used to select the closest beach from the sandy beach layer.
29. Turtle feeding areas	Preferred seagrass habitat where sea turtles are either known or predicted to spend a part of their life cycle foraging as determined by Karen Bjorndal and Alan Bolten at University of Florida.
30. Bonefish flats	Map of key bonefish habitat or bonefish flats around the Bahamas representing home ranges, spawning migration routes and juvenile habitats which was shared with The Nature Conservancy by Bonefish & Tarpon Trust.
31. General model of fish and crustacean nursery areas	A general area model to encompasses anything within 100 meters of the coast including all area between offshore islands and 3km of the coast and enclosing bays and estuaries with less than a 6 km opening.
32. Cetacean areas	The basis of this layer was the habitat model developed in 2007 of whale sighting data and bathymetry (all slopes between 7 and 10 degrees and depths from 400m to 1700m). This was further modified with input from Diane Claridge of BMMRO, with the addition of dolphin and manatee areas.

CONSERVATION FEATURES	DESCRIPTION
33. Blue holes	This dataset contains the general landcover feature of blue holes created by heads-up digitizing from 1:25,000m scanned topographic quadrangle maps produced by the Department of Lands and Surveys 1968-1975. Features were digitized at a 1:10,000m scale. Digitizing began October 2005 and ended February 2006. Geographic coverage of this original data included The Bahamian Islands of Abaco, Acklins/Crooked, Andros, Berry, Bimini, Cat, Eleuthera, Exuma, Grand Bahama, Inagua, Long, Mayaguana, New Providence, Ragged, Rum Cay, San Salvador, and surrounding cays. Blue holes on Andros were originally mapped for the Andros Conservation Action Plan (CAP) process using a variety of information sources including local knowledge, GPS points from research scientists, the Lands and Survey topographic maps and through the interpretation of Landsat imagery. This dataset was added to over the years and was revised and updated through heads-up digitizing in QGIS using the Google and Bing imagery base layers in September 2015 by Teresa Gomez, a student contractor of The Nature Conservancy, with funding from the Inter-American Development Bank's Ecosystem-based Development for Andros Island, The Bahamas Project. Other islands have had spot updates using heads up digitizing from Esri imagery.
34. Coral reef role in reducing coastal vulnerability near areas with relative higher human population density	The ecosystem service index for the role coral reefs have in reducing coastal vulnerability along the shoreline were generated by the Natural Capital Project for a "A National Coastal Hazard and Social Vulnerability Analysis for The Bahamas" (2017). An average of these shoreline index values was associated to the planning units that overlapped the forereef within a 10 km distance. Planning units that were not near relatively larger human communities were removed.
35. Mangrove role in reducing coastal vulnerability near areas with relative higher human population density	The ecosystem service index for the role mangrove have in reducing coastal vulnerability along the shoreline were generated by the Natural Capital Project for a "A National Coastal Hazard and Social Vulnerability Analysis for The Bahamas" (2017). An average of these shoreline index values was associated to the planning units that overlapped mangroves within a 2 km distance. Planning units that were not near relatively larger human communities were removed.
36. Standing stock of coral reef fisheries species	All Atlantic and Gulf Rapid Reef Assessment (AGRRA) species at each fish survey site for current standing stock in g/m^2 modelled against a range of continuously mapped explanatory variables (including the fishing intensity) to extrapolate standing stock across The Bahamas on the forereef (Harborne 2017).
37. Potential gain in standing stock of coral reef fisheries species	The coefficients of the model of current standing stock can be adjusted to estimate potential standing stock (g/m^2) under different conservation and management initiatives. This includes perhaps the most obvious conservation scenario, namely with fishing intensity hypothetically reduced to zero, simulating the effects of a no-take reserve or other fisheries management tool (Harborne 2017).

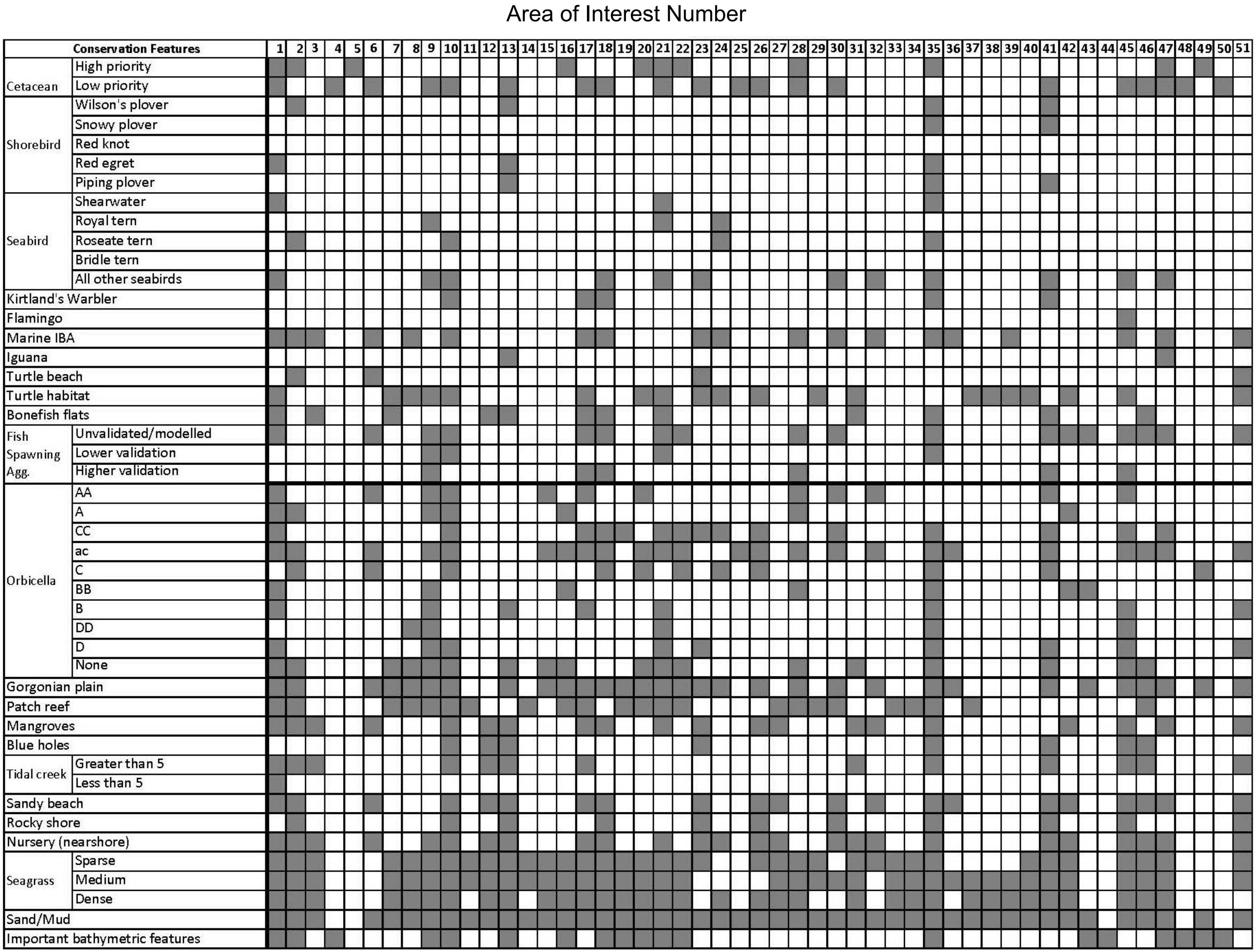
Appendix 2
Table of Conservation Features in Each AOI



Yellowmouth Grouper cruises above the reef. Shot in Exuma Cays Land and Sea Park, The Bahamas. © Jeff Yonover

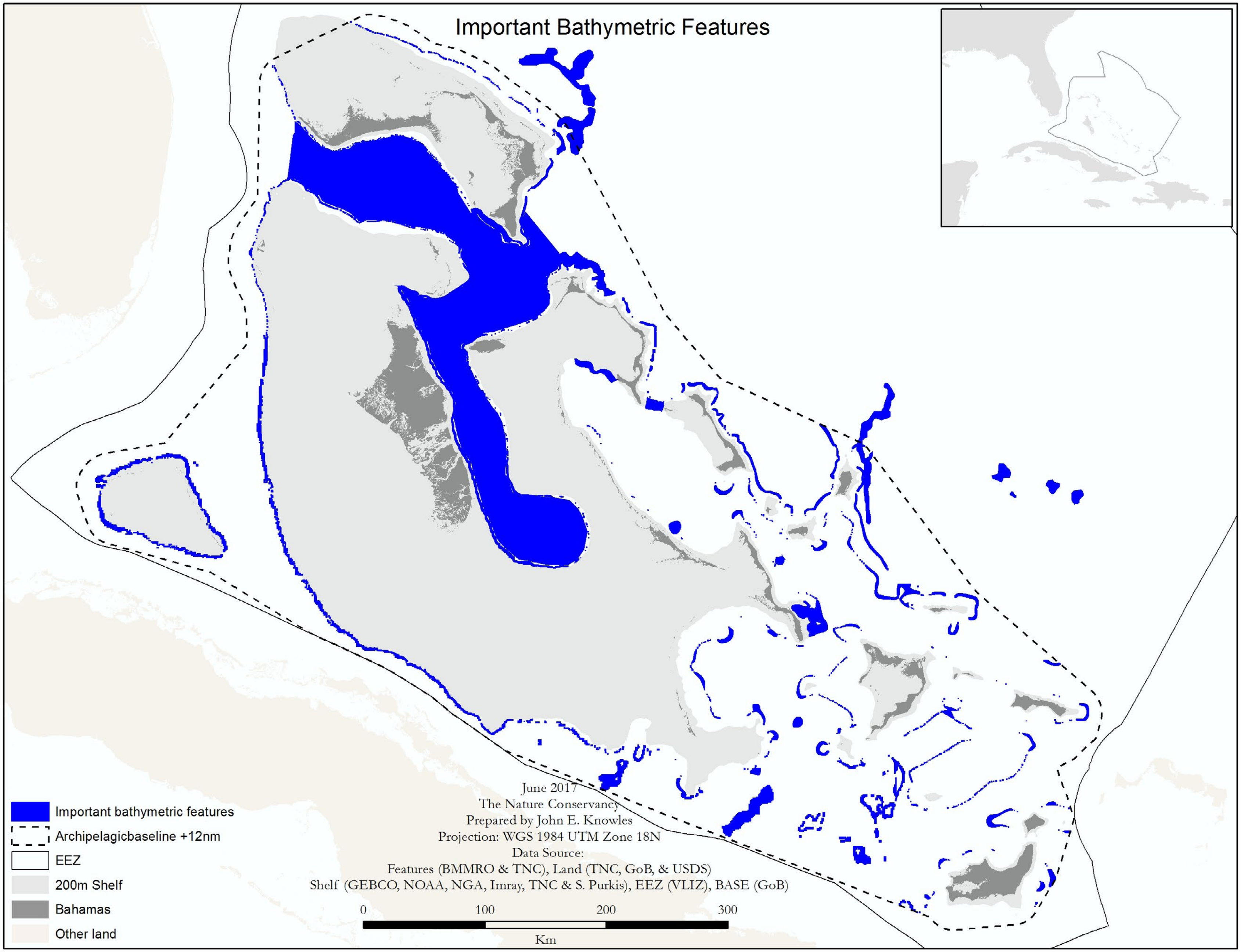
Appendix 2 Table of Conservation Features in Each AOI

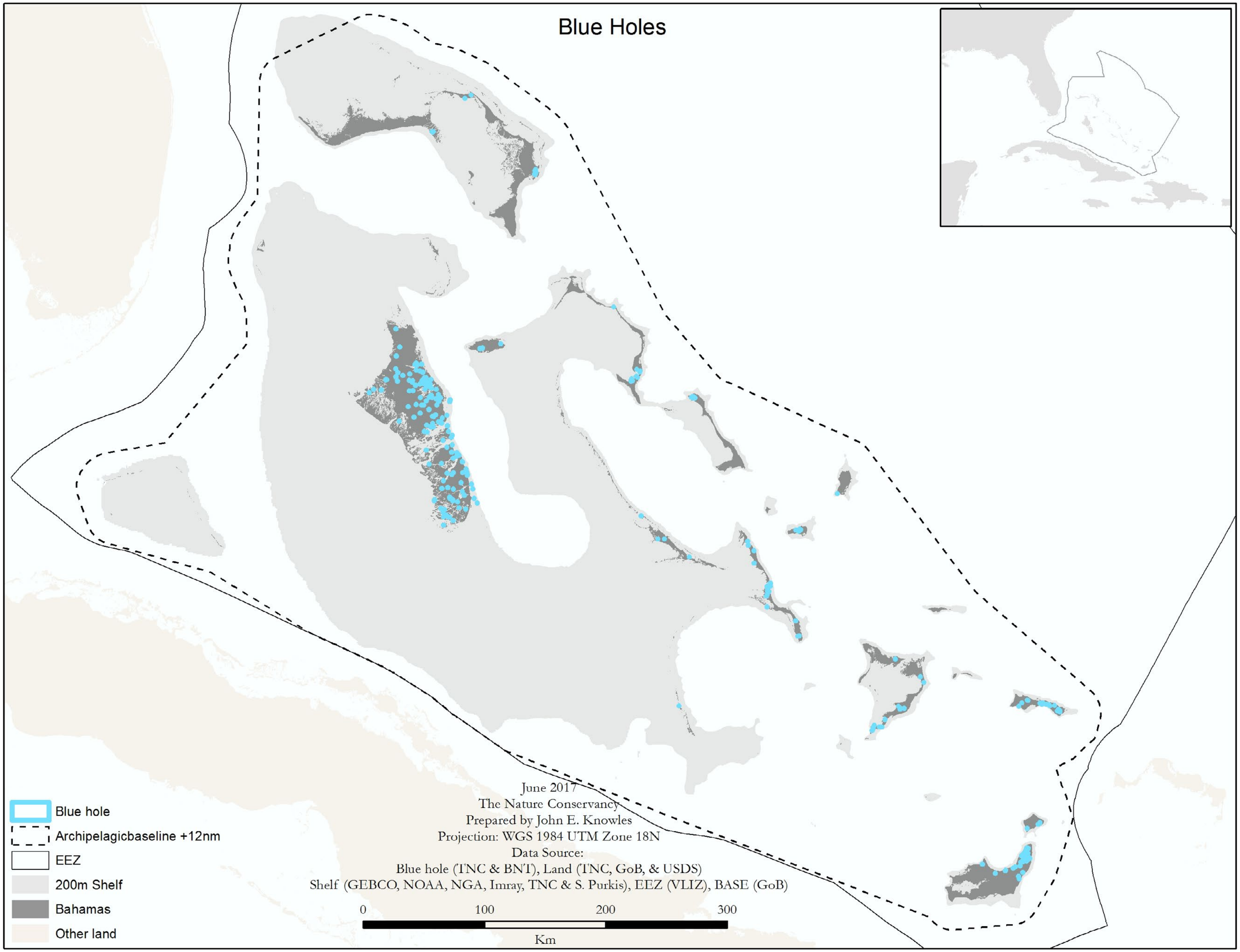
A list of conservation features found in each AOI by number as shown in Table 4. Some AOIs have many conservation features (the large AOI #35), others do not (e.g. AOI #5 only includes high priority cetacean areas). Some conservation features are included in almost every AOI (e.g. sand/mud), while others are only included in one or two (e.g. A tidal creek occurring on an island with 5 or less tidal creeks in total is only included in AOI #1). A high percentage of red knots locations are already included in existing protected areas and do not show up in any AOIs.

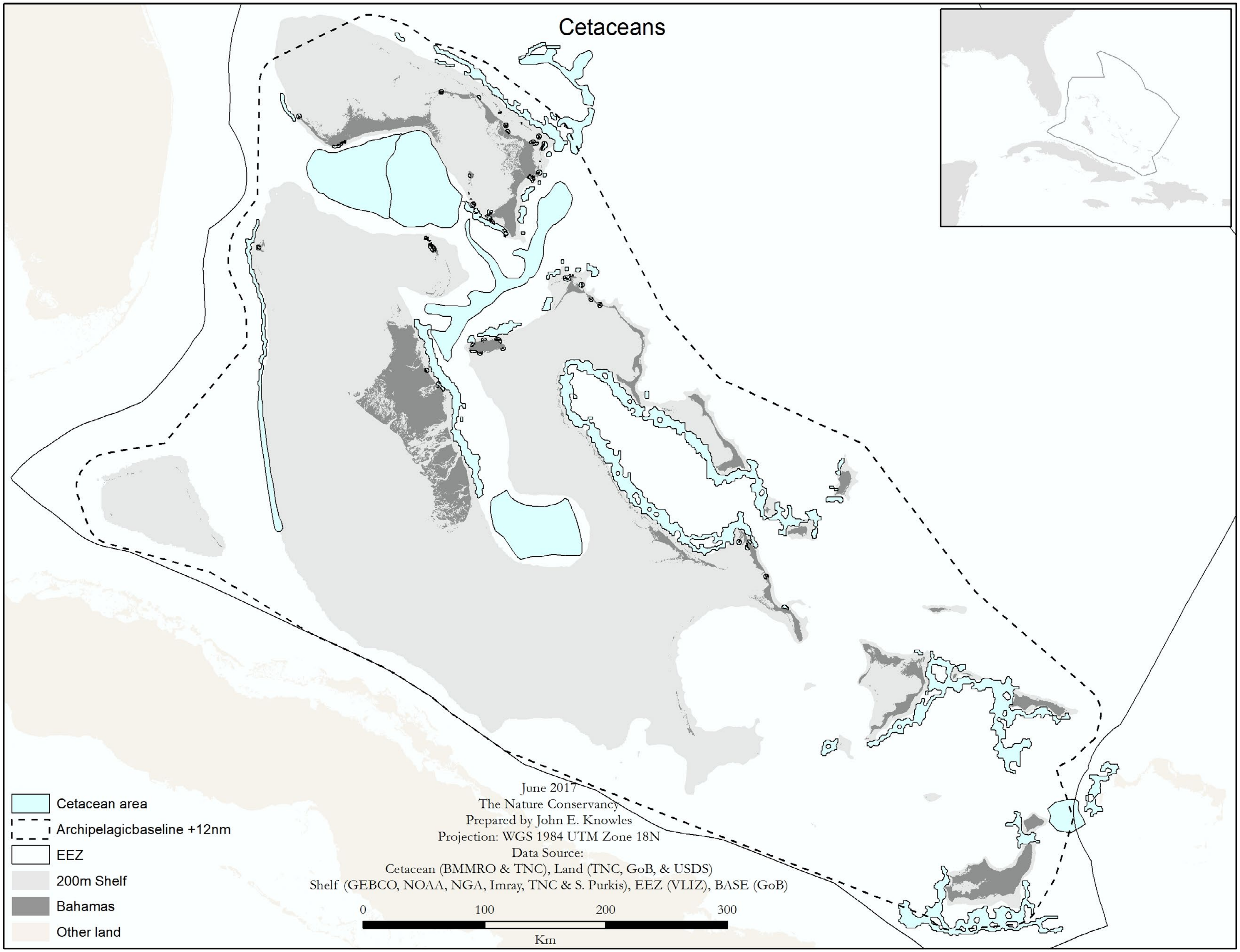

Area of Interest Number
Conservation Features
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51
Cetacean
High priority
Low priority
Shorebird
Wilson's plover
Snowy plover
Red knot
Red egret
Piping plover
Seabird
Shearwater
Royal tern
Roseate tern
Bridle tern
All other seabirds
Kirtland's Warbler
Flamingo
Marine IBA
Iguana
Turtle beach
Turtle habitat
Bonefish flats
Fish Spawning Agg.
Unvalidated/modelled
Lower validation
Higher validation
Orbicella
AA
A
CC
ac
C
BB
B
DD
D
None
Gorgonian plain
Patch reef
Mangroves
Blue holes
Tidal creek
Greater than 5
Less than 5
Sandy beach
Rocky shore
Nursery (nearshore)
Seagrass
Sparse
Medium
Dense
Sand/Mud
Important bathymetric features

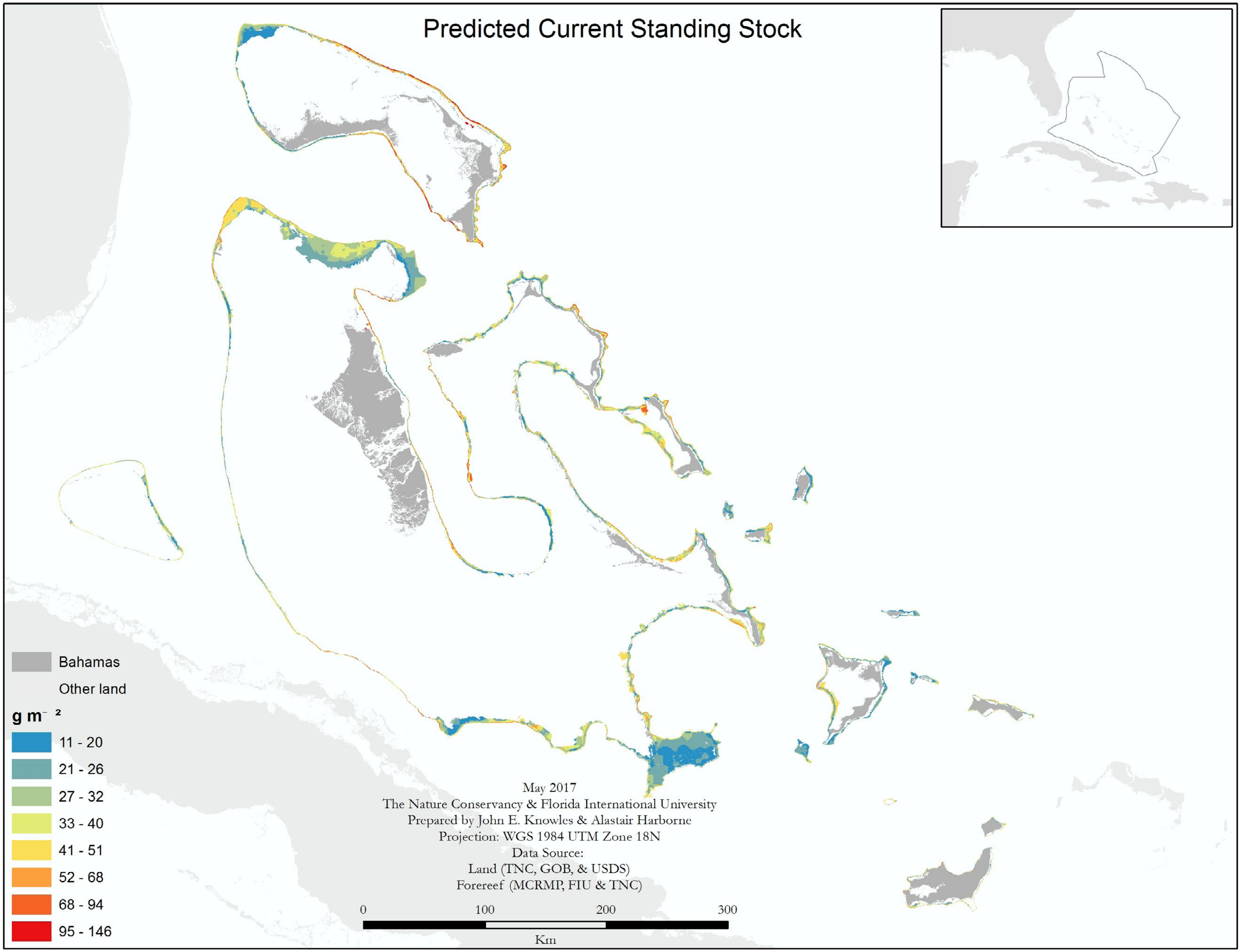
Appendix 3
Maps of data layers

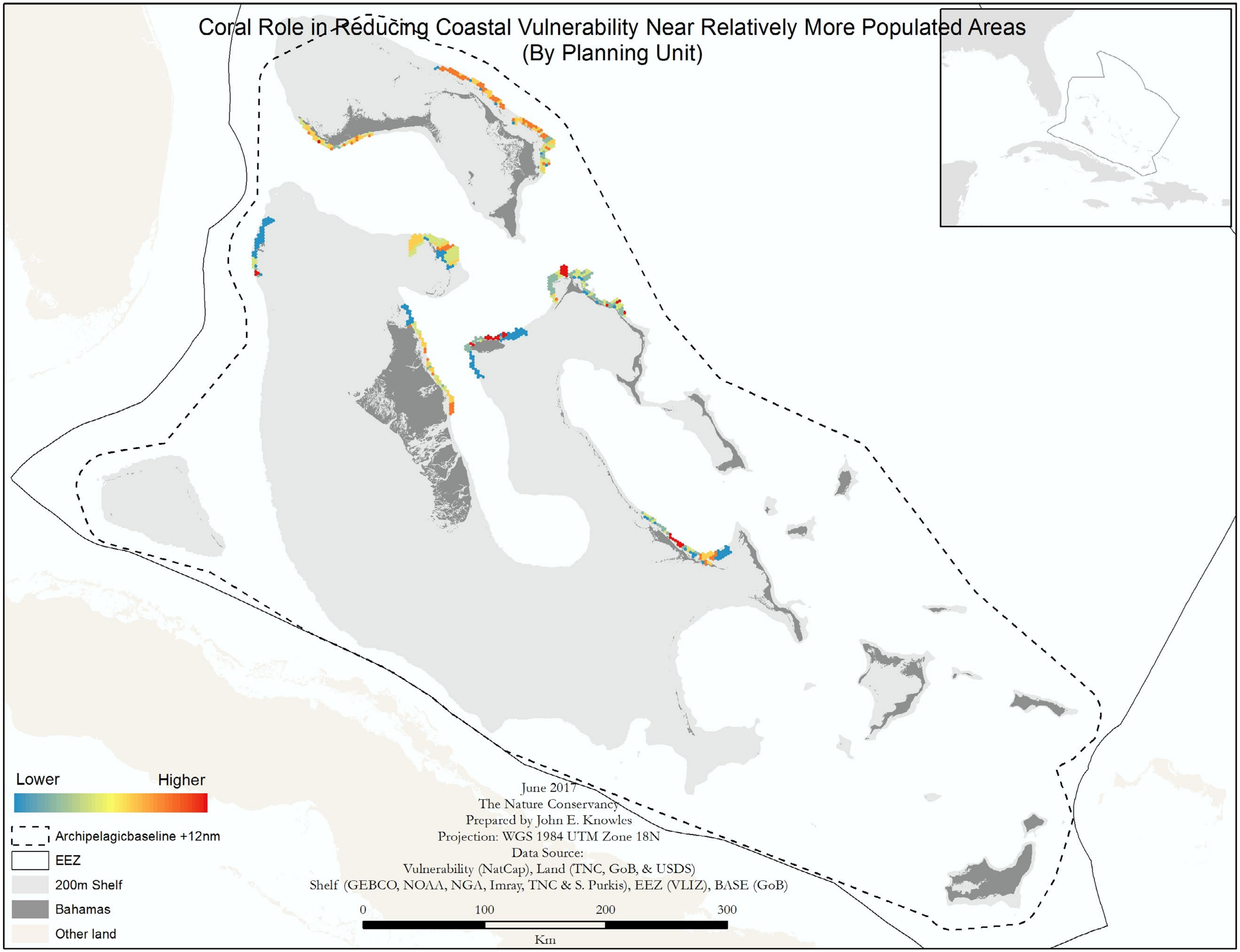
Rat Cay near Andros Island in The Bahamas. © Erika Nortemann/TNC

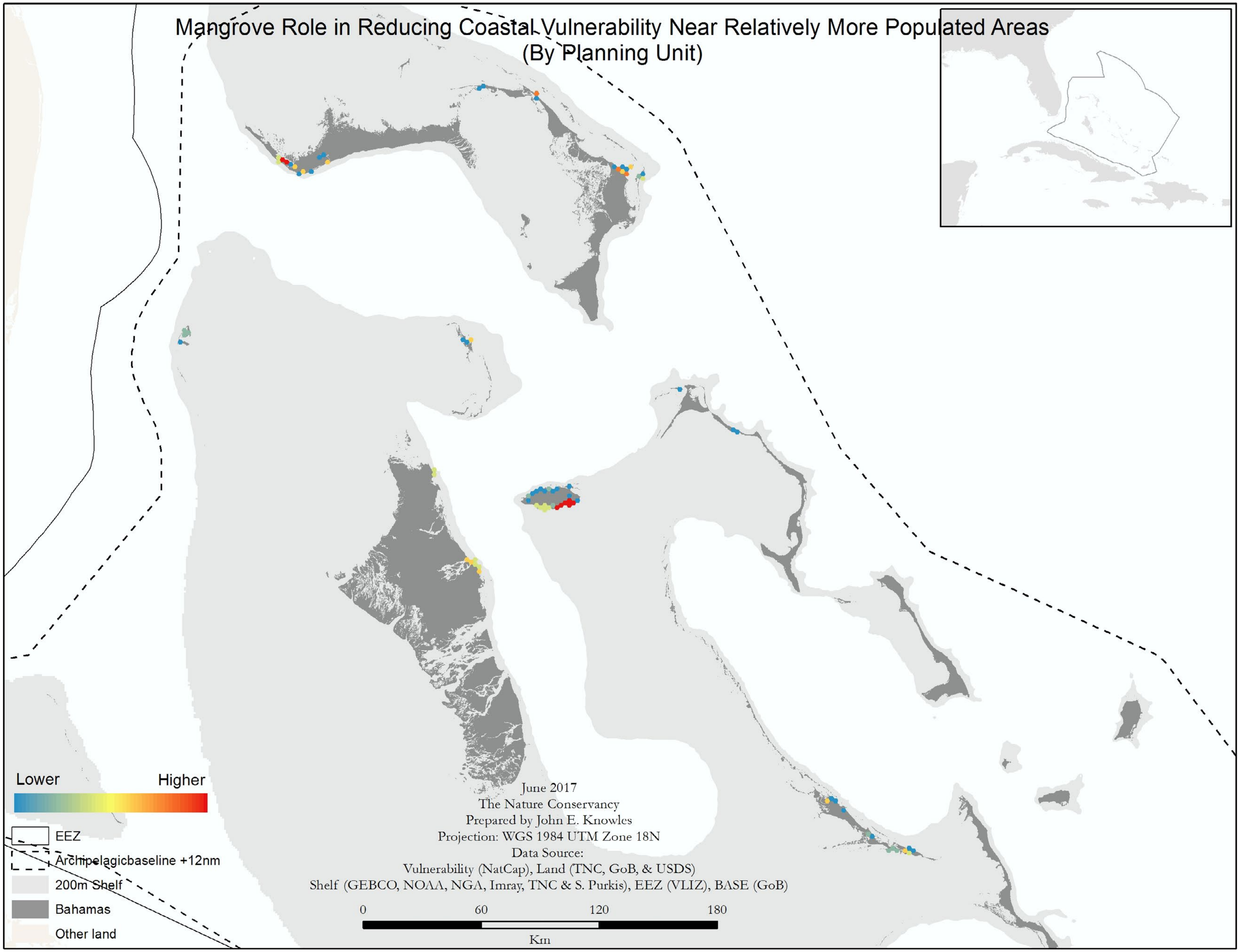

Important Bathymetric Features
Important bathymetric features
Archipelagicbaseline +12nm
EEZ
200m Shelf
Bahamas
Other land
June 2017
The Nature Conservancy
Prepared by John E. Knowles
Projection: WGS 1984 UTM Zone 18N
Data Source:
Features (BMMRO & TNC), Land (TNC, GoB, & USDS)
Shelf (GEBCO, NOAA, NGA, Imray, TNC & S. Purkis), EEZ (VLIZ), BASE (GoB)
0
100
200
300
Km

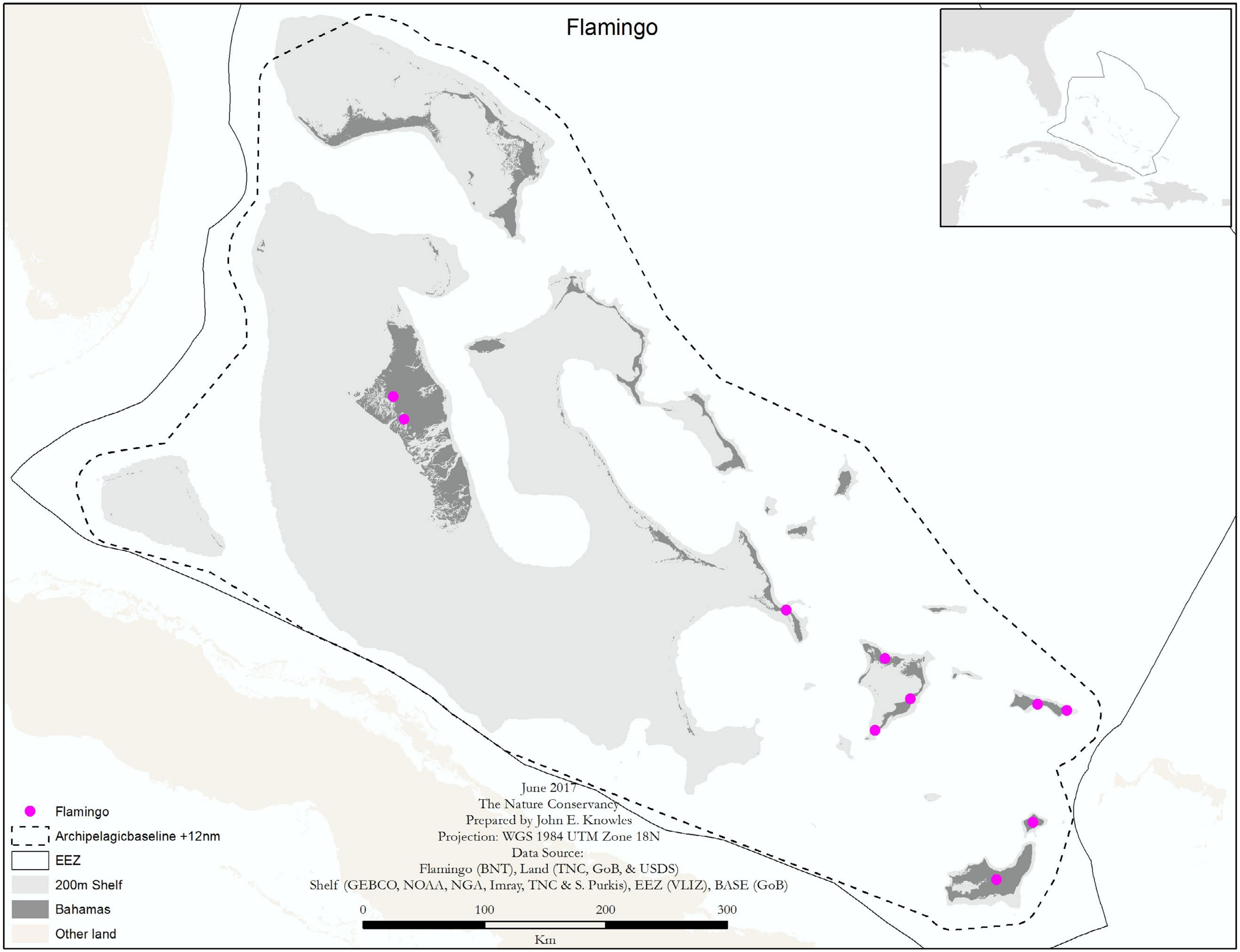

Blue Holes
Blue hole
Archipelagicbaseline +12nm
EEZ
200m Shelf
Bahamas
Other land
June 2017
The Nature Conservancy
Prepared by John E. Knowles
Projection: WGS 1984 UTM Zone 18N
Data Source:
Blue hole (TNC & BNT), Land (TNC, GoB, & USDS)
Shelf (GEBCO, NOAA, NGA, Imray, TNC & S. Purkis), EEZ (VLIZ), BASE (GoB)
0
100
200
300
Km

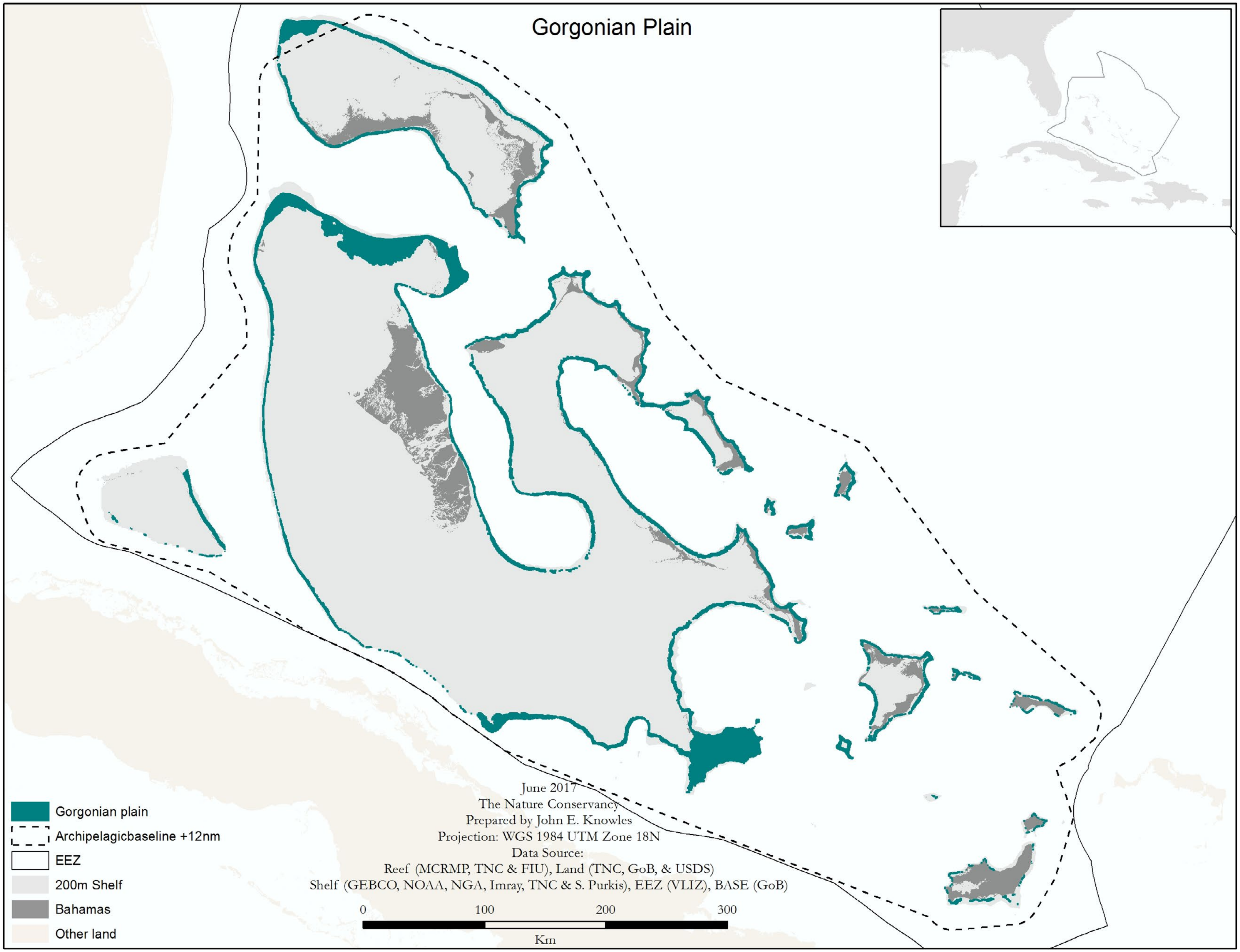

Cetaceans
Cetacean area
Archipelagicbaseline +12nm
EEZ
200m Shelf
Bahamas
Other land
June 2017
The Nature Conservancy
Prepared by John E. Knowles
Projection: WGS 1984 UTM Zone 18N
Data Source:
Cetacean (BMMRO & TNC), Land (TNC, GoB, & USDS)
Shelf (GEBCO, NOAA, NGA, Imray, TNC & S. Purkis), EEZ (VLIZ), BASE (GoB)
0
100
200
300
Km


Predicted Current Standing Stock
Bahamas
Other land
g m⁻²
11 - 20
21 - 26
27 - 32
33 - 40
41 - 51
52 - 68
68 - 94
95 - 146
May 2017
The Nature Conservancy & Florida International University
Prepared by John E. Knowles & Alastair Harborne
Projection: WGS 1984 UTM Zone 18N
Data Source:
Land (TNC, GOB, & USDS)
Forereef (MCRMP, FIU & TNC)
0
100
200
300
Km

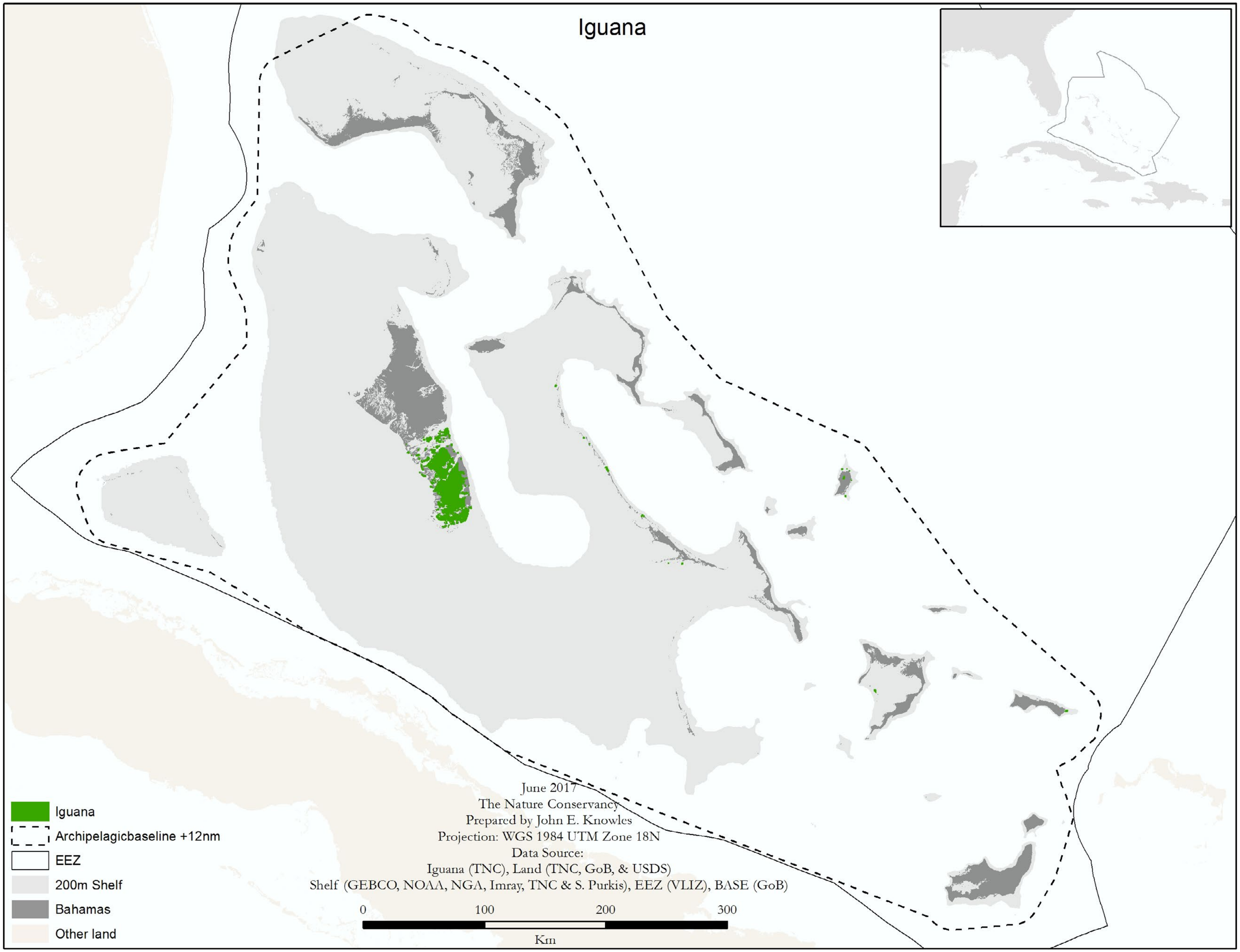

Coral Role in Reducing Coastal Vulnerability Near Relatively More Populated Areas
(By Planning Unit)
Lower
Higher
Archipelagicbaseline +12nm
EEZ
200m Shelf
Bahamas
Other land
June 2017
The Nature Conservancy
Prepared by John E. Knowles
Projection: WGS 1984 UTM Zone 18N
Data Source:
Vulnerability (NatCap), Land (TNC, GoB, & USDS)
Shelf (GEBCO, NOAA, NGA, Imray, TNC & S. Purkis), EEZ (VLIZ), BASE (GoB)
0
100
200
300
Km

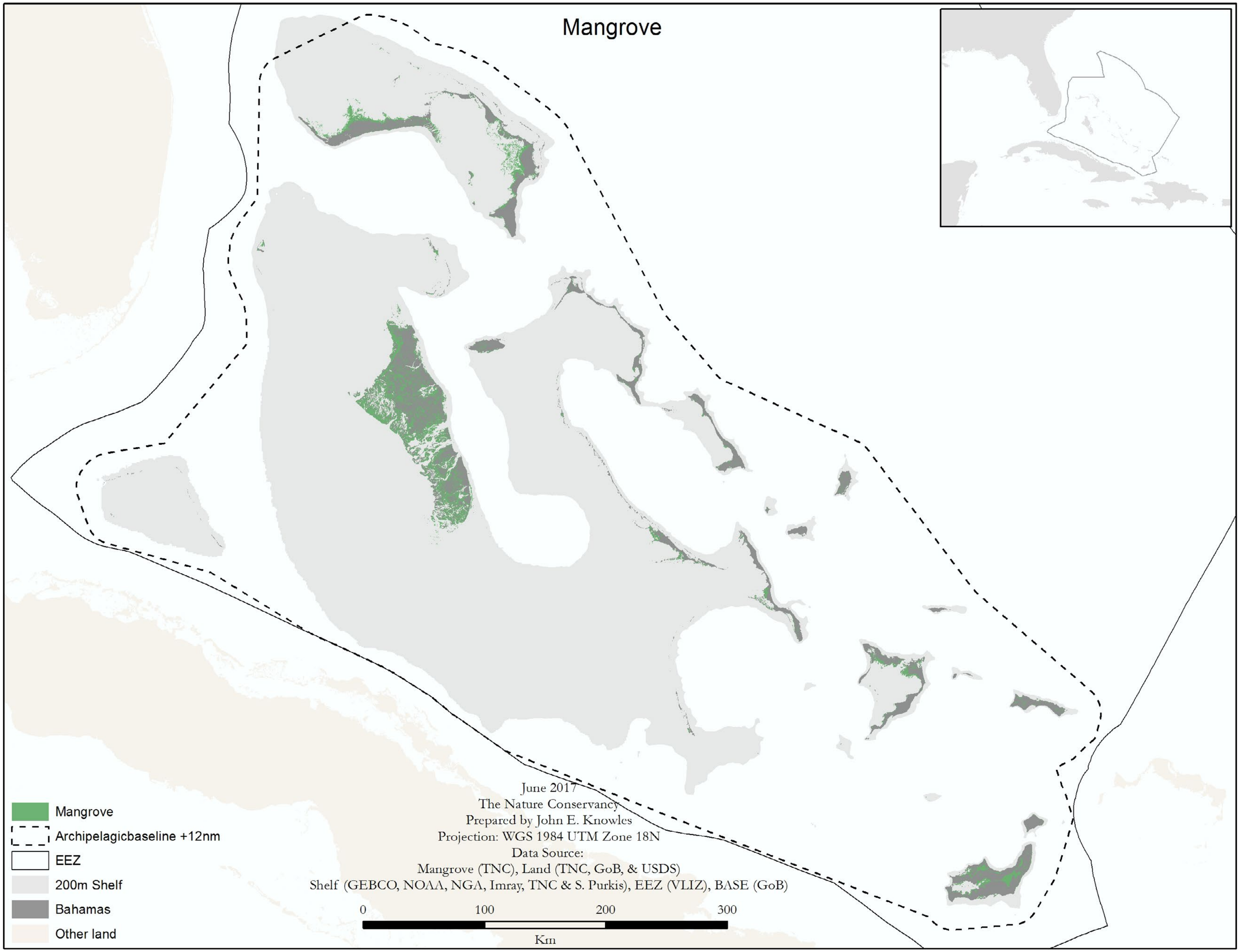

Mangrove Role in Reducing Coastal Vulnerability Near Relatively More Populated Areas
(By Planning Unit)
Lower
Higher
EEZ
Archipelagicbaseline +12nm
200m Shelf
Bahamas
Other land
June 2017
The Nature Conservancy
Prepared by John E. Knowles
Projection: WGS 1984 UTM Zone 18N
Data Source:
Vulnerability (NatCap), Land (TNC, GoB, & USDS)
Shelf (GEBCO, NOAA, NGA, Imray, TNC & S. Purkis), EEZ (VLIZ), BASE (GoB)
0
60
120
180
Km

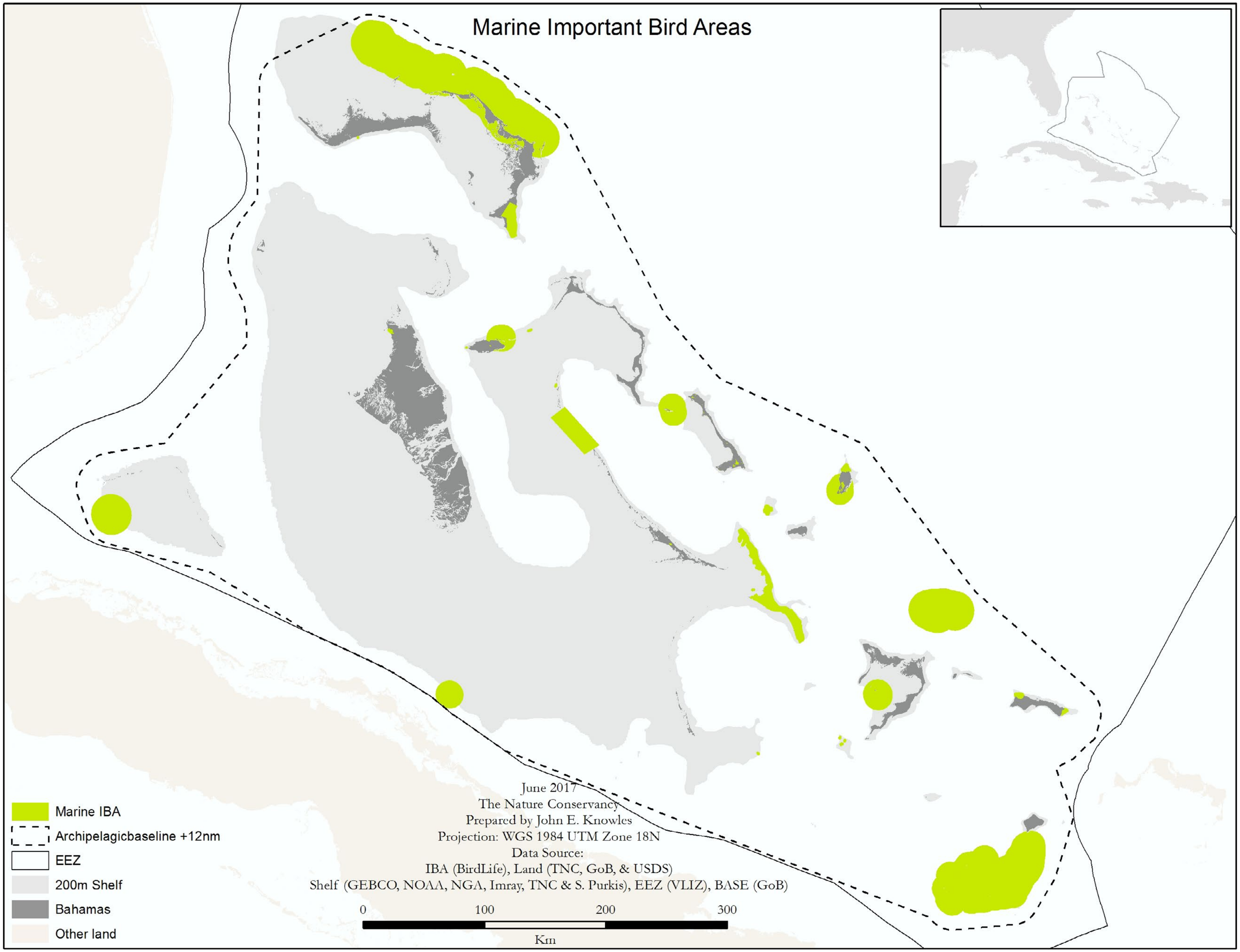

Flamingo
June 2017
The Nature Conservancy
Prepared by John E. Knowles
Projection: WGS 1984 UTM Zone 18N
Data Source:
Flamingo (BNT), Land (TNC, GoB, & USDS)
Shelf (GEBCO, NOAA, NGA, Imray, TNC & S. Purkis), EEZ (VLIZ), BASE (GoB)
0
100
200
300
Km
Flamingo
Archipelagicbaseline +12nm
EEZ
200m Shelf
Bahamas
Other land



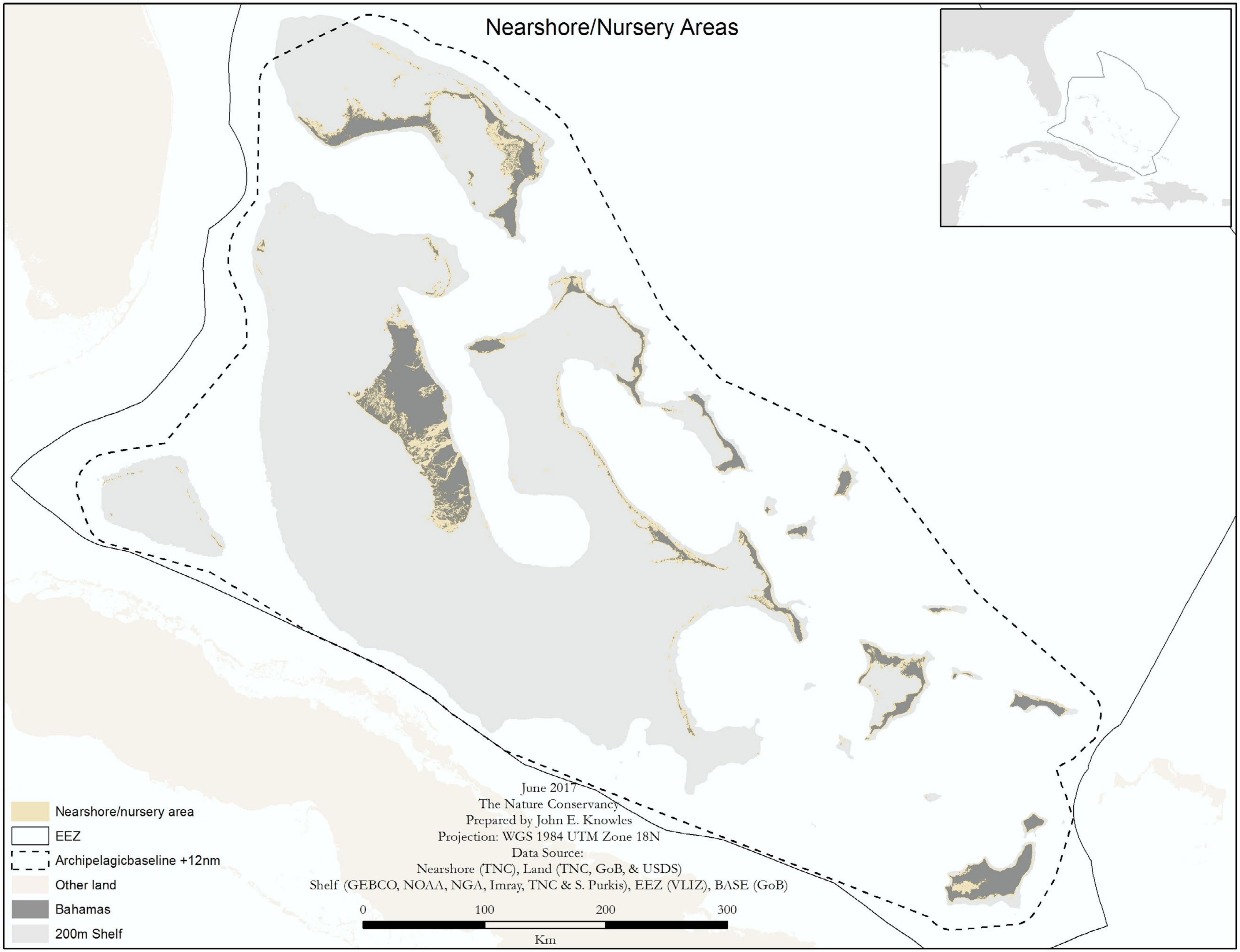
Gorgonian Plain
Gorgonian plain
Archipelagicbaseline +12nm
EEZ
200m Shelf
Bahamas
Other land
June 2017
The Nature Conservancy
Prepared by John E. Knowles
Projection: WGS 1984 UTM Zone 18N
Data Source:
Reef (MCRMP, TNC & FIU), Land (TNC, GoB, & USDS)
Shelf (GEBCO, NOAA, NGA, Imray, TNC & S. Purkis), EEZ (VLIZ), BASE (GoB)
0
100
200
300
Km

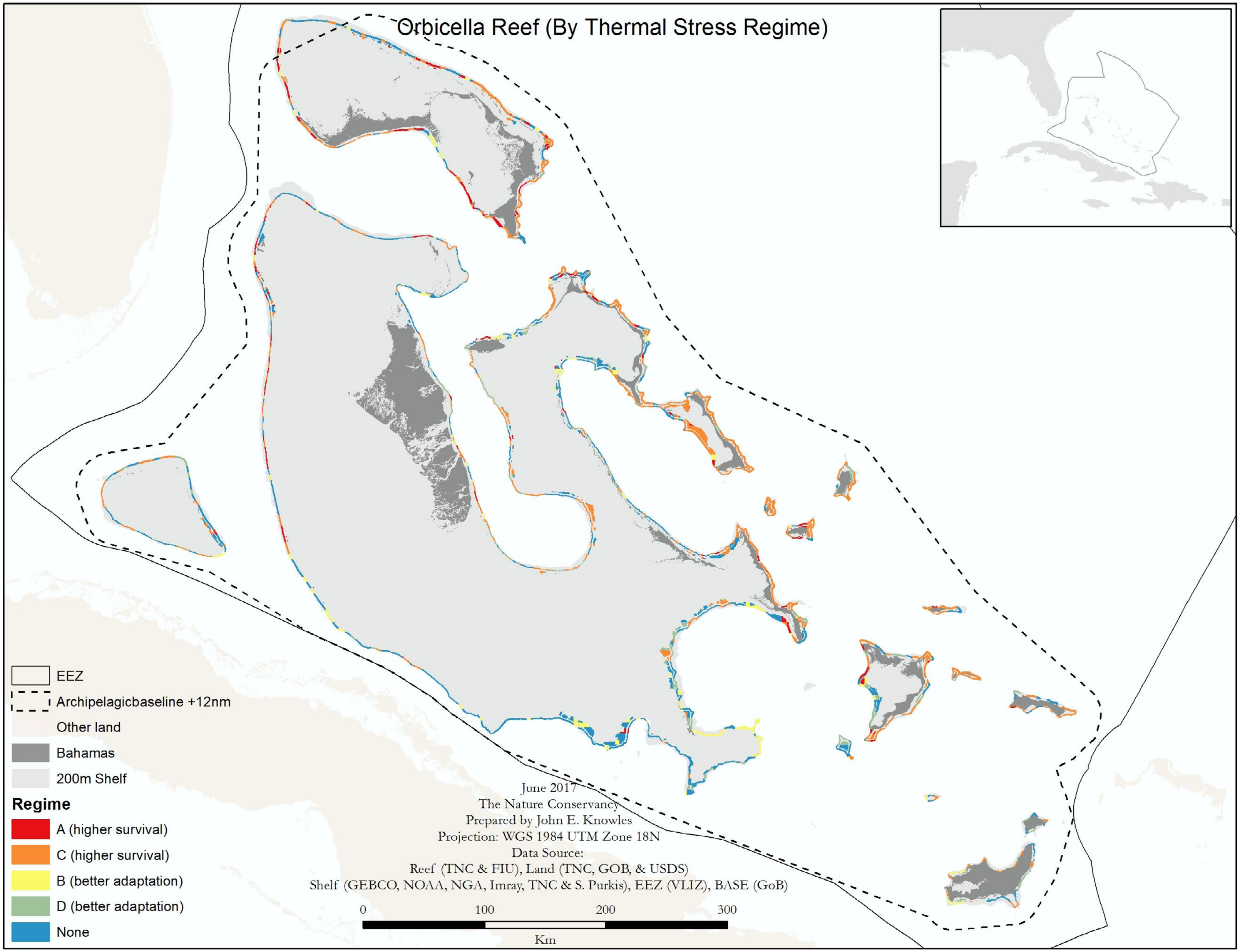

Iguana
Iguana
Archipelagicbaseline +12nm
EEZ
200m Shelf
Bahamas
Other land
June 2017
The Nature Conservancy
Prepared by John E. Knowles
Projection: WGS 1984 UTM Zone 18N
Data Source:
Iguana (TNC), Land (TNC, GoB, & USDS)
Shelf (GEBCO, NOAA, NGA, Imray, TNC & S. Purkis), EEZ (VLIZ), BASE (GoB)
0
100
200
300
Km

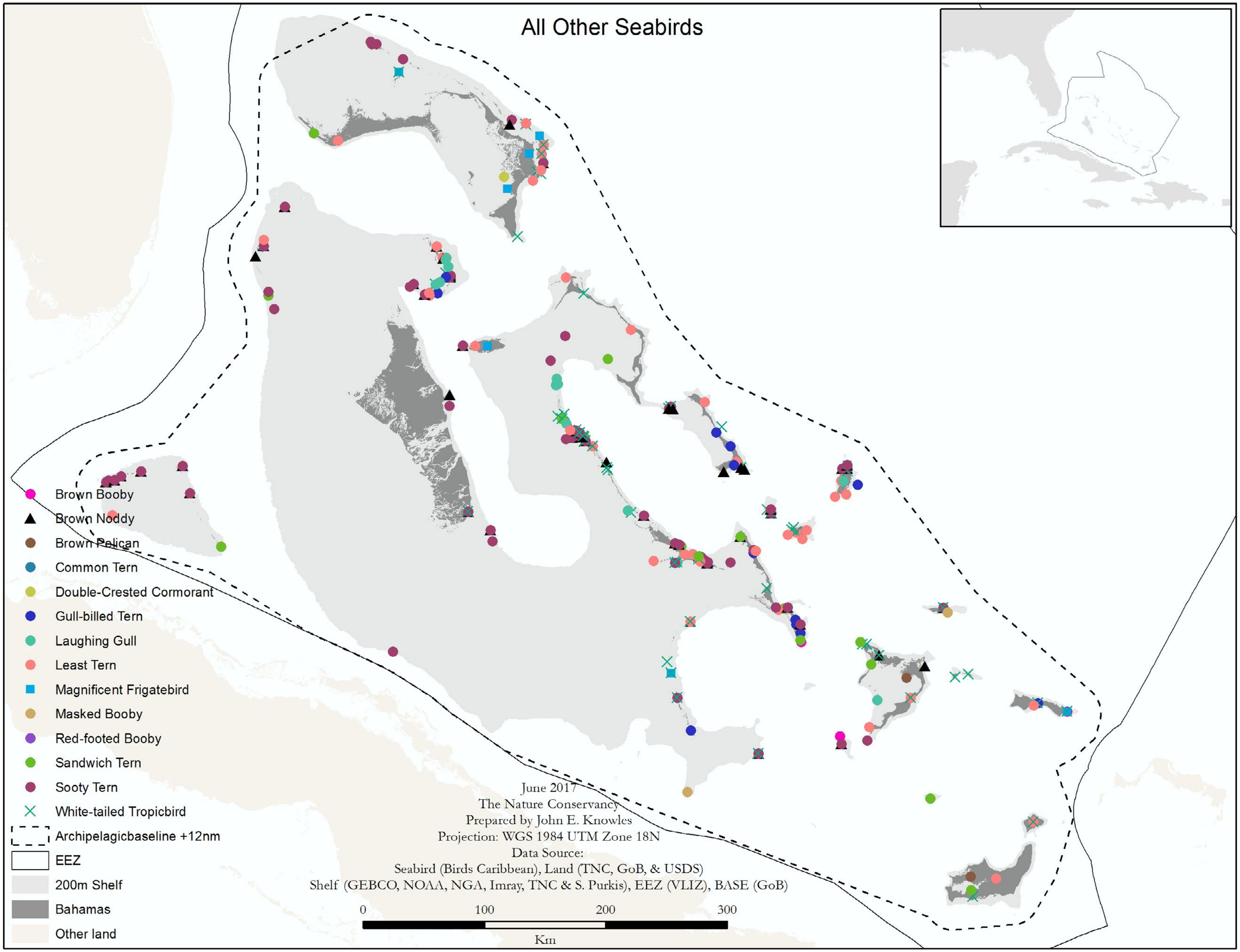

Mangrove
June 2017
The Nature Conservancy
Prepared by John E. Knowles
Projection: WGS 1984 UTM Zone 18N
Data Source:
Mangrove (TNC), Land (TNC, GoB, & USDS)
Shelf (GEBCO, NOAA, NGA, Imray, TNC & S. Purkis), EEZ (VLIZ), BASE (GoB)
0
100
200
300
Km
Mangrove
Archipelagicbaseline +12nm
EEZ
200m Shelf
Bahamas
Other land

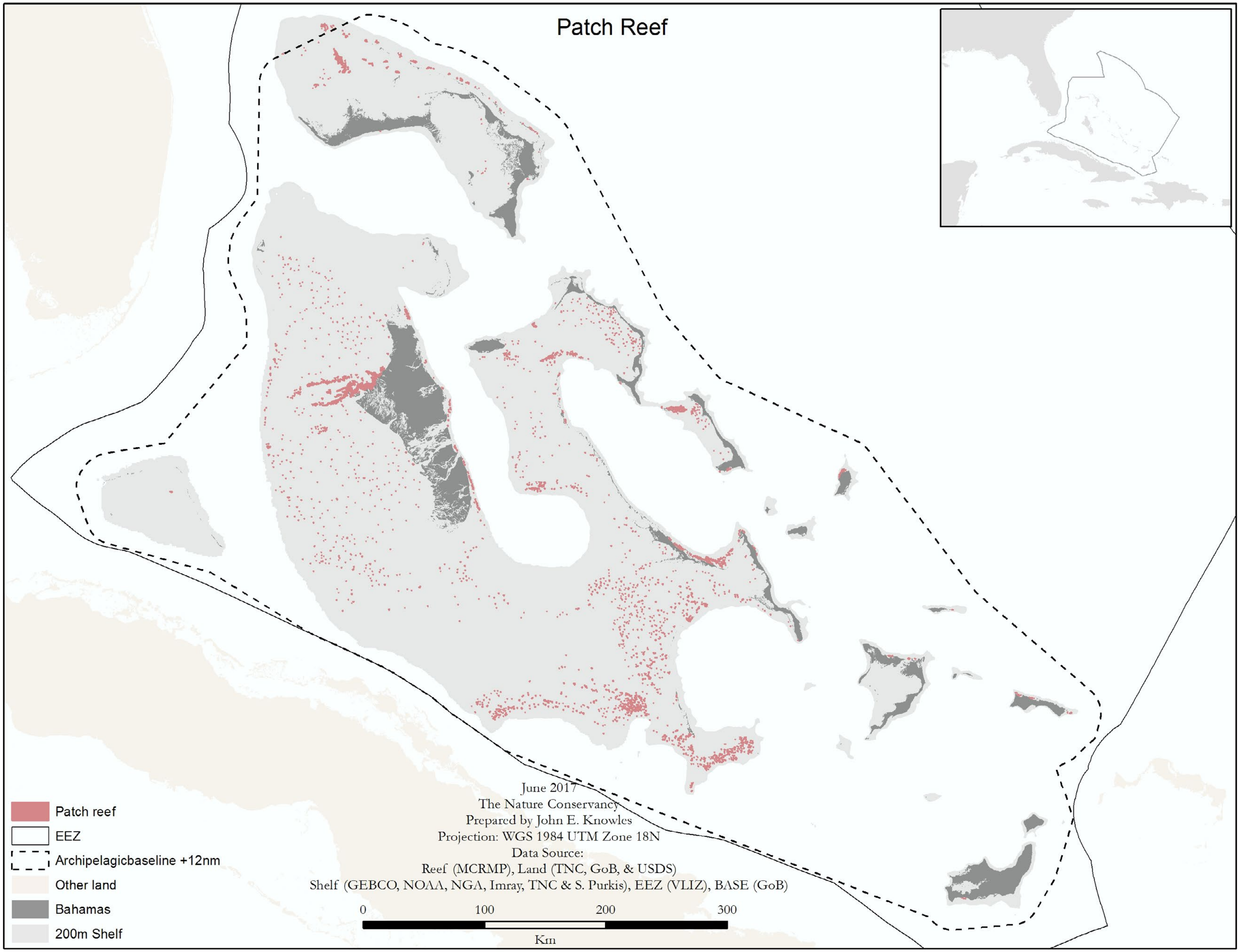


Marine Important Bird Areas
Marine IBA
Archipelagicbaseline +12nm
EEZ
200m Shelf
Bahamas
Other land
June 2017
The Nature Conservancy
Prepared by John E. Knowles
Projection: WGS 1984 UTM Zone 18N
Data Source:
IBA (BirdLife), Land (TNC, GoB, & USDS)
Shelf (GEBCO, NOAA, NGA, Imray, TNC & S. Purkis), EEZ (VLIZ), BASE (GoB)
0
100
200
300
Km

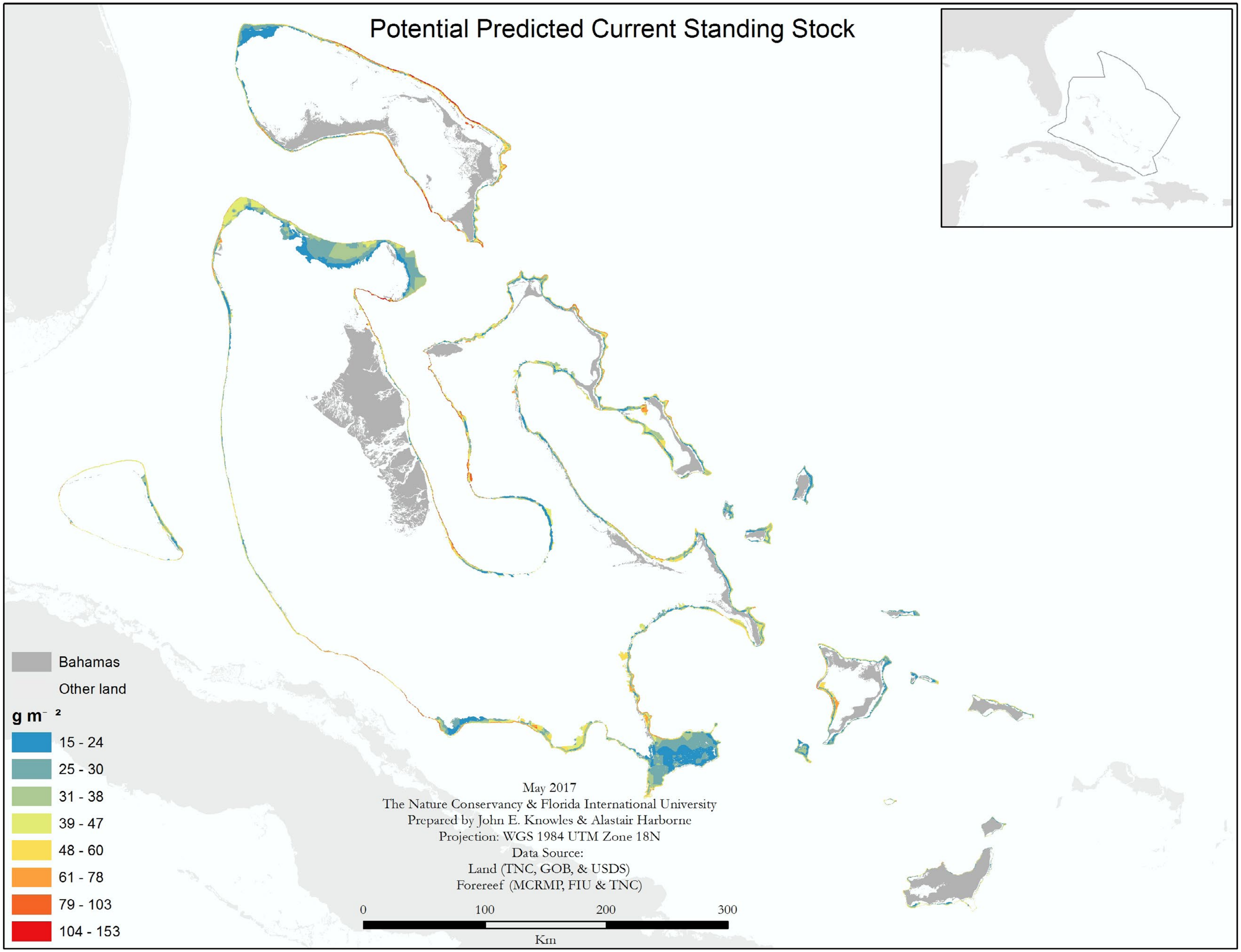

Nearshore/Nursery Areas
Nearshore/nursery area
EEZ
Archipelagicbaseline +12nm
Other land
Bahamas
200m Shelf
June 2017
The Nature Conservancy
Prepared by John E. Knowles
Projection: WGS 1984 UTM Zone 18N
Data Source:
Nearshore (TNC), Land (TNC, GoB, & USDS)
Shelf (GEBCO, NOAA, NGA, Imray, TNC & S. Purkis), EEZ (VLIZ), BASE (GoB)
0
100
200
300
Km


Orbicella Reef (By Thermal Stress Regime)
EEZ
Archipelagicbaseline +12nm
Other land
Bahamas
200m Shelf
Regime
A (higher survival)
C (higher survival)
B (better adaptation)
D (better adaptation)
None
June 2017
The Nature Conservancy
Prepared by John E. Knowles
Projection: WGS 1984 UTM Zone 18N
Data Source:
Reef (TNC & FIU), Land (TNC, GOB, & USDS)
Shelf (GEBCO, NOAA, NGA, Imray, TNC & S. Purkis), EEZ (VLIZ), BASE (GoB)
0
100
200
300
Km

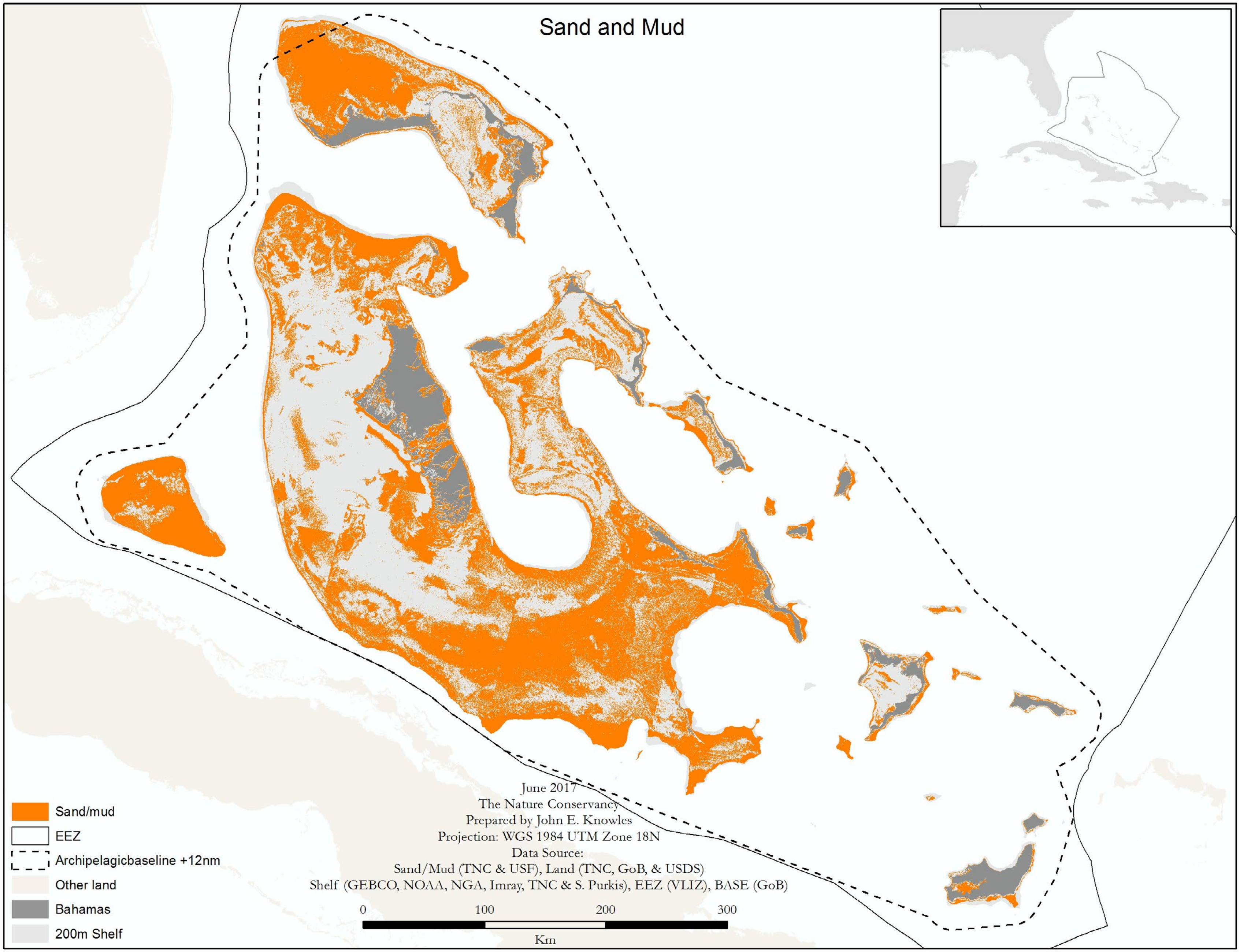

All Other Seabirds
Brown Booby
Brown Noddy
Brown Pelican
Common Tern
Double-Crested Cormorant
Gull-billed Tern
Laughing Gull
Least Tern
Magnificent Frigatebird
Masked Booby
Red-footed Booby
Sandwich Tern
Sooty Tern
White-tailed Tropicbird
Archipelagicbaseline +12nm
EEZ
200m Shelf
Bahamas
Other land
June 2017
The Nature Conservancy
Prepared by John E. Knowles
Projection: WGS 1984 UTM Zone 18N
Data Source:
Seabird (Birds Caribbean), Land (TNC, GoB, & USDS)
Shelf (GEBCO, NOAA, NGA, Imray, TNC & S. Purkis), EEZ (VLIZ), BASE (GoB)
0
100
200
300
Km



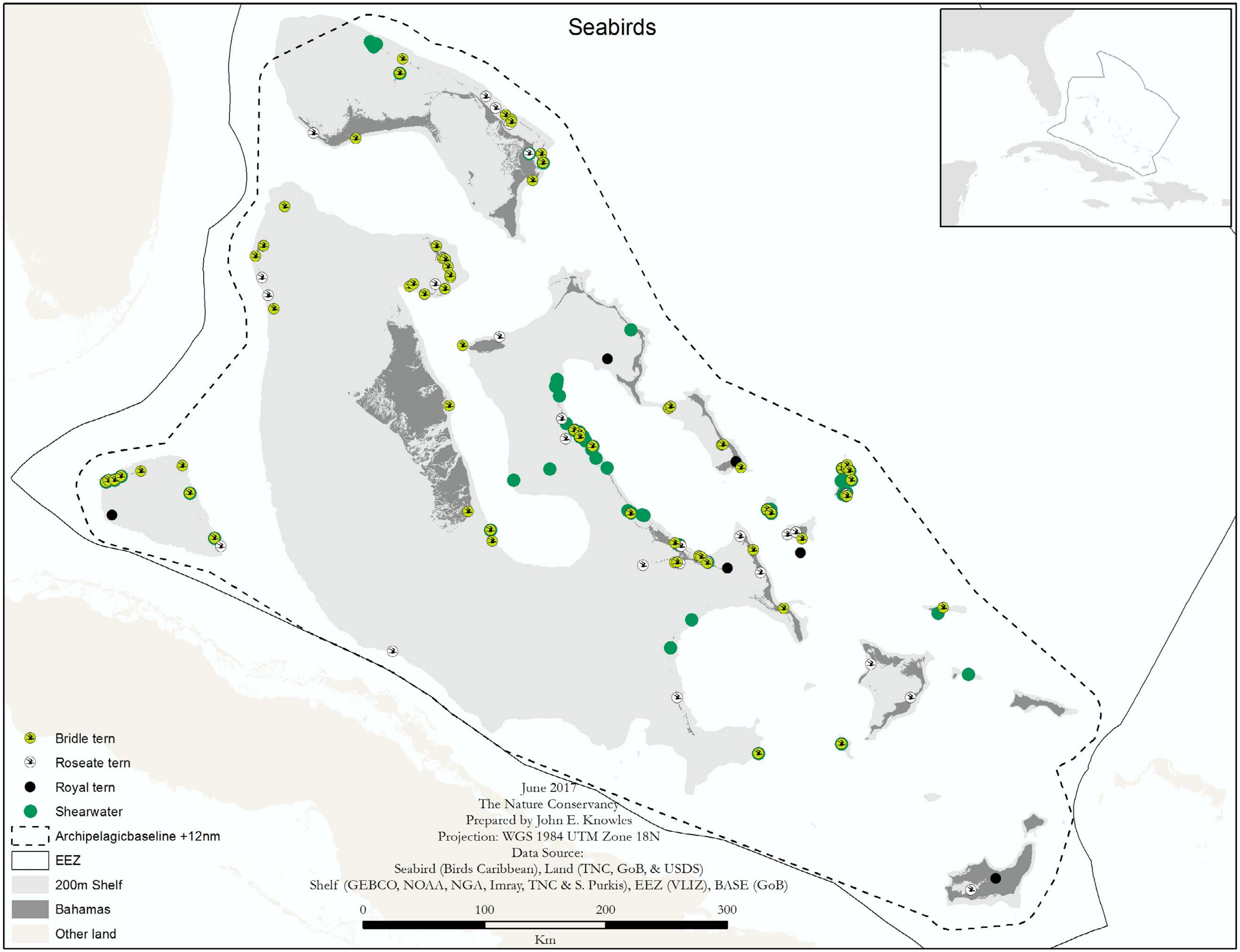
Patch Reef
Patch reef
EEZ
Archipelagicbaseline +12nm
Other land
Bahamas
200m Shelf
June 2017
The Nature Conservancy
Prepared by John E. Knowles
Projection: WGS 1984 UTM Zone 18N
Data Source:
Reef (MCRMP), Land (TNC, GoB, & USDS)
Shelf (GEBCO, NOAA, NGA, Imray, TNC & S. Purkis), EEZ (VLIZ), BASE (GoB)
0
100
200
300
Km

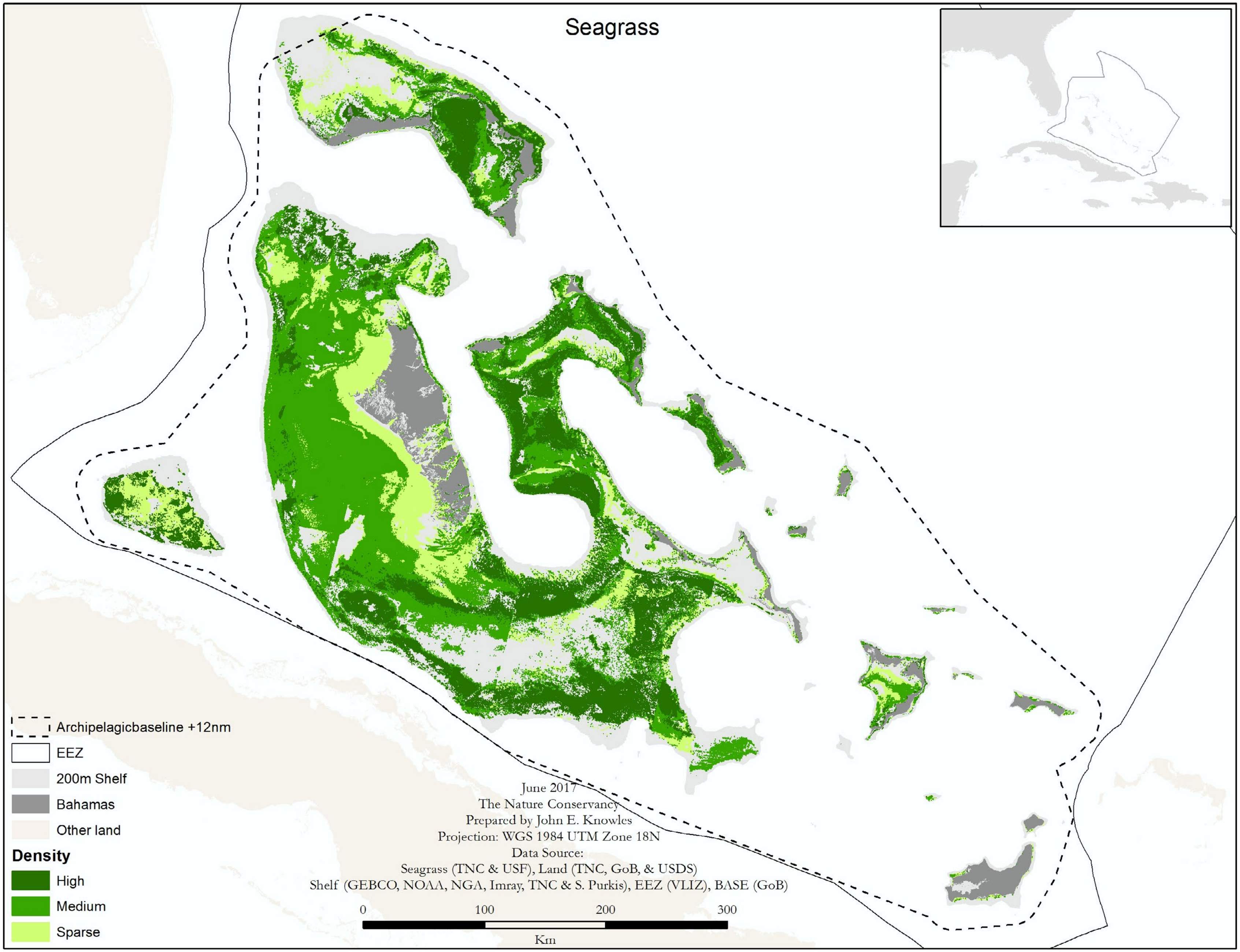


Potential Predicted Current Standing Stock
Bahamas
Other land
g m⁻²
15 - 24
25 - 30
31 - 38
39 - 47
48 - 60
61 - 78
79 - 103
104 - 153
May 2017
The Nature Conservancy & Florida International University
Prepared by John E. Knowles & Alastair Harborne
Projection: WGS 1984 UTM Zone 18N
Data Source:
Land (TNC, GOB, & USDS)
Forereef (MCRMP, FIU & TNC)
0
100
200
300
Km

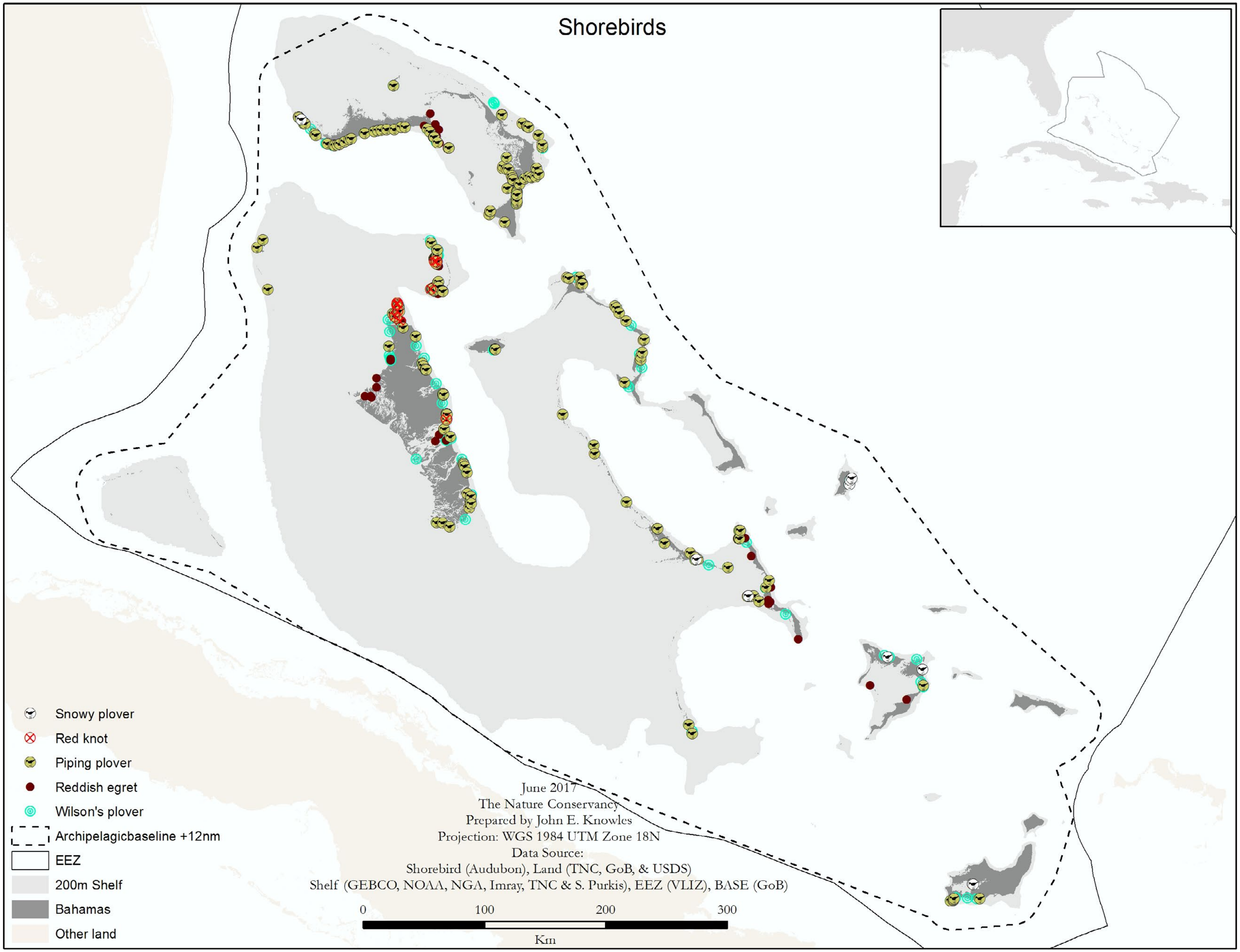


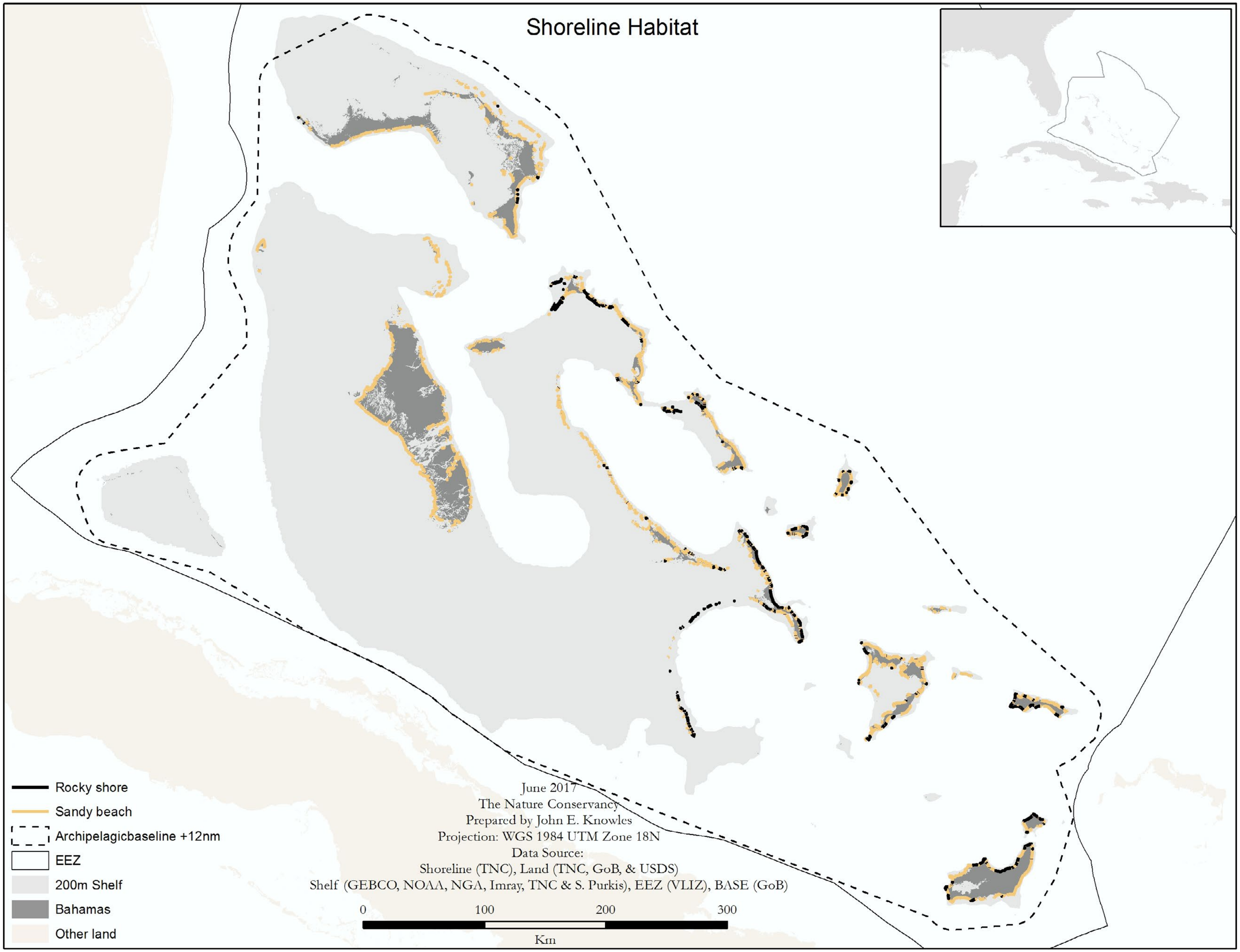
Sand and Mud
June 2017
The Nature Conservancy
Prepared by John E. Knowles
Projection: WGS 1984 UTM Zone 18N
Data Source:
Sand/Mud (TNC & USF), Land (TNC, GoB, & USDS)
Shelf (GEBCO, NOAA, NGA, Imray, TNC & S. Purkis), EEZ (VLIZ), BASE (GoB)
0
100
200
300
Km
Sand/mud
EEZ
Archipelagicbaseline +12nm
Other land
Bahamas
200m Shelf


Seabirds
Bridle tern
Roseate tern
Royal tern
Shearwater
Archipelagicbaseline +12nm
EEZ
200m Shelf
Bahamas
Other land
June 2017
The Nature Conservancy
Prepared by John E. Knowles
Projection: WGS 1984 UTM Zone 18N
Data Source:
Seabird (Birds Caribbean), Land (TNC, GoB, & USDS)
Shelf (GEBCO, NOAA, NGA, Imray, TNC & S. Purkis), EEZ (VLIZ), BASE (GoB)
0
100
200
300
Km

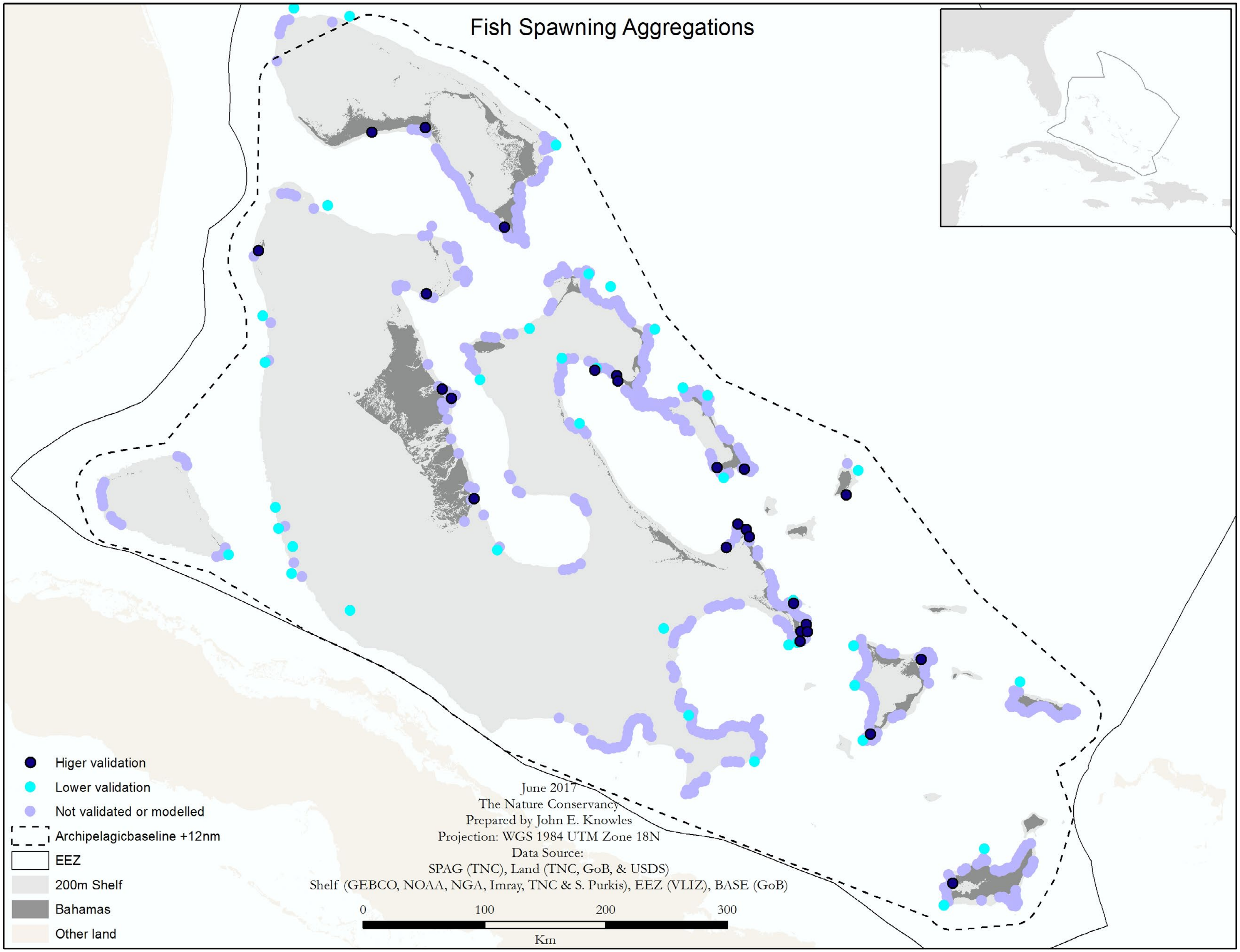


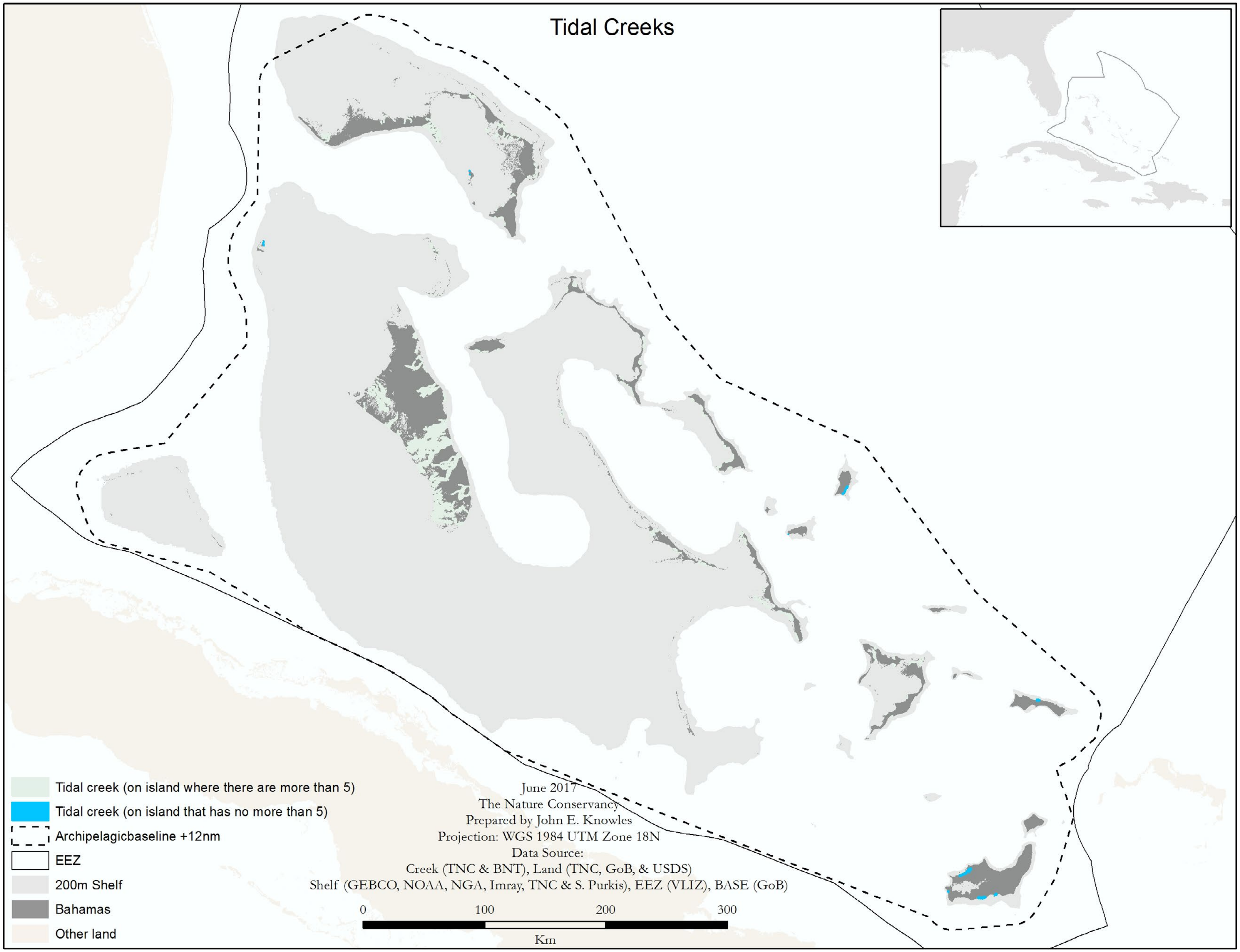
Seagrass
Archipelagicbaseline +12nm
EEZ
200m Shelf
Bahamas
Other land
Density
High
Medium
Sparse
June 2017
The Nature Conservancy
Prepared by John E. Knowles
Projection: WGS 1984 UTM Zone 18N
Data Source:
Seagrass (TNC & USF), Land (TNC, GoB, & USDS)
Shelf (GEBCO, NOAA, NGA, Imray, TNC & S. Purkis), EEZ (VLIZ), BASE (GoB)
0
100
200
300
Km


Shorebirds
Snowy plover
Red knot
Piping plover
Reddish egret
Wilson's plover
Archipelagicbaseline +12nm
EEZ
200m Shelf
Bahamas
Other land
June 2017
The Nature Conservancy
Prepared by John E. Knowles
Projection: WGS 1984 UTM Zone 18N
Data Source:
Shorebird (Audubon), Land (TNC, GoB, & USDS)
Shelf (GEBCO, NOAA, NGA, Imray, TNC & S. Purkis), EEZ (VLIZ), BASE (GoB)
0
100
200
300
Km

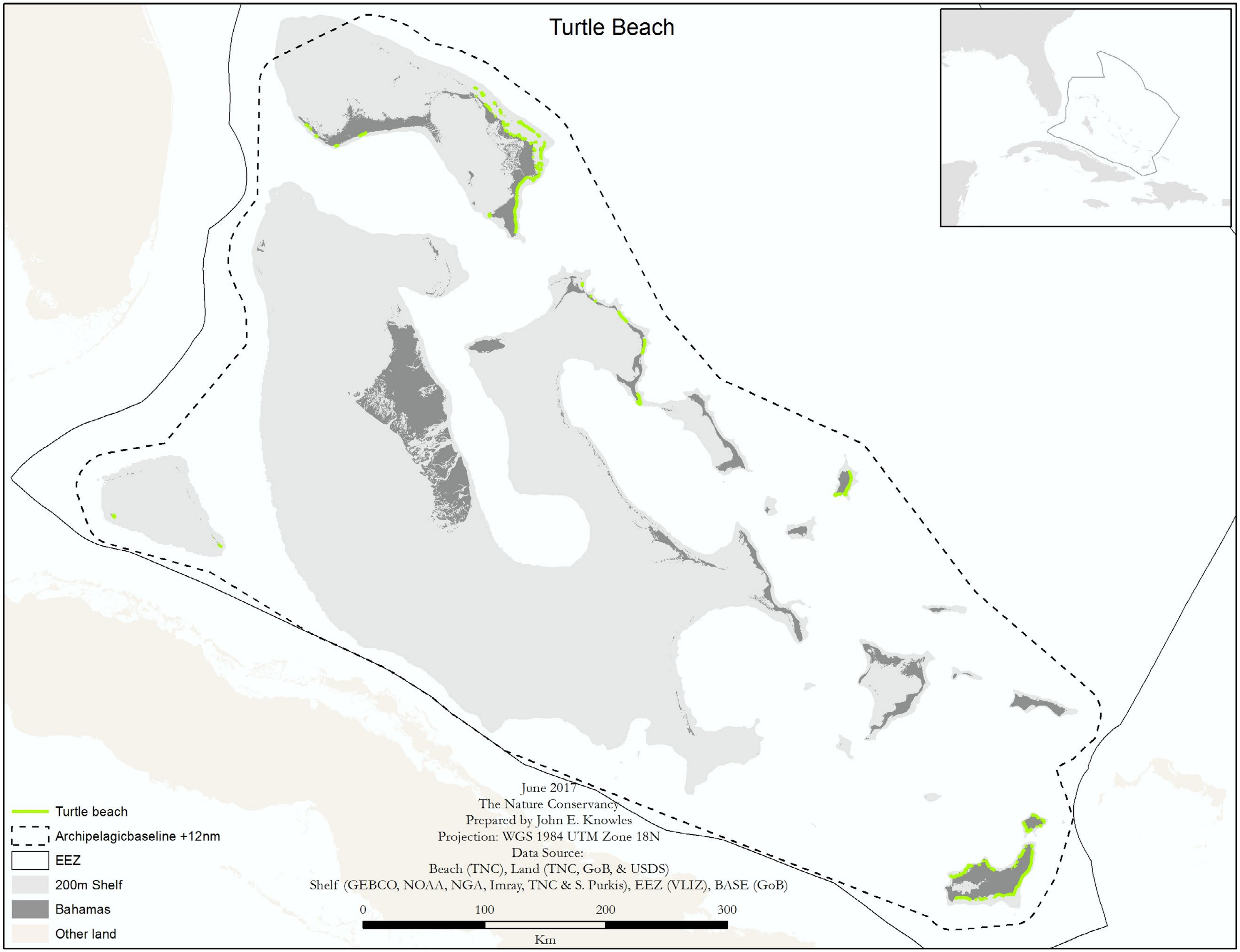


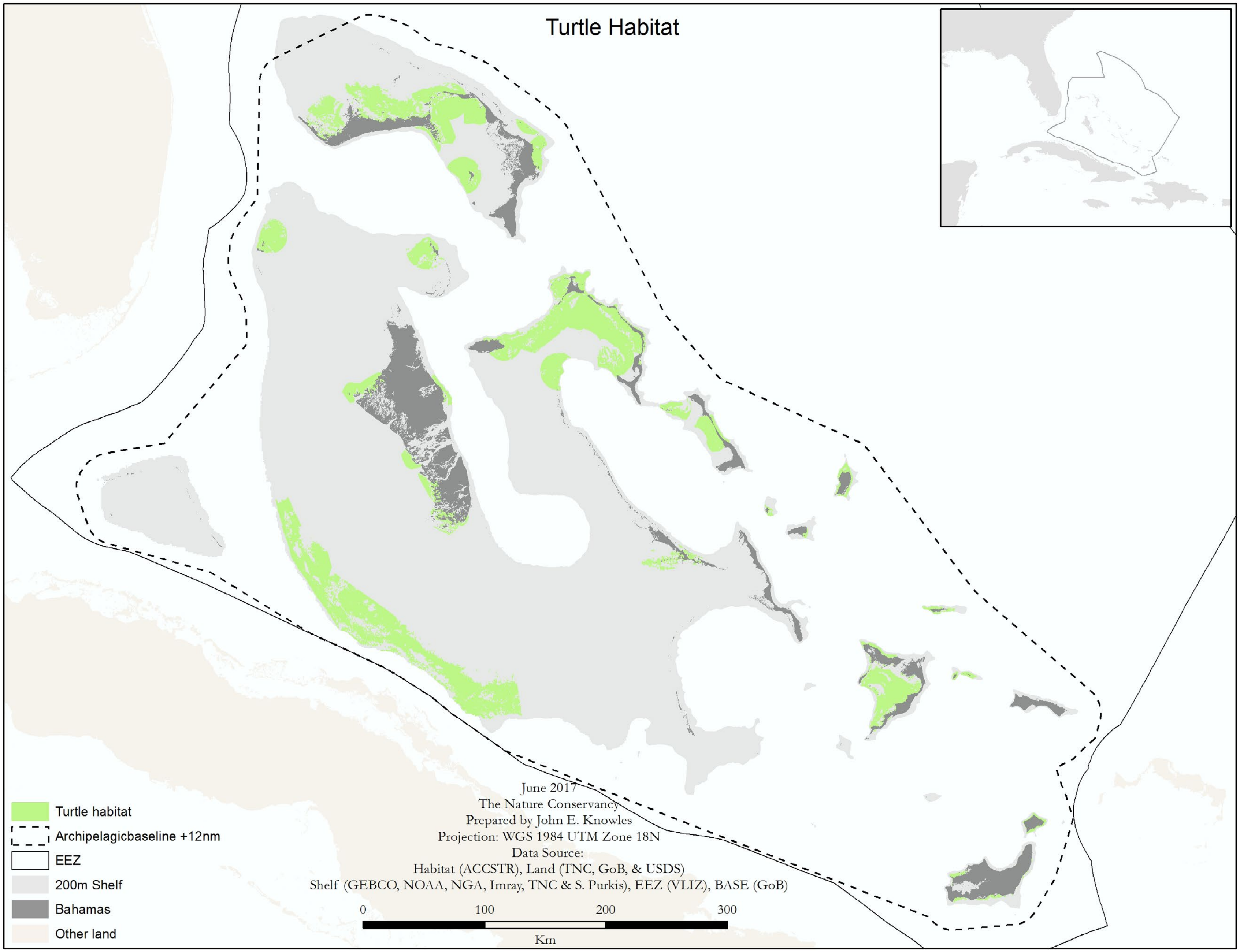
Shoreline Habitat
Rocky shore
Sandy beach
Archipelagicbaseline +12nm
EEZ
200m Shelf
Bahamas
Other land
June 2017
The Nature Conservancy
Prepared by John E. Knowles
Projection: WGS 1984 UTM Zone 18N
Data Source:
Shoreline (TNC), Land (TNC, GoB, & USDS)
Shelf (GEBCO, NOAA, NGA, Imray, TNC & S. Purkis), EEZ (VLIZ), BASE (GoB)
0
100
200
300
Km


Fish Spawning Aggregations
Higer validation
Lower validation
Not validated or modelled
Archipelagicbaseline +12nm
EEZ
200m Shelf
Bahamas
Other land
June 2017
The Nature Conservancy
Prepared by John E. Knowles
Projection: WGS 1984 UTM Zone 18N
Data Source:
SPAG (TNC), Land (TNC, GoB, & USDS)
Shelf (GEBCO, NOAA, NGA, Imray, TNC & S. Purkis), EEZ (VLIZ), BASE (GoB)
0
100
200
300
Km



Tidal Creeks
Tidal creek (on island where there are more than 5)
Tidal creek (on island that has no more than 5)
Archipelagicbaseline +12nm
EEZ
200m Shelf
Bahamas
Other land
June 2017
The Nature Conservancy
Prepared by John E. Knowles
Projection: WGS 1984 UTM Zone 18N
Data Source:
Creek (TNC & BNT), Land (TNC, GoB, & USDS)
Shelf (GEBCO, NOAA, NGA, Imray, TNC & S. Purkis), EEZ (VLIZ), BASE (GoB)
0
100
200
300
Km


Turtle Beach
June 2017
The Nature Conservancy
Prepared by John E. Knowles
Projection: WGS 1984 UTM Zone 18N
Data Source:
Beach (TNC), Land (TNC, GoB, & USDS)
Shelf (GEBCO, NOAA, NGA, Imray, TNC & S. Purkis), EEZ (VLIZ), BASE (GoB)
0
100
200
300
Km
Turtle beach
Archipelagicbaseline +12nm
EEZ
200m Shelf
Bahamas
Other land


Turtle Habitat
Turtle habitat
Archipelagicbaseline +12nm
EEZ
200m Shelf
Bahamas
Other land
June 2017
The Nature Conservancy
Prepared by John E. Knowles
Projection: WGS 1984 UTM Zone 18N
Data Source:
Habitat (ACCSTR), Land (TNC, GoB, & USDS)
Shelf (GEBCO, NOAA, NGA, Imray, TNC & S. Purkis), EEZ (VLIZ), BASE (GoB)
0
100
200
300
Km