Nassau Grouper (*Epinephelus striatus*) Conservation Management Plan

for

The Commonwealth of The Bahamas

Submitted to the: Department of Marine Resources

Nassau, Bahamas

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List of Abbreviations

AGRRA	Atlantic Gulf Rapid Reef Assessment
BNT	Bahamas National Trust
BCFA	Bahamas Commercial Fishers Alliance
BNPAS	Bahamas National Protected Area System
BPAF	Bahamas Protected Area Fund
BREEF	Bahamas Reef Environment Educational Foundation
CBD	Convention on Biological Diversity
CEI	Cape Eleuthera Institute
CFMC	Caribbean Fishery Management Council
CMU	Conservation Management Unit
CPUE	Catch Per Unit Effort
CRFM	Caribbean Regional Fisheries Mechanism
DMR	Department of Marine Resources
EEZ	Exclusive Economic Zone
ESA	Endangered Species Act
FAO	Food and Agriculture Organization
FSA	Fish Spawning Aggregation
GCFI	Gulf and Caribbean Fisheries Institute
GEF	Global Environment Facility
IAS	Invasive Alien Species
IUCN	World Conservation Union (formerly International Union for Conservation of Nature)
IUU	Illegal Unreported and Unregulated Fishing
MPA	Marine Protected Area
MSY	Maximum Sustainable Yield
NGO	Non-Governmental Organization
NISP	National Implementation Support Programme
NISS	National Invasive Species Strategy
NOAA	National Oceanic and Atmospheric Administration
POWPA	Programme of Work on Protected Areas
RTD	Disney Conservation Fund’s Reverse The Decline Program
SOSF	Save Our Seas Foundation
SNP	Single nucleotide polymorphism
SPAW	Special Protected Areas and Wildlife
TOTO	Tongue of the Ocean
WECAFC	Western Central Atlantic Fisheries Commission

Executive Summary

Nassau grouper (*Epinephelus striatus*) are listed as a **critically endangered species** by the World Conservation Union (IUCN), with one of the last viable populations found in The Bahamas, where they are of significant cultural, ecological and economic value as a fishery species. Because Nassau grouper are slow growing and late maturing fish that migrate 300 km (186 mi) or more to spawn once each year in mass aggregations, they are easily overfished. Thus, balancing the conservation of a critically endangered species with maintaining an economically viable fishery requires a well-defined conservation and management strategy. Sustainable fisheries strategies are implemented to promote the maintenance of healthy stocks and biological functions of marine species and habitats while maximizing economic gain and ensuring food security. This management strategy discusses the current status of Nassau grouper stocks in The Bahamas and addresses threats to Nassau grouper stocks within the country to promote long-term sustainable use of the species.

Nassau grouper fisheries peaked in the 1990's with landings of 514 tonnes and a value of over $3 million making it the most productive and most valuable scalefish fishery in The Bahamas. Over the past 20 years however, landings have declined by 86% and the value of the fishery has decreased by two thirds. This decline is also evident in decreases in abundance within marine habitats, collapses of known historic spawning aggregations and noticeable losses in effective population size throughout The Bahamas. Of the 30-40 reported spawning aggregations in The Bahamas that have been reported, most remain unverified with no information on whether they still form. Those that have been assessed show that several historic Nassau grouper spawning aggregations no longer form. Similarly, while historical information from spawning aggregations indicates that aggregations of 10,000 to 100,000 fish was common, most of the remaining aggregations surveyed to date only support hundreds of spawning fish during peak periods, with only two having over 1,000 Nassau grouper aggregating at any time. Clearly, these declines indicate the need for more effective management to rebuild stocks and ensure sustainable fisheries.

The overall goal of this management plan is to promote population recovery and sustainability of the Bahamian Nassau grouper fishery.

Specific management objectives are to:

1. Increase Nassau grouper density and spawning stock biomass
2. Improve harvest regulations to promote sustainability of the fishery
3. Reduce anthropogenic threats
4. Maintain and/ or improve essential marine habitats.

At present, Nassau grouper in The Bahamas face threats from both natural and anthropogenic factors including high levels of fishing, habitat degradation, invasive alien species, disease and predation, and climate change. Of these threats, those related to fishing are the most severe and the ones that may be managed most effectively, but loss of juvenile nursery habitat in mangrove systems was also rated high as a threat. The threats posed by fishing come in the form of both illegal fishing (e.g., capture of fish below the legal size limit or during the closed season) and by fishing practices that may be within the scope of fisheries regulations, but are unsustainable due to the biology of the species (e.g., certain fishing gears that are legal, but threaten populations by landing legal sized fish that are still sexually immature or inexperienced spawners). The former requires strategies aimed at building compliance with fisheries regulations through education, enforcement and other means. The latter requires strategies to improve fisheries regulations based on science.

To address legal but unsustainable fishing practices the following actions are recommended that require amending current fishing regulations:

1. ***Extending the closed season from November 1 through March 31*** The current season is December 1-February 28. During years when the full moon falls early in December or the last week of November, fish may migrate to spawning aggregations before the start of the closed season. Similarly, when the full moon falls in late February, fish may still be at spawning aggregations after the season opens.
2. ***Increasing the minimum size limit to 54 cm TL (21.3 in.) or 4 kg (~9 lbs.)*** The current minimum size is 3 lbs. While fish may reach reproductive maturity as early as 3 lbs., 54 cm TL (roughly 4 kg or 9 lbs.) is the size at which >75% of the population is mature and the size at which fish migrate to spawning aggregations. The increase in minimum size limit would effectively prevent the capture of most immature fish before they can reproduce. Furthermore, we suggest including a minimum length in addition to weight to help fishers easily gauge size of fish at capture.
3. ***Banning the use of traps around FSAs during the spawning season*** There are no current restrictions on traps. While traps may be used to target a number of species, they are highly effective for capturing Nassau grouper at spawning aggregations. Furthermore, traps that are lost may continue to capture and kill fish indiscriminately as ghost traps. To prevent capture of Nassau grouper as bycatch at spawning sites and to prevent ghost traps at spawning sites, a ban on fish traps in these areas should be implemented during the spawning season.
4. ***Protect multi-species fish spawning aggregations*** No protection of multi-species aggregations exists at present. Because many species of grouper and snapper use the same spawning sites as Nassau grouper at other times of the year, and face the same threats of fishing at spawning times that Nassau grouper do, establishing protection for these sites is recommended.
5. ***Establishment of a maximum size limit*** There is currently no maximum size limit. Because larger females contribute disproportionately to reproductive output due to their high fecundity, the possibility of protecting these larger fish should be considered.

In addition to these recommendations, it is also recommended to further support ongoing FSA monitoring and stock assessment efforts, enforce existing regulations through improved strategic surveillance during the closed season, including patrols of spawning sites, inspections at points of sale and other parts of the supply chain such as fish houses or mailboats, increasing fines for illegal activities, enlisting help of fishers in reporting illegal activity and publishing fines associated with illegal fishing activity. Furthermore, incorporation of priority spawning sites into marine protected areas as part of the expansion of the Bahamas National Protected Area System is also recommended to help with enforcement.

Finally, a framework for periodic evaluation of management effectiveness and adaptation of the management plan is recommended to ensure that specific goals or targets are being met to promote recovery of Nassau grouper stocks and ensure sustainable fishing practices are used to preserve this fishery for generations of Bahamians.

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Introduction

Overview

The Nassau grouper is an ecologically, economically and culturally valuable species that is exploited by commercial, recreational and subsistence fisheries in The Bahamas and throughout the Caribbean. In 1996, the World Conservation Union (IUCN) classified Nassau grouper as endangered (EN A2ad) on the Red List of Threatened Species (Cornish and Eklund 2003). Global efforts to rebuild Nassau grouper populations have included complete moratoriums, seasonal closures, size limits, the implementation of marine protected areas (MPAs), quotas and fish spawning aggregation (FSA) closures and FSA protected areas (Sadovy de Mitcheson et al. 2013). However, anthropogenic impacts persist, and significant declines of 60% or more have been documented worldwide along with the disappearance of 33% of historic FSAs (Sadovy de Mitcheson et al. 2008; Sadovy de Mitcheson and Erisman 2012). More recently, worsening trends in population abundance led to Nassau grouper being re-classified as a critically endangered (CR A2bd) species by the IUCN (Carpenter et al. 2015; http://www.iucnredlist.org/details/7862/25) and listed as a threatened species on the United States Endangered Species Act (Federal Register 2016). In The Bahamas, declining fish stock biomass and FSAs threaten the long-term sustainability of the Nassau grouper fishery (Sherman et al. 2016; Stump et al. 2017; Sherman et al. 2017) and Chueng et al. (2013) have suggested that the fishery has already been overexploited. To address this, we have developed a scientifically-based sustainable conservation management plan for Nassau grouper in consultation with experts and key stakeholders. The purpose of this conservation management strategy is to:

1. Describe and summarize the coordinated efforts required to sustainably manage Nassau grouper populations and its critical habitats in The Bahamas;
2. Specify the population(s), habitat, and harvest regulations to maintain recovered (i.e. abundant, reproductively viable and genetically diverse) Nassau grouper populations;
3. Explain the regulatory mechanisms, legal authorities, policies, management, and monitoring programs that exist to manage Nassau grouper in The Bahamas.
4. Document the individuals and agencies committed to the restoration of Nassau grouper populations and the sustainable management of the commercial fishery in The Bahamas.

This management plan is designed to be adaptive and its implementation should facilitate recovery of Nassau grouper populations and promote sustainable harvest of the commercial fishery in The Bahamas.

Species Description & Taxonomic Classification

Photo 1. Various colour phases adopted by Nassau grouper: normal or barred, bicolour, white belly and dark.

Photo credits: top (l-r) - Keith Pamper, Krista Sherman, bottom (l-r) Shane Gross, Charles Knapp

Bloch (1792) first described the species now commonly known as Nassau grouper, *Epinephelus striatus*. Scales are ctenoid and fish possess an opercula spine, 11-12 dorsal spines, 16-18 dorsal fin rays, 3 anal spines and 8 anal rays (Heemstra and Randall 1993; Sadovy and Eklund 1999; Froese and Pauly 2016). Normal skin colouration is light grey or olive to reddish brown (Photo 1 – top l). Distinguishing features include five dark bars along the body, a tuning fork shaped pattern on the head, a black blotch on the caudal peduncle and a series of black dots posterior to or below the eye. Territorial, mating and other behaviours can result in rapid colour and pattern changes including bicolour, white belly and dark phase (Photo 1; Heemstra and Randall 1993; Archer et al. 2012; Watson et al. 2014). Variations of these colour phases and patterns have also been documented (e.g. Colin 1992; Whaylen et al. 2007; Watson et al. 2014; Photo 2).

Although previously classified as a member of the seabass Family, Serranidae (Heemstra and Randall 1993), more recent taxonomic classifications place the species under the Family Epinephelidae (Craig et al. 2011; Ma et al. 2016). The largest Nassau grouper on record (122 cm TL; 27 kg) was from Puerto Rico (Sadovy and Eklund 1999), but adults in fished areas typically range between 55-70 cm TL (Bush et al. 2006).

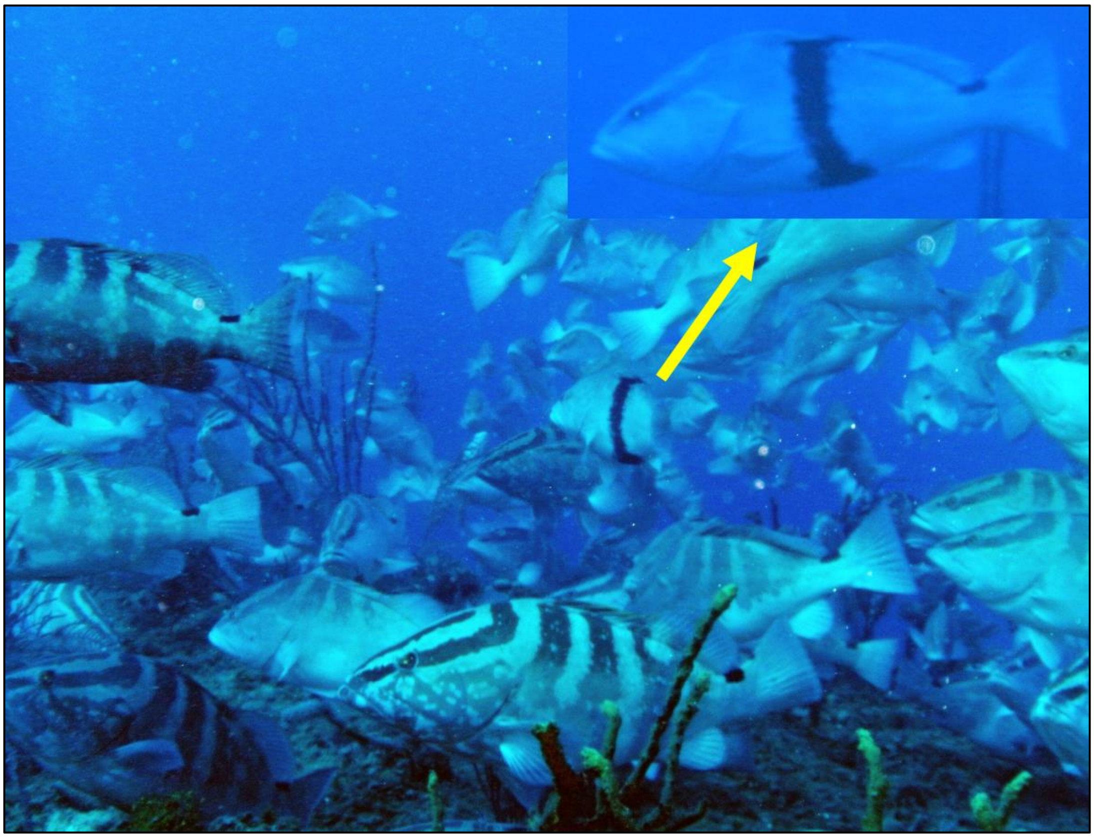

Photo 2. Aberrant colour phase of a Nassau grouper observed at the Hail Mary spawning aggregation site off Long Island during December 2013.
Photo credits: Krista Sherman

Taxonomy

Kingdom Animalia
Phylum Chordata
Class Actinopterygii
Order Perciformes
Family Epinephelidae
Subfamily Epinepheinae
Genus *Epinephelus*
Species *striatus*

Geographic Distribution & Habitat Use

Nassau grouper inhabit insular marine habitats (i.e. mangroves, seagrasses, hardbottom and coral reefs), with a maximum reported depth of 255 m (Starr et al. 2007). Their natural distribution includes the Tropical Western Atlantic including Bermuda, Florida, The Bahamas and Yucatan Peninsula, the Caribbean Sea and parts of the Gulf of Mexico (Heemstra and Randall 1993; Albins et al. 2009; Froese and Pauly 2016; Fig. 1).

Figure 1. Global distribution map of Nassau grouper, *Epinephelus striatus*. Image created by Jack Cook, Woods Hole Oceanographic Institute Graphic Services.

As an archipelagic nation, The Bahamas possesses large stretches (~260,000 km^2) of potentially suitable marine habitats for Nassau grouper (Figs. 2, 3, 4). Newly settled recruits are strongly associated with small colonies of *Porites* sp., macroalage and seagrass – particularly *Laurencia* spp. and *Thalassia testudinum* (Sadovy and Eklund 1999). Juveniles and subadults are more prevalent in shallow water, inhabiting microhabitats within nursery areas and patch reefs (Eggleston 1995; Eggleston et al. 1998; Grover et al. 1998; Dahlgren end Eggleston 2001; Dahlgren et al. 2006; Camp et al. 2013). Adults tend to establish home ranges (0.1-0.2 km) in more rugose coral reefs, hardbottom habitats, or other high-relief structures (Bolden 2000).

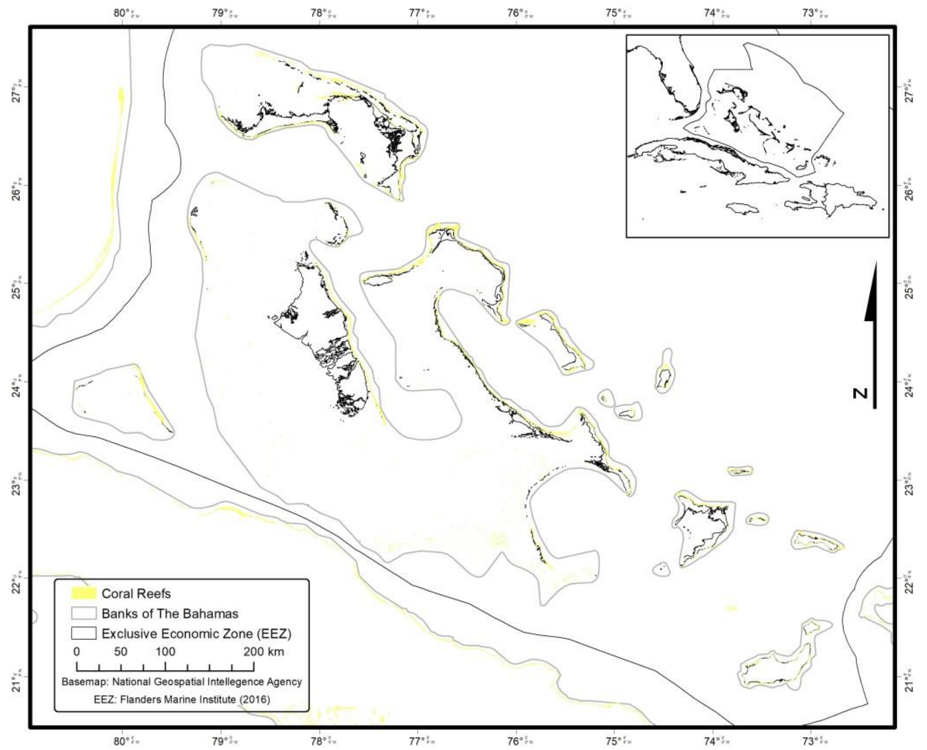

Figure 2. GIS map of coral reef habitats in The Bahamas.
Map: *Lindy Knowles*

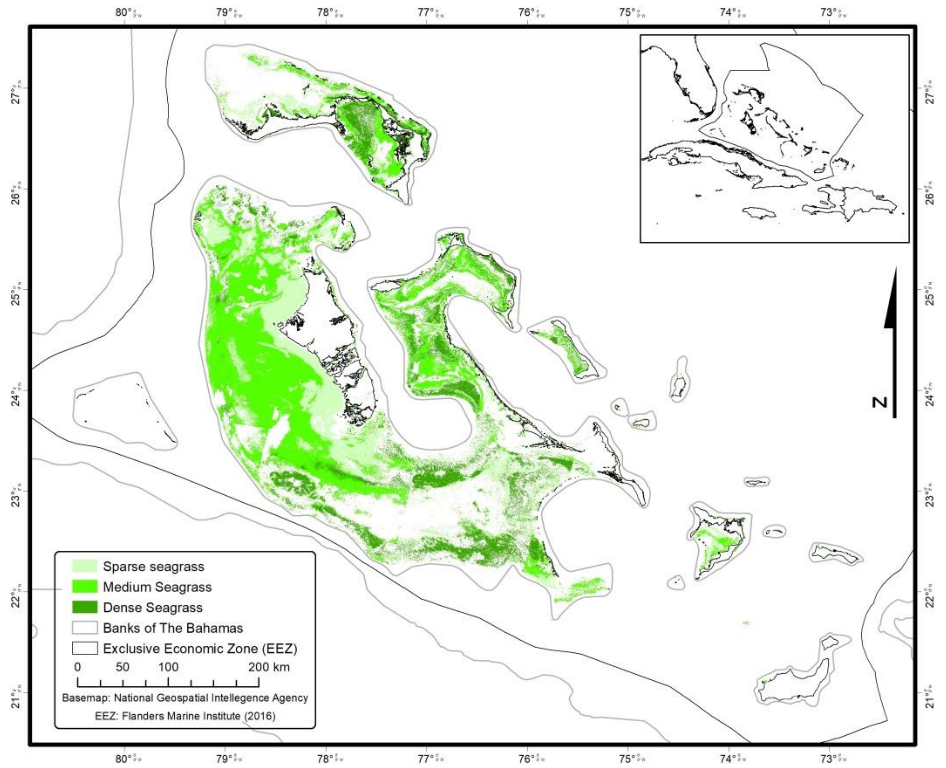

Figure 3. GIS habitat map of seagrasses (by density) in The Bahamas.
Map: *Lindy Knowles*

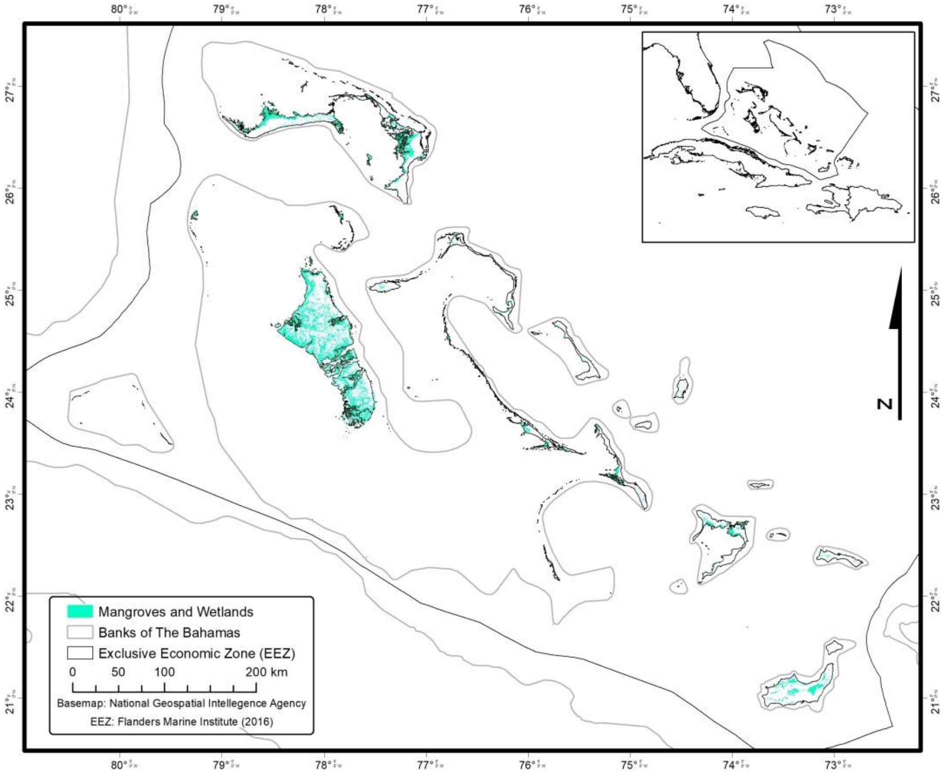

Figure 4. GIS habitat map of mangroves and wetlands in The Bahamas.
Map: *Lindy Knowles*

Ecology

Zooplankton and copepods are the primary food source for pelagic juveniles ranging between 22-27 mm SL (Colin 1992; Grover 1993; Colin et al. 1997; Grover et al. 1998). Following recruitment to appropriate macroalgal habitats as demersal juveniles (25-35 mm TL), Nassau grouper undergo a series of ontogenetic dietary and associated habitat shifts (Dahlgren and Eggleston 2001; Dahlgren et al. 2014). Nassau grouper are important generalist predators within the marine environment, regulating ecosystem dynamics through the consumption of lower trophic level species. Their diet is comprised of a diverse range of both invertebrates and vertebrates (reviewed by Sadovy and Eklund 1999), although adults are mostly piscivores (>50% fish; Heemstra and Randall 1993) as evidenced by stomach content and stable isotope analyses (Appendix A; Carter et al. 1994; Eggleston et al. 1998; O'Farrell et al. 2014). Using ambush feeding tactics, Nassau grouper consume the majority of their prey during crepuscular hours (Sadovy and Eklund 1999).

Reproduction & Life History

Nassau grouper are gonochoristic (i.e. they have separate sexes), oviparous pelagic spawners (Sadovy and Colin 1995), reaching sexual maturity between the ages of 4-8 years (≥48 cm TL) (Sadovy and Eklund 1999; Froese and Pauly 2016), as evidenced by the presence of mature vitellogenic or hydrated oocytes in the ovaries and spermatozoa and spermatids in the testis (Sadovy and Colin 1995; Cushion et al. 2008). Nassau grouper gonads are bilobate, possessing a llamellar structure and lumen (Carter et al. 1991; Sadovy and Colin 1995). Fish are classified as immature to mature based on stages of ovarian and testicular development including the presence of primary oocytes, cortical alveoli, vitellogenic oocytes and hydrated oocytes in females; and the presence of spermatogonia, spermatocytes, spermatocysts and spermatozoa in males (Cushion et al. 2008).

Reproduction occurs at annual spawning events in synchrony with the lunar cycle and is also associated with cooler water temperatures (Colin 1992; Table 1). Histology, telemetry studies and spawning surveys have provided evidence to support that peak spawning in The Bahamas occurs within a few days around the full moon during the months of December and January (Colin 1992; Sadvoy and Colin 1995; Cushion et al. 2008; Dahlgren et al. 2016a). Hundreds to thousands of adults migrate 25 - >300 km to and from resident home reefs to spawn at masse gatherings with conspecifics (Smith 1972; Colin 1992; Bolden 2000; Dahlgren et al. 2016a; Stump et al. 2017) at specific locations. Around 30-40 Nassau grouper FSAs have been reported in The Bahamas and 60-80 have been reported worldwide (Fig. 5).

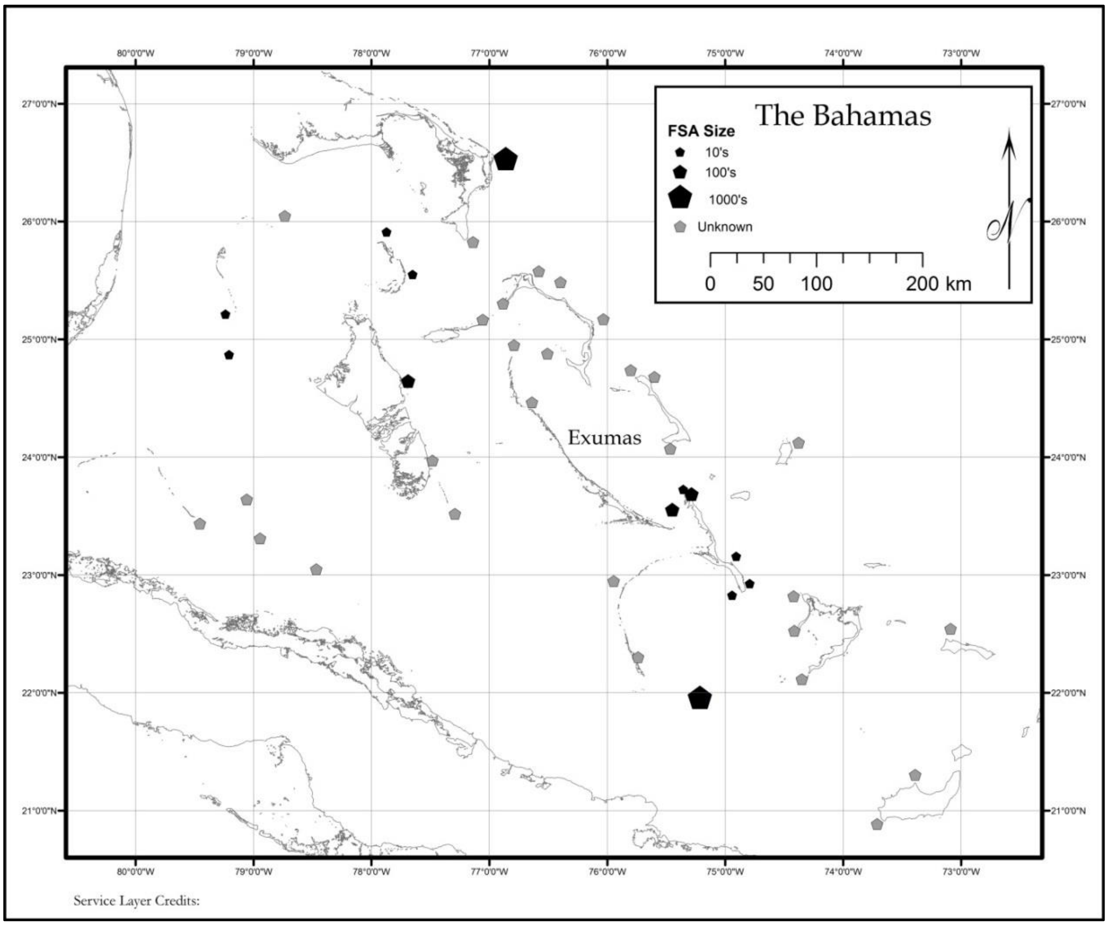

Figure 5. Map of reported Nassau grouper FSAs in The Bahamas (Sherman et al. 2016).

Courtship and mating behaviours are elaborate and complex, increasing in frequency and intensity leading up to and on the night of the full moon (Colin 1992). Readiness to reproduce is typically signalled by a noticeable shift from normal or barred coloration to bicolour phase (Colin 1992; Archer et al. 2012). Spawning rushes and gamete release usually occur one hour before and within 10-15 min after sunset (Colin 1992; Whaylen et al. 2004; Whaylen et al. 2007). Females are highly fecund, releasing millions of buoyant eggs (~ 1mm in diameter), which are fertilized and dispersed with water currents (Colin 1992; Sadovy and Eklund 1999; Fig. 6). Embryos hatch approximately 24 to 40 hours post fertilization (Powell and Tucker 1992). Pelagic larval development occurs over a 37-45 day period, with a mean pelagic larval dispersal (PLD) of 42 days (Colin et al. 1997; Fig. 6). Shenker (1993) hypothesized that wind-driven currents across continental shelves deliver larvae to appropriate settlement areas, which may help explain the episodic nature of recruitment.

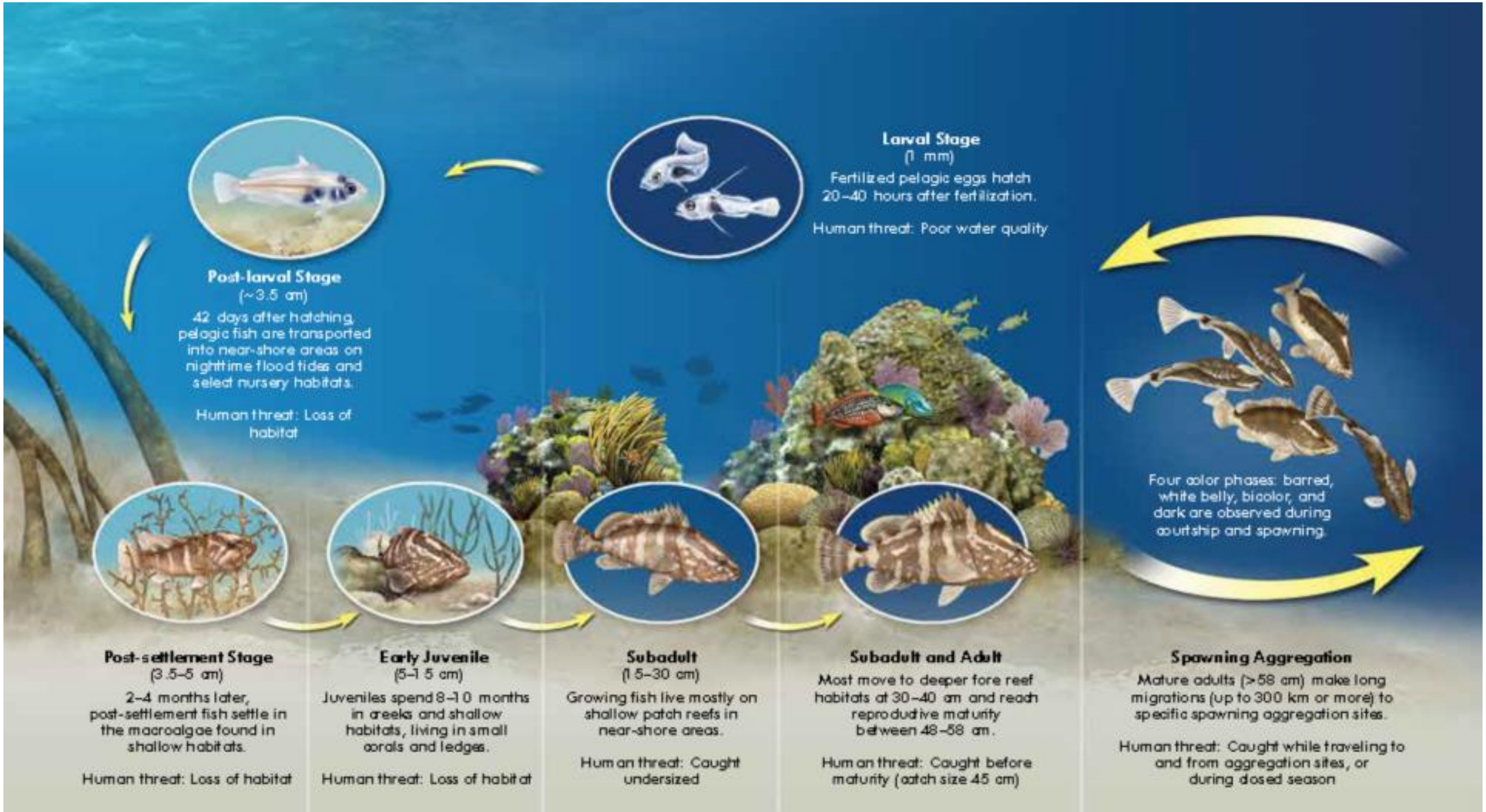

Figure 6. Life history, ontogenetic habitat requirements and associated anthropogenic threats to each life stage of Nassau grouper in The Bahamas. Graphic taken from the New Providence and Rose Island Coral Reef Report Card (Dahlgren et al. 2014).

Table 1. Intraspecific differences in Nassau grouper spawning occurrence throughout The Bahamas and Caribbean.

Location	Spawning Season	References
Belize	Full moon (December - March)	Carter et al. 1991; Heyman and Kjerfve 2008
Bermuda	Full moon (May - August)	Aguilar-Perera and Aguilar-Davila 1996; Whaylen et al. 2007
Cayman Islands	Full moon (December - March)	Whaylen et al. 2004; Whaylen et al. 2007
Cuba	Full moon or between the full and new moon (December - February)	Sadovy and Eklund 1999; Claro and Lindeman 2003
Jamaica	Full moon (January - April)	Thompson and Munro 1978
Honduras	Full moon (December - March)	Canty and Box 2013
Mexico	Full moon (December - January)	Aguilar-Perera et al. 2008
Puerto Rico	Full moon or between the full and new moon (January - May)	Schärer et al. 2010; Schärer et al. 2012; Schärer-Umpierre et al. 2014
The Bahamas	Full moon (November - March)	Smith 1972; Colin 1992; Ray 2000; Cushion and Sullivan-Sealey 2008; Dahlgren et al. 2016; Stump et al. 2017
U. S. Virgin Islands	Full moon or between the full and new moon (January - May)	Olsen and LaPlace 1978; Nemeth et al. 2006; Kadison et al. 2010

Age and Growth

Fertilized larvae grow up to 3.0 cm TL while in the planktonic phase (Shenker et al. 1993; Colin 1992; Colin et al. 1997; Fig. 6). Juvenile growth rates have been calculated based on otolith analysis and measurements of individual fish captured from both field and laboratory studies. Juveniles grow quickly, averaging 10 mm/month (Eggleston 1995; Photo 3). Adult growth and natural mortality rates vary throughout the species' native range (Sadovy and Eklund 1999). Sadovy and Colin (1995) estimated 21 years for the maximum age of Nassau grouper in The Bahamas, which is 8 years younger than the oldest fish on record (29 yrs, 85 cm TL), reported from the Cayman Islands (Bush et al. 2006). However, fish ≥85 cm TL have been observed in the Exuma Cays Land and Sea Park (K. Sherman pers. obs and Dahlgren unpubl. data), suggesting that individuals older than 21 yrs. may also exist in The Bahamas. A summary of population growth and mortality estimates is provided (Table 3).

Photo 3. Juvenile Nassau grouper observed amongst *Laurencia* sp.
Photo credit: Craig Dahlgren

Table 2. Summary of population growth parameters, mortality and exploitation estimates for Nassau grouper (*Epinephelus striatus*) in The Bahamas and Caribbean.

	Von Bertalanffy Growth Parameters					Mortality & Exploitation Estimates			
Location	L∞ (cm)	K	t_0	A	B	M	F	F/Z	**References**
Belize	–	–	–	0.0107	3.08	–	0.35		Carter et al. 1991; Ehrhardt and Deleveaux 2007
Cayman Islands	76.5	0.202	-0.638	–	–	–	0.21	–	Bush et al. 2006; Ehrhardt and Deleveaux 2007
Cuba	76.0 - 94.0	0.063 - 0.127	–	0.0052 - 0.1980	2.98 - 3.30	0.18	–	–	Baisre and Paez 1981; Sadovy and Eklund 1999
Jamaica	90	0.09	–	0.0107	3.11	0.17 - 0.30	–	–	Thompson and Munro 1978
Puerto Rico	–	–	–	1.26×10^{-5}	3.04	–	0.30	–	Sadovy and Eklund 1999; Ehrhardt and Deleveaux 2007
The Bahamas	–	–	–	2.14×10^{-5}	3.03	–	0.06 - 0.011	0.25 - 0.38	Sadovy and Colin 1995; Ehrhardt and Deleveaux 2007
Virgin Islands	97.4	0.185	0.488	0.0097	3.23	–	–	–	Olsen and LaPlace 1979

Status of Nassau Grouper in The Bahamas

Historically, research efforts in The Bahamas have focused on describing FSAs (e.g., Smith 1972; Colin 1997), quantifying density as part of on-going reef monitoring (Sherman et al. 2013; Dahlgren et al. 2016b; Dahlgren et al. unpubl. data), recruitment processes (Dahlgren and Eggleston 2001) or understanding ontogenetic habitat use and migratory behaviour (e.g., Sluka et al. 1996; Bolden 2000; Chiappone et al. 2000; Dahlgren et al. 2006; Dahlgren et al. 2016a). More recently, this research has been expanded to identify national research priorities outlined during the 2013 strategic planning meeting including:

1. Stock assessments of Nassau grouper FSAs
2. Perceptions of Nassau grouper
3. Catch assessments to engage fishers
4. Identification of key nursery habitats and threats to habitats
5. Movement patterns of Nassau grouper across FSAs
6. Identification of multi-species FSAs
7. Population connectivity
8. Larval dispersal and genetic connectivity
9. Geomorphology and oceanography of shelf in relation to FSA sites
10. Reproductive biology of Nassau grouper.

A summary of research activities related to these priorities is discussed below.

Density & Abundance

Quantitative fishery independent surveys of Nassau grouper populations have been conducted by divers using the Atlantic and Gulf Rapid Reef Assessment (AGRRA) protocols at over 360 reef sites over the past decade. Average density of Nassau grouper across all surveys was 0.13 fish per 100 m^2 (AGRRA: Marks and Lang 2016). The vast majority of these fish were below reproductive size, with fully protected areas such as the Exuma Cays Land and Sea park (ECLSP) having the greatest number and proportion of adult fish (>50 cm TL) surveyed (Dahlgren et al. 2014, 2016b; Dahlgren unpubl. data). However, declining trends in Nassau grouper densities for reef habitats have been documented in the ECLSP (Sherman et al. In Press).

Spawning Aggregations

Between 30-40 Nassau grouper FSAs have been reported to occur within The Bahamas. The first of these sites – Cat Cay, Bimini was described by Smith (1972), with abundance estimates ranging up to 100,000 individuals. Subsequent FSA studies were completed by Colin, Dahlgren, Eggleston and Ray (reviewed by Sherman et al. 2016), with more recent research led by Dahlgren, Sherman and Stump around Abaco, the Berry Islands, Andros, Eleuthera and Long Island (Dahlgren et al. unpubl. data; Sherman et al. unpubl. data; Sherman et al. in prep; Stump et al. 2017). Findings from current studies indicate the likely collapse of a historically active site in Andros (Stump et al. 2017) and decreased abundances at FSAs around Long Island (Dahlgren et al. unpubl. data; Sherman et al. in prep; Fig. 7). Contemporary estimates of the larger Nassau grouper FSAs within the country range in the thousands (Fig. 7). In the absence of baseline data for most FSAs (Fig. 7) and known variability in fish biomass during the spawning period (Dahlgren et al. 2016a; Sherman et al. in prep) continued monitoring will be required to provide reliable estimates of spawning stock biomass for other reported FSAs. Monitoring data will be important to assess the effectiveness of management practices and refine policies for the conservation of the species.

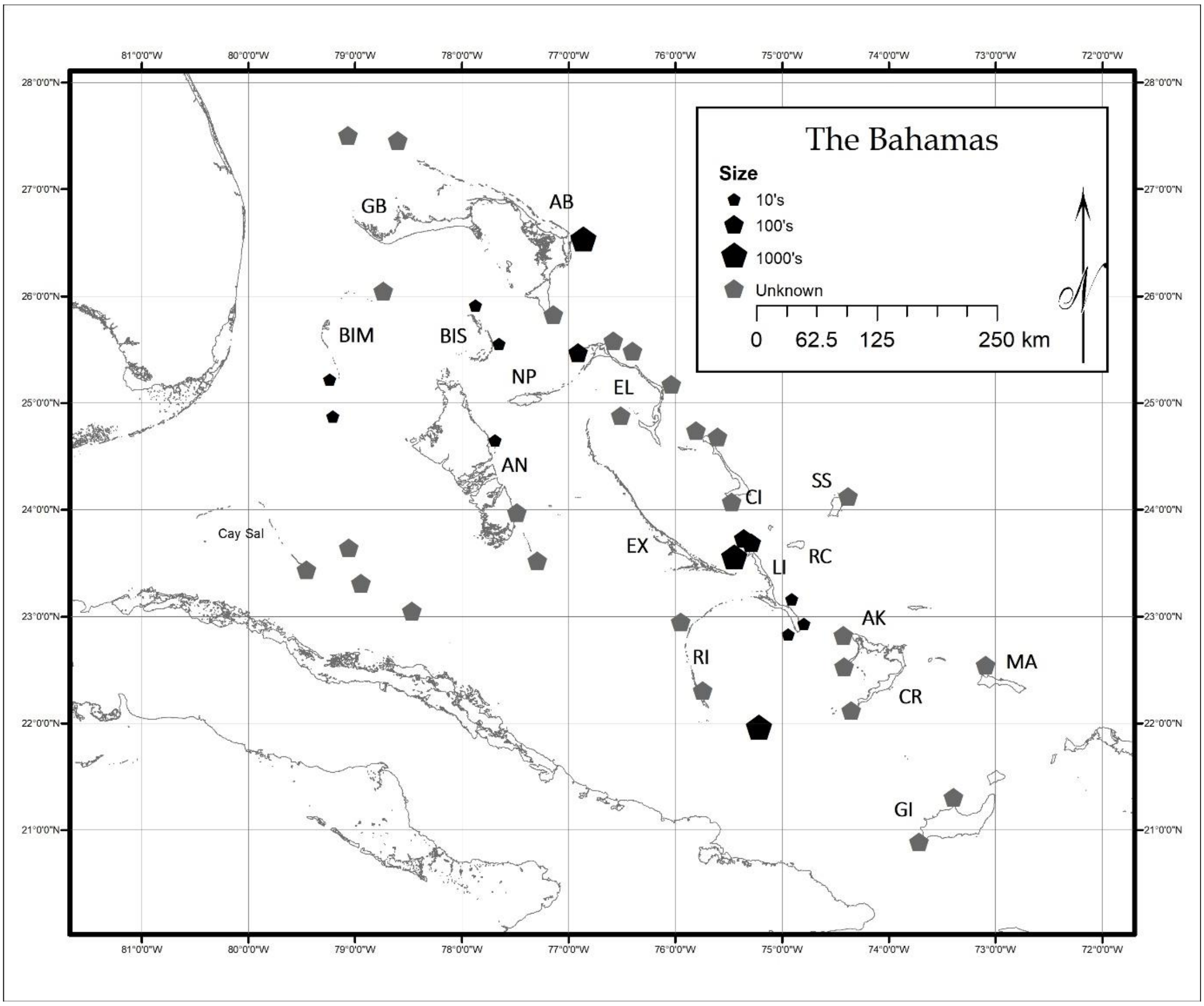

Figure 7. Status of Nassau groper FSAs in The Bahamas as of December 2017.
Map: *Lindy Knowles*

Geomorphology & Oceanography

Efforts to investigate the geomorphology and oceanography of the shelf in relation to FSAs have been limited to bathymetric mapping (i.e. mapping the topography and depths of the ocean floor) and the deployment of drifters (used to track sub-surface currents). Over the past three years, we have mapped and characterized benthic habitats and topographic features around five reported Nassau grouper spawning aggregations: High Cay (Fig. 8), Hail Mary (Fig. 9), North Point (Fig. 10), Newton's Cay (Fig. 11), and Little Egg Island (Fig. 12).

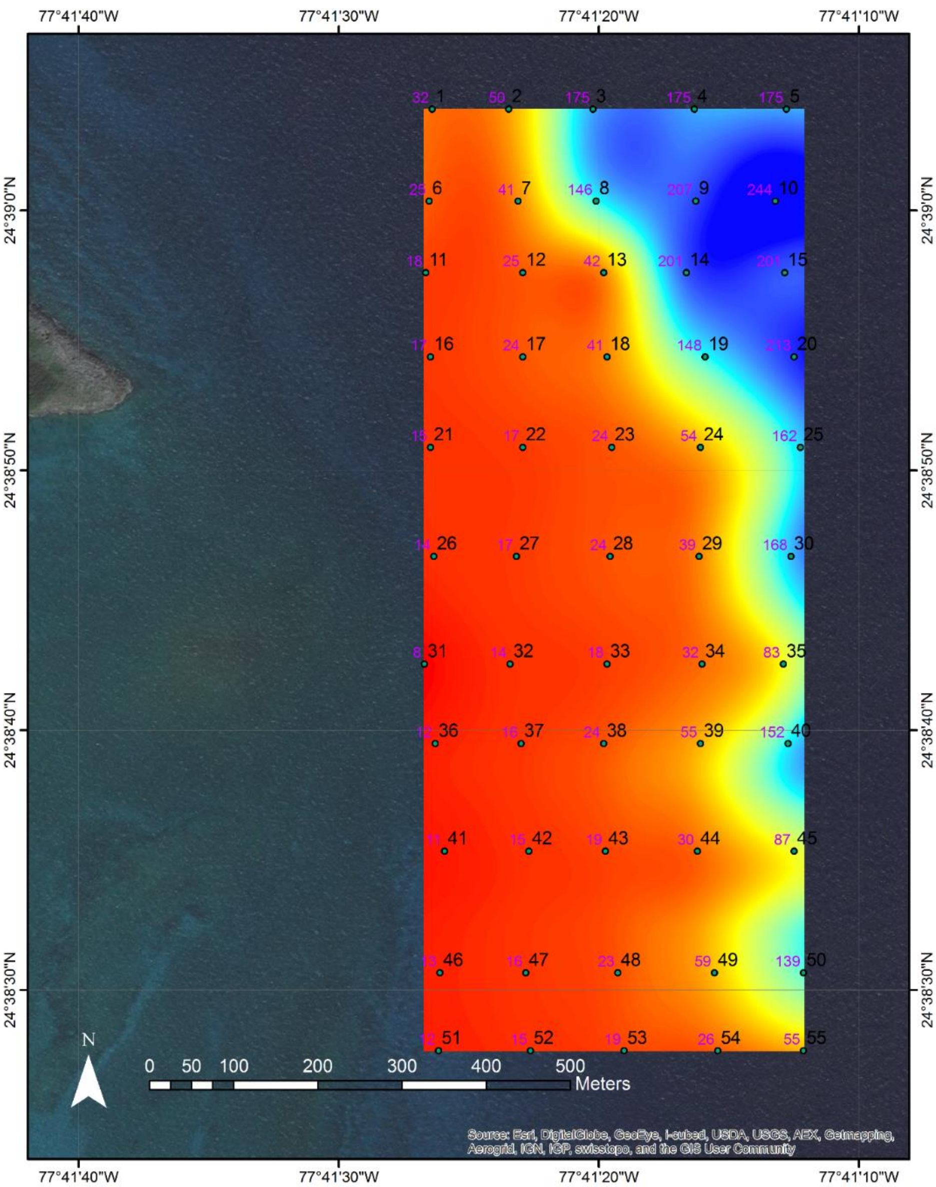

Figure 8. Bathymetry map of the High Cay FSA.
Map: *Gwilym Rolands* (Living Oceans Foundation).

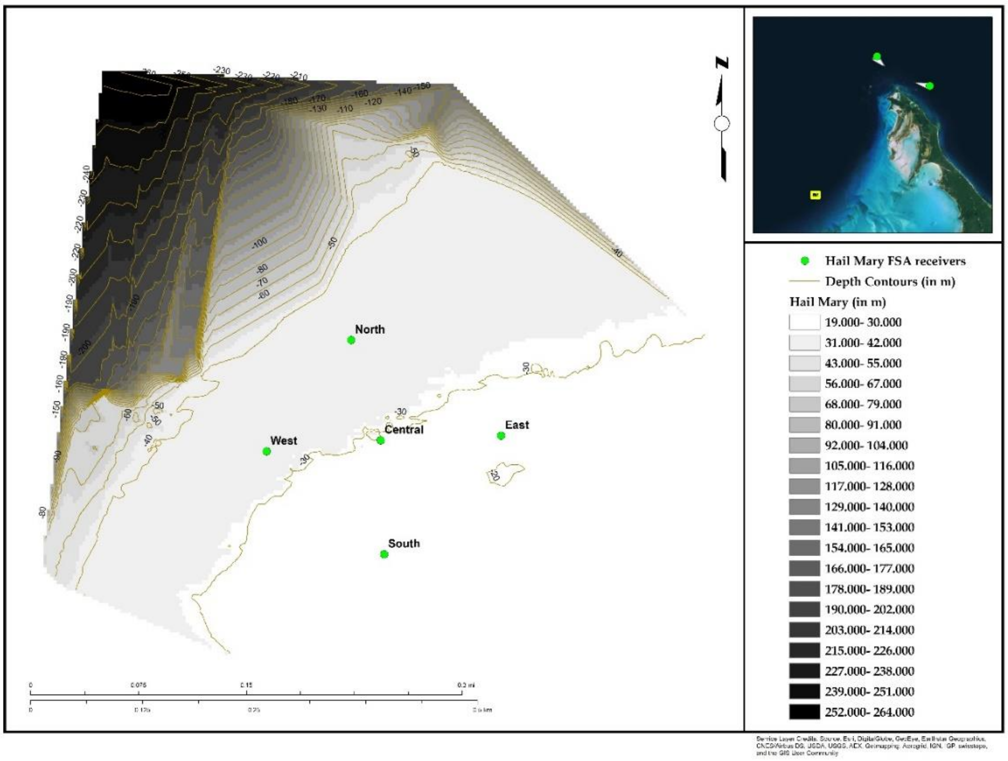

Figure 9. Bathymetry map of the Hail Mary FSA.
Map: *Lindy Knowles*

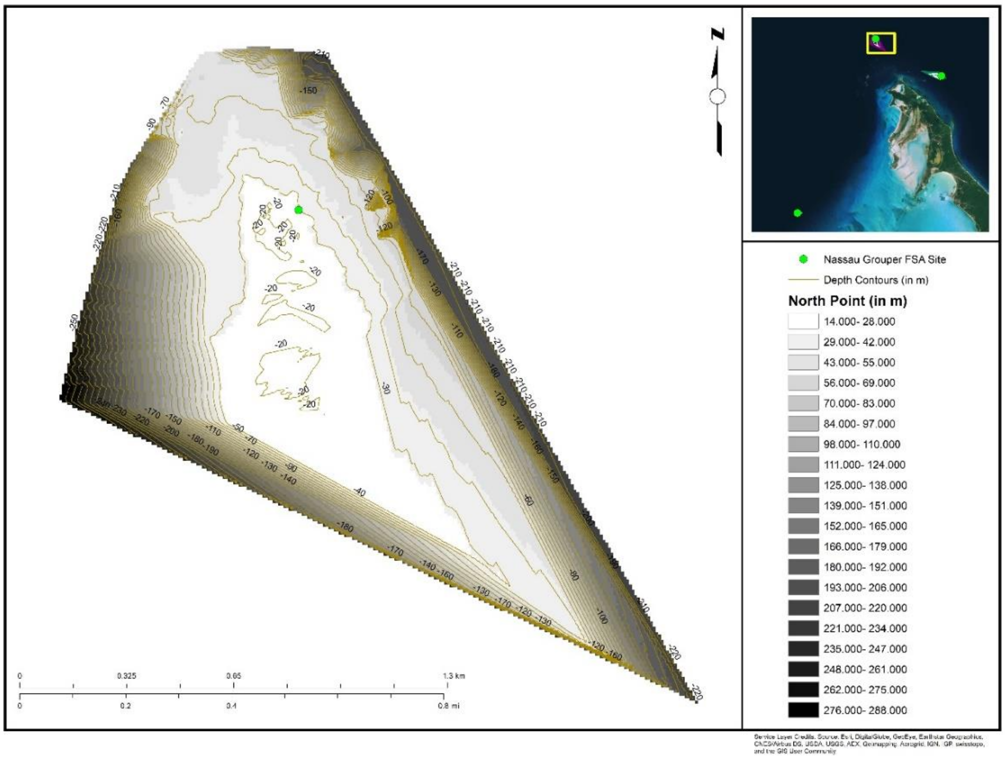

Figure 10. Bathymetry map of the North Point FSA.
Map: *Lindy Knowles*

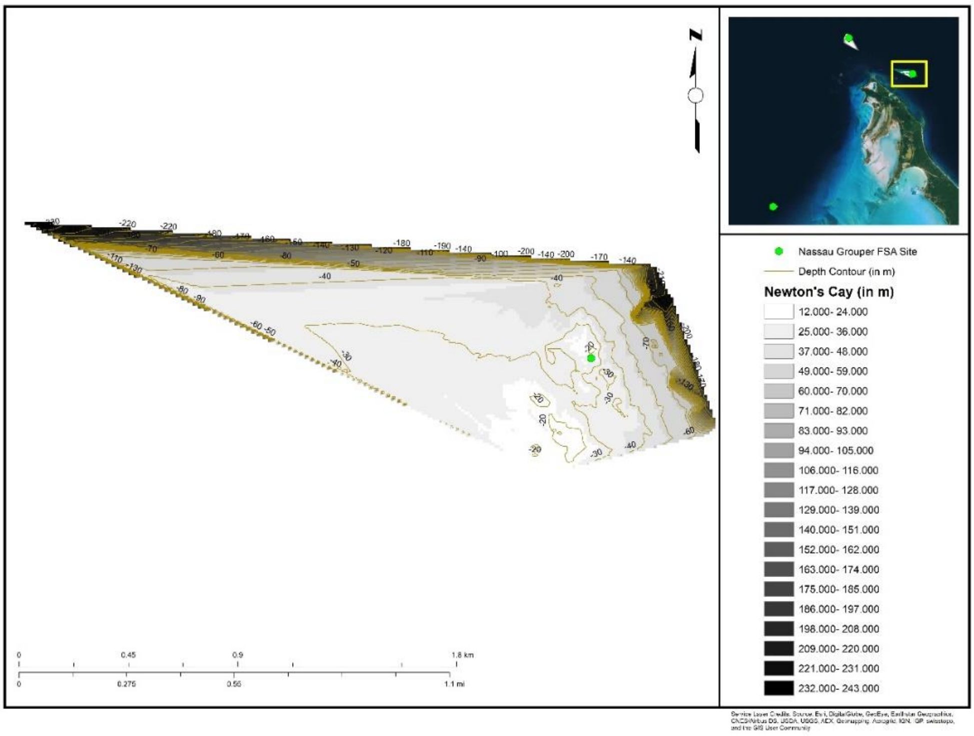

Figure 11. Bathymetry map of the Newton's Cay FSA.
Map: *Lindy Knowles*

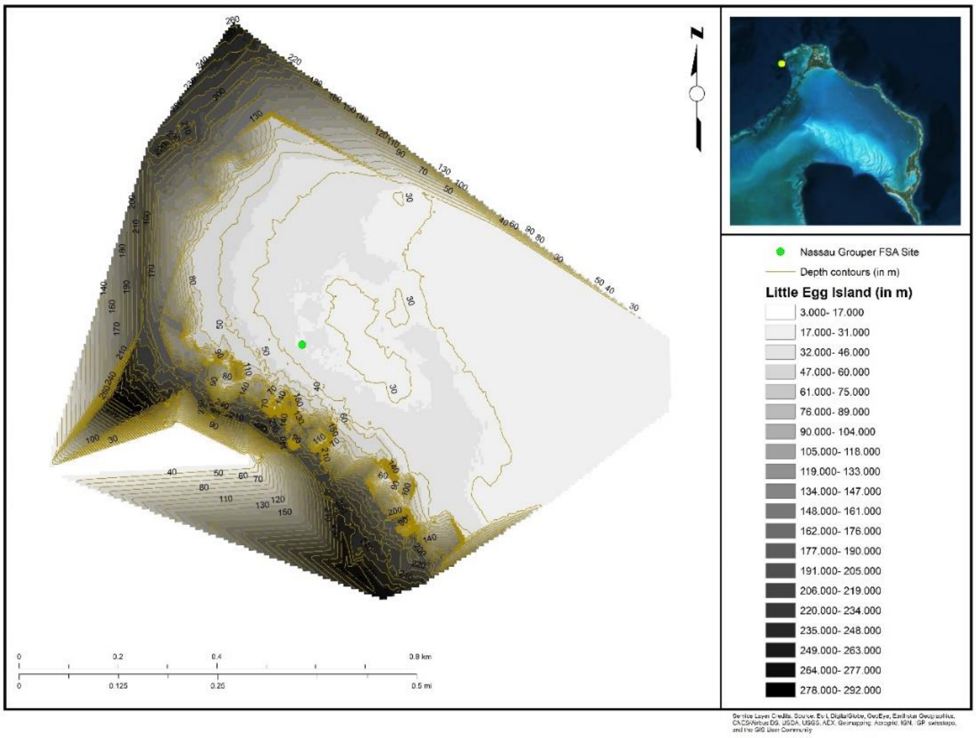

Figure 12. Bathymetry map of the Little Egg Island FSA.
Map: *Lindy Knowles*

Oceanographic patterns have been explored in preliminary work using drifters deployed around two Nassau grouper FSAs. Track data from drifters released at the Hopetown FSA in January 2016 showed that surface currents carried drifters out into the Atlantic Ocean. However, after 30 days, they looped back to the northwest portion of the Little Bahama Bank, crossing reef habitat around the time larval Nassau grouper would be expected to recruit (i.e. settle) into nursery habitats. Conversely, drifters released from the Hail Mary FSA revealed northwest moving currents, with tracks following along the edge of the Exuma Sound. Future research is planned to develop a larval biophysical model for Nassau grouper, which integrates genetic data, larval behaviour and oceanographic conditions (Paris, Sherman and Dahlgren) to better understand source-sink dynamics and the main driver(s) of connectivity.

Movement Patterns

To date several studies have examined movement of Nassau grouper through their development, within home ranges and during spawning migrations. Studies by Dahlgren and Eggleston documented habitat use by juvenile Nassau grouper and tracked ontogenetic habitat shifts as they grow and develop, from settling into off-reef habitats such as clumps of the seaweed *Laurencia* spp. in tidal creeks and sounds to small patch reefs in seagrass beds during the first year of their life before moving to larger reef systems, often several kilometers away (Eggleston 1995, Dahlgren and Eggleston 2000; 2001). For older subadult and adult Nassau grouper, research of tagged fish (i.e., visual mark recapture/re-sightings and acoustic telemetry studies) show a small home range size. For example, a study of visually and acoustically tagged fish on patch reefs ranging in size from 15-35 cm showed little movement between reefs spaces ~250 m apart and movement rarely exceeding 10 m off the home reef (Dahlgren, unpublished data). Adult Nassau grouper in the ECLSP, similarly showed a home range of only 18,305 m^2 on average (Bolden 2001). In contrast to these small home range sizes, adult Nassau grouper larger than 50 cm TL tagged with acoustic transmitters and/or externally visible (e.g. Floy™) tags have been shown to make long distance spawning migrations of 35 to over 200 km along the shelf edge in The Bahamas (e.g., Bolden 2000, Dahlgren et al. 2016a, Stump et al. 2017). These migrations typically last up to 1-2 weeks with fish swimming at relatively constant speeds averaging 1.3 to 1.7 km/hr to and from spawning sites where they stay to spawn for only 1-2 days (Dahlgren et al. 2016a; Stump et al. 2017) before returning to their home reef. In some cases, however, fish may spend a month or more away from their home range during spawning times when the first full moon of the spawning season is early in the season (i.e., late November or first week of December) and water temperatures remain warm (Dahlgren et al. 2016a).

Populations Genetics & Connectivity

Molecular markers commonly used for investigations of genetic connectivity and population structure include microsatellites and single nucleotide polymorphisms (SNPs). Recently, both markers have been employed to assess the genetic health of Nassau grouper within The Bahamas. Microsatellite analysis has shown that Nassau grouper have undergone drastic declines in their effective population size (N_e) and contemporary values of allelic richness (an indicator of genetic diversity) are low compared to other species (Sherman et al. 2017). However, estimates of genetic differentiation were low and values of heterozygosity were similar across locations, implying moderate to high levels of gene flow within the country (Sherman et al. 2017). Moreover, two genetic stocks of Nassau grouper appear to exist in The Bahamas, but one stock is less abundant (Fig. 13; Sherman et al. 2017). Indeed, if there are genuinely two genetic stocks (i.e. population structure), they do not appear to be driven by contemporary geography or geographical barriers to gene flow. Instead, this pattern may be reflective of either the historical background of both stocks, and/or some other intrinsic (non-geographic) factor. Thus, these findings further underscore the need for better management of the species.

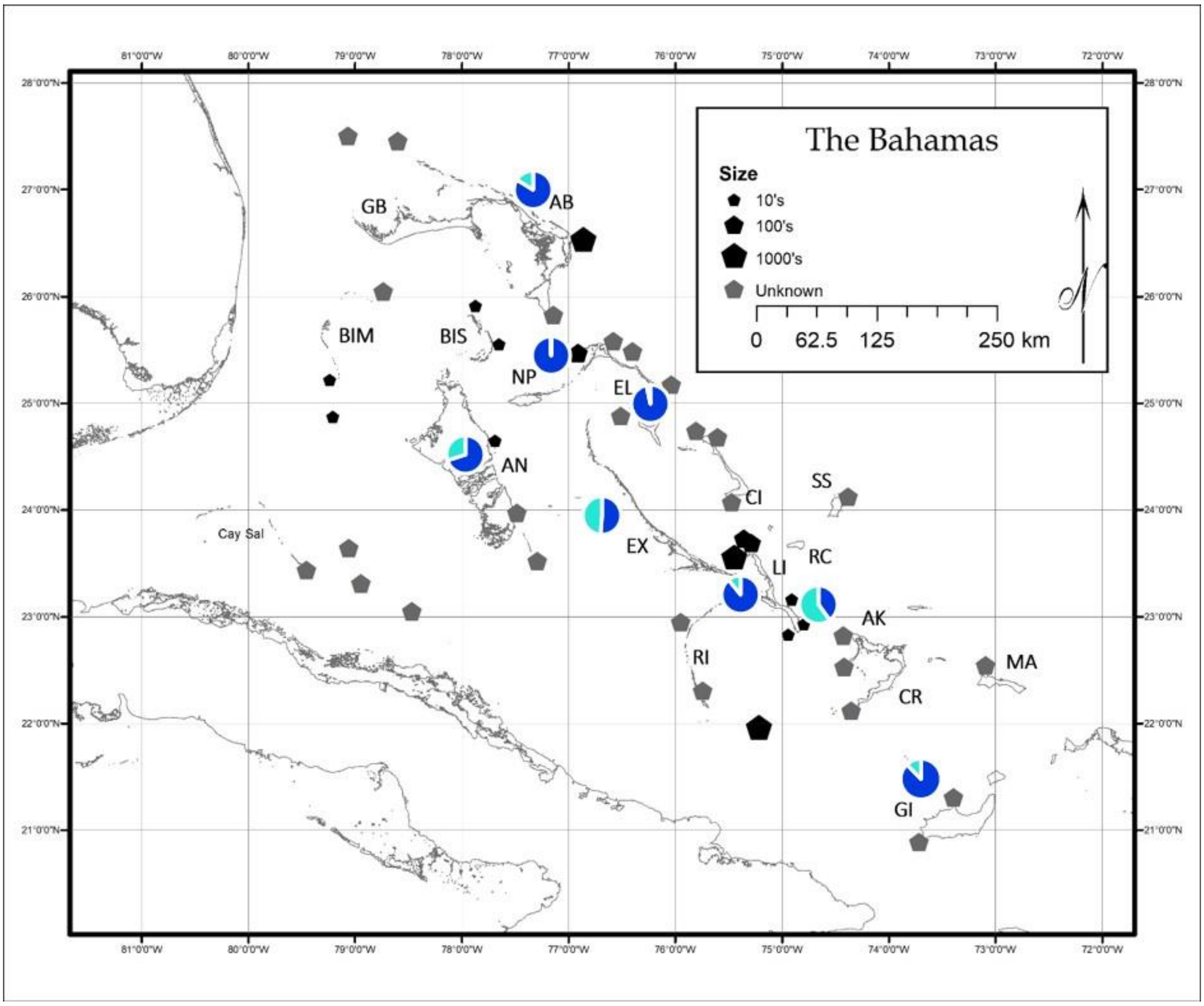

Figure 13. Genetic composition depicting the two stocks of Nassau grouper within The Bahamas overlaid on FSA map. Based on microsatellite data from Sherman et al. (2017).

Emerging results from SNP data are providing insight into patterns of gene flow (i.e. genetic connectivity) and evidence in support of population structure that was not observed through microsatellite analysis (Sherman el al. 2017; Sherman et al. in prep). Future research is being planned to integrate biophysical modelling with population genetics to provide additional insights into the mechanisms influencing source-sink dynamics for the species (Paris, Sherman and Dahlgren). These findings will have direct implications for improving Nassau grouper management within The Bahamas.

Stakeholder Assessments

Under the theme "Reversing the Decline", a Nassau Grouper Fishery Management Workshop was held on March 17th, 2016 during the third Bahamas Natural History Conference to outline key components and promote the establishment of a comprehensive national Nassau grouper sustainable management plan for The Bahamas (Appendix D). The workshop consisted of 15 stakeholders including policy-makers, law enforcement officials, fishermen, marine resource managers, scientists, non-governmental organizations (NGOs) and the private sector. Participants completed a SWOT analysis, identifying 10 strengths, 18 weaknesses, 17 opportunities and 11 threats of the Nassau grouper fishery (Table 3).

Table 3. SWOT analysis of the Bahamian Nassau grouper fishery. Results are reported verbatim.

Strengths	Weaknesses	Opportunities	Threats
We know that the species is threatened	Schooling behaviour for spawning makes them vulnerable	Need fishery-independent data to help management	Overfishing/Probably already below critical population threshold
Fixed closed season	Decreasing number/distribution of spawning schools	Data collection has improved	Low spawning stock biomass
Viable population in The Bahamas	Unsustainable to fish spawning aggregations that are well known by fishermen and easy to harvest	New Fisheries Officers could enforce current regulations	Lack of compliance (e.g. illegal fishing during the closed season by foreigners and Bahamians and catching undersized fish)
Economic benefits (direct & indirect, e.g. > $1 mil in revenue, trickle-down economics, higher valued compared to other fish species, etc.)	Need to amend closed season to include November & March due to early and late spawning	RBDF and Police could better support enforcement and research	Lack of enforcement
Food source/diet (grouper bigger than other fish)	Poor enforcement	Training for Fisheries Officers (e.g. why regulations exist, what they are, conflict resolution, etc.)	High demand by Bahamians and foreigners
Compliance by many Bahamians for closed season	Family/community connection decreases willingness to enforce regulations	Increase fines for Bahamians and foreigners violating regulations	No gear restrictions (e.g. hookah rigs, no trap limits)
Public understands importance of species	Lack of education of fishermen	Change policy to allow ticketing/administrative fines	No bag limits/quotas
Science/research is on-going	Lack of knowledge of regulations by public	Communication strategy for changes to Fisheries Regulation 35	Lack of knowledge/Misconceptions about biology/behaviour (e.g. Illegal fishing creates a "catch it while you can" mentality. Tragedy of the Commons)
Cultural value/benefits	Boom fishery	Fishermen willing to participate in collaborative patrolling/enforcement	Lack of alternative/sustainable livelihood options for fishermen
More fisheries officers recently added to DMR	Monitoring of fishery	Some fishermen keen to get involved in research	Lionfish
	Lack of funding for scientific research and FSA monitoring	Explore sustainable harvesting strategies for other species	Potential climate change impacts (e.g. OA data deficient)

	Source-sink dynamics unknown	Intervene in markets (supply-demand chain)/outreach campaign designed for restaurants, hotels, fish processing plants, tourists, etc.	
	Not dealing with markets buying grouper but rather targeting fishermen	More public awareness programs (e.g. local meetings, fishermen focus groups, workshops, walk-a-bouts, etc.)	
	Educational/outreach materials not targeting right age groups	Develop material for recreational fishing and diving tourists	
	Lack of support for fishermen (e.g. tax/duty free breaks)	Conserve pelagic environment important for larvae	
	Bureaucratic decision-making processes/Lack of governmental mechanisms to allow willing fishermen to participate in enforcement	Collaboration among conservation partners to support development of sustainable fishery management plan	
	Need N. Grouper Fisheries Improvement Plan Working Group	Aquaculture potential	
	Lack of sustainable fisheries plan for grouper		

To further explore and assess stakeholder perspectives regarding the status and management of the fishery, a questionnaire was developed incorporating aspects of the SWOT analysis and distributed to relevant individuals. Key results (from Sherman and Tyler. in prep) are summarized below:

1.) Conservation and enforcement stakeholders have varied opinions regarding the current state of the fishery and how it should be managed.
2.) Both stakeholder groups are in favour of amending existing regulations and in support of new regulations.
3.) Most enforcement officers believe existing penalties for violating fishery regulations should increase.
4.) Enforcement stakeholders have conflicting opinions about which enforcement methods are the most effective for managing the fishery.
5.) Conservation and enforcement stakeholders do not view current education and outreach efforts as very effective.
6.) Stakeholders are supportive of quick action to strengthen protection for Nassau grouper.

Importance of a National Conservation Management Plan for Nassau Grouper

Biological Justification for Conservation

Predator-prey interactions are important for shaping and maintaining trophic structure in both marine and terrestrial ecosystems. Nassau grouper are important top predators of coral reef habitats and are also a food source for larger apex predators, e.g. sharks (Eggleston et al. 1998; Stallings 2008; Mumby et al. 2012; O'Farrell et al. 2014). Moreover, their formation of annual FSAs is not only responsible for replenishing fish stocks, but also for the addition of key nutrients (e.g., nitrogen and phosphorous) that are important for coral reef health (Archer et al. 2015). The protection of FSAs has been identified as a biodiversity target for The Bahamas (Moultrie 2012) and has been incorporated into Marxan analyses for the establishment of new MPAs (Moultrie & Moss-Hackett 2014).

Socioeconomic & Cultural Value

Nassau grouper are a highly prized commercial and recreational fish species (Buchan 2000; Cushion and Sullivan-Sealey 2008) and are also an integral part of Bahamian culture. Commercial landings data from the Department of Marine Resources (DMR) indicate that commercial harvest peaked at 514 tonnes in 1997, but have declined by 86% over the past twenty years (Sherman et al. in 2016). The value of commercially landed Nassau grouper has also declined from nearly $3 million to less than $1 million (Sherman et al. 2016).

Threats to Nassau Grouper

Fishery pressure

High market demand ($120-200 per Nassau grouper) coupled with the illegal capture of sexually immature fish, legal capture of sexually immature and/or mature but inexperienced spawners (i.e. fish ≤48 cm TL that may or may not have undertaken first spawning migration), and illegal capture of fish from FSAs all impede population recovery. Individuals are typically removed from the fishery between 2-9 years old (Bush et al. 1996). The perception of fishers that spawning sites are still supporting large numbers of fish is often inaccurate due to hyperstability (Sadovy de Mitcheson and Erisman 2012; Figure 14). Moreover, no quotas or bag limits have been established (for Bahamian commercial fishers) and fishing gears for catching Nassau grouper are unrestricted with the exception spearguns and fishing on SCUBA, which are prohibited in the country. The bag limit for foreign recreational fishers is 20 lbs of reef fish (not exceeding 60 lbs maximum in total weight) and 250 lbs per vessel is restricted for non-commercial Bahamian fishers.

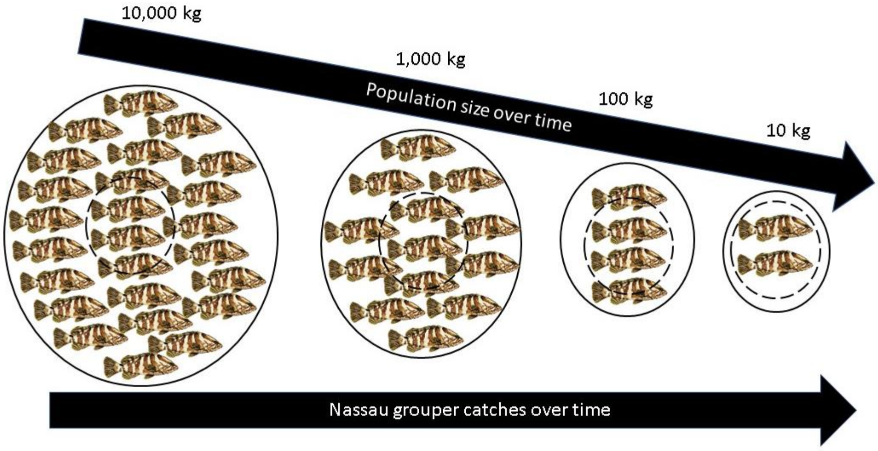

Figure 14. Consequences of spawning aggregation fishing. Recreated based on image from Sadovy de Mitcheson and Erisman 2012.

Threat: Overfishing

Actions: 1) Eliminate fishery pressure from foreign and Bahamian fishers at Nassau grouper FSAs

2) Enforce existing policies and amend fishery regulations to reduce fishing pressure and promote sustainable harvesting.

3) Remove **all** grouper species from the sportsfishing permit

4) Strengthen regional and international relationships to deter illegal fishing by foreigners (i.e. "poaching").

Habitat Degradation & Loss

Nassau grouper utilize a variety of habitats throughout their life cycle. However, the habitats which are most impacted include mangroves and coral reefs. Mangroves and other nursery habitats (e.g. seagrass beds) are often severely impacted by coastal development and associated pollution (Lotze et al. 2006). Coral reefs are being impacted by a range of anthropogenic activities including unsustainable fishing, invasive species, increasing incidences of coral bleaching and disease (Gardner et al. 2003; Allvarez-Filip et al. 2015). Degradation and loss of these essential habitats will impact both juvenile and adult fish.

Threat: Habitat degradation and loss

Actions: 1) Stringent monitoring of coastal development to minimize pollution and damage to key habitats

2) Protection of critical Nassau grouper habitats through MPA and marine reserve designation.

3) Support habitat restoration programmes (e.g., coral reef and mangrove restoration).

Invasive Alien Species

Several marine fish species have been introduced into the Atlantic Ocean (Schofield et al. 2009), including invasive species (de Castro et al. 2017), and have the potential to impact native reef fish composition (Albins and Hixon 2008). For example, invasive Indo-pacific lionfishes (*Pterois volitans/miles*), established within The Bahamas since 2004 (Schofield 2010), opportunistically consume Nassau grouper (Morris and Akins 2009; Muñoz et al. 2011; Layman and Allgeier 2012) and compete with them for both food and space (O'Farrell et al. 2014; Raymond et al. 2015). High densities (~393 lionfish ha^{-1}) of invasive lionfishes in The Bahamas (Green and Côté 2009) significantly affect recruitment processes of native fish species (Albins and Hixon 2008) and can retard recovery of an already declining Nassau grouper population through resource competition and predation.

Threat: Invasive species (e.g., lionfish)

Action: 1) Continued native reef fish monitoring (see Monitoring Plan for BNPAS)

2) Lionfish removal in critical marine habitats (see National Lionfish Response Plan; CSA; NISS; Smith et al. 2017)

3) Implementation of prevention and control strategies outlined in the NISS.

We also recommend shifting the timing of lionfish tournaments to December or another month during the Nassau grouper closed season to offer an alternative source of revenue to fishers, which would also assist with on-going lionfish removal efforts.

Disease & Predation

Incidences of disease and infections in Nassau grouper are rare. However, parasitic tapeworms, nematodes and isopods have been documented in the eyes, nostrils, bucaal cavity, gills and stomach of fish collected from Florida, Jamaica and the Cayman Islands (Thompson and Munro 1978; Sadovy and Eklund 1999; Semmens et al. 2006. Additionally, parasitic isopods (e.g. *Excorallana tricornis tricornis*) have been shown to infest fish following spawning events in the Cayman Islands (Semmens et al. 2006). This is likely to increase their susceptibility to capture and predation. However, with low natural morality rates and few documented natural predators including great barracuda (*Sphyraena barracuda*), carnivorous sharks, and conspecifics (Albins et al. 2009), fishery pressure is still the biggest threat affecting recovery of Nassau grouper populations.

Threats: Parasites and predators

Action: 1) Eliminate fishery pressure at Nassau grouper FSAs.

Climate Change

Hypothesized ecosystem responses to climate change include poleward migration and redistribution of organisms, population collapses, local extinctions, disruptions to large-scale migrations, and alterations to food availability and trophic structure (Pörtner and Farrell 2008). Fish exhibit a range of responses to climate-induced stressors (Munday et al. 2009; Crozier and Hutchings 2014). Temperature changes are known to affect larval development (Ellis et al. 1997) and influence spawning for Nassau grouper (Colin 1992). However, predictions on how Nassau grouper behaviour and distribution could change as ocean temperatures and acidity increase due to climate change are data deficient. Coral reefs are being affected by thermal stress (Hughes et al. 2003; Hoegh-Guldberg et al. 2007) and a reduction or loss of reef habitat is likely to negatively impact Nassau grouper. A delayed start to the spawning season has also been predicted (Asch and Erisman unpubl. data). While climate change does pose a threat to both Nassau grouper and their habitats, unsustainable fishing practices represent a more immediate threat to the species.

Threat: Climate Change

Actions: 1) Assess impacts of climate change-linked abiotic factors on Nassau grouper

2) Support monitoring and restoration programmes for critical habitats (e.g. coral reefs and mangroves) to promote resilient ecosystems (see Monitoring Plan for BNPAS; Reverse The Decline Project).

Table 4. Threat Assessment for Nassau grouper (*Epinephelus striatus*). Threats were assigned a score for severity (low = 1, medium = 2, high = 3) and restoration likelihood (unlikely = 1, possible = 2, likely = 3) then multiplied to obtain an overall threat rating score. For the overall threat rating, scores ranging between 1-3 = low, 4-6 = medium, and 7-9 = high. Higher scores (in red) indicate priority areas of concern, which can be mitigated with appropriate management.

Threats	Limits to Species Recovery	Source of Threats	Threat Severity (Score A)	Restoration Likelihood (Score B)	Total Threat Score (A x B)	Overall Threat Rating
Fishery Pressure						
Nassau grouper FSA fishing (during closed season)	Removes large quantities of spawning fish biomass; likely to reduce diversity and negatively impact reproductive success of FSAs	Commercial, recreational & subsistence fishing on FSAs	3	3	9	High
Legal removal of sexually immature or inexperienced spawners (i.e. 3 lb. fish)	Likely to delay population recovery because fish are not spawning before removal for the fishery	Commercial, recreational & subsistence fisheries	3	3	9	High
Unrestricted fishing gears	Use of hookahs and compressors, fish traps/pots, at or around FSAs increases potential to remove large quantities of fish biomass compared to other fishing gears (e.g. hand-line or rod-and-reel)	Commercial, recreational & subsistence fisheries	3	3	9	High
Ghost traps at FSAs	Mortality of fish (adults & juveniles)	Commercial, recreational & subsistence fisheries	3	2	6	Medium
IUU fishing (during open season)	Removes unknown quantities of fish biomass	Illegal capture of fish by Bahamians and foreigners	3	1	3	Low

Habitat Degradation & Loss						
Degradation/Loss of mangroves	Limits available habitat and food for recruits and juveniles; increases predation risk; likely to reduce long-term survival of recruits and juveniles	Mangrove destruction for coastal development	3	3	9	High
Degradation/loss of coral reefs	Limits available habitat and food for sub-adults and adults; increases predation risk; likely to reduce long-term survival of sub-adults and adults	Coral bleaching, coral diseases, loss of grazers (i.e. urchins, parrotfish, etc.)	3	2	6	Medium
Reduced larval development/survival due to poor water quality	Reduces number of recruits	Eutrophication, effluent discharges, oil spills, etc.	2	2	4	Medium
Compromised fish health	Impaired development/reproductive output/feeding	Eutrophication, effluent discharges, oil spills, etc.	2	2	4	Medium
Loss of seagrass	Limits available habitat and food for recruits and juveniles; increases predation risk; likely to reduce long-term survival of recruits and juveniles	Smothering or removal of seagrass for coastal development	3	1	3	Low
Invasive Alien Species						
Lionfish predation and competition	Removal of juveniles; decreases available Nassau grouper prey	High densities of invasive lionfish	1	2	2	Low
Disease & Predation						
Diseases & parasites	Likely to lead to increased incidences of infections or mortality of fish	Parasitic isopods, trematodes, etc.	1	1	1	Low

Natural predators	Mortality of fish	Sharks, Great barracuda, Nassau grouper	1	1	1	Low
Climate Change						
Forecasted increases in SSTs	Possible reduced larval development/survival	Anthropogenic-induced climate change	2	1	2	Low
	Possible shifts in spawning occurrence	Anthropogenic-induced climate change	2	1	2	Low
Ocean acidification	Unknown	Anthropogenic-induced climate change	1	1	1	Low

Nassau Grouper Conservation & Management

National Policies and Regulations

The legislative framework governing the management of the Nassau grouper fishery in The Bahamas is the Fisheries Resources Jurisdiction and Conservation Act. Fisheries regulations are created under the umbrella of this Act via the Fisheries Resources (Jurisdiction and Conservation) Regulations (http://laws.bahamas.gov.bs/cms/en/). Information regarding protected species, gear usage, quotas, size limits, closed seasons, fish processing, fishing permits and licenses, and penalties for offenses are outlined within the regulations, which were established to conserve and manage fishery resources for the benefit of Bahamians. By law, only Bahamians or citizens of The Bahamas that legally reside within the country are permitted to engage in commercial fishing activities. A permit is required for any foreign vessel engaged in recreational or sportsfishing within the EEZ of The Bahamas. A prerequisite for the permit is clearance at an official port of entry by Customs officials or the Department of Marine Resources (DMR). A maximum of six rods or reels is usually permitted along with the catch of up to 20 lbs of reef fish (not exceeding 60 lbs maximum in total weight). The use of spearguns is illegal and commercial fishing on SCUBA is not allowed. The Fisheries Act (Regulation 35 of Sub. Leg. Vol. IV, Ch. 244-3) was amended on September 29th, 2015 and current regulations pertinent to Nassau grouper are outlined as follows:

- Landed Nassau grouper must be ≥3 lb.
- "During the closed season, no person shall land any fish commonly known as "grouper" unless its head, tail and skin is intact.
- No person shall take, land, process, sell or offer for sale any fish commonly known as "Nassau grouper" during the closed season, except where such taking or landing is carried out with the written approval of the Director of Fisheries for scientific research purposes.
- For the purposes of Regulation 35, "closed season" means the period commencing on the 1st day of December in any year and ending on the 28th of February of the immediate succeeding year".

International Policies, Regulations, Agreements & Conventions

Wold Conservation for Nature (IUCN) Red List

Despite more than 30 years of protective measures, Nassau grouper populations in most countries have substantially decreased. Rapid global declines (≥ 60%) in Nassau grouper populations coupled with the extirpation of historic FSAs and continued fishery pressure led to its most recent listing as critically endangered by the IUCN (re-assessed by Carpenter et al. 2015). Critically endangered species on the Red List v. 3.1 are defined as species "facing an **extremely high risk** of extinction in the wild" (http://www.iucnredlist.org/static/categories_criteria_3_1).

Endangered Species Act (ESA)

The United States Endangered Species Act (ESA) was established in 1973 to prevent the extinction of threatened and endangered species. Under this act, threatened species are classified as those which are "likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range" (ESA 1973). Following a petition initiated by WildEarth

Guardians in 2010, Nassau grouper was officially listed on the ESA (81 FR 42268) in June 2016 as a threatened species (https://www.federalregister.gov/articles/2016/06/29/2016-15101/endangered-and-threatened-wildlife-and-plants-final-listing-determination-on-the-proposal-to-list). Stipulations of this act mean that a US federal recovery plan will be created to restore Nassau grouper populations and if successfully implemented, should eventually result in its downlisting.

Convention on Biological Diversity (CBD)

Conserving biodiversity is the primary objective of the Convention of Biological Diversity (CBD). After ratification in 1993, The Bahamas pledged to adhere to principles stipulated under the CBD's Articles. Several obligations relevant to the protection of Nassau grouper and its associated habitats are highlighted:

- "Develop national strategies, plans or programmes for the conservation and sustainable use of biodiversity or adapt for this purpose existing strategies, plans or programmes (Article 6).
- Identify and monitor components of biodiversity that need to be conserved and used sustainably (Article 7).
- Promote the protection of ecosystems, natural habitats and the maintenance of viable populations of species in natural surroundings (Article 8).
- Develop or maintain necessary legislation and/or other regulatory provisions for the protection of threatened species and populations (Article 8)
- Rehabilitate and restore degraded ecosystems and promote the recovery of threatened species (Article 8).
- Promote and encourage research which contributes to the conservation and sustainable use of biodiversity (Article 12)".

Progress in achieving these objectives is overseen by the Bahamas Environment Science and Technology (BEST) Commission with the support of National Implementation Support Programme (NISP) partner agencies, which also include the BNT, DMR and The Nature Conservancy (TNC).

Specially Protected Areas and Wildlife (SPAW) Protocol

The SPAW protocol under the Cartagena Convention was designed to support existing international conservation and environmental sustainability efforts (e.g. CBD). The Bahamas ratified the SPAW protocol in 2010. One of the objectives of the protocol is to "support the conservation of threatened and endangered species and sustainable use of natural resources to prevent them from being threatened or endangered". Most of the work under the SPAW protocol has been directed toward sea turtles, invasive species and marine mammals. However, Nassau grouper was recently listed under the SPAW protocol (SPAW annex III), and as a critically endangered species, the development of a species-specific national plan for Nassau grouper would represent an important contribution to ongoing conservation management efforts in The Bahamas.

The Lacey Act

The Lacey Act is a federal law in the United States of America that was enacted to protect wildlife. "Under the Lacey Act**,** it is unlawful to import, export, sell, acquire, or purchase fish, wildlife or plants that are taken, possessed, transported, or sold: 1) in violation of U.S. or Indian law, or 2) in interstate or foreign commerce involving any fish, wildlife, or plants taken possessed or sold in violation of State or foreign law". As such, the Lacey Act provides a measure of deterring IUU fishing by U.S. citizens.

Regional Policies and Regulations

As a member of the [Caribbean Regional Fisheries Mechanism] (CRFM), The Bahamas is collaborating with 16 (English speaking) Caribbean countries to tackle issues related to the sustainable harvest and management of fisheries resources (CRFM 2013). The Bahamas has also been involved with regional meetings of the CRFM, Western Central Atlantic Fishery Commission (WECAFC) and Caribbean Fisheries Management Council (CFMC) working group for spawning aggregations. This working group successfully advocated for Nassau grouper to be added to the SPAW protocol. Strengthened national and regional support to achieve sustainable management and other outlined CRFM strategic objectives should complement on-going national management efforts for the Bahamian Nassau grouper fishery. Spanish speaking countries such as Cuba and the Dominican Republic are not formally part of the CRFM. Bilateral discussions with the Dominican Republic have occurred to address IUU fishing via a Technical Cooperation Agreement, but were unsuccessful. Continued efforts to address IUU fishing with Spanish speaking countries are encouraged.

National Management Authorities

The following governmental and non-governmental entities are **legally** tasked with the management of Nassau grouper (i.e. through enforcement or habitat protection) in The Bahamas:

1. Department of Marine Resources
2. Royal Bahamas Defence Force
3. Royal Bahamas Police Force
4. Bahamas National Trust
5. Customs.

Recommendations for Advancing Conservation & Management

We have reviewed and assessed the adequacy of existing regulatory mechanisms related to the management of Nassau grouper in The Bahamas. Based on our evaluation, two existing regulations should be revised as they fail to assist with population recovery and by extension a sustainable fishery. In addition, we also recommend the establishment and implementation of new regulations. Justifications for these amendments are also provided.

Revisions to Existing Regulations

Regulation: **Amendment #1 Extend closed season (1 November-March 31)**

Justification for Amendment: Telemetry data and visual observations indicate migrations to FSAs also occur during November and March if the timing of the full moon falls either early or late in the month. Moreover, emerging research has predicted shifts in the timing of spawning due to increased sea surface temperatures (Asch and Erisman unpubl. data). Amending the existing regulation to protect early and late spawners would prevent the (currently) legal capture of spawning individuals during the reproductive season. We recommend changing the wording of the closed season to prohibit the fishing, sale and possession of Nassau grouper **during the entire spawning period**.

Regulation: **Amendment #2 Increase size limit to ≥54 cm (21.3 in) TL / ~4 kg (9 lb)**

Justification for Amendment: Approximately 77% of fish are ≥ 54 cm TL when they first migrate to spawn. The average weight of tagged fish ≥ 54 cm TL was ~4 kg or 9 lb (Fig. 15). The current 3 lb regulation results in the removal of Nassau grouper from the fishery **before** they contribute to stock replenishment (Fig. 15). Moreover, fishers and consumers purchasing Nassau grouper are unlikely to know exactly how big a 3 lb fish is, which may lead to the continued capture of undersized fish (e.g. Photo 4). We strongly recommend amending the fishery regulation to **ban harvesting any Nassau grouper <54 cm TL (21.3 in)**. Additionally, we suggest the inclusion of both metrics of size (i.e. length and weight) in the fishery regulation and educational materials moving forward. As a supportive measure, DMR is advised to advocate for a complete ban of selling and serving any Nassau grouper (fresh or frozen) during the seasonal closure.

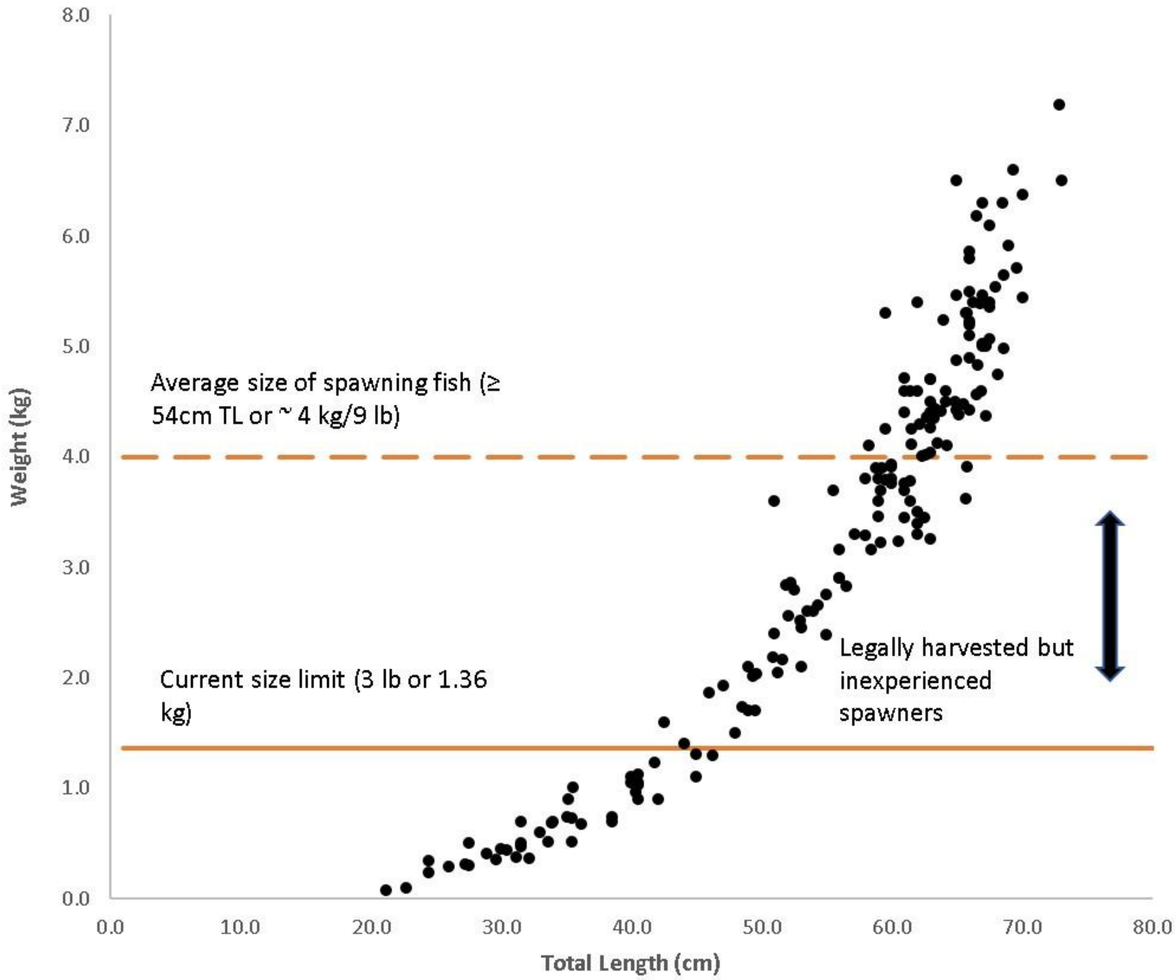

Figure 15. Morphometric data from externally and surgically tagged Nassau grouper (n=177) captured and released in The Bahamas between 2014-2017 for genetic and telemetry studies (Sherman et al. unpubl. data). The red line represents the current minimum size limit and the dashed red line denotes the mean size at which Nassau grouper first migrate in The Bahamas.

Photo 4. Undersized Nassau grouper at a fish landing site in Eleuthera.
Photo Credit: Aaron Shultz

Establishment & Implementation of New National Regulations

1. **Ban use of fish traps/pots around FSAs during the spawning season**

Justification for new regulation: Baited fish traps or pots are the gear type primarily used at FSAs (Photo 5). Deployment of these traps at or within the vicinity of FSAs increases the probability that Nassau grouper migrating to and from FSAs to home reefs during the spawning season will be captured. Moreover, traps that become lost at sea are responsible for "ghost fishing", which also contributes to reducing Nassau grouper biomass. Given the prevalence for fish traps used in The Bahamas, fishers should be encouraged to build or purchase biodegradable traps. Additionally, we suggest **restricting deployment of traps throughout The Bahamas to ≤30 ft** during the spawning season.

Photo 5. Nassau groupers caught in a fish trap at an active FSA off Long Island, Bahamas
Photo credit: Krista Sherman

The use of compressors/hookahs is presently restricted to depths between 9.1-18.3 m (30-60 ft), which means this gear type should NOT be used at any FSA as these sites are typically ≥30.48 m (≥100 ft). Because Nassau grouper are solitary dwelling species outside of the reproductive season, the continued use of this gear type during non-breeding periods, is unlikely to lead to overharvest of the species.

2. **Protect multi-species FSAs**

Justification for new regulation: FSAs may be utilized by other fish species, e.g. black grouper (*Mycteroperca bonaci*) throughout the year. Spawning aggregation fishing of any species is not a sustainable practice and if unchecked can result in population collapse (Sadovy de Mitcheson and Colin 2012). Multi-species FSAs are important and unique ecological features that warrant protection. There are a few reported multi-species FSAs in The Bahamas, which are used by Nassau grouper, black grouper (*Mycteroperca bonaci*) and other species (e.g. mutton snapper, *Lutjanus analis*).

3. **Establish maximum size limit**

Justification for new regulation: It is important to preserve size structure to maintain healthy fish populations (Hixon et al. 2013). Fishers are already reporting a decrease in both abundance and size of Nassau grouper, which is typically an indication of overfishing (Cheung et al. 2013; Wise et al. unpubl. data). Protecting juveniles, subadults and experienced, large sexually mature fish will be important for assisting with replenishing fish stocks. However, increasing the current minimum size limit to ≥54 cm (21.3 in) TL, should be prioritized to prevent further harvest of subadults or inexperienced spawners.

Strategic Surveillance & Enforcement

We recommend implementation of the following to assist with improving surveillance and enforcement for Nassau grouper:

1. RBDF patrols of active FSAs 3-4 days around the full moon during December and January (or peak spawning months moving forward)
2. Fisheries Officer inspections of local fish houses, landing sites and mailboats one week before the closed season and 2x per week during week of full moon during spawning season
3. Establish and enforce fines for grouper species landed without skin intact – proceeds to assist with on-going surveillance and enforcement
4. Increase and enforce fines for illegally caught and purchased fish – proceeds to assist with on-going surveillance and enforcement
5. Fishermen have expressed interested in assisting with enforcement to deter foreign poaching (illegal fishing). Develop a system (e.g. hotline, app, etc.) to encourage cooperation and facilitate faster reporting and response by enforcement officers
6. Publicise when fines and arrests have been made in association with IUU fishing.

Bahamas National Protected Area System (BNPAS) expansion

The following FSAs have been identified as important based on spawning stock biomass, genetic diversity and genetic connectivity, acoustic telemetry, and/or multi-species use:

1. Cay Verde (Ragged Island)
2. Hopetown (Abaco)
3. Hail Mary (between Little Exuma and Long Island)
4. Hole in the Wall (Abaco)
5. Tinker Rocks (Andros)
6. Newton's Cay (Long Island)
7. Grouper Hole (Eleuthera)
8. Little Egg Island (Eleuthera)
9. Tommy Sound (Eleuthera).

Other FSAs will be added to this list as data become available. If possible, incorporating these areas into the BNPAS should be considered. Additionally, the continental shelf of the Exuma Sound and Tongue of the Ocean (TOTO) represent important adult migratory and larval dispersal corridors, connecting natal reefs with FSAs. Drifter tracks and current trajectories indicate that larvae and pelagic juveniles are likely to spend a portion of their life cycle (35-50 days) in pelagic waters prior to recruiting to appropriate nursery habitats. Anthropogenic activities that have the potential to significantly alter water quality in the Exuma Sound and TOTO should be strictly regulated.

Monitoring & Evaluation

Monitoring and evaluation are critical components of the adaptive management cycle, which is an iterative learning process (Fig. 16).

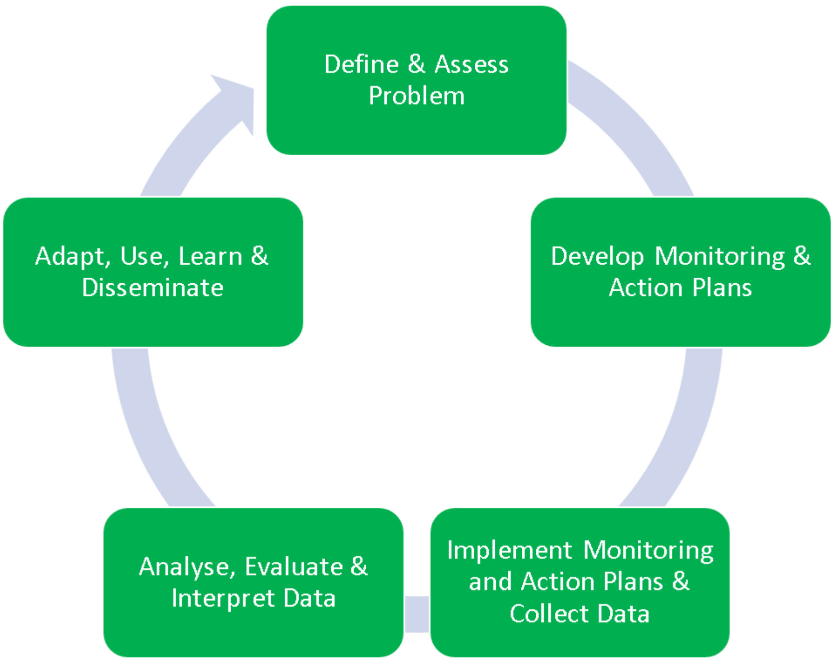

Figure 16. Simplified adaptive management cycle modified from The Open Standards for the Practice of Conservation.

To assess spatial and temporal changes in the health of Nassau grouper (i.e. abundance, size distribution, density, spawning stock biomass, genetic diversity and habitat use), both fishery-independent and fishery-dependent data are required (Table 5). These data should be collected routinely as they are critical for understanding population trends over time and applying appropriate management actions, which should be reviewed and amended as necessary (Appendices B-D).

Table 5. Data required for monitoring the status of Nassau grouper.

Fishery-independent Data	Fishery-dependent Data
• Spawning stock biomass (FSA monitoring) • Density of Nassau grouper (across all	• Commercial landings

habitats) • Size distribution/structure (across all habitats) • Genetic diversity (H_E, H_O, A_R) • Effective population size, N_e • Sighting frequency data (i.e. roving diver surveys) • Habitat use (e.g. tagging, stable isotope analysis) • Sex ratios	• CPUE from commercial, recreational and subsistence fisheries

Education, Outreach and Advocacy

Considerable efforts have been undertaken to improve education and outreach for Nassau grouper conservation in The Bahamas. To further advance these initiatives, we recommend developing an expert-led communication strategy and plan, strengthening the electronic exchange of materials, increased use of social media channels, and executing a holistic targeted national campaign to promote regulatory compliance and sustainable consumption for **all** harvested marine species. Cultivating and/or strengthening a rapport with key representatives from the fishing community should assist with transmission issues.

Assessing Management Effectiveness

This conservation plan has four specific objectives along with actions to rebuild and monitor the Bahamian Nassau grouper population while also eliminating or managing the threats that compromise its recovery. The first objective is to increase Nassau grouper density and spawning stock biomass. The second objective is to establish sustainable harvest regulations to promote a healthy fishery. Reducing anthropogenic threats, which negatively impact the species is the third objective. The fourth and final objective is to maintain and/or improve critical marine habitats for all life stages (e.g. mangroves, coral reefs, spawning sites). To promote management effectiveness, measurable criteria should be used to assess whether the recovery objectives have been satisfactorily met. To achieve objectives, DMR is encouraged to strategically collaborate with local law enforcement organizations (e.g. RBDF, RBPF), local government, scientists, fishers, NGOs, regional networks and other relevant stakeholders through an adaptive management process (Figs. 16 and 17). The specific actions and activities required to accomplish these objectives are outlined below.

Recommended Recovery Actions

- ✓ Establish and implement surveillance programme for targeted enforcement of active FSAs and no-take MPAs
- ✓ Revise Fisheries Act based on current scientific data
- ✓ Protection of critical Nassau grouper habitats through MPA and marine reserve designation
- ✓ Continued Nassau grouper FSA verification and monitoring (see Appendix B)
- ✓ Continued native reef fish monitoring for key habitats (e.g. coral reefs, mangroves and seagrass beds)
- ✓ Establish national sustainable seafood consumption campaign
- ✓ Assess physiological responses of Nassau grouper to climate change related stressors

- ✓ Support restoration programmes for habitats used across all life stages
- ✓ Stringent monitoring of coastal development activities to minimize pollution and damage to the benthos, nursery and pelagic habitats
- ✓ Sustained lionfish removal in critical marine habitats
- ✓ Follow-through with "Early detection and rapid response" for marine IAS (see NISS)

Warning Indicators

The following indicators can be used to help monitor and guide management decisions to assist with promoting recovery for Nassau grouper:

↓CPUE
↓Commercial landings
↓Nassau grouper density/biomass on reefs
↓Nassau grouper recruitment and density in nursery habitats
↓Nassau grouper FSA abundance & biomass
↓Nassau grouper effective population size (N_e) & genetic diversity
↑Habitat degradation and loss
↑Invasive species (e.g. lionfish) abundance/density
↑Pollution (e.g. eutrophication, oil spills, etc.).

Recovery Criteria

1. Demographic Criterion

- Protection of 50% minimum nursery habitats
- Protection of 20% minimum reef and hardbottom habitats
- Protection of 5% minimum of pelagic habitats
- Protection & enforcement of **all active FSAs**

2. Threat-based Criterion

- 85-90% reduction in FSA fishing (e.g. decreased number of traps at FSAs)
- 85-90% decrease in the capture of undersized fish (i.e. <54 cm TL)

3. Management Effectiveness Criterion

- Closed season actively enforced with emphasis on known active FSAs
- Enforcement officers receive adequate and regular training (minimum of once per year)
- Increased resources available for consistent FSA monitoring
- Enforcement at point-of-sale areas (e.g. landing sites, fish houses)

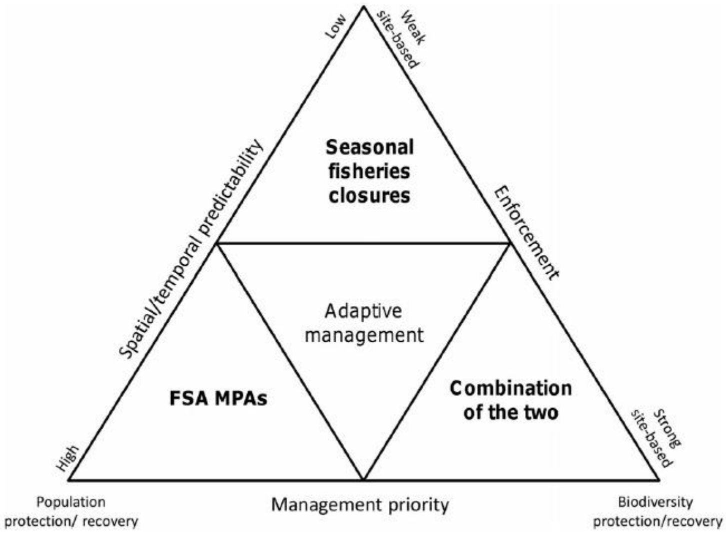

Figure 17. Conceptual model of adaptive management process for FSAs. Image from Grüss et al. 2014.

A summary of management objectives with linked tasks and associated timelines are provided in Table 6.

Implementation Timeline

The restoration of threatened and endangered species requires timely implementation of species-specific recovery plans to protect species and essential habitats (Taylor et al. 2005). **Immediate action** is required to stabilize remaining populations and facilitate the process of recovery because: 1) Nassau grouper FSAs are unlikely to recover once extirpated, 2) fish have experienced dramatic reductions in effective population size (N_e), 3) commercial fisheries are declining, 4) fish density/biomass in coral reef habitats is decreasing, and 5) on-going anthropogenic threats to FSAs and marine habitats (e.g., overfishing and climate change) persist. The technical advisory team will liaise closely with relevant management authorities and the Nassau grouper working group to fund and implement the national management plan.


Epinephelus striatus
"The Nassau Grouper"

Table 6. Five-year Implementation timeline with associated tasks and responsible entities.

Tasks	Responsible Organization(s)/Individual(s)	Supporting Organization(s)/Individual(s)	Year 1	Year 2	Year 3	Year 4	Year 5	On-going
Secure Funding								
Identify possible funders	DMR & Scientists	National & international NGOs						
Write grants/funding proposals to support: research & monitoring, outreach & advocacy, capacity building	Scientists	National & international NGOs						
Leverage local organizations/agencies to provide in-kind support (as appropriate)	National NGO	National & international NGOs						
Engage Stakeholders								
Develop communication plan/strategy	Consultant	National NGOs						
Conduct fishermen focus group meetings on major fishing islands: 1) acquire information (i.e. incorporate local knowledge into research) 2) share information/increase awareness	DMR/Consultant	National NGOs						
Workshops/Community Meetings/Public Lecture Series for: policy-makers, restaurants, processing plants, fish houses, general public)	National NGO	National NGOs						
Create & Implement Restaurant Reward Program to promote sustainable seafood	Consultant	National NGOs						

Develop targeted stakeholder materials/refine existing materials to 1) raise awareness (importance, vulnerability, status) & 2) advocate for sustainable fishery	Consultant	National & international NGOs						
Evaluate effectiveness of communication/outreach initiatives	Consultant	National NGOs						
Revise communication/outreach initiatives based on evaluation report	Consultant	National NGOs						
Research & Monitoring								
Identify active Nassau grouper FSAs	Scientists	National NGOs						
Identify multi-species FSAs	Scientists	National NGOs						
Stock assessment analysis	Scientists	GOB						
Standardize & implement consistent monitoring program to assess abundances & evaluate status/health of active FSAs	Scientists	National NGOs						
Establish important source-sink areas, migratory corridors and establish mechanisms influencing contemporary patterns of genetic connectivity	Scientists	National NGOs						
Prioritise FSAs for management	Scientists	GOB & National NGOs						
Complete economic evaluation for the species	Consultant	Scientists						
Incorporate biological and socioeconomic research into Nassau Grouper Conservation/Sustainable Fishery	Scientists	GOB						

Management Plan as new information becomes available								
Re-evaluate Fishery Regulations/Policies, Enforcement & Governance								
Strengthen institutional relationships & support among enforcement agencies	DMR	BNT, RBDF						
Engage fish processing plants to comply with fishery regulations (i.e. not purchasing undersized Nassau grouper or Nassau grouper caught during the closed season)	DMR	National NGOs						
Revise Fisheries Act or create FSA Management Act based on management plan recommendations	DMR	AG's office						

Estimated Costs

Estimated expenditures associated with this management plan are based on projections for the next five years.

Recovery Costs
Monitoring & Evaluation = $2,000,000
Surveillance & Enforcement = $5,000,000
Education, Outreach & Advocacy = $500,000
Estimated Total = $7.5 million

Conclusion

Available ecological and socioeconomic data highlight the urgency of improving conservation management for Nassau grouper in The Bahamas. Existing management frameworks need to be amended to promote sustainability of the commercial fishery and provide adequate protection to inexperienced spawners and spawning stocks through strategic enforcement, species and habitat monitoring, and effective public engagement. Recommendations for addressing these issues and assessing management strategies should be revised and adapted as new information becomes available. Regional and international cooperation (e.g., FAO WECAFC Spawning Aggregations Working Group) is strongly encouraged to assist with achieving recovery objectives.

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Appendices

Disclaimer: The recommendations outlined in this management plan do not necessarily reflect those of the Department of Marine Resources.

Appendix A. Diet composition of Nassau grouper (*Epinephelus striatus*).

Prey Taxa	Common Name	References
TELEOSTS		
Acanthuridae	**Surgeonfish**	
Acanthurus coeruleus	Blue tang	Sadovy and Eklund 1999
Acanthurus sp.	Surgeonfish sp.	Carter et al. 1994; Sadovy and Eklund 1999
Apogonidae	**Cardinalfish**	Sadovy and Eklund 1999
Atherinidae	**Silversides**	Sadovy and Eklund 1999
Balistidae	**Triggerfish**	
Balistes vetula	Queen triggerfish	Sadovy and Eklund 1999
Bothidae	Left-eye flounders	Sadovy and Eklund 1999
Carangidae	**Jacks**	Sadovy and Eklund 1999
Caranx ruber	Bar jack	Sadovy and Eklund 1999
Clupeidae	**Herrings, shads, sardines**	
Harengula clupeola	False herring	Sadovy and Eklund 1999
Harengula humeralis	Redear herring	Sadovy and Eklund 1999
Jenkinsia lamprotaenia	Dwarf round herring	Sadovy and Eklund 1999
Epinephelidae	**Groupers**	
Cephalopholis fulva	Coney	Sadovy and Eklund 1999
Epinephelus striatus	Nassau grouper	Sadovy and Eklund 1999
Gerreidae	**Mojarra (colloquially "Shad")**	
Geres cinereus	Yellowfin mojarra	Sadovy and Eklund 1999
Gobiidae	**Gobies**	
Coryphopterus sp.	Goby sp.	Sadovy and Eklund 1999
Haemulidae	**Grunts**	
Haemulon album	White margate	Sadovy and Eklund 1999
Haemulon aurolineatum	Tomtate	Sadovy and Eklund 1999
Haemulon flavolineatum	French grunt	Sadovy and Eklund 1999
Haemulon plumieri	White grunt	Sadovy and Eklund 1999
Haemulon sciurus	Bluestriped grunt	Sadovy and Eklund 1999
Haemulon sp.	Grunts	Carter et al. 1994; Sadovy and Eklund 1999
Holocentridae	**Squirrelfishes & Soldierfishes**	

Holocentrus rufus	Longspine squirrelfish	Sadovy and Eklund 1999
Holocentrus sp.	Squirrelfish sp.	Carter et al. 1994; Sadovy and Eklund 1999
Myripristis Jacobus	Blackbar soldierfish	Sadovy and Eklund 1999
Sargocentron vexillarium	Dusky squirrelfish	Sadovy and Eklund 1999
Labridae	**Wrasse**	
Clepticus parrae	Creole wrasse	Sadovy and Eklund 1999
Halichoeres bivvitatus	Slippery dick	Sadovy and Eklund 1999
Halichoeres garnoti	Yellowhead wrasse	Sadovy and Eklund 1999
Halichoeres sp.	Wrasse sp.	Carter et al. 1994; Sadovy and Eklund 1999
Xyrichtys sp.	Razorfishes	Sadovy and Eklund 1999
Lutjanidae	**Snapper**	
Lutjanus synagris	Lane snapper	Sadovy and Eklund 1999
Lutjanus sp.	Snappers	Carter et al. 1994; Sadovy and Eklund 1999
Ocyurus chrysurus	Yellowtail snapper	Sadovy and Eklund 1999
Monacanthidae	**Filefish**	
Cantherhines pullus	Orangespotted filefish	Sadovy and Eklund 1999
Monacanthus ciliates	Fringed filefish	Sadovy and Eklund 1999
Monacanthus sp.	Filefish sp.	Sadovy and Eklund 1999
Mullidae	**Goatfish**	
Pseudupeneus maculatus	Spotted goatfish	Sadovy and Eklund 1999
Muraenidae	**Eels**	
Enchelycore nigricans	Viper moray eel	Sadovy and Eklund 1999
Gymnothorax moringa	Spotted moray eel	Sadovy and Eklund 1999
Gymnothorax sp.	Moray eels	Sadovy and Eklund 1999
Muraena miliaris	Goldentail moray eel	Sadovy and Eklund 1999
Muraena sp.	Mediterranean moray eels	Sadovy and Eklund 1999
Ostraciidae	**Boxfish**	Sadovy and Eklund 1999
Lactophrys sp.	Trunkfishes	Sadovy and Eklund 1999
Pomacentridae	**Damselfish**	
Abudefduf saxatalis	Sergeant major	Sadovy and Eklund 1999
Chromis cyanea	Blue chromis	Sadovy and Eklund 1999
Chromis mutlinieata	Brown chromis	Sadovy and Eklund 1999
Microspathodon chrysurus	Yellowtail damselfish	Sadovy and Eklund 1999

Pomacentrus fuscus	Brazilian damselfish	Sadovy and Eklund 1999
Pomacentrus sp.	Damselfish sp.	Carter et al. 1994; Sadovy and Eklund 1999
Priacanthidae	**Bigeyes**	
Priacanthus cruentatus	Glasseye snapper	Sadovy and Eklund 1999
Scarinae	**Parrotfish**	
Scarus croicensis	Striped parrotfish	Sadovy and Eklund 1999
Scarus sp.	Parrotfishes	Carter et al. 1994; Sadovy and Eklund 1999
Scarus vetula	Queen parrotfish	Sadovy and Eklund 1999
Sparisoma aurofrentatum	Redband parrotfish	Sadovy and Eklund 1999
Sparisoma chrysopterum	Redtail parrotfish	Sadovy and Eklund 1999
Sparisoma rubripinne	Redfin parrotfish	Sadovy and Eklund 1999
Sparisoma sp.	Parrotfish sp.	Carter et al. 1994; Sadovy and Eklund 1999
Serranidae	**Seabass & Basslets**	
Hypoplectrus puella	Barred hamlet	Sadovy and Eklund 1999
Synodontidae	**Lizzardfish**	Sadovy and Eklund 1999
Synodus intermedius	Sand diver	Sadovy and Eklund 1999
Synodus sp.	Lizzardfish sp.	Sadovy and Eklund 1999
Urolophidae	**Round Rays**	
Urolophus jamaicensis	Yellow stingray	Sadovy and Eklund 1999
BIVALVES		
Barbatia cancellaria	Red-brown ark clam	Sadovy and Eklund 1999
Pelecypoda	Oysters, clams, mussels, cockles	Eggleston et al. 1998; Sadovy and Eklund 1999
CRUSTACEANS		
Amphipods	Amphipods	Grover et al. 1998; Dahlgren and Eggleston 2000
Caprellidae	Skeleton shrimp amphipod	Grover et al. 1998
Gammaridea	Gammaridean amphipods	Grover et al. 1998
Copepods		
Calanoida	Calanoid copepods	Grover 1993; Grover et al. 1998
Cyclopoida	Cyclopoid copepods	Grover et al. 1998
Harpacticoida	Harpacticoid copepods	Grover 1993; Grover et al. 1998
Poecilostomatoida	Poecilostomatoid copepods	Grover 1993; Grover et al. 1998

Siphonostomatoida	Siphonostomatoid copepods	Grover 1993
Crabs		
Calappa flammea	Flame box crab	Sadovy and Eklund 1999
Calappa gallus	Rough box crab	Eggleston et al. 1998; Sadovy and Eklund 1999
Calappa sp.	Box crabs	Eggleston et al. 1998; Sadovy and Eklund 1999
Cronius tumidulus	Sculling crab	Eggleston et al. 1998
Euryplax nitida	Glabrous broadface crab	Sadovy and Eklund 1999
Grapsids	Marsh or shore crabs	Sadovy and Eklund 1999
Macrocoelema diplacanthum	Decorator crab	Eggleston et al. 1998; Sadovy and Eklund 1999
Macrocoelema sp.	Crabs	Sadovy and Eklund 1999
Micropanope pusilla	Puffy mud crab	Eggleston et al. 1998; Sadovy and Eklund 1999
Micropanope sp.	Mud crab sp.	Eggleston et al. 1998; Sadovy and Eklund 1999
Mithrax cinctimanus	Banded clinging crab	Sadovy and Eklund 1999
Mithrax coryphe	Nodose clinging crab	Eggleston et al. 1998; Sadovy and Eklund 1999
Mithrax forceps	Red-ridged clinging crab	Eggleston et al. 1998; Sadovy and Eklund 1999
Mithrax sp.	Clinging crabs	Eggleston et al. 1998; Sadovy and Eklund 1999
Mithrax spinosissiums	Channel clinging crab	Eggleston et al. 1998
Mithrax verrucosus	Paved clinging crab	Sadovy and Eklund 1999
Paguristes depressus	Hermit crab	Carter et al. 1994; Grover et al. 1998
Panopeus sp.	Mud crab sp.	Eggleston et al. 1998; Sadovy and Eklund 1999
Petrochirus Diogenes	Giant hermit crab	Sadovy and Eklund 1999
Petrolisthes galathinus	Amphi-American porcelain crab	Sadovy and Eklund 1999
Petrolisthes sp.	Porcelain crabs	Eggleston et al. 1998
Pitho aculeate	Massive urn crab	Eggleston et al. 1998; Sadovy and Eklund 1999
Pitho sp.	Urn crabs	Eggleston et al. 1998
Portunus sebae	Ocellate swimming crab	Sadovy and Eklund 1999
Portunus ordwayi	Redhair swimming crab	Eggleston et al. 1998
Portunus sp.	Swimming crab	Eggleston et al. 1998; Grover et al. 1998
Stenorhynchus seticornis	Yellowline arrow crab	Sadovy and Eklund 1999
Euphausiids	Krill	Grover et al. 1998
Isopods		Carter et al. 1994; Eggleston et al. 1998
Rocinela signata	Isopod	Eggleston et al. 1998
Lobsters		Carter et al. 1994

Justitia longimana	West Indian furrow lobster	Sadovy and Eklund 1999
Leptostraca	Leptostracans	Grover et al. 1998
Ostracods	Ostracods	Grover et al. 1998
Shrimp		
Alpheus sp.	Snapping shrimp	Eggleston et al. 1998
Artemia sp.	Brine shrimp	Tucker and Woodward 1991
Carideans	Emperor shrimp sp.	Grover et al. 1998; Eggleston et al. 1998
Cumaceans	Comma or hooded shrimp	Grover et al. 1998
Mysids	Mysid shrimp	Grover 1993; Grover et al. 1998
Paneidae	Paneid shrimp	Eggleston et al. 1998
Synalpheus sp.	Snapping shrimp	Eggleston et al. 1998
Thor sp.	Cleaner shrimp	Eggleston et al. 1998
Trachycaris restricta	Cleaner shrimp	Eggleston et al. 1998
Stomatopods		Carter et al. 1994; Eggleston et al. 1998; Grover et al. 1998
Alima sp.	Mantis shrimp	Carter et al. 1994; Eggleston et al. 1998
Pseudosquilla sp.	Common mantis shrimp	Eggleston et al. 1998
Squilla sp.	Mantis shrimp	Eggleston et al. 1998
ROTIFERA	Rotifers	Tucker and Woodward 1991
TANAIDACEA	Tanaids	Grover et al. 1998
CHAETOGNATHS	Arrow worms	Grover et al. 1998
CILLIATES	Protozoans	Grover et al. 1998
DINOFLAGELLATES	Flagellate protists (marine phytoplankton)	Grover 1993
FORAMINIFERANS	Forams (single-celled protists)	Grover 1993
MOLLUSCS		
Cephalopoda	Octopi	Carter et al. 1994; Eggleston et al. 1998

Cerithium sp.	Sea snail	Eggleston et al. 1998
Fasciolaria tulipa	True tulip snail	Eggleston et al. 1998
Lobatus gigas	Queen conch	Eggleston et al. 1998
Loligo sp.	Squid	Eggleston et al. 1998
Pteropoda	Pelagic sea snails and slugs	Grover et al. 1998
Strombus sp.	Conch	Eggleston et al. 1998
POLYCHAETA	Polychaete worms	Grover et al. 1998
PYCNOGONIDS	Sea spiders	
Pycnogonida sp.	Sea spider sp.	Carter et al. 1994; Eggleston et al. 1998; Grover et al. 1998
UKNOWN		
Invertebrate eggs	Invertebrate eggs	Grover 1993
Fish larvae	Fish larvae	Grover 1993
Decapod larvae	Decapod larvae	Grover et al. 1998

Appendix B - Nassau grouper FSA survey monitoring protocol

Nassau grouper FSA Survey Protocol

- Record metadata - surveyor name(s), date, survey start and end time, depth, temp, GPS & site name/location. Make sure the GPS location is as close as possible to where fish are observed to aggregate vs. the location of the boat at anchor at the site, which may be 100 m or more away.

- In addition to taking GPS points, it's also useful to take lots of photos and videos.
- Compose sketch of the site and describe habitat and any interesting features of the site. This should be done with someone experienced at underwater navigation or mapping.

- If possible, have the boat do multiple passes for 1-2 km around the site recording depth and GPS coordinates every 100 m or so (more frequently is possible) for a large scale map of the area.

- Documenting populations at the site should be done throughout the day. Because numbers of fish and possibly locations of fish change throughout the day, surveys should be conducted as many times as possible during the day (every 1-2 hours if personnel, logistics and weather allow).
    - Roving diver surveys (RDS) to estimate total number of individuals in the SPAG
    - Record size range (TL in cm) of groupers observed
    - Estimate the proportion in each of the 4 colour phases (normal or barred, bicolor, white belly, dark)
    - Estimate proportion with distended abdomens
    - Note direction which the school is moving (if they're moving), and other behaviours
    - Conduct multiple (30 x 2 m) * belt transect surveys (if fish are near or on the bottom) to record density, colour phase, and size (TL nearest cm) for Nassau grouper

*NB - will depend on size of team, survey area and the available bottom time)

- 3-4 days before & 1-2 days after the full moon conduct dives closer to sunset to document spawning behaviour. This should include dives anywhere from 1hr before to ½ hour after sunset. So in addition to RDS:
    - record any spawning behaviour observed including chasing (no. fish and information about size, time and colour phase), false rushes and other behaviours
    - document time of spawning release, number of individuals involved, colour phases, size estimates

- Note occurrence of poaching or illegal fishing. Take pics, record names of vessels (if possible).
    - number of boats per day/night
    - gear used & number of traps
    - numbers of fish in traps (release fish from traps if possible)

Appendix C – Nassau grouper fin clip sampling protocol

Nassau grouper Fin Clip Sampling Protocol

Live Fish Sampling: To ensure robust genetic analysis of a population, ideally samples of **50** fish should be collected from each site. Collected (fin clip) sample volume should NOT exceed 1/20th of the 2ml tube.

1. Cut ~5mm x 5mm fin clip from anesthetized (MS 222 buffered bath) fish using a pair of scissors.
2. Use tweezers to deposit sample in screw top vials with 95% ETOH.
3. Rinse/Wash scissors and tweezers between each sample to avoid cross contamination.
4. In pencil, write fish ID, SL cm, TL cm, Wt. (kg) collection date, site information (i.e. island and location) on waterproof slip and insert into vial. Ensure vial is properly sealed.
5. Label outside of vial with fish ID number using alcohol-proof pen. If unavailable, record information on a piece of paper in regular pen and cover with clear scotch tape.
6. Record tube number, site metadata and fish meristics on master data sheet and transfer to Excel spreadsheet.

Dead Fish Sampling: If samples are obtained from dead fish it is important to ensure that the sample is taken within a few minutes of death.

1. Cut ~5mm x 5mm fin clip from fish using a pair of scissors.
2. Use tweezers to deposit sample in screw top vials with 95% ETOH.
3. Rinse/Wash scissors and tweezers between each sample to avoid cross contamination.
4. In pencil, write fish ID, SL cm, TL cm, Wt. (kg) collection date, site information (i.e. island and location) on waterproof slip and insert into vial. Ensure vial is properly sealed.
5. Label outside of vial with fish ID number using alcohol-proof pen. If unavailable, record information on a piece of paper in regular pen and cover with clear scotch tape.
6. Record the tube number, details of date and place of fish capture, SL cm and TL cm. When sending samples for analysis, include a data sheet with sampling details for each tube.

Sample Storage: Samples are to be kept and stored in a refrigerator at all times until delivery to the Exeter lab.

Author: Krista D. Sherman Page 1

Appendix D – Nassau grouper Fishery Management Workshop Report

Nassau Grouper Fishery Management Workshop

Nassau Grouper (*Epinephelus striatus*) Photo: Keith Pamper © 2011

Workshop Report
New Providence, Bahamas
March 17th, 2016

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Nassau Grouper Fishery Management Workshop

Date: Thursday, March 17th, 2016

Time: 1:00-3:00 PM

Venue: Harry C Moore Library Bibliographic Instruction Classroom, College of The Bahamas

Workshop Summary

The Nassau grouper (*Epinephelus striatus*) is a cultural icon as well as an economically and ecologically key marine fish species for The Bahamas. Approximately $1 million is generated through annual landings, and the fishery supports thousands of livelihoods throughout the archipelago. The species is at risk from a range of threats, most notably overfishing and illegal aggregation fishing, which threaten the long-term viability of the fishery.

Research has shown that fishing on spawning aggregations has decimated Nassau grouper populations regionally by as much as 90% over the past three decades. It is listed as endangered on the IUCN Red List and is a candidate species to be listed for special protection under the United States Endangered Species Act (ESA). The Bahamas government's decision in 2015 to impose a permanent annual three-month seasonal closure for grouper fishing is a positive step towards protecting this at-risk species. However, a multi-faceted approach is required to effectively manage the fishery because management strategies to date have not been effective in reversing the decline of Nassau grouper stocks.

In 2013, the Bahamas National Trust (BNT) hosted a Nassau Grouper Conservation Strategy Workshop to discuss ways to promote recovery for grouper populations. Both biological or ecological and sociocultural considerations were outlined. Specific research needs were identified and prioritized that would form the foundation for a science-driven conservation plan for the Bahamian Nassau grouper fishery. Under the theme "Reversing the Decline", a Nassau Grouper Fishery Management Workshop was held during the Bahamas Natural History Conference 2016 to outline key components and promote the establishment of a comprehensive national Nassau grouper sustainable management plan for The Bahamas (see workshop objectives).

Workshop introductions were led by Krista Sherman and meeting norms were established for the session. This was followed by a brief presentation by K. Sherman to outline previously agreed upon priorities and strategies that were discussed during the 2013 Nassau Grouper National Conservation Strategy Meeting. Dr. Kristine Stump and Casuarina McKinney-Lambert provided updates on research and education/outreach activities respectively toward achieving 2013 goals. Information about the pilot Nassau grouper aquaculture project that is currently underway at Tropic Seafood was shared by Jon Chaiton. Michael Braynen delivered the final presentation on current fishery regulations and enforcement in The Bahamas.

These presentations set the stage for a structured break-out session with stakeholders. The discussions that followed were used to gather additional input about the status of the fishery as well as advancing existing and future policies to promote recovery of Nassau grouper populations in The Bahamas. Participants were divided into two smaller groups to complete a SWOT analysis[1] of the Nassau grouper fishery. Notes from each group were recorded by facilitators. Specifically, each group addressed the following questions (which were also provided via email a week prior to the workshop):

1. How would you characterize/describe (e.g. status, primary gears used, no. of people involved, etc.) the Nassau grouper fishery in your island? in The Bahamas?
2. In your opinion what are the strengths/benefits of the Nassau grouper fishery?
3. How would your rank/prioritize these strengths/benefits?
4. In your opinion what are the threats/issues facing the Nassau grouper fishery?
5. How would you rank/prioritize these threats/issues?
6. Do you have any recommendations on how these threats/issues can be addressed?

After reporting out from the small group exercises to the larger group, there was insufficient time to completely address workshop objectives 3 and 4, which were to identify short and long-term goals to promote the development of a comprehensive Nassau grouper management and conservation strategy for The Bahamas, and individuals/organizations and timelines to support various components of the national conservation plan (see workshop objectives).

Anticipated outcomes of this workshop included the formation of a multi-sector working group and Nassau grouper technical advisory committee comprised of policy-makers, law enforcement officials, fishermen, marine resource managers, scientists, non-governmental organizations (NGOs) and the private sector. It is envisioned that these groups will work together to identify management alternatives and strategies to promote a sustainable Nassau grouper fishery for The Bahamas. Closing remarks were given by Dr. Craig Dahlgren. A summary of the minutes from the workshop is provided within this report. The participant list and agenda are provided as Appendix I and II, respectively.

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[1]Please review spreadsheet for details from the SWOT Analysis.

Workshop Objectives:

1) Status update on national research, conservation and outreach priorities outlined in 2013 for Nassau grouper stocks in The Bahamas.
2) Summarize progress on Nassau grouper research in the country.
3) Identify short and long-term goals to promote the development of a comprehensive Nassau grouper management and conservation strategy for The Bahamas.
4) Identify individuals/organizations and timelines to support various components of the national conservation plan.

Workshop Minutes

Characterizations of the Nassau Grouper Fishery

Mr. Braynen confirmed that Nassau grouper are not exported from The Bahamas due to within-country demand fulfilling and/or surpassing supply. A variety of methods are used to capture groupers. These include hand-line fishing, free and compressor diving with spears, recreational drop lines, and pots or fish traps, which are the most frequently used method to catch groupers. Concerns were expressed over the status of the fishery from participants residing in different islands. In Eleuthera, there is no attention to regulations. All gears are being used even during the closed season. Harvesting of parrotfish has also increased as a substitute for Nassau grouper and other traditionally eaten fish (e.g. snappers). This emerging fishery is currently not regulated and is spreading throughout the country. Nassau grouper are consistently seen hitting the docks during the closed season in New Providence (e.g. Potter's Cay and Montague). Tourists are also reported to be fishing them year-round in areas such as Bimini. In Acklins, Nassau grouper are also being harvested year-round.

Key Challenges/Issues

"We can inform thousands of people, but are we already at the point of no return with the grouper population? How do we better enforce the laws already in place?" *– T. Thompson*

A number of challenges and issues relating to Nassau grouper conservation were brought-up and discussed. One of the key areas discussed was relating to enforcement, monitoring and compliance. A question was raised as to how we can enforce the laws we already have. Responses from the group included securing funding to strengthen the resources and capacity to assist with enforcement, monitoring/research, education and advocacy.

The following non-prioritized issues were raised during the workshop as barriers to Nassau grouper conservation:

- Inadequate enforcement – huge area to cover
- Non-compliance with current fishery regulations (e.g. illegal domestic and foreign fishing)
- Lack of effective education/outreach
- Lack of training and resources for Fisheries Officers and other law enforcement representatives
- Officers may choose not to enforce the law because fishermen know where they live and they are part of these communities
- Lack of administrative penalties for violating fishery regulations
- Reluctance of fishermen to reveal locations of other FSAs (e.g. High Cay was closed to fishing once this location was provided by fishermen)
- Scientific gaps with regards to status of Bahamian Nassau Grouper FSAs and stock size.

Recommendations

"The best way to communicate science to fishermen is to go to the fishing community and talk to the fishermen directly. Send teams to areas/islands because fishermen are not educated on the issue. Put signs up around the islands that say when seasons are closed". – *Dwain "Tall Boy" Bastian*

The group also discussed possible ways to overcome these challenges. With regards to enforcement, it was recommended that Fisheries Officers be sent to docks since it is cheaper than patrolling via boat. Fishermen also volunteered to use their boats to help with enforcement. However, Mr. Braynen advised that this would require a policy change to address liability issues. The Department of Marine Resources also has 12 new Fisheries Officers that will be assigned to various islands throughout the country. Fishermen noted that mailboats often have bags of grouper and these should also be inspected. Consensus from the group was that stricter penalties need to be implemented at an administrative level to act as a deterrent. Examples discussed included issuing tickets and increasing fines.

In terms of education and outreach, a suggestion was also made to have regular trainings for enforcement officers and other regulatory agencies so that they are aware of all fishery regulations (e.g. size limits, closed seasons, gear restrictions), locations of MPAs, boundaries, etc. NGOs are also willing to cross-post existing educational materials on other islands. However, new approaches need to be developed and tested to target market-demand issues. Recommendations included the development of materials for tourists, hotel associations, fish processing plants/vendors and restaurants as they help to create the demand for Nassau grouper.

It was also stated that we need to find better ways to engage fishermen. Fishermen advised that the best way to communicate science and relevant information to the local fishing communities is through one-on-one conservations, posting on informational boards at landings sites and identifying and training a few fishermen that are willing to represent each island and educate other fishermen.

There is also a need to understand and address fisher's perceptions and concerns as these vary throughout the country. The viewpoints below are reflective of the fishermen who attended the workshop:

- Some fishermen believe that fish size has increased since the ban.
- Some fishermen think that Nassau groupers have spread out to other areas as some aggregations disappear, but new aggregations are forming in other areas.
- Spearing is bad because it "breaks up schools and attracts sharks", which is dangerous for fishermen. The method that should be practiced more is bringing live fish to the boat. This was done in the past and some fishermen believe that it should resume because it helps to limit the numbers of fish that can be caught at a time. Only fish that could fit into a live well were caught. "Divers would bring live fish to the boat. Hold fish under arm, stick under left fin with needle to release air then bring to the surface". Concern was still raised with regard to this method because it sounds like it occurred at during spawning aggregations.

Other points raised included the need to improve upon data collection including the quality and consistency of fishery-dependent data (e.g. landings) to better understand trends in the fishery. The fishery data collected does not accurately reflect all Nassau grouper landings and excludes recreational and subsistence fishery data. Increasing reports of sea turtles being harvested and sharks being killed also highlight the need for better "follow through" with law enforcement, education and outreach. Additional needs include addressing knowledge gaps relating to the status of spawning stocks (currently underway) and undertaking an economic evaluation of the Nassau grouper fishery. Other organizations or agencies that could potentially be contacted to assist with ongoing conservation efforts include the Royal Bahamas Defence Force (RBDF), Royal Bahamas Police Force (RBPF) Customs, Ministry of Tourism and the Maritime Authority.

Next Steps

Securing funding to complete the various tasks associated with Nassau grouper conservation management remains a top priority. Reducing this funding gap is likely to help address issues with increasing capacity and resources available for consistent research, FSA monitoring, fishery regulatory enforcement and expanding education and outreach programmes tailored to various groups. Next steps are to:

- Review and provide comments on the workshop report
- Provide feedback and prioritize the SWOT analysis
- Form a multi-sector Nassau grouper working group
- Assign a point-person within each agency to become a member of the Nassau grouper working group

- Identify possible sources of funding (actual and in-kind) for a socioeconomic evaluation of the fishery, research into the status and health of grouper stocks, and communications to key stakeholders and the general public about the closed season
- Incorporate “low-hanging fruit” activities into organizational workplans
- Complete a questionnaire that will be used to pilot test a national survey on the Nassau grouper fishery.

Appendix I: Workshop Participants

Attendees

1. Michael Braynen (Director, Department of Marine Resources)
2. Eric Carey (Executive Director, Bahamas National Trust)
3. Casuarina McKinney-Lambert (Director, BREEF)
4. Jon Chaiton (Quality Assurance & Aquaculture Manager, Tropic Seafood)
5. Leroy Miller (Immigration Officer, Department of Immigration
6. Tavares Thompson (Fisherman & Entrepreneur, Andros)
7. Henry Bannister (Fisherman, Bahamas Commercial Fishers Alliance)
8. Dwain Bastian (Fisherman, New Providence)
9. Indira Brown (Assistant Fisheries Officer, Department of Marine Resources)
10. Lindy Knowles (Senior Science Officer, Bahamas National Trust)
11. Frederick Arnett (Conservation Practitioner, The Nature Conservancy)
12. Dr. Aaron Shultz (Scientist, Fisheries Conservation Foundation)
13. Candice Brittain (Applied Scientific Research Department Head, Cape Eleuthera Institute)
14. Angela Rosenberg (Director of Programs and Policies, International SeaKeepers Society)
15. Dr. Mark Bond (Consultant, Moore Charitable Foundation)

Facilitators

1) Krista Sherman (PhD Candidate, University of Exeter)
2) Dr. Kristine Stump (Postdoctoral Associate, Shedd Aquarium)
3) Dr. Craig Dahlgren (Senior Scientist, Bahamas National Trust)
4) Janeen Bullard (Environmental Specialist)

Apologies

1. Shenique Albury-Smith (The Nature Conservancy)
2. Kristin Williams (Friends of the Environment)
3. Catherine Booker (The Exuma Foundation)
4. Nick Rademaker (Harbourside Marine)
5. Dr. Valierre Deleveaux (BAMSI)
6. Mia Isaacs (Bahamas Marine Exporters Association)
7. Vanessa Haley-Benjamin (College of The Bahamas)

Appendix II – Agenda

Nassau Grouper Fishery Management Workshop

Date: Thursday, March 17th, 2016

Time: 1:00-3:00 PM

Venue: Harry C Moore Library Bibliographic Instruction Classroom, College of The Bahamas

Time	Topic	Name
1:00-1:05 PM	Welcome and Introductions	Krista Sherman (Research Scientist)
1:10-1:20 PM	Research Guided Policy-Making	Krista Sherman, Research Scientist
1:25-1:35 PM	Summary of Research Findings	Dr. Kristine Stump, Shedd Aquarium
1:40-1:50 PM	Education & Outreach	Casuarina McKinney-Lambert (BREEF)
1:55-2:00 PM	New Approaches to Commercial Fisheries	Jon Chaiton, Tropic Seafood
2:05-2:15 PM	Overview of Fishery Regulations & Enforcement	Michael Braynen, Director of Marine Resources
2:20-2:50 PM	Developing a National Nassau Grouper Conservation Plan	Focused Group Discussion (Moderator: Janeen Bullard) & Facilitators
2:50-3:00 PM	Conclusion	Dr. Craig Dahlgren, Research Scientist