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Seventh Meeting of the Scientific and Technical Advisory Committee (STAC7) to the Protocol Concerning Specially Protected Areas and Wildlife (SPAW) in the Wider Caribbean Region

Miami, Florida, 2- 4 November 2016

Proposals Submitted by Parties of Species for listing under the Annexes of the SPAW Protocol

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United States of America

Nomination of the Nassau grouper (Epinephelus striatus)

for inclusion in Annex III

United States of America

Nomination of the Nassau grouper (*Epinephelus striatus*) for inclusion in Annex III of the Protocol on Specially Protected Areas and Wildlife in the Wider Caribbean Region of the Convention for the Protection and Development of the Marine Environment in the Wider Caribbean Region (SPAW Protocol)

I. Nomination Requirements

Requirements regarding species nomination are set forth in SPAW Protocol Articles 11, 19, and guidelines and criteria adopted by the Parties pursuant to Article 21. The procedures to amend the annexes, contained in Article 11(4), state that ñany Party may nominate an endangered or threatened species of flora or fauna for inclusion in or deletion from these annexes,ò and that, after review and evaluation by the Scientific and Technical Advisory Committee, the Parties shall review the nominations, supporting documentation and the reports of the Scientific and Technical Advisory Committee and shall consider the species for listing. Such a nomination is to be made in accordance with guidelines and criteria adopted by the Parties pursuant to Article 21. As such, this nomination addresses the 2014 ñRevised criteria for the listing of species in the Annexes of the Protocol Concerning Specially Protected Areas and Wildlife (SPAW) and Procedure for the submission and approval of nominations of species for inclusion in, or deletion from Annexes I, II and III.ò Finally, Article 19(3) lists the type of information that should be included, to the extent possible, in reports relevant to protected species.

Article 1 of the SPAW Protocol defines Annex III as the ñthe annex to the Protocol containing the agreed list of species of marine and coastal flora and fauna that may be utilized on a rational and sustainable basis and that require the protection measures indicated in Article 11(1)(c).ò Further, Article 11 of the Protocol specifies that ñeach Party shall, in co-operation with other Parties, formulate, adopt and implement plans for the management and use of such speciesé ò

II. Nomination Statement and Description of Appendices

In accordance with these requirements, the United States nominates Nassau grouper (*Epinephelus striatus*) for inclusion in Annex III of the SPAW Protocol. We believe that the life history and migratory patterns of this species require a cooperative regional approach to conservation, as called for in Article 11(1).

The United States National Marine Fisheries Service (NMFS) on September 2, 2014, announced a 12-month finding on a petition from WildEarth Guardians to list the Nassau grouper (*Epinephelus striatus*) as threatened or endangered under the United States Endangered Species Act (ESA). This finding was published following the completion of a status review of the Nassau grouper. After reviewing the best scientific and commercial data available, NMFS determined that the Nassau grouper met the definition of a threatened species and proposed an ESA listing. The announcement contained a Biological Report, which is annexed as Appendix A to this nomination. The United States National Marine Fisheries Service received public comments, including international comments, on the proposed ESA listing and, after consideration of the public comments, NMFS made a final determination to list Nassau grouper under the ESA as threatened (likely to become in danger of extinction within the foreseeable future). The final ESA listing rule is Appendix B to this nomination.

Appendix C to this nomination is the report of the First Meeting of the Caribbean Fisheries Management Council (CFMC)/ Western Central Atlantic Fishery Commission (WECAFC)/ Central American Organization of the Fisheries and Aquaculture Sector (OSPESCA)/ Caribbean Regional Fishery Mechanism (CRFM) Working Group on Spawning Aggregations, Miami, 29-31 October 2013. The Declaration of Miami, produced by the workshop participants, recommended *inter alia,* regional harmonized closed seasons for specific species known to aggregate for spawning (starting with Nassau grouper and adding others as appropriate), collection and sharing of biological and trade data for the species. The Declaration also called for regional management and conservation of fish species that aggregate to spawn. Of most interest to the Parties to the SPAW Protocol, the Declaration of Miami recommended "that WECAFC members propose the listing of species that aggregate to spawn (in particular Nassau grouper and Goliath grouper) under Annex III of the SPAW Protocol…"

III. Substantiated Nomination Requirements to Support Inclusion in Annex III

Following is a review of information on Nassau grouper (*Epinephelus striatus*) to substantiate the nomination requirements presented in the **I. Nomination Requirements** section of this document. This review supports the inclusion of Nassau grouper in Annex III of the SPAW Protocol. More detailed information can be found in the Biological Report and final listing rule pursuant to the ESA (Appendices A and B).

A. Article 19(3) – Information to be included in reports relevant to protected species, to the extent possible

1. Article 19(3)(a) – Scientific and Common Names of the Species

Scientific Name: *Epinephelus striatus* (Block, 1792)

Common Name(s): Nassau grouper, Cherna, Cherna criolla

2. Article 19(3)(2) - Estimated Populations of Species and their Geographic Ranges

The Nassau grouper is made up of a single population over its entire geographic range and no clearly defined population substructuring has been identified (Hinegardner and Rosen 1972, Sedberry et al. 1996, Hateley 2005). Although a recent study (Jackson et al. 2014) reported genetic differentiation, it does not indicate a high degree of population structuring across the range. When the Jackson *et al.* study is considered in the context of the larger body of literature, there remains some uncertainty as to population substructuring for Nassau grouper.

The Nassau grouper is found throughout the Caribbean Sea from Bermuda to southern Brazil. It is native to the following countries: Anguilla; Antigua and Barbuda; Aruba; Bahamas; Barbados; Belize; Bermuda; Cayman Islands; Colombia; Costa Rica; Cuba; Curaçao; Dominica; Dominican Republic; French Guiana; Grenada; Guadeloupe;

Guatemala; Guyana; Haiti; Honduras; Jamaica; Mexico; Montserrat; Netherlands Antilles; Nicaragua; Panama; Puerto Rico; Saint Kitts and Nevis; Saint Lucia; Saint Vincent and the Grenadines; Suriname; Trinidad and Tobago; Turks and Caicos Islands; United States (Florida); United States Minor Outlying Islands; Venezuela, Bolivarian Republic of; Virgin Islands, British; Virgin Islands, U.S.

3. Article 19(3)(c) - Status of Legal Protection, with Reference to Relevant National Legislation or Regulation

As stated above, NMFS has made a final determination to list Nassau grouper under the ESA as threatened (likely to become in danger of extinction within the foreseeable future). The final listing rule is Appendix B to this nomination.

4. Article 19(3)(d) - Ecological Interactions with Other Species and Specific Habitat Requirements

Similar to most reef fishes, the habitat of Nassau grouper changes as the fish grow. Very small Nassau grouper are found in macroalgal clumps, seagrass beds, and coral (Eggleston 1995, Dahlgren 1998) in nearshore areas at depths between 1-4m. Microhabitat of newly settled Nassau grouper was described as within coral clumps (Porites spp.) covered by masses of macroalgae (primarily *Laurencia* spp.) although often the habitat has simply been cited as *Laurencia*. The open lattice of these algal-covered coral clumps provided cover and facilitated the movement of individuals within the interstices of the clumps (Eggleston 1995). Recently settled Nassau grouper have also been collected from tilefish, *Malacanthus plumieri*, rubble mounds at 18m, with as many as 3 fish together (Colin et al. 1997). They have been reported as associated with discarded queen conch, *Strombus gigas*, shells and other debris around *Thalassia* beds (Claydon et al. 2010, Wicklund , pers. comm.).

Small juvenile Nassau grouper are common in shallow seagrass beds, macroalgae, and around clumps of *Porites* spp. coral as they begin to shift from settlement habitats or microhabitats (Randall 1983, Eggleston 1995). As juveniles grow, they move from inshore patch reefs offshore to progressively deeper fore reef areas. As adults, Nassau grouper are classified as reef fish and they are found on reefs throughout the Caribbean. They utilize the reef for shelter and therefore do not require live coral or living habitat, simply some structure such as reef crevices or artificial structures.

As far as ecological interaction, information on predation upon groupers is largely lacking, although sharks were reported to attack Nassau groupers at spawning aggregations in the Virgin Islands (Olsen and LaPlace 1979) and there is one report of cannibalism in this species (Silva Lee 1974). No predation was observed on spawning fish in the Bahamas, despite the presence of sharks in the area (Colin 1992). One mutilated fish was recovered, possibly attacked by a barracuda or shark following release of tagged, laboratory-reared, naive individuals onto a reef in the Virgin Islands (Roberts et al. 1995). Early post-settlement juvenile preferences for macroalgae rather than seagrass beds are probably related, in part, to higher levels of predation in seagrass beds (Nadeau and Eggleston 1996). Reports of lionfish predation on small reef fish and small life stages are a concern throughout the Caribbean as the invasive spread has widened (Albins and Hixon 2008).

Little is published on either intra- or inter-specific competition in Nassau grouper. Juveniles exhibit aggression towards similar-sized conspecifics and display interspecific aggression (J. Dunham, Caribbean Marine Research Center, c/o Florida State Marine Laboratory, unpubl. report to the Caribbean Marine Research Center, March 29, 1989). When two non-reproductive adults, or an adult and large juvenile, encounter one another, the smaller fish acquires the bicolor pattern described for aggregating fish in apparent submission, then turns laterally and usually swims away (Colin 1992, P. Colin, Coral Reef Research Foundation – Palau, pers. comm. to Y. Sadovy, NMFS, 1990).

The Nassau grouper is a top-level predator on coral reefs. Nassau grouper are unspecialized-ambush-suction foragers (Randall 1965, Thompson and Munro 1978) that swallow prey whole (Werner 1974, 1977). Numerous studies describe Nassau grouper as piscivorous as adults (Randall and Brock 1960, Randall 1965, Randall 1967, Parrish 1987, Carter et al. 1994, Eggleston et al. 1998). This species takes many types and sizes of food and moves among different habitats, such as seagrass beds and coral reefs, at different life-history stages or reproductive phases, or while hunting.

5. Article 19(3)(e) - Management and Recovery Plans for Endangered and Threatened Species

We are not aware of any relevant management or recovery plans in the United States or elsewhere, although there is a wide array of regulatory mechanisms (including Bahamas, USA, Belize, Bermuda, Cayman Islands, Cuba, Mexico, Turks and Caicos, Colombia, and others) that exist throughout the range of the Nassau grouper that are intended to limit harvest and thus maintain abundance.

6. Article 19(3)(f) - Research Programs and Available Scientific and Technical Publications Relevant to the Species

Please refer to Appendices for a list of publications/references by particular researchers and research programs.

7. Article 19(3)(g) - Threats to the Protected Species, their Habitats and their Associated Ecosystems, Especially Threats which Originate Outside the Jurisdiction of the Party

The main threats to Nassau grouper are over-harvest and inadequacy of law enforcement. The targeted and heavy removal by fishing at spawning aggregation sites is a great concern in relation to the threat of over-harvest. The species has largely disappeared as a commercially important fish in most countries in the region because of these main threats. The known number of spawning aggregations for the species has plummeted, some no longer form, such as Cat Cay, Bimini, the first one ever described to science (Erisaman et al. 2013), and Mahahual, Mexico (Aguilar-Perera, A. 2014), and all known remaining aggregations are at least 10-fold smaller in fish number than they once were. The strong appeal of spawning aggregations as targets for fishing, their importance in many seasonal fisheries, and the apparent abundance of fish at aggregations make spawning aggregations particularly susceptible to over-harvest.

The vulnerability of this species to over-harvest calls for an evaluation of whether existing regulatory mechanisms are controlling or mitigating the threat of overexploitation. Regulatory mechanisms for this species are inadequate, which includes a consideration of whether enforcement of those mechanisms is adequate. The extent to which regulatory mechanisms could or do control the threats that are contributing to the Nassau grouper's decline is a key threat. The United States' final ESA listing rule (Appendix A) examined regulatory mechanisms of the Bahamas, Belize, Bermuda, Cayman Islands, Cuba, Mexico, Turks and Caicos, USA, Colombia, Dominican Republic, and the British Virgin Islands.

B. Article 21 – Establishment of Common Guidelines or Criteria

The 2014 "Revised criteria for the listing of species in the Annexes of the Protocol Concerning Specially Protected Areas and Wildlife (SPAW) and Procedure for the submission and approval of nominations of species for inclusion in, or deletion from Annexes I, II and III" enumerated specific factors to be included in the threats analysis of a scientific evaluation of the threatened or endangered status of the nominated species. Factors for the purpose of the scientific evaluation of threatened or endangered status, specifically outlined in the criteria, are reviewed here and addressed in further detail in Appendix A and B of this nomination.

1. Size of Populations

The International Union for Conservation of Nature (IUCN) Red List of Threatened Species reports that estimates of country stock size of Nassau Grouper are rare, but also estimates current population size at >10,000 mature individuals with an estimated population decline of at least 60% over the last three generations (27-30 years). Because the estimated decline of 60% meets one of the IUCN criteria for a species at high risk of extinction in the wild, IUCN classifies the Nassau grouper as "endangered." The IUCN first classified Nassau grouper as endangered in 1996; the most recent assessment occurred in 2003 and Nassau grouper retained the IUCN classification of "endangered."

2. Evidence of Decline

Other than the IUCN estimate, there is a lack of sufficient stock assessments or population estimates for the Nassau grouper, so spawning aggregation trends can be used as a proxy for population trends. The status of spawning aggregations is likely to be reflective of the overall population, because adults migrate to spawning aggregations for the only known reproductive events. Historically, fifty spawning aggregation sites had been identified throughout the Caribbean (Sadovy de Mitcheson et al. 2008). Of these 50, less than 20 probably still remain (Sadovy de Mitcheson et al. 2008). Furthermore, while numbers of fish at aggregation sites [once] numbered in the tens of thousands (30,000–100,000 fish; Smith 1972), they have now been reduced to less than 3,000 at those sites where counts have been made (Sadovy de Mitcheson et al. 2008). In general, slow-growing, long-lived species (such as snappers and groupers) with limited spawning periods and, possibly, with only a narrow recruitment window are susceptible to overexploitation (Bannerot et al. 1987, Polovina and Ralston 1987).

There are reports from across the Caribbean where Nassau grouper spawning aggregations have repeatedly been discovered, fished, and then ceased to exist, or exist at such low densities that spawning fails. Nassau grouper were exclusively fished during aggregation formation during the 1970's in Bermuda. Commercial landings in 1975 were 75,000 tons; by 1981, landings had fallen to 10,000 tons (Sadovy de Mitcheson and Erisman 2012). The four known spawning aggregation sites ceased to form shortly after and have still not recovered (Sadovy de Mitcheson and Erisman 2012). In Mahahual, Quintana Roo, Mexico, aggregations of up to 15,000 fish formed each year at the same site, but due to increased fishing pressure in the 1990's, aggregations have not formed since 1996, and management measures designed to protect spawning aggregations are not enforced (AguilarPerera 2007). Nassau grouper were almost exclusively targeted during aggregation formation in Cuba; because of this, 20 of the 21 known aggregations no longer form (Claro et al. 2009). In Belize there has been an eighty percent decline in the last 25 years in size of the Glover's Reef aggregation (15,000 fish to 3,000). Additionally, only 2 of the 9 known aggregations still formed as of 2001, and those had been reduced from 30,000 fish to 1,000–5,000 fish. Recent work has identified 15 spawning aggregation sites in Belize. Seven of these sites were monitored for a ten year period (2003–2012). The number of fish counted at all seven sites has remained very low (five sites have less than 170 fish, the other two have 1,050 and 1,350), with no sign of recovery (Belize SPAG workgroup 2012). Similar situations are known to have occurred in in the Bahamas, U.S.V.I., Puerto Rico, and Honduras (Sadovy de Mitcheson and Erisman 2012, see also Hill and Sadovy de Mitcheson 2013).

Further indicators of population decline are the reduced size and/or age of fish in many of the spawning aggregations that remain. It is unusual to obtain individuals of more than 12 years of age in exploited fisheries, with more heavily fished areas yielding much younger fish on average. The maximum age estimate in the heavily exploited U.S.V.I. population is 9 years (Olsen and LaPlace 1979), 12 years in northern Cuba, 17 years in southern Cuba (Claro et al. 1990), and 21 years from the Bahamas, (Sadovy and Colin 1995). Most individuals caught from a U.S.V.I. spawning aggregation were between about 500 and 600 mm TL (Olsen and LaPlace 1979). Nemeth et al. (2006) found that adult Nassau grouper at a different spawning aggregation site (Grammanik Bank) in the U.S.V.I. ranged between 480 and 800 mm with average total length for males (603 mm, n = 18) and females (591 mm, n = 44) being similar.

3. Restrictions on its Range of Distribution

The Nassau grouper's confirmed distribution currently includes "Bermuda and Florida (USA), throughout the Bahamas and Caribbean Sea" (e.g., Heemstra and Randall 1993). The species is broadly distributed, and its current range is similar to its historic range. This conclusion is based on the Range Wide Distribution section of the Biological Report (Appendix A), which concluded that available information suggests that the current range is equivalent to the historic range although abundance has been depleted.

4. Degree of Population Fragmentation

There is no indication that population fragmentation is an operative threat to Nassau grouper. As stated above in III.A.2, the Nassau grouper is made up of a single population over its entire geographic range, with no evidence of a range contraction.

5. Biology and Behavior of the Species, as well as other Aspects of Population Dynamics

As mentioned previously, the spawning behavior of this species makes it susceptible to overexploitation. The Nassau grouper migrates to predictable places at predictable times to spawn during only a few weeks each year. Reproduction is only known to occur during annual aggregations, in which large numbers of Nassau grouper, ranging from dozens to tens of thousands, collectively spawn (Smith 1972, Olsen and LaPlace 1979, Colin et al. 1987, Fine 1990, Fine 1992, Colin 1992). Many fish travel long distances to arrive at predictable places during the few weeks, spread over several months, each year when spawning occurs and then return to their home reefs (Sadovy and Eklund 1999).

The Nassau grouper aggregates in large numbers to spawn each year; the largest aggregation studied had an estimated 30,000-100,000 spawning fish (Smith 1972) in Bimini, Bahamas. As far as is known, all reproductive activity occurs in these aggregations that form consistently at specific sites ("grouper holes") and times. Aggregations have consisted of hundreds, thousands, or, historically, tens of thousands of individuals and have persisted at known locations for periods of 90 years or more (Smith 1972, Olsen and LaPlace 1979, Colin et al. 1987, Fine 1990, 1992, Colin 1992, Carter et al. 1994, Sadovy 1997, R. Claro, Laboratory of Fish Ecology – Cuba, pers. comm. to Y. Sadovy, NMFS, 1991).

6. Other Conditions Clearly Increasing the Vulnerability of the Species

As described in the threats III.A.7 section above, our U.S. ESA listing rule found that overharvest and inadequate law enforcement are the two main threats to Nassau grouper. Appendix A and B provide more detail in addition to III.A.7.

7. Importance of the Species to the Maintenance of Fragile or Vulnerable Ecosystems and Habitats

As a top predator in fragile reef ecosystems, the Nassau grouper serves ecological functions that are still being clarified (Mumby et al. 2006). Its presence maintains grazers and grazing pressure on reef alga providing an important benefit to stony corals (Mumby et al. 2006). The predatory Nassau grouper may help limit the impact of the invasive lionfish, but the evidence is far from conclusive at this time (Mumby et al. 2011). Its absence has been speculated to affect ecological release for smaller predators, including small groupers, with resultant changes in the trophic relationships in reef ecosystems (Stallings 2008, Mumby et al. 2012).

C. Article 11(1) - Usefulness of Regional Cooperative Efforts

Nassau grouper are known to migrate hundreds of kilometers, crossing jurisdictional boundaries, to reach specific spawning locales. As presented numerous times, these aggregations sites are transient, site specific and are usually known by local fishermen who fish them intensely during the spawning period at these known spawning aggregation sites (Bolden, 2000). Over-harvest is especially concerning due to the large concentrations of Nassau grouper at small nearshore locations.

As presented in Appendix C to this nomination, the report of the First meeting of the Caribbean CFMC/ WECAFC/OSPESCA/CRFM Working Group on Spawning Aggregations, recommended *inter alia*, regional harmonized closed seasons for specific species known to aggregate for spawning (starting with Nassau grouper and adding others as appropriate), collection and sharing of biological and trade data for the species, and regional management and conservation of fish species that aggregate to spawn.

Nassau Grouper, *Epinephelus striatus* (Bloch 1792)

Biological Report

PURPOSE

This report summarizes and synthesizes biological information covering Nassau grouper, *Epinephelus striatus*, throughout its natural distribution. It seeks to present the best available information from published and unpublished sources, (e.g., literature searches, interviews). This document does not represent a decision by NMFS on whether this taxon should be proposed for listing as threatened or endangered under the Endangered Species Act.

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INTRODUCTION

The Nassau grouper, *Epinephelus striatus*, is a large member of the family Serranidae (Sea Basses and Groupers). As with many serranids, the Nassau grouper is slow growing, long-lived and slow to mature. It is fished with spear, traps, and hook-and-line. The Nassau grouper migrates to predictable places at predictable times to spawn during only a few weeks each year. In many locations aggregation-fishing may produce the bulk of annual landings of the species.

Commercial and recreational landings data between 1986-91 shows that the Nassau grouper harvest in the US decreased both in terms of pounds landed and average size. As a result of this decrease in yield, the Caribbean (1990), South Atlantic (1991) and the Gulf of Mexico (1996) Fishery Management Councils and the state of Florida (1993) prohibited take and possession of Nassau grouper. Currently all three Councils classify them as "overfished." In 1991, the National Marine Fisheries Service declared Nassau grouper to be a "species of concern" under the Endangered Species Act. Nassau grouper was classified as "Endangered" in the IUCN (World Conservation Union) Red list following a 2003 assessment that showed population declines of approximately 60% over the previous three generations (27-30 years). The American Fisheries Society (AFS) considers the Nassau grouper as "Threatened" in the U.S. and Mexico (Musik et al. 2000).

This report is intended to document the current state of knowledge of Nassau grouper, throughout its biological range. It borrows sections generously from an earlier NOAA Technical Report, NMFS 146 (Sadovy and Eklund 1999), and a recent Caribbean Fishery Management Council report (Sadovy de Mitcheson 2012), with additional information added from other publications, reports and personal accounts. In an attempt to consolidate and streamline the relevant information some references to reports, communications, tables, and figures point to those two original reports; they are considered companions to this report.

1. NATURAL HISTORY

1.a. Description of species

General Overview. The Nassau grouper is, primarily, a shallow-water, insular species that has long been valued as a major fishery resource throughout the wider Caribbean, South Florida, Bermuda and the Bahamas (Carter et al. 1994). As with many serranids, the Nassau grouper is slow-growing and long-lived; estimates range up to 29 years (Bush et al. 1996). The Nassau grouper is considered a reef fish, but it transitions through a series of ontogenetic shifts of both habitat and diet. As larvae they are planktonic. As juveniles, they are found in nearshore shallow waters in macroalgal and seagrass habitats. They shift progressively deeper with increasing size and maturation into predominantly reef habitat (e.g., forereef and reef crest). Adult Nassau grouper tend to be relatively sedentary and are found most abundantly on high relief coral reefs or rocky substrate in clear waters (Sadovy and Eklund 1999), although they can be found from the shoreline to about 100-130 m. Larger adults tend to occupy deeper, more rugose, reef areas (Semmens et al. 2007a). Both adults and juveniles will use either natural or artificial reefs (Smith 1971, Beets and Hixon 1994, Colin et al. 1997).

As a top predator in reef ecosystems, the Nassau grouper serves ecological functions that are still being clarified (Mumby et al. 2006). Its presence maintains grazers and grazing pressure on reef alga providing an important benefit to stony corals (Mumby et al. 2006). The predatory Nassau grouper may help limit the impact of the invasive lionfish, but the evidence is far from conclusive at this time (Mumby et al. 2011). Its absence has been speculated to affect ecological release for smaller predators, including small groupers, with resultant changes in the trophic relationships in reef ecosystems (Stallings 2008, Mumby et al. 2012).

As with most large marine reef fishes, Nassau grouper demonstrate a bi-partite life cycle with demersal juveniles and adults but pelagic eggs and larvae. Reproduction is only known to occur during annual aggregations, in which large numbers of Nassau grouper, ranging from dozens to tens of thousands, collectively spawn (Smith 1972, Olsen and LaPlace 1979, Colin et al. 1987, Fine 1990, Fine 1992, Colin 1992). Many fish travel long distances to arrive at predictable places during the few weeks, spread over several months, each year when spawning occurs and then return to their home reefs (Sadovy and Eklund 1999). Fertilization is external. Fertilized eggs hatch after 23 to 40 hours depending on environmental temperatures. After hatching, pelagic larval duration may range from 42-70 days with transformation from pelagic to demersal form occurring in less than one week (Powell and Tucker 1992, Tucker and Woodward 1994). Newly settled fish (mean = 31.7 mm Total Length (TL), standard deviation (SD) = 2.9, N = 31) near Exuma Cays, Bahamas, were found within coral clumps (*Porites* spp.) covered by masses of macroalgae (primarily the red alga *Laurencia* spp.).

Nassau Grouper Juvenile Stages

Newly settled juveniles (~2.5 – 5 cm TL). Following settlement, Nassau grouper juveniles are reported to inhabit macroalgal clumps, seagrass beds, and coral (Eggleston 1995, Dahlgren 1998). Most of what is known about the earliest life stages comes from a series of studies conducted from 1987-1994 near Lee Stocking Island in the Exuma Cays in the Bahamas. The surveys and experiments in mangrove-lined lagoons and tidal creeks (1-4 m deep), seagrass beds and sand/patch reef habitats helped identify the Nassau grouper's series of ontogenetic habitat changes. Some variation exists in the exact body size at which habitat shifts occur but shifts are common across studies. Microhabitat of newly settled Nassau grouper was described as within coral clumps (*Porites* spp.) covered by masses of macroalgae (primarily *Laurencia* spp.), although often the habitat has simply been cited as *Laurencia*. The open lattice of the algal-covered coral clumps provided cover and facilitated the movement of individuals within the interstices of the clumps (Eggleston 1995). Several newly-settled Nassau grouper (up to 8) were found close together in neighboring algal clumps. Abundance of late-larval to early-juvenile

Nassau grouper was substantially higher in *Laurencia* spp. habitats than in seagrass. Within the Barraterre Bay macroalgal system, percent algal cover was correlated with post-settlement grouper density; other habitat characteristics such as algal displacement volume, and the numbers of holes, ledges, and corals, were not (Eggleston 1995). The functional relationship between percent algal cover and post-settlement density was linear and positive (Eggleston 1995). Recently-settled Nassau grouper have also been collected from tilefish, *Malacanthus plumieri*, rubble mounds at 18 m, with as many as 3 fish together (Colin et al. 1997). They have been reported as associated with discarded queen conch, *Strombus gigas*, shells and other debris around *Thalassia* beds (Claydon et al. 2010, B. Wicklund, Caribbean Marine Research Center, pers. comm. to Y. Sadovy, NMFS, 1990) in the Turks and Caicos Islands, although the exact fish sizes observed are not clear. Post-settlement survival in macroalgal habitats is higher than in seagrass beds, showing a likely adaptive advantage for the demonstrated habitat selection (Dahlgren and Eggleston 2000).

Early juveniles (~4.5 – 15cm TL). Small juvenile Nassau grouper are common in shallow seagrass beds, macroalgae, and around clumps of *Porites* spp. coral as they begin to shift from settlement habitats or microhabitats (Randall 1983, Eggleston 1995). The relationship between *Laurencia* and new settler and early juvenile densities was maintained until about 5 months after settlement. After that time, mortality as well as movement to patch reef habitat reflect changes in distribution and abundance (Eggleston 1995). Band transects performed near Lee Stocking Island, Bahamas, 4-5 months after the settlement period (June 1991-93) found that early juveniles demonstrated a subtle change in microhabitat; 88% were solitary within or adjacent to algal-covered coral clumps. Reef habitats, including solution holes and ledges, took on comparatively greater importance as habitats for early juveniles as they grew. Repeated monthly censuses of a presumed cohort indicated that juvenile density decreased sharply after settlement, until fish emerged from algal habitat at several months of age, and thereafter remained relatively constant (Dahlgren 1998). On shallow constructed block reefs in the Virgin Islands, 30-80 mm TL newly settled/early juveniles occupied small separate burrows beneath the reef while larger juveniles occupied holes in the reefs (Beets and Hixon 1994).

During the sampling period in 1993 around Lee Stocking Island, mean size increased from 31.7 to 85.0 mm TL (~ 10 mm/month). Growth rates were consistent with those reported for early juveniles inhabiting artificial patch reefs in the U.S.V.I. (Beets and Hixon 1994). Habitat usage of newly settled juveniles reportedly maximizes survival while habitat shifts for early juveniles and juveniles facilitate increased growth rates (Dahlgren and Eggleston 2000).

Juveniles (~15 – 35; 30 – 50cm TL). Juvenile Nassau grouper are relatively solitary and, while they remain in specific areas for extended periods (Bardach 1958), they may exhibit distinct ontogenetic shifts in habitat and diet as sizes increase. Juveniles in the Bahamas shifted from macroalgal habitats to natural and artificial patch reefs over a 3-month period at 120-150 mm TL (Eggleston 1995). A subsequent gradual shift appears to occur at between 300 and 350 mm TL from inshore patch reefs to forereef areas (Dahlgren et al. in prep) although all noted shifts are likely to be highly dependent on available habitat and the researchers' abilities to distinguish and test for them. As juveniles grow, they move progressively deeper, to deeper water banks and offshore reefs (Tucker et al. 1993, Colin et al. 1997). Schools of 30- 40 juveniles (250-350 mm TL) were observed at 8-10 m depths in the Cayman Islands (Tucker et al. 1993). Several of the juvenile stages show diversity in their tolerance for schooling versus a solidary existence. Recent work by Nemeth and coworkers in the U.S.V.I. (manuscript, in prep) found that smaller juveniles tend to show overlapping home ranges, but larger juveniles and adults tend to demonstrate more territoriality with larger home ranges.

Juveniles apparently have some familiarity with their surroundings and are able to home to residential reefs over short distances based on visual cues; blinded fish do not home (Bardach 1958). Ten recaptures, out of 11 fish originally tagged in Bermuda, demonstrated homing between isolated patch reefs separated by 100 m of sandy substrate (Bardach 1958). Over 12 months, in one area in Bermuda, a gradual turnover of individuals was detected until the original population had been replaced (Bardach 1958). In a classic tagging study in the U.S.V.I., the greatest distance traveled was 16 km in 12 days, although this was a large juvenile and possibly a maturing adult (Randall 1962, 1963). In the Florida Keys and the Virgin Islands, tagged, translocated juveniles exhibited strong home-reef specificity (Beaumariage and Bullock 1976, Beets and Hixon 1994). Twenty-seven tagged, 31-month old fish (310-380mm TL), which had been raised from eggs in captivity, survived at least 200 days in the field with one fish moving 12 km in eight days (Roberts et al. 1995). In the Bahamas, juveniles moved from inshore areas offshore to natural and artificial reefs within a year of settling out of the plankton (Eggleston 1995).

No clear distinction can be made between types of adult and juvenile habitats, although a general size segregation with depth occurs with smaller fish in shallow inshore waters (2 to 9 fathoms) and larger individuals more common on deeper (10 to 30 fathoms) offshore banks (Bardach et al. 1958, Cervigón 1966, Silva Lee 1974, Radakov et al. 1975, Thompson and Munro 1978). Adults lead solitary lives outside of the spawning season, rarely venturing far from cover (Bohlke and Chaplin 1993, Smith 1971, Carter et al. 1994, Sluka et al. l998).

Nassau Grouper Adult Stage

Size and age at maturity. Male and female Nassau grouper typically mature between 400 and 450 mm SL (440 and 504 mm TL), with most individuals attaining sexual maturity by about 500 mm SL (557 mm TL) and about 4-5 years of age (Table 1), although the smallest mature fish recorded in Cuba was a male in the 360-390mm TL size class (Claro et al. 1990). Olsen and LaPlace (1979) reported A_{95} (the age at which 95% of the asymptotic length is reached) is 15.9 years. In sampling fishery catches at Mahahual, southern Quintana Roo, Mexico, during 1991-1993 and 1997, Aguilar-Perera (2004) reported the smallest male as 390 mm TL and the smallest female as 460 mm TL. Most individuals caught from a U.S.V.I. spawning aggregation were between about 500 and 600 mm TL (Olsen and LaPlace 1979). Nemeth et al. (2006) found that adult Nassau grouper at a different spawning aggregation site (Grammanik Bank) in the U.S.V.I. ranged between 480 and 800 mm with average total length for males (603 mm, n = 18) and females (591 mm, n = 44) being similar. From otolith aging work, the minimum age at sexual maturity is between 4 and 8 years (Bush et al. 1996, 2006) with most fish spawning by age 7+ years (Bush et al. 2006). Nassau grouper raised from the egg in captivity matured at 27-28 months (400-450 mm SL/440-504 mm TL) (Tucker and Woodward 1994). Size, rather than age, may be the major determinant of sexual maturation (Sadovy and Eklund 1999).

Habitat and Home Range. Although there can be overlap between juvenile and adult habitats there is normally a positive correlation between size and depth. Nassau grouper are diurnal or crepuscular in their movements (Collette and Talbot 1972) and do not usually move far from cover (Starck and Davis 1966). Three sonically tagged fish were most active in the hours prior to and

Table 1. Summary of Age and Length Parameters for Nassau grouper, *Epinephelus striatus* (from Table 3, Sadovy and Eklund 1999; "Bush et al., in press" refers to Bush et al. 2006)

	Epinephelus striatus
Age and length at maturity	5 yrs, 580 mm SL (Virgin Islands) (Olsen and LaPlace, 1979) 420-450 mm SL females 400-450 mm SL males\4+ yrs (Cayman Islands) (Colin et al., 1987; Bush et al., in press) 500 mm TL (minimum size ripe males) (Cayman Islands) (Tucker et al., 1993) 425 mm SL females; 402 mm SL males, immatures are 3-6 yrs (otolith growth zones not validated) (Bahamas) (Sadovy and Colin, 1995) 483 mm TL (North Carolina-Florida) (SAFMC, text footnote 24) 480 mm TL (Jamaica) (Thompson and Munro, 1978)
Age and length at first capture	< 300 mm TL & 4-5 yrs (Virgin Islands) (Olsen and LaPlace, 1979; CFMC, text footnote 26) 6-7 yrs (Cayman Islands) (Bush et al., in press) 275-625 mm TL (mean = 570) (Jamaica) (Thompson and Munro, 1978) 300-500 mm TL depending on size limits (North Carolina-Florida) (SAFMC, text footnote 46) 450 mm TL (South Florida) (Bohnsack, 1990)
Maximum age and length	1200 mm TL (CFMC, text footnote 26) 9 yrs, 910-960 mm SL (Olsen and LaPlace, 1979) (Virgin Islands) 17 yrs, 710 mm TL, 6700 g (Cuba) (Claro et al., 1990) 755 mm SL (Bermuda) (Bardach et al., 1958) 840 mm TL (Jamaica) (Thompson and Munro, 1978) 640 mm TL (Netherlands Antilles) (Nagelkerken, 1981) 29 yrs, 850mm FL (Cayman Islands) (Bush et al., in press)

following sunrise and sunset (Carter et al. 1994). Two of the fish moved randomly within a 160 m x 80 m rectangle during the day, returning in the evening to where they had initiated daily activities (Carter et al. 1994). Sullivan and de Garine-Wichatitsky (1994) estimated that individuals moved at least 400 m/day and 20 m or more from their home reefs. Mean home-range area was calculated at 18,305m^2 +/- 5,806 (SE) Bolden (2001). Nassau grouper had larger home ranges at less structurally complex reefs and resource availability (habitat and prey) influences home range size more than body size (Bolden 2001). Bolden (2001) investigated diel activity patterns via continuous acoustic telemetry and found Nassau groupers are more active diurnally and less active nocturnally with activity peaks at 1000 and 2000 hours. Nemeth and coworkers (University of the Virgin Islands, manuscript in prep) have found a significant positive relationship between body size and home range, for fish tagged in Lameshur Bay, St. John, with mean minimum convex polygon (MCP) variations from 89.5-9913.9 m^2. Recent studies in a marine reserve in Cuba suggest that relative densities may control movements, changes in location, and, possibly, home range size (Amargós et al. 2010).

Depth ranges. Adult Nassau grouper are generally associated with shallow reef habitats to depths of 100 m. Reports from fishing activities in the Leeward Islands show that although Nassau grouper was fished to 130 m, the greatest trap catches were from 52-60 m (Brownell and Rainey 1971). In Venezuela, Nassau grouper were cited as common to 40 m in the Archipelago Los Roques, but rare in northeastern islands (Cervigón 1966). Recent tagging studies in Belize have shown that individuals regularly descend to depths of at least 255m (Starr et al. 2007). The shift in depth followed spawning and was synchronous to an average of 71.9 m ± 0.1 (SE), with a maximum depth of 255 m, and persisted about 3 months, throughout the winter spawning season in Belize. Starr and co-authors (2007) hypothesized that these deep migrations might facilitate physiological recovery and/or that spawning might continue at depth, but the true purpose requires future research.

Sizes and size distribution. Mean male and female sizes are similar within a given area, or at a specific aggregation site, with some indication that sizes of both sexes decline in areas within a specific region with higher exploitation (reviewed in Sadovy and Eklund 1999). For example, in Belize, the average length of both sexes was 100 mm smaller in catches from exploited compared to unexploited aggregations (Carter et al. 1994). Individual Nassau grouper can live for almost three decades, but most fish collected are substantially smaller and presumably younger. Bush et al. (2006) reported that the oldest Nassau grouper in their study in the Cayman Islands was 29 years, based on an ageing study using sagittal otoliths.

Reproductive mode. The Nassau grouper was originally considered to be a monandric protogynous hermaphrodite, like most other groupers, with all males deriving from the sex change of adult females (Smith 1971, Claro et al. 1990, Carter et al. 1994). Evidence of the change from adult female to adult male in the Nassau grouper (i.e., fish undergoing sexual transformation whereby the gonads show degeneration of mature tissue of one sex and proliferation of reproductive tissue of the other), however, was weak (Sadovy and Shapiro 1987, Shapiro 1987). Other characteristics were found to be inconsistent with a diagnosis of monandric protogyny such as the strong male/female size overlap, the presence of males that develop directly from the juvenile phase, and the mating system (Colin 1992, Sadovy and Colin 1995).

Nassau grouper pass through a juvenile bisexual phase (the gonads consist of both immature spermatogenic and immature ovarian tissue) (Table 2), and mature directly as male or female (Sadovy and Colin 1995). Although the Nassau grouper is capable of changing sex following hormone injection-one Nassau grouper reproduced as a female and subsequently as a male approximately 6 months later, following an LHRH-a implant in captivity (W. Watanabe and W. Head, Caribbean Marine Research Center, pers. comm. to Y. Sadovy, NMFS, 1992, Watanabe et al. 1995b)-natural sex change has not been confirmed. The close affinity of this species with other hermaphroditic serranids accounts for the gonad structure of this species and although it may retain a capacity for natural sex change available evidence indicates that this is not typical and that the Nassau grouper is primarily gonochoristic (separate sexes) (Sadovy and Colin 1995).

Table 2. Gonadal maturity according to size for Nassau grouper (from Sadovy and Eklund 1999)

Stages of gonadal maturation for 230 *Epinephelus striatus* collected in the Bahamas between May 1988 and October 1990 (from Sadovy and Colin,1995- Fig. 3). Bisexual fish are those in which the gonads contain both ovarian and testicular tissue and include both immature (both male and female tissue immature) and mature (in parentheses) bisexuals.

Size class (mm SL)	Bisexual	Female Immature	Female Mature	Male Immature	Male Mature
151-200	1	1			
201-250	2				
251-300	8	3			1
301-350	11	3			1
351-400	15	2			
401-450	4	1	2	1	1
451-500	9		10		23
501-550	4(1)		36		15
551-600	(3)		33		9
601-650			13		4
651-700			5		6
701-750			1		1
Total	58	10	100	1	61

Spawning migrations. The Nassau grouper aggregates in large numbers to spawn each year; the largest aggregation studied had an estimated 30,000-100,000 spawning fish (Smith 1972) in Bimini, Bahamas. As far as is known, all reproductive activity occurs in these aggregations that form consistently at specific sites ("grouper holes") and times. Aggregations have consisted of hundreds, thousands, or, historically, tens of thousands of individuals and have persisted at known locations for periods of 90 years or more (Smith 1972, Olsen and LaPlace 1979, Colin et al. 1987, Fine 1990, 1992, Colin 1992, Carter et al. 1994, Sadovy 1997, R. Claro, Laboratory of Fish Ecology – Cuba, pers. comm. to Y. Sadovy, NMFS, 1991).

It is not known how Nassau grouper select and locate aggregation sites or why they aggregate to spawn. Aggregations are typically located near significant geomorphological features, such as the ends of islands or projections (promontories) of the reef seaward from the general reef contour (Colin et al. 1987, Heyman and Kjerfve 2008). To locate a site, grouper could swim up- or down-current along the shelf break to reach the most seaward up-current extension of the reef where aggregation sites are generally located (Carter 1986, Colin et al.

1987). The timing and synchronization of spawning may be determined by the necessity for widely dispersed adults to coordinate their reproductive activities, may facilitate egg dispersal, may minimize egg dispersal, or minimize predation on adults or eggs (Colin 1992).

Prior to spawning, fish migrate toward aggregation sites in groups numbering between 25 and 500, moving parallel to the coast or along the shelf edge (Colin 1992, Carter et al. 1994, Aguilar-Perera and Aguilar-Davila 1996). Over 5 years of observations (2002-2006) in the Cayman Islands, migrating Nassau grouper were reported at the shelf edge, typically at depths ranging from 20 to 33 m. According to Whaylen et al. (2007): "Migrating grouper were mainly in the dark color phase, although the white belly phase was not uncommon." Peak numbers of migrating groupers were observed 2 to 3 days after full moon with clusters of up to 100 groupers traveling together along the wall towards the aggregation site. Nassau grouper migrating to the Grammanik Bank spawning site off St. Thomas, U.S.V.I. moved along a linear reef 300-500 m inshore rather than swimming along the actual shelf edge (Nemeth et al. 2009).

"*Corridas de desove*" (spawning runs), which refers both to the migration of fish toward a spawning site and to the aggregation itself, were first described in Nassau grouper from Cuba in 1884 by Vilaro Diaz, and later by Guitart-Manday and Juarez-Fernandez (1966). All three workers noted that fishers reported spawning runs occurring mainly between November and February and at different moon phases. It is not known whether *corridas* are exclusively associated with spawning or occur at other times, unassociated with reproductive activity.

During the several-month spawning season each year, Nassau grouper move from their residential habitats to spawning aggregation habitats. Spawners appear to show some site fidelity to the same aggregation sites year after year. Movement away from resident reefs occurs as spawning time approaches and distances traveled vary depending on distance to aggregation site. Distance traveled is highly variable. Some fish move only a few kilometers, but some individuals are known to travel up to several hundred kilometers to reproduce. Observations of migrating groups of fish, on or before the full moon of spawning, indicate that at least some fish travel to aggregation sites in groups ranging from a few fish up to about 500 individuals (Colin 1992). Several dozen fish were observed passing slowly along the 30-40 m shelf break contour at several localities along a reef in Belize in late October and early November (Carter et al. 1994); in other words, a month or two before spawning was likely. In Honduras, groupers normally located 48 km from an aggregation site disappeared from resident reefs at spawning time (Fine 1992). One tagged fish in the Bahamas covered a distance of at least 110 km in two months to an aggregation site (Colin 1992). Another fish, tagged on an aggregation site in Belize, was recaptured 2 years later 240 km north of the tagging site (Carter et al. 1994). A Nassau grouper (58 cm TL) tagged with an external tag for a home range study in the central Bahamas was released in July 1997 and recaptured 185 days later by a fisherman at the Long Island spawning aggregation approximately 220 km from the release point (Bolden 2000). Ongoing research in the Exuma Sound, Bahamas has tracked fish up to 200 km (125 mi) with likely estimates of up to 330 km (205 mi) as they move to spawning sites (C. Dahlgren, Perry

Institute for Marine Science Caribbean Marine Research Center, pers. comm. to R. Hill, NMFS SEFSC, 2013). Spawners migrating along larger contiguous reef tracts seem to move greater distances to aggregate than those on small islands or atolls; the constraint is likely their reluctance or inability to navigate extreme water depths to reach suitable habitat (Starr et al 2007).

From acoustic tagging studies around Glover's Reef, Belize, Starr et al. (2007) measured average swimming speed of Nassau grouper migrating to and from the spawning site as 1.90 ± 0.05 (SE) km/hour. The speed of movement to the spawning site was identical to the speed of travel away from the spawning site. They noted that several tagged groupers were recorded at receivers 30 km away from the spawning site and at the spawning site less than 24 hours later. They found sex based differences in swimming speed with mean speed of males, 2.0 ± 0.2 (SE), being significantly faster than female groupers, 1.8 ± 0.2 (SE) km/hr. They also used all swimming segments that were >5 km to evaluate time of day of grouper movements to the spawning site by, and found that 16 tagged fish moved only during the day (defined as 1 h before sunrise through to sunset) and 8 fish moved both during the day and at night. Grouper swim speeds during the day averaged 1.96 ± 0.03 (SE) km/hr and were significantly faster than mean grouper swim speeds at night (1.4 ± 0.1 km/hr).

Observations suggest that individuals can return to their original home reef following spawning. Several large adult Nassau grouper in the Bahamas, clearly swollen with gametes, disappeared from residential areas for periods ranging from 10 days before, to a few days after, the full moon of December 1989. They remained in home areas for the January 1990 full moon and were seen neither to swell with gametes nor to exhibit courtship behavior, suggesting that not all mature fish aggregate or spawn in every aggregation month in each reproductive season (P. Colin, Coral Reef Research Foundation – Palau, pers. comm. to Y. Sadovy, NMFS, 1990). Bolden (2001) reported tagged fish returning to home reefs in subsequent years. Sonic tracking studies around Little Cayman Island have demonstrated that spawners may return to the aggregation site in successive months with returns to or towards their residential reefs in between (Semmens et al. 2007). Larger fish are more likely to return and spawn in successive months than smaller fish (Semmens et al. 2007).

Spawning habitat. Spawning aggregation sites typically occur near the edge of insular platforms, as little as 50 m from the shore, and close to a drop-off into deep water over a wide (6-60 m) depth range and diversity of substrate types (Craig 1966, Smith 1972, Burnett-Herkes 1975, Olsen and LaPlace 1979, Colin et al. 1987, Carter 1989, Fine 1990, Beets and Friedlander 1992, Colin 1992, Aguilar-Perera 1994). Sites are characteristically small, highly circumscribed areas, measuring several hundred meters in diameter, with soft corals, sponges, stony coral outcrops, and sandy depressions (Craig 1966, Smith 1972, Burnett-Herkes 1975, Olsen and LaPlace 1979, Colin et al. 1987, Carter 1989, Fine 1990, Beets and Friedlander 1992, Colin 1992, Aguilar-Perera 1994). About 60-80 aggregation sites have been recorded, mostly from insular areas, although many no longer form. Recent work has identified geomorphological similarities in spawning sites that may be useful in applying remote sensing techniques to discover previously unknown spawning sites (Kobara and Heyman 2010). At spawning aggregation sites, Nassau grouper tend to meander around in a “staging area” adjacent to the core area where spawning activity actually takes place (Kadison et al. 2010, Nemeth 2012). These aggregation staging areas have been reported at depths of 6-50 m. As sunset approaches, the spawners typically move seaward, into slightly deeper water (30-60m). Spawning rushes have been described either as a column or cone of fish of different color phases rising to within 20-25 m of the water surface or as a series of rushes by small groups of males following a single female (Olsen and LaPlace 1979, Carter 1986, Aguilar-Perera and Aguilar-Davila 1996).

All spawning, as far as is known, occurs in distinct aggregations at sites that remain consistent over long time periods. There are no reports of pair spawning. Spawning aggregations have been reported from the Bahamas, Belize, Bermuda, British Virgin Islands, Cayman Islands, Cuba, Honduras, Jamaica, Mexico, Puerto Rico, Turks and Caicos and the U.S. Virgin Islands (Olson and LaPlace 1979, Colin et al. 1987, Carter 1988, Colin 1992, Aguilar-Perera and Aguilar-Davila 1996, Paz and Grimshaw 2001). Suspected or anecdotal evidence also identifies spawning aggregations in Los Roques, Venezuela (Boomhower et al. 2010) and Old Providence (Prada et al. 2004) in Colombia’s San Andrés Archipelago. Neither aggregation nor spawning has been reported from South America although ripe Nassau groupers are frequently taken in certain areas (F. Cervigón, Fundacion Cientifica Los Roques – Venezuela, pers. comm. to Y. Sadovy, NMFS, 1991). Aggregation spawning is likewise unknown from the Lesser Antilles, from Central America south of Honduras, or from Florida. The environmental and social triggers that cause Nassau grouper to aggregate are not well understood, although changing lunar light conditions, water temperature, currents, learned behavior, or a combination of these or other factors are the postulated basis for aggregation formation (Colin et al. 1987, Carter 1989, Tucker et al. 1993, Domeier and Colin1997, Sadovy and Eklund 1999, Paz and Grimshaw 2001).

Spawning timing. The Nassau grouper’s well-known reproductive mode of forming transient spawning aggregations is generally predictable within a prescribed area. Aggregations occur at predictable times and places each year around the time of the full moon, usually between December and March (reviewed in Sadovy and Eklund 1999), although in Bermuda aggregation spawning occurred in the northern summer period from May to July (Bardach et al. 1958). Olsen and LaPlace (1979) reported spawning occurring on the first full moon after the winter solstice. Working from gonad examinations, Munro and colleagues (1973) reported Nassau grouper from Jamaica’s offshore oceanic banks to be in spawning condition predominantly in February, but also to a lesser degree in April and May. Recent evidence suggests that spawning is also occurring at what appear to be reconstituted or novel spawning sites in both Puerto Rico and the U.S.V.I. during June (R. Appeldoorn, University of Puerto Rico-Mayagüez, Department of Marine Science. pers. comm. to R. Hill, NMFS SEFSC, 2012; R. Nemeth, University of the Virgin Islands - Center for Marine and Environmental Studies, pers.

comm. to R. Hill, NMFS SEFSC, 2012; D. Olsen, Chief Scientist - St. Thomas Fishermen's Association reporting the findings of R. Gomez VI DFW, pers. comm. to R. Hill, NMFS SEFSC, 2012) rather than during the winter months, although further work is needed to fully document these observations. Spawning occurs for up to 1.5 hours around the time of sunset for several days in each of several months (Whaylen et al. 2007). The gonadosomatic index (GSI) of females (i.e., the relative ovary-to-body weight) is a good indicator of spawning seasonality (Fig. 1).

The reproductive season in the Nassau grouper is brief and evidently associated with temperature and moon phase, according to GSI, gonadal histology, macroscopic, and oocyte diameter analyses. At lower latitudes, reproductive activity lasts for about one week per month, for one to three months each year, between December and February (Fig. 1), either peaking in January (Smith 1972, Olsen and LaPlace 1979, Claro et al. 1990, Colin 1992, Powell and Tucker 1992, Aguilar-Perera 1994, Miller[1]) or between January and April (Thompson and Munro 1978). In more northerly latitudes (i.e., Bermuda), the reproductive season falls between May and August, peaking in July (La Gorce 1939, Smith 1971, Burnett-Herkes 1975). Exceptions to the possible latitudinal pattern were the capture of recently-spawned females in September in Cuba coupled with the observation, of a group of Nassau grouper at 29 m depth in the same location (Claro et al. 1990).

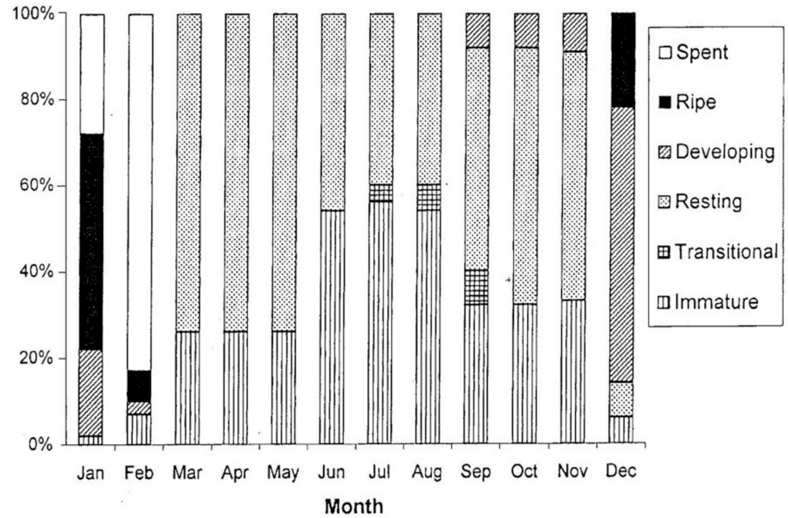


Figure 1. Percent frequency of different gonad development stages for female Nassau grouper by month collected from Belize from 1984-86 (n=1,232) [redrafted from Carter et al. 1994]

Spawning is highly synchronized and occurs briefly within about a week of full moon, or between full and new moon (Smith 1971, Colin 1992, Tucker et al. 1993, Aguilar-Perera 1994, Carter et al. 1994, Tucker and Woodward 1994), within the narrow temperature range of 25-26°C and over a wide range of day-lengths (Colin 1992, Tucker et al. 1993, Carter et al. 1994). Whaylen et al. (2007) have proposed a predictive guide for the Cayman Islands that if the span of time from the winter solstice to January's full moon is less than 30 days, then February was the major spawning month. Conversely, if it was greater than 30 days, January was the major

[1] Miller, W. 1984. Spawning aggregations of the Nassau grouper, *Epinephelus striatus*, and associated fishery in Belize. Advances in Reef Sciences, October 26- 28, 1984, University of Miami, Florida. Unpubl. data, p. 19.

spawning month. Other researchers have recognized that the timing of the full month, early or late in the month, can give an indication of when the peak spawning will occur (R. Appeldoorn, University of Puerto Rico-Mayagüez, Department of Marine Science, pers. comm. to R. Hill, NMFS, 2011; M. Schärer, University of Puerto Rico-Mayagüez, Department of Marine Science, pers. comm. to R. Hill, NMFS, 2011).

Sea surface temperature, as it falls beyond 26°C to seasonal lows, has also been proposed as a key control on spawning timing (Colin 1992). Similar associations between reproduction, temperature, and lunar phase were also noted in captive animals. Nassau grouper raised from egg to maturity in Florida and Bermuda under conditions of ambient light, temperature, and salinity, exhibited ovarian maturation, ovulation, behavior, and color changes characteristic of spawning, at 26°C, although no spawning was observed (Tucker and Woodward 1994).

Temperature is evidently a more important stimulus for spawning than day length, according to patterns of voluntary spawning in captive fish. While spawning occurred at temperatures ranging from 23.1 - 27.9°C, 24-27°C was the most suitable based on spawning frequency and volume, and egg and larval development (Tucker 1994, Watanabe et al. 1995a, Tucker et al. 1996). Nassau grouper spawned spontaneously one day prior to the new moon in April 1963 in an aquarium in Cuba under artificial light and water temperature of 24.9°C (Guitart-Manday and Juárez-Fernandez 1966).

Spawning behavior. Fish generally gather near the spawning site a day or two prior to initiation of spawning. Surveys can identify unusually high numbers of individuals either interacting or resting on/near the bottom. Prior to spawning, individuals mill around over the substrate exhibiting one of four distinctive color phases: (1) barred (normal); (2) bicolor; (3) white belly; or (4) dark phase (Fig. 2). There are intergradations of these patterns, with rapid changes among patterns possible (Colin 1992). The barred (typical) color phase is found among fish in the aggregation in the morning. The bicolor phase, first described by Smith (1972), occurs in both males and females and is dominant during the late afternoon with most fish becoming bicolored by dusk, when spawning occurs (Colin 1992). In this phase, the upper body and head become dark while the belly, lower sides, lips, and all fins but the dorsal are white. A white eyebar is prominent on the head (Colin 1992). In the white belly phase, seen among presumed females with

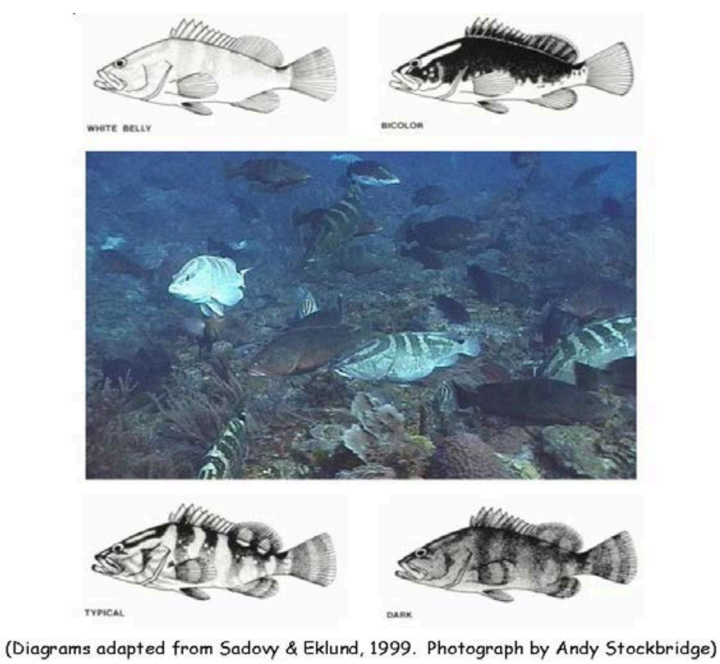
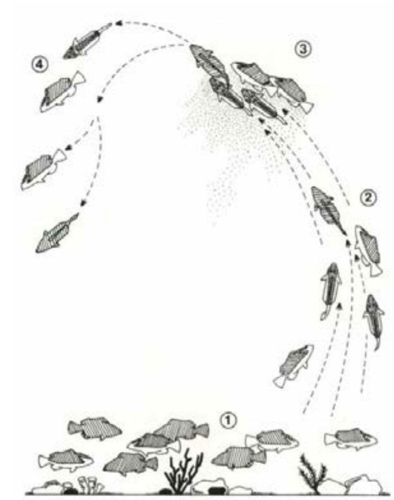


Figure 2. Color phases of Nassau grouper. From Paz and Grimshaw 2001b.

bulging abdomens (probably full of ova), the normal color pattern is modified such that the abdominal area is distinctly white (Colin 1992). The last pattern, the "dark" phase, is found in courting and spawning fish; the body and fins become dark gray to black with the barred pattern visible beneath the dark pigmentation. These fish are probably females ready to spawn since they appear to lead group-spawning events (Colin 1992).

Courtship is indicated by two behaviors which occur late in the afternoon: “following” and “circling” (Colin 1992). “Following” occurs as one or more fish in the bicolor phase swim closely behind an apparent female while “circling” occurs as a bicolor phase fish circles a barred or dark phase fish. Progression from courtship to spawning may depend on aggregation size but generally occurs as follows. Towards the late afternoon fish move progressively higher in the water column, with an increasing number exhibiting the bicolor phase (Colin 1992, Carter et al. 1994). The aggregation then moves into deeper water shortly before spawning (Colin 1992, Tucker et al. 1993, Carter et al. 1994) by which time all individuals are either “dark phase” or “bicolor.” Bicolor fish then follow dark phase fish closely and group-spawning occurs in sub-groups of 3-25 fish (Fig. 3). Similar accounts of spawning behavior from the U.S.V.I. described the aggregated fish as a cone (Fig 4.) in the water column rather than being dispersed across the bottom (Olsen and LaPlace 1979).



Spawning Behavior of Nassau Grouper (Adapted from Sadovy & Eklund, 1999)

Figure 3. Depiction of spawning rush. From Sadovy and Eklund 1999.

Smaller aggregations tend to include fewer bicolor phase fish and general activity and color changes are less intense (Colin 1992, Aguilar-Perera and Aguilar-Davila 1996). Spawning involves a rapid horizontal swim followed by a circling ascent of small sub-groups into the water column, with release of sperm and eggs and a rapid return of the fragmented sub-group to the substrate. Gamete release is well above the bottom. On the basis of observations of over 50 spawning events, the earliest and latest spawning occurred within 20 minutes of sunset and most within 10 minutes of sunset (Colin 1992). Hydration of vitellogenic eggs occurs in the afternoon shortly before spawning.

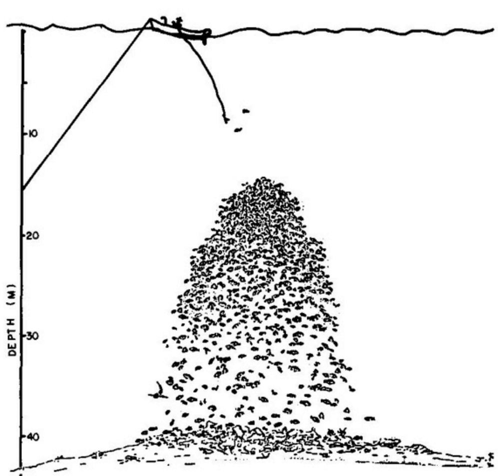


Figure 4. Depiction of spawning rush. From Olsen and LaPlace 1979.

Although aggregations form more than once at a particular site during a reproductive season, it is unclear whether the same individuals participate each time. However, several females from one aggregation contained ripe and sub-ripe oocytes together with postovulatory follicles (which remain after mature oocytes have been released), suggesting that individual females spawn repeatedly on different days during one aggregation (Smith 1972, Sadovy, NMFS, pers. obs.). Moreover, examination of spawning on videotape indicated that during 3-4 successive gamete releases by a sub-group within a 15-20 second period, the same female led all spawning events, again indicating multiple egg releases in one evening (Colin 1992). No data are available, however, addressing whether each mature female spawns in every aggregation month, or indeed, each year.

In larger aggregations, a clear increase in the proportion of the bicolor phase to other color phases from 0.05 early in the aggregation to 0.40 on the day of spawning suggested the color phase indicated behavioral and physiological preparedness to spawn (Archer et al. 2012). While Nassau grouper in groups of as few as 20 fish were seen to spawn, Colin (1992) reported such small groups appeared to show substantially fewer fish in the bicolor phase that typically precedes spawning. In the Cayman Islands, fish in small aggregations gathered on site for longer than those in large groups (B. Semmens, Scripps Institute of Oceanography University of California – San Diego, pers. comm. to Y. Sadovy, University of Hong Kong, 2012) presumably extending or delaying spawning.

Fecundity. Fecundity estimates from wild-caught Nassau grouper are few and varied, but suggest a mean relative fecundity of between 3 and 5 eggs/mg of ripe ovary, depending on the method used, in other words, which stages of oocytes are included in egg counts. Estimates from Belize (Fig. 5) yielded a mean relative fecundity of 4.1 eggs/mg ovary weight and a mean total number of oocytes (stage unspecified) of 4,200,000 (range = 350,000-6,500,000 for females from 300 to 700 mm SL) (Carter et al. 1994). Estimated number of eggs in the ripe ovary (90.7 g) of a 445 mm SL individual from Bermuda was 785,101 (Bardach et al. 1958). In the Virgin Islands, fecundity estimates made from 42 mature females gave a mean value of 4.97 eggs/mg of ovary (s.d. = 2.32) with mean egg production of 4,800,000 eggs (Olsen and LaPlace 1979). However, since this latter estimate includes pre-vitellogenic oocytes, which may not recruit into the vitellogenic stock prior to spawning, it is considered to be an overestimate. Fecundity estimates were also made, based on vitellogenic oocytes only, from Bahamas fish producing a mean relative fecundity of 2.9 eggs/mg ripe ovary (s.d. = 1.09; n = 64) and a mean fecundity of 716,664 (range = 11,724 - 4,327,440 for females, 475-686 mm SL). Estimates of oocyte production from animals induced to spawn in captivity are closer to those based solely on vitellogenic oocyte counts.

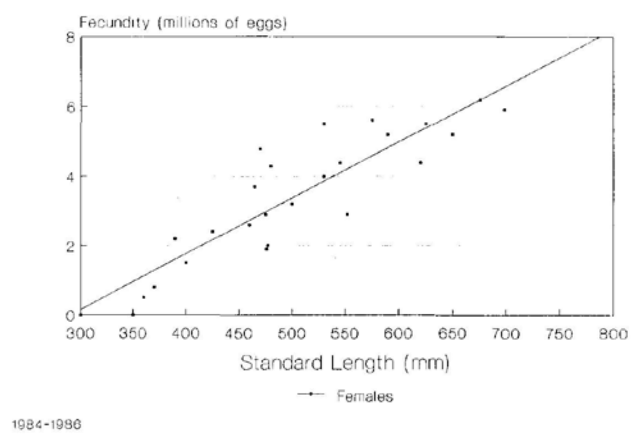


Figure 5. Fecundity of female Nassau groupers as a function of size (from Carter et al 1994)

Nassau Grouper Egg Stage

Fertilized eggs are pelagic, measure about 1 mm in diameter, and have a single oil droplet about 0.22 mm in diameter (Guitart-Manday and Juárez-Fernandez 1966). Artificially fertilized eggs in seawater of 32 parts per thousand salinity or above are neutrally or positively buoyant and measure 0.86-1.0 mm (mean 0.92 mm) in diameter, with a single oil globule averaging 0.24 mm (Colin 1992, Powell and Tucker 1992). Based on laboratory studies with a similar grouper egg, Colin (unpub. data, cited in Colin 1992) estimated an ascent rate of 110 mm/min for fertilized eggs. At this rate, eggs should reach the surface in 3-5 hours when released at 20-30 m deep. Following voluntary spawning under artificial conditions, sperm were collected and described as having a piriform (pear-shaped) cephalic portion and an extraordinarily long tail (Guitart-Manday and Juarez-Fernandez 1966).

Buoyant eggs hatch 23 to 40 hours following fertilization. Embryonic development of eggs produced in a Havana aquarium was followed from fertilization to absorption of the yolk sac at 2.8mm TL (72 hours); eggs hatched in about 40 hours at 25°C (Guitart-Manday and Juarez-Fernandez 1966). Artificially fertilized eggs hatched within 27-29 hours of fertilization at 25°C, 23-25 hours at 28°C (Powell and Tucker 1992), and 24 hours in ambient (25.2-26.2°C) water temperature (Colin 1992). The pelagic larvae begin feeding on zooplankton approximately 2-4 days after hatching (Tucker and Woodward 1994). The larvae develop elongate dorsal and pelvic fin spines for buoyancy and protection that are reabsorbed prior to transformation.

Nassau Grouper Larval Stage

Grouper larvae are usually rare in ichthyoplankton samples, but are characterized by having a very short and stout first dorsal spine; an elongate and serrate second dorsal spine with a modified and serially associated (first) pterygiophore; elongate and serrate pelvic-fin spines; a moderately-deep, laterally compressed body; and 24 myomeres. The third dorsal spine may be elongate in some species. Larvae have a small, triangular gut and pigmentation dorsally over the visceral mass varies. The head and mouth are large, and the eye round. Head pigmentation is sparse and generally confined to the mid and hind-brain areas. All members of the subfamily Epinephalinae have spines on the preopercle, posttemporal, and supracleithrum bones (Leis 1986), and all but the genus *Gonioplectrus* have spines on the interopercle and subopercle (Kendall & Fahay 1979, Baldwin et al. 1991). The spine at the angle of the preopercle is long and serrate. Larvae of some species have pigment laterally on the caudal peduncle, and those of the genus *Mycteroperca* and a few species of the genus *Epinephelus* also have pigment at the cleithral symphysis. The second and third spines of the dorsal fin, and pelvic spine have consistent spinelet morphology, which together with numbers of dorsal- and pectoral-fin elements, may be useful in identifying grouper larvae as small as 4-5 mm SL to genus and some of the genus *Epinephelus* to species (Johnson & Keener 1984).

Larvae of most specimens should be cleared and stained to assist in making accurate counts and characterizing spinelet morphology due to morphological similarity among taxa

(Richards et al. 2005). The long dorsal and pelvic spines are fragile and few specimens have spines intact, which makes identification problematic if meristics and spinelet morphology cannot be assessed. Richards et al. (2005) provide a provisional key to discriminate larvae of some to species or species groups.

Larval and early juvenile phases are well described for the Nassau grouper because of successful captive fertilization and spawning. Newly hatched larvae collected from induced spawning measured 1.7-1.8 mm notochord length (NL) (Powell and Tucker 1992). Larvae had pigmented eyes 48 hours post-hatching and began feeding within 60 hours (Tucker et al. 1991). Development has been described for laboratory-reared specimens from the egg to a 13.5mm SL larva approximately 40 days posthatching (Powell and Tucker 1992) (Figs. 13A- 13G in Sadovy and Eklund 1999). Fins develop in the order of pelvic, first dorsal, caudal, pectoral, anal, and second dorsal. The adult complement of principal caudal fin rays was attained at 6.0mm SL and of dorsal spines at the postflexion stage at approximately 6.6mm SL with completion of first and second dorsal and anal fins at 7.4mm SL. Preflexion larvae become flexion larvae over the range of 5.0- 5.4mm NL and flexion to postflexion occurs between 6.0 and 6.5mm NL (Powell and Tucker 1992). Larvae were planktonic until 42- 70 days post-hatching with transformation occurring in less than one week (Powell and Tucker 1992, Tucker and Woodward 1994).

Newly-hatched larvae are inconspicuously pigmented and slightly curved around the yolk sac when artificially reared (Powell and Tucker 1992). Wild-caught larvae exhibit several small, dendritic melanophores on the snout (Smith 1971, Laroche[2]). Yolk-sac larvae with a developing mouth have a characteristic pigment pattern in the form of a distinct "inverted saddle" on the ventral midline and lateral surface of the caudal peduncle (Powell and Tucker 1992) and specimens <21 mm SL also lack the caudal peduncle blotch which is found in all fish >35 mm (Smith 1971). Pigment patterns change markedly during the flexion stage, and young postflexion larvae (<6.8 mm SL) are similar to late flexion larvae. In small juveniles there is a characteristic line of black spots along the bases of the dorsal rays posterior to the fifth spine (Smith 1961). The pattern of vertical bars seems to develop at about 40mm in specimens from the Bahamas (Smith 1961).

Preflexion and flexion epinephelinae larvae are difficult to identify positively as *Epinephelus striatus*, although certain combinations of pigment, fin spinelets, and spine lengths narrow down possibilities (Kendall 1979, Johnson and Keener 1984, Powell and Tucker 1992). With postflexion larvae greater than 7.4 mm SL it is possible to separate Nassau grouper from other groupers, except for *E. adscensionis*, on the basis of dorsal and anal fin ray counts, spinelet configuration, second first-dorsal-fin spine length relative to SL, and capture location (Powell and Tucker 1992).

Larvae attain a maximum size of 30 mm SL (average 23.4 mm) by 36 days after presumptive spawning (Shenker et al. 1993). Larvae collected 10 days after probable spawning

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[2] Laroche, Wayne. Stonefish Environmental and Taxonomic Services, Box 216, Enosburg Falls, VT 05450. Unpubl. data.

measured 6-10 mm SL. Over a 15-day period, 8-22 days after the full moon, larval sizes increased from 5.7 to 10 mm SL (Greenwood 1991, Shenker et al. 1993). Pelagic juveniles were collected up to 46 days following a presumptive spawning moon, and benthic juveniles were first found on artificial and natural reefs at 47 days. Pelagic juveniles taken in channel nets just prior to settlement measured 22-27 mm SL (Colin 1992, Colin et al. 1997). Transition from larval to juvenile phases occurs at 6-7 weeks for wild fish and 6-10 weeks for fish raised under artificial conditions from induced spawns. The wild-caught larvae grew more slowly than larvae from induced spawns (Shenker et al. 1993, Tucker and Woodward 1994, Colin et al. 1997). From hatchery studies, larval duration is estimated to range between 25 and 75 days (Leis 1987, Tucker and Woodward 1994). Otolith analysis of newly settled juveniles in the Bahamas estimated pelagic larval duration as ranging from 37 to 45 days (Colin et al. 1997).

Presumptive daily increments in lapilli of wild-caught larvae indicate a larval period of 35- 40 days and support fertilization at the full moon. A mean larval period of 41.6 days was indicated from net-caught samples (Colin 1992, Colin et al. 1997). Presettlement otolith increments were distinct and easily counted; however, settlement marks were not as apparent. It was assumed that the first otolith increment forms after yolk absorption, at least 4 days post-fertilization and three days post-hatch, since larvae reared in aquaria up to the stage of yolk sac absorption showed no evidence of increment formation (Colin et al. 1997).

Larvae of *Epinephelus striatus* cannot be distinguished from *E. adscensionis* (rock hind) meristically as counts and pigmentation are nearly identical. Both *Epinephelus striatus* and *E. adscensionis* have small, simple, and straight spinelets, and cannot be separated from *E. morio* (red grouper), *E. guttatus* (red hind) and *E. drummondhayi* (speckled hind) until development of the anal fin is complete (Richards et al. 2005).

Larval distribution and recruitment. Nassau grouper larvae are rarely reported from offshore waters (Leis 1987) and little is known of their movements or distribution, other than limited data on settlement patterns. After a mean 35-40 day pelagic larval period, larvae recruit from an oceanic environment into demersal, bank habitats through tidal channels (Colin 1992). This recruitment process can be brief and intense, and is apparently driven by prevailing winds, currents, and lunar phase (Shenker et al. 1993). Pelagic larvae were collected 0.8-16 km off Lee Stocking Island, Bahamas, at night, at 2-50m depths and from tidal channels leading onto the Exuma Bank during the day (Greenwood 1991). However, the link between spawning sites and settlement sites is not well understood. Larval sampling adjacent to a spawning aggregation at Mahahual, Mexico (Vásquez-Yeomans et al. 1998) failed to capture even one Nassau grouper larvae. By way of explanation, the authors questioned both their methodology and the robustness of the local spawning as additional explanations.

The geomorphology of spawning sites has led researchers to assume that offshore transport was a desirable property of selected sites. However, currents in the vicinity of aggregation sites do not necessarily favor offshore egg transport, leaving open the possibility that some stocks are at least partially self-recruiting. For example, drogues (floats which drift with water currents) deployed near the point of gamete release at eastern Long Island, Bahamas, moved little from the shelf edge for several days immediately following spawning and one ended up inshore (Colin 1992). In similar studies around a spawning aggregation site at Little Cayman, surface velocity profile drifters released on the night of peak spawning showed significant eddy formation so that drifters tended to remain near or return to the spawning reef but drifters released on the days preceding tended to move away in more of a straight line with the dominant currents (Heppell et al. 2011). Additional research is needed to understand these spatial dynamics.

Data on recruitment of larvae onto reefs suggest that their onshore transport can rely heavily on cross-shelf winds and currents and occurs in short pulses during highly limited periods each year (Shenker et al. 1993). Recruitment of Nassau grouper larvae occurs at an average of 32 mm TL (Eggleston 1995) and was monitored for a 75-day period from mid-December through February using channel nets suspended in tidal passes between islands on the edge of the Exuma Sound, Bahamas. Assuming that the full recruitment window was sampled, 86% of the total annual recruitment of Nassau grouper occurred in this area during a single 4-day storm, while another 10% recruited during a second storm event. During the sampling period, 13% of all larvae sampled were Nassau grouper, which recruited during particularly short, discrete pulses when compared to other taxa taken throughout the study. While early recruitment occurs into both coral-macroalgae and seagrass beds, subsequently higher abundances in coral-macroalgae are probably due to a combination of active selection for coral-macroalgae and high post-settlement predation in seagrass (Nadeau and Eggleston 1996).

1.b. Taxonomy and distinctive characteristics

Phylum: Chordata
Class: Actinopterygii
Order: Perciformes
Family: Serranidae
Subfamily: Epinephelinae
Genus: *Epinephelus*
Species: *striatus*

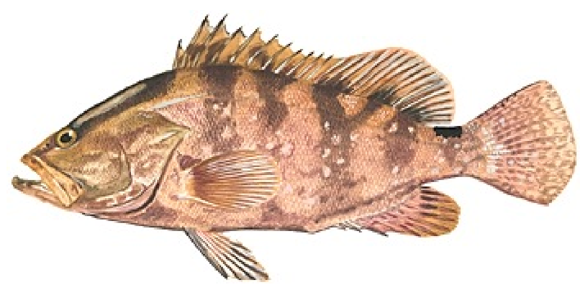

Figure 6. Nassau grouper adult

Recent genetic taxonomy suggests that family groupings may be challenged (Craig and Hastings 2007, Craig et al. 2001); nonetheless, previous descriptions are presented until modifications are widely accepted.

Reaching a maximum size of 122cm (48in) total length (TL) (Humann and Deloach 2002, Froese and Pauly 2010) and maximum weight of 25 kg (Heemstra and Randall 1993), the Nassau grouper is one of the larger serranids of the tropical Western Atlantic and Caribbean and can live for nearly 3 decades. Similar to many other grouper species, Nassau grouper juveniles and adults are known for their large gapes and protruding jaws, which, when opened rapidly, produce suction that facilitates feeding. The Nassau grouper can be distinguished from other groupers at all life history phases by the characteristic vertical bar pattern and dark "saddle" coloration along the dorsal part of the caudal peduncle.

Smith (1971) identified an "*Epinephelus striatus* Species-Group" comprised of *E. striatus, E. guttatus* (red hind), *E. morio* (red grouper): "*E. striatus* and *E. guttatus* are so similar that sun-bleached display specimens are difficult to identify although there are several meristic characters that can be used to separate them. Red grouper (*E. morio*) differs in fin outlines, but otherwise strongly resembles the other two species. They are all moderately large fishes with tapering and somewhat compressed body outlines. Red grouper has spotted and barred transient color phases and individuals in these color phases bear a remarkable resemblance to Nassau grouper. This is reflected in the Bermudan common name deer hamlet for *E. morio,* contrasting with hamlet (without a modifier) for *E. striatus*. These three species are certainly close to each other and well separated from other American groupers."

The following descriptions are based predominantly on Smith (1971), Acero et al. (1991), and Heemstra and Randall (1993), as presented in Sadovy and Eklund 1999:

The Nassau grouper, *Epinephelus striatus* (Bloch 1792), is a moderate sized *Epinephelus* with large eyes and a robust body. Body depth is distinctly less than head length, depth contained 2.6 to 2.9 times in SL (for fish 160 to 330mm SL). Head length is contained 2.4 to 2.6 times in SL; interorbital convex; preopercle evenly serrate, without salient angle; posterior nostrils somewhat enlarged and elongated or comma-shaped in large adults. Ground color is generally buff, with 5 dark brown vertical bars and a large black saddle blotch on top of caudal peduncle; a row of black spots below and behind eye. Distinctive dark tuning-fork mark beginning at front of upper jaw, extending dorsally along interorbital region, and bifurcating on top of head behind the eyes; another dark band from tip of snout through eye and then curving upward to meet its fellow just before dorsal-fin origin. Some fish have irregular pale spots and blotches all over the head and body while specimens from deep water are somewhat pinkish or reddish ventrally. The inside of the mouth is red, the teeth are caniniform and villiform and are in two series in each jaw (Smith 1978). The range of color is wide. Color pattern can change within minutes from almost white to bicolored to uniformly dark brown, according to the behavioral state of the fish (Longley 1917, Colin 1992, Heemstra and Randall 1993, Carter et al. 1994). A distinctive bicolored pattern is seen when two adults or an adult and large juvenile meet and is frequently observed in spawning aggregations (Heemstra and Randall 1993). Only dots around the eyes and the blotch on the caudal peduncle do not change (Smith 1971). Juveniles exhibit a color pattern similar to adults (e.g., Silva Lee 1977).

1.c. Range wide distribution

The Nassau grouper's confirmed distribution currently includes "Bermuda and Florida (USA), throughout the Bahamas and Caribbean Sea (Fig. 7) (Smith 1971, Acero and Garzon-Ferreira 1991, Heemstra and Randall 1993, Cervigon 1994). The previous report of *E. striatus* from the Brazilian coast south of the equator (Fig. 414 (distribution map) in Heemstra and Randall 1993, p. 237) is unsubstantiated" (Craig et al. 2011). The Nassau grouper has been documented in the western Gulf of Mexico, to the west off the Yucatan Peninsula, Mexico, at Arrecife Alacranes (north of Progreso) (Hildebrand et al. 1964). It was cited as a rare or transient species in the northwestern Gulf of Mexico, off Texas (Gunter and Knapp 1951 in Hoese and Moore 1977). Foley et al. (2007) reported the first photographed and confirmed sighting in the Flower Garden Banks National Marine Sanctuary, which is located in the northwest Gulf of Mexico, approximately 180 km southeast of Galveston, Texas. Nassau grouper is generally replaced ecologically in the eastern Gulf by *Epinephelus morio* (Smith 1971) in areas north of Key West or the Tortugas. Many of the earlier descriptions extend the range up the Atlantic coast to North Carolina, but confirmation is currently lacking.

The Nassau grouper is listed as "Native" to the following countries/states (Cornish and Eklund 2003.): Anguilla; Antigua and Barbuda; Aruba; Bahamas; Barbados; Belize; Bermuda; Cayman Islands; Colombia; Costa Rica; Cuba; Curaçao; Dominica; Dominican Republic; French Guiana; Grenada; Guadeloupe; Guatemala; Guyana; Haiti; Honduras; Jamaica; Mexico; Montserrat; Netherlands Antilles (Curaçao); Nicaragua; Panama; Puerto Rico; Saint Kitts and Nevis; Saint Lucia; Saint Vincent and the Grenadines; Suriname; Trinidad and Tobago; Turks and Caicos Islands; United States (Florida); United States Minor Outlying Islands (Caribbean: i.e., Navassa Island); Venezuela; British Virgin Islands; U.S. Virgin Islands.

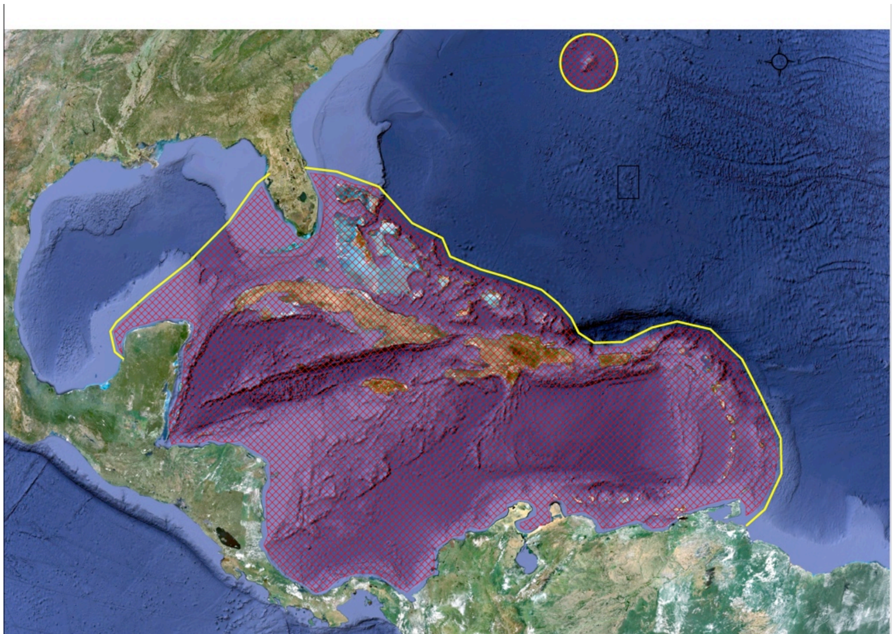

Figure 7. Range of Nassau grouper (Epinephelus striatus). Habitat zones include shoreline to insular or continental shelf throughout the indicated range.

1.c.i. Historical Distribution

Nassau grouper otoliths have been retrieved from a variety of sites (middens) in prehistoric fishing communities of the Caribbean, and the species represented an important component of these communities. Otoliths were relatively abundant at sites on eastern Antigua (AD 500-1150), in Grenada (AD 0-500, AD 1000-1500), San Salvador, Bahamas (AD 850-1100), St. John, Virgin Islands (AD 700-1200), Florida west coast (2000-1000 BC, AD 150-300, AD 400-1000), St. Lucia, West Indies (AD 0-1500) and on the north coast of Jamaica (no date) (Wing et al. 1968 and Wing and Reitz 1982, as cited in Sadovy and Eklund 1999).

1.c.ii. Influences on Distribution

Primary determinants of distribution in Nassau grouper are not known although water clarity, habitat, and substrate type appear to be important (Smith 1971, Eggleston 1995). This species is most abundant in clear waters on high-relief coral or rocky reefs. Small juveniles are associated with macroalgae, seagrass beds, or *Porites* clumps. The mean depth range of the Nassau grouper (0-130 m) may be influenced more by the availability of suitable habitat than by food resources, since diet is highly varied and more a function of body size than of water depth.

Despite adults migrating long distances to reach spawning sites (Starr et al. 2007), proximity to these sites during non-reproductive periods is apparently not critical although the aggregation sites themselves may be essential for reproduction either because of physical characteristics of the substrate or because of the oceanographic conditions at the site. The loss of local stocks in a number of insular areas (e.g., Bermuda and Puerto Rico) suggests that some populations are partially self-recruiting, although further genetic studies are necessary to test this hypothesis (Sadovy 1993).

1.d. Biological characteristics

1.d.i. Age, growth and mortality

Growth in Nassau grouper has been examined by size-frequency analyses, tagging studies, field observations, and reading annular rings in sagittal otoliths (Table 3, Fig. 8). Most studies indicate rapid growth, about 10mm/month for small juveniles. Mean monthly growth of Nassau juveniles 30-270 mm TL on artificial and natural reefs in the Virgin Islands was 8.4 to 11.7 mm/month, determined during six visual censuses over 11 months, (Beets and Hixon 1994). Similarly, juveniles sampled at Lee Stocking Island in the Bahamas grew at about 10 mm/month between 32 and 85 mm TL (Eggleston 1995). Near sexual maturity at about 4-7 years, Nassau grouper growth slows to about 2mm/month, with lower rates in larger or sexually mature fish (Bush et al. 2006).

Marginal increment analysis of sagittal otoliths suggested that growth zones were formed annually and that annual increment deposition occurred from April to May in Cuba (Claro et al. 1990). The growth zones deposited in otoliths were validated as annual using oxytetracycline (OTC) marking techniques; otolith legibility was approximately 80-95% (Bush et al. 1996).

Data from scales and otoliths indicate that fish reach 400-450 mm SL (i.e., sexual maturity) in approximately 4-7 years. However, estimates of size-at-age derived from length-frequency data (Table 3) suggest more rapid growth (Olsen and LaPlace 1979). This apparent discrepancy between otolith- and length-based methods of age determination could result from

Table 3. Size at age data for Nassau grouper (from Sadovy and Eklund 1999; "Bush et al., in press" should refer to Bush et al. 2006)

Epinephelus striatus size-at-age data for ages 1-13 years. All lengths are in mm (standard/SL or total/TL lengths as indicated). Ageing method is given.

	Age (years)												
Source	1	2	3	4	5	6	7	8	9	10	11	12	13
a	293	354	390	464	537	561	634	659	-	-	-	-	-
b	160	270	-	410	480	540	570	600	640	650	660	700	710
c	175	253	309	358	401	436	468	497	519	542	563	580	591
d	174	254	315	366	414	451	483	518	559	583	594	617	-
e	235	370	435	500	543	605	660	720	760	800	-	-	-

a: Buesa, 1987; Cuba, aged by scales/TL.
b: Bush et al., in press; Cayman Islands, aged by otoliths/TL lengths estimated from observed growth curve.
c & d: Claro et al., 1990; SW and NE Cuba, respectively, fish from both areas were aged by otoliths and backcalculation/TL.
e: Olsen and LaPlace, 1979; Jamaica, aged by length-frequency data/SL.

the unavailability of age class-1 individuals, resulting in older (i.e., age 2+ years) individuals designated as age 1 year class (Sadovy and Eklund 1999). Moreover, length frequency analysis can be less reliable for long-lived species than otolith-based studies as older cohorts soon begin to merge into each other obscuring individual age classes.

Von Bertalanffy growth parameters derived for the Nassau grouper with the Brody growth coefficient (K) range from 0.063- 0.185 (Table 4).

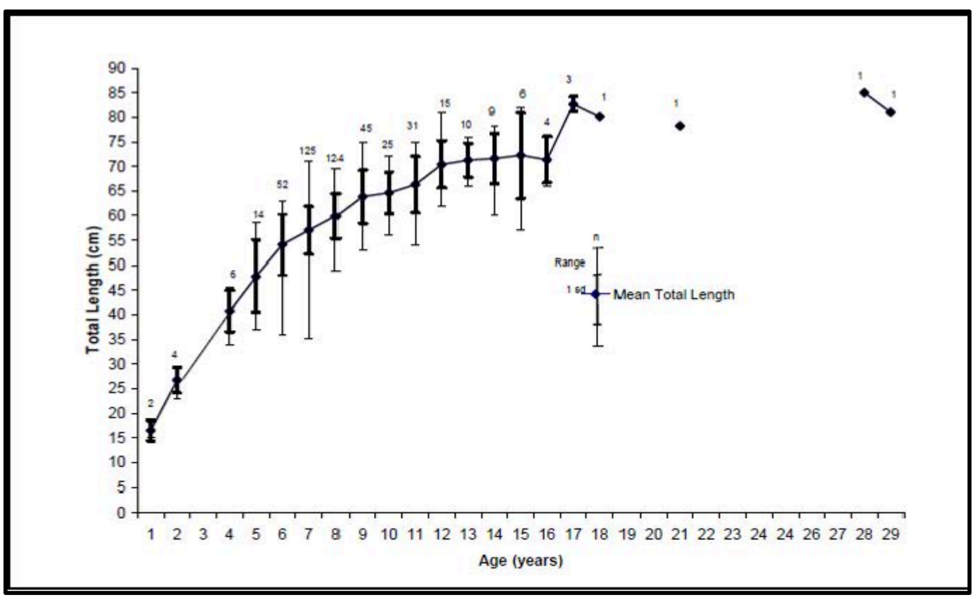

Figure 8. Growth curve for Nassau grouper sampled from aggregations between 1987 and 1992 in the Cayman Islands (from Bush et al, 2006)

Table 4. Von Bertalanffy growth equation parameters for Nassau grouper

Von Bertalanffy growth equation parameters for Nassau grouper, *Epinephelus striatus*. Standard equation for length-at-age is: $L_t = L_\infty(1 - e^{-k(t-t_0)})$. Lengths are in cm (length type indicated).

Source & method	Locality	Length type	Parameter L_∞	t_0	K
Olsen & LaPlace, 1979	Virgin Islands	SL	97.4	0.488[1]	0.185
Claro et al., 1990	Cuba (SW)	TL	94.0	- 3.27	0.063
	Cuba (NE)		76.0	- 1.12[2]	0.127
Thompson & Munro, 1978	Jamaica	TL	90.0[3]	-	0.090
Baisre & Páez, 1981	Cuba	-	92.8	-	0.100

[1] Appears also as t_o = - 0.488 in some places.
[2] Appears also as - 4.13 in Abstract.
[3] L_∞ assumed, based on tagging data from Randall, 1962, 1963.

Growth rates were also determined in field observations and tagging studies. In the Virgin Islands, animals tagged for less than 300 days yielded the following growth rates: 175-250 mm TL grew about 4.55 mm/month; 251- 325 mm TL about 3.5 mm/month; 326-451 mm TL about 1.92 mm/month (Randall 1962, 1963, Table 8 in Sadovy and Eklund 1999). However, growth rates were evidently underestimated because of growth suppression due to tagging (Thompson and Munro 1978). Fish that remained in the field for 313 to 737 days had higher growth rates, varying from 4 to 6.6 mm/month for fish in the 256- 380 mm TL size. Growth in Nassau grouper was also measured by calculating weight increments of marked fish in the field: weight increase for 7 individuals in the 700 g size class was 20-50% per year with an average of 38% (Bardach and Menzel 1957) however, the authors suggested a decline in growth rate after jaw tags were applied when data were compared to dart-tagged fish. Age-size parameters are presented in Table 5 and length-weight relationships for standard, total, and fork lengths, and TL-SL relationships are shown in Table 6.

Table 5. Age and size parameters for Nassau grouper. [excerpt from Sadovy and Eklund 1999: Bush et al, in press refers to Bush et al, 2006, CFMC footnote 26 refers to CFMC 1985, SAFMC footnote 24 refers to SAFMC 1983)

	Epinephelus striatus
Age and length at maturity	5 yrs, 580 mm SL (Virgin Islands) (Olsen and LaPlace, 1979) 420-450 mm SL females 400-450 mm SL males\4+ yrs (Cayman Islands) (Colin et al., 1987; Bush et al., in press) 500 mm TL (minimum size ripe males) (Cayman Islands) (Tucker et al., 1993) 425 mm SL females; 402 mm SL males, immatures are 3-6 yrs (otolith growth zones not validated) (Bahamas) (Sadovy and Colin, 1995) 483 mm TL (North Carolina-Florida) (SAFMC, text footnote 24) 480 mm TL (Jamaica) (Thompson and Munro, 1978)
Age and length at first capture	< 300 mm TL & 4-5 yrs (Virgin Islands) (Olsen and LaPlace, 1979; CFMC, text footnote 26) 6-7 yrs (Cayman Islands) (Bush et al., in press) 275-625 mm TL (mean = 570) (Jamaica) (Thompson and Munro, 1978) 300-500 mm TL depending on size limits (North Carolina-Florida) (SAFMC, text footnote 46) 450 mm TL (South Florida) (Bohnsack, 1990)
Maximum age and length	1200 mm TL (CFMC, text footnote 26) 9 yrs, 910-960 mm SL (Olsen and LaPlace, 1979) (Virgin Islands) 17 yrs, 710 mm TL, 6700 g (Cuba) (Claro et al., 1990) 755 mm SL (Bermuda) (Bardach et al., 1958) 840 mm TL (Jamaica) (Thompson and Munro, 1978) 640 mm TL (Netherlands Antilles) (Nagelkerken, 1981) 29 yrs, 850mm FL (Cayman Islands) (Bush et al., in press)

Table 6. Length-weight and length-length conversion parameters for Nassau grouper (excerpt from Sadovy and Eklund 1999)

Length-weight and length-length parameters for *Epinephelus striatus* and *E. itajara*. The length-weight relationship is defined as: $W=aL^b$, where L is length (standard/SL, fork/FL or total/TL, as indicated) in mm and W is body weight in grams (gutted, G, or ungutted, UG, as indicated- where known). The standard length-total length relationship is defined as: TL=a+bSL.

Locality	Restrictions[1]	Parameter a	Parameter b	Source
Length-weight				
Epinephelus striatus				
Virgin Islands	180-760 (SL) *n*=241	0.0097	3.23	Olsen and LaPlace, 1979
(St. Thomas/St. John)	330-770 (SL) *n*=73	1.43×10^{-6}	3.38	Bohnsack and Harper, 1988 (UG)
Puerto Rico	210-645 (FL) *n*=60	1.26×10^{-5}	3.04	Bohnsack and Harper, 1988 (UG)
Cuba (NE)	*n*=75 (TL)	0.1980	2.98	Claro et al., 1990
Cuba (SW)	*n*=270 (TL)	0.0052	3.30	Claro et al., 1990
Jamaica	325-825 (TL) *n*=112	0.0107	3.11	Thompson and Munro, 1978 (UG)
Belize	180-802 (SL) *n*=930	0.0107	3.08	Carter et al., 1994 (UG implied)
Florida	203-516 (TL) *n*=9	3.8×10^{-6}	3.23	Bohnsack and Harper, 1988 (UG)
Bahamas	174-724 (SL)	2.14×10^{-5}	3.03	Sadovy and Colin, 1995 (UG)
Total length-standard length				
Epinephelus striatus				
Cuba	*n*=330	2.24	1.11	Claro et al., 1990
Jamaica	430-750 *n*=26	3.00	1.09	Thompson and Munro, 1978
Bahamas	174-695 *n*=33	2.81	1.13	Sadovy and Colin, 1995

[1] Restrictions are upper and lower sizes in samples analyzed.

Longevity. The maximum age recorded for Nassau grouper is 29 years, using sagittal otoliths from the Cayman Islands (Bush et al. 1996, 2006) (Fig. 8). Using length-frequency analysis, which tends to exclude younger animals, a theoretical maximum age at 95% asymptotic size is 16 years. Other maximum age estimates include individuals of up to 9 years in the heavily exploited Virgin Islands fishery (Olsen and LaPlace l979), 12 years in northern Cuba, 17 years in southern Cuba (Claro et al. 1990), and 21 years from the Bahamas, assuming, as demonstrated in some locations, that rings are formed annually (Sadovy and Colin 1995). These differences in maximum age estimates are due to the samples available for aging and methodological differences. Individuals of more than 12 years of age are not common in fisheries, with more heavily fished areas yielding much younger fish on average. Generation time (the average age of parents in the population) is estimated as 9-10 years based on average fish size from an unexploited aggregation in Belize, the growth curve from the five Cayman Island spawning aggregations, and the SL-TL conversion curve from Sadovy and Colin (1995).

Mortality rates. Estimates of natural mortality (M), based on length-frequency data from Nassau grouper taken on unexploited banks in Jamaica, ranged from 0.17 to 0.30 (Thompson and

Munro 1978). Total mortality (Z), using length frequency data, was estimated at 0.55 in Cuba. With a low natural mortality (M) determined to be 0.18, this indicates a fishing mortality (F) of 0.37 (Baisre and Paez 1981).

1.d.ii. Ecological Roles

As Prey. Information on predation upon groupers is largely lacking, although sharks were reported to attack Nassau groupers at spawning aggregations in the Virgin Islands (Olsen and LaPlace 1979) and there is one report of cannibalism in this species (Silva Lee 1974). No predation was observed on spawning fish in the Bahamas, despite the presence of sharks in the area (Colin 1992). One mutilated fish was recovered, possibly attacked by a barracuda or shark following release of tagged, laboratory-reared, naive individuals onto a reef in the Virgin Islands (Roberts et al. 1995). Early post-settlement juvenile preferences for macroalgae rather than seagrass beds are probably related, in part, to higher levels of predation in seagrass beds (Nadeau and Eggleston 1996). Reports of lionfish predation on small reef fish and small life stages are a concern throughout the Caribbean as the invasive spread has widened (Albins and Hixon 2008).

As Competitors. Little is published on either intra- or inter-specific competition in Nassau grouper. Juveniles exhibit aggression towards similar-sized conspecifics and display interspecific aggression (J. Dunham, Caribbean Marine Research Center, c/o Florida State Marine Laboratory, unpubl. report to the Caribbean Marine Research Center, March 29, 1989). When two non-reproductive adults, or an adult and large juvenile, encounter one another, the smaller fish acquires the bicolor pattern described for aggregating fish in apparent submission, then turns laterally and usually swims away (Colin 1992, P. Colin, Coral Reef Research Foundation – Palau, pers. comm. to Y. Sadovy, NMFS, 1990).

As Predators. The Nassau grouper is a top-level predator on coral reefs. Nassau grouper are unspecialized-ambush-suction foragers (Randall 1965, Thompson and Munro 1978) that swallow prey whole (Werner 1974, 1977). Numerous studies describe Nassau grouper as piscivorous as adults (Randall and Brock 1960, Randall 1965, Randall 1967, Parrish 1987, Carter et al. 1994, Eggleston et al. 1998). This species takes many types and sizes of food and moves among different habitats, such as seagrass beds and coral reefs, at different life-history stages or reproductive phases, or while hunting.

Groupers are unspecialized, bottom-dwelling, solitary predators (Randall and Brock 1960, Randall 1965, 1967). Feeding takes place throughout the diel cycle although most fresh food is found in stomachs collected in the early morning and at dusk (Randall 1967). Empty stomachs were also noted throughout daylight hours (Silva Lee 1974). Individuals feed by

Table 7. Food items recorded in the stomachs of Nassau grouper

Food items recorded in the stomachs of the Nassau grouper, *Epinephelus striatus* (from Randall, 1965, 1967; Silva Lee,1974; Claro et al., 1990; Carter et al., 1994).

- **Nekton**
  - Fishes
    - Acanthuridae
      - *Acanthurus* sp.
      - *Acanthurus coeruleus*
    - Apogonidae
    - Atherinidae
    - Balistidae
      - *Balistes vetula*
    - Bothidae
    - Carangidae
      - *Caranx ruber*
    - Clupeidae
      - *Harengula humeralis*
      - *Harengula clupeola*
      - *Jenkinsia lamprotaenia*
    - Gerreidae
      - *Gerres cinereus*
    - Haemulidae
      - *Haemulon aurolineatum*
      - *Haemulon flavolineatum*
      - *Haemulon album*
      - *Haemulon sciurus*
      - *Haemulon plumieri*
      - *Haemulon* sp.
    - Holocentridae
      - *Sargocentron vexillarium*
      - *Myripristis jacobus*
      - *Holocentrus rufus*
      - *Holocentrus* sp.
    - Labridae
      - *Halichoeres garnoti*
      - *Halichoeres bivittatus*
      - *Halichoeres* sp.
      - *Hemipteronotus* sp.
      - *Clepticus parrae*
    - Lutjanidae
      - *Lutjanus synagris*
      - *Lutjanus* sp.
      - *Ocyurus chrysurus*
    - Monacanthidae
      - *Monacanthus ciliatus*
      - *Monacanthus* sp.
      - *Cantherines pullus*
    - Mullidae
      - *Pseudupeneus maculatus*
    - Muraenidae
      - *Gymnothorax moringa*
      - *Gymnothorax* sp.
      - *Enchelycore nigricans*
      - *Lycodontis moringa*
      - *Muraena miliaris*
      - *Muraena* sp.
    - Ostraciidae
      - *Lactophrys* sp.
    - Pomacentridae
      - *Chromis cyanea*
      - *Chromis multilineata*
      - *Pomacentrus fuscus*
      - *Pomacentrus* sp.
      - *Abudefduf saxatilis*
      - *Microspathodon chrysurus*
    - Priacanthidae
      - *Priacanthus cruentatus*
    - Scaridae
      - *Sparisoma aurofrenatum*
      - *Sparisoma rubripinne*
      - *Sparisoma chrysopterum*
      - *Sparisoma* sp.
      - *Scarus vetula*
      - *Scarus croicensis*
      - *Scarus* sp.
    - Serranidae
      - *Hypoplectrus puella*
      - *Cephalopholis fulva*
      - *Epinephelus striatus*
    - Synodontidae
      - *Synodus intermedius*
      - *Synodus* sp.
    - Urolophidae
      - *Urolophus jamaicensis*
  - Molluscs
    - Squids
      - *Loligo* sp.
    - Cuttlefish/octopi
- **Benthic animals**
  - Molluscs
    - Gastropods
      - *Strombus gigas*
      - *Strombus* sp.
      - *Fasciolaria tulipa*
    - Bivalves
      - *Barbatia cancellaria*
      - Pelecypods
  - Crustaceans
    - Isopods
    - Stomatopods
      - *Gonodactylus perstedi*
      - *Pseudosquilla ciliata*
      - *Squilla* sp.
    - Shrimps/prawns
      - Alpheids
      - Carideans
      - Penaeids
    - Lobsters
      - *Panulirus argus*
      - *Panulirus guttatus*
      - *Justitia longimana*
      - *Palinurellus gundlachi*
    - Hermit crabs
      - *Paguristes depressus*
      - *Petrochirus diogenes*
    - Crabs
      - *Calappa flammea*
      - *Calappa* sp.
      - *Stenorhynchus seticornis*
      - *Mithrax verrucosus*
      - *Mithrax cinctimanus*
      - *Mithrax* sp.
      - *Macrocoelema* sp.
      - *Petrolisthes galathinus*
      - *Chronus ruber*
      - *Portunus sebae*
      - *Portunus* sp.
      - Xanthids
      - Grapsids

rapidly dilating the gill covers to engulf prey by suction (Thompson and Munro1978, Carter 1986) and take a wide variety and size range of fishes and invertebrates, both benthic and pelagic (Tables 7 and 8). With increasing age, there is a shift from consuming crustaceans to taking fishes, larger bivalves, lobster, and gastropods (e.g., Eggleston et al. 1998). However, the relationship between fish size and prey size shows much variation, with large fish eating small prey and vice versa. One report documented a 580 mm FL Nassau grouper swallowing a 620 mm *Gymnothorax*; but overall, mean prey size was about 15% of the Nassau grouper fork length (Silva Lee 1974). Four studies provide a feeding profile of the Nassau grouper (Table 7). Fish predominated, with scarids and labrids most commonly identified, possibly because the former can be readily recognized from stomach contents by their unique dentition (Randall 1965). Crabs were the most common invertebrates. Although hermit crabs and the operculae of *Strombus* and *Fasciolaria* were found, stomachs did not contain shells. In one Cuban study, the most abundant items (by weight) were grunts, parrotfishes, and octopus with a suggestion that more grunts were taken in winter months (Claro et al. 1990).

Table 8. Comparison of 4 studies of stomach contents of Nassau grouper

Principal categories of food items encountered in the stomachs of Nassau grouper, *Epinephelus striatus*, in four studies: (A) Virgin Islands (Randall, 1965, percent by volume); (B) Cuba (Silva Lee, 1974, percent frequency occurrence); (C) Cuba (Claro et al., 1990, percent by weight); (D) Belize (Carter et al., 1994, percent frequency occurrence).

Food category	A	B	C	D
Nekton, fish	53	39	71	58
Benthic, crustaceans				
crabs	23	29	8	16
stomatopods	6	3	<1	1
shrimp/prawn	5	8	<1	3
spiny lobster	4	6	4	6
hermit crab	1	<1	-	1
isopod	<1	<1	-	-
unidentified	1	4	-	3
Nekton, molluscs				
cephalopods	5	9	15	6
Benthic, molluscs				
gastropods	2	2	2	1
Unidentified	-	-	-	5

In Belize, the predominant food, by percentage frequency of occurrence, was fish, with a high percentage of crustaceans, especially crabs, and a small number of gastropods, cephalopods, and pelecypods. The principal prey fish families were grunts and snappers (Carter et al. 1994). Like other groupers, Nassau follow and feed with other predators, such as triggerfish, octopus, or eel (Carter et al. 1994, Sullivan and de Garine-Wichatitsky 1994, Roberts et al. 1995, Sadovy pers. obs.) presumably benefiting from spoils made available directly, or from disturbance of prey species.

Some anecdotal and photographic evidence provided by fishers and divers suggests that native grouper species are preying on the invasive red lionfish with some regularity. Lionfish are generally unfamiliar to local predators and are defended by long venomous fin spines, such that, even when sharks or large grouper do attack, they have been observed immediately retreating without obvious injury to the lionfish (Sadovy, pers. obs.). Nonetheless, there is a published report of fishermen in the Bahamas capturing one tiger grouper (*Mycteroperca tigris*) and two Nassau grouper (*E. striatus*), each with a lionfish in its stomach (Maljković et al. 2008): "…five Nassau groupers, *E. striatus*, caught off Eleuthera Island at an approximate depth of 14 m on 5 March 2008, were dissected. Two of the stomachs contained red lionfish. The first grouper (477-mm SL) contained a partially digested lionfish, identifiable only by the morphology and multiplicity of the remaining fin rays. The second slightly larger grouper (482-mm SL) contained a red lionfish of 137-mm SL, which was in almost pristine condition." Some of this feeding may result from attempts to condition local predators to feed on the non-native species. Divers in the Cayman Islands have trained wild Nassau grouper to consume lionfish, without the grouper showing ill effects (W. Heyman, Texas A&M University, pers. comm. to Y. Sadovy, University of Hong Kong, 2012). It is, however, uncertain whether large Atlantic groupers will effectively prey on the invasive lionfish. As related in Albins and Hixon (2011): "one large Nassau grouper that ate a large lionfish tail first appeared to be literally stunned (authors [Albins and Hixon] pers. obs.). Additionally, large and clearly hungry Nassau grouper held in tanks will not eat small lionfish (M. Cook[3] and W. Raymond[4] unpubl. data). In controlled field experiments, Nassau grouper have no effect on the growth and survival of small lionfish (T. J. Pusack[5] unpubl. data)."

Just as adult Nassau groupers are unspecialized predators, early life-history stages exhibit a high degree of trophic plasticity with evidence of filter feeding, particulate feeding, and piscivory (Grover 1993, 1994). Pelagic-phase Nassau grouper feed on pteropods, amphipods, and copepods (especially *Corycaeus* spp.), which comprised approximately 40% of identifiable items found in one study (Greenwood 1991, Grover et al. 1998). Pelagic early-juvenile Nassau grouper (20.2-27.2 mm SL) take food items ranging from dinoflagellates (± 99% by number) to fish larvae and mysids (28-79% by volume).

1.d.iii. Population connectivity/population genetics

Limited work on genetic variability in the Nassau grouper suggests that, while gene flow occurs throughout much of its geographic range, the relative contributions of local and foreign recruitment to particular populations have yet to be determined (Hinegardner and Rosen 1972, Hateley 2005). Cellular DNA in Nassau grouper was reported to be 1.3 picograms (haploid), similar to that of other serranids and similar to the average value of a wide diversity of other percomorph fishes (Hinegardner and Rosen 1972). Hateley (2005) presented preliminary results on genetic variability in the Nassau grouper, based on enzyme electrophoresis. Clearly resolved enzyme phenotypes were obtained at 20 loci, of which 5 exhibited polymorphisms. On the basis of a sample of 264 individuals taken from Belize, Bahamas, Turks and Caicos, and Cayman Islands, intermediate to low levels of genetic variability were indicated; mean heterozygosity per locus was 0.024; proportion of polymorphic loci = 0.15, and the mean effective number of alleles was 1.45. There was no evidence for population sub-structuring by sex or small-scale spatial distribution, or for macrogeographic stock separation. The results were interpreted as being consistent with a single panmictic population within the northern Caribbean basin and suggested high gene flow in the region. However, because gel electrophoresis can detect only differences among samples and not similarities; it may not detect real inter-stock differences and more sensitive methods must be applied to increase resolution (J. Hateley, Bermuda Division of Fisheries – Department of Agriculture, Fisheries, and Parks, pers. comm. to Y. Sadovy, NMFS, 1994).

A study of genetic population structure in the Goliath grouper (*E. itajara*) and Nassau

[3] Megan Cook, Oregon State Univ. (Hixon Lab), as cited in Albins and Hixon 2011.
[4] Wendel Raymond, Oregon State Univ. (Hixon Lab), as cited in Albins and Hixon 2011.
[5] Tim Pusack, Oregon State Univ. (Hixon Lab), as cited in Albins and Hixon 2011.

grouper, using PCR (Polymerase Chain Reaction)-amplified mtDNA genes and nuclear microsatellites, revealed no clearly defined population substructuring for either species at the geographic locations sampled, i.e. Belize, Cuba, Bahamas, Florida for Nassau grouper (Sedberry et al. 1996). These data indicate that spawning aggregations are not exclusively self-recruiting and that the larval stages can disperse over great distances, however the relative importance of self-recruitment and larval immigration to local populations was not clear (Sedberry et al. 1996). Recent advances might be applied to examine source or nursery areas and shifts in fish between habitats with contrasting microchemical signatures.

Results of both Hateley (2005) and Sedberry et al. (1996) indicate a single panmictic population of Nassau grouper in the northern Caribbean basin with high gene flow between Florida, Cuba, Belize and the Bahamas. However, they do not quantify the connection. Results of an ongoing PhD study using more fine-scale genetic techniques may provide a more detailed understanding of population structure. (Alexis Jackson, PhD. research in progress, Department of Ecology & Evolutionary Biology, University of California, Santa Cruz).

2. THREATS OR STRESSORS

Key threats are presented although they are unlikely to be all that are possible.

2.a. Anthropogenic Effects

Fishing effects. Two different aspects of fishing effect Nassau grouper stocks, fishing effort throughout the non-spawning months and fishing effort directed at spawning aggregations or migratory access to spawning aggregations.

Nassau grouper are fished commercially and recreationally throughout the year by handline, longline, fish traps, spear guns, and gillnets (NMFS General Canvas Landing System). Aggregations are mainly exploited by handlines or by fish traps, although gillnets were being used in Mexico in the early to mid-1990s (Aguilar-Perera 2004). Sadovy and Eklund (1999) show declines in landings, catch per unit effort (CPUE) and, by implication, abundance in the late 1980's and early 1990's throughout its range, which has led Nassau grouper to now be considered commercially extinct in a number of areas (Sadovy and Eklund 1999). Recent reports from throughout the Nassau grouper's range document continued population declines and loss of aggregations (Sadovy de Mitcheson 2012).

The aggregative reproduction style - gathering at predictable sites in large concentrations to spawn during a few weeks (over a few months) each year - makes the Nassau grouper vulnerable as a target of fishing like many other reef species that form large aggregations to spawn. In many places, aggregation-fishing once produced most of the annual landings of the species (e.g., Claro et al. 1990, Bush 1992). Because Nassau grouper are only known to reproduce in spawning aggregations, removing ripe individuals during spawning has the potential to greatly influence population dynamics and future fishery yields (Shapiro 1987). The fact that much of the catch in many countries historically came from spawning aggregations (Olsen and LePlace 1978, Aguilar-Perera 1994, Sadovy and Eklund 1999) likely magnified the effects to the extent that targeted aggregations have collapsed in many countries (Sadovy de Mitcheson 2012). Its declines have compromised the ecological function of a major top predator in the reef ecosystem (Randall 1987, Mumby et al. 2006, Mumby et al. 2012).

Prior to regulations prohibiting the harvest and possession, the U.S. Virgin Islands and Puerto Rico's reef fisheries commonly took Nassau groupers at aggregation sites (SAFMC 1990, CFMC 1993). Nassau grouper have also been caught from several sites off the Jamaican coast and off the northern coast of the Dominican Republic (Thompson and Munro 1983, Sadovy 1997). In Mexico, at least seven aggregation sites have been fished along the Yucatan Peninsula since the beginning of the 20th century (1910-1920) (Aguilar-Perera 1994). Thompson (1945) described one large aggregation site off Cay Glory, Belize, that had been fished for many decades and postulated that other congregations occur, but had escaped detection because of their ephemeral nature; other sites have been identified since Thompson’s work (Paz and Grimshaw 2001). In Cuba, 21 spawning aggregation sites were identified; only 10 of these aggregation sites were Nassau grouper spawning aggregation sites. Of the 10 Nassau grouper aggregation sites, two were “aggregation statuses” were identified as “declined” and eight were identified as “sharply declined” (Claro and Lindeman 2003). In Atlantic waters, Nassau grouper have been caught in the Florida Keys and the Bahamas (Bohnsack 2003). The Bahamian Department of Fisheries reported that in 1992, over 20 spawning locations were fished (R. Thompson, Bahamas Department of Fisheries, pers. comm. to Y. Sadovy, NMFS, 1992), although the current status of many is unknown. A research trip during the spawning season of 2013 (B. Erismas, SCRFA Newsletter 17, June 2013) failed to find any sign of Nassau groupers at the spawning aggregation site that was the original site described by Smith (1972). There are no known spawning aggregation sites in Florida waters. In the Gulf of Mexico, Nassau grouper were caught primarily off southwest Florida, with commercial and recreational catch reported from the southwest Florida Keys. Both recreational and commercial catches of Nassau grouper were higher from the Florida-Gulf of Mexico than from the Florida-Atlantic coast from 1986-1993 (NMFS General Canvass Landings System). After 1991, these differences were probably partially due to fishery regulations banning all capture of Nassau groupers from the U.S. Atlantic waters, though not from the Gulf of Mexico; harvest and possession are now banned in all U.S. waters (CFMC 1990, SAFMC 1991, GMFMC 1996, compiled in Sadovy and Eklund 1999).

Age composition of fishery catches. Nassau grouper sampled from catches at 5 spawning aggregations in the Cayman Island’s from 1987-1992 generally fell within age classes 2-9 years and included many immature individuals (Bush et al. 2006). No size-at-age differences between males and females have generally been noted (Bush et al. 2006). Over 80% of the samples taken (n = 816) from a known aggregation in the Virgin Islands between 1974 and 1978 were aged 4-6 years (as estimated by probit analysis) (Olsen and LaPlace 1979), while most fish landed from aggregations in the Cayman Islands from 1987-1992 were aged 7-8 years (Bush et al. 2006).

Age classes 6-9 dominated all landings in southwestern Cuba and 3-8 years in northeastern Cuba between the early 1960s and late 1980s with 50% of landings coming from aggregations (Claro et al. 1990).

Size composition of fishery catches. A maximum length of 1,220 mm TL and weight of 23-27 kg are recorded for the Nassau grouper (Evermann 1900, Randall 1963, Smith 1971, Buesa 1987). Most fish in markets, however, are considerably smaller (i.e., 2-11 kg) (Smith 1971). Weights of aggregating fish ranged from 5-12 kg, with a maximum of 14 kg (Smith 1971, 1978, Aguilar-Perera 1994). Grouper up to 960 mm SL were taken in the Virgin Islands although fish larger than about 700 mm were uncommon (70 of 816 fish sampled) (Olsen and LaPlace 1979). Maximum theoretical mean length (L_∞ from the von Bertalanffy growth function - von Bertalanffy 1957) has been estimated at between 760-1,129 mm TL (Thompson and Munro 1978, Olsen and LaPlace 1979, Claro et al. 1990).

As stated previously, mean male and female sizes are similar within a given area, or at a specific aggregation site. There is some indication that sizes of both sexes decline in areas of higher exploitation versus unexploited populations within a specific region (Carter et al 1994) (Fig. 9).

When exploitation is high, catches are largely comprised of juveniles (growth overfishing). For example, in Belize, the average length of both sexes was 100 mm smaller in catches from exploited compared to unexploited aggregations (Fig. 9). In only two cases were females significantly longer than males, while males were never larger than females (Thompson and Munro 1978, Sadovy and Colin 1995). Most catches consisted of juveniles in heavily exploited areas of Puerto Rico, Florida (Figs. 22 and 23 in Sadovy and Eklund 1999), and Cuba (Espinosa 1980).

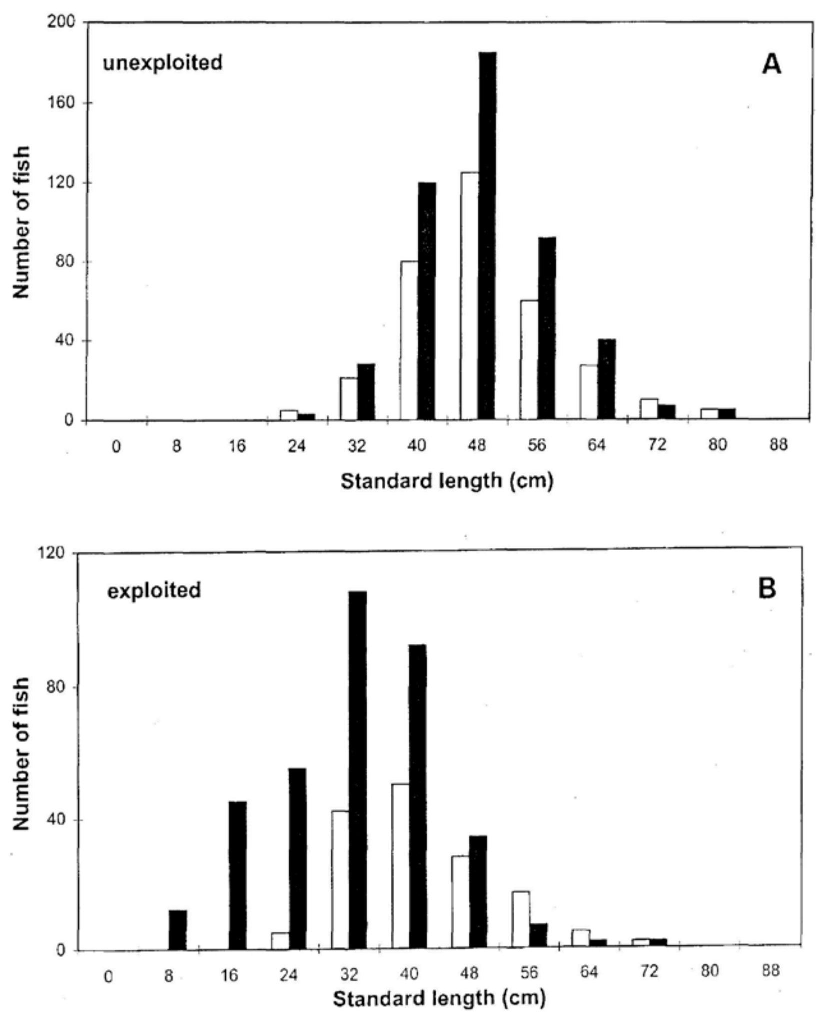

Figure 21
Length-frequency distributions of male and female Nassau grouper, *Epinephelus striatus*, taken from aggregations [males = white bars, females = black bars] in Belize: (A) unexploited site (*n*=694); (B) exploited site (*n*=485) (Carter et al., 1994).

Figure 8. Length-frequency distributions by sex for exploited and unexploited sites in Belize

Table 9. Mean sizes and sex ratio across a gradient of fishing pressure (excerpt from Sadovy and Eklund 1999)

Mean sizes and sex ratios of aggregating and non-aggregating Nassau grouper, *Epinephelus striatus*, in the western Atlantic, from lightly (top of table) to heavily (bottom of table) exploited areas. Fishing intensity implied by descriptions of current and historic fishing activity (from Sadovy and Colin, 1995). Number in parentheses refers to references.

Sex ratio F:M	Mean SL in mm F	Mean SL in mm M	Max SL in mm	Gear used[1]	Location and source[2]
0.57:1 (*n*=750)	526	529	750	T,H	Bermuda, offshore banks > 60 m deep (1)
0.72:1 (*n*=163)	554[3]		718	H,T	Jamaica, offshore (3)
1.5:1 (*n*=694)	517	521	802	H,S	Belize, aggregation (4)
2.0:1 (*n*=42)	502	487	568	G	Mexico, aggregation (2)
0.67:1 (*n*=70)	514	503[4]	657	G	Mexico, aggregation (2)
1.0:1 (*n*=940)	589	585	940	T,H	U.S.V.I., aggregation (5)
1.9:1 (*n*=95)	516	512	640	H	Caymans, aggregation (6)
2.0:1 (*n*=140)	506	538	772	H	Caymans, aggregation (7)
2.2:1 (*n*=717)	418	420	760	H,S	Belize, nonaggregated (4)
2.4:1 (*n*=485)	418	420	690	H,S	Belize, aggregation (4)
2.5:1 (*n*=216)	549	517[4]	700	T	Bahamas, aggregation (8)
4.0:1 (*n*=319)	>500[3]			710	S,T Cuba, (9) (only adults assessed)

[1] Gear used: T=trap; H=handline; S=spear; G=gillnet.
[2] Sources: (1) Bardach et al., 1958; (2) Sosa-Cordero & Cárdenas-Vidal ,1997; Aguilar-Perera, 1994; (3) Thompson & Munro, 1978; (4) Carter et al., 1994; (5) Olsen and LaPlace, 1979; (6) Colin et al., 1987; (7) Bush (text footnote 42); (8) Colin, 1992; (9) Claro et al., 1990.
[3] Males and females combined.
[4] Females significantly larger than males at $p<0.05$, otherwise no sex difference in size.

2.b. Habitat loss or degradation

During its various life history stages, the Nassau grouper uses many different communities or habitat types within the coral reef ecosystem. The increase in urban, industrial, and tourist developments throughout the species' range impacts coastal mangroves, seagrass beds, estuaries, and live coral (Mahon 1990). Loss of juvenile habitat, such as macroalgae, seagrass beds, and mangrove channels is likely to negatively affect recruitment rates. As shown in the Bahamas (Dahlgren and Eggleston 2001), habitat preferences or selection may be key to early survival and subsequent population size and loss of those preferred coral-algal settlement habitats may pose a threat to grouper populations (Kaufman and Romero 2011). Poor water quality is a threat to both corals and macroalgae in nearshore areas. Increased sedimentation resulting from poor land development practices adds turbidity and pollutants into nearshore habitats and can change water flow patterns in creeks, where newly settled juveniles may be found. Dredging operations are also capable of destroying macroalgal beds that may be used as grouper nursery areas. Affects to Nassau grouper through habitat loss or degradation are summarized best by Semmens et al. (2008a):

> “While Nassau grouper are typically thought of as strictly a reef associated species, they transition through a series of ontogenetic shifts, from planktonic larvae, to nearshore sea-grass and algae habitat, to predominantly reef habitat (e.g. fore reef and reef crest). Even within reef habitat, there appears to be ontogenetic sorting, such that the larger individuals tend to occupy the deeper, more rugose reef areas. Each of these general habitats has undergone and continues to undergo change. Open-ocean larval habitat is being influenced by the ongoing increase in ocean sea-surface temperatures. These changes in temperature may influence habitat quality directly through physiological stress, or indirectly through impacts to prey and predator densities (Anderson 1988).

Seagrasses are in decline globally (Lotze et al. 2006); the decline of turtle grass in the Caribbean may reduce the amount of suitable habitat for newly settled Nassau grouper, and may influence the abundance of prey items for new recruits. Coral reef biogenic structure is in decline, owing in large part to the dramatic decline in Acroporid corals. Furthermore, the ongoing decease in ocean acidity is likely to have a dramatic influence on the accretion rate of coral species in the future (Hoegh-Guldberg et al. 2007). It is possible that the ongoing and projected decline in biogeneic structure on Caribbean coral reefs will have a dramatic impact on the availability and quality of reef habitat for mature Nassau grouper."

Suitable habitat for the Nassau grouper is also likely to be in decline (Semmens et al. 2008a, Lotze et al. 2006). Of the 20,000 km^2 of coral reef estimated for the Caribbean in the mid-1990s, 29% was estimated to be under high risk of degradation from human activities, 32% is at medium risk and 39% is at low risk (Bryant et al. 1998). A decade ago, Gardner and coworkers (2003) documented basin-wide losses of hard coral cover from about 50% to about 10%. With no indications of recovery of scleractinian coral cover, it is likely that many Caribbean reefs will continue to loose three-dimensional structure through uncompensated bioerosion and increases in macroalgal cover (McClanahan et al. 2002).

Under natural conditions the Nassau grouper appears to prefer clear waters (Albins et al. 2009), but is fairly tolerant of a range of water qualities: one adult survived for more than seven years in the old New York Aquarium in which the water at times became nearly fresh and was frequently quite polluted (Townsend 1905).

2.c. Climate change implications

Nassau grouper have been found across a range of temperatures with the only implication being that spawning occurs when sea surface temperatures are approximately 25°C. If sea surface temperatures rise, the geographic range of the species may shift in response to any changes. One of the other potential effects of climate change could relate to the loss of structural habitat in the coral reef ecosystems (Munday et al. 2008). Ocean acidification is anticipated to affect the integrity of coral reefs and changing sea level could modify the depth regime with such rapidity that coral and coral reefs will be affected (Munday et al. 2008). Increased sea surface temperatures have been responsible for coral loss through bleaching and disease and bioerosion may reduce 3-dimensional structure in affected areas (Alvarez-Filip et al. 2009), reducing adult habitat for Nassau grouper (Coleman and Koenig 2010, Rogers and Beets 2001). Changes in reproductive output or seasonal timing are also possible with unknown consequences for population abundance. Increased global temperatures are also predicted to change parasite-host relationships and may present unknown concerns (Harvell et al. 2002, Marcogliese 2001).

2.d. Limits to recruitment/depensation

Depensation, also referred to as the Allee effect, occurs when the abundance or density of individuals drops below a critical threshold and reproduction becomes ineffective in sustaining the population. The different mechanisms hypothesized to cause depensation (after Semmens et al. 2008a) in Nassau grouper can be loosely classified as either: 1) biological or ecological (e.g., low reproductive rates/low fertilization rates through poor mate choice or high predation at low population levels) or; 2) behavioral (e.g., lack of behavioral cues leading to spawning) (Semmens et al. 2008a, Sadovy de Mitcheson and Erisman 2011). Colin (1992) and Semmens (B. Semmens, Scripps Institute of Oceanography University of California – San Diego, pers. comm. to Y. Sadovy, University of Hong Kong, 2012) have described variance in behavior of small groups of spawning Nassau grouper. They tend to stay at the spawning aggregation sites longer, they show spawning coloration and behavior to lesser degrees than spawners in larger numbers. In the U.S. Virgin Islands (Nemeth et al. 2006), although small numbers of Nassau groupers showed up at a presumed spawning aggregation site south of St. Thomas, they showed only minimal color change and they did not spawn.

Because of the size and apparent behavioral complexity (Whaylen et al. 2004) of Nassau grouper spawning migrations and aggregations, behavioral depensation could be the most widely accepted mechanism for the lack of aggregation formations and recovery (Bolden 2000, Sadovy 2001). Bolden (2000) and Nemeth and coworkers (2006) have suggested that the "ecological knowledge" of spawning site locations, timing, and behavior may be lost to grouper populations when intense fishing on aggregation sites removes the old individuals with such knowledge. If true, this could have important implications for any future spawning aggregation formations.

Semmens et al. (2006) hypothesize: "Alternatively, it may be that the grouper are migrating to spawning site locations, but due to low densities, individuals are choosing to leave and explore alternative shelf edges and reef promontories in expectation of finding higher densities elsewhere. Thus, fish spend the spawning season in search of spawning sites, and never spawn. Finally, it may be that fish are able to find the spawning site, and stay at the spawning site during spawning season, but due to perceived poor mate choice and low densities, fish forgo spawning."

Given that many of the spawning aggregations have become severely depleted and between 25-50% no longer form, it is probable that reproductive output and potential for some populations have been seriously compromised (Smith 1972; Sadovy and Eklund 1999; Sala et al. 2001; Whaylen et al. 2004; Belize Spawning Aggregation Working Group, unpublished data; R. Claro, unpublished data; E. Sala, unpublished data, as presented in Sadovy de Mitcheson et al. 2008). Two of the most well-known sites, one off Bimini, Bahamas (Smith 1972) and one at Mahahual, Mexico (Aguilar-Perera, pers. obs. June 2013, http://www.scrfa.org/images/stories/pdf/newsletter/news17_final.pdf) appear to have disappeared. Moreover, observations of reproductive activity, duration of aggregations, and intensity of color changes suggest that spawning becomes abbreviated or ceases when fish numbers are low (Colin 1992, Aguilar-Perera and Aguilar-Davila 1996). In extreme cases, such as Bermuda, or Puerto Rico, where aggregations no longer form, Nassau grouper are now rarely taken or observed and the only reports of Nassau are from these rare fishery interactions.

2.e. Disease, parasites, and abnormalities

Parasites occur in both wild-caught and cultivated Nassau grouper, predominantly in the viscera and gonads. Encysted larval tapeworms are common in the viscera and a reddish brown nematode occurs in the gonads (Thompson and Munro 1978). Parasitic isopods are found in nostrils (Thompson and Munro 1978). The digenetic trematode *Helicometra tort*a (pyloric caeca), *Lecithochirum parvum* and *L. microstomum* (stomach), and *Sterrhurus musculus* (stomach) were identified in Florida-caught fish (Manter 1947, Overstreet 1969).

Diseases and abnormalities are not described. Although several species of western Atlantic groupers are known to be ciguatoxic (especially when large), Nassau groupers have been thought to be uniformly non-toxic throughout their range (Halstead 1967, Jory and Iverson 1989) with the interesting exception of one small toxic Nassau grouper in the Virgin Islands (Brownell and Rainey 1971). Excrescences were noted on otoliths and one fish had a completely malformed sagittal pair with the whole of the concave surface overgrown with a large excrescence (Thompson and Munro 1978).

2.f. Aquaculture – successes, failures, potential threats

The Nassau grouper is considered a prime species for aquaculture (Tucker 1992a, 1992b). In the late 1980s and into the 1990s, considerable progress was made in hatchery spawning and rearing of groupers under aquarium conditions (Tucker 1992a, Watanabe et al. 1995a, 1995b, Tucker et al. 1996).

Female Nassau groupers were induced to ovulate using human chorionic gonadotropin (HCG) injections, luteinizing hormone-releasing hormone analog (LHRHa) and carp pituitary homogenate (CPH), or combinations thereof (Tucker 1992b, Kelley et al. 1994, Watanabe et al. 1995b). Females with mean oocyte diameters ranging from 482-561 micrometers (μm) were suitable for hormone-induced spawning (Watanabe et al. 1995b). Tucker et al. (1996) described four methods for achieving fertilized eggs, including combinations of induced or natural ovulation and artificial fertilization with fresh milt or natural spawning in tanks.

Fertilization rates in artificially induced spawns ranged from 18-100% and hatching success ranged from 68-100% (Head et al. 1996, Tucker et al. 1996). Multiple spawns occurred on consecutive days and hatchery reared juvenile Nassau groupers grew to 1.5- 2.0 kg in 2 years (Tucker and Woodward 1993).

Following hormone injections, Nassau grouper females produced clutches of between 23,000 and 600,000 mature eggs per kg of body weight, with large females capable of yielding almost 5,000,000 eggs. Kelley et al. (1994) reported one to two clutches produced during the natural reproductive season, with each clutch totaling 50,000-600,000 eggs per kilogram body weight. Head et al. (1996) found that females could spawn two to three times at intervals of 28 to 75 days, producing 200,000- 2,000,000 eggs per female (54,000 and 340,000 eggs/kg body weight) with females ranging in size from 3.5-6.8 kg. Tucker et al. (1991) noted clutches of 500,000 to 700,000 for females ranging from 3-5 kg (166,666 to 140,000 eggs/kg), while Watanabe et al. (1995b) reported stripped females of 4.2-12 kg releasing between 95,000 and 4,750,000 eggs (22,619-395,833 eggs/kg), with a significant relationship between body weight and eggs stripped ($y = 0.385x-0.5589$; $r^2 = 0.40$, $n = 41$, $p<0.001$; y is eggs stripped and x is body weight in kg).

Larval survival to first feeding was generally high, with declines thereafter depending on feeding regime. Survival of larvae to first feeding in one set of experiments was 65% (Tucker 1992b) but was found to decline to about 1% by day 62 post-hatching in another (Watanabe et al. 1994, 1996); larval survival declined once the yolk sac was absorbed. Feeding with oyster trochophores and sieved rotifers, combined, achieved higher larval survival rates than feeding with unsieved rotifers alone (Watanabe et al. 1994) and small prey size was important (Watanabe et al. 1996). Results of feeding experiments indicated that cultured juveniles require a dietary protein level above 55% and an energy-to-protein ratio of below 28.9 kJ/g for optimum growth (Ellis et al. 1996). Control of turbulence, salinity, and light intensity improves survival to the first feeding stage (Ellis et al. 1997b). Increased growth and feeding rates occurred with increased water temperatures (Ellis et al. 1997a).

Experiments to determine the success rate of larval Nassau grouper culture (Watanabe et al. 1995a, 1995b) and survival of released hatchery-reared juveniles (Roberts et al. 1994) have been conducted. Although temperature manipulation might be used to condition Nassau grouper to spawn any month of the year (Tucker et al. 1996), hatching success was higher between 26-28°C compared to hatching at 30°C (Watanabe et al. 1995b). Nassau grouper juveniles (309-367 mm TL) reared from eggs (n = 27) at Harbor Branch were used to test the feasibility of restocking reefs (Roberts et al. 1994) in St. Thomas. Despite some mortality and dispersal, a few tagged fish were observed up to nine months after release. The potential of Nassau grouper stock enhancement, as with any other grouper species, has yet to be determined (Roberts et al. 1994). Serious concerns about the genetic consequences of introductions and about possible problems of juvenile habitat availability, introduction of maladapted individuals, or inability to locate traditional spawning aggregations, continue to be raised.

3. DESCRIPTION OF FISHERIES AND FISHERIES MANAGEMENT AND CONSERVATION

Data on recruitment into the fishery indicate that age and size first susceptible to capture are 4-7 years and 275+ mm TL, respectively. In some areas, most of the catch is, or has been, composed of juveniles (e.g. Puerto Rico and Cuba) (Puerto Rico Fisheries Research Laboratory 1991, Claro et al. 1990). Olsen and LaPlace (1979) calculated age of first capture at 4-5 years, although immature fish of 2 years (< 300 mm TL) were also recruited. Mean size of recruitment into the fishery in Jamaica was estimated at 570 mm TL (about 5 years old) on oceanic banks for handline and fish trap fisheries; the minimum length captured was 275 mm TL and the full retention length was 625 mm TL (Thompson and Munro 1978). Modal ages reported for a Cayman Islands aggregation and a stock in Cuba were 6-8 years (Claro et al. 1990, Bush et al. 2006), suggesting that individuals were not fully recruited until this age range.

3.a. Abundance indices and trends over time

Stock assessments. Few formal stock assessments have been conducted for the Nassau grouper, likely because of limited data. The most recent published assessment, conducted in the Bahamas, indicates fishing effort in the Bahamas needs to be reduced from the 1998 to 2001 level, otherwise the stocks are likely to be overexploited relative to biological reference points. (Cheung et al. 2013). The population dynamic modeling by Cheung et. al (2013) found: "assuming that the closure of the spawning aggregation season is perfectly implemented and enforced, the median value of *F*SPR = 35% on non-spawning fish would be 50% of the fishing mortality of the 1998 to 2001 level. The 5% and 95% confidence limits are estimated to be less than 20% and more than 100% of the fishing mortality at the 1998 to 2001 level, respectively. In other words, if (1) fishing mortality rates of non-spawning fish are maintained at the 1998 to 2001 level, and (2) fishing on spawning aggregations is negligible, the median spawning potential (spawner biomass relative to the unexploited level) is expected to be around 25% (5 and 95% CI of 20 and 30%, respectively). This level is significantly below the reference limit of 35% of spawning potential, meaning that there is a high chance of recruitment overfishing because of the low spawning stock biomass."

During the first U.S. survey of the fishery resources of Puerto Rico, the Nassau grouper was noted as a common and very important food fish, reaching a weight of 50 lbs. (22.7 kg) or more (Evermann 1900). By 1970, Nassau grouper was still the fourth most common shallow-water species landed in Puerto Rico (Thompson 1978), and it was common in the reef fish fishery of the Virgin Islands, where an aggregation in the 1970s contained an estimated 2,000-3,000 individuals (Olsen and LaPlace 1979). During the 1980s, port sampling in the U.S.V.I. showed that Nassau grouper accounted for 22 percent of grouper landings with 85 percent of the Nassau grouper catch coming from spawning aggregations (D. Olsen, Chief Scientist – St. Thomas Fishermen's Association, pers. comm. to J. Rueter, NMFS, October, 2013). By 1981, "the Nassau grouper ha(d) practically disappeared from the local catches and the ones that d(id) appear (were)-small compared with previous years" (CFMC 1985) and by 1986, the Nassau grouper was considered commercially extinct in the U.S. Virgin Islands/Puerto Rico region (Bohnsack et al. 1986). About 1,000 kg were landed from the Reef Fish fishery during the latter half of the 1980s in Puerto Rico, most of them were less than 500 mm, indicating they were likely sexually immature (Sadovy 1997).

Little is known about the dynamics of unexploited stocks of Nassau grouper although some of the data from the 1980s give us some insight (Carter et al. 1994). Spawning stock biomass per recruit has not been quantified for the species but landings data clearly show a chronological trend from abundance to rarity in many areas (e.g., Sadovy 1997). Of particular concern has been the rapid and extreme decline in numbers taken from traditional aggregation sites (Sala et al. 2001). In general, slow-growing, long-lived species (such as snappers and groupers) with limited spawning periods and, possibly, with only a narrow recruitment window are susceptible to overexploitation (Bannerot et al. 1987, Polovina and Ralston 1987). Hodgson and Liebeler (2002) noted that Nassau grouper were absent from 82% of shallow Caribbean reefs (3–10m) during a 5-year period (1997-2001) of underwater surveys for the ReefCheck project. This is derived from underwater surveys in most countries in the range of the species.

Known spawning aggregations of Nassau grouper are displayed in Figure 9 as available in published and gray literature and interviews (Sadovy de Mitcheson et al. 2008). Data have been archived in the scrfa.org website database. The map shows all known aggregations reported to exist since 1884 (a). In the few cases where aggregation numbers were estimated, abundances ranged from approximately 10,000 to somewhere between 30,000 and 100,000 fish (Smith 1972, Olsen and LaPlace 1979, Colin et al. 1987, Fine 1990, 1992, Carter et al. 1994, Sadovy 1997). For comparison, it also shows those aggregation sites reported to exist as of about 2007 (b). The closed circles represent sites believed to exist, with fish numbers estimated at between 100 and 3000 (estimates from fishing and direct observations). The open circles represent sites in Cuba still believed to produce small catches of Nassau grouper but sites have not been assessed directly.

While heavy fishing on spawning aggregations may have been a primary driver of population declines (Sadovy de Mitcheson and Erisman 2012), other factors may affect populations at a national level. Heavy fishing of adults away from or during spawning runs, the intensive capture of juveniles, either through direct targeting (e.g., spearfishing) or using small mesh traps or nets, will compromise population stability and spawning potential, and loss or degradation of habitat could affect populations because reef associated habitats are used as shelter at all life history phases may all have detrimental effects (e.g., Semmens et al. 2007a), though it is not clear if one factor is more detrimental than the others, or if these deleterious effects work in combination.

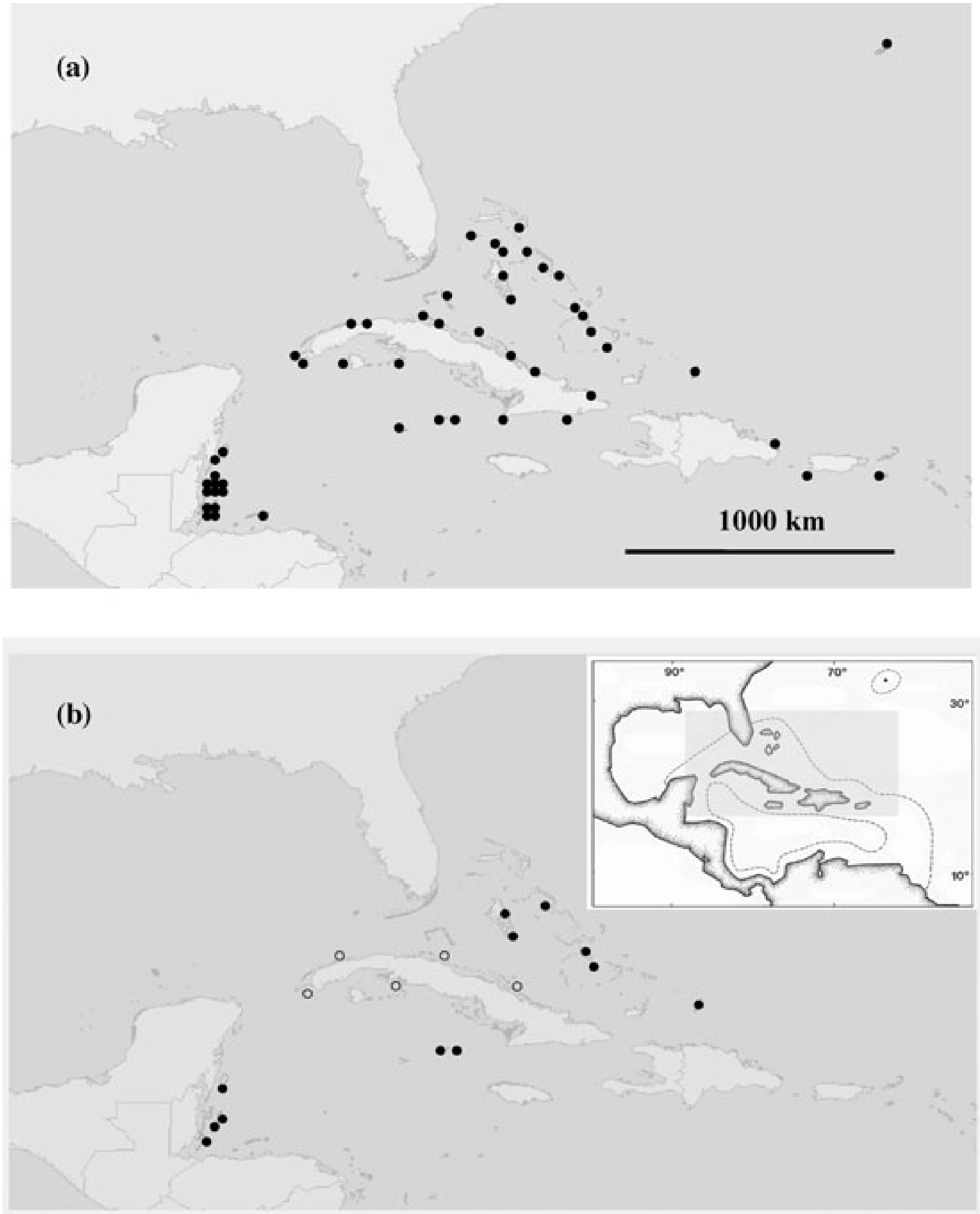

Figure 10. Maps showing locations of known Nassau grouper spawning aggregations both historically (a) and as of about 2007 (b) according to available information-not all sites have been validated. Inset shows full geographic range, main concentrations (shaded) and extended areas (dashed lines). Each closed circle represents 1, or occasionally 2, reported site(s). Open circles are "probable" sites. (Sources: Smith 1972; Sadovy and Eklund 1999; Sala et al. 2001; Whaylen et al. 2004; Belize Spawning Aggregation Working Group, unpublished data; R. Claro, unpublished data; E. Sala, unpublished data, as presented in Sadovy de Mitcheson et al. 2008)

Ecological assessments. The Nassau grouper was formerly one of the most common and important commercial groupers in the insular tropical western Atlantic and Caribbean (Smith 1978, Randall 1983, Appeldoorn et al. 1987, Sadovy 1997). Declines in landings, catch per unit of effort (CPUE), and, by implication, abundance, have been reported throughout its range, and it is now considered to be commercially extinct (the species is extinct for fishery purposes due to low catch per unit effort) in a number of areas. Information on past and present abundance and density, in both aggregation and non-aggregation habitat, is based on a combination of anecdotal accounts, visual census surveys, and fisheries data. The lack of species-level fisheries data severely limits fishery dependent analysis of the species throughout its range. Fishery independent surveys provide the only broad scale data with which to access current population condition. Such studies are referenced in the following sections, as available. Unfortunately, time series data are generally lacking and comparisons between reefs or between countries are the only possible ways to compare as a measure of relative abundance.

A number of organizations or agencies have undertaken surveys to elucidate the status of coral reefs and reef fish populations throughout the western Atlantic, as well as other parts of the world. Results from these monitoring studies (Kellison et al. 2009) offer some indication of relative abundance in various locations for Nassau grouper (Table 10), although generally different methods are employed and results cannot be directly compared. Sighting frequency and density may offer information. Results from Atlantic and Gulf Rapid Reef Assessment Program (AGRRA) show few Nassau groupers throughout their surveys. The sighting frequency (proportion of all surveys with at least one Nassau present) ranged from less than 1% to less than 10%. Densities would scale up to range from 1 to 15 fish/hectare with a mean of 5.6 fish/hectare across all areas surveyed. NOAA's Coral Reef Ecosystem Monitoring Program (CREMP) has conducted studies in Puerto Rico and the U.S. Virgin Islands since 2000 and sighting frequency has ranged from 0 to 0.5% and density has ranged from 0 to 0.5 fish/hectare. Data from University of the Virgin Islands (UVI Vis. Sur.) sampling as part of their jurisdictional coral reef monitoring (funded by the NOAA Coral Reef Conservation Program), was not readily available to compute sighting frequency but densities were 4 fish/hectare. NOAA's (NMFS FRVC) and Florida's Fish and Wildlife Conservation Commission (FFWCC Vis. Sur.) studies that focus on the Florida Keys indicate sighting frequencies ranged between 2-10%; densities from both studies were 1 fish/hectare (Table 10). Beyond these monitoring surveys, the Reef Environmental Education Foundation (REEF) sponsors and supports volunteer dive-based surveys across the region. Observers rank species abundance as Single = 1, Few = 2-10, Many = 11-100, and Abundant = over 100 rather than recording precise numbers. The data are then calculated as a Density Index (Den), which is a measure of relative abundance when the species is seen but does not give an indication of lack of occurrence and as a Sighting Frequency (%SF), which is a measure of how often the species was observed. The Den and %SF scores could be multiplied to provide a measure of species abundance, which accounts for zero observations. Where REEF survey information is available, it is included in the following Country Accounts. The data are not necessarily as easy to interpret as desired without additional spatial context (e.g., management regime).

Table10. Fishery Independent Surveys from various sources. Sighting Frequency is the number of surveys in which at least one Nassau grouper was encountered; Density is the total number counted per unit area, standardized by area of each survey type. AGRRA info: Kramer 2003.

Survey	Location/Extent	Year	Num. E. Stri. Observed	Num. Surveys w/ E. Stri.	Total Num. of Surveys	Sighting Frequency	Density (Num/m^2)
AGRRA	Andros Island, Bahamas	1998	23	23	295	0.078	0.0013
AGRRA	Abaco Islands, Bahamas	1999	4	4	130	0.031	0.0005
AGRRA	Lighthouse Atoll, Belize	1999	1	1	110	0.009	0.0002
AGRRA	Glovers, Turneffe, Barrier Reefs, Belize	2000	6	6	349	0.017	0.0003
AGRRA	Little and Grand Cayman	1999	23	20	341	0.059	0.0011
AGRRA	Batabano, Cuba	2001	29	27	686	0.039	0.0007
AGRRA	Sabana and Camaguey, Cuba	2001	6	6	368	0.016	0.0003
AGRRA	Jardines de la Reina, Cuba	2001	7	7	535	0.013	0.0002
AGRRA	Boca del Toro and Comarca de Kuna, Panama	2002	4	4	451	0.009	0.0001
AGRRA	Caicos, Turks, and Mouchair Banks, Turks and Caicos	1999	25	25	279	0.09	0.0015
AGRRA	Culebra, Vieques, and Cayos de la Cordillera, PR	2003	2	2	174	0.011	0.0002
CREMP	La Parguera, PR	Average 2000-2007	2	2	1010	0.002	0.000025
CREMP**	Vieques, PR	2007	0	0	75	0	0
AGRRA	Biscayne National Park and Keys NMS, Florida	2003	8	7	381	0.018	0.0003
FFWCC Vis. Sur.	Keys NMS (Key Largo to Key West)	Average 1999-2007	79	76	7396	0.01	0.0001
NMFS FRVC	Keys NMS (Key Largo to Dry Tortugas)	Average 2000-2007	210	198	8563	0.0208	0.0001
AGRRA	St Croix, St Thomas, USVI and Guana, BVI	1999	1	1	144	0.007	0.0001
AGRRA	St Thomas, St John, USVI and Anegada, Virgin Gorda, BVI	2000	6	6	100	0.06	0.001
UVI Vis. Sur.	St. Thomas, USVI	Average 2003-2007	8	N/A*	290	N/A*	0.0004
CREMP USVI	St. John and St. Croix, USVI	Average 2001-2008	14	13	2638	0.005	0.00005

* Lack of raw dataset prevented computation of surveys in which Nassau grouper were sighted, and hence, sighting frequency as well
**This data not included in computation of density and sighting frequency trends for CREMP visual surveys in Puerto Rico

3.b. COUNTRY ACCOUNTS

Few population analyses or stock assessments have been conducted on the Nassau grouper. Therefore we summarize below fishery trends (catches or catch per unit of effort) over time, fishery-independent underwater reef fish surveys, sizes landed, and a narrow range of biological studies to inform current population status. Genetic work to date suggests a single panmictic population connected throughout its range. Studies of circulation patterns at spawning aggregation sites generally have indicated the presence of eddies and local retention mechanisms that result in self-recruitment in most areas although a mix of local and long-distance egg and larval transport appears most likely and somewhat unpredictable.

Hodgson and Liebeler (2002) noted that Nassau grouper were absent from 82% of shallow Caribbean reefs during a 5-year period of underwater surveys for the ReefCheck project. Of 162 reefs surveyed for Nassau grouper, only eight reefs had more than one fish. Of the 106 total fish counted during five years of monitoring, 76 were found on two reefs in the World Heritage Site in San Andrés Archipelago in Colombia, where spearfishing is prohibited on both reefs. In the Atlantic region, grouper abundance (including Nassau grouper) declined from 1999 (1.13 grouper ± 3.2 per 100 m2) to 2000 (0.25 ± 0.54 per 100 m2) although this is not statistically significant. This trend is consistent with underwater surveys in most countries across the range of the species.

Many of the countries where Nassau grouper have been reported have mechanisms to report fishery landings, either as a means of understanding local management status and needs or as a participant in broader regional or international management or conservation efforts (i.e., Food and Agriculture Organization of the United Nations). Unfortunately, many do not collect data at the species level but rather collect data, landings or effort; for instance, only at some functional group or family level. While this may be mildly informative, it is rarely useful in understanding fishery impacts to individual species. Most of what is known of the current status of Nassau grouper stocks must be derived from research or monitoring efforts or as interpretation of the scarce data.

In addition to the country accounts that follow, IUCN lists the following as islands/countries where Nassau grouper is considered to be native (Heemstra and Randall 1993). To date, little ecological or fisheries data, information or anecdotal evidence is available to provide insight into the status of Nassau grouper in the following jurisdictions: Antigua and Barbuda; Aruba; Costa Rica; Curaçao; Dominica; French Guiana; Grenada; Guadeloupe; Guatemala; Guyana; Haiti; Montserrat; Netherlands Antilles (Curaçao); Nicaragua; Panama; Saint Kitts and Nevis; Saint Lucia; Saint Vincent and the Grenadines; Suriname; Trinidad and Tobago; United States Minor Outlying Islands (i.e., Navassa); and Venezuela. Some of these locations are combined into the section entitled “Lesser Antilles, Central, and South America.”

ANGUILLA

The following information was obtained via James C. Gumbs, Director of Fisheries and Marine Resources, Ministry of Home Affairs, Government of Anguilla. (pers. comm. to R. Hill, NMFS SEFSC, 2013.)

Anguilla – Populations

Little information is available from published sources on the status of Nassau grouper in Anguilla's waters. According to the Fisheries Department in 2012: "With regards to the Nassau grouper it is not very abundant in Anguilla. Officers at the Department have reported only seeing one or two juveniles on their dives and other in-water work. We do not have the historical data in Anguilla to determine their former abundance, however it is believed that they were more abundant than they are now, judging from past fish catch observations."

Anguilla – Fisheries

No data are available from published sources on the fisheries that take or have taken Nassau grouper. According to the Fisheries Department in 2012: "The Nassau grouper is a species that was observed in fish catches in the 80s and prior to that (not any great amounts) but now they are not a part of the current fish catches (fish traps and lines). A fish catch data collection program [has only been] implemented at the department in the past four years and so an analysis of historical trends is not possible. However…this species is not present in current fish catches."

Anguilla – Conservation and Management

"There are no known spawning aggregation sites and there are no special conservation or management regulations in place."

BAHAMAS

Bahamas – Abundance and Distribution

The Bahamas with its many islands and extensive shallow reef areas very possibly holds or held one of the largest populations of Nassau grouper throughout its range. The species has long been the major landed finfish for the country and the first and largest ever reported spawning aggregation (with an estimated 30,000 to 100,000 fish) was documented from the Bahamas in Bimini (Smith 1972). By the late 1990s/early 2000s, the Nassau grouper population(s) in the Bahamas was likely fully exploited to over-exploited (Ehrhardt and Deleveaux 2007, Cheung et al. 2013). Both fisheries landings and mean body size in catches have declined since the 1990s, despite a minimum size regulation, protection during the spawning aggregation season, establishment of several protected aggregation sites, and marine protected areas (Cheung et al. 2013). There is no indication that these declines are due to reduced fishing effort or to changes in fishing practices; overfishing is most likely the cause. Reductions in numbers of fish observed in reef surveys, also suggest that populations are declining. One major concern is with poaching, especially by non-Bahamians: Bahamian fishermen largely abide by the seasonal closures for Nassau grouper (M. Braynen, Bahamas Department of Marine Resources, pers. comm. to Y. Sadovy, University of Hong Kong, 2012).

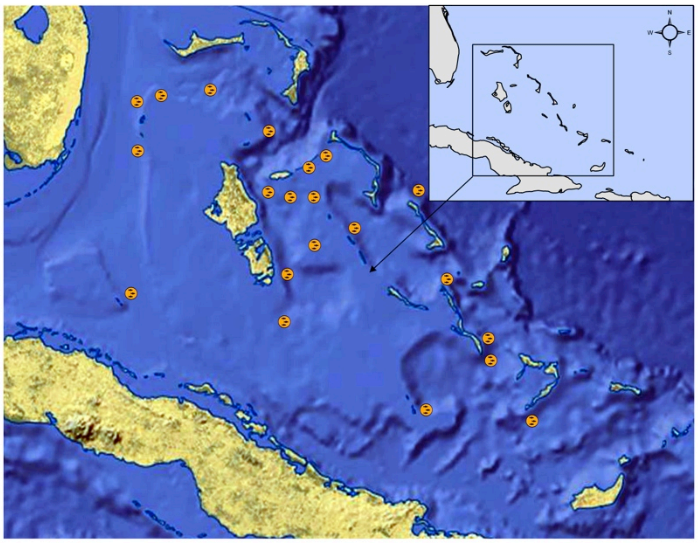

Figure 11. Approximate locations of Nassau grouper spawning aggregation sites in the Bahamas.

More than 20 aggregations have been reported from the Bahamas, but very few have been studied in any detail and the current status of the great majority is unknown. Cumulative data from REEF (2003-2013) show high numbers of sightings of 402 Nassau grouper in 1471 surveys (density index 1.5, sighting frequency 27.3%) in the north Bahamas, 3729 Nassau grouper in 6527 surveys (density index 1.6, sighting frequency 57.1%) in the central Bahamas, and 49 Nassau grouper in 75 surveys (density index 1.6, sighting frequency 65.3%) in the south Bahamas across the 10-year period. Examinations of time periods of 1990-95 vs. 2008-13 do not show great differences in sighting frequency or density index, but spatial/management zone data are lacking so comparability of sites is not known (http://www.reef.org/db/reports/dist/species/TWA/0097/2003-01-01/2013-04-07). Atlantic and Gulf Rapid Reef Assessment (AGRRA) surveys in Andros Island (1998) and Abaco Islands (1999) found relatively low numbers of encounters (sighting frequencies of 7.8% and 3.1%, respectively; densities of 13 fish/hectare and 5 fish/hectare, respectively) (AGRRA data, from T. Kellison, NMFS SEFSC – Beaufort Laboratory, NC). These are between 37.5% and 14.4% of the densities cited by Bardach in a relatively lightly impacted Bermuda in the 1950s.

Extensive and repeated surveys of spawning aggregations may provide some evidence of trends in abundance if effort is consistent and timing of surveys relative to spawning activity can be assured. Although systematic surveys have not been common, some studies can highlight major changes. At Cat Cay, Smith (1972), in the first scientific report of a Nassau grouper spawning aggregation, documented tens of thousands (30,000-100,000) of spawning Nassau groupers. A survey in January 2013 during the full moon period revisited the aggregation site reported by Smith in 1972. The site and extensive surrounding areas (4.5 linear miles) along the reef were surveyed multiple times. No evidence of spawning fish or a viable spawning aggregation was found. When queried, local fishers said the aggregation had disappeared by the early 1980s (http://www.scrfa.org/images/stories/pdf/newsletter/news17_final.pdf)

Bahamas - Fisheries

Nassau grouper are targeted by artisanal/subsistence, recreational and commercial (including for export) fisheries. Buchan (2000) indicated that the shallow banks throughout Great and Little Bahamas Banks, the Cay Sal Bank, and the Crooked Island and Acklins Island Banks were the major fishing grounds for Nassau grouper. In the Bahamas, fishermen use handlines, traps, and spears (including compressors/compressed air) to take Nassau grouper (Sadovy 1997). The use of a speargun is illegal, but a spear with a sling (e.g., Hawaiian sling) is legal. Spearfishing and fish-trapping, in particular, result in significantly higher CPUE than other fishing methods (Cheung et al. 2013). Regulations began to limit some aggregation fishing in 1998 and were implemented, as a 3-month closure, nationally in 2005. Fishing for Nassau grouper in other months continues.

In terms of weight and value, Nassau grouper has been the fourth most important commercial fishery resource in the Bahamas Exclusive Economic Zone behind spiny lobster, snappers and queen conch (Buchan 2000). In 2007, the most recent summary available, Nassau grouper comprised 2% by both weight and value of the recorded commercial landings of all commercially exploited species in the Bahamas (FA0 2009); spiny lobster makes up the greatest majority of the country's commercial landings. Nassau grouper in 2007 accounted for 73% of all commercial grouper landings in the country; recreational and subsistence use data of the species are not available (FAO 2009). A seafood consumption survey in 2003-2004 by Talaue-

McManus and Hazell estimated that the fisheries monitoring system in the Bahamas did not document 94% of total grouper catch based on consumption and trade statistics (L. McManus, The Global Environment Facility Transboundary Waters Assessment Programme, unpub. data, pers. comm. to R. Hill, NMFS, 2014). Therefore, reported landings are projected to represent only 6% of the total production needed to meet export and consumption levels.

Much of the annual landings historically came from spawning aggregations (Colin 1992); as many as 31 different sites (Table 11) have been reported (Sadovy de Mitcheson 2012). While BREEF (1998) reported between 13 and 31 aggregations, 23 have been confirmed by direct observation or catch monitoring (Sadovy and Eklund 1999). Landings data from 1995-2006 showed that most Nassau grouper were landed between December to February, although current regulations restrict fishing for Nassau grouper during most of that period.

Early research by Smith (1972) and Colin (1992) identified spawning aggregation sites in the 1970-1980s with numbers of spawners ranging from hundreds to tens of thousands. Subsequent research has rarely found abundances nearly so high. In an attempt to resurvey the sites documented by Colin (1992), researchers from North Carolina State University in January 2002 conducted diver and hydroacoustic surveys around Long Island, Bahamas (Gascoigne (2002, D. Eggelston, North Carolina State University, pers. comm. to R. Hill, NMFS SEFSC, 2014). None of the sites visited had more than 28 fish and none of the fish observed exhibited spawning behavior. It is possible that spawning had occurred the previous months although discussions with area fishers and fish marketers led the researchers to believe that spawning aggregations no longer occurred at these sites (D. Eggelston, North Carolina State University, unpub. data, pers. comm. to R. Hill, NMFS SEFSC, 2014).

The aggregation site at High Cay was also reported to consist of an order of magnitude fewer spawners than its historical size. Diver estimates ranged from 100 - 1,000 fish for 1999 - 2000 (Ehrhardt and Deleveaux 2007, Gascoigne 2002, Ray et al. 2000). In 1999, 2000, and 2001, hydroacoustic surveys were undertaken at High Cay as a novel assessment of the number of fish in single spawning aggregations (Ehrhardt and Deleveaux 2007). This study reported estimates of 10,523 (1999), 9,300 (2000), and 12,857 (2001) fish based on acoustic signal strength but there is little detail on the sampling method or the in-water observations necessary to validate the data. In 2000 - 2001, divers returned to the location and did not locate an aggregation, concluding fish may not have aggregated at the site (G. Carleton Ray, University of Virginia, pers. comm., as reported in Gascoigne 2002). There was no survey data available for the High Cay site in 2002, but catch was low following a three – year moratorium (J. Birch, Small Hope Bay, Andros, pers. comm. to J. Gascoigne, University of Virginia, 2002). The number of spawning Nassau grouper at the High Cay aggregation was evidently decreasing relative to historic estimates (Ray et al. 2000).

Table 4. Aggregation sites in the Bahamas in 1998
Bahamas aggregations - modified from BREEF (1998): DoF = Department of Fisheries

Location	**Number**	**Discussion/Source**
Cat Cay	1	100,000 individuals observed 1970.[1] 2013 survey at January full moon and local interviews indicate that the aggregation has long ceased to form (SCRFA Newsletter 17).
Great Issac Light	1	May have disappeared due to fishing pressure from Florida [2]
Andros	2	Locations High Cay and Tinker Rock [3]
Andros	3 more	Locations and source of report not known.[4] Not apparently known by local fishermen so probably not true.
Long Island	1	Decline in catches from several thousand to less than 100 fish. [5] However, 1997 catches on the aggregation reported to be good by Long Island fishermen. One aggregation site in Long Island reported by fishermen in San Salvador as their nearest aggregation
Long Island	*2 more*	Locations and source not given.[6] DoF believe that there are two aggregation sites in Long Island.
Exuma Cays	1	From work by Pat Colin [7]
Cat Island	1	Locations and source of report not given [8]
Berry Islands	4	Locations and source of report not given
New Providence	1	Locations and source of report not given. Not reported by New Providence fishermen so unlikely to be true.
Ragged Island	1	Locations and source of report not given. If exists may be threatened by fishing pressure from other countries
Cay Sal	1	Locations and source of report not given. If exists may be threatened by fishing pressure from other countries
Eleuthera	4	Locations and sources of report not given
Acklins	1	Locations and source of report not given. If exists, may be threatened by fishing pressure from other countries.
Abaco	3	Discussions with Hopetown and Marsh Harbour fishermen
Grand Bahamas	4	Reported to be known and fished by a Grand Bahama based fishing company [9]
Minimum total	4	Aggregations confirmed in recent scientific literature
Approximation	13	Aggregations confirmed by local reports and literature
Maximum total	31	All reports above, some of which are fairly unlikely

Sources: (1) Smith, 1972; (2) Reported by CL Smith in the early 1970s; (3) From discussions with fishermen- Dr. Tim Turnbull (4) 5 spawning aggregations in Andros reported in Sadovy (1997) (5) Colin 1992; (6) Sadovy (1997); (7) Dr. Tim Turnbull, Sadovy (1997); (8) Sadovy (1997)-also source for Berry Islands, New Providence, Ragged Island, Cal Say, Eleuthera and Acklins; (9) Vallierre Deleveaux, Bahamas Dept. of Fisheries

In a recent detailed analysis, catches from 1994 to 2009 were assessed using fishery-modeling approaches (Cheung et al. 2013). The study showed that total landings of Nassau grouper in the Bahamas declined gradually from 1994 to 2009 (Fig. 13). Compensating for unreported catch (converted from Cheung et al. 2013), the Bahamas' Nassau grouper catches should have been estimated at around 10,800 t in 1994 to around 2600 t in 2009, a decrease to only 24% of the catch in 1994. Moreover, the proportion of Nassau grouper in the total fishery landings (all species) in the Bahamas also declined from 10% to 4% during this period, suggesting that the decline in landings was not mirrored in other exploited taxa which would have indicated a change in fishing effort or market conditions. This strongly suggests a differentially high decline in the Nassau grouper landings compared to other species taken in the multi-species fishery. Various reasons may explain the decline in Nassau grouper's landings, including decline in stock abundance, reduction in fishing effort (unlikely for reason given above), and an increase in level of under-reporting of fishery landings. It is noteworthy that unit price appears to be increasing as commercial landings decline, consistent with declining availability (Cheung et al. 2013).

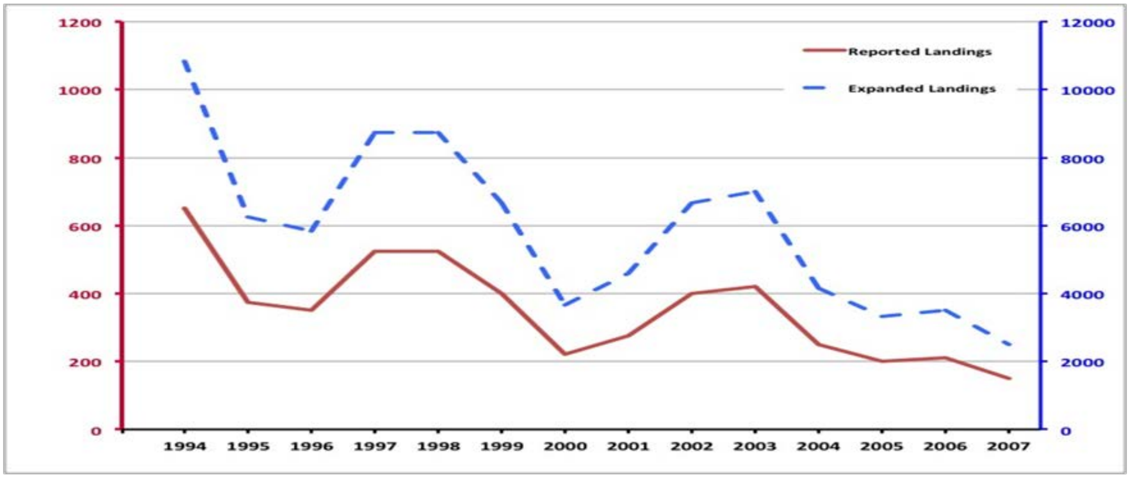

Figure 12. Reported landings (in tonnes) of Nassau grouper in the Bahamas from 1994 to 2009 as compiled by the Bahamas Department of Marine Resources (solid line) and corrected for under reporting of fisheries landings by a factor of 94% (broken line, sensu Ehrhardt and Deleveaux, 2007). Limitation of fishing spawning aggregations began in isolated locations in 1998 and was implemented nationally in 2005 as a 3-month area closure (redrawn and modified from Cheung et al. 2013).

The stock assessment of Ehrhardt and Deleveaux (2007) determined that the stocks of Nassau grouper in the Bahamas were fully-, if not, over-exploited in the 1999-2001 period. The results of the Cheung et al. (2013) study of the same time period suggest that the population is now fully- to over-exploited and undergoing decline, although the analysis could be strengthened with more fishery and population dynamics data. Results of the study suggest that the fishing mortality rate from 1999-2001 during non-aggregation fishing is sufficient to drive populations below a target Spawning Potential Ratio (SPR) of 35% to SPR of 20% even without fishing spawning aggregations. Poaching during the aggregation season should continue to be a concern.

Depletion of spawning aggregations may mean that reproductive efforts are ineffectual or altered, such as seasonal changes in spawning hypothesized in USVI (Nemeth et al. 2006). A decade ago, Sullivan-Sealy et al. (2002) found that the majority of Nassau grouper landed in New Providence, a major landing area, from 24 November 1999 to 15 February 2000 were not in spawning condition; almost one third were likely immature or reproductively inactive, being within the size range of late juveniles and early adults (528 +/- 61 mm TL.). They were either caught during spawning migrations or were sexually immature. Fishers reported that 'aggregations' of migrating fish, which were not ripe, were quite common, but this behavior is not widely reported.

Information on trade is largely limited to within-country sales except for grouper imports from the Bahamas into the United States. Market surveys reveal different aspects of the fishery than those gleamed just from landings data. According to monthly fishermen interviews and landing abundance surveys conducted at Montagu ramp (Nassau), a key market outlet, from May 2007 to October 2007, the cost for a 4-4.5 kg Nassau grouper averaged US$35.00. Of a total of 54,000 fish landed during the 6-month survey period, Nassau groupers made up an average of 10% (by number) monthly (i.e. about 5,400 individual fish) with June being the lowest (4%) and October being the highest (13%) (Cushion and Sullivan-Sealey 2007). This study also noted that a sizeable proportion of Nassau grouper were marketed by sellers who purchased them from large-scale commercial fisheries in New Providence. Thus, the total abundance noted in the study did not solely represent the effort of Montagu-based fishermen.

There is a history of exportation of grouper from the Bahamas to the United States. There is speculation that continued importation of the generic grouper classification may include Nassau grouper, since it has traditionally represented 70% or more of the Bahamian grouper landings (Sadovy de Mitcheson 2012). At this time the data are not available to confirm the magnitude of these imports or the effect of continued exports on the status of Nassau groupers in the Bahamas. Collection and analysis of these data should be a priority.

The Bahamas – Conservation and Management

In the Bahamas, both spatial and seasonal protective measures are in place for the management of the Nassau grouper in the Bahamas. In the 1980s a minimum size of 3 lbs. (1.36 kg) was introduced, seasonal closures of several spawning aggregation sites were first implemented in 1998, and an annual "two-month" (variable according to full moon) fishery closure to coincide with the spawning period was first implemented in December 2003. This closure was extended to three months in 2005 to encompass the spawning period from December through February. The closure is applied on a yearly basis and it may be shortened or otherwise influenced by such factors as the economy (Sadovy and Eklund 1999). For example, following the economic downturn of 2008 the closure was lifted to lessen the economic burden of a closed fishery to fishermen. During the aggregation period, during which there is a national ban on Nassau grouper catches, large numbers of fish were being taken according to fisher accounts with photo-documentation and confirming reports of poaching of the species during the aggregation season (Bahamas Reef Educational Foundation [BREEF], unpub. data).

The Exuma Cays Land and Sea Park, first established in 1959, has been closed to fishing since 1986, thus protecting both nursery and adult habitat for Nassau grouper and other depleted marine species, such as queen conch, spiny lobster and marine turtles. Evidence from the Exuma

Cays Land and Sea Park shows a clear difference in the number and size of all large grouper species between fished and non-fished areas. The biomass of Nassau grouper was shown to be statistically greater inside and within 5 km of the Park boundaries and reproductive output (egg production) was calculated as six times higher than outside the park (Sluka et al. 1997). Recent studies by Dahlgren et al. (unpub. data) have seen additional increases in biomass from less than 300 g/100 m^2 in 2000-2004 to near 1100 g/100 m^2 in the 2005-2009 period and more than 1100 g/m^2 from 2010 -2013. The current level is about twice that seen by Sluka et al. (1997) in the mid-1990s. Other sites, including the South Berry Islands Marine Reserve (declared on December 29, 2008), Southwest New Providence National Park site, and north Exumas study site also have shown some increases in biomass in recent surveys, but the response is much less than that seen in the Exuma Cays Land and Sea Park.

Fishing was closed for a 10 day period around the full moons of Dec through February 1998-2006 to protect spawning Nassau grouper at the High Cay aggregation site and the eastern coasts of Long Island. On December 16, 2003, the Bahamas Director of Fisheries announced the first-ever closed season for the species, thus prohibiting throughout the country the "taking, landing, processing, selling and offering for sale of fresh Nassau grouper" during spawning periods. Subsequently the closure was replaced by an annually renewable nationwide closure of fishing for the Nassau grouper during the winter months (December to February) (Department of Marine Resources 2007, Cheung et al. 2013). Local non-government organizations (NGOs) are working to have this changed to a permanent rather than an annually renewable measure (BREEF.org).

There are also several gear controls in the Bahamas relevant for, but not specific to, the Nassau grouper. Fishing with SCUBA and the use of explosives, poisons, and spearguns is prohibited, although sling spears are allowed. The use of bleach or other noxious or poisonous substances for fishing, or possession of such substances on board a fishing vessel, without written approval of the Minister, is prohibited. Government policy restricts commercial fishing to the native population and, as a consequence, all vessels fishing within the Bahamas Exclusive Fishery Zone must be fully owned by a Bahamian citizen residing in the Bahamas.

Spear fishing within one mile of the coast of New Providence and Freeport and 200 yards of the coast of all other Family Islands is prohibited, as is the use of firearms or explosives. For nets, a minimum mesh size of 2 in. is necessary, except when fishing goggle-eye (big-eye scad) or pilchard. Fish traps are required to have self-destruct panels and minimum mesh sizes of 1 by 2 in. for rectangular wire mesh traps and 1.5 in. (greatest length of mesh) for hexagonal wire mesh traps. A permit is required to sell catch. A permit is required to use air compressors for fishing purposes and the use of compressors is restricted to the period 1 August-31 March and to depths of 10-20 m. The capture of grouper and rockfish weighing less than 3 lbs. is prohibited. Dahlgren (pers. comm.) has noted a 3 lb. Nassau grouper is only about 45 cm long, roughly 3 cm shorter than the minimum size of maturity for females. Dahlgren suggested that an increase in the catch limit to 57 cm would ensure that at least 75% of fish could spawn before legal fishery removals.

Cheng et al. (2013) suggested a reduction in fishing effort during the non-spawning periods from the 1998-2001 level to improve Nassau grouper sustainability. They also stressed the need to ensure that poaching is controlled during the spawning seasons. These measures would address the main concerns expressed by fishers about the Nassau grouper fishery in interviews. Although a reduction in fishing mortality through reduction of fishing effort, may affect the short-term economic benefits, the fishery would perform better economically and as a food source over the long-term (Cheung et al. 2013).

There is no mechanism in the Bahamas for declaring a species “endangered,” “threatened,” or “protected.” To advise the public and develop support for, and understanding of, the need for protective measures, outreach campaigns were conducted on the utility of the seasonal fishing closures and to discourage the purchase of Nassau grouper by consumers during the protected season. The invasive lionfish was suggested, with some success, as an alternative fishing target and food choice.

BELIZE

Belize -- Populations

Belize, with its extensive reef system and coastline, was once a major habitat for the Nassau grouper and by all accounts, the species was historically extremely abundant (Craig 1966). Grouper aggregations have been severely reduced at many locations in Belize, at sites such as Mexico Rocks, Rise and Fall Bank, and Caye Glory, as indicated by Green Reef's national Grouper Spawning Aggregation Assessment (2001). Estimated numbers of fish taken from spawning aggregations was the main indicator available of population size with these once exceeding an estimated 30 thousand fish during just one spawning season at just one aggregation site (Caye Glory) and reports of tens of thousands of fish were once the norm (Craig 1966). At Caye Glory, where grouper catches reached 2 tons per day in the late 1960's, a January 2001 survey located 21 fish. Fishermen at the site caught only 9 fish during four days of intense fishing (Heyman and Wade 2005).

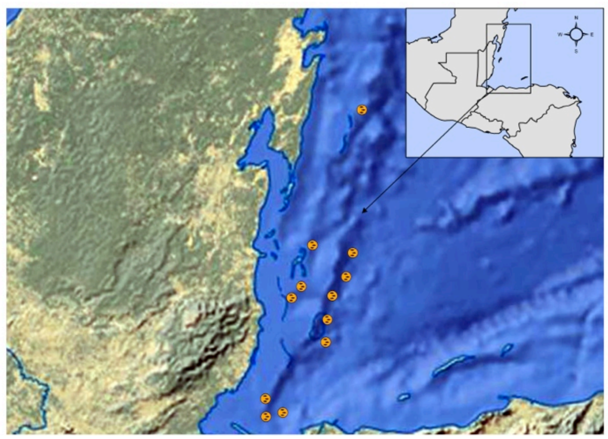

Figure 13. Known Nassau grouper spawning sites (noted by an orange circle) on the east coast of Belize.

In Belize, there are at least 15 known spawning aggregation sites (Fig. 15) that occur along the barrier reef and on outer atolls. All sites occur within 120 m of the shelf edge, with the average distance to the shelf edge being about 80 m. Most sites are near inflection points of convex-shaped seaward-extending reefs (within 360 m of reef promontories) (Kobara and Heyman 2007, Kobara 2009). These features have been used to try to identify unknown spawning aggregations in Belize and other parts of the Nassau groupers range but have been successful to date.

Species-specific annual landings data at the national level are not available, although starting in 2003, an effort was undertaken to monitor number of Nassau groupers at priority spawning sites. Recent monitoring yielded counts of a few hundred fish in most remaining aggregations surveyed (Table 10), and a few thousand fish at others (Belize Spawning Aggregation working group: (http://collaborations.wcs.org/Default.aspx?alias=collaborations.wcs.org/spag&). Dog Flea Caye was highlighted as a site where illegal fishing has continued and the numbers of spawners have greatly decreased compared to sites with good enforcement (e.g., NE Point in Glovers Reef and Sandbore Cay in Lighthouse) (Belize Spawning Aggregation working group).

Table 5. Number of Nassau grouper at priority spawning aggregation sites in Belize. (Belize Spawning Aggregation Working Group Information Circular 10, November 2012.) Effort is variable as noted in footnotes.

Maximum Nassau Grouper Counts for 2003 – 2012

Site	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Rocky Point	0	200	200	0 [1]	N/A	0	N/A	N/A	0	2
Dog Flea Caye, Turneffe	1,500	100 [3]	-	2 [2]	N/A	N/A	N/A	N/A	4	4
Sandbore, Lighthouse	1,800	2,500	1,800	1,205 [4]	1,495	1,250	2,050	2,000	1,300	1,350
Caye Glory	1,000	1,000	350	7 [5]	69	405	3,000	N/A	400	120
NE Pt., Glover's	2,400	1,700	2,240	3,000	800	1190	1,100	3,328	1,800	1,050
Gladden Spit [5]	250	450	360	700	500	1106	260	238	375	164
Nicholas Caye	52	~50	80	48	80	100	25	30	45	85

([1] Only one dive; [2] Site only monitored in February; [3] Site only monitored in January; [4] Probably missed peak spawning due to bad weather, [5] Numbers for Gladden Spit revised by SEA in 2011)

Declines in the overall abundance of Nassau grouper can be inferred from spawning aggregation counts. Most of the declines occurred prior to the initiation of spawning aggregation monitoring (Table 10). At Glover's Reef, the spawning aggregation which harbored 15,000 Nassau groupers in 1975 had declined by 80% to less than 3,000 groupers in 1999 (Sala et al. 2001) and to about a thousand in 2011 and 2012 (Y. Sadovy, University of Hong Kong, pers. obs. 2012). Only 2 of the 9 aggregation sites identified in 1994 (Carter et al. 1994) had more than 150 Nassau groupers; the rest of the sites had been fished out (Heyman 2001, Paz and Grimshaw 2001). Caye Glory, also known as Emily, was exploited for over 80 years with declines attributed to lack of management and a lucrative fishing industry that attracted many fishers (Paz and Truly 2007). All known aggregation sites have undergone dramatic declines in the abundance of spawning fish over the last two decades. Current aggregation protection does not appear to be restoring this species although almost certainly the efforts have stemmed decline.

Aggregation numbers assessed during the period 2003-2007 ranged from a high of 3,000 fish at Glover's Reef to lows of less than 10 fish at three other sites, although it was noted that surveys were not always as complete as desired. The 2012 data showed two sites with fewer than 5 fish, three sites with less than 200 fish and two sites with between 1000-1500 fish. Apparent declines resumed after the 2009-2010 surveys.

Several studies have examined movements of tagged fish. The movements of Nassau grouper along the barrier coastal reef have been recorded in excess of 200 km (Carter et al. 1994). At Glover's Reef (an atoll), Nassau grouper showed strong fidelity to both non-reproductive and spawning areas on the atoll and may not migrate at all (Starr et al. 2007). Based on the findings of acoustic telemetry, Nassau grouper exhibited greatly synchronous migration to spawning sites during full moons from December through March despite their otherwise solitary habits. Groups of 50-100 fish have been observed moving to aggregation sites. Reproductive adults move from their shallow water habitat during the winter full moons, and migrate to the same spawning site up to four times per year staying an average of 11.6 days at the site during the winter full moons (Starr et al. 2007). Using tagging with VEMCO V16 acoustic tags at 7 locations, including spawning aggregation sites off the coast of Belize from April 2000 to January 2003, Heyman and Carr (2007) demonstrated that individuals stayed near spawning aggregations during their spawning season. Following spawning Starr et al. (2007a) reported a remarkable population-wide depth change within an hour as individuals in a group dive to a maximum depth of 255 meters.

Belize - Fishing

Historically, the Nassau grouper was the basis of a very important finfish fishery in Belize, which included export trade, using handline, speargun, and fish traps (Carter et al. 1994). Along with Cuba and the Bahamas, Belize reefs were among the most important locales for Nassau grouper, an assumption based on documentation of spawning sites and the large reef areas (i.e., suitable habitat for the species) available. Spearguns and handlines were used to fish grouper aggregations at least as early as the 1940s (Thompson 1945, Perkins 1983), and the use of fish traps increased after 1986 (S. Aui1, University of the West Indies, pers. comm. to Y. Sadovy, NMFS, 1991). Handlines are often rigged with 3 to 15 hooks per line (Munro 1983a). The fishing boats of Belize are typically 5-7 m vessels equipped with outboard engines or larger sail-powered boats (Perkins 1983). Although there are no official annual national landings statistics for Nassau grouper, as finfish are lumped in landings data, accounts of the reef fishery over the years are clear testimony to its one-time importance to the country as compiled by Craig (1968), Carter et al. (1994), and Paz and Truly (2007).

Craig (1966) reports that apparent reductions in Belize population(s) of Nassau grouper are most strongly indicated by a trend of reduced catches from spawning aggregations, once the major source of annual landings of the species, and historic accounts: "*On the seaward side of the reef (Caye Glory), grouper (Epinephelus striatus) congregate in astonishing numbers in waters fifteen to twenty fathoms deep where they can be seen moving slowly over the rocky bottom. These fish are believed to be spawning…*" Craig's account reports up to 300 boats at the site with a single experienced crew catching from 1200 to 1800 fish during a single reproductive season, estimated by Craig (1968) to reach 90,000 kg per season.

Overfishing was already apparent by the 1960s as indicated by reduced aggregation catches. Despite the declines, the fishery still has value. Although the volume of Nassau grouper exported internationally has surely declined, most sales today are evidently made within the country (Paz and Truly 2007). Shortly before fishing on spawning aggregations was banned countrywide, the economic value of the 2000-2001 Nassau grouper catch in Belize, largely derived from the domestic market and although negligible relative to prior years, was estimated at approximately US$210 per fisherman, or US$40 per fisherman per day; approximately four times the minimum wage in Belize (Paz and Grimshaw 2001b). Fishermen continue to have an economic incentive to catch Nassau grouper in Belize, even though its reduced population cannot support a large number of fishermen (Paz and Truly 2007).

Fishing for Nassau grouper outside of the aggregation sites continues to be important. Beginning in the 1970s, Nassau grouper were taken throughout the year (Paz and Truly 2007) with Sala et al. (2001) noting that 14% of the adult population is removed annually by year-round spear fishing. Information on length of Nassau grouper caught outside of the spawning season suggests the start of a recovery. At Glover's reef, likely a largely self-recruiting area, surveys of fisher catches from 2004 to 2010 suggest an increase in average length of Nassau grouper from a mean of 371 mm – 493 mm TL in 2007 to 563 mm TL in 2010 (J. Gibson, Wildlife Conservation Society - Belize City, Belize, pers. comm. to Y. Sadovy, University Hong Kong, 2010).

Belize – Conservation and Management

Management of the Nassau grouper has a long history in Belize even though annual landings for the species are not available. Instead, the status is determined by numbers of fish at spawning aggregations and also by fishermen experiences and sporadic reports. The Fisheries Department is responsible for the monitoring, control, and surveillance of the fishing industry (Carcamo 2008). The first measure to protect Nassau grouper was a seasonal closure within the Glover's Reef Marine Reserve in 1993; the area was closed from December 1 to March 1 of the following year. In 1996, the new marine reserve, Bacalar Chico, also included a seasonal closure zone for the protection of the Nassau grouper spawning aggregation (Paz and Truly 2007). Minimum and maximum capture sizes were introduced a decade ago (Sala et al. 2001; Carter et al. 1994; Heyman and Requena 2002; J. Gibson, Wildlife Conservation Society - Belize City, Belize, pers. comm. to Y. Sadovy, University Hong Kong, 2010; Sadovy de Mitcheson et al. 2008).

Given growing interest and concern for the species, in 2001 the Belize National Spawning Aggregation Working Group was established. During 2002, a coalition of seven NGOs, government, fishers, and other stakeholders worked successfully to establish protective legislation for 11 of the known Nassau grouper spawning sites, and to introduce a four-month closed reproductive season in 2003 (O'Connor 2002, Gibson 2008). Seven of those 11 sites (Table 10) are monitored as regularly as possible and include: Rocky Pt. (Bacalar Chico Marine Reserve), Dogflea Caye (Turneffe Islands), Sandbore (Lighthouse Reef), Emily/Caye Glory, Gladden Spit (Gladden Spit and Silk Cayes Marine Reserve), Northeast Point (Glover's Reef Marine Reserve) and Nicholas Caye (Sapodilla Cayes Marine Reserve). The Working Group meets regularly to share data and develop management strategies (www.spagbelize.org; retrieved on 15 April 2012) and monitoring continues at several sites.

In 2003, two Statutory Instruments were enacted. The first declared 11 sites, including "Emily" (Caye Glory), as marine reserves closed to fishing all year round. Those sites that were wholly or partially located in marine reserves, but not included in any seasonal closure or conservation zone, could be used only by traditional fishermen recommended by the respective co-managers of the reserve and with special license granted by the Fisheries Administrator. The second Statutory Instrument established a four-month closed season to protect spawning Nassau grouper, extending from December to March. Fishermen at Maugre Caye and Northern Two Cayes, however, were allowed to fish during the spawning season, but only under special license granted by the Fisheries Administrator, a condition of which was that all catch would be verified by a Fisheries Officer (Paz and Truly 2007) in order to monitor stock structure. These exceptions made the national protection difficult to enforce and hence starting in the 2010-2011 season, special licenses to fish for Nassau grouper at these two sites during the closed season were no longer issued. These final two sites, however, are not yet designated as fully protected areas closed to fishing. Therefore, 13 of the 15 known aggregation sites are fully closed to fishing during the spawning season. Of the remaining two known aggregation sites, Maugre Caye should be protected when the Turneffe Islands marine reserve is declared. Belize is still seeking North Two Caye's protection.

In early April 2009, the Minister of Fisheries signed into law additional measures to help manage and protect the Nassau grouper. These include minimum and maximum size limits of 510 mm (20 inches) and 760 mm (30 inches), respectively, and a planned ban on spear fishing within all marine reserves (yet to be implemented). Furthermore, as a large proportion of finfish are landed as fillets, the new regulations require that all Nassau grouper be landed whole, and if filleted must have a 1-2 inch (25-50 mm) skin patch (The Belize Spawning Aggregation Working Group 2009). Other gear restrictions are in place for reef fishes generally to aid in their management, such as no spearfishing on compressed air.

Gibson et al. (2007) indicated that the provision of assistance for management and enforcement, and sustaining the political will at the highest levels, would be necessary to enforce the laws to enhance the protection of Nassau grouper spawning aggregations in Belize. There has been extensive public outreach in the country to inform the public of the management measures and the need to protect the Nassau grouper, including film, TV, radio, etc. Although marked recoveries have not yet been noted following implementation of management, it is almost certain that this has prevented further declines and more time will be needed for recovery to be evident. The multi-sector national working group model in Belize appears to have been very effective in gathering support for management measures and may serve as a useful model.

BERMUDA

Bermuda – Populations

The understanding of population change and status of Nassau grouper in Bermuda must be derived from a combination of ecological studies and fishery dependent data reports as species-specific information is not available. In a historical context, groupers have dominated Bermuda's fisheries. Bardach et al. (1958) discussed the abundance and importance of groupers to the island while providing information on aspects of their biology. Density of Nassau grouper on shallow reefs in Bermuda in the 1950s was estimated at 12 fish per acre (34.6/hectare), with the fish weighing an average of 1.1 kg (2.42 lbs.) (Bardach and Menzel 1957). Bardach et al. (1958) estimated that groupers comprised approximately 70% of total food-fish landings during the period of their study (mid 1950s), with snappers contributing 20% to the total. Cumulative data from REEF (2003-2013) reported nine Nassau grouper in 1594 surveys (density index 1.1, sighting frequency 0.3%) across the 10-year period (http://www.reef.org/db/reports/dist/species/TWA/0097/2003-01-01/2013-04-07). These data indicate a single Nassau grouper was surveyed on a dive on only 0.3% of the dives. While the surveys do not have a way to convert to areal comparisons, the frequency of occurrence is quite low compared to earlier conditions (e.g. Bardach and Menzel 1957).

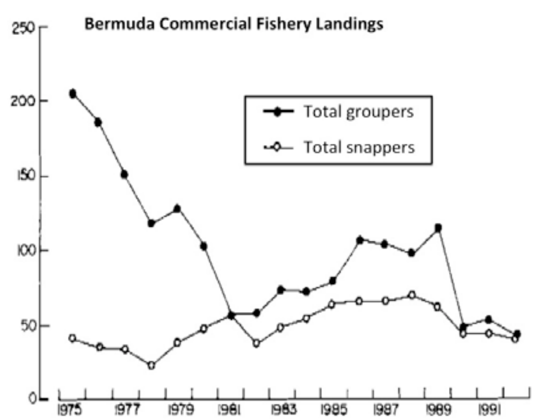

Figure 14. Proportions of Groupers and Snappers in Commercial Landings from Bermuda 1975-1992.

In 1975, a fisheries statistics program became fully operational providing catch and effort data from the industry on a compulsory basis. In the first year of the program (Fig. 16), groupers comprised 47.6% of the total landed weight of food-fish (total 431 mt) while snappers contributed 9.8% (Luckhurst and Ward 1996). Landings declined drastically between 1975 and 1981 (Luckhurst 1996). The grouper landings at this time were dominated by red hind (Fig. 17). By 1989, species composition had been reduced significantly with the grouper landings being reduced to 18.7% of the total, while snappers were largely unchanged at 10.1 % (Fig. 16).

The overall pattern in landings of groupers declined sharply from about 231 mt in 1975 to approximately 58 mt in 1981 (Fig. 17), followed by an increasing trend until 1989. During that time, the species composition of the grouper catch changed markedly during the 1980s from red hind to two smaller species (coney and creole-fish) comprising almost 50% of total landings in 1989 (Luckhurst and Ward 1996). A fish pot ban was put into effect in April 1990 in an effort to allow the recovery of reef fish stocks, which had been subjected to heavy fishing pressure with fish pots (traps).

Following the fish pot ban in 1990, the total grouper landings level declined by 58% and remained stable through 1992 (Figure 16). An analysis of the trends in individual grouper species indicates the relative contribution of each species to this general pattern. Nassau grouper landings show a steep decline from over 33 mt in 1975 to less than 2 mt in 1981, a drop of 95.0% in landings. Despite over 10-years of no-take protection of the Nassau grouper in Bermuda, there has not been an appreciable recovery and numbers remained extremely low as of 1999 and into the early 2000s (Sadovy and Eklund 1999, Semmens et al. 2008a). The species had not shown any evidence of a subsequent recovery by 2005 (Luckhurst 2005). Although they are still considered rare, there are some anecdotal reports by divers of more Nassau grouper in the past 10-15 years (B. Luckhurst, Bermuda Department of Agriculture, Fisheries, and Parks, Division of Fisheries, pers. comm. to Y. Sadovy, University of Hong Kong, 2012). As far as is known, Nassau grouper spawning aggregations no longer form in Bermuda (B. Luckhurst, Bermuda Department of Agriculture, Fisheries, and Parks, Division of Fisheries, pers. comm. to Y. Sadovy, University of Hong Kong, 2012).

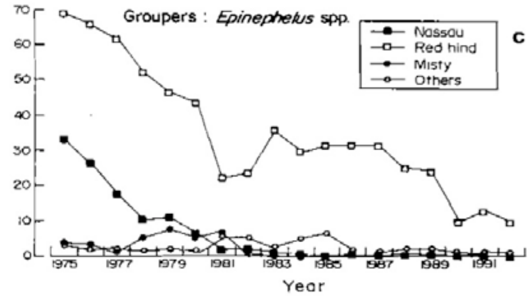

Figure 15. Proportion of grouper species in landing from Bermuda commercial catch

Bermuda – Fishing

In the 1950s, the annual food-fish harvest totaled approximately 450,000 kg (450 mt) and consisted of an estimated 70% grouper (grouper and rockfish); 20% snapper; 9% jack, mackerel and tuna and 1% other species (e.g., hogfish) (Bardach et al. 1958). According to fishery records available since 1975, commercial grouper landings declined in Bermuda despite an increase in effort over the period (Bannerot et al. 1987). By 1989, the total catch of food-fish had increased to about 621,000 kg (621 mt) per year. The composition of the catch in 1989 showed significant changes, 18.7% of the catch consisted of grouper; 10.1% snapper; 15% jacks; 25% tunas and related species and 31% was comprised of miscellaneous reef fish, such as parrotfish, porgy, grunt, triggerfish, hogfish and Bermuda chub. The shift from a catch dominated by grouper and snapper to one dominated by herbivorous reef fish, such as parrotfish and surgeonfish, resulted from the severe decline in the preferred target species (groupers) (Burnett-Herkes and Barnes 1996). While all groupers were affected, among those most severely reduced was the Nassau grouper. Landings of Nassau grouper declined from 16% of total grouper (all species) catch, by weight, in 1975 to <1% in 1989 (Bannerot et al. 1987, Report of the Commission of Inquiry, Bermuda 1991).

Nassau grouper were fished primarily during aggregation periods using handlines, traps, and spearguns; commercial fishermen exploited concentrations for generations (Bardach et al. 1958, Burnett-Herkes 1975). Aggregations were known from the Challenger and Argus (Plantagenet) banks. Three sites were fished until the mid-1970s (Burnett-Herkes 1975). By 1981, all four known historical aggregation sites no longer formed and had probably crashed according to fisher accounts (Bannerot et al. 1987, Luckhurst 1996). Despite subsequent protection, the fishery for this species is considered commercially extinct (Bannerot et al. 1987; Luckhurst 1996; B. Luckhurst, Bermuda Department of Agriculture, Fisheries, and Parks, Division of Fisheries, pers. comm. to Y. Sadovy, University of Hong Kong, Sept. 2012).

It appears that the spawning stock biomass was reduced below a critical but unknown level so that the population has apparently been unable to recover (see Sadovy 1996). Mean size and frequency of sighting has reflected these changes. Mean size sampled at offshore banks in the mid-1950s was approximately 620 mm FL (Bardach et al. 1958) with considerably smaller individuals inshore. Following the collapse of the aggregations in 1981, only juvenile Nassau grouper were seen, but only rarely inshore (J. Ward, Bermuda Department of Agriculture, Fisheries, and Parks, Division of Fisheries, pers. comm. to Y. Sadovy, NMFS, 1992). There have been anecdotal accounts of catches of Nassau grouper, involving good-sized fish, however, since Nassau groupers are protected fishermen are reluctant to report catching or possessing them. Fish are often filleted to avoid detection so the extent of any perceived increase is unknown (B. Luckhurst, Bermuda Department of Agriculture, Fisheries, and Parks, Division of Fisheries, pers. comm. to Y. Sadovy, University of Hong Kong, Sept. 2012).

Bermuda – Conservation and Management

The earliest fisheries management measure to conserve spawning aggregations in Bermuda occurred in 1974. This involved the seasonal closure (4 months) of two red hind aggregation sites. This management action was called for by commercial fishermen and the regulation was enacted by the Fisheries Department. The seasonal closure of the red hind aggregation sites is still in effect 31 years later although there have been some modifications of boundaries and the size of the protected areas. Following this measure, catches continued to decline but then stabilized in the longer term. Compliance or enforcement is not well documented. Nassau grouper aggregations seaward of these red hind sites were not protected under the regulations and were heavily fished. As a result, Nassau grouper landings declined 95% from 1975-1981 and all known aggregations disappeared. Bag limits (2 fish) and minimum size restrictions (356 mm FL) were in effect for the Nassau grouper prior to 1990 (Luckhurst 1990).

Nassau grouper in Bermuda have been managed since 1996 with no-take and no-possession regulations but in spite of those conservation measures, Nassau grouper has made no appreciable recovery. The species is completely protected through prohibition on take and possession and possibly benefits from numerous no-take marine reserves (B. Luckhurst, Bermuda Department of Agriculture, Fisheries, and Parks, Division of Fisheries, pers. comm. to Y. Sadovy, University of Hong Kong, Sept. 2012).

BRITISH VIRGIN ISLANDS

British Virgin Islands – Abundance and Distribution

Little information is available on Nassau grouper in the British Virgin Islands (BVI) although anecdotal accounts suggest that considerable landings still occur although not from aggregations. Cumulative data from REEF (2003-2013) show sightings of 107 Nassau grouper in 2003 surveys (density index 1.2, sighting frequency 5.3%) across the 10-year period (http://www.reef.org/db/reports/dist/species/TWA/0097/2003-01-01/2013-04-07). Requests for updated information through the fisheries department for this status report have received no response.

In the mid-1990s, large Nassau grouper were still being caught east of Pajaros Point, Virgin Gorda, but these were incidental catches and not targeted catches (Munro and Blok 2005). More recently, fishers report that medium-sized Nassau grouper are still quite common but that aggregations are no longer actively targeted. Only a few Nassau grouper where landed at the BVI Fisheries Complex during the winter months of 2003 (Munro and Blok 2005). Based on the findings of a survey conducted in January to February 2003, Munro and Blok (2005) found no evidence of any spawning aggregation from a previously reported site on the Saba shelf. Fishers interviewed claimed that they could catch 20-40 Nassau groupers per day at the site 15-20 years ago.

British Virgin Islands – Conservation and Management

Nassau grouper can be seen for sale in the BVI Fisheries Complex and in supermarkets. There is a closed season for landing Nassau grouper between March 1 and May 31 (Munro and Blok 2005).

CAYMAN ISLANDS

Cayman Islands – Populations

The Nassau grouper may still be relatively abundant in the Cayman Islands compared to many other locations (Patengill-Semmens and Semmens 2003) according to visual surveys and the status of several spawning aggregations. Cumulative data from REEF (2003-2013) show sightings of 1857 Nassau grouper in 3746 surveys (density index 1.7, sighting frequency 49.6%) across the 10-year period (http://www.reef.org/db/reports/dist/species/TWA/0097/2003-01-01/2013-04-07). In the Cayman Islands, the Nassau grouper fishery was once considered to be on the brink of collapse even though fishing was managed. The Nassau grouper stocks in the Cayman Islands appear to have shown some degree of resilience under fishing pressure, due to the cumulative effects of inclement weather during the aggregation seasons (i.e., limiting fishing opportunities), some protection from poaching with the regular presence of researchers at the site during the spawning season, possible recruitment from nearby offshore banks, and a possible shifting of aggregation sites that remain unfished or unknown (Whaylen et al. 2007). Researchers observed shifting of the aggregated spawners on the scale of several hundred meters (Whaylen et al. 2007) and there are some reports of similar shifts at other sites (Aguilar 2006) that make this a possibility. "It is possible there are other minor satellite aggregation sites that remain unfished, but it is unlikely and over the last 16 years catches have steadily declined in the Nassau grouper fishery (P. Bush, Cayman Islands Department of Environment, pers. observ. as reported in Whaylen et al. 2004)." Fishing on the sites produced thousands of fish annually and in the 1970s even included the sale of catch to Jamaican vessels (Whaylen et al. 2004).

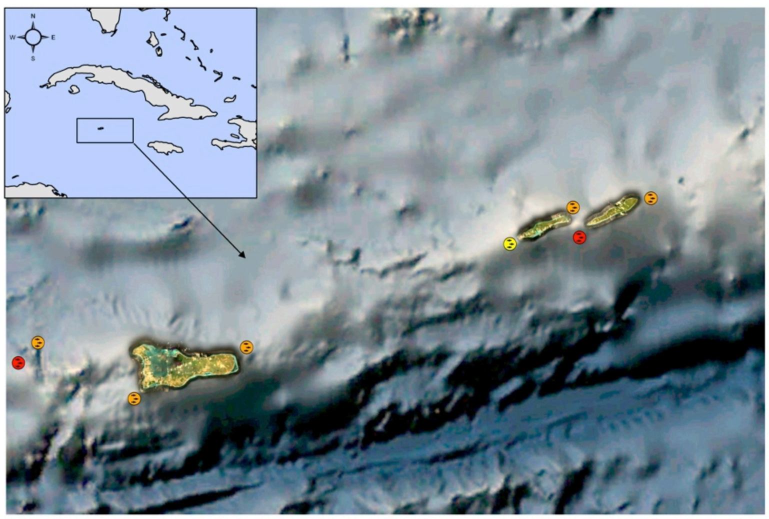

Figure 16. Cayman Islands (islands west to east Grand Cayman, Little Cayman and Cayman Brac)

There are 5 traditional aggregation sites confirmed in the Cayman Islands, one of which, off Little Cayman's west end, is likely the largest aggregation (in terms of fish numbers) known in recent times anywhere within the geographic range of the species. The Little Cayman site is located on a reef promontory on the western edge of Little Cayman Island (Rand et al. 2005). Whaylen et al. (2004) recorded (from underwater observations) that the average estimated number of Nassau grouper present at the aggregation site off Little Cayman in 2002 was 5,200 individuals two days after full moon. The mean size of aggregating grouper was 620 mm TL and the overall female to male sex ratio was 1:1.6. Whaylen et al. (2004) report that females exhibit dark phase and males exhibit bicolor phase at the point of gamete release although in the lead-up to spawning both sexes might display both colors at other times (Archer et al. 2012). A hydroacoustic study of the aggregation suggested the presence of more fish than counted by divers due to the fact that the aggregation appeared to be spread patchily over a wider area than that covered by divers; on the other hand, fish close to the substrate were noted by divers but not hydroacoustically; a combination of divers and hydroacoustics is suggested for such studies (Taylor et al. 2006).

In the Cayman Islands, all spawning aggregation sites are located within 50 m of the shelf edge (30 or 40 m depth) and adjacent to deep water (> 200 m). Heppell et al. (2008) proposed that spawning might be timed to allow larvae to return on local gyres to Cayman Island waters suggesting that the condition of local populations may be critical to their long-term sustainability. Kobara (2009) revealed that all 5 best-known Cayman Islands spawning aggregation sites are located at convex-shaped seaward extending reefs (reef promontories) jutting into deep water, within 1 km of reef promontory tips.

Cayman Islands – Fishing

The Cayman Islands once had a small local traditional fishery for Nassau grouper with 90% or more of the landings coming from the 5 then-known annual spawning aggregations (Whaylen et al. 2004b). The traditional fishing culture evolved into one economically dependent on marine tourism and finance over the past 30 years (Bush et al. 2006). Tucker et al. (1993) reported five Nassau grouper spawning aggregation sites historically in the country: one at the southeast corners of each of the three islands, one at the southwestern corner of Grand Cayman, and another at the southeast corner of the Twelve Mile Banks west of Grand Cayman. The aggregations at the eastern ends of the islands were the most well-known, and traditionally exploited since the early 1900s with the use of small open boats and hand lines (Bush et al. 2006). K. P. Tibbets of Cayman Brac (pers. comm. in Colin 1987) reported having fished these aggregating locations since 1925-1926, and his father had fished them since about 1903.

In 2001, fishermen found aggregated Nassau grouper on the west end of Little Cayman Island (Whaylen et al. 2004, Bush et al. 2006), although based on more recent discussions with elders in the fishing community, it appears that the west end spawning site was fished earlier in the century (late 1960s), but perhaps fished out. Two more sites have been noted as potential spawning aggregations bringing the likely total to eight (Bush et al. 2006).

Of the sites monitored between 1987 and 2001, (Bush et al. 2006): “three of the country’s sites were considered fished out, catch from Grand Cayman and Little Cayman during the early years of the monitoring period was in the low hundreds and has since dwindled. In Cayman Brac, while catch was in the low thousands during the initial years following the re-discovery of the spawning aggregation, it too has declined drastically in the last six years. Little Cayman east end site was abandoned in 1993 when the aggregation ceased to form, three sites were in serious decline (Catch, CPUE, and size all declined), and one, the rediscovered site off the western end of Little Cayman, though affected by two years of heavy fishing, is still relatively healthy. Catch-per-unit effort and size for all three islands show similar marked trends.” During 20 days of fishing at the aggregation site off the western end of Little Cayman, approximately 4,000 fish were taken during the 2001 and 2002 spawning season (Whaylen et al. 2004). Pre-fishing abundance for this aggregation was estimated at over 7,000 fish so a large proportion of estimated fish were removed in a very short time period (Bush et al. 2006).

The sharp decline in catches of Nassau grouper in the Cayman Islands since 1996 (Whaylen et al. 2004, Bush et al. 2006) is presumably due both to aggregation and non-aggregation catches. Based on a mark-recapture study from Cayman Brac, fishermen are capturing 15-20% of the spawning population outside the spawning season, implying the Nassau grouper population may continue to decline even with a full spawning season closure (B. Semmens, Scripps Institute of Oceanography University of California – San Diego, pers. comm. to Y. Sadovy, University of Hong Kong, 2012).

According to the estimated spawning aggregation fish numbers in Grand Cayman, and a detailed report of poaching, it is believed that about 30% of all adult Nassau grouper were caught while spawning (Dept. of Environment 2011). Semmens et al. (2007b) suggested that older, larger fish are more susceptible to harvest on unprotected spawning sites due to the amount of time they spend aggregating compared to smaller individuals. Also, smaller aggregations tend to stay longer on site possibly exposing them to more fishing (B. Semmens, Scripps Institute of Oceanography University of California – San Diego, pers. comm. to Y. Sadovy, University of Hong Kong, 2012).

Cayman Islands – Conservation and Management

Nassau grouper have long been a target of local traditional fishermen. In about 1978 (P. Bush, pers. comm. Protection and Conservation Unit, Department of the Environment, Grand Cayman, British West Indies, pers. comm. to Y. Sadovy, NMFS, 2001), the three main (“traditional”) grouper “holes” were officially recognized as such and only residents were allowed to fish at the designated grouper holes during spawning season. Only line fishing was permitted. In 1986, increasing complaints from fishermen of a decline in both numbers and size of Nassau grouper taken from the fishery prompted the implementation of a monitoring program by the Department of the Environment (Bush et al. 2006).

In the 1990s, several management measures were tried. In 1995, an "Alternate Year Fishing" strategy was recommended but was not implemented due to lack of political support (Bush et al. 2006). In 1998, the three main spawning areas at the eastern ends of the islands were formally designated as "Restricted Marine Areas" for which access required licensing by the Marine Conservation Board (the statutory authority responsible for the administration of the Marine Conservation Law) (Bush et al. 2006). In the 1990s, legislation prohibited spearfishing at spawning aggregation sites. In February 2002, protective legislation defined a spawning season as November 1 to March 31, and the "Alternate Year Fishing" rule was passed. This law allowed fishing every other year with the first non-fishing year starting with 2003, and also set a catch limit of 12 Nassau grouper per boat per day during fishing years. The law defined the one nautical mile (nm) "no trapping" zones around each spawning site, and set a minimum size limit of 12 inches for Nassau grouper in 2002 in response to juveniles being taken by fish traps inside the sounds (Whaylen et al. 2004, Bush et al. 2006). In 2003, spearguns were restricted from use within 1 nautical mile of any designated grouper spawning area (DGSA) from November through March.

Effective December 29, 2003, fishing was closed at all designated Nassau grouper spawning sites for a period of 8 years. In adopting this decision, the Marine Conservation Board noted that two of the six areas were "fished out and three in serious decline." According to research results from surveys on the Little Cayman west end spawning site, the number of spawners increased from approximately 2,500 fish to 4,000 fish over the eight year protection period (Semmens et al. 2007a). The conservation measure was renewed for a further 8 years in 2011 and, indeed, numbers of fish are showing promising signs of increase in at least one aggregation site (Department of Environment 2011, Heppell et al. 2012). In 2008, it was prohibited to take any Nassau grouper by speargun anywhere in Cayman waters with no trapping within 1 nm of a protected aggregation during the spawning season (Nov. 1 – Mar. 31). Seasonal and spatial measures state that no Nassau grouper is to be taken from any DGSA from November to March until 2019. Total area of the current 8 DGSA's is 17.56 km^2. From the results of a mark-recapture study on Cayman Brac, Cayman Island fishermen appear to catch sufficient adult grouper outside the spawning season to seriously impact populations (Semmens et al. 2012).

The indications of recovery (as determined by increased abundance of fish) are encouraging in Little Cayman and on Cayman Brac; however, there has been no recent survey of the spawning aggregation. There are few grouper at Grand Cayman, however, and the high fishing pressure surrounding the small no-take area aggregation site, as well as poaching, appear to keep the population depressed (Semmens et al. 2012). There is no evidence larvae from the Cayman Islands contribute to other individuals.

COLOMBIA

Colombia – Populations

There is little data available on the status of Nassau grouper in Colombia. Cumulative data from REEF (2003-2013) report 11 Nassau grouper in 401 surveys (density index 1, sighting frequency 2.7%) across the 10-year period from the populated islands of the San Andrés Archipelago (San Andrés Island, Providencia, and Santa Catalina (http://www.reef.org/db/reports/dist/species/TWA/0097/2003-01-01/2013-04-07). In a report by Prada et al. (2004) artisanal fishermen indicated that in the San Andrés, Providencia, and Santa Catalina Archipelago (Old Providence) on the northeast and south banks, local people once fished Nassau grouper during spawning aggregations from approximately five different sites. Occasionally, a few Nassau grouper are still caught, but past abundances had not been seen in a decade (Prada et al. (2004). In the study, ten sites were identified as potential spawning aggregation sites, including five for Nassau grouper, fished for many years, although now only a few individuals are ever seen (Prada et al. (2004).

Colombia – Fishing

Colombia reported to FAO a maximum of 120 mt of Nassau grouper landed in the early 1990s (Sadovy de Mitcheson 2012). However, by the early 2000s the fishery may have collapsed with no landings reported to the FAO since. No large spawning aggregations have been reported for this species from Colombia. Commercial fishing companies reported Nassau grouper represented 12% of longline catches of large serranids in San Andrés between 2006 - 2007; aggregations of 50 or so Nassau grouper have been reported (H.C.B. Hooker, Universidad Nacional de Colombia, Sede Caribe, pers. comm. to Y. Sadovy, University of Hong Kong, 2012).

Colombia – Conservation and Management

In the San Andrés Archipelago of Colombia, there are a number of areas that are designated as no-take fishing zones; in 2000, the archipelago was declared by UNESCO as the Seaflower Biosphere Reserve. In 2004, large portions of the archipelago were declared as a system of marine protected areas with varying zones of fisheries management however enforcement is largely lacking. Right-to-fish laws also require that fishermen, particularly elder fishermen, be allowed to fish at a subsistence level even within the no-take zones (M. Prada, Coralina, San Andres, Colombia, pers. comm. R. Hill, NMFS, 2010). No other regulations could be identified that might benefit Nassau grouper within Colombian waters.

CUBA

Cuba – Populations

Biological studies on the Nassau grouper have not been undertaken in recent years but biological and fishery details may be found in Claro et al. (1990, 2009). Claro et al. (2001) and Claro and Lindeman 2003 documented known spawning aggregation sites of snapper and grouper, most of them multi-species; information was primarily fishery-dependent rather than from underwater surveys. The earliest documentation of Nassau grouper aggregations and seasonal migrations was from Cuba in the 1800s indicating a substantial fishery at that time (Vilaro Diaz 1884). Little information on the current status of the species is available (Fabian Pina, Centro de Investigaciones de Ecosistemas Costeros, Cayo Coco, Cuba, pers. comm. to Y. Sadovy, University of Hong Kong, 2011). Cumulative data from REEF (2003-2013) show sightings of 38 Nassau grouper in 120 surveys (density index 1.6, sighting frequency 31.7%) across the 10-year period. The bulk of these samples (n=105, 33 Nassau grouper/ density index: 1.6, sighting frequency: 31.4) were from the west side of Cuba (http://www.reef.org/db/reports/dist/species/TWA/0097/2003-01-01/2013-04-07).

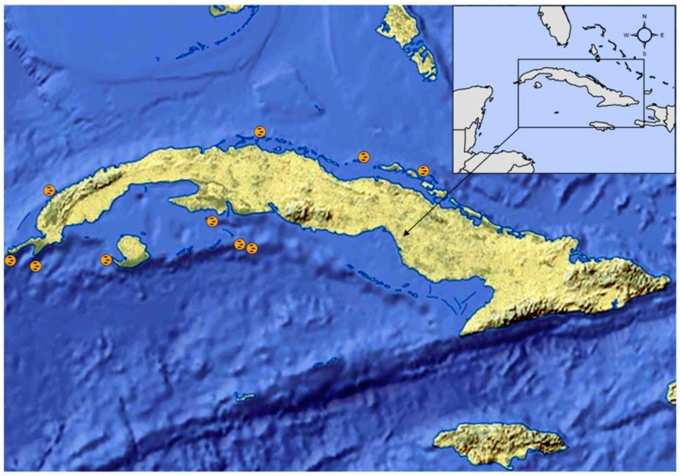

Figure 17. Confirmed Nassau grouper spawning aggregation sites of Cuba.

Cuba – Fishing

Trap fishing has been the primary method for catching grouper (Munro and Thompson 1983). Boats are typically non-mechanized and less than 6 m long (Claro et al. 1990, Baisre 1993). The Antillean (arrowhead) fish traps are wooden-framed with galvanized wire mesh and one or two entrance funnels (Munro 1983a). The single funnel “chevron traps” are commonly used in the eastern Caribbean, and the “S” or “Z” shaped traps, with dual entrance funnels, are found in Cuba and Jamaica. Most traps had mesh sizes between 25-50 mm (Munro 1983a).

Historically, the Nassau grouper was among the most important finfish species landed in Cuban fisheries, yielding some of the highest catches for the species anywhere within its geographic range. Given the very high quality of landings data for key commercial species in the country, which extends from the 1960s and, for some species was recorded monthly, there is an excellent and unmatched record of landings for this species over almost 5 decades (Claro et al. 2002, 2009). Fishing pressure on the Nassau grouper increased notably after 1959, reaching 1,700 mt in 1963, after which time landings declined (Fig. 20). The detailed dataset from the 1960s shows that the great majority of landings was taken from spawning aggregation sites and times, 50% of the annual catch from December to February (Fig. 21). Most catches of Nassau grouper (35-50% of the national capture of the species) were historically taken in the Archipelago Sabana-Camagüey (north-central area), although up until 1969 an important proportion of this catch was obtained from the Bahamas shelf. A somewhat sudden collapse, suggesting a *hyperstability* condition (in which concentrations of fish, e.g., aggregating for spawning, mask a general population decline), occurred in the late 1970s, despite some protective management. The data also show that, despite a gradual increase in finfish landings (Fig. 20) between 1962 and 1998 (Claro et al. 2001), probably due to increasing fishing effort, Nassau grouper showed a precipitous decline, strongly suggesting that it is more vulnerable to fishing, or more heavily targeted, than other reef fish species (Claro et al. 2009, Sadovy de Mitcheson et al. 2008).

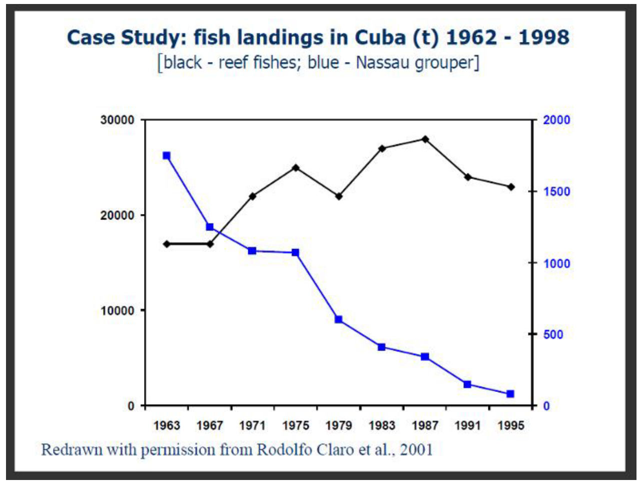

Figure 190. Fishery landings in Cuba (1962-1998)

Most landings of Nassau grouper in Cuba were reportedly taken by fish traps and, of the 20 or so historically reported aggregation sites, none have been confirmed to still form in significant numbers in recent years although about 9 have been reported in the most recently available fisher accounts. Claro et al. 2009: "Due to declining fish yields over time and the resulting reduction in profitability of fishing on aggregations, fishing effort on the spawning aggregations declined. The peak catches noted after 1980

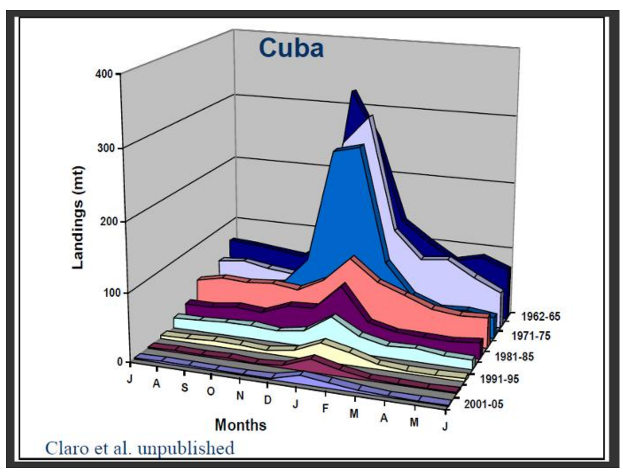

Figure 18. Seasonal landings from Cuba, noting decrease of catches of Nassau grouper during spawning season

occurred mainly during spawning migrations when the vulnerability of fishes to fishing gears such as set nets was high. Nevertheless, there persisted an important recreational fishery, using both hook and line and spear-gun, on the spawning aggregation sites in the northern Cuban Archipelago. The size of this fishery is unknown due to lack of statistical information and divers have not surveyed spawning aggregation sites to assess the numbers of fish assembling to spawn. The main aggregation sites in southern Cuba (Puntalón de C. Guano and Banco de Jagua) are no longer regularly fished due to the difficult accessibility of these sites. Overall, relatively few viable spawning aggregations are thought to persist in Cuba today."

Cuba – Conservation and Management

Cuba has a long and well-documented history of exploitation and management of the Nassau grouper, which was once an important commercial species landed in the country. Cuban fleets also fished extensively for the species outside of Cuban waters, particularly in the Bahamas (Claro et al. 2009). The fishery was largely based on catches taken during the spawning aggregation season (Fig. 21). In the 1970s, aggregation catches suddenly dropped, indicating a severe reduction in the fishery which was not attributable to change in effort or other factors as far as could be determined (Claro et al. 2009). Data on current status of the fishery are unavailable. There are reported to persist a possible 9 out of 20/21 previously known aggregation sites although these have not been validated recently.

Since the 1980s, many regulations have been introduced to address particular species, issues, such as declines in catches, or regions, e.g. seasonal spawning closures, gear bans, fishing effort control, etc. These were often introduced for short periods of time and by particular Fishing Associations. For Nassau grouper, there was an almost complete absence of species-specific protective management, with the exception of a minimum legal size (32cm TL=570g) that is too small for the species based on size at maturity. Of some benefit to the Nassau grouper were bag limits for recreational fishing, regulations to increase selectivity of several fishing gears (mesh size) to avoid the catch of juveniles, control of set net use, and limits during spawning aggregation time, and controls of speargun use, both commercially and recreationally. Marine protected areas have been introduced. In 2002, the total number of recreational licenses was limited to 3,500 for the whole country hoping to reduce directed fishing pressure. Enforcement of these regulations has been variously effective (Claro et al. 2009) but recovery of the species is not recorded.

DOMINICAN REPUBLIC

Dominican Republic - Populations

The current status of Nassau grouper is largely unknown although indications are that the species has been largely depleted from local reefs (J. Mateo, Consejo Dominicano de Pesca y Acuicultura, Edif. Secretaría de Agricultura, pers. comm. to R. Hill, NMFS, 2012). Reports suggest that large fish can still be seen in the fish markets on the north coast (J. Mateo, Consejo Dominicano de Pesca y Acuicultura, Edif. Secretaría de Agricultura, pers. comm. to R. Hill, NMFS, 2012) although the locations from which those catches derive are unknown (but see Bahamas, above). Cumulative data from REEF (2003-2013) show sightings of only 4 Nassau grouper in 116 surveys (density index 1.3, sighting frequency 3.4%) across the 10-year period. All sighting in these samples (n=84, 4 Nassau grouper/ density index: 1.3, sighting frequency: 4.8%) were from Manzanillo Bay to Cabo Engano on the north coast (http://www.reef.org/db/reports/dist/species/TWA/0097/2003-01-01/2013-04-07). Data from Sadovy (1997) indicated one known spawning aggregation from Punta Rusia although status was listed at the time, as "probably disappeared." Underwater coral reef visual censuses in the Dominican Republic produced no records of Nassau grouper (Schmitt and Sullivan 1994).

Dominican Republic – Fishing

Trap fishing has been the primary method for catching grouper in the Dominican Republic (Munro and Thompson 1983). No landings have been reported from the Dominican Republic for many years and the species appears to have been severely depleted in local waters. Poaching by Dominican vessels in Bahamian waters for this species has been reported.

Dominican Republic – Conservation and Management

Little information is available describing specific fishing regulations; however it is reported that since the mid-1980s, no catch or sale of ripe females in spawning season is allowed (Bohnsack 1989, Sadovy and Eklund 1999, Box and Bonilla Mejia 2008). At least one marine park has been established with fishing regulations although no information is available on Nassau grouper presence in the park.

HONDURAS

Honduras – Populations

Despite the economic importance of the Nassau grouper in Honduras there are few data on the species or its fishery, either artisanal or commercial. Much of the ecological studies have appeared in reports that are not readily available (see citations in Fonseca et al 2004). Cumulative data from REEF (2003-2013) report 809 Nassau grouper in 3047 surveys (density index 1.3, sighting frequency 26.6%) across the 10-year period. Most of the sighting in these samples came from Roatan (n = 1884, 585 Nassau grouper-density index: 1.4, sighting frequency: 31.1%) and Utila (n = 1071, 202 Nassau grouper-density index: 1.2, sighting frequency: 18.9%) (http://www.reef.org/db/reports/dist/species/TWA/0097/2003-01-01/2013-04-07). No government unit or institution collects data on the species. To provide an overview of the species, a review was commissioned (Box and Bonilla Mejia 2008). The only other published studies located are those by Fine (1990, 1992), which document the rapid demise of one aggregation site.

The Box and Bonilla Mejia (2008) report found that Nassau grouper landings increased up until the end of the 1980s and early 1990s and then declined, losing commercial importance in 2003. In the early 1990s, there was evidence of uncontrolled fishing of Nassau grouper spawning aggregations. For example, at one site close to Guanaja, local and foreign vessels reduced the aggregations from approximately 10,000 fish to less than 500 in 2 years; fishers removed 13.64 t (30,000 lbs.) per season (Fine 1990, 1992). Other aggregations probably occurred in the area historically but since declined, according to anecdotal fisher accounts (Box and Bonilla Mejia 2008).

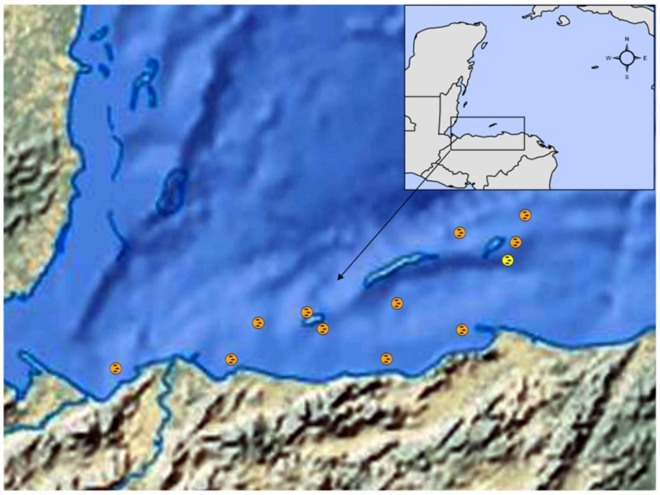

Figure 20. Confirmed and suspected (yellow circle) spawning sites in Honduras

Further evidence of declines of this species is reflected in reduced exports of Nassau and red groupers in the last few decades (Box and Bonilla Mejia 2008). Peak exports occurred during the Nassau grouper spawning season but declined severely overall between 1995 and 2004. Anecdotal reports from fishing communities suggest that the 'Grouper's Joy' site and migration routes into spawning areas have been intensively fished since the late 1990s and that the fish is now uncommon. The 2008 report concludes that the species is now a much smaller proportion of reef fish taken in the country, representing <5% of income from the fishery. Nassau grouper declined from 7% by weight of exports to the USA in 1996 to 0.7% in 2007. Fishing communities report that Nassau grouper are being replaced in the landings by *Mycteroperca venenosa*, yellowfin grouper. Catch of Nassau grouper tends to be incidental to that of snappers and lobster fisheries.

Honduras – Fishing

Local fishermen and commercial boats in the Bay Islands have exploited Nassau grouper; Roatan, La Ceiba, and Guanaja are the main commercial fishery centers for the country, including the landings of Nassau grouper. Spawning aggregations were fished with traps and spears (Box and Bonilla Mejia 2008). Most Nassau grouper landed were exported to the USA (about 95%); there has never been an important market for the species within Honduras (Box and Bonilla Mejia 2008). The one documented spawning in Honduras, Caldera del Diablo, outside Guanaja appears to have been eradicated in the early 1990s (Fine 1990, 1992) although there are no supporting biological data on its current condition. Fishers have reported many other locations that are likely to be spawning sites, although their current condition is unknown. It is thought that only the more inaccessible sites, such as Banco Campiche, are still likely to have aggregations (Box and Bonilla Mejia 2008).

One instance of poaching/enforcement was documented in February 2009. Four Honduran fishermen from Puerto Cortez were arrested while actively night fishing in Belize waters at the closed Nassau grouper site in Gladden Spit and Silk Cayes Marine Reserve (GSSCMR). Their catch, including 19 Nassau groupers was inventoried and they were fined approximately $19,200. Two fishermen, unable to pay their fines, were remanded to jail (Belize Spawning Aggregation Working Group Information Circular No. 7, June 2009).

Honduras – Conservation and Management

There is no legislation that controls fishing in the snapper/grouper fishery in the country although traps and spear are illegal in the Bay Islands. A black market evidently continues particularly in the illegal sale of fish by lobster fishermen, but its extent and impact are unknown (Box and Bonilla Mejia 2008). Some fish leave the country illegally on vessels and some are taken illegally on local boats not licensed to take fish (Box and Bonilla Mejia 2008). Confidential interviews indicated that during the spawning season of up to 1,000 lbs. of grouper per boat were once landed causing local saturation and reducing sale prices (Box and Bonilla Mejia 2008).

JAMAICA

Jamaica – Populations

Jamaica's coral reefs are among the best studied in the world beginning with research by T.F. Goreau and co-workers in the 1950s (Goreau 1992). Observations by researchers at the Discovery Bay Marine Laboratory of the University of West Indies and other scientists have added to the information base (M. Vierros, www.agrra.org/reports/jamaica2.html). Jamaica is located at the center of coral diversity in the Atlantic Ocean (Wells and Lang 1973), with over 60 species of reef building corals, and with fringing reefs occurring on a narrow, 1-2 km shelf along most of the north coast of Jamaica. Reefs also grow sporadically on the south coast on a broad shelf over 20 km wide (Hughes 1994). In addition, reefs and corals can be found on the neighboring banks of the Pedro Cays, 70 km to the south, and the Morant Cays, 50 km to the southwest (Woodley et al. 1998).

Depletion of reef fish populations in Jamaica has been well documented. Extensive studies in Jamaica by Munro (1993) showed that in the decades leading up to the 1960s fish biomass had been reduced up to 80% on the extensive fringing reefs of the north coast, mainly a result of intensive artisanal trap fishing. By 1973, the number of fishing canoes deploying traps on the north coast was approximately 1800 (or 3.5 canoes per square kilometer of coastal shelf), which was two to three times the sustainable levels (Munro 1983). The taxonomic composition of fish had changed markedly and large predatory species, including groupers had virtually disappeared (Hughes 1994) and a marked a decline in the equilibrium productivity of the fishery (Koslow et al. 1994).

When asked about present conditions, K. Aiken (University of West Indies, pers. comm. to R. Hill, NMFS, 2012) stated that while Nassau grouper were occasional in the 1970s, they are now rare. "I haven't seen one since 2011, and only at one location at the extreme east of Jamaica."

Jamaica – Fishing

The fisheries of Jamaica, as reported by Aiken and Street (1993) were largely made up of artisanal fishermen operating from open canoe type boats powered by either outboard motors or oars. Approximately 12,000 registered fishermen using approximately 400 boats (reduced from earlier reports) worked from 168 fishing beaches scattered around Jamaica's coastline. The fisheries may be further subdivided into the inshore fishery and the offshore fishery. The offshore fishery began operating primarily from the south coast following a government program to mechanize more than half of the fishing boats. The offshore fishery harvests from offshore cays, as well as remote deepwater areas. The fishery of Jamaica is multispecies, targeting all coral reef fish resources.

The Fisheries Division collects catch and effort data under the LRS (Licensing and Registration System). Jamaica also enters the data collected under a statistical sampling frame into the TIP (Trip Interview Program database developed by CFRAMP (CARICOM Fisheries Resource Assessment and Management Programme). A query to the CARICOMP data manager failed to uncover any data pertinent to Nassau grouper (M. Creary, Environmental Data Manager, Caribbean Coastal Data Centre, Centre for Marine Sciences, University of the West Indies, Mona, Kingston, Jamaica WI, pers. comm. to R. Hill, NMFS, Dec. 2012).

Trap fishing has been the primary method for catching grouper in Jamaica (Munro and Thompson 1983). The Antillean (arrowhead) fish traps are wooden-framed with galvanized wire mesh and one or two entrance funnels (Munro 1983a). The single funnel “chevron traps” are commonly used in the eastern Caribbean, and the "S" or" Z" shaped traps, with dual entrance funnels, are found in Cuba and Jamaica. Most traps have mesh sizes between 25-50 mm (Munro 1983a).

In Jamaica, fishing surveys conducted in the early 1970s resulted in Nassau grouper CPUE of 1.4 kg per line hour in 20-30 m of water and 1.7 kg per line hour in 30- 45 m (Munro, 1983b). With the advent of motorized boats and mechanized gears, intense exploitation led to lower catch rates of all reef fish and the disappearance of some species from multispecies catches (Stevenson 1981). An underwater survey of reef fishes in Jamaica in 1986 revealed no groupers (Koslow et al. 1988) and by 1989 Nassau grouper were rarely caught (Sadovy 1997).

Jamaica – Conservation and Management

No special regulations exist for Nassau grouper, specifically. Jamaica has identified areas as MPAs, but the designation was enacted only 2 years ago, so not a lot of changes are expected yet (K. Aiken University of West Indies, pers. comm. to R. Hill, NMFS, 2012).

LESSER ANTILLES, CENTRAL AMERICA, AND SOUTH AMERICA

Lesser Antilles, Central America, and South America – Populations

Nassau grouper are known to occur on the northern coast of South America, but aggregations have never been recorded from the continental shelf even where substantial fisheries have existed such as in Colombia (Sadovy and Eklund 1999). Little abundance information could be found from Venezuela, although they were reported at least from Los Roques (Cervigón 1994, Boomhower et al. 2010). Cumulative data from REEF (2003-2013) report 2 Nassau grouper in 32 surveys (density index 1, sighting frequency 6.3%) across the 10-year period. Additional surveys are listed for Venezuela (n = 148), but locations are not given and Nassau grouper were not recorded (http://www.reef.org/db/reports/dist/species/TWA/0097/2003-01-01/2013-04-07).

In the Lesser Antilles, Nassau grouper were reported in 2005 to be very scarce in St. Eustatius (Munro and Blok 2005). On the Antigua-Barbuda bank, Munro and Blok (2005) reported a spawning aggregation site in January and February 2003 at Knolls in the central area of the shelf of Antigua-Barbuda Bank. Cumulative data from REEF (2003-2013) report 123 Nassau grouper in the Leeward Islands (i.e., Anguilla, St. Martin/St. Maarten, St. Bartholomy, Saba, St. Eustatius, St. Kitts, Nevis, Antigua, Guadeloupe, and Dominica) in 1815 surveys (density index 1.3, sighting frequency 6.8%) across the 10-year period. Sightings in the Windward Islands (i.e., Martinique, St. Lucia, St. Vincent, Barbados, The Grenadines, Grenada) for the same period (n = 3004, 12 Nassau grouper/ density index: 1.8, sighting frequency: 0.4%) suggest that Nassau grouper are much more scarce (http://www.reef.org/db/reports/dist/species/TWA/0097/2003-01-01/2013-04-07). H. Oxenford (Oxenford, Centre for Resource Management and Environmental Studies, University of the West Indies, Cave Hill Campus, Barbados, pers. comm. to R. Hill, NMFS, 2012) stated that she has not seen a Nassau grouper in 30 years of diving for reef research in Barbados.

In Trinidad and Tobago, Nassau grouper are considered to be locally extinct (Bouchon et al. 2008). Contacts to the fisheries department elicited the response that Nassau grouper are quite rare and never show up in the fish market (J. Alemu, Department of Fisheries, pers. comm. to R. Hill, NMFS, 2012).

Lesser Antilles, Central America, and South America – Fishing

In the Lesser Antilles, larger groupers are fished with handlines and with traps from 4-8 m long boats equipped with 8- to 48-horsepower outboard engines (Mahon 1990); because the shelf is so narrow off the Lesser Antillean Islands, there has been no great need for larger boats. Groupers are sometimes caught off the deeper slopes using electric reels or mechanized winches for hauling traps (Mahon 1990). Little information is available regarding other fisheries from the area that target Nassau grouper.

Lesser Antilles, Central America, and South America – Conservation and Management

In Antigua-Barbuda the Fisheries Act, No.14 of 1983 and the Fisheries Regulations, No.10 of 1990, are the primary legislative basis for fisheries management and development of all fisheries including the (Nassau) grouper fishery. The Act and Regulations make provision for: 1) fisheries management elements, such as fishing licensing, enhanced fisheries research and enforcement, the registration of fishing vessels and the establishment of a fisheries advisory committee and; 2) conservation measures, such as prohibiting the use of certain fishing methods and gear, setting species size restrictions, establishing closed seasons, and creating marine reserves. With the assistance from FAO, initiated in 2003, the Fisheries Act, No. 22 of 2006 was passed and enacted (Horsford 2009) to better align local regulations with current international fisheries laws including the European seafood provisions, primarily benefiting exports. It also gave the Minister improved management capabilities, such as moving most fisheries from open access to licensed or permitted fishing. While Nassau grouper is not specifically managed or protected, closed seasons were considered in 2008 for Nassau grouper and red hind, the more dominant species in the local grouper fishery.

In Guadeloupe and Martinique, there are plans to protect the species (F Gourdin, Regional Activity Center for Specially Protected Areas and Wildlife SPAW/RAC – UNEP, pers. comm. to Y. Sadovy, University of Hong Kong, 2011) although no details are available at this time.

Other locations seem to have a few spatial closures (e.g., St. Lucia) that would benefit Nassau grouper but they were not designed for the species or their aggregations.

MEXICO

Mexico – Populations

A total of 28 aggregation sites have been reported in Mexico (Aguilar et al. 2009) but, only four (Fig. 23) have been verified (Aguilar-Perera et al. 2009). The two best-studied sites (Aguilar-Perera 2006) include Mahahual, which apparently no longer forms (recent checks from Dr. A. Aguilar-Perera found no fish spawning in 2013 [A. Aguilar-Perera, Departamento de Biología Marina, Facultad de Medicina Veterinaria y Zootecnia, Universidad Autónoma de Yucatán, México, pers comm. to R. Hill, NMFS, 2012.]), and Xcalak, the largest known aggregation in Mexico. Historically, aggregations of up to 15,000 fish formed each year at Mahuhual, but due to increased fishing pressure in the 1990s aggregations have not formed since 1996 (Aguilar-Perera et al. 2009). Despite conservation concerns, the Nassau grouper receives little management (except where noted below), with the limited exception of the Xcalak site, which is in a national park. In addition to these two locations, two other aggregation sites have been confirmed by diving (Nichehabin and San Juan Chenchomac). One location had 800 groupers and was first identified by fisher accounts in 2005 (Aguilar-Perera et al. 2009). An additional 24 aggregation sites have been reported from fisher interviews along the coast and on Chinchorro Bank, but have not yet been verified to have Nassau grouper. These additional locations may be along migratory routes rather than actual aggregation sites (Sosa-Cordero et al. 2002, Aguilar-Perera et al. 2009; A. Aguilar-Perera, Departamento de Biología Marina, Facultad de Medicina Veterinaria y Zootecnia, Universidad Autónoma de Yucatán, México, pers comm. to R. Hill, NMFS, 2012).

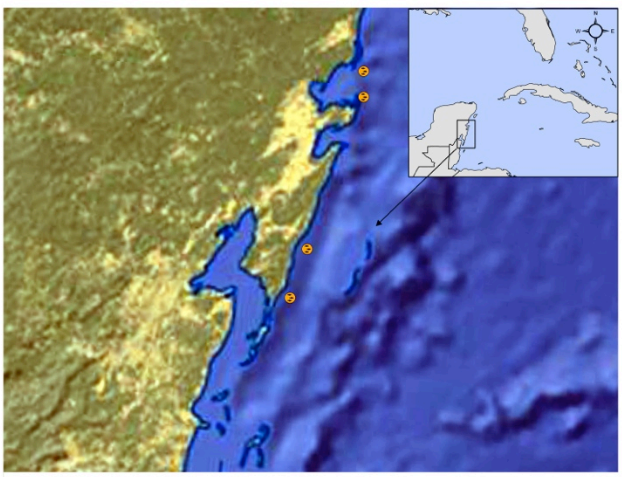

Figure 21. Nassau grouper spawning aggregation sites confirmed off Quintana Roo, Mexico.

Detailed reports are available for two sites, Xcalak and Mahahual, the latter, highly accessible to fishing. The aggregation site at Xcalak was the largest known in Mexico with 4,100 fish reported in 2004-5, up from 203 fish in 2001-2 (Medina-Quej et al. 2004, Aguilar-Perera 2006, Bolio-Moguel 2007). Underwater surveys at Mahahual during the reproductive seasons of December and January from 1991 to 1997, reported groups of between 50 and 800 Nassau groupers moving along the forereef border 1 km south of the traditional aggregation site. In

December 1993, 15 groupers were observed at the site, while no aggregation was found during the 1996 and 1997 seasons (Aguilar-Perera 2006), suggesting that the aggregation had not formed or formed elsewhere. Extensive searches of the area by divers failed to locate any Nassau grouper within kilometers of the spawning site (A. Aguilar-Perera, Departamento de Biología Marina, Facultad de Medicina Veterinaria y Zootecnia, Universidad Autónoma de Yucatán, México, pers comm. to R. Hill, NMFS, 2012). Aguilar-Perera (2006) suggested that decline and apparent disappearance of individuals from the traditional aggregation site off Mahahual was due to overfishing over the last 50 years.

The other studied aggregations occur at "El Blanquizal" on the south coast of Quintana Roo and Punta Gavilan (Medina-Quej et al. 2004). Fisher interviews suggested the presence of several extant spawning aggregations on the offshore Chinchorro Bank but these have not been validated (Aguilar-Perera et al. 2009). There is little indication of overall population status of the Nassau grouper in Mexico but concern exists about the overfishing of any remaining spawning aggregations.

Cumulative data from REEF (2003-2013) report 314 Nassau grouper in 5916 surveys in the Mexican Caribbean (density index 1.2, sighting frequency 5.3%) across the 10-year period. The largest number of these surveys were conducted at Isla Cozumel (n = 5218) with sightings of 279 Nassau grouper (s.f. = 5.3%, d.i. = 1.2). The coastline including Veracruz also lists 11 Nassau grouper from 625 surveys with sighting frequency of 1.2% (http://www.reef.org/db/reports/dist/species/TWA/0097/2003-01-01/2013-04-07).

Mexico – Fishing

The Nassau grouper has long been an important food and commercial fish in Mexico, exploited for over 70 years. In the Mexican Caribbean, while secondary as a fishing target to the Caribbean spiny lobster (*Panulirus argus*) and the queen conch (*Strombus gigas*), the Nassau grouper has been seasonally important and generally taken at its spawning aggregations in December, January, and February(Aguilar-Perera et al. 2009). There has been concern by fishers, biologists, and fisheries authorities over declines in catches although there are no species-specific landings data collected (A. Aguilar-Perera, Departamento de Biología Marina, Facultad de Medicina Veterinaria y Zootecnia, Universidad Autónoma de Yucatán, México, pers comm. to R. Hill, NMFS, 2012).

At Mahahual, Mexico, fishermen used 3 types of fishing gears (i.e., hook-and-line, speargun, and gillnets) for exploiting the aggregation (Aguilar-Perera 1994). From the early 1950s to the 1970s, hook-and-line was used; spear guns were used in the late 1960s through the early1990s. The efficiency of spearguns led to a decline in annual landings (Aguilar-Perera 1994). Gillnets were used from 1989 and after spearguns were banned (1993) at spawning aggregations, gillnets (15-20.3 cm mesh) use increased as barrier nets around aggregation sites and blocking migration routes. Mean size for gillnetted fish caught at two aggregations sites was about 600 mm TL (Sosa-Cordero and Cardenas-Vidal 1997). In Quintana Roo, Mexican fishermen are known to capture grouper by tying a live female grouper to a line, pulling her up rapidly, and netting the males that follow her to the surface (A. Aguilar-Perera, Departamento de Biología Marina, Facultad de Medicina Veterinaria y Zootecnia, Universidad Autónoma de Yucatán, México, pers comm. to R. Hill, NMFS, 2012).

At Mahahual in Quintana Roo, fishermen's accounts (as early as the 1950s) indicate catches of up to 24 t of Nassau grouper per reproductive season directly from the spawning aggregation off Mahahual. This catch represents only 4 to 5 days of fishing during December and January using only hook-and-line gear (Aguilar 2006). These landings contrast sharply with data gathered from the commercial catch (using gillnets with 15-cm mesh size) during the reproductive seasons each December and January from 1991-1997. By the early to mid-1990s landings from the Mahahual aggregation in the month of December had dropped to 3 mt and landings from January aggregations dropped to 1 mt (Aguilar-Perera 2006).

Mexico – Conservation and Management

In the Mexican Caribbean Sea, there were no traditional fishery regulations (e.g. size, quotas, and fishing gear restrictions) from fishery authorities governing the exploitation of Nassau grouper aggregations. However, regulations were established following scientific documentation of declines at Mahahual (Aguilar-Perera 1994). Two prohibitions that afford protection to Nassau grouper were enacted: 1) spear-fishing was banned at any spawning aggregation sites in southern Quintana Roo in 1993; and 2) later in 1997 the fishing of any grouper species was banned during December and January (Aguilar-Perera 2006). However, these measures were temporary, no longer in effect, and were evidently not respected by fishermen. As is common in so many areas, lack of enforcement has been a persistent problem (Aguilar-Perera et al. 2009).

In 2003, a closed season for all grouper was implemented from February 15 to March 15 and applies to all waters of the Mexican EEZ from Campeche and Yucatán (Gulf of Mexico) and Quintana Roo (Caribbean) states, as well as from Rio San Pedro, between Tabasco and Campeche states to the Belize border. While mainly offering protection for red grouper, *E. morio,* Nassau grouper is also included as a prohibited species (Aguilar-Perera et al. 2008. This law prohibits the removal of other grouper species (including yellowfin grouper, *Mycteroperca venenosa*) during the reproductive season. It is difficult to assess the effects of this prohibition given the absence of continuous population monitoring prior to the ban.

By the end of 2012, a management plan was to have gone into effect in the southern Gulf of Mexico and Caribbean for all commercially exploited groupers (about 17 species); the plan has not been implemented, but there is expectation that it will be put into place in 2014 (A. Aguilar-Perera, Departamento de Biología Marina, Facultad de Medicina Veterinaria y Zootecnia, Universidad Autónoma de Yucatán, México, pers comm. to R. Hill, NMFS, 2012).

This management plan is an initiative of the federal government through its office, INAPESCA, supported by scientists based on the best scientific knowledge available. For the first time, spawning Nassau grouper will be specifically protected between December 1 and January 31 annually, mainly for the Mexican Caribbean where this species is more abundant. An additional ban for catching all groupers in the Gulf of Mexico will extend from January 15 to March 14 annually. Within the jurisdiction of Mexico in the Caribbean Sea, all aggregating groupers, such as black grouper, *Myceteroperca bonaci*, will be protected. Status of the ban at this time is uncertain.

TURKS AND CAICOS ISLANDS

Turks and Caicos Islands – Populations

Nassau grouper in the Turks and Caicos Islands (TCI) are not subjected to significant commercial fishing pressure; they are considered to be in healthy condition with relatively high densities in some areas (Tupper 2002). Tupper (2002) and Tupper and Rudd (2002) reported densities in the range of 0.45 to 0.9 individuals per 100 square meters (45-90/hectare), with higher densities on deeper reefs and no difference in fish length by depth (Tupper 2002, Tupper and Rudd 2002, Rudd 2003a, Rudd, 2004). Chiappone et al. (2000) reported a density of 0.35-0.62 Nassau grouper per 100 square meters at South Caicos sites. These figures compare favorably with 0.01 per 100 square meters in the depleted Florida area and 0.16-0.20 per 100 square meters in the Bahamas in non-spawning times. Cumulative data from REEF (2003-2013) report 885 Nassau grouper in 1345 surveys (density index 1.7, sighting frequency 65.8%) across the 10-year period. With the exception of Salt Cay (s.f. = 18.3%), all other survey sites have sighting frequencies ranging from 59.3% to 100% (http://www.reef.org/db/reports/dist/species/TWA/0097/2003-01-01/2013-04-07).

Because fishing pressure is low, field studies can provide valuable insights into the ecology and biology of Nassau grouper. Nassau grouper from South Caicos have been reported to travel approximately 40 km to a large spawning aggregation at Philips Reef, off the island of East Caicos around the full moon in January (Rudd 2003a). This aggregation is rarely fished due its remote location and rough seas (Rudd 2003a); additional information about this aggregation is scarce. Studies have shown juveniles settle inshore (Claydon and Kroetz 2007). In an underwater survey conducted from 20 May to 23 August 2007 south of South Caicos, 209 Nassau grouper juveniles (< 12 cm TL) were observed within or close to (20 m) seagrass beds. Solitary conch shells were occupied by early juvenile Nassau grouper but these were largely absent from seagrass areas to the north of Dove Cay possibly because these habitats are in close proximity to land and the activities of large vessels as they are heading to and leaving the nearby dock.

Turks and Caicos Islands – Fishing

The Nassau grouper is highly valued for the local tourism and restaurant markets and is also important in the diver tourism sector. Local populations are assumed to be in good health. Main target species in the fishery are queen conch and lobster although catch of scale fish, including Nassau grouper, for the local markets has recently increased (unpublished Dept. of Environment and Coastal Resources, Turks and Caicos Islands National Report, 2008). The TCI are moving to diversify fisheries including for scale fish, which are evidently underutilized (unpublished Dept. of Environment and Coastal Resources, Turks and Caicos Islands National

Report, 2008).

Larger boats with electric reels have now established a local market for their catch and increased harvest. The growth in tourism has increased the demand in the local market for Nassau grouper. Many local fishers gain additional income from targeting reef fish. Because not all scale fish are taken to licensed processors, it is difficult to know total catch. Rudd and Tupper (2002) reported that the landing prices for the Nassau grouper at dockside reached US$3.50 per kg while fishermen might sell Nassau grouper directly to restaurants for up to US$15.00 per kg. Some South Caicos fishers have begun to target grouper more recently as the value of the catch is often worth the expense of travelling 60 km to Providenciales to sell their catch when it exceeds about 100 kg (Rudd, 2003b).

Nassau grouper are an important component of the menu of restaurants for local consumption. The Nassau grouper is a popular grouper because some other grouper species (e.g. tiger grouper, *Mycteroperca tigris*) may contain ciguatoxin which limits their sales in restaurants. Rudd (2004) found that the introduction of an import tariff on fish significantly increased demand for local Nassau grouper. Many Nassau grouper caught on the South Caicos fishing grounds are taken by lobster divers who opportunistically spear fish (Rudd 2003b).

Few data are available on total catch of Nassau grouper but limited CPUE data suggest relatively low catch rates compared to other reef fishes. Tupper and Rudd (2002) found CPUE for Nassau grouper to be 0.7 kg per hour compared with 3.2 kg per hour for all reef fish. Fish abundance, as indicated by CPUE, is lower by 50% or more in fished rather than lightly fished or unfished (i.e. protected) areas but differed little between the latter two zones (Tupper and Rudd 2002). Tupper and Rudd (2002) found no differences in size, abundance or biomass between zones of different fishing intensity and suggested that fishing intensity was unlikely to explain the greater abundance and biomass on deeper reefs.

In addition to food, Nassau groupers provide non-extractive economic value (e.g. non-lethal catch-and-release fishing and wildlife viewing) to divers for tourism. An increase in Nassau grouper abundance and/or mean size adds value to the dive experience because most divers have preferences for viewing more fish and many divers express preferences for viewing larger fish (Rudd 2003a). Rudd and Tupper (2002) also reported that snorkelers as well as divers prefer viewing larger and/or more abundant Nassau grouper.

Turks and Caicos Islands – Conservation and Management

One spawning aggregation site is protected from fishing in Northwest Point Marine National Park, Providenciales (DECR 2004; National Parks Ordinance and Subsidiary Legislation CAP. 80 of 1988). In the Turks and Caicos Islands, the main aggregation site is remote and rough weather during the spawning season has generally restricted fishing activity. Seasonal closures may play a role in fisheries management planning in the future but in the short-term are not significant factors for Nassau grouper conservation in the Turks and Caicos

Islands (Rudd, 2003b). Full protection of essential Nassau grouper habitat and spawning migration corridors on the very narrow fringe of Caicos Bank would impose economic hardship on local fishers who depend on those areas for commercial species (spiny lobsters) and subsistence fishing (Rudd 2004). Tupper and Rudd (2002) suggested that seasonal spawning closures in the Turks and Caicos Islands might have to be several months in length (e.g. November through March) to be effective. Despite relatively little fishery focus on the Nassau grouper, there is consumer interest in the species (a strong local tourism sector) and a significant proportion of fish in one recent study was taken below the size-at-maturation so pressure is expected to grow in the absence of management (Landsman et al. 2009).

UNITED STATES (FLORIDA)

United States (Florida) – Populations

Although there are few data on historic abundance of Nassau grouper off the U.S. mainland, it appears that abundance was once high in southern Florida (Springer and McErlean, 1962). Anecdotal reports from spearfishers noted large daily catches in the 1950s (Bohnsack 1990). Interviews of Florida Keys' residents suggested that Nassau grouper were once caught in much greater numbers from the upper Florida Keys and the Bahamas (Sadovy and Eklund 1999). Starck (1968) reported Nassau grouper frequently at Alligator Reef in the Florida Keys.

Historically, Nassau grouper was a component of the grouper fishery in Florida, suggesting once healthy (sub)population(s) in southeastern U.S. mainland waters (Sadovy and Eklund 1999). In contrast, now the species is rarely encountered (Sadovy and Eklund 1999). In the Dry Tortugas, where Nassau grouper were once abundant, only one individual was recorded in 1994 out of 183 point censuses and none in 37 predator censuses (Sluka et al. 1998). On Elbow Reef, Florida Keys, mean Nassau grouper densities were 0.01- 0.04 fish per 100 m^2 in 1993-94 (Sluka et al. 1998), with few seen on census dives through the Florida Keys. Censuses comparing areas protected and unprotected from fishing indicated that Nassau grouper, where protected, had a higher density and were one of the dominant grouper species observed (Sluka et al. 1994). Despite 10-20 years of no-take protection of the Nassau grouper in the Florida Keys, Nassau grouper has made no appreciable recovery and numbers remain extremely low (Semmens et al., 2007a, Don DeMaria pers. comm. 2012).

Reef fish surveys by the NMFS Southeast Fisheries Science Center's (SEFSC) Reef Team revealed low densities from 1980-1994 in southern Florida (Fig. 24); of 3,518 visual point

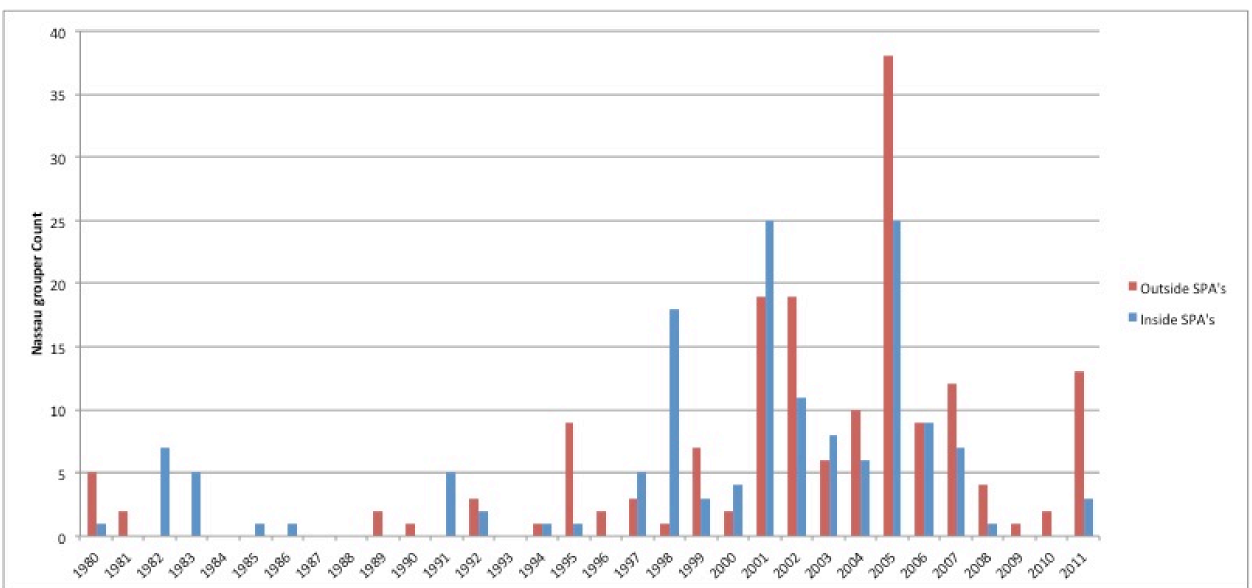

Figure 22. Counts of Nassau grouper observed in SEFSC reef fish visual census in the Florida Keys from 1980-2011

counts Nassau grouper were recorded 29 times, the number declining to zero in 1993. Both the number of Nassau grouper and the number of surveys increased from 1995 up to 2005 (Fig. 25).

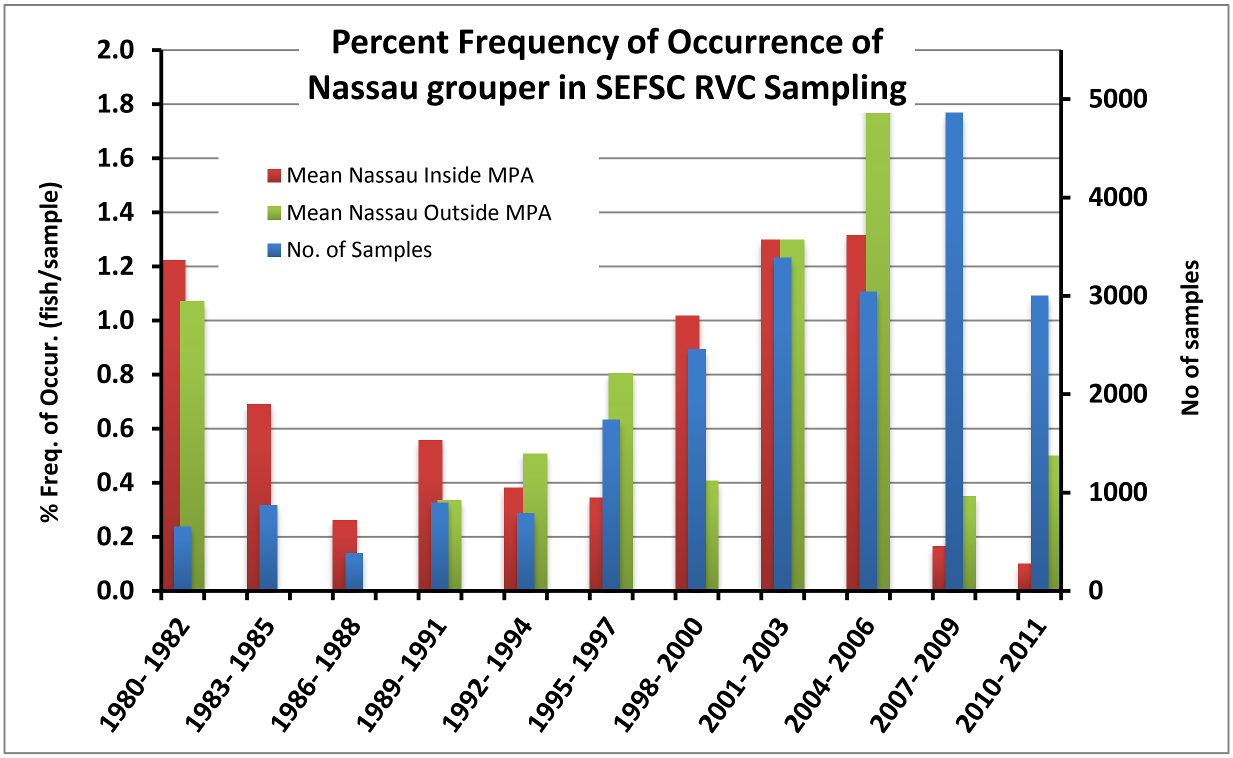

Figure 23. Mean Percent Frequency of Occurrence of Nassau grouper in 3-year Intervals (except for 2010-2011), data from SEFSC

From 1980 to 1996, Looe Key and Molasses were the only protected (marine reserve) sites. In 1997, the marine reserve zones for the Florida Keys National Marine Sanctuary were established, including SPAs (Sanctuary Preservation Areas), and the Keys wide sampling design was developed to monitor reef ecosystem conditions. Throughout the range of surveys (Fig. 25), frequency of occurrence for Nassau grouper was low and comparable both inside and outside of marine reserves: 0 to 1.9% of samples included Nassau grouper (NMFS SEFSC data, supplied by J. Blondeau, 2012). A map of the distribution of positive encounters suggests they are distributed throughout Monroe County and does not suggest any clear pattern (Fig. 26). Separate data for

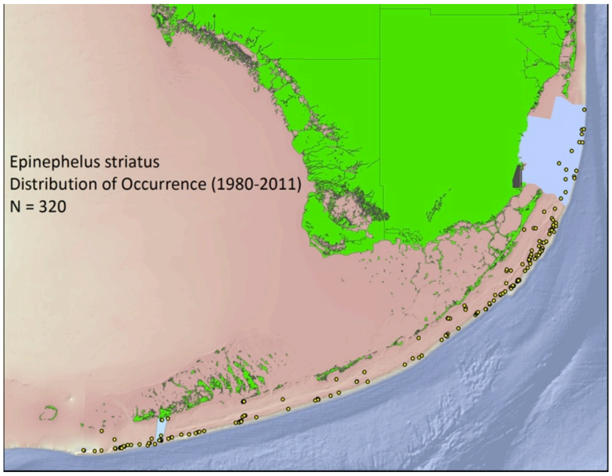

Figure 24. Distribution of samples with positive counts of Nassau grouper (SEFSC data, map by J. Blondeau)

surveys between 2000-2007 (Key Largo to Dry Tortugas), with 8563 surveys observed 210 Nassau grouper on 198 of the surveys (density: 0.0001/m^2 and 2.1% sighting frequency) (SEFSC data, supplied by T. Kellison 2012).

A large number and diversity of additional fishery-independent surveys by state port samplers over the last decade have resulted in records of a few hundred Nassau grouper landed (Alejandro Acosta, FWCC, pers. comm.). Additional underwater surveys by the Florida Fish and Wildlife Commission have been conducted from 1999-2007 using two sampling approaches: 1) linear transects (a total of 10 individual Nassau grouper were recorded from 1127 transects (30m by 10m wide); and 2) point counts (a total of 69 individual Nassau grouper were recorded from 7398 (5 m radius) surveys). During eight years of surveys 79 Nassau groupers (out of 3927 total groupers) were observed with 92% of the Nassau grouper between 35 and 70 cm in length (J. McCawley, Director, Div. of Marine Fisheries Management letter to SERO).

Cumulative data from REEF (2003-2013) report 1322 Nassau grouper in 9706 surveys (density index 1.2, sighting frequency 13.6%) over the 10-year period. Surveys up the east coast of Florida to Jupiter Inlet report 83 Nassau grouper in 6763 surveys (density index 1.2, sighting frequency 1.2%) and on the west coast of Florida from Cape Sable to Tampa Bay 12 Nassau grouper in 590 surveys (density index 2, sighting frequency 2%) (http://www.reef.org/db/reports/dist/species/TWA/0097/2003-01-01/2013-04-07).

No Nassau grouper spawning aggregation sites have been reported in Florida waters.

United States (Florida) – Fishing

Commercial landings of Nassau grouper off Florida's Atlantic coast were caught primarily by handlines, although catches from spearfishing took more than one quarter of the commercial landings in 1989, 1991, and 1992 (cited in Sadovy and Eklund 1999). Commercial fisheries data prior to 1986 did not distinguish landings to species (e.g., grouper) so detailed data for Nassau grouper landings are not available prior to that 1986 as they were grouped with other grouper species. Most recreational catch in the U.S. Atlantic came from private/rental boats.

Commercial landings of Nassau grouper from the eastern Gulf of Mexico, were by handlines and longlines and accounted for 80-100% of Nassau grouper commercially landed, by weight, from 1986-1992 (Sadovy and Eklund 1999). Incidental catch of Nassau grouper also occurred in fish traps, with the number of trap-caught groupers increasing since 1984 (GMFMC 1989). In the 1990s, most catch from the recreational fishery was from private/rental boats (detailed in Sadovy and Eklund 1999). An analysis of the headboat sector of the fishery showed a peak in headboat catches in 1981-1982 around 1.4 mt with a steep decline to about 0.35 mt by 1989 (Bohnsack 2003). By matching trends with Cuban fisheries, it is not unreasonable to conclude that headboat catches in the Florida Keys in the 1960s would have been 3 to 4 times higher than existing and temporally limited landings data (Bohnsack 2003).

There is currently no fishery for Nassau grouper in the United States and possession is prohibited (for additional details of the history, see Sadovy and Eklund 1999). Nassau grouper may show up as bycatch in various fisheries around south Florida. Barotrauma from rapid decompression, increased time in warm surface waters, and increased exposure to predation threats may result in species mortality in the absence of a directed fishery (Bartholomew and Bohnsack 2005). Additional bycatch mortality could also occur in the hook-and-line, longline, and trap fisheries.

United States (Florida) – Conservation and Management

The species was once part of the multi-species commercial fishery in the southeastern United States. Take and possession of Nassau grouper have been prohibited in federal waters since 1990. This includes federal waters around Puerto Rico and the U.S. Virgin Islands. A ban on fishing/possessing Nassau grouper has been in effect in the state of Florida since 1993 and has been enacted in all U.S. state waters. The species is protected in Dry Tortugas Marine Reserve and Florida Keys National Marine Sanctuary. Information on import of the species into the US is needed to understand implications of international trade on regional Nassau grouper populations.

UNITED STATES (PUERTO RICO)

United States (Puerto Rico) – Populations

Puerto Rico once had significant landings and, hence, (sub)population(s) of Nassau grouper and at least one substantial aggregation in its southwest corner, according to anecdotal reports (Sadovy 1993). This aggregation appears to have long since disappeared and landings of the species, according to regular port surveys conducted by the government's 'Laboratorio de Investigaciones Pesqueras' (Fishery Research Laboratory) over several decades, dropped to negligible levels before the species was fully protected (in commonwealth and federal waters) in 2004. Although only a single (perhaps reforming) spawning aggregation has recently been found (Schärer et al. 2012), there were occasional reports of juvenile settlement in local waters suggesting either spawning aggregations at unknown sites in the region, and/or that mating in smaller groups (e.g., paired individuals) occurs. It is also possible that larvae are coming on currents from distant islands in the region (Aguilar-Perera et al. 2006).

Several studies have been conducted around the islands of Puerto Rico in recent years by visual surveys. At Mona and Monito, small islands to the west of Puerto Rico, in 2000 and 2005, 7 Nassau grouper juveniles were found in shallow seagrass and rubble habitats within the reef lagoon. In winter 2004, 2 adult Nassau grouper were found in coral reefs off southern Mona during surveys for grouper spawning aggregations (Aguilar-Perera et al. 2006). According to underwater visual surveys from 2004 to 2007 at Mona Island, Puerto Rico, the abundance of Nassau grouper is extremely low and its distribution is limited to specific depths and habitat types according to fish size class (Schärer et al. 2007). No spawning aggregations of Nassau grouper were encountered (Appeldoorn pers. obs.) even though reports from fishermen described abundant aggregations dating back decades (Schärer et al. 2007). Early juveniles (< 10 cm TL) are occasionally observed, suggesting successful reproduction somewhere at or near Mona (Schärer et al. 2007) although the larval life of about 40 days (Colin et al. 1997) would provide time for larvae to reach Mona from more distant locations where aggregations are still present.

Currently research is underway at three grouper spawning sites off the western coast of Puerto Rico. This work is using passive acoustic monitoring and divers to quantify spatial extent, spawner abundance, and spawning timing. At one of the three sites, the researchers have identified a small number of Nassau grouper associated with spawners of other species (Schärer et al. 2012). Additional work is being undertaken to measure and characterize the spawning of Nassau grouper at this site (R. Appeldoorn and M. Schärer pers. comm.). One of the peculiarities of the possibly "reconstituted" spawning aggregation is that the timing seems to differ from the traditional winter months and evidence suggests it may be occurring months later than expected.

Cumulative data from REEF (2003-2013) report 32 Nassau grouper in 1239 surveys (density index 1.1, sighting frequency 2.6%) across the 10-year period. Of the Nassau grouper included in these surveys almost one-third of them are from the island of Culebra where the

Luis Peña No-Take Marine Reserve is located. (http://www.reef.org/db/reports/dist/species/TWA/0097/2003-01-01/2013-04-07).

United States (Puerto Rico) – Fishing

In the U.S. Virgin Islands and Puerto Rico, reef fish are caught by fish trap with some spearfishing and handlining. The boats used are small, ranging from 14 to 40 ft. in the trap fishery—less than 7.9 m long (Appeldoorn and Myers 1993, Agar et al. 2005, CFMC). Fishers have targeted Nassau grouper spawning aggregations since the 1950s. According to fisher interviews Nassau grouper landings from Mona Island ranged from 227 kg (500 pounds) to 681 kg (1,500 pounds) per 5-7 day trip before the 1980s, but subsequently declined so that fishing trips to Mona Island were no longer feasible (Schärer et al. 2007).

Puerto Rico has long collected some landings data at the species level from its fishing communities. It is thus well-documented that the Nassau grouper, dominant in the 1950s to 1970s, has since vanished from the commercial fishery (PRDNR 2012). The species was evidently heavily fished, including during its spawning periods, with smaller (immature sized) fish taken in fish traps (Sadovy 1993, Sadovy and Eklund 1999, Sadovy pers. obs.). During the early 1980s, landings declined and, by 1988-1989, Nassau grouper, the dominant commercial grouper since the 1950s, was rare and represented only 2% of all grouper landings and 0.2% of all demersal fish species (PRDNR 2012). It was considered extinct commercially before 1990 (Matos-Caraballo 2008); although the species still appears in landings reports where it has averaged approximately 11,000 pounds a year from 1994-2006.

Similar long-term declines were seen in commercial landings from Puerto Rico and the U.S. Virgin Islands. Commercial landings of Nassau grouper in Puerto Rico represented a major component of the fishery in the late 1800s (Wilcox 1899, Nichols 1929) but declined to an insignificant component by the 1990s. Appeldoorn et al. (1992) reported that Nassau grouper accounted for 141 out of 26,294 total fishes sampled in 1985 and only 38 out of 26,054 fish sampled in 1990 (Bohnsack 2003).

United States (Puerto Rico) – Conservation and Management

The management of fishery resources, including Nassau grouper, is shared between the local jurisdictional fishery managers of Puerto Rico and the Caribbean Fisheries Management Council with some authorities split between commonwealth/territorial waters and federal waters. A minimum size for Nassau grouper was introduced in 1985 and, effective November 1990, take and possession of the species were prohibited in U.S. federal waters (CFMC 1996). In Puerto Rico, the species was fully protected in both state and federal waters by 2004. Because most of the capture of Nassau grouper in the U.S. Caribbean occurs in territorial waters (Puerto Rico and the U.S. Virgin Islands), where federal fisheries restrictions do not apply, the introduction of protection in Puerto Rico jurisdictional waters in 2004 was particularly important (Table 11).

Table 6. Summary of Nassau grouper regulations in the U.S. Caribbean (García-Moliner and Sadovy 2008); PR = Puerto Rico, St. Thomas and St. Croix = U.S.V.I.

Year	Reef Fish FMP Regulations
1985	Min Size 12” to 24” (increasing 1 in/yr); Seasonal closure (prohibition on take) from January 1 to March 31 each year in Federal waters
1990	No harvest or possession in US federal waters (9-200 nm); Seasonal closure at Red Hind Bank St. Thomas (Dec-Feb) [1999 no-take]
1993	Seasonal closure for red hind at Tourmaline (PR) and Lang Bank (St. Croix)
1996	Seasonal closure for red hind Bajo de Sico, Abrir La Sierra (PR)
2004	No harvest or possession in Puerto Rico state waters (to 9 nm); no filleting at sea
2005	All seasonal area closures: prohibit bottom tending gear; no filleting fish at sea
2006	No harvest or possession in U.S.V.I.; no filleting at sea

UNITED STATES (VIRGIN ISLANDS)

United States (Virgin Islands) – Populations

Some of the earliest examples of ecological studies examined fish assemblages on reefs and these provide the chance to examine declines in Nassau grouper from St. John in the U.S. Virgin Islands. Between 1959 and 1961, a total of 124 adult Nassau grouper were tagged at Lameshur Bay, St. John (Randall 1962, 1963) and about 255 Nassau grouper, ranging in size from 170 to 686 mm SL, were speared for stomach content analyses prior to 1965 (Randall 1967). By the 1990s, only 37 Nassau grouper were seen over five years of intensive field sampling in 32 sample plots of 5000 m^2 each around St. John (Beets and Rogers 2000). During the same time frame, using *in situ* fish trap observations for sampling off Yawzi Point reef, Lameshur Bay, researchers marked a severe decline. Among the 22 numerically dominant fish species observed in the fish traps, Nassau grouper declined from 30 of 1164 fish (2.58%) observed in 1982-83 to 4 of 934 fish (0.43%) observed in 1993–1994 (Beets 1996).

One of the longest running data sets in the U.S.V.I. is maintained by Beets and Friedlander from surveys associated with the National Parks in St. John and St. Croix. From the St. John work, surveys have been conducted annually at the same sites (since 1989, average number of sites=7.9). These data show a small number of Nassau grouper were observed each

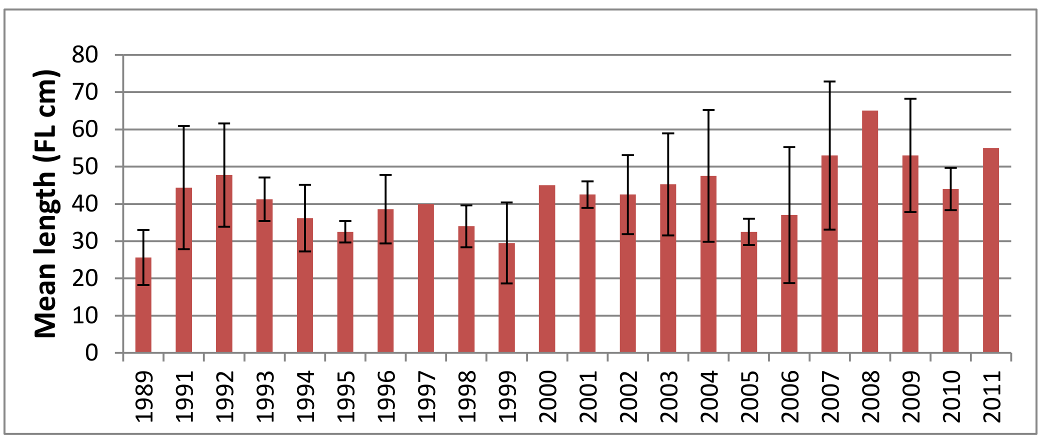

Figure 25. Mean Length of Nassau grouper from St. John surveys (A. Friedlander, unpub. data)

year and all were near or below the size at first maturity (Fig. 27). In the years from 1989-1994, a mean number of 10 Nassau grouper were seen annually. The average number of Nassau grouper declined to 2.8 during the period 1995-2011. Only 97 Nassau grouper were recorded through two decades of monitoring (A. Friedlander, 2012, unpub. data.). Estimates of biomass (Fig. 28), while low, seem to show that recent surveys are equivalent to surveys early in the series, although those samples were also taken at a time after the extirpation of known spawning aggregations in the northern U.S.V.I. In other UVC surveys conducted at random sites during daylight hours along 25-meter long by 4-meter wide belt-transects between 2001 and 2006, only three Nassau grouper were observed in the study region over the course of the six years of monitoring, giving mean abundance, frequency, and mean biomass of 0.2, <0.01, and 69.9 gram, respectively (Pittman et al. 2008).

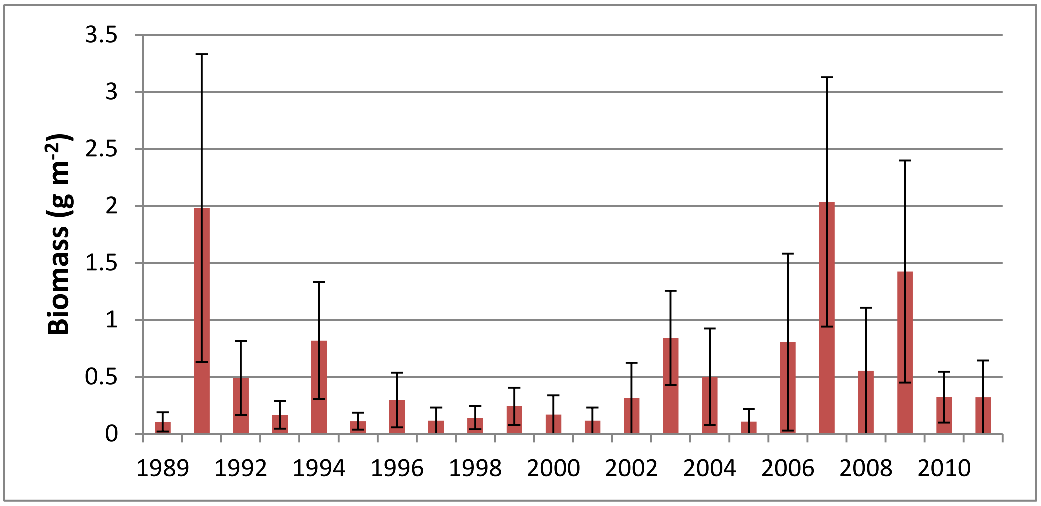

Figure 26. Mean biomass of Nassau grouper from St. John surveys (A. Friedlander, unpub. data).

Following the collapse of the Nassau grouper fishery in the USVI in the late 1970s (Olsen and LaPlace 1979), there was no significant spawning aggregation for this species on the shelf south of St. Thomas or St. John. However, fishermen are reporting a possible recurrence south of St. John (D. Olsen pers. comm. 2011) and Kadison et al. (2010) and Nemeth et al. (2006) suggest that there might be an aggregation re-forming at one of the sites south of St. Thomas. According to diver surveys conducted in 2001-2004, a small Nassau grouper aggregation has been observed at the Grammanik Bank, a deep reef (30-40 m) located on the shelf edge south of St. Thomas (Kadison et al. 2010, Nemeth et al. 2006). In 2002, small clusters of Nassau grouper, possibly representing the earliest stages in the recovery of a spawning aggregation, were noted at Grammanik Bank, while in March 2003, a single cluster of Nassau grouper, not previously recorded in either December or January, was observed at the same site (Nemeth et al. 2006). There was, however, no clear evidence (*e.g.*, behavior, coloration) that Nassau grouper successfully spawned in 2002 or 2003 at Grammanik Bank. In April 2004, about 60 Nassau groupers aggregated on the Grammanik Bank; 4 out of 60 fish were seen in bicolor phase but no courtship or spawning was observed (Nemeth et al. 2006). Recent work by Nemeth and coworkers (pers. comm.) has documented some increased settlement/recruitment (2004-2006) in nearshore habitats in both St. Thomas and St. John, and they have demonstrated success tracking Nassau grouper to the Grammanik Bank spawning site. It is possible that a year or two of strong recruitment occurred with resulting small increases in local abundance (Nemeth et al. in prep).

According to Kadison et al. (2010): "On St. Croix, where no Nassau grouper aggregation is believed to exist, fishermen and dive operators agree that grouper are almost completely absent from their isolated shelf (Gerson Martinez, fisherman pers. comm., Michele Pugh, dive business owner and operator pers. comm.). Only one has been observed in six years of fish surveys conducted annually on 14 sites around St. Croix (Nemeth Unpub. data)."

United States (Virgin Islands) – Fishing

In the U.S. Virgin Islands and Puerto Rico, reef fish are caught by fish trap with some spearfishing and handlining. The St. Croix fishery tends to be a diver-dominated fishery, whereas in St. Thomas the fishery tends to be trap-dominated (Olsen, pers. comm.). Traps are designed with biodegradable panels and mesh sizes have been adjusted repeatedly to reduce the bycatch of small fish. Given the mesh size, juvenile Nassau grouper would be readily retained in traps.

As reported by Munro and Blok (2005): "Grouper aggregations in U.S.V.I. waters were heavily exploited from the 1960s through the 1980s with the greatest effort having started north of the Puerto Rican island of Culebra. Aggregations on the Barracouta Bank, north of St. Thomas, were fished to extinction by the late 1970s, producing as much as 2.3 mt (metric tons)(5000 lbs.) of grouper per day at its peak" (K. Turbe, pers comm).

United States (Virgin Islands) – Conservation and Management

In the 1970s, the commercial harvest of the Nassau grouper in the U.S.V.I. reached its highest recorded point and it was also in this decade that well-documented declines occurred at one important aggregation site (Olsen and LaPlace 1979). Local fishermen were so concerned with catch levels that in 1976, St. Thomas fishermen requested (to the local government) that the grouper bank be closed for 5 years. Their only condition was that the closure was to be accompanied by enforcement. This request was ignored entirely (Olsen, STFA, pers. comm. to J. Rueter, NMFS, 2013). In 1990, the Caribbean Fishery Management Council (CFMC) enacted a prohibition on "fishing for or possession of Nassau grouper in or from the US Caribbean Exclusive Economic Zone" through its Shallow-water Reef Fish Management Plan. In addition, the CFMC, with support of local fishermen, established a no-take marine protected area off the southwest coast of St. Thomas, Hind Bank Marine Conservation District (Brown 2007) intended to protect red hind and red hind spawning aggregations. The Hind Bank Marine Conservation District was first subject to a seasonal closure, beginning in 1990 (Beets and Friedlander 1999, Nemeth 2005, Nemeth et al. 2006) to protect spawning aggregations of red hind, followed by year-round closure to fishing in 1998 (DPNR 2005). The closed area has been effective at restoring red hind even though compliance has, at times, been questionable (J. Rivera, SERO, pers. comm./unpub. data), although a St. Thomas fisherman was arrested and prosecuted in 2008 by NOAA Law Enforcement (D. Olsen, STFA, pers. comm. to J. Rueter, NMFS, 2013).

In U.S. Virgin Islands territorial waters, the species, prior to 2006, benefited from general fisheries restrictions, such as gear restrictions and rules on the marketing of fish, and those applying to specifically protected sites, such as the Virgin Islands Coral Reef National Monument (no-take), Virgin Islands National Park (no commercial fishing), Buck Island Reef National Monument (no-take) and several U.S.V.I. marine reserves. In 2006, the U.S.V.I. instituted regulations to prohibit harvest or possession of Nassau grouper in U.S.V.I. water and to prohibit fileting at sea (García-Moliner and Sadovy 2007). In 2010, as part of a SeaGrant project to bring attention to the Nassau grouper, the St. Thomas Fisherman's Association (STFA) distributed needles to vent swim bladders and record all Nassau grouper caught from April to July. Nassau grouper were regularly caught, although not as abundantly as in the past (D. Olsen, STFA, pers. comm. to J. Rueter, NMFS, 2013).

Following research for many years documenting grouper spawning and migration, Nemeth et al. (2006) suggested that the seasonal closure of the Grammanik Bank from February 1 to April 30 could provide protection (via management measures in a multi-species spawning aggregation site) for the potentially reforming Nassau grouper spawning aggregation. The Grammanik Bank spawning aggregation site has been seasonally protected from February through April since 2006 but recent evidence from acoustic tagging and hydrophone vocalizations suggests that Nassau aggregate to spawn at the Grammanik Bank from January through May which may warrant an extension of the Grammanik Bank closed season to five months. The Hind Bank Marine Conservation District, St. Thomas, remains closed to fishing year-round, protecting a red hind spawning aggregation and a former Nassau grouper spawning site.

LITERATURE CITED

Acero, A.P., and J. Garzon-Ferreira. 1991. Meros, chernas y cabrillas del Caribe Colombiano (Pisces: Serranidae: epinephelinae: epinephelini). Caldasia 16 (78):355-376.

Agar, J.J., M. Shivlani, J.R. Waters, M. Valdés-Pizzini, T. Murray, J. Kirkley, and D. Suman. 2005. *U.S. Caribbean Fish Trap Fishery Costs and Earnings Study*. NOAA Technical Memorandum NMFS-SEFSC- 534, 127 p.

Aguilar-Perera, A. 1994. Preliminary observations of the spawning aggregation of Nassau grouper, *Epinephelus striatus*, at Majahual, Quintana Roo, Mexico. *Proceedings of the Gulf and Caribbean Fisheries Institute*, **43:**112-122.

Aguilar-Perera, A. 2004. Detection of fishing effects on a Nassau grouper spawning aggregation from southern Quintana Roo, Mexico. *Proceedings of the Gulf and Caribbean Fisheries Institute*, **55:**544-556.

Aguilar-Perera, A. 2006. Disappearance of a Nassau grouper spawning aggregation off the southern Mexican Caribbean coast. *Marine Ecology Progress Series*, **327:**289-296.

Aguilar-Perera, J.A. 2000. Stock analysis for an aggregating reef fish, the Nassau grouper *Epinephelus striatus* (Pisces: Serranidae) from the Mexican Caribbean. MS Thesis, UPR-Mayagüez, 85 pp.

Aguilar-Perera A., and Aguilar-Davila W. 1996. A spawning aggregation of Nassau grouper *Epinephelus striatus* (Pisces: Serranidae) in the Mexican Caribbean. *Environmental Biology of Fishes,* **45:**351-361.

Aguilar-Perera, A., M. Schärer, and M. Nemeth. 2006. Occurrence of juvenile Nassau grouper, *Epinephelus striatus* (Teleostei: Serranidae), off Mona Island, Puerto Rico: considerations of recruitment potential. *Caribbean Journal of Science*, **42(2):** 261-265.

Aguilar-Perera, A., C. González-Salas, and H. Villegas-Hernández. 2009. Fishing, management, and conservation of the Nassau grouper, *Epinephelus striatus*, in the Mexican Caribbean. *Proceedings of the Gulf and Caribbean Fisheries Institute*, **61:**313-319.

Aiken, K.A., and T. Street. 1993. Jamaica. Part III. In: *Marine Fishery Resources of the Antilles: Lesser Antilles, Puerto Rico and Hispaniola, Jamaica, Cuba*, p. 159-180. FAO Fisheries Technical Paper. 326, 235 pp.

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

Albins and Hixon. 2011. Worst case scenario: potential long-term effects of invasive predatory lionfish (*Pterois volitans*) on Atlantic and Caribbean coral-reef communities. *Environmental Biology of Fishes*, Online First. DOI: 10.1007/s10641-011-9795-1.

Albins, M.A., M.A. Hixon, and Y. Sadovy. 2009. Threatened fishes of the world: *Epinephelus striatus* (Bloch, 1792) (Serranidae). *Environmental Biology of Fishes*, **86:**309-310.

Alvarez-Filip L., N.K. Dulvy, J.A. Gill, I.M. Cote, and A.R. Watkinson. 2009. Flattening of Caribbean coral reefs: region-wide declines in architectural complexity. *Proceedings of the Royal Society B*. **276:**3019–3025.

Amargós, F.P., G.G. Sansón, A.J. del Castillo, A.Z. Fernández, F.M. Blanco, and W.A. de la Red. 2010. An experiment of fish spillover from a marine reserve in Cuba. *Environmental Biology of Fishes,* **87:**363–372.

Appeldoorn, R., and S. Meyers. 1993. Puerto Rico and Hispaniola. Part II. In: *Marine Fishery Resources of the Antilles: Lesser Antilles, Puerto Rico and Hispaniola, Jamaica, Cuba*, p. 99-158. FAO Fisheries Technical Paper. 326, 235 pp.

Appeldoorn, R. S., G.D. Dennis, and O. Monterrosa Lopez. 1987. Review of shared demersal resources of Puerto Rico and the Lesser Antilles region, p. 36-106, i*n:* Report and proceedings of the expert consultation on shared fishery resources of the Lesser Antilles region, Mayaguez, Puerto Rico, 8-12 September 1986. FAO Fisheries Report 383, 278 pp.

Appeldoorn, R.S, J. Beets, J. Bohnsack, S. Bolden, D. Matos, S. Meyers, A. Rosario, Y. Sadovy, and W. Tobias. 1992. *Shallow water reef fish stock assessment for the U.S. Caribbean*. NOAA Technical Memorandum NMFS-SEFSC-304, 70 pp.

Archer, S.K., S.A. Heppell, B.X. Semmens, C.V. Pattengell-Semmens, P.G. Bush, C. McCoy, and B.C. Johnson. 2012. Patterns of color phase indicate spawn timing at a Nassau grouper *Epinephelus striatus* spawning aggregation. *Current Zoology* 58 (1): 73−83.

Baisre, J.A. 1993. Cuba. Part IV. In, *Marine Fishery Resources of the Antilles: Lesser Antilles, Puerto Rico and Hispaniola, Jamaica, Cuba*, p. 181- 235. FAO Fisheries Technical Paper 326, 235 p.

Baisre, J.A., and J. Paez. 1981. Los recursos pesqueros del archipelago Cubano. WECAF Stud. 8, 79 pp.

Baldwin, C.C., G.D. Johnson, and P.L. Colin. 1991. Larvae of *Diplorion bifasciatum*, *Belonoperca chabanaudi* and *Grammistes sellineatus* (Serranidae: Epinephelinae) with a comparison of known larvae of other epinephelines. *Bulletin of Marine Science*, **48(1):**67-93.

Bannerot S.P., W.W. Fox, Jr, and J.E. Powers. 1987. Reproductive strategies and the management of snappers and groupers in the Gulf of Mexico and Caribbean, p. 561-603, i*n:* J.J. Polovina and S. Ralston (eds). Tropical Snappers and Groupers: Biology and Fisheries Management. Westview Press, Boulder, CO.

Bardach, J.E. 1958. On the movements of certain Bermuda reef fishes. *Ecology* 39(1):139-146.

Bardach, J.E., and D.W. Menzel. 1957. Field and laboratory observations on the growth of some Bermuda reef fishes. *Proceedings of the Gulf and Caribbean Fisheries Institute,* **9:**106-112.

Bardach, J.E., C.L. Smith, and D.W. Menzel. 1958. Bermuda fisheries research program final report. Bermuda Trade Development Board, Hamilton, 59 p.

Bartholomew, A., and J.A. Bohnsack. 2005. A review of catch-and-release angling mortality with implications for no-take reserves. *Reviews in Fish Biology and Fisheries*, **15:**129–154

Beaumariage, D.S., and L.H. Bullock. 1976. Biological research on snappers and groupers as related to fishery management requirements, p. 86- 94, *in:* H.R. Bullis, Jr. and A.C. Jones (eds.), Proceedings of the Colloquium on snapper-grouper fishery resources of the western central Atlantic Ocean,. Fla. Sea Grant Coll. Rep. 17. 333 pp.

Beets, J. 1996. The effects of fishing and fish traps on fish assemblages within Virgin Islands National Park and Buck Island Reef National Monument. A technical report for the U.S. Department of Interior, National Park Service. Technical Report VINP 5/96. 21 p.

Beets J., and A. Friedlander. 1999. Evaluation of a conservation strategy: a spawning aggregation closure for red hind, *Epinephelus guttatus*, in the U.S. Virgin Islands. *Environmental Biology of Fishes,* **55:**91-98.

Beets, J., and M.A. Hixon. 1994. Distribution, persistence, and growth of groupers (Pisces: Serranidae) on artificial and natural patch reefs in the Virgin Islands. *Bulletin of Marine Science*, **55:**470- 483.

Beets, J. and C. Rogers. 2000. Decline of fishery resources in marine protected areas in the U.S. Virgin Islands: The need for marine reserves. *Proceedings of the International Coral Reef Symposium*. **9(1):**449-454.

The Belize Spawning Aggregation Working Group. 2009. Information Circular No 7. June 2009, 2pp. from http://www.spagbelize.org/LinkClick.aspx?fileticket=7doBoeM1PRk%3d&tabid=2807&language=en-US retrieved on 15 December 2011.

The Belize Spawning Aggregation Working Group. 2012. Information Circular No 10. November 2012, 2pp. from http://www.spagbelize.org/Portals/3/PDFs/SpAg_Newsletter_10_final.pdf retrieved on 15 April 2013.

Böhlke, J.E., and C.G. Chaplin. 1968. *Fishes of the Bahamas and Adjacent Tropical Waters*. Livingston Publ. Co., Wynnewood, PA, 771 pp.

Bohnsack, J.A. 1989. Protection of grouper spawning aggregations. Coastal Resources Division Contr. No. 88-89-06, 8 p.

Bohnsack, J.A. 1990. Black and Nassau grouper fishery trends. Appendix in South Atlantic Reeffish Plan Development Team Report of the Snapper-Grouper Assessment of the South Atlantic Fishery Management Council, 18 p.

Bohnsack, J.A. 2003. Shifting baselines, marine reserves, and Leopold's biotic ethic. *Gulf and Caribbean Research* **14(2):**1-7.

Bohnsack, J.A., and S.P. Bannerot. 1986. A stationary visual census technique for quantitatively assessing community structure of coral reef fishes. NOAA Tech. Rep. NMFS 41. 15 p.

Bohnsack, J.A., and D.E. Harper. 1988. *Length-weight relationships of selected marine reef fishes from the southeastern United States and the Caribbean.* NOAA Tech. Memo. NMFS-SEFC-215. 31 pp.

Bohnsack, J.A., D.L. Sutherland, A. Brown, D.E. Harper, and D.B. McClellan. 1986. An analysis of the Caribbean biostatistical database for 1985. Coast. Res. Dev. Rep. CFMC Contr. No. CRD-86/87-10, 35 p.

Bolden, S.K. 1994. A summary of biological and fishery data on red hind **(***Epinephelus guttatus***)** and coney (*Cephalopholis fulva***)** stocks in the U.S. Virgin Islands. NOAA/NMFS Miami Laboratory Contrib. No. 93/94-32, 33 p.

Bolden, S.K. 2000. Long-distance movement of a Nassau grouper (*Epinephelus striatus*) to spawning aggregation in the central Bahamas. *Fishery Bulletin,* **98(3):**642-645.

Bolden, S.K. 2001. Using Ultrasonic Telemetry to Determine Home Range of a Coral-Reef Fish. *in:* J.R. Sibert and J.L. Nielsen (eds.), Proceedings of the Symposium on Tagging and Tracking Marine Fish with Electronic Devices, February 2000, Hawaii, (Springer Publishing). Reviews: Methods and Technologies in Fish Biology and Fisheries 1:167-188.

Bolio-Moguel, K.M. 2007. Caracterización y descripción pesquera del sitio de agrupación de peces "El blanquizal – Santa Julia", Quintana Roo, México: Invierno 2004-Primavera 2005. Tesis Maestría. ECOSUR, 90 pp.

Boomhower, J., M. Romero, J. Posada, S. Kobara, and W. Heyman. 2008. Identification of reef fish spawning aggregation sites in Los Roques Archipelago National Park, Venezuela. *Proceedings of the Gulf and Caribbean Fisheries Institute,* **60:**559-565.

Boomhower, J., M. Romero, J. Posada, S. Kobara, and W. Heyman. 2010. Prediction and verification of possible reef-fish spawning aggregation sites in Los Roques Archipelago National Park, Venezuela. *Journal of Fish Biology* **77:**822-840.

Bouchon, C., P. Portillo, Y. Bouchon-Navaro, M. Loius, P. Hoetjes, K. De Meyer, D. Macrae, H. Armstrong, V. Datadin, S. Harding, J. Mallela, R. Parkinson, J-W. Van Bochove, D. Lirman, J, Herlan, A. Baker, L. Collado and S.C. Isaac. 2008. Status of Coral Reef Resources of the Lesser Antilles: The French West Indies, The Netherlands Antilles, Anguilla, Antigua, Grenada, Trinidad and Tobago . In: Wilkinson, C. (ed.). Status of Coral Reefs of the World: 2008. Global Coral Reef Monitoring Network and Reef and Rainforest Research Center, Townsville, Australia. p265-280.

Box, S., and Bonilla Mejía. 2008. El estado de la conservación y explotación del Mero Nassau en la Costa Atlántica de Honduras June 2008, TNC Report, pp. 51

BREEF (Bahamas Reef Environment Educational Foundation). 1998. Fisheries Management Action Plan for the Bahamas. Report to the Bahamas Department of Fisheries. The Bahamas Reef Environment Educational Foundation and MacAlister Elliott and Partners Ltd.

Brown, V. 2007. The policymaking process and the politics of managing the Nassau grouper and other marine resources. *Proceedings of the Gulf and Caribbean Fisheries Institute*, **60:**605-606.

Brownell, W.N., and W.E. Rainey. 1971. Research and development of deep water commercial and sport fisheries around the Virgin Islands plateau. Virgin Islands Ecological Research Station Contrib. No. 3, 88 pp.

Bryant, D., L. Burke, J.W. McManus, and M. Spalding. 1998. Reefs at Risk: a Map-based Indicator of Potential Threats to the World’s Coral Reefs. World Resources Institute, Washington, D.C. 56 pp.

Buchan, K. 2000. The Bahamas. *Marine Pollution Bulletin*, **41(1-6):**94-111.

Buesa, R.J. 1987. Growth rate of tropical demersal fishes. *Marine Ecology Progress Series* **36:**191- 199.

Burnett-Herkes, J. 1975. Contribution to the biology of the red hind, *Epinephelus guttatus*, a commercially important serranid fish from the tropical western Atlantic. PhD dissertation, U. Miami, Coral Gables, 154 p.

Burnett-Herkes, James, and John A. Barnes. 1996. Banning the use of pots and other management introduced in Bermuda to protect declining reef fish stocks. *Proceedings of the Gulf and Caribbean Fisheries Institute*. **44:** 239-256.

Bush, P.G., Ebanks, G.C. and Lane, E.D. 1996. Validation of the ageing technique for the Nassau grouper (*Epinephelus striatus*) in the Cayman Islands, p. 150-158, *in:* F. Arreguin-Sanchez, J.L. Munro, M.C. Balgos, and D. Pauly (eds.) *Biology, fisheries and culture of tropical groupers and snappers*. ICLARM Conf. Proc. 48, 449pp.

Bush, P.G., D.E. Lane, G.C. Ebanks-Petrie, K. Luke, B. Johnson, C. McCoy, J. Bothwell, and, E. Parsons. 2006. The Nassau grouper spawning aggregation fishery of the Cayman Islands – an historical and management perspective. *Proceedings of the Gulf and Caribbean Fisheries Institute*, **57:**515-524.

Carcamo, R., Jr. 2008. National Report of the Nassau Grouper (*Epinephelus striatus*), Fishery of Belize. Belize Fisheries Department, Ministry of Agriculture & Fisheries, October 2008.

Carleton Ray G., M.G. McCormick-Ray, C.A. Layman, and B.R. Silliman. 2000. *Investigations of Nassau grouper breeding aggregations at High Cay, Andros: implication for a conservation strategy*. Final report. The Department of Fisheries, Ministry of Agriculture and Fisheries, Nassau, The Bahamas

Carter, J. 1986. Moonlight mating of the multitudes. *Animal Kingdom Magazine* **89(6):**63-71.

Carter, J. 1988. Grouper mating ritual on a Caribbean reef. *Underwater Naturalist* **17:**8-11.

Carter, J. 1989. Grouper sex in Belize. *Natural History*, Oct: 60- 69.

Carter, J., G.J. Marrow, and V. Pryor. 1994. Aspects of the ecology and reproduction of Nassau grouper, *Epinephelus striatus*, off the coast of Belize, Central America. *Proceedings of the Gulf and Caribbean Fisheries Institute,* **43:**65–111.

Cervigón, F. 1966. Los Peces Marinas de Venezuela. Vols. I and II. Fund. La Salle Cienc. Nat., 951 p.

Cervigón, F. 1994. *Los peces marinas de Venezuela, Fundacion Cientifica Los Roques,* C. Fundaci6n Cientifica las Roques (ed.), Caracas, Venezuela, 2nd edition Vol 3, 295 p.

CFMC (Caribbean Fishery Management Council). 1985. Fishery Management Plan, Final Environmental Impact Statement, and Draft Regulatory Impact Review, for the Shallow-water Reef Fish Fishery of Puerto Rico and the U.S. Virgin Islands, 104 pp.

CFMC (Caribbean Fishery Management Council). 1993. Amendment 2 to the Fishery Management Plan for the Shallow-water Reef Fish Fishery of Puerto Rico and the U.S. Virgin Islands. 29 pp.

CFMC (Caribbean Fishery Management Council). 1996. Regulatory Amendment to the Fishery Management Plan for the Reef Fish Fishery of Puerto Rico and the United States Virgin Islands Concerning Red Hind Spawning Aggregation Closures including a Regulatory Impact Review and an Environmental Assessment. August. http://www.caribbeanfmc.com/SCANNED%20FMPS/REEF-FISH%20FMP.htm

Cheung, W.W.L., Y. Sadovy, M.T. Braynen, and L.G. Gittens. 2013. Are the last remaining Nassau grouper (*Epinephelus striatus*) fisheries sustainable? The case in the Bahamas. *Endangered Species Research*, **20:**27-39.

Chiappone, M., R. Sluka, and K. Sullivan Sealey. 2000. Groupers (Pisces: Serranidae) in fished and protected areas of the Florida Keys, Bahamas and northern Caribbean. *Marine Ecology Progress Series,* **198:**261-272.

Clark, M.R., O.F. Anderson, R.I.C. Chris Francis, and D. M. Tracey. 2000. The effects of commercial exploitation on orange roughy (*Hoplostethus atlanticus*) from the continental slope of the Chatham Rise, New Zealand, from 1979 to 1997. *Fisheries Research*, **45:**217–238.

Claro, R. and K.C. Lindeman. 2003. Spawning aggregation sites of snapper and grouper species (Lutjanidae and Serranidae) on the insular shelf of Cuba. *Gulf and Caribbean Research* **14(2):**91-106.

Claro, R., García-Cagide, A., Sierra, L.M., García-Arteaga, J.P. 1990. Características biológico-pesqueras de la cherna criolla *Epinephelus striatus* (Bloch) (Pisces: Serranidae) en la plataforma cubana. *Cienc. Biol*. 23: 23–42.

Claro, R., K.C. Lindeman, and L.R. Parenti. 2002. *Ecology of the Marine Fishes of Cuba*. Washington, DC: Smithsonian Institution Press.

Claro R., J.A. Baisre, K.C. Lindeman, J.P. García-Arteaga. 2001. Cuban fisheries: historical trends and current status, p. 194-219, *in:* R. Claro, K.C. Lindeman, L.R. Parenti (eds.) *Ecology of the Marine Fishes of Cuba*. Smithsonian Institution Press, Washington, D.C. 253 pp.

Claro, R., Y. Sadovy de Mitcheson, K.C. Lindeman, A.R. García-Cagide. 2009. Historical analysis of Cuban commercial fishing effort and the effects of management interventions on important reef fishes from 1960–2005. *Fisheries Research* **99(1):**7-16

Claydon, J. 2004. Spawning aggregations of coral reef fishes: characteristics, hypothesis, threats and management.

Oceanography and Marine Biology: An annual review 2004: 42, 265-302.

Claydon, J.A.B., and A.M. Kroetz. 2007. The distribution of early juvenile groupers around South Caicos, Turks and Caicos Islands. *Proceedings of the Gulf and Caribbean Fisheries Institute*, **60:**345-350.

Claydon, J.A.B., M.C. Calosso, and S.E. Jacob. 2010. Large-scale deployment of discarded conch shells enhances juvenile habitat for spiny lobster, Nassau grouper and red hind. *Proceedings of the Gulf and Caribbean Fisheries Institute*, **63:**457-461.

Coleman, F.C., W.F. Figueira, J.S. Ueland, and L.B. Crowder. 2004. The impact of United States recreational fisheries on marine fish populations. *Science* **305:**1958-1960.

Coleman, F.C., and C.C. Koenig. 2010. The effects of fishing, climate change, and other anthropogenic disturbances on red grouper and other reef fishes in the Gulf of Mexico. Integrative and Comparative Biology 50(2): 201-212.

Colin P.L. 1992. Reproduction of the Nassau grouper, *Epinephelus striatus* (Pisces: Serranidae) and its relationship to environmental conditions. *Environmental Biology of Fishes*, **34:**357-377.

Colin, P.L., W.A. Laroche, and E.B. Brothers. 1997. Ingress and settlement in the Nassau grouper, *Epinephelus striatus* (Pisces: Serranidae), with relationship to spawning occurrence. *Bulletin of Marine Science*, **60(3):**656-667.

Colin, P.L., D.Y. Shapiro, and D. Weiler. 1987. Preliminary investigations of reproduction of two species of groupers. *Epinephelus guttatus* and *E. striatus* in the West Indies. *Bulletin of Marine Science*, **40:**220-230.

Collette, B. B., and F. H. Talbot. 1972. Activity patterns of coral reef fishes with emphasis on nocturnal-diurnal changeover p. 98-124, *in* B. B. Collette and S. A. Earle (eds.), Results of the Tektite Program: ecology of coral reef fishes. *Bulletin of Natural History of the Museum of Los Angeles County* 14.

Cooke, S.J., and I.G. Cowx. 2006. Contrasting recreational and commercial fishing: searching for common issues to promote unified conservation of fisheries resources and aquatic environments. *Biological Conservation*, **128:**93-108.

Cornish, A., and A.-M. Eklund. 2003. *Epinephelus striatus*. In: IUCN 2012. IUCN Red List of Threatened Species. Version 2012.2. <www.iucnredlist.org>. Downloaded on 09 January 2013.

Craig, A.K. 1966. Geography of fishing in British Honduras and adjacent coastal areas. Technical Report no. 28 Coastal Studies Institute Louisiana State University, Louisiana. Cont. No. 66-2. 143 pp. available on-line: ambergriscaye.com/pages/mayan/geographyoffishing.html, accessed April 2013.

Craig, A.K. 1968. The Grouper Fishery at Cay Glory, British Honduras. *Annals of the Association of American Geographers*, 59: 252-263.

Craig, M.T., and P.A. Hastings. 2007. A molecular phylogeny of the groupers of the subfamily Epinephelinae (Serranidae) with a revised classification of the Epinephelini. *Ichthyological Research,* **54(1):** 1-17.

Craig, M.T., Y.J. Sadovy de Mitcheson, and P.C. Heemstra. 2011. Groupers of the World: A Field and Market Guide. Grahamstown: NISC (Pty) Ltd. 424pp

Craig, M.T., D. Pondella, II, J.P.C Franckb, and J.C. Hafner. 2001. On the status of the serranid fish genus *Epinephelus*: evidence for paraphyly based upon 16S rDNA sequence. *Molecular Phylogenetics and Evolution,* **19(1):**121-130.

Cushion, N.M. and K. Sullivan-Sealey. 2007. Landings, effort and socio-economics of a small scale commercial fishery in the Bahamas. *Proceedings of the Gulf and Caribbean Fisheries Institute* **60:**162-166.

Dahlgren C.P. 1998. *Population dynamics of early juvenile Nassau grouper: an integrated modeling and field study*. Ph.D. dissertation. North Carolina State University. Raleigh, NC USA. 145 pp.

Dahlgren C.P., and D.B. Eggleston. 2000. Ecological Processes Underlying Ontogenetic Habitat Shifts in a Coral Reef Fish. *Ecology* **81(8):**2227-2240.

Dahlgren C.P., and D.B. Eggleston. 2001. Spatio-temporal variability in abundance, size and microhabitat associations of early juvenile Nassau grouper *Epinephelus striatus* in an off-reef nursery system. *Marine Ecology Progress Series*, **217:**145-156.

Dahlgren et al, [in prep]

Department of Marine Resources. 2007. The Bahamas. April 2007. Briefing Documents, 55pp.

DNER (Puerto Rico Department of Natural and Environmental Resources). 2004. Puerto Rico Fishing Regulations. Nº6768. Supplementary Flier. http://www.drna.gobierno.pr/

DPNR (Division of Planning and Natural Resources, US Virgin Islands). 2005. Commercial & Recreational Fisher's Information Booklet. Department of Planning and Natural Resources, Division of Fish & Wildlife and Division of Environmental Enforcement. July 2005. http://www.vifishandwildlife.com.

Domeier, M.L., and P.L. Colin. 1997. Tropical reef fish spawning aggregations defined and reviewed. *Bulletin of Marine Science*, **60(3):**698-726.

Eggleston D.B. 1995. Recruitment in Nassau grouper *Epinephelus striatus*: post-settlement abundance, microhabitat features and ontogenetic habitat shifts. *Marine Ecology Progress Series*, **124:**9-22.

Eggleston, D.B., J.J. Grover, and R.N. Lipcius. 1998. Ontogenetic diet shifts in Nassau grouper: trophic linkages and predatory impact. *Bulletin of Marine Science*, **63(1):**111-126.

Ehrhardt, N.M., and V.K.W. Deleveaux. 2007. The Bahamas' Nassau grouper (*Epinephelus striatus*) fishery - two assessment methods applied to a data - deficient coastal population. *Fisheries Research*, **87:**17-27.

Ellis, S., G. Viala, and W.O. Watanabe. 1996. Growth and feed utilization of hatchery-reared juvenile Nassau grouper fed four practical diets. *Progressive Fish-Culturist*, **58(3):**67-172.

Ellis, S. C., W.O. Watanabe, and E.P. Ellis. 1997a. Temperature effects on feed utilization and growth of post-settlement stage Nassau grouper. *Transactions of the American Fisheries Society*, **126(2):**309- 315.

Ellis, E. P., W.O. Watanabe, S.C. Ellis, J. Ginoza, and A. Moriwake. 1997b. Effects of turbulence, salinity, and light intensity on hatching rate and survival of larval Nassau grouper, *Epinephelus striatus*. *Journal of Applied Aquaculture*, **7(3):**33-43.

Erdman, D.S. 1976. Spawning patterns of fishes from the northeastern Caribbean. Contrib. Agric. Pesq., Dept. Agric. Commonwealth of Puerto Rico, 8:1-37.

Evermann, B.W. 1900. *Fishes and Fisheries of Porto Rico*. U.S. Commission on Fish and Fisheries, 350 p.

FAO. 2009. National Fishery Sector Overview. The Commonwealth of the Bahamas. Fishery and Aquaculture Country Profiles, FAO, FID/CP/BHS May 2009; 8 pp.

Fine, J.C. 1990. Groupers in Love: Spawning aggregations of Nassau groupers in Honduras. *Sea Frontiers*, p 42-45.

Fine J.C. 1992. Greedy for Groupers. *Wildlife Conservation*. May/June 1992:1-5.

Foley, K.A., C. Caldow, E. Hickerson. 2007. *Gulf of Mexico Science*. First confirmed record of Nassau grouper *Epinephelus striatus* (Pisces: Serranidae) in the Flower Garden Banks National Marine Sanctuary. Pp. 162-165.

Froese, R. and D. Pauly. 2010. Fishbase. www.fishbase.org.

Garcia-Moliner, G., and Y. Sadovy. 2008. The case for regional management of the Nassau grouper, *Epinephelus striatus*. *Proceedings of the Gulf and Caribbean Fisheries Institute*, **60:**576-602.

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

Gascoigne, J. 2002. *Nassau Grouper and Queen Conch in the Bahamas. Status and Management Options*. MacAlister Elliott and Partners Lt. for The Bahamas Reef Environment Educational Foundation. BREEF. 44 pp.

Gibson, J., R.F. Pott, G. Paz, I. Majil, N. Requena. 2007. Experiences of the Belize spawning aggregation working group. *Proceedings of the Gulf and Caribbean Fisheries Institute*, **59:**455-462.

Gibson, J. 2008. Managing a Nassau Grouper Fishery – A Case Study from Belize. *Proceedings of the Gulf and Caribbean Fisheries Institute*, **60:**603-604.

GMFMC (Gulf of Mexico Fishery Management Council). 1989. Amendment Number 1 to the Fishery Management Plan for the Reef Fish Fishery of the Gulf of Mexico. Tampa, Florida. 356 p.

Goodyear, C. P. 1993. Spawning stock biomass per recruit in fisheries management: foundation and current use, p. 67- 81, *in:* S.J. Smith, J.J. Hunt, and D. Rivard (eds.), Risk evaluation and biological reference points for fisheries management, Can. Spec. Publ. Fish. Aquat. Sci. 120.

Goreau, T.J. 1992. Bleaching and reef community change in Jamaica: 1851-1991. *American Zoologist*, **32:**683-695.

Greenwood, C.B. 1991. Distribution and feeding habits of larval Epinepheline groupers in Exuma Sound, Bahamas. MS thesis, Florida Institute of Technology, Melbourne, FL, 61 pp.

Grover, J.J. 1993. Trophic ecology of pelagic early-juvenile Nassau grouper, *Epinephelus striatus*, during an early phase of recruitment into demersal habitats. *Bulletin of Marine Science*, **53:**1117-1125.

Grover, J.J. 1994. Feeding habits of early-juvenile Nassau grouper. *Bahamas Journal of Science* **2(1):**22-26.

Grover, J.J., D.B. Eggleston, and J.M. Shenker. 1998. Transition from pelagic to demersal phase in early-juvenile Nassau grouper, *Epinephelus striatus*: Pigmentation, squamation, and ontogeny of diet. *Bulletin of Marine Science*, **62(1):**97-113.

Guitart-Manday, D., and F. Juárez-Fernandez. 1966. Desarrollo embrionario y primeros estudios larvales de la cherna criolla, *Epinephelus striatus* (Bloch) (Perciformes: Serranidae). Academia Ciencias de Cuba, Instituto de Oceanologica. La Habana **1:**35-45.

Gunter, G., and L. Knapp. 1951. Fishes, new, rare or seldom recorded from the Texas coast. *Texas Journal of Science*, **3(1):** 134-138.

Halstead, B.W. 1967. *Poisonous and Venomous Marine Animals of the World. Vol. 2- Vertebrates*. U.S. Govt. Printing Office, 1,070 pp.

Harvell, C.D., C.E. Mitchell, J.R. Ward, S. Altizer, A.P. Dobson, R.S. Ostfeld, and M.D. Samuel. 2002. Climate warming and disease risks for
terrestrial and marine biota. Science 296: 2158–2162.

Hateley, J.G. 2005. Preliminary results of a protein electrophoretic analysis of genetic variation, population structure and gene flow in the Nassau grouper, *Epinephelus striatus*. *Proceedings of the Gulf and Caribbean Fisheries Institute*. **47:**888-905.

Head, W. D., W.O. Watanabe, S.C. Ellis, and E.P. Ellis. 1996. Hormone-induced multiple spawning of captive Nassau grouper broodstock. *Progressive Fish-Culturist,* **58(1):**65-69.

Heemstra, P.C., and J.E. Randall. 1993. FAO species catalogue. Vol. 16. Groupers of the world (Family Serranidae, Subfamily Epinephelinae). An annotated and illustrated catalogue of the grouper, rockcod, hind, coral grouper and lyretail species known to date. FAO Fisheries Synopsis. No. 125, Vol. 16. Rome, FAO.

Heppell, S.A., B.X. Semmens, C.V. Pattengill-Semmens, P.G. Bush, B.C. Johnson, C.M. McCoy, J. Gibb, and S.S. Heppell. 2011. Oceanographic patterns associated with Nassau grouper aggregation spawn timing: shifts in surface currents on the nights of peak spawning. *Proceedings of the Gulf and Caribbean Fisheries Institute* 63: 152-154.

Heppell, S.A., B.X. Semmens, S.K. Archer, C.V. Pattengill-Semmens, P.G. Bush, C.M. McCoy, S.S. Heppell, and B.C. Johnson. 2012. Documenting recovery of a spawning aggregation through size frequency analysis from underwater laser calipers measurements. *Biological Conservation.* **155:**119-127.

Heyman, W., and L. Carr. 2007, Using acoustic tags to track fish movements at spawning aggregations in Belize. *Proceedings of the Gulf and Caribbean Fisheries Institute* **60:**651.

Heyman W., and N. Requena. 2002. Status of multi-species spawning aggregations in Belize. The Nature Conservancy, Punta Gorda (report)

Heyman, W., and B. Kjerfve. 2008. Characterization of transient multi-species reef fish spawning aggregations at Gladden Spit, Belize. *Bulletin of Marine Science*, **83(3):**531-551.

Heyman, W.D., and B. Wade. 2007. Status of reef fish spawning aggregations in Belize. *Proceedings of the Gulf and Caribbean Fisheries Institute*, **58:**286-291.

Hildebrand, H.H., H. Chavez, and H. Compton. 1964. Aporte al conocimiento de los peces del arrecife Alacranes, Yucatan (Mexico). *Ciencia* (Mex.) 23 **(3):**107-134.

Hinegardner, R., and D.E. Rosen. 1972. Cellular DNA content and the evolution of teleostean fishes. *American Naturalist*, **106:**621-644

Hodgson, G. and J. Liebeler. 2002. *The Global Coral Reef Crisis: Trends and Solutions*. Los Angeles: Reef Check Foundation.

Hoese, H. D., and R. H. Moore. 1998. Fishes of the Gulf of Mexico: Texas, Louisiana, and adjacent waters. Texas A&M Univ. Press, College Station. 422 pp.

Hooker, H.C.B. 2012. Los grandes serranidos de la Reserva de Biosfera Seaflower, Caribe Insular Colombiano: evaluacion de la pesca, abundancia relative y agregaciones reproductivas. Thesis Universidad Nacional de Colombia, CECIMAR, San Andrés, Colombia. Pages 152.

Horsford, I. 2009. The Grouper Fishery of Antigua and Barbuda. Report on Regional Workshop of Nassau Grouper, Cartagena, Colombia, 20-21 October 2008, revised January 2009, 12 pp.

Hughes, T.P. 1994. Catastrophes, phase-shifts, and large-scale degradation of a Caribbean coral reef. *Science* **265:**1547-1551.

Humann, P., and N. DeLoach. 2002. *Reef Fish Identification -- Florida-Caribbean-Bahamas* (3rd Edition). New World Publications, Inc. Jacksonville, Florida.

IUCN. 2003. 2003 IUCN Red List of Threatened Species. www.iucnredlist.org. Downloaded on 18 November 2003.

Johnson, D.G., and Keener, P. 1984. Aid to identification of American grouper larvae. *Bulletin of Marine Science*, **34(1):**106-134.

Jones, G.P., S. Planes, S.R. Thorrold. 2005. Coral reef fish larvae settle close to home." *Current Biology* **15(14):**1314-1318.

Jory, D.E., and E.S. Iversen. 1989. Species profiles: life histories and environmental requirements of coastal fishes and invertebrates (south Florida) -- black, red, and Nassau groupers. U.S. Fish Wildl. Serv. Biol. Rep. 82(11.110). U.S. Army Corps of Engineers, TR EL-82-4. 21 pp.

Kadison, E., R.S. Nemeth, J. Blondeau, T. Smith, and J. Calnan. 2010. Nassau grouper (*Epinephelus striatus*) in St. Thomas, US Virgin Islands, with evidence for a spawning aggregation site recovery. *Proceedings of the Gulf and Caribbean Fisheries Institute*, **62:**273-279.

Kaufman, L., and E. Romero. 2011. Fisheries based on Belizean biodiversity: why they're so vulnerable to offshore oil, p. 135-141, *in:* M.L.D. Palomares and D. Pauly (eds.), *Too Precious to Drill: the Marine Biodiversity of Belize*. Fisheries Centre Research Reports 19(6). Fisheries Centre, University of British Columbia [ISSN 1198-6727].

Kelley, C.D., A. Moriwake, G. Miyamoto, V. Nicol, and W. Watanabe. 1994. The use of LHRH-a for induced spawning of five different species of marine teleost fishes. Abstract for World Aquaculture '94. World Aquaculture Society. New Orleans. LA. January 14-18, 1994. 147 p.

Kellison, T., S. Heppell, B. Semmens, N. Ehrhardt, I. Zink. 2009. Review of Databases Available and Trends in Abundance Relating to Nassau Grouper *Epinephelus striatus* in United States and U.S. Territorial Waters Including Recommendations for a Formal Status Review. Workgroup Report. 14 pp.

Kendall, A.W., Jr. 1979. Morphological comparisons of North American sea bass larvae (Pisces: Serranidae) NOAA Tech. Rep. NMFS Circ. 428, 50 p.

Kendall, A.W., Jr, and M.P. Fahay. 1979. Larva of the serranid fish *Gonioplectrus hispanus* with comments on its relationships. *Bulletin of Marine Science*, **29:**117-121.

Kobara, S. 2009. Regional Analysis of Seafloor Characteristics at Reef Fish Spawning Aggregation Sites in the Caribbean. Ph.D. Dissertation, Texas A&M University (Geography).

Kobara, S. and Heyman, W.D. 2007. Comparative geomorphic analysis of Nassau grouper spawning aggregation sites in Belize and the Cayman Islands. *Proceedings of the Gulf and Caribbean Fisheries Institute*, **60:**573-576.

Kobara, S. and Heyman, W.D. 2010. Sea bottom geomorphology of multi-species spawning aggregation sites in Belize. *Marine Ecology Progress Series*, **405:**243-254.

Koslow, J.A., F. Hanley, and R. Wicklund. 1988. Effects of fishing on reef fish communities at Pedro Bank and Port Royal Cays, Jamaica. *Marine Ecology Progress Series* **43:**201-212.

Koslow, J. A., K. Aiken, S. Auil, and A. Clementson. 1994. Catch and effort analysis of the reef fisheries of Jamaica and Belize. *Fishery Bulletin* **92:**737-747.

Koslow, J. A., G.W. Boehlert, J.D.M. Gordon, R.L. Haedrich, P. Lorance, and N. Parin. 2000. Continental slope and deep-sea fisheries: implications for a fragile ecosystem. *ICES Journal of Marine Science*, **57:**548–557.

Kramer, P. 2003. Synthesis of coral reef health indicators for the western Atlantic: results of the AGRRA Programme (1997–2000). *Atoll Research Bulletin,* **496:**1–58.

La Gorce, J. Oliver (ed.). 1939. *The Book of Fishes*. National Geographic Society, Washington, D.C., 367 p.

Landsman, S.J., C. Jadot, M. Ashley, and J.A.B. Claydon. 2009. Investigation of the Nassau grouper (*Epinephelus striatus*) fishery in the Turks and Caicos Islands: implications for conservation and management. *Proceedings of the Gulf and Caribbean Fisheries Institute*, **61:**82-89.

Leis, J.M.1986. Larval development in four species of Indo-Pacific coral trout *Plectropomus* (Pisces: Serranidae: Epinephelinae) with an analysis of the relationships of the genus. *Bulletin Marine Science*, **38(3):**525-552.

Leis, J.M.1987. Review of the early life history of tropical groupers (Serranidae) and snappers (Lutjanidae), p. 189-238, *in:* J.J. Polivina and S. Ralston (eds.), *Tropical Snappers and Groupers: Biology and Fisheries Management*. Westview Press. Boulder.

Longley, W.H. 1917. Studies upon the biological significance of animal coloration. I. The colors and color changes of West Indian reef fishes. *Journal of Experimental Zoology*, **23(3):**533-601.

Luckhurst, B.E. 1996. Trends in commercial fishery landings of groupers and snappers in Bermuda from 1975 to 1992 and associated fishery management issues, p 286-297, *in:* F. Arregun-Sanchez, J.L. Munro, M.C. Balgos, and D. Pauly (eds.). *Biology, Fisheries and Culture of Tropical Groupers and Snappers*, ICLARM No. 48, 449 pp.

Luckhurst, B.E. 2003. Development of a Caribbean regional conservation strategy for reef fish spawning aggregations*. Proceedings of the Gulf and Caribbean Fisheries Institute*, **54:**668-678.

Luckhurst, B.E. 2004. Current status of conservation and management of reef fish spawning aggregations in the Greater Caribbean. *Proceedings of the Gulf and Caribbean Fisheries Institute*, **55:**530-542.

Luckhurst, B.E. 2005. Evaluation of fisheries management and conservation measures taken to protect grouper spawning aggregations in the wider Caribbean: Case studies of Bermuda, Belize and Cayman Islands. *Proceedings of the Gulf and Caribbean Fisheries Institute*, **58:**268-269.

Luckhurst, B.E., and J.A. Ward. 1996. Analysis of trends in Bermuda's Fishery Statistical Database from 1975 to 1990, with reference to fishery management measures implemented during this period. *Proceedings of the Gulf and Caribbean Fisheries Institute*, **44:**306-324.

Mahon, R. 1990. *Fishery Management Options for Lesser Antilles Countries (Antigua and Barbuda, Barbados, Dominica, Granada, St. Kitts and Nevis, St. Lucia, St. Vincent and the Grenadines).* FAO Tech. Pap. 313. FAO, Rome.

Mahon, R. 1993. Lesser Antilles. Part I, p. 1-98*, in: Marine Fishery Resources of the Antilles: Lesser Antilles, Puerto Rico and Hispaniola, Jamaica, Cuba*. FAO Tech. Pap. 326, 235 pp.

Maljković, A., T.E. van Leeuwen, and S.N. Cove 2008. Reef Sites: Predation on the invasive red lionfish, *Pterois volitans* (Pisces: Scorpaenidae), by native groupers in the Bahamas. *Coral Reefs,* **27:**501

Manter, H. W. 1947. The digenetic trematodes of marine fishes of Tortugas, Florida. *American Midland Naturalist*, **38(2):**257-416.

Marcogliese, DJ. 2001. Implications of climate change for parasitism of animals in the aquatic environment. Canadian Journal of Zoology 79(8): 1331-1352.

Matos-Caraballo, D. 2008. Lessons learned from Puerto Rico's commercial fishery 1988-2008. *Proceedings of the Gulf and Caribbean Fisheries Institute,* **61:**123-129.

McClanahan, T., N. Polunin, and T. Done. 2002. Ecological states and the resilience of coral reefs. *Conservation Ecology* **6(2):**18.

Medina-Quej, A., A.R. Herrera-Pavon, G.Poot-Lopez, E. Sosa-Cordero, K. Bolio-Moguel, and W. Hadad. 2004. A preliminary survey of the Nassau grouper *Epinephelus striatus* spawning aggregation at "El Blanquizal" in the south coast of Quintana Roo, Mexico. *Proceedings of the Gulf and Caribbean Fisheries Institute,* **55:**557-569.

Mora, C., and P.F. Sale. 2002. Are populations of coral reef fish open or closed? *Trends in Ecology & Evolution* **17(9):** 422-428.

Morris, J.A., and J.L. Akins. 2009. Feeding ecology of invasive lionfish (*Pterois volitans*) in the Bahamian archipelago. *Environmental Biology of Fishes,* **86:**389-398.

Moura, R.L. 2001. Serranidae. *In:* P.A. Buckup and N.A. Menezes (eds). Catálogo das Especies de Peixes Marinhos do Brasil. Museu de Zoologia Universidade de São Paulo

Mumby, P.J., A.R. Harborne, and D.R. Brumbaugh. 2011. Grouper as a natural biocontrol of invasive lionfish. *PLoS ONE* 6(6): e21510. doi:10.1371/journal.pone.0021510.

Mumby, P.J., C.P. Dahlgren, A.R. Harborne, C.V. Kappel, F. Micheli, D.R. Brumbaugh, K.E. Holmes, J.M. Mendes, K. Broad, J.N. Sanchirico, K. Buch, S. Box, R.W. Stoffle and A.B. Gill. 2006. Fishing, trophic cascades, and the process of grazing on coral reefs. *Science* **311:**98−101

Mumby, P.J., R.S. Steneck, A.J. Edwards, R. Ferrari, R. Coleman, A.R. Harborne, and J.P. Gibson. 2012. Fishing down a Caribbean food web relaxes trophic cascades. *Marine Ecology Progress Series* **445:**13-24.

Munday, P.L., G.PJones, M.S. Pratchett, A.J. Williams. 2008 Climate change and the future for coral reef fishes. *Fish and Fisheries*, **9(3):**261-285.

Munro, J.L. 1983a. Chapter 1: Coral reef fish and fisheries of the Caribbean Sea, p. 1-9, *in,* J.L. Munro (ed.), Caribbean Coral Reef Fishery Resources: ICLARM Studies and Reviews, Vol. 7. International Center for Living and Aquatic Resources Management, Manila, Philippines. Contrib. 125. 2nd ed., 276 p.

Munro, J.L. 1983b. Chapter 4: The composition and magnitude of line catches in Jamaican waters, p. 26-32 *in:* J.L. Munro (ed.), Caribbean Coral Reef Fishery Resources: ICLARM Studies and Reviews, Vol. 7. International Center for Living and Aquatic Resources Management, Manila, Philippines. Contrib. 125. 2nd ed., 276 p.

Munro, J.L. 1983c. Chapter 5: The composition and magnitude of trap catches in Jamaican waters, p. 33-49, *in:* J.L. Munro (ed.), Caribbean Coral Reef Fishery Resources: ICLARM Studies and Reviews, Vol. 7.

International Center for Living and Aquatic Resources Management, Manila, Philippines. Contrib. 125. 2nd ed., 276 p.

Munro, J.L., and L. Blok. 2005. The status of stocks of groupers and hinds in the northeastern Caribbean. *Proceedings of the Gulf and Caribbean Fisheries Institute*, **56:** 283-294.

Munro, J.L., and R. Thompson. 1983. Chapter 2: The Jamaican fishing industry, p. 10-14, *in:* J.L. Munro (ed.), Caribbean Coral Reef Fishery Resources: ICLARM Studies and Reviews, Vol. 7. International Center for Living and Aquatic Resources Management, Manila, Philippines. Contrib. 125, 2nd ed., 276 p.

Munro, J.L., V.C. Gaut, R. Thompson, and P.H. Reeson. 1973. The spawning seasons of Caribbean reef fishes. *Journal of Fish Biology*, **5:**69-84.

Musick, J.A., M.M. Harbin, S.A. Berkeley, G.H. Burgess, A.-M. Eklund, L. Findley, R.G. Gilmore, J.T. Golden, D.S. Ha, G.R. Huntsman, J.C. McGovern, S.J. Parker, S.G. Poss, E. Sala, T.W. Scmidt, G.R. Sedberry, H. Weeks, and S.G. Wright. 2000. Marine, estuarine and diadromous fish stocks at risk of extinction in North America (Exclusive of Pacific Salmonids). *Fisheries*, **25(11):**6-30.

Nadeau, D.A., and D.B. Eggleston. 1996. Determinants of Nassau grouper recruitment success in macroalgae versus seagrass (Abstract). 24th Annual Benthic Ecology Meeting, Colombia, SC (USA), 7- 10 Mar. 1996, p. 62.

Nagelkerken, W.P. 1981. Distribution and ecology of the groupers (Serranidae) and snappers (Lutjanidae) of the Netherlands Antilles. Found. Scientif. Research Surinam and the Netherland Antilles, 107, 71 pp.

Nagelkerken, W.P. 1982. Distribution of the groupers and snappers of the Netherlands Antilles. *Proceedings of the International Coral Reef Symposium.* Manila, 1981, **4(2):**479-484.

Nemeth, R.S. 2005. Population characteristics of a recovering US Virgin Islands red hind spawning aggregation following protection. *Marine Ecology Progress Series*, **286:**81-97.

Nemeth, R.S. 2012. Chapter 2. Ecosystem aspects of species that aggregate to spawn, p. 21-55, *in:* Y. Sadovy de Mitcheson and P.L. Colin (eds.) *Reef Fish Spawning Aggregations: Biology, Research, and Management*, Fish & Fisheries Series 35. Springer Science, pp. 644.

Nemeth, R.S., E. Kadison, and J. Blondeau. 2009. Defining marine protected areas for yellowfin and Nassau grouper spawning aggregation sites. *Proceedings of the Gulf and Caribbean Fisheries Institute*, **61:**329-330.

Nemeth, R.S., B. Legare, K. Maize, and S. Hitt. (in prep) Habitat preferences, home range, activity patterns and ontogenetic movements of juvenile Nassau grouper (*Epinephelus striatus*) in the United States Virgin Islands.

Nemeth, R.S., E. Kadison, S. Herzlieb, J. Blondeau, and E.A. Whiteman. 2006. Status of a yellowfin (*Mycteroperca venenosa*) grouper spawning aggregation in the US Virgin Islands with notes on other species. *Proceedings of the Gulf and Caribbean Fisheries Institute*, **57:**543-558.

Nichols, J.T. 1929. Scientific survey of Puerto Rico, and the Virgin Islands: Vol. X, Part 2, Branchiostomidae to Sciaenidae. New York Academy of Sciences. N.Y., USA.

O'Connor, A. 2002. New Help for Nassau Grouper, a Sitting Duck Facing Extinction. The New York Times, 3 December 2002.

Olsen, D.A. and J.A. LaPlace. 1979. A study of the Virgin Island grouper fishery based on breeding aggregations. *Proceedings of the Gulf and Caribbean Fisheries Institute*, **31:**130-144.

Overstreet, R. M. 1969. Digenetic trematodes of marine teleost fishes from Biscayne Bay, Florida. *Tulane Studies in Zoology and Botany*, **15(4):**119-175.

Patengill-Semmens, C.V. and B.X. Semmens. 2003. The status of reef fishes in the Cayman Islands (BWI). Status of coral reefs in the Western Atlantic: Results of initial survey, Atlantic Gulf Rapid Reef Assessment (AGRRA) Program. *Atoll Research Bulletin*, **498:**226-247.

Patterson, H.M., S.R. Thorrold, and J.M. Shenker. 1999. Analysis of otolith chemistry in Nassau grouper (*Epinephelus striatus*) from the Bahamas and Belize using solution-based ICP-MS. *Coral Reefs*, **18:**171-178.

Paz, G. and Grimshaw, T. 2001a. Status report on Nassau groupers for Belize, central America. Scientific report of the Green Reef Environmental Institute. San Pedro Town, Ambergris Caye, Belize

Paz, G. and Grimshaw, T. 2001b. Status Report on Nassau Grouper Aggregations in Belize, Central America. *Proceedings of the First National Workshop on the Status of Nassau Groupers in Belize: Working Towards Sustainable Management*, at Belize City, 30 July 2001, Green Reef Environmental Institute pp.27-36.

Paz, G.E., and T. Grimshaw. 2001c. Life History Characteristics & Management Recommendations for the Nassau Grouper Population in Belize. Report by Green Reef Environmental Institute. (UNEP/GEF Grant No. BZE 98 G52-PRO 03)

Paz, G., and E. Truly. 2007. The Nassau grouper spawning aggregation at Caye Glory, Belize: A brief history. A case study by The Nature Conservancy, Mesoamerican Reef Program. 64pp.

PDT (Plan Development Team). 1990a. South Atlantic reef fish: Plan Development Team report to the South Atlantic Fishery Management Council, 527 p.

PDT (Plan Development Team). 1990b. The potential of marine fishery reserves for reef fish management in the U.S. southern Atlantic. NOAA. NMFS, Coastal Resources Division, Contr. No. CRD/89-90/04. 41 pp.

Perkins. J.S. 1983. The Belize Barrier Reef Ecosystem: An assessment of its resources, conservation status and management. New York Zoological Society Report, 148 p.

Pittman, S.J., S.D. Hile, C.F.G. Jeffrey, C. Caldow, M.S. Kendall, M.E. Monaco, and Z. Hillis-Starr. 2008. Fish Assemblages and Benthic Habitats of Buck Island Reef National Monument (St. Croix, U.S. Virgin Islands) and the Surrounding Seascape: A Characterization of Spatial and Temporal Patterns. NOAA Technical Memorandum NOS NCCOS 71. Silver Spring, MD. 96pp.

Polovina, J.J. and S. Ralston (eds). 1987. *Tropical Snappers and Groupers: Biology and Fisheries Management*. pp. 561-603. Westview Press, Boulder, CO.

Polunin, N.V.C., and C.M. Roberts. 1993. Greater biomass and value of target coral reef fishes in two small Caribbean marine reserves. *Marine Ecology Progress Series*, **100:**167-176.

Powell, A.B., and J.W. Tucker Jr. 1992. Egg and larval development of laboratory-reared Nassau grouper, *Epinephelus striatus* (Pisces: Serranidae). *Bulletin of Marine Science,* **50(1):**171-185.

Prada, M.C., G. Penaloza, S. Posada, N. Howard, P. Herron, L. Salinas, E. Castro, F. Cabezas, and H. Robinson. 2004. Fish spawning aggregations in the San Andres Archipelago, a first approximation. Final Report. Coralina and The Ocean Conservancy, 50 pp.

Radakov, D. V., A.D. Motchek, Y.N. Sbikin, R. Claro Madruga, and A. Silva Lee. 1975. Acerca de la longitud de los peces comerciales en capturas de la zona noroccidental de Cuba. Serie Oceanologica. No. 28. Academia de Ciencias de Cuba. Instituto de Oceanologia. Habana. Cuba, 9 pp.

Rand, P., C. Taylor, and D. Eggleston. 2005. A video method for quantifying size distribution, density and three-dimensional spatial structure of reef fish spawning aggregations. Emerging Technologies Abstracts. *Proceedings of the Gulf and Caribbean Fisheries Institute*, **56:**429-430.

Randall, J.E. 1962. Tagging reef fishes in the Virgin Islands. *Proceedings of the Gulf and Caribbean Fisheries Institute* **14:**201–241.

Randall, J.E. 1963. Additional recoveries of tagged reef fishes from the Virgin Islands. *Proceedings of the Gulf and Caribbean Fisheries Institute* **15:**155-157.

Randall, J.E. 1965. Food habits of the Nassau grouper (*Epinephelus striatus*). Assoc. Island Mar. Labs Carib. 6th Meeting. Jan. 1965:13- 16.

Randall, J.E. 1967. Food habits of reef fishes of the West Indies. Studies in Tropical Oceanography, Miami **5:**665–847.

Randall, J.E. 1983. Caribbean Reef Fishes. Second edition. T.F.H. Publications, Neptune City. NJ. 350 p.

Randall, J.E., and V.E. Brock. 1960. Observations on the ecology of epinepheline and lutjanid fishes of the Society Islands with emphasis on food habits. *Transactions of the American Fisheries Society*, **89(1):**9-16.

Ray G.C., M.G. McCormick-Ray, C.A. Layman, and B.R. Silliman. 2000. Investigations of Nassau Grouper Breeding Aggregations at High Cay, Andros: Implications for a Conservation Strategy. Report to the Department of Fisheries, Nassau, Bahamas.

Reed, C.T. 1941. Marine life in Texas waters. *Texas Academy Sci. Publ. Nat. Hist.* Vol. 2. 88 pp.

REEF. 2012. Reef Environmental Education Foundation Volunteer Survey Project Database. World Wide Web electronic publication. www.reef.org. date of download: December 2012.

Report of the Commission of Inquiry. 1991. Report of the Commission of Inquiry to examine and make recommendations for the future of the fishing industry and for the future protection of the marine environment in Bermuda. Government of Bermuda. February, 1991.

Richards, W.J., C.C. Baldwin, and A. Röpke. 2006. Chapter 119. Serranidae: Sea basses, p. 1225-1332 *in:* W.J. Richards (ed.), *Early Stages of Atlantic Fishes: An Identification Guide for the Western Central North Atlantic*, Vol. I. CRC Press, Boca Raton, FL, 1335 p.

Roberts, C.M., and N.V.C. Polunin. 1991. Are marine reserves effective in management of reef fisheries? *Reviews in Fish Biology and Fisheries* **1:**65-91.

Roberts, C.M., N. Quinn, J.W. Tucker Jr., and P.N. Woodward. 1995. Introduction of hatchery-reared Nassau grouper to a coral reef environment. *North American Journal of Fisheries Management*, **15(1):**159-164.

Rogers, C.S., and J. Beets. 2001. Degradation of marine ecosystems and decline of fishery resources in marine protected areas in the US Virgin Islands. *Environmental Conservation*, **28(4):**312-322.

Rudd, M.A. 2003a. Institutional analysis of marine reserves and fisheries governance policy experiments: a case study of Nassau grouper conservation in the Turks and Caicos Islands. Ph.D. thesis. Wageningen University, The Netherlands, 276pp.

Rudd, M. A. 2003b. Fisheries Landings and Trade of the Turks and Caicos Islands. *Fisheries Centre Research Reports* (2003), **11(6):**149-161.

Rudd, M.A. 2004. The effects of seafood import tariffs on market demand of Nassau grouper in the Turks and Caicos Islands. *Proceedings of the Gulf and Caribbean Fisheries Institute,* **55:**179-190.

Rudd, M.A. and M.H. Tupper. 2002. The impact of Nassau grouper size and abundance on scuba diver site selection and MPA economics. *Coastal Management,* **30:**133-151.

Sadovy Y. 1993. The Nassau grouper, endangered or just unlucky? *Reef Encounters* June 10–12.

Sadovy Y. 1994. Grouper stocks of the western central Atlantic: the need for management and management needs. *Proceedings of the Gulf and Caribbean Fisheries Institute*, **43:**43-64.

Sadovy, Y. 1996. Reproduction in reef fishery species, pp. 15-59 *in,* N. V. C. Polunin & C.M. Roberts (eds.). *Reef Fisheries* London: Chapman & Hall. 477 pp.

Sadovy, Y. 1997. The case of the disappearing grouper: *Epinephelus striatus*, the Nassau grouper in the Caribbean and western Atlantic. *Proceedings of the Gulf and Caribbean Fisheries Institute* **45:**5-22

Sadovy, Y. 2001. The threat of fishing to highly fecund fishes. *Journal of Fish Biology*, **59:**90-108.

Sadovy Y, and P.L. Colin. 1995. Sexual development and sexuality in the Nassau grouper, *Epinephelus striatus* (Bloch) (Pisces: Serranidae). *Journal of Fish Biology* **46:**961–976

Sadovy, Y., and M. Domeier. 2005. Are aggregation-fisheries sustainable? Reef fish fisheries as a case study. *Coral Reefs***, 24:**254–262.

Sadovy, Y. and Eklund, A.-M. 1999. *Synopsis of biological information on the Nassau Grouper, Epinephelus striatus (Bloch, 1792), and the Jewfish, E. itajara (Lichtenstein, 1822).* NOAA Technical Report NMFS 146. Technical Report of the *Fishery Bulletin*. FAO Fisheries Synopsis 157. US Department of Commerce, Seattle, WA USA, 65 pp.

Sadovy, Y., and M. Figuerola. 1992. The status of the red hind fishery in Puerto Rico and St. Thomas as determined by yield-per-recruit analysis. *Proceedings of the Gulf and Caribbean Fisheries Institute* **42:**23-38.

Sadovy, Y., and D.Y. Shapiro. 1987. Criteria for the diagnosis of hermaphroditism in fishes. *Copeia* **1987:**136-156.

Sadovy de Mitcheson, Y. 2009. Visit to the Bahamas regarding Nassau grouper, *Epinephelus striatus*, 18-28 January 2009. Summary report February 2009 on visit 18-28 January. 8pp.

Sadovy de Mitcheson, Y. 2012. Status Update: The Nassau Grouper, *Epinephelus striatus.* Final Report to the Caribbean Fishery Management Council. 70 pp.

Sadovy de Mitcheson, Y. and B. Erisman. 2012. Chapter 8. Fishery and biological implications of fishing spawning aggregations, and the social and economic importance of aggregating fishes, p. 225-284 *in:* Y. Sadovy de Mitcheson and P.L. Colin (eds.), *Reef Fish Spawning Aggregations: Biology, Research and Management*, Fish & Fisheries Series 35, Springer, 644 pp.

Sadovy de Mitcheson, Y., S.A. Heppell, and P.L. Colin. 2012. Chapter 12.6, Nassau grouper – *Epinephelus striatus*, p. 429-445 *in:* Y. Sadovy de Mitcheson and P.L. Colin (eds.), *Reef Fish Spawning Aggregations: Biology, Research and Management*, Fish & Fisheries Series 35, Springer, 644 pp.

Sadovy de Mitcheson, Y., A. Cornish, M. Domeier, P. Colin, M. Russell, and K. Lindeman. 2008. A Global Baseline for Spawning Aggregations of Reef Fishes. *Conservation Biology* **22(5):**1233-1244.

SAFMC (South Atlantic Fishery Management Council). 1983. Fishery Management Plan, Regulatory Impact Review, and Final Environmental Impact Statement for the Snapper Grouper Fishery of the South Atlantic Region, 173 p.

SAFMC (South Atlantic Fishery Management Council). 1990. Amendment Number 2, Regulatory Impact Review, Regulatory Flexibility Analysis and Environmental Assessment for Fishery Management Plan for the Snapper Grouper Fishery of the South Atlantic Region, 47 pp.

Sala, E., and E. Ballesteros. 2000. *Conservation status and dynamics of the Glover's Reef, Belize, spawning aggregation*. *December 1999 - January 2000*. Scientific report to the Wildlife Conservation Society's Glover's Reef Marine Research Station, Belize, Central America.

Sala, E., E. Ballesteros, and R.M. Starr. 2001. Rapid decline of Nassau grouper spawning aggregations in Belize: fishery management and conservation needs. *Fisheries*, **26(10):**23-30.

Schärer, M., M. Nemeth, and R. Appeldoorn. 2007. Past exploitation and present distribution of Nassau grouper at Mona Island, Puerto Rico (poster and abstract). *Proceedings of the Gulf and Caribbean Fisheries Institute*, **60:** 675.

Schärer, M.T., T.J. Rowell, M.I. Nemeth, R.S. Appeldoorn. 2012. Sound production associated with reproductive behavior of Nassau grouper *Epinephelus striatus* at spawning aggregations. *Endangered Species Research*, **19:**29-38.

Schmitt, E.F., and K.M. Sullivan. 1994. Research applications of volunteer generated coral reef fish surveys. The Nature Conservancy and the University of Miami, Department of Biology Report. Coral Gables, Florida. 38 pp.

SCRFA (2003) SCRFA Newsletter Number 4. December 2003. Society for the Conservation of Reef Fish Aggregations. www.scrfa.org

Sedberry, G.R., D.E. Stevenson, and R.W. Chapman. 1996. Stock identification in potentially threatened species of grouper (Teleostei: Serranidae: Epinephelinae) in Atlantic and Caribbean Waters. Final Rep. MARFIN Grant No. NA47FF0012. South Carolina Dept. of Natural Resources, Marine Resources Research Institute. 51 pp.

Semmens, B.X., P. Bush, S. Heppell, B. Johnson, C. McCoy, C. Pattengill-Semmens. 2012. An *in situ* visual mark-recapture method to assess the abundance of spawners at an aggregation site. *Proceedings of the Gulf and Caribbean Fisheries Institute*, **64:**224-226.

Semmens, B.X., K.E. Luke, P.G. Bush, C. Pattengill-Semmens, B. Johnson, C. McCoy, and S. Heppell. 2007. Investigating the reproductive migration and spatial ecology of Nassau grouper (*Epinephelus striatus*) on Little Cayman Island using acoustic tags – an overview. *Proceedings of the Gulf and Caribbean Fisheries Institute*, **58:**191-198.

Semmens, B.X., P. Bush, S. Heppell, B. Johnson, C. McCoy, C. Pattengill-Semmens, and L. Whaylen. 2008a. Charting a course for Nassau grouper recovery in the Caribbean: what we've learned and what we still need to know. *Proceedings of the Gulf and Caribbean Fisheries Institute*, **60:**607-609.

Semmens, B.X., S. Heppell, P. Bush, B. Johnson, C. McCoy, C. Pattengill-Semmens, and L. Whaylen. 2008b. An intra- and inter-annual analysis of Nassau grouper size distributions from a recently protected spawning aggregation in the Cayman Islands. *Proceedings of the Gulf and Caribbean Fisheries Institute*, **60:**585-586.

Shapiro, D.Y. 1987. Reproduction in groupers, p. 295-327, *in*, J.J. Polovina and S. Ralston (eds.), *Tropical Snappers and Groupers: Biology and Fisheries Management*. Westview Press. Boulder, CO.

Shenker, J.M., E.D. Maddox, E. Wishinski, A. Pearl, S.R. Thorrold, and N. Smith. 1993. Onshore transport of settlement-stage Nassau grouper (*Epinephelus striatus*) and other fishes in Exuma Sound, Bahamas. *Marine Ecology Progress Series*, **98:**31-43.

Silva Lee, A.F. 1974. Hábitos alimentarios de la cherna criolla *Epinephelus striatus* Bloch y algunos datos sobre su biologia. *Serie Oceanologica Academia de Ciencias de Cuba* **25:**3-14.

Silva Lee, A.F. 1977. Nota sobre la coloración y la conducta de la cherna criolla (*Epinephelus striatus* Bloch). Academia de Ciencias de Cuba, Institute de Oceanologia, Informe Cientifico Tecnico No. 14, Cuba, 8 pp.

Sluka, R., M. Chiappone, K.M. Sullivan, and R. Wright. 1996. Habitat and Life in the Exuma Cays, the Bahamas: the status of groupers and coral reefs in the Northern Cays. The Nature Conservancy.

Sluka, R., M. Chiappone, K.M. Sullivan, T. Potts, J.M. Levy, E.F. Schmitt, and G. Meester. 1998. Density, species and size distribution of groupers (Serranidae) in three habitats at Elbow Reef, Florida Keys. *Bulletin Marine Science*, **62:**219-228.

Smith, C.L. 1961. Synopsis of biological data on groupers (Epinephelus and allied genera) of the western North Atlantic. FAO Fish. Biol. Synop. No. 23, 61 pp.

Smith, C.L. 1971. A revision of the American groupers: *Epinephelus* and allied genera. *Bulletin of the American Museum of Natural History.* **146:**69-241.

Smith, C. L. 1972. A spawning aggregation of Nassau grouper, *Epinephelus striatus* (Bloch). *Transactions of the American Fisheries Society,* **101:**257-261

Smith, C. L. 1978. Serranidae. *in:* W. Fischer (ed.), FAO Species Identification Sheets for Fishery Purposes, Western Central Atlantic, Fishing Area 31. Vols. IV, V. FAO, Rome. [Unpaginated].

Smith-Vaniz, W.F., B.B. Collette, and B.E. Luckhurst. 1999. *Fishes Of Bermuda: History, Zoogeography, Annotated Checklist, and Identification Keys*. American Society of Ichthyologists and Herpetologist Special Publication No. 4. *Reviews in Fish Biology and Fisheries*.

Sosa-Cordero E., A. Medina-Quej, R. Herrera, and W. Aguilar Dávila. 2002. Agregaciones reproductivas de peces en el Sistema Arrecifal Mesoamericano: Consultoría Nacional México. Informe preparado para el consultor internacional, Research Planning Inc. y Proyecto sam. Ecosur, Chetumal, Quintana Roo. 25 pp.

Springer, V.G., and A.J. McErlean. 1962. A study of the behavior of some tagged Southern Florida coral reef fishes. *American Midland Naturalist,* **67:**386-397.

Stallings, C.D. 2008. Indirect effects of an exploited predator on recruitment of coral-reef fishes. *Ecology*. 89(8).

Starck, W.A., II. 1968. A list of fishes of Alligator Reef, Florida with comments on the nature of the Florida reef fish fauna. *Undersea Biology*, **1:**5-36.

Starck, W.A., II, and W.P. Davis. 1966. Night habits of fishes at Alligator Reef, Florida. *Ichthyologica* **38(4):**313-356.

Starr, R.M., E. Sala, E. Ballesteros, and M. Zabala. 2007. Spatial dynamics of the Nassau grouper *Epinephelus striatus* in a Caribbean atoll. *Marine Ecology Progress Series*, **343:**239-249.

Stevenson, D.K. 1981. *A review of the marine resources of the Western Central Atlantic Fisheries Commission (WECAFC) Region*. FAO Fish. Tech. Pap. 211. FAO, Rome, 132 p.

Sullivan, K.M., and M. de Garine-Witchatitsky. 1994. Energetics of juvenile *Epinephelus* groupers: impact of summer temperatures and activity patterns on growth rates. *Proceedings of the Gulf and Caribbean Fisheries Institute,* **43:**148-167.

Sullivan-Sealey, K., T. Rahming, and M. Rolle. 2002. Size, sex ratio, and fecundity of Nassau grouper (*Epinephelus striatus*) landed during spawning season in the Central Bahamas. *Proceedings of the Gulf and Caribbean Fisheries Institute*, **53:**472-481.

Taylor, J. C., D.B. Eggleston, and P.S. Rand. 2006. Nassau grouper (*Epinephelus striatus*) spawning aggregations: hydroacoustic surveys and geostatistical analysis. In: Emerging Technologies For Reef Fisheries Research And Management. NOAA Professional Papers NMFS (5). NOAA, Seattle, WA, pp. 18-25

Thompson, E.F. 1945. *The Fisheries of British Honduras*. Development and Welfare in the West Indies, Advocate Co., Bridgetown, Barbados. Bull. **21:**1-32.

Thompson, R.W. 1978. Results of the UNDP /FAO Bahamas deep water fishery survey 1972-1975. *Proceedings of the Gulf and Caribbean Fisheries Institute,* **30:**44-70.

Thompson, R., and J.L. Munro. 1978. Aspects of the biology and ecology of Caribbean reef fishes: Serranidae (hinds and groupers). *Journal of Fish Biology,* **12:**115-146.

Thompson, R., and J.L. Munro. 1983. Chapter 7: The biology, ecology and bionomics of the hinds and groupers, Serranidae, p. 59-81, *in:* J.L. Munro (ed.), *Caribbean Coral Reef Fishery Resources.* ICLARM Studies and Reviews, Vol. 7. International Center for Living and Aquatic Resources Management, Manila, Philippines. Contrib. 125, 2nd ed., 276 p.

Townsend, C.H. 1905. Report of the director of the aquarium. Ninth Annual Report of the New York Zoological Society, Biology. **9:**89-103.

Tucker, J.W., Jr. 1992a. Spawning serranid fishes in captivity. In, *Aquaculture '92 -Growing towards the 21st Century*, p. 219.

Tucker, J.W., Jr. 1992b. Grouper culture for the Caribbean. Progress report. *Proceedings of the Gulf and Caribbean Fisheries Institute,* **41:**587.

Tucker, J.W., Jr. 1994. Spawning by captive serranid fishes: a review. *Journal of the World Aquaculture Society*, **25:**345-359.

Tucker, J.W., Jr., and P.N. Woodward. 1993. Nassau grouper aquaculture, p. 363-377, *in:* F. Arreguin-Sanchez, J. L. Munro, M.C. Balgos, and D. Pauly (eds.), *Biology, Fisheries, and Culture of Tropical Groupers and Snappers*, ICLARM Conf. Proc. 48, 449 p.

Tucker, J.W., Jr., and P.N. Woodward. 1994. Growth and development of domestic juvenile Nassau groupers. *Proceedings of the Gulf and Caribbean Fisheries Institute*, **43:**389-391.

Tucker, J.W., P.G. Bush, and S.T. Slaybaugh. 1993. Reproductive patterns of Cayman Islands Nassau grouper (*Epinephelus striatus*) populations. *Bulletin of Marine Science,* **52:**961–969.

Tucker, J.W., Jr., P.N. Woodward, and D.G. Sennet. 1996. Voluntary spawning of captive Nassau groupers *Epinephelus striatus* in a concrete raceway. *Journal of the World Aquaculture Society,* **27(4):**373-383.

Tucker, J.W., Jr., J.E. Parsons, G.C. Ebanks, and P.G. Bush. 1991. Induced spawning of Nassau grouper *Epinephelus striatus*. *Journal of the World Aquaculture Society*, **22:**187-191.

Tupper, M. 2002. Essential fish habitat and marine reserves for groupers in the Turks and Caicos Islands. *Proceedings of the Gulf Caribbean Fisheries Institute*, **53:**606-622.

Tupper, M.H. and Rudd, M.A. 2002. Species-specific impacts of a small marine reserve on reef fish production and fishing productivity in the Turks and Caicos Islands. *Environmental Conservation*, **29:**484-492.

L. Vásquez-Yeomans, U. Ordoñez-López and E. Sosa-Cordero. 1998. Fish larvae adjacent to a coral reef in the western Caribbean Sea off Mahahual, Mexico. *Bulletin of Marine Science*, **62(1):**229-245.

Vilaro Diaz, D.J. 1884. Corrida y arribazon de algunos peces cubanos. Manuel Gomez de la Maza, La Habana, Cuba

Watanabe, W.O., C.S. Lee, S.C. Ellis, and E.P. Ellis. 1995a. Hatchery study of the effects of temperature on eggs and yolksac larvae of the Nassau grouper *Epinephelus striatus*. *Aquaculture*, **136:**141- 147.

Watanabe, W.O., S.C. Ellis, E.P. Ellis, W.D. Head, C.D. Kelley, A. Moriwake, C-S Lee, and P.K. Bienfang. 1995b. Progress in controlled breeding of Nassau grouper (*Epinephelus striatus*) broodstock by hormone induction. *Aquaculture*, **138:**205-219.

Watanabe, W.O., S.C. Ellis, E.P. Ellis, Y.G. Lopez, P. Bass, J. Ginoza, and A. Moriwake. 1996. Evaluation of first-feeding regimens for larval Nassau grouper *Epinephelus striatus* and preliminary, pilot-scale culture through metamorphosis. *Journal of the World Aquaculture Society*, **27(3):**323-331.

Watanabe, W.O., C.S. Lee, S.C. Ellis, E.P. Ellis, W.D. Head, C.D. Kelley, G. Miyamoto, K. Liu, and J. Ginoza. 1994. Experimental culture of larval Nassau grouper (*E. striatus*): the effects of temperature on egg and yolksac stages and of prey quality on survival at first feeding. Abstract for World Aquaculture '94, p. 287. World Aquaculture Society. New Orleans, LA, Jan. 14- 18, 1994.

Wells, J.W. and J.C. Lang. 1973. Systematic list of Jamaican shallow-water scleractinia. *Bulletin of Marine Science*, **23:**55-58.

Whaylen, L., C.V. Pattengill-Semmens, B.X. Semmens, P.G. Bush, and M.R. Boardman. 2004. Observations of a Nassau grouper, *Epinephelus striatus*, spawning aggregation site in Little Cayman, Cayman Islands, including multi-species spawning information. *Environmental Biology of Fishes*, **70:**305-313.

Whaylen, L., P. Bush, B. Johnson, K. Luke, C. McCroy, S. Heppell, B. Semmens, M.R. Boardman. 2007. Aggregation dynamics and lessons learned from five years of monitoring at a Nassau grouper (*Epinephelus striatus*) spawning aggregation in Little Cayman, Cayman Islands, BWI. *Proceedings of the Gulf and Caribbean Fisheries Institute*, **59:**413–421

Wilcox, W.A. 1899. The fisheries and fish trade of Porto Rico, p. 27–48, *in:* Investigations of the aquatic resources and fisheries of Porto Rico. U.S. Commission of Fish and Fisheries.

Wing, E. S., and E.J. Reitz. 1982. Prehistoric fishing economies of the Caribbean. *Journal of New World Archaeology*, **5(2):**13-32.

Wing, E.S., C.A. Hoffman, Jr, and C.E. Ray. 1968. Vertebrate remains from Indian sites on Antigua, West Indies. *Caribbean Journal of Science*, **8(3&4):**123-139.

Woodley, J.D. 1995. *Tropical Americas Regional Report on the Issues and Activities Associated with Coral Reefs and Related Ecosystems*. Prepared for the 1995 International Coral Reef Initiative Workshop, Dumaguete

City, Philippines.

Woodley, J.D., K. De Meyer, P. Bush, G. Ebanks-Petrie, J. Garzon-Ferreira, E. Klein, L. Pors, and C. Wilson. 1998. Status of coral reefs in the south-central Caribbean. In: *Status of Coral Reefs of the World: 1998*. C. Wilkinson (ed.) Australian Institute of Marine Science.

United States of America

Nomination of the Nassau grouper (Epinephelus striatus) for inclusion in Annex III

Appendix B_FINAL Nassau grouper ESA rule also reduce, eliminate, or prevent unnecessary differences in regulatory requirements.

Similarly, the Trade Agreements Act of 1979 (Pub. L. 96–39), as amended by the Uruguay Round Agreements Act (Pub. L. 103–465), prohibits Federal agencies from establishing any standards or engaging in related activities that create unnecessary obstacles to the foreign commerce of the United States. For purposes of these requirements, Federal agencies may participate in the establishment of international standards, so long as the standards have a legitimate domestic objective, such as providing for safety, and do not operate to exclude imports that meet this objective. The statute also requires consideration of international standards and, where appropriate, that they be the basis for U.S. standards.

PHMSA participates in the establishment of international standards in order to protect the safety of the American public, and we have assessed the effects of the interim final rule to ensure that it does not cause unnecessary obstacles to foreign trade. Accordingly, this rulemaking is consistent with Executive Order 13609 and PHMSA's obligations.

List of Subjects

49 CFR Part 107

Administrative practices and procedure, Hazardous materials transportation, Packaging and containers, Penalties, Reporting and recordkeeping requirements.

49 CFR Part 171

General information, Regulations, and Definitions.

In consideration of the foregoing, 49 CFR Chapter I is amended as follows:

PART 107—HAZARDOUS MATERIALS PROGRAM PROCEDURES

■ 1. The authority citation for part 107 is revised to read as follows:

Authority: 49 U.S.C. 5101–5128, 44701; Pub. L. 101–410 section 4; Pub. L. 104–121, sections 212–213; Pub. L. 104–134, section 31001; Pub. L. 114–74 section 4 (28 U.S.C. 2461 note); 49 CFR 1.81 and 1.97.

■ 2. Revise § 107.329 to read as follows:

§ 107.329 Maximum penalties.

(a) A person who knowingly violates a requirement of the Federal hazardous material transportation law, an order issued thereunder, this subchapter, subchapter C of the chapter, or a special permit or approval issued under this subchapter applicable to the transportation of hazardous materials or the causing of them to be transported or shipped is liable for a civil penalty of not more than $77,114 for each violation, except the maximum civil penalty is $179,933 if the violation results in death, serious illness or severe injury to any person or substantial destruction of property. There is no minimum civil penalty, except for a minimum civil penalty of $463 for violations relating to training. When the violation is a continuing one, each day of the violation constitutes a separate offense.

(b) A person who knowingly violates a requirement of the Federal hazardous material transportation law, an order issued thereunder, this subchapter, subchapter C of the chapter, or a special permit or approval issued under this subchapter applicable to the design, manufacture, fabrication, inspection, marking, maintenance, reconditioning, repair or testing of a package, container, or packaging component which is represented, marked, certified, or sold by that person as qualified for use in the transportation of hazardous materials in commerce is liable for a civil penalty of not more than $77,114 for each violation, except the maximum civil penalty is $179,933 if the violation results in death, serious illness or severe injury to any person or substantial destruction of property. There is no minimum civil penalty, except for a minimum civil penalty of $463 for violations relating to training.

■ 3. In Appendix A to subpart D of part 107, Section II.B. (''Penalty Increases for Multiple Counts''), the first sentence of the second paragraph is revised to read as follows:

Appendix A to Subpart D of Part 107—Guidelines for Civil Penalties

* * * * *

Under the Federal hazmat law, 49 U.S.C. 5123(a), each violation of the HMR and each day of a continuing violation (except for violations relating to packaging manufacture or qualification) is subject to a civil penalty of up to $77,114 or $179,933 for a violation occurring on or after August 1, 2016.

* * * * *

PART 171—GENERAL INFORMATION, REGULATIONS, AND DEFINITIONS

■ 4. The authority citation for part 171 is revised to read as follows:

Authority: 49 U.S.C. 5101–5128, 44701; Pub. L. 101–410 section 4; Pub. L. 104–134, section 31001; Pub. L. 114–74 section 4 (28 U.S.C. 2461 note); 49 CFR 1.81 and 1.97.

■ 5. In § 171.1, paragraph (g) is revised to read as follows:

§ 171.1 Applicability of Hazardous Materials Regulations (HMR) to persons and functions.

* * * * *

(g) *Penalties for noncompliance.* Each person who knowingly violates a requirement of the Federal hazardous material transportation law, an order issued under Federal hazardous material transportation law, subchapter A of this chapter, or a special permit or approval issued under subchapter A or C of this chapter is liable for a civil penalty of not more than $77,114 for each violation, except the maximum civil penalty is $179,933 if the violation results in death, serious illness or severe injury to any person or substantial destruction of property. There is no minimum civil penalty, except for a minimum civil penalty of $463 for a violation relating to training.

Issued in Washington, DC, on June 14, 2016 under authority delegated in 49 CFR part 1.97.

Marie Therese Dominguez,

Administrator, Pipeline and Hazardous Materials Safety Administration.

[FR Doc. 2016–15404 Filed 6–28–16; 8:45 am]

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DEPARTMENT OF COMMERCE

National Oceanic and Atmospheric Administration

50 CFR Part 223

[Docket No. 1206013326–6497–03]

RIN 0648–XA984

Endangered and Threatened Wildlife and Plants: Final Listing Determination on the Proposal To List the Nassau Grouper as Threatened Under the Endangered Species Act

AGENCY: National Marine Fisheries Service (NMFS), National Oceanic and Atmospheric Administration (NOAA), Commerce.

ACTION: Final rule; request for information.

SUMMARY: We, NMFS, are publishing this final rule to implement our determination to list the Nassau grouper (*Epinephelus striatus*) as threatened under the Endangered Species Act of 1973, as amended (ESA). We have completed a status review of the Nassau grouper in response to a petition submitted by WildEarth Guardians. After reviewing the best scientific and commercial data available, including the status review and comments received on the proposed rule, we have determined that the Nassau grouper

meets the definition of a threatened species. While the species still occupies its historical range, overutilization through historical harvest has reduced the number of individuals which in turn has reduced the number and size of spawning aggregations. Although harvest of Nassau grouper has diminished due to management measures, the reduced number and size of spawning aggregations and the inadequacy of law enforcement continue to present extinction risk to Nassau grouper. Based on these considerations, described in more detail within this action, we conclude that the Nassau grouper is not currently in danger of extinction throughout all or a significant portion of its range, but is likely to become so within the foreseeable future. We also solicit information that may be relevant to the designation of critical habitat for Nassau grouper, including information on physical or biological features essential to the species' conservation, areas containing these features, and potential impacts of a designation.

DATES: The effective date of this final rule is July 29, 2016. Information on features, areas, and potential impacts, that may support designation of critical habitat for Nassau grouper must be received by August 29, 2016.

ADDRESSES: Information regarding this final rule may be obtained by contacting NMFS, Southeast Regional Office, 263 13th Avenue South, Saint Petersburg, FL 33701. Supporting information, including the Biological Report, is available electronically on the NMFS Web site at: *http://sero.nmfs.noaa.gov/protected_resources/listing_petitions/species_esa_consideration/index.html.*

You may submit information regarding potential critical habitat designation to the Protected Resources Division by either of the following methods:

- *Electronic Submissions:* Submit all electronic comments via the Federal eRulemaking Portal. Go to *www.regulations.gov/#!docketDetail;D=NOAA-NMFS-2015-0130,* click the ''Comment Now!'' icon, complete the required fields, and enter or attach your comments.
- *Mail:* Submit written information to the Protected Resources Division, NMFS Southeast Regional Office, 263 13th Avenue South, Saint Petersburg, FL 33701.

FOR FURTHER INFORMATION CONTACT: Adam Brame, NMFS, Southeast Regional Office (727) 209–5958; or Lisa Manning, NMFS, Office of Protected Resources (301) 427–8466.

SUPPLEMENTARY INFORMATION:

Background

On September 3, 2010, we received a petition from the WildEarth Guardians to list speckled hind (*Epinephelus drummondhayi*), goliath grouper (*E. itajara*), and Nassau grouper (*E. striatus*) as threatened or endangered under the ESA. The petition asserted that (1) the present or threatened destruction, modification, or curtailment of habitat or range; (2) overutilization for commercial, recreational, scientific, or educational purposes; (3) inadequacy of existing regulatory mechanisms; and (4) other natural or manmade factors are affecting the continued existence of and contributing to the imperiled statuses of these species. The petitioner also requested that critical habitat be designated for these species concurrent with listing under the ESA. Due to the scope of the WildEarth Guardians' petition, as well as the breadth and extent of the required evaluation and response, we provided species-specific 90-day findings (76 FR 31592, June 1, 2011; 77 FR 25687, May 1, 2012; 77 FR 61559, October 10, 2012).

On October 10, 2012, we published a 90-day finding for Nassau grouper with our determination that the petition presented substantial scientific and commercial information indicating that the petitioned action may be warranted (77 FR 61559). At that time, we announced the initiation of a formal status review and requested scientific and commercial information from the public on: (1) The status of historical and current spawning aggregation sites; (2) historical and current distribution, abundance, and population trends; (3) biological information (life history, genetics, population connectivity, etc.); (4) management measures, regulatory mechanisms designed to protect spawning aggregations, and enforcement information; (5) any current or planned activities that may adversely impact the species; and (6) ongoing or planned efforts to protect and restore the species and its habitat.

As part of the status review process to determine whether the Nassau grouper warrants listing under the ESA, we completed a Biological Report and an extinction risk analysis (ERA). The Biological Report summarizes the taxonomy, distribution, abundance, life history, and biology of the species. The Biological Report also identifies threats or stressors affecting the status of the species as well as a description of the fisheries, fisheries management, and conservation efforts. The Biological Report incorporates information received in response to our request for information (77 FR 61559, October 10, 2012) and comments from three independent peer reviewers. We used the Biological Report to complete a threats evaluation and an ERA to determine the status of the species.

After completing the Biological Report and considering the information received on the 90-day finding, we published a proposed rule to list Nassau grouper as a threatened species on September 2, 2014 (79 FR 51929). During a 90-day comment period, we solicited comments on our proposal from the public and any other interested parties.

Listing Determinations Under the ESA

We are responsible for determining whether the Nassau grouper is threatened or endangered under the ESA (16 U.S.C. 1531 *et seq.*). Section 4(b)(1)(A) of the ESA requires us to make listing determinations based solely on the best scientific and commercial data available after conducting a review of the status of the species and after taking into account efforts being made by any state or foreign nation to protect the species. To be considered for listing under the ESA, a group of organisms must constitute a ''species,'' which is defined in section 3 of the ESA to include taxonomic species and ''any subspecies of fish, or wildlife, or plants, and any distinct population segment of any species of vertebrate fish or wildlife which interbreeds when mature.''

Section 3 of the ESA defines an endangered species as ''any species which is in danger of extinction throughout all or a significant portion of its range'' and a threatened species as one ''which is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range.'' Thus, we interpret an ''endangered species'' to be one that is presently in danger of extinction. A ''threatened species,'' on the other hand, is not currently in danger of extinction but is likely to become so in the foreseeable future. In other words, a key statutory difference between a threatened and endangered species is the timing of when a species may be in danger of extinction, either presently (endangered) or in the foreseeable future (threatened).

Under section 4(a) of the ESA, we must determine whether any species is endangered or threatened due to any of the following five factors: (A) The present or threatened destruction, modification, or curtailment of its habitat or range; (B) overutilization for commercial, recreational, scientific, or educational purposes; (C) disease or predation; (D) the inadequacy of existing regulatory mechanisms; or (E) other natural or manmade factors affecting its continued existence (sections 4(a)(1)(A) through (E)). We are required to make listing determinations based solely on the best scientific and commercial data available after conducting a review of the status of the species and after taking into account efforts being made by any state or foreign nation to protect the species.

In determining whether the Nassau grouper meets the standard of endangered or threatened, we followed a stepwise approach. First we considered the specific life history, ecology, and status of the species as documented in the Biological Report. We then considered information on factors adversely affecting and posing extinction risk to the species in a threats evaluation. In this evaluation we assessed the threats affecting the status of the species using the factors identified in ESA section 4(a)(1). We considered the nature of the threats and the species response to those threats. We also considered each threat identified, both individually and cumulatively. Once we evaluated the threats, we assessed the efforts being made to protect the species to determine if these conservation efforts were adequate to mitigate the existing threats and alter extinction risk. Finally, we considered the public comments received in response to the proposed rule. In making this finding, we have relied on the best available scientific and commercial data.

Summary of Comments Received

Below we address the comments received on the proposed listing for Nassau grouper. In response to our request for public comments, we received 17 written responses. The overall feedback was supportive of the rule with the exception of three commenters, who believe current regulations within the United States are sufficient in protecting this species. No comments addressed threats to Nassau grouper throughout the rest of their range. We did not receive any information on additional conservation efforts being taken.

Comment 1: Multiple commenters supported the proposed rule to list Nassau grouper as a threatened species and further encouraged regional collaboration to develop adequate management measures.

Response: We agree that regional collaboration will strengthen efforts to consistently manage and conserve the species, and we hope this listing will encourage collaborative efforts. In some cases, adding a species to the endangered species list leads to increased funding opportunities and potential for collaboration between state and federal partners, as well as stakeholders. We will seek regional collaborative conservation efforts within the Caribbean region to further the conservation of the species.

Comment 2: We received comments that the existing management measures implemented by Fishery Management Councils are already effective at protecting Nassau grouper within U.S. waters, (including U.S. territorial waters of Puerto Rico and the U.S. Virgin Islands) and that the listing may add unnecessary burdens on our domestic fisheries.

Response: We agree that the South Atlantic Fishery Management Council and the Caribbean Fishery Management Council have taken significant steps to protect and rebuild the Nassau grouper population in U.S. waters. Unfortunately, a large part of the species' range and population is outside of U.S. jurisdiction and is therefore not directly aided by Council protections. We must make our determination based on the best scientific and commercial data available, independent of the potential burdens to our other domestic fisheries. This standard has been applied when making the Nassau grouper final listing determination.

Comment 3: Some comments expressed concern over the economic consequences of listing Nassau grouper, including possible effects on commercial fishermen.

Response: We are unable to consider economic impacts in a listing determination. The ESA requires us to make listing determinations by evaluating the standards and factors in section 4 of the ESA, and based solely on the best scientific and commercial data available. Listing Nassau grouper as a threatened species would not create any immediate additional regulatory requirements directly affecting commercial fishermen. Potential future regulations affecting conservation of Nassau grouper, including take and import regulations may be proposed via a separate rulemaking process which would include consideration of certain economic impacts (*e.g.,* impacts on small businesses) and opportunities for public input. Individuals that require federal permits or funding for actions that might affect Nassau grouper might need to make adjustments to their activities to avoid jeopardizing Nassau grouper, and to avoid or minimize take of the species, but that would be a determination for a specific section 7 consultation in the future.

Comment 4: Several comments indicated that spawning aggregation sites need to be protected and that proper enforcement of both existing and future rules is paramount in protecting the species.

Response: We agree that the lack of adequate protections for Nassau grouper spawning aggregations and the inadequacy of law enforcement are major contributors to the species' decline throughout its range. These threats were rated 'high' during the ERA as explained in the proposed rule and, as such, were taken into consideration when making our final listing determination.

Comment 5: One commenter supported the rule stating, ''We agree that the best available science demonstrates that Nassau grouper is likely to be at risk of extinction in the foreseeable future, and may in fact be in danger of extinction now.'' They further encouraged swift designation of critical habitat to protect spawning aggregation sites, nursery and juvenile habitat, and feeding habitat.

Response: We acknowledge the concern raised by the commenter that the species may be in danger of extinction now and provide further detail below as to how we reached our listing determination in this final rule. With regard to critical habitat, section 4(a)(3)(A) of the ESA (16 U.S.C. 1533(a)(3)(A)) requires that, if prudent and determinable, critical habitat be designated concurrently with the listing of a species. We do not currently have sufficient information to determine what physical and biological features within Nassau grouper habitats facilitate the species' life history strategy and thus are essential to the species' conservation. Therefore, we cannot yet determine what areas meet the definition of critical habitat under the ESA. Because critical habitat is not currently determinable, we will not designate critical habitat concurrently with this final rule. Designation of critical habitat may occur via a subsequent rule-making process if we can identify critical habitat and designation is prudent. We are soliciting information on features, areas, and impacts of designation, that may support designation of critical habitat for Nassau grouper.

Comment 6: One commenter suggested the use of size restrictions, monitoring, closed fishing seasons for the protection of spawning aggregations, and the use of marine protected areas as measures to protect the species.

Response: We summarize in this rule the existing regulations currently in place throughout the Caribbean Sea that include many of these suggested practices. Within U.S. waters, measures to protect Nassau grouper are already in place under the Magnuson-Stevens Act and State and Territorial fishery management authorities. As a species listed as threatened under the ESA, any federal action implemented, authorized or funded that ''may affect'' Nassau grouper will require consultation to ensure the action is not likely to jeopardize the species' continued existence. We may also implement additional protective regulations for Nassau grouper under section 4(d) of the ESA if we determine such regulations are necessary and advisable for the conservation of this threatened species. Issuance of a 4(d) rule would be a separate rule-making process that would include specific opportunities for public input.

Comment 7: The U.S. Navy identified three Navy installations or properties that are within the geographic range of Nassau grouper. They expressed concern over their ability to utilize and maintain those areas with a listing and designation of critical habitat. In particular, the Navy expressed concern over their ability to conduct maintenance dredging and requested we consult with them prior to proposing critical habitat.

Response: A rule to list Nassau grouper will require federal agencies to assess whether any actions implemented, authorized, or funded within the range of the species ''may affect'' Nassau grouper, and consult with NMFS to ensure their actions are not likely to jeopardize the species' continued existence. The rule-making process for identifying critical habitat is separate from this final listing rule and would include opportunities for public participation and input, as well as coordination with all military branches. Unlike ESA listing decisions, the designation of critical habitat requires us to consider economic, national security, and other impacts of the designation.

Comment 8: One commenter opposed the proposed rule to list Nassau grouper as a threatened species stating this is ''merely a precursor to an attempt to form a basis for a push for Marine Protection Areas.''

Response: The proposed rule to list Nassau grouper was the result of the petition we received from WildEarth Guardians, our 90-day finding that the petition presented substantial information that listing may be warranted, and our 12-month finding that listing as a threatened species was warranted. Section 4(b)(1)(A) of the ESA requires us to make listing determinations based solely on the best scientific and commercial data available after conducting a review of the status of the species and after taking into account efforts being made by any state or foreign nation to protect the species. We have not proposed any additional regulations affecting management of Nassau grouper as a result of the proposed listing rule. However, we will need to determine whether we can identify critical habitat for this species, and if so, make an appropriate designation of critical habitat. A critical habitat designation could have implications for fishing activities. Any designation of critical habitat would include opportunities for public input. As previously mentioned, we could also implement additional protective regulations for Nassau grouper under section 4(d) of the ESA, if we determine they are necessary and advisable for the conservation of this threatened species. Issuance of a 4(d) rule would be a separate rule-making process that would include specific opportunities for public input.

Changes From the Proposed Rule

In addition to responding to the comments, we made a number of changes in this final rule. These included making revisions to the Biological Review section (most notably in the Population Structure and Genetics, and the Fishing Impacts on Spawning Aggregations subsections), including a more detailed description of our role in the Threats Evaluation, providing more detail in the Extinction Risk Analysis section, and clarifying the role of foreign conservation measures as they relate to making our final listing determination. We made several of these changes to provide clarity on how we reached our listing determination in response to the comment that, ''. . . Nassau grouper is likely to be at risk of extinction in the foreseeable future, and may in fact be in danger of extinction now.''

Biological Review

This section provides a summary of key biological information presented in the Biological Report (Hill and Sadovy de Mitcheson 2013), which provides the baseline context and foundation for our listing determination.

Species Description

The Nassau grouper, *E. striatus* (Bloch 1792), is a long-lived, moderate sized serranid fish with large eyes and a robust body. Coloration is variable, but adult fish are generally buff, with five dark brown vertical bars, a large black saddle blotch on top of the base of the tail, and a row of black spots below and behind each eye. Color pattern can also change within minutes from almost white to bicolored to uniformly dark brown, according to the behavioral state of the fish (Longley 1917, Colin 1992, Heemstra and Randall 1993, Carter *et al.* 1994). A distinctive bicolor pattern is seen when two adults or an adult and large juvenile meet and is frequently observed at spawning aggregations (Heemstra and Randall 1993). There is also a distinctive dark tuning-fork mark that begins at the front of the upper jaw, extends back between the eyes, and then divides into two branches on top of the head behind the eyes. Another dark band runs from the tip of the snout through the eye and then curves upward to meet its corresponding band from the opposite side just in front of the dorsal fin. Juveniles exhibit a color pattern similar to adults (*e.g.,* Silva Lee 1977).

Maximum age has been estimated as 29 years, based on an ageing study using sagittal otoliths (Bush *et al.* 2006). Most studies indicate a rapid growth rate for juveniles, which has been estimated to be about 10 mm/month total length (TL) for small juveniles, and 8.4 to 11.7 mm/month TL for larger juveniles (Beets and Hixon 1994, Eggleston 1995). Maximum size is about 122 cm TL and maximum weight is about 25 kg (Heemstra and Randall 1993, Humann and Deloach 2002, Froese and Pauly 2010). Generation time (the interval between the birth of an individual and the subsequent birth of its first offspring) is estimated as 9–10 years (Sadovy and Eklund 1999).

Distribution

The Nassau grouper's confirmed distribution currently includes ''Bermuda and Florida (USA), throughout the Bahamas and Caribbean Sea'' (*e.g.,* Heemstra and Randall 1993). The occurrence of Nassau grouper from the Brazilian coast south of the equator as reported in Heemstra and Randall (1993) is ''unsubstantiated'' (Craig *et al.* 2011). The Nassau grouper has been documented in the Gulf of Mexico, at Arrecife Alacranes (north of Progreso) to the west off the Yucatan Peninsula, Mexico, (Hildebrand *et al.* 1964). Nassau grouper is generally replaced ecologically in the eastern Gulf by red grouper (*E. morio*) in areas north of Key West or the Tortugas (Smith 1971). They are considered a rare or transient species off Texas in the northwestern Gulf of Mexico (Gunter and Knapp 1951 in Hoese and Moore 1998). The first confirmed sighting of Nassau grouper in the Flower Garden Banks National Marine Sanctuary, which is located in the northwest Gulf of Mexico approximately 180 km southeast of Galveston, Texas, was reported by Foley *et al.* (2007). Many earlier reports of Nassau grouper up the Atlantic coast to North Carolina have not been confirmed. The Biological Report (Hill and Sadovy de Mitcheson, 2013) provides a detailed description of their distribution.

Habitat and Depth

The Nassau grouper is primarily a shallow-water, insular fish species that has long been valued as a major fishery resource throughout the wider Caribbean, South Florida, Bermuda, and the Bahamas (Carter *et al.* 1994). The Nassau grouper is considered a reef fish, but it transitions through a series of developmental shifts in habitat. As larvae, they are planktonic. After an average of 35–40 days and at an average size of 32 mm TL, larvae recruit from an oceanic environment into demersal habitats (Colin 1992, Eggleston 1995). Following settlement, juvenile Nassau grouper inhabit macroalgae (primarily *Laurencia* spp.), coral clumps (*Porites* spp.), and seagrass beds (Eggleston 1995, Dahlgren 1998). Recently-settled Nassau grouper have also been collected from rubble mounds, some from tilefish (*Malacanthus plumieri*), at 18 m depth (Colin *et al.* 1997). Post-settlement, small Nassau grouper have been reported with discarded queen conch shells (*Strombus gigas*) and other debris around *Thalassia* beds (Randall 1983, Eggleston 1995).

Juvenile Nassau grouper (12–15 cm TL) are relatively solitary and remain in specific areas for months (Bardach 1958). Juveniles of this size class are associated with macroalgae, and both natural and artificial reef structure. As juveniles grow, they move progressively to deeper areas and offshore reefs (Tucker *et al.* 1993, Colin *et al.* 1997). Schools of 30–40 juveniles (25–35 cm TL) were observed at 8–10 m depths in the Cayman Islands (Tucker *et al.* 1993). No clear distinction can be made between types of adult and juvenile habitats, although a general size segregation with depth occurs—with smaller Nassau grouper in shallower inshore waters (3.7–16.5 m) and larger individuals more common on deeper (18.3–54.9 m) offshore banks (Bardach *et al.* 1958, Cervigón 1966, Silva Lee 1974, Radakov *et al.* 1975, Thompson and Munro 1978).

Recent work by Nemeth and coworkers in the U. S. Virgin Islands (U.S.V.I.; manuscript, in prep) found more overlap in home ranges of smaller juveniles compared to larger juveniles and adults have larger home ranges with less overlap. Mean home range of adult Nassau grouper in the Bahamas was 18,305 m^2 ± 5,806 (SD) with larger ranges at less structurally-complex reefs (Bolden 2001). The availability of habitat and prey was found to significantly influence home range of adults (Bolden 2001).

Adult Nassau grouper tend to be relatively sedentary and are generally associated with high-relief coral reefs or rocky substrate in clear waters to depths of 130 m. Generally, adults are most common at depths less than 100 m (Hill and Sadovy de Mitcheson, 2013) except when at spawning aggregations where they are known to descend to depths of 255 m (Starr *et al.* 2007).

Diet and Feeding

Adult Nassau grouper are unspecialized, bottom-dwelling, ambush-suction predators (Randall 1965, Thompson and Munro 1978). Numerous studies describe adult Nassau grouper as piscivorous (Randall and Brock 1960, Randall 1965, Randall 1967, Carter *et al.* 1994, Eggleston *et al.* 1998). Feeding can take place around the clock although most fresh food is found in stomachs collected in the early morning and at dusk (Randall 1967). Young Nassau grouper (20.2–27.2 mm standard length; SL) feed on a variety of plankton, including pteropods, amphipods, and copepods (Greenwood 1991, Grover *et al.* 1998).

Population Structure and Genetics

Early genetic analyses indicated high gene flow throughout the geographic range of Nassau grouper but were unable to determine the relative contributions of populations (Hinegardner and Rosen 1972, Hateley 2005). A study of Nassau grouper genetic population structure, using mitochondrial DNA (mtDNA) and nuclear microsatellite DNA, revealed no clearly defined population substructuring based on samples from Belize, Cuba, Bahamas, and Florida. These data indicated that spawning aggregations are not exclusively self-recruiting and that larvae can disperse over great distances, but the relative importance of self-recruitment and larval immigration to local populations was unclear (Sedberry *et al.* 1996). Similarly, a study by Hateley (2005) that analyzed samples from Belize, Bahamas, Turks and Caicos, and Cayman Islands using enzyme electrophoresis indicated low to intermediate levels of genetic variability. Results from this study provided no evidence for population substructuring by sex or small-scale spatial distribution, or for macrogeographic stock separation. These results are consistent with a single panmictic population within the northern Caribbean basin with high gene flow through the region.

A recent study, published subsequent to the Biological Report, analyzed genetic variation in mtDNA, microsatellites, and single nucleotide polymorphisms for Nassau grouper (Jackson *et al.* 2014). The study identified three potential ''permeable'' barriers to dispersal and concluded that large-scale oceanographic patterns likely influence larval dispersal and population structuring (regional genetic differentiation). However, the evidence of population structuring was limited. In pairwise analyses of genetic distance between the sample populations (using Fst for microsatellites and Φst for mtDNA), zero (of 171) comparisons based on microsatellite DNA were statistically signficant, only 47 (of 153) comparisons based on mtDNA were statistically significant ($p < 0.00029$), and there was no indication of isolation by distance in any of the genetic datasets. Overall, while this study indicated some instances of genetic differentiation, the results do not indicate a high degree of population structuring across the range. When the Jackson *et al.* study is considered in the context of the larger body of literature, there remains some uncertainty as to population substructuring for Nassau grouper.

Reproductive Biology

The Nassau grouper was originally considered to be a monandric protogynous hermaphrodite, meaning males derive from adult females that undergo a change in sex (Smith 1971, Claro *et al.* 1990, Carter *et al.* 1994). While it is taxonomically similar to other hermaphroditic groupers, the Nassau grouper is now primarily considered a gonochore with separate sexes (Sadovy and Colin 1995). Juveniles were found to possess both male and female tissue, indicating they can mature directly into either sex (Sadovy and Colin 1995). Other characteristics such as the strong size overlap between males and females, the presence of males that develop directly from the juvenile phase, the reproductive behavior of forming spawning aggregations, and the mating system were found to be inconsistent with the protogynous reproductive strategy (Colin 1992, Sadovy and Colin 1995).

Both male and female Nassau grouper typically mature at 4–5 years of age and at lengths between 40 and 45 cm SL (44 and 50 cm TL). Size, rather than age, may be the major determinant of sexual maturation (Sadovy and Eklund 1999).

Nassau grouper raised from eggs in captivity matured at 40–45 cm SL (44–50 cm TL) in just over 2 years (Tucker and Woodward 1994). Yet, the minimum age at sexual maturity based on otoliths is between 4 and 8 years (Bush *et al.* 1996, 2006). Most fish have spawned by age 7+ years (Bush *et al.* 2006).

Fecundity estimates vary by location throughout the Caribbean. Mean fecundity estimates are generally between 3 and 5 eggs/mg of ripe ovary. For example, Carter *et al.* (1994) found female Nassau grouper between 30–70 cm SL from Belize yielded a mean relative fecundity of 4.1 eggs/mg ovary weight and a mean total number of 4,200,000 oocytes (range = 350,000 − 6,500,000). Estimated number of eggs in the ripe ovary (90.7 g) of a 44.5 cm SL Nassau grouper from Bermuda was 785,101 (Bardach *et al.* 1958). In the U.S.V.I., mean fecundity was 4.97 eggs/mg of ovary (s.d. = 2.32) with mean egg production of 4,800,000 eggs (Olsen and LaPlace 1979); however, this may be an overestimate as it included premature eggs that may not develop. Fecundity estimates based only on vitellogenic oocytes, from fish captured in the Bahamas indicated a mean relative fecundity of 2.9 eggs/mg ripe ovary (s.d. = 1.09; n = 64) and a mean egg production of 716,664 (range = 11,724 − 4,327,440 for females between 47.5–68.6 cm SL). Estimates of oocyte production from Nassau grouper induced to spawn in captivity are closer to the lower estimates based solely on vitellogenic oocyte counts.

Spawning Behavior and Habitat

Nassau grouper form spawning aggregations at predictable locations around the winter full moons, or between full and new moons (Smith 1971, Colin 1992, Tucker *et al.* 1993, Aguilar-Perera 1994, Carter *et al.* 1994, Tucker and Woodward 1994). Aggregations consist of hundreds, thousands, or, historically, tens of thousands of individuals. Some aggregations have persisted at known locations for periods of 90 years or more (see references in Hill and Sadovy de Mitcheson 2013). Pair spawning has not been observed.

About 50 individual spawning aggregation sites have been recorded, mostly from insular areas in the Bahamas, Belize, Bermuda, British Virgin Islands, Cayman Islands, Cuba, Honduras, Jamaica, Mexico, Puerto Rico, Turks and Caicos, and the U.S.V.I.; however, many of these may no longer form (Figure 10 in Hill and Sadovy de Mitcheson 2013). Recent evidence suggests that spawning is occurring at what may be reconstituted or novel spawning sites in both Puerto Rico and the U.S.V.I. (Hill and Sadovy de Mitcheson 2013). Suspected or anecdotal evidence also identifies spawning aggregations in Los Roques, Venezuela (Boomhower *et al.* 2010) and Old Providence in Colombia's San Andrés Archipelago (Prada *et al.* 2004). Neither aggregation nor spawning has been reported from South America, despite the fact ripe Nassau grouper are frequently caught in certain areas (F. Cervigón, Fundacion Cientifica Los Roques-Venezuela, pers. comm. to Y. Sadovy, NMFS, 1991). Spawning aggregation sites have not been reported in the Lesser Antilles, Central America south of Honduras, or Florida.

''Spawning runs,'' or movements of adult Nassau grouper from coral reefs to spawning aggregation sites, were first described in Cuba in 1884 by Vilaro Diaz, and later by Guitart-Manday and Juarez-Fernandez (1966). Nassau grouper migrate to aggregation sites in groups numbering between 25 and 500, moving parallel to the coast or along shelf edges or even inshore reefs (Colin 1992, Carter *et al.* 1994, Aguilar-Perera and Aguilar-Davila 1996, Nemeth *et al.* 2009). Distance traveled by Nassau grouper to aggregation sites is highly variable; some fish move only a few kilometers (km), while others move up to several hundred km (Colin 1992, Carter *et al.* 1994, Bolden 2000). Ongoing research in the Exuma Sound, Bahamas has tracked migrating Nassau grouper up to 200 km, with likely estimates of up to 330 km, as they move to aggregation sites (Hill and Sadovy de Mitcheson 2013).

Observations suggest that individuals can return to their original home reef following spawning. Bolden (2001) reported 2 out of 22 tagged fish returning to home reefs in the Bahamas one year after spawning. Sonic tracking studies around Little Cayman Island have demonstrated that spawners may return to the aggregation site in successive months with returns to their residential reefs in between (Semmens *et al.* 2007). Sixty percent of fish tagged at the west end spawning aggregation site in Little Cayman in January 2005 returned to the same aggregation site in February 2005 (Semmens *et al.* 2007). Larger fish are more likely to return to aggregation sites and spawn in successive months than smaller fish (Semmens *et al.* 2007).

It is not known how Nassau grouper select and locate aggregation sites or why they aggregate to spawn. Spawning aggregation sites are typically located near significant geomorphological features, such as projections (promontories) of the reef as little as 50 m from the shore, and close to a drop-off into deep water over a wide (6–60 m) depth range (Craig 1966, Smith 1972, Burnett-Herkes 1975, Olsen and LaPlace 1979, Colin *et al.* 1987, Carter 1989, Fine 1990, Beets and Friedlander 1998, Colin 1992, Aguilar-Perera 1994). Sites are characteristically small, highly circumscribed areas, measuring several hundred meters in diameter, with soft corals, sponges, stony coral outcrops, and sandy depressions (Craig 1966, Smith 1972, Burnett-Herkes 1975, Olsen and LaPlace 1979, Colin *et al.* 1987, Carter 1989, Fine 1990, Beets and Friedlander 1999, Colin 1992, Aguilar-Perera 1994). Recent work has identified geomorphological similarities in spawning sites that may be useful in applying remote sensing techniques to discover previously unknown spawning sites (Kobara and Heyman 2010).

The link between spawning sites and settlement sites is also not well understood. Researchers speculate the location of spawning sites assists offshore transport of fertilized eggs. However, currents nearby aggregation sites do not necessarily favor offshore egg transport, indicating some locations may be at least partially self-recruiting (*e.g.,* Colin 1992). In a study around a spawning aggregation site at Little Cayman, surface velocity profile drifters released on the night of peak spawning tended to remain near or returned to the spawning reef due to eddy formation, while drifters released on the days preceding the peak spawn tended to move away from the reef in line with the dominant currents (Heppell *et al.* 2011).

Spawning aggregations form around the full moon between December and March (reviewed in Sadovy and Eklund 1999), though this may occur later (May–August) in more northerly latitudes (La Gorce 1939, Bardach *et al.* 1958, Smith 1971, Burnett-Herkes 1975). The formation of spawning aggregations is triggered by a very narrow range of water temperatures between 25°–26 °C. While day length has also been considered as a trigger for aggregation formation (Colin 1992, Tucker *et al.* 1993, Carter *et al.* 1994), temperature is evidently a more important stimulus (Hill and Sadovy de Mitcheson 2013). The narrow range of water temperature is likely responsible for the later reproductive season in more northerly latitudes like Bermuda.

Spawning occurs for up to 1.5 hours around sunset for several days (Whaylen *et al.* 2007). At spawning aggregation sites, Nassau grouper tend to mill around for a day or two in a ''staging area'' adjacent to the core area where spawning activity later occurs (Colin 1992, Kadison *et al.* 2010, Nemeth 2012). Courtship is indicated by two behaviors that occur late in the afternoon: ''following'' and ''circling'' (Colin 1992). The aggregation then moves into deeper water shortly before spawning (Colin 1992, Tucker *et al.* 1993, Carter *et al.* 1994). Progression from courtship to spawning may depend on aggregation size, but generally fish move up into the water column, with an increasing number exhibiting the bicolor phase (Colin 1992, Carter *et al.* 1994).

Spawning involves a rapid horizontal swim or a ''rush'' of bicolor fish following dark fish closely in either a column or cone rising to within 20–25 m of the water surface where group-spawning occurs in sub-groups of 3–25 fish (Olsen and LaPlace 1979, Carter 1986, Aguilar-Perera and Aguilar-Davila 1996). Following the release of sperm and eggs, there is a rapid return of the fragmented sub-group to the bottom. All spawning events have been recorded within 20 minutes of sunset, with most within 10 minutes of sunset (Colin 1992).

Repeated spawning occurs at the same site for up to three consecutive months generally around the full moon or between the full and new moons (Smith 1971, Colin 1992, Tucker *et al.* 1993, Aguilar-Perera 1994, Carter *et al.* 1994, Tucker and Woodward 1994). Participation by individual fish across the months is unknown. Examination of female reproductive tissue suggests multiple spawning events across several days at a single aggregation (Smith 1972, Sadovy, NMFS, pers. obs.). A video recording shows a single female in repeated spawning rushes during a single night, repeatedly releasing eggs (Colin 1992). It is unknown whether a single, mature female will spawn continuously throughout the spawning season or just once per year.

Status Assessments

Few formal stock assessments have been conducted for the Nassau grouper. The most recent published assessment, conducted in the Bahamas, indicates fishing effort, and hence fishing mortality (F), in the Bahamas needs to be reduced from the 1998–2001 levels, otherwise the stocks are likely to be overexploited relative to biological reference points (Cheung *et al.* 2013). The population dynamic modeling by Cheung *et al.* (2013) found: ''assuming that the closure of the spawning aggregation season is perfectly implemented and enforced, the median value of F_{SPR} (the fishing mortality rate that produces a certain spawning potential ratio) = 35 percent on non-spawning fish would be 50 percent of the fishing mortality of the 1998 to 2001 level. The 5 percent and 95 percent confidence limits are estimated to be less than 20 percent and more than 100 percent of the fishing mortality at the 1998 to 2001 level, respectively. In other words, if (1) fishing mortality (F) rates of non-spawning fish are maintained at the 1998 to 2001 level, and (2) fishing on spawning aggregations is negligible, the median spawning potential (spawner biomass relative to the unexploited level) is expected to be around 25 percent (5 and 95 percent confidence interval (CI) of 20 and 30 percent, respectively). This level is significantly below the reference limit of 35 percent of spawning potential, meaning that there is a high chance of recruitment overfishing because of the low spawning stock biomass.''

The Nassau grouper was formerly one of the most common and important commercial groupers in the insular tropical western Atlantic and Caribbean (Smith 1978, Randall 1983, Appeldoorn *et al.* 1987, Sadovy 1997). Declines in landings and catch per unit of effort (CPUE) have been reported throughout its range, and it is now considered to be commercially extinct (*i.e.,* the species is extinct for fishery purposes due to low catch per unit effort) in a number of areas, including Jamaica, Dominican Republic, U.S.V.I., and Puerto Rico (Sadovy and Eklund 1999). Information on past and present abundance and density, at coral reefs and aggregation sites, is based on a combination of anecdotal accounts, visual census surveys, and fisheries data. Because grouper species are reported collectively in landings data, there are limited species-specific data to determine catch of Nassau grouper throughout its range.

While fisheries dependent data are generally limited for the species throughout its range, there are some 1970s and 1980s port-sampling data from the U.S.V.I. and Puerto Rico. In the U.S.V.I., Nassau grouper accounted for 22 percent of total grouper landings, and 85 percent of the Nassau grouper catch came from spawning aggregations (D. Olsen, Chief Scientist—St. Thomas Fishermen's Association, pers. comm. to J. Rueter, NMFS, October 2013). The first U.S. survey of the fishery resources of Puerto Rico noted the Nassau grouper was common and a very important food fish, reaching a weight of 22.7 kg or more (Evermann 1900). The Nassau grouper was still the fourth-most common shallow-water species landed in Puerto Rico in the 1970s (Thompson 1978), and it was common in the reef fish fishery of the U.S.V.I. (Olsen and LaPlace 1979). By 1981, ''the Nassau grouper ha[d] practically disappeared from the local catches and the ones that d[id] appear [were] small compared with previous years'' (CFMC 1985). By 1986, the Nassau grouper was considered commercially extinct in the U.S. Caribbean (Bohnsack *et al.* 1986). About 1,000 kg of Nassau grouper landings were reported in the Puerto Rico Reef Fish Fishery during the latter half of the 1980s, and most of them were less than 50 cm indicating they were likely sexually immature (Sadovy 1997).

A number of organizations and agencies have conducted surveys to examine the status of coral reefs and reef-fish populations throughout the western Atlantic. Results from these monitoring studies offer some indication of relative abundance of Nassau grouper in various locations, although different methods are often employed and thus results of different studies cannot be directly compared (Kellison *et al.* 2009). The Atlantic and Gulf Rapid Reef Assessment Program (AGRRA), which samples a broad spectrum of western Atlantic reefs, includes few reports of Nassau grouper, as sighting frequency (proportion of all surveys with at least one Nassau grouper present) ranged from less than 1 percent to less than 10 percent per survey from 1997–2000. Density of Nassau grouper ranged from 1 to 15 fish/hectare with a mean of 5.6 fish/hectare across all areas surveyed (AGRRA). NOAA's Coral Reef Ecosystem Monitoring Program (CREMP) has conducted studies on coral reefs in Puerto Rico and the U.S.V.I. since 2000, and sighting frequency of Nassau grouper has ranged from 0 to 0.5 percent with density between 0 to 0.5 fish/hectare. Data from SCUBA surveys conducted by the University of the Virgin Islands report a density of 4 Nassau grouper/hectare per survey across reef habitat types in the U.S.V.I. SCUBA surveys by NOAA in the Florida Keys across reef habitat types have sighting frequencies of 2–10 percent per survey, with a density of 1 Nassau grouper/hectare (NOAA's NMFS FRVC). In addition to these surveys, Hodgson and Liebeler (2002) noted that Nassau grouper were absent from 82 percent of shallow Caribbean reefs surveyed (3–10 m) during a 5-year period (1997–2001) for the ReefCheck project.

Fishing Impacts on Spawning Aggregations

Because we lack sufficient stock assessments or population estimates, we considered the changes in spawning aggregations as a proxy for the status of the current population. We believe the status of spawning aggregations is likely to be reflective of the overall population because adults migrate to spawning aggregations for the only known reproductive events. Historically, 50 spawning aggregation sites had been identified throughout the Caribbean (Sadovy de Mitcheson *et al.* 2008). Of these 50, less than 20 probably still remain (Sadovy de Mitcheson *et al.* 2008). Furthermore, while numbers of fish at aggregation sites once numbered in the tens of thousands (30,000–100,000 fish; Smith 1972), they have now been reduced to less than 3,000 at those sites where counts have been made (Sadovy de Mitcheson *et al.* 2008). Based on the size and number of current spawning aggregations the Nassau grouper population appears to be just a fraction of its historical size.

In general, slow-growing, long-lived species (such as snappers and groupers) with limited spawning periods, and possibly with narrow recruitment windows, are susceptible to overexploitation (Bannerot *et al.* 1987, Polovina and Ralston 1987). The strong appeal of spawning aggregations as targets for fishing, their importance in many seasonal fisheries, and the apparent abundance of fish at aggregations make spawning aggregations particularly susceptible to over-exploitation. There are repeated reports from across the Caribbean where Nassau grouper spawning aggregations have been discovered and fished to the point that the aggregation ceased to form, or formed at such low densities that spawning was no longer viable. For example, the commercial fishing of Nassau grouper aggregations in Bermuda resulted in decreased landings from 75,000 tons in 1975 to 10,000 tons by 1981 (Luckhurst 1996, Sadovy de Mitcheson and Erisman 2012). The four known spawning aggregation sites in Bermuda ceased to form shortly thereafter and have yet to recover (Sadovy de Mitcheson and Erisman 2012). However, Nassau grouper are still present in Bermuda and reported observations have slightly increased over the last 10–15 years (B. Luckhurst, Bermuda Department of Agriculture, Fisheries, and Parks, Division of Fisheries, pers. comm. to Y. Sadovy, University of Hong Kong, 2012). In Puerto Rico, historical spawning aggregations no longer form, though a small aggregation has recently been found, and may be a reconstitution of one of the former aggregations (Schärer et al. 2012). In Mahahual, Quintana Roo, Mexico, aggregations of up to 15,000 fish formed each year, but due to increased fishing pressure in the 1990's, aggregations have not formed in Mahahual since 1996 (Aguilar-Perera 2006). Inadequate enforcement of management measures designed to protect spawning aggregations in Mexico has further affected aggregations (Aguilar-Perera 2006), though at least three aggregation sites remain viable. In Cuba, Nassau grouper were almost exclusively targeted during aggregation formation; because of this, there have been severe declines in the number of Nassau grouper at 8 of the 10 aggregations and moderate declines in the other 2 (Claro *et al.* 2009). Similar situations are known to have occurred in the Bahamas, U.S.V.I., Puerto Rico, and Honduras (Sadovy de Mitcheson and Erisman 2012, see also Hill and Sadovy de Mitcheson 2013).

Overexploitation has also occurred in Belize. Between 1975 and 2001 there was an 80 percent decline in the number of Nassau grouper (15,000 fish to 3,000) at the Glover's Reef aggregation (Sala *et al.* 2001). Additionally, a 2001 assessment concluded that only 2 of the 9 aggregation sites identified in 1994 remained viable, and those had been reduced from 30,000 fish to 3,000–5,000 fish (Heyman 2002). More recent monitoring (2003–2012) at the two sites at Glover's Reef indicates further declines in the sizes of these aggregations. A maximum of 800–3,000 Nassau grouper were counted per year at these sites over the ten years of monitoring (Belize SPAG Working Group 2012).

Further indicators of population decline through over-exploitation include reduced size and/or age of fish harvested compared to maximum sizes and ages. Nassau grouper can attain sizes of greater than 120 cm (Heemstra and Randall 1993, Humann and Deloach 2002, Froese and Pauly 2010) and live as long as 29 years (Bush *et al.* 2006). However, it is unusual to obtain individuals of more than 12 years of age in exploited fisheries, and more heavily fished areas yield much younger fish on average. The maximum age estimates in heavily exploited areas are depressed—9 years in the U.S.V.I. (Olsen and LaPlace 1979), 12 years in northern Cuba, 17 years in southern Cuba (Claro *et al.* 1990), and 21 years in the Bahamas (Sadovy and Colin 1995). Similarly, there is some indication that size at capture of both sexes declined in areas of higher exploitation versus unexploited populations within a specific region (Carter et al 1994). When exploitation is high, catches are largely comprised of juveniles. For example, most catches of Nassau grouper in heavily exploited areas of Puerto Rico, Florida (Sadovy and Eklund 1999), and Cuba (Espinosa 1980) consisted of juveniles. In exploited U.S.V.I. aggregations, harvest of Nassau grouper larger than 70 cm TL was uncommon (Olsen and LaPlace 1979).

While direct fishing of spawning aggregations was a primary driver of Nassau grouper population declines as indicated by the observed declines in spawning aggregations (Sadovy de Mitcheson and Erisman 2012), other factors also affect abundance. For example, removal of adults from spawning runs and intensive capture of juveniles, either through direct targeting (*e.g.,* spearfishing) or using small mesh traps or nets, also occur (Hill and Sadovy de Mitcheson 2013). In addition to the high fishing pressure in some areas, poaching also appears to be affecting some populations (*e.g.,* in the Cayman Islands; Semmens *et al.* 2012).

NMFS's Conclusions From the Biological Report

The species is made up of a single population over its entire geographic range. As summarized above, multiple genetic analyses indicate that there is high gene flow throughout the geographic range of the Nassau grouper, and no clearly defined population substructuring has been identified (Hinegardner and Rosen 1972, Sedberry *et al.* 1996, Hateley 2005). Although a recent study (Jackson *et al.* 2014) reported genetic differentiation, it does not provide evidence to support biological differences between populations. We believe further studies are needed to verify and expand upon the work presented by Jackson *et al* (2014). Based on the best available information, we conclude there is a single population of Nassau grouper throughout the Caribbean.

The species has patchy abundance, with declines identified in many areas. The Biological Report describes the reduction in both size and number of spawning aggregations throughout the range. Patchy abundance throughout the range of a species is common due to differences in habitat quality/quantity or exploitation levels at different locations. However, dramatic, consistent declines of Nassau grouper have been noted throughout its range. In many areas throughout the Caribbean, the species is now considered commercially extinct and numerous spawning aggregations have been extirpated with no signs of recovery.

The species possesses life history characteristics that increase vulnerability to harvest, including slow growth to a large size, late maturation, formation of large spawning aggregations, and occurrence in shallow *habitat.* This conclusion is based on the Description of the Species in the Biological Report (Hill and Sadovy de Mitcheson 2013). Slow growth and late maturation expose sub-adults to harvest prior to reproduction. Sub-adult and adult Nassau grouper form large conspicuous spawning aggregations. These aggregations are often in shallow habitat areas that are easily accessible to fishermen and thus heavily exploited. Despite these life-history vulnerabilities, there are remaining spawning aggregations that, while reduced in size and number, still function and provide recruits into the population.

The species is broadly distributed, and its current range is similar to its historical range. The Range-wide Distribution section of the Biological Report (Hill and Sadovy de Mitcheson 2013) concluded that the current range is equivalent to the historical range, though abundance has been severely depleted.

Threats Evaluation

The threats evaluation was the second step in the process of making an ESA listing determination for Nassau grouper as described above in ''Listing Determinations under the ESA''. The Extinction Risk Analysis Group (ERAG), which consisted of 12 NOAA Fisheries Science Center and Regional Office personnel, was asked to independently review the Biological Report and assess 4 demographic factors (abundance, growth rate/productivity, spatial structure/connectivity, and diversity) and 13 specific threats (see ERA Threat Table under supporting documents). The group members were asked to provide qualitative scores based on their perceived severity of each factor and threat.

Members of the ERAG were asked to independently evaluate the severity, scope, and certainty for these threats currently and in the foreseeable future (30 years from now). The foreseeable future was based on the upper estimate of generation time for Nassau grouper (9–10 years) as described by Sadovy and Eklund (1999) and an age at maturity of 8 years (Bush *et al.* 1996, 2006). We chose 30 years, which would potentially allow recruitment of 2–3 generations of mature individuals to appear in spawning aggregations as a result of fishery management actions. Given the limited information we have to predict the impacts of threats, we felt the 30 year timeframe was the most appropriate to assess threats in the foreseeable future.

Members of the ERAG were asked to rank each of four demographic factors and 13 identified threats as ''very low risk,'' ''low risk,'' ''moderate risk,'' ''increasing risk,'' ''high risk,'' or ''unknown.'' ''Very low risk'' meant that it is unlikely that the demographic factor or threat affects the species' overall status. ''Low risk'' meant that the demographic factor may affect species' status, but only to a degree that it is unlikely that this factor significantly elevates risk of extinction now or in the future. ''Moderate risk'' meant that the demographic factor or threat contributes significantly to long term risk of extinction, but does not constitute a danger of extinction in the near future. ''Increasing risk'' meant that the present demographic risk or threat is low or moderate, but is likely to increase to high risk in the foreseeable future if present conditions continue. Finally, ''high risk'' meant that the demographic factor or threat indicates danger of extinction in the near future. Each member of the ERAG evaluated risk on this scale, and we then interpreted these rankings against the statutory language for threatened or endangered to determine the status of Nassau grouper. We did not directly relate the risk levels with particular listing outcomes, because the risk levels alone are not very informative. Acknowledging the differences in terminology between the ERAG risk scale and the ESA statutory definitions of threatened and endangered, we relied upon our own judgment and expertise in reviewing the ERA to determine the status of Nassau grouper and form our final listing determination.

ERAG members were also asked to consider the potential interactions between demographic factors and threats. If the demographic factor or threat was ranked higher due to interactions with other demographic factors or threats, each member was asked to then identify those factors or threats that caused them to score the risk higher or lower than it would have been if it were considered independently. We then examined the independent responses from each ERAG member for each demographic factor and threat and used the modal response to determine the level of threat to Nassau grouper.

Climate change and international trade regulations (*e.g.,* the Convention on International Trade in Endangered Species (CITES), as described in the Biological Report) were categorized by the ERAG as ''unknown.'' Habitat alteration, U.S. federal regulations, disease/parasites/abnormalities, and aquaculture were ranked as ''very low risk'' to ''low risk.'' State/territorial regulations, growth rate/productivity, abundance, spatial structure/connectivity, commercial harvest, foreign regulations, artificial selection, and diversity were ranked as ''moderate risk'' to ''increasing risk.'' Historical harvest (the effect of prior harvest on current population status), fishing at spawning aggregations, and inadequate law enforcement were classified as ''high risk.'' The demographic factors and threats are described below by the five ESA factors with the corresponding ERAG ranking and our analysis.

A. The Present or Threatened Destruction, Modification, or Curtailment of Its Habitat or Range

Spatial structure/connectivity and habitat alteration were considered under ESA Factor A; this included habitat loss or degradation, and the loss of habitat patches, critical source populations, subpopulations, or dispersal among populations.

Nassau grouper use many different habitat types within the coral reef ecosystem. The increase in urban, industrial, and tourist developments throughout the species range impacts coastal mangroves, seagrass beds, estuaries, and live coral (Mahon 1990). Loss of juvenile habitat, such as macroalgae, seagrass beds, and mangrove channels is likely to negatively affect recruitment rates. Habitat alteration was ranked by the ERAG as a ''low risk'' threat to Nassau grouper. We agree with the ERAG that habitat alteration presents a low risk to the species and is unlikely to contribute to the threat of extinction presently or over the foreseeable future. The use of many different habitat types by Nassau grouper may spread the risk of impacts associated with habitat loss to a point that reduces overall extinction risk to the species.

The range of Nassau grouper is influenced by spatial structure and connectivity of the population. As described in Hill and Sadovy de Mitcheson (2013), a study of genetic population structure in Nassau grouper revealed no clearly defined population substructuring at the geographic locations sampled, *i.e.,* Belize, Cuba, Bahamas, and Florida (Sedberry *et al.* 1996). Based on ERAG scores, spatial structure/connectivity was characterized as an ''increasing'' risk for Nassau grouper. We agree with the ERAG ranking and believe this increasing risk is due, in part, to the declining number and size of spawning aggregations, which affects population structure. Given the increasing risk associated with this demographic factor we believe it could lead the species to become endangered over the foreseeable future.

B. Overutilization for Commercial, Recreational, Scientific, or Educational Purposes

Based on ERAG rankings, historical harvest and fishing at spawning aggregations are two of the three most severe threats (the third being inadequate law enforcement) to Nassau grouper. Historical harvest and fishing at spawning aggregations were both classified as ''high'' risk threats to Nassau grouper. Curiously, the ERAG rankings for commercial harvest, which often includes the fishing on spawning aggregations, were lower and indicated current commercial harvest was a ''moderate'' threat for Nassau grouper. We believe this lower ranking may be related to the fact that the species has declined to the point that commercial harvest is not as large a threat as in decades past. This is also related to abundance which was similarly classified as a ''moderate'' risk for Nassau grouper.

Two different aspects of fishing affect Nassau grouper abundance: Fishing effort throughout the non-spawning months and directed fishing at spawning aggregations or on migrating adults. In some countries Nassau grouper are fished commercially and recreationally throughout the year by handline, longline, fish traps, spear guns, and gillnets (NMFS General Canvas Landing System). Fishing at spawning aggregations is mainly conducted by handlines or by fish traps, although gillnets were being used in Mexico in the early to mid-1990s (Aguilar-Perera 2004). Declines in landings, catch per unit effort (CPUE) and, by implication, abundance in the late 1980s and early 1990s occurred throughout its range, which has led Nassau grouper to now be considered commercially extinct in a number of areas (Sadovy and Eklund 1999). Population declines and loss of spawning aggregations continue throughout the Nassau grouper's range (Sadovy de Mitcheson 2012).

We agree with the ERAG's assessment for the threat of abundance. It is clear that the abundance of Nassau grouper has diminished dramatically over the past several decades. This decline is a direct impact of historical harvest and the overfishing of spawning aggregations. The current abundance of Nassau grouper is not causing or contributing to the species currently being in danger of extinction but does raise concern for the status of the species over the foreseeable future if abundance continues to decline.

We disagree with the ERAG's ''high risk'' rating for historical harvest. We believe that while historical harvest has reduced the population size of Nassau grouper, which has in turn affected the ability of the population to recover, we don't agree that this threat continues to be a ''high risk''. It seems more appropriate to consider the ERAG's risk assessment for the abundance of the current population in making our listing determination.

Predictable spawning aggregations make Nassau grouper a vulnerable fishing target. In many places, annual landings for Nassau grouper were mostly from aggregation-fishing (*e.g.,* Claro *et al.* 1990, Bush *et al.* 2006). Because Nassau grouper are only known to reproduce in spawning aggregations, removing ripe individuals from the spawning aggregations greatly influences population dynamics and future fishery yields (Shapiro 1987). Harvesting a species during its reproductive period increases adult mortality and diminishes juvenile recruitment rates. The loss of adults and the lack of recruitment greatly increase a species' extinction risk. The collapse of aggregations in many countries (Sadovy de Mitcheson 2012) was likely a result of overharvesting fish from spawning aggregations (Olsen and LaPlace 1979, Aguilar-Perera 1994, Sadovy and Eklund 1999). As Semmens *et al.* (2012) noted from the results of a mark-recapture study on Cayman Brac, Cayman Island fishermen appear to catch sufficient adult grouper outside the spawning season to seriously impact population size. It appears that fishing at spawning aggregations has depressed population size such that fishing operations away from the aggregations are also impacting population status.

We agree that fishing at spawning aggregations has reduced the population of Nassau grouper and has affected its current status. While the ERAG determined this is a ''high risk'' threat, we are less certain about our determination. We believe that this threat is in large part exacerbated by the inadequacy of regulatory mechanisms as discussed further below under Factor D. If existing regulatory mechanisms and corresponding law enforcement were adequate, this threat would be less of a concern. In the absence of adequate law enforcement, we believe that fishing at spawning aggregations is increasing the extinction risk of Nassau grouper.

The final threat analyzed for Factor B was artificial selection. The ERAG scores indicated artificial selection was a ''moderate'' threat; however, ranking of this threat was widely distributed amongst ERAG members, indicating a high level of uncertainty about the effects of artificial selection on Nassau grouper. We recognize the uncertainty associated with this threat and believe more information is needed. That said, we do not believe available information indicates artificial selection is currently impacting the species' risk of extinction.

C. Disease

There is very little information on the impacts of disease, parasites, and abnormalities on Nassau grouper, yet the species is not known to be affected by any specific disease or parasite. Given this, NMFS agrees with the ERAG ranking indicating a ''very low risk'' threat from disease, parasites, and abnormalities. We do not believe any of these threats will rise to the level of impacting the species' status over the foreseeable future.

D. Inadequacy of Existing Regulatory Mechanisms

Consideration of the inadequacy of existing regulatory mechanisms, includes whether enforcement of those mechanisms is adequate. The relevance of existing regulatory mechanisms to extinction risk for an individual species depends on the vulnerability of that species to each of the threats identified under the other factors of ESA section 4, and the extent to which regulatory mechanisms could or do control the threats that are contributing to the species' extinction risk. If a species is not currently, and not expected within the foreseeable future to become, vulnerable to a particular threat, it is not necessary to evaluate the adequacy of existing regulatory mechanisms for addressing that threat. Conversely, if a species is vulnerable to a particular threat (now or in the foreseeable future), we do evaluate the adequacy of existing measures, if any, in controlling or mitigating that threat. In the following paragraphs, we will discuss existing regulatory mechanisms for addressing the threats to Nassau grouper generally, and assess their adequacy for controlling those threats. In the Extinction Risk Analysis section, we determine if the inadequacy of regulatory mechanisms is a contributing factor to the species' status as threatened or endangered because the existing regulatory mechanisms fail to adequately control or mitigate the underlying threats.

Summary of Existing Regulatory Mechanisms

As discussed in detail in the Biological Report (Hill and Sadovy de Mitcheson 2013), a wide array of regulatory mechanisms exists throughout the range of Nassau grouper that are intended to limit harvest and thus maintain abundance. Existing regulatory mechanisms include minimum size restrictions, seasonal closures, spatial closures, and gear and access restrictions. We summarize some of these regulatory mechanisms below by country.

The Bahamas has implemented a number of regulatory mechanisms to limit harvest. In the 1980s, the Bahamas introduced a minimum size of 3 lbs. (1.36 kg) for Nassau grouper. This was followed in 1998 with a 10-day seasonal closure at several spawning aggregations. An annual ''two-month'' fishery closure was added in December 2003 to coincide with the spawning period and was extended to three months in 2005 to encompass the December through February spawning period. Up until 2015, the implementation of the 3-month closure was determined annually and could be shortened or otherwise influenced by such factors as the economy (Sadovy and Eklund 1999). In 2015, the annual assessment of the closure was removed ensuring a fixed 3-month closure each year moving forward (Fisheries Resources [Jurisdiction and Conservation] [Amendment] Regulations 2015). During the 3-month closure there is a national ban on Nassau grouper catches; however, the Bahamas Reef Educational Foundation (BREEF; unpub. data), has reported large numbers of fish being taken according to fisher accounts with photo-documentation and confirming reports of poaching of the species during the aggregation season.

The Bahamas has implemented several other actions that aid the conservation of Nassau grouper. There are marine parks in the Bahamas that are closed to fishing year round and therefore protect Nassau grouper. The Exuma Cays Land and Sea Park, first established in 1959, has been closed to fishing since 1986, thus protecting both nursery and adult habitat for Nassau grouper and other depleted marine species. Other sites, including the South Berry Islands Marine Reserve (established on December 29, 2008), Southwest New Providence National Park, and North Exumas Study Site have also been established and closed to fishing. Several gear restrictions in the Bahamas are also protective of Nassau grouper. Fishing with SCUBA and the use of explosives, poisons, and spearguns is prohibited in the Bahamas, although snorkeling with sling spears is allowed. The use of bleach or other noxious or poisonous substances for fishing, or possession of such substances on board a fishing vessel, without written approval of the Minister, is prohibited. Commercial fishing in the Bahamas is restricted to only the native population and, as a consequence, all vessels fishing within the Bahamas Exclusive Fishery Zone must be fully owned by a Bahamian citizen residing in the Bahamas.

In Belize, the first measure to protect Nassau grouper was a seasonal closure within the Glover's Reef Marine Reserve in 1993; the area was closed from December 1 to March 1 to protect spawning aggregations. A seasonal closure zone to protect Nassau grouper spawning aggregations was included when the Bacalar Chico marine reserve was established in 1996 (Paz and Truly 2007). Minimum and maximum capture sizes were later introduced (Hill and Sadovy de Mitcheson 2013 and citations therein).

In 2001 the Belize National Spawning Aggregation Working Group established protective legislation for 11 of the known Nassau grouper spawning sites within Belize. Seven of those 11 sites are monitored as regularly as possible. The Working Group meets regularly to share data and develop management strategies (*www.spagbelize.org;* retrieved on 15 April 2012). In 2003, Belize introduced a four-month closed season to protect spawning fish (O'Connor 2002, Gibson 2008). However, the 2003 legislation also allowed for exemptions to the closures by special license granted by the Fisheries Administrator, provided data be taken on any Nassau grouper removed. These special licenses made it difficult to enforce the national prohibition and in 2010 Belize stopped issuing permits to fish for Nassau grouper during the 4-month spawning period, except at Maugre Caye and Northern Two Caye.

In 2009, Belize issued additional protective measures to help manage and protect the Nassau grouper. These include minimum and maximum size limits of 20 inches and 30 inches, respectively. Belize has also introduced a plan to ban spear fishing within all marine reserves (yet to be implemented). Furthermore, as a large proportion of finfish are landed as fillets, the new regulations require that all Nassau grouper be landed whole, and if filleted must have a 1-inch by 2-inch skin patch (The Belize Spawning Aggregation Working Group 2009). Other gear restrictions are in place to generally aid in the management of reef fish, such as no spearfishing on compressed air.

Although Bermuda closed red hind aggregation sites in 1974, Nassau grouper aggregation sites located seaward of these sites were not included and continued to be fished. In 1990, a two-fish bag limit and minimum size restriction (35.6 cm FL) were enacted in Bermuda (Luckhurst 1996). Since 1996, Nassau grouper has been completely protected through a prohibition on take and possession and likely benefits from numerous no-take marine reserves (Hill and Sadovy de Mitcheson 2013).

In the Cayman Islands, the three main (''traditional'') grouper ''holes'' were officially protected in the late 1970's and only residents were allowed to fish by lines during the spawning season (Hill and Sadovy de Mitcheson 2013). In 1986, increasing complaints from fishermen of a decline in both numbers and size of Nassau grouper taken from the fishery prompted the implementation of a monitoring program by the Department of the Environment (Bush *et al.* 2006).

Following the development of the monitoring program, the Cayman Islands implemented a number of management measures. In the early 1990s, legislation prohibited spearfishing at spawning aggregation sites. In 1998, the three main grouper holes at the eastern end of the islands were formally designated as ''Restricted Marine Areas'' where access requires licensing by the Marine Conservation Board (Bush *et al.* 2006). In February 2002, protective legislation defined a spawning season as November 1 to March 31, and an ''Alternate Year Fishing'' rule was passed. This law allowed fishing of the spawning aggregations to occur every other year with the first non-fishing year starting in 2003. A catch limit of 12 Nassau grouper per boat, per day during fishing years was also set. The 2002 law defined a one nautical mile (nm) ''no trapping'' zone around each spawning site, and set a minimum size limit of 12 inches for Nassau grouper in response to juveniles being taken by fish traps inside the sounds (Whaylen *et al.* 2004, Bush *et al.* 2006). In 2003, spearguns were restricted from use within 1 nm of any designated grouper spawning area from November through March. In 2008, it was prohibited to take any Nassau grouper by speargun anywhere in Cayman waters. Effective December 29, 2003, the Marine Conservation Board, closed fishing at all designated Nassau grouper spawning sites for a period of 8 years. The conservation measure was renewed for a further 8 years in 2011.

In Cuba, there is a minimum size limit for Nassau grouper though this regulation is largely unprotective. The minimum size of 32 cm TL (or 570g) for Nassau grouper is less than the reported average size at maturity of 50 cm TL, indicating that Nassau grouper can be harvested before having the opportunity to reproduce. Of some benefit to Nassau grouper are more general fishing regulations such as bag limits for recreational fishing, regulations to increase selectivity of fishing gears to avoid the catch of juveniles, limits of net use during spawning aggregation time, and controls of speargun use, both commercially and recreationally. Marine protected areas have also been introduced throughout the country. In 2002, the total number of recreational licenses was limited to 3,500 for the whole country hoping to reduce directed fishing pressure nationally.

In Mexico, following scientific documentation of declines of Nassau grouper at Mahahual (Aguilar-Perera 1994), two regulations were enacted: (1) In 1993 spear-fishing was banned at any spawning aggregation site in southern Quintana Roo; and (2) in 1997 the fishing of any grouper species was banned during December and January (Aguilar-Perera 2006). Then, in 2003, a closed season for all grouper was implemented from February 15 to March 15 in all waters of the Mexican Exclusive Economic Zone. Although aimed at protecting red grouper this closure also protects Nassau grouper during a part of its spawning season (Aguilar-Perera *et al.* 2008). A management plan was to have gone into effect in 2012 to protect all commercially exploited groupers in Mexico's southern Gulf of Mexico and Caribbean Sea; yet at this time the plan has not been implemented.

In the Turks and Caicos Islands, the only documented Nassau grouper spawning aggregation site is protected from fishing in Northwest Point Marine National Park, Providenciales (DECR 2004; National Parks Ordinance and Subsidiary Legislation CAP. 80 of 1988). Similar to situations in other countries, protection of Nassau grouper habitat and spawning migration corridors on the narrow ledge of Caicos Bank is problematic as it would impose economic hardship on local fishers who depend on those areas for commercial species (*e.g.,* spiny lobsters) and subsistence fishing (Rudd 2001).

In U.S. federal waters, including those federal waters around Puerto Rico and the U.S.V.I., take and possession of Nassau grouper have been prohibited since 1990. Since 1993, a ban on fishing/possessing Nassau grouper was implemented for the state of Florida and has since been enacted in all U.S. state waters. The species was fully protected in both state and federal waters of Puerto Rico by 2004. The Caribbean Fishery Management Council, with support of local fishermen, established a no-take marine protected area off the southwest coast of St. Thomas, U.S.V.I. in 1990. This area, known as the Hind Bank Marine Conservation District (HBMCD), was intended to protect red hind and their spawning aggregations, as well as a former Nassau grouper spawning site (Brown 2007). The HBMCD was first subject to a seasonal closure beginning in 1990 (Beets and Friedlander 1999, Nemeth 2005, Nemeth *et al.* 2006) to protect spawning aggregations of red hind, and was later closed to fishing year-round in 1998 (DPNR 2005). Additional fishing restrictions in the U.S.V.I. such as gear restrictions, rules on the sale of fish, and protected areas such as the Virgin Islands Coral Reef National Monument and Buck Island Reef National Monument where all take is prohibited, Virgin Islands National Park (commercial fishing prohibited), and several U.S.V.I. marine reserves offer additional protection to Nassau grouper. In 2006, the U.S.V.I. instituted regulations to prohibit harvest and possession of Nassau grouper in territorial waters and filleting at sea was prohibited (García-Moliner and Sadovy 2008).

In Colombia, the San Andrés Archipelago has a number of areas that are designated as no-take fishing zones, and in 2000 the entire archipelago was declared by the United Nations Educational, Scientific and Cultural Organization (UNESCO) as the Seaflower Biosphere Reserve. In 2004, large portions of the archipelago were declared as a system of marine protected areas with varying zones of fisheries management; however, enforcement is largely lacking (M. Prada, Coralina, San Andres, Colombia, pers. comm. R. Hill, NMFS, 2010). Right-to-fish laws in Colombia also require that fishermen be allowed to fish at a subsistence level even within the no-take zones (M. Prada, Coralina, San Andres, Colombia, pers. comm. R. Hill, NMFS, 2010).

There are other Caribbean countries that have either few management measures in place or have yet to implement any conservation measures for Nassau grouper. We are not aware of special conservation or management regulations for Nassau grouper in Anguilla. In Antigua-Barbuda, while Nassau grouper is not specifically managed or protected, closed seasons were considered in 2008 for Nassau grouper and red hind, though the status of these closed seasons is not known. In the British Virgin Islands, there is a closed season for landing Nassau grouper between March 1 and May 31 (Munro and Blok 2005). In the Dominican Republic the catch and sale of ripe female Nassau grouper during the spawning season is not allowed (Bohnsack 1989, Sadovy and Eklund 1999, Box and Bonilla Mejia 2008) and at least one marine park has been established with fishing regulations. In Guadeloupe and Martinique, there are plans to protect the species (F. Gourdin, Regional Activity Center for Specially Protected Areas and Wildlife—UNEP, pers. comm. to Y. Sadovy, University of Hong Kong, 2011) although no details are available at this time. In Honduras, there is no legislation that controls fishing in the snapper/grouper fishery; however, traps and spears are illegal in the Bay Islands. There are no Nassau grouper special regulations in Jamaica; yet, some marine protected areas were designated in 2011.

Analysis of Existing Regulatory Mechanisms

The ERAG considered several threats under Factor D including law enforcement, international trade regulations, foreign regulations in their jurisdictional waters, U.S. federal laws, and U.S. state and territorial laws. The ERAG determined that these threats substantially contribute to the overall risk to the species. Inadequate law enforcement was noted by several ERAG members as influencing their scoring for abundance, fishing of spawning aggregations, commercial harvest, and historical harvest. Inadequate law enforcement led to higher risk scores for each of these threats. The ERAG scored law enforcement as a ''high risk'' threat for Nassau grouper. ERAG rankings for the other threats were widely distributed. The inadequacy of foreign regulations in jurisdictional waters was considered an ''increasing'' risk while the risk of international trade regulations was ''unknown.'' The remaining two categories of regulations (U.S. Federal and State of Florida/U.S. territory regulations) were considered ''low risk'' and ''moderate risk'' respectively. While the ERAG rankings for threats impacting the adequacy of regulatory mechanisms were generally moderate, we believe the concern about fishing at spawning aggregations (''high risk'' according to the ERAG) is due in part to the inadequacy of existing regulatory mechanisms.

Overall, we believe existing regulatory mechanisms throughout the species' range (international trade, foreign, U.S. federal, and U.S. state and territorial regulations) vary in their effectiveness, especially in addressing the most serious threat to Nassau grouper—fishing of spawning aggregations. In some countries, an array of national regulatory mechanisms, increases in marine protected areas, and customary management may be effective at addressing fishing of spawning aggregations. For example, the Exuma Cays Land and Sea Park (Bahamas), has been closed to fishing for over 25 years and protects both nursery and adult habitat for Nassau grouper and other marine species. In that park, there is a clear difference in the number, biomass, and size of Nassau grouper in comparison to adjacent areas where fishing is permitted (Sluka *et al.* 1997).

We note, however, that many countries have few, if any, specific Nassau grouper regulations. Instead they rely on general fisheries regulations (*e.g.,* Anguilla, Antigua-Barbuda, Colombia, and Cuba all rely only on size limits, while Guadeloupe and Martinique, Honduras, Jamaica, Mexico, St. Lucia, and the Turks and Caicos rely on a variety of general fishing regulations). Additionally, where Nassau grouper-specific regulations do exist, the ERAG scores indicated that law enforcement still presents a high risk threat to the species. We agree with the ERAG's risk assessment and believe that law enforcement in many foreign countries is less than adequate, thus rendering the regulations ineffective.

Some foreign regulations may be ephemeral, unprotective of migrating adults, or inadequate to conserve the viability of a species. In some cases, regulations do not completely protect all known spawning aggregations (*e.g.,* Belize, where 2 spawning aggregations are fished by license). In another instance, we found no protections for Nassau grouper in any foreign country during the period they move to and from spawning aggregation sites. Foreign regulations in some countries specify exemptions for ''historical,'' ''local,'' or artisanal fishermen (*e.g.,* Colombia). Finally, some particular types of regulations are insufficient to protect the species (*e.g.,* minimum size limits in both the Bahamas and Cuba are less than size-at-maturity).

In some places, such as Bermuda, no recovery has been documented after years of regulations (B. Luckhurst, Bermuda Department of Agriculture, Fisheries, and Parks, pers. comm. to Y. Sadovy, University of Hong Kong, September, 2012). In other places (*e.g.,* Cayman Islands) there are indications of potential recovery at spawning aggregation sites, but fishing continues to keep the population depressed (Semmens *et al.* 2012) and inconsistent surveys do not provide data adequate to realize impacts. Additionally, larval recruitment is highly variable due to currents in the Caribbean basin. Some populations may receive larval input from neighboring spawning aggregations, while other local circulation patterns may entrain larvae (Colin *et al.* 1987) making the population entirely self-recruiting.

In conclusion, although many countries have taken regulatory measures to conserve Nassau grouper, the species faces an ongoing threat due to the inadequacy of regulatory mechanisms to prevent or remediate the impacts of other threats that are elevating the species' extinction risk, particularly fishing of spawning aggregations.

E. Other Natural or Manmade Factors Affecting Its Continued Existence

The ERAG considered climate change as a threat to Nassau grouper including global warming, sea level rise, and ocean acidification for Factor E. Although Nassau grouper occur across a range of temperatures, spawning occurs when sea surface temperatures range between 25 °C–26 °C (Colin 1992, Tucker and Woodward 1996). Because Nassau grouper spawn in a narrow window of temperatures, a rise in sea surface temperature outside that range could impact spawning or shift the geographic range of it to overlap with waters within the required temperature parameters. Increased sea surface temperatures have also been linked to coral loss through bleaching and disease. Further, increased global temperatures are also predicted to change parasite-host relationships and may present additional unknown concerns (Harvell *et al.* 2002, Marcogliese 2001). Rising sea surface temperatures are also associated with sea level rise. If sea level changed rapidly, water depth at reef sites may be modified with such rapidity that coral and coral reefs could be affected (Munday *et al.* 2008).

Another potential effect of climate change could be the loss of structural habitat in coral reef ecosystems as ocean acidification is anticipated to affect the integrity of coral reefs (Munday *et al.* 2008). Bioerosion may reduce the 3-dimensional structure of coral reefs (Alvarez-Filip *et al.* 2009), reducing adult habitat for Nassau grouper (Coleman and Koenig 2010, Rogers and Beets 2001). Results of the ERAG scores indicated that climate change was an ''unknown risk'' to Nassau grouper. We agree with the assessment of the ERAG and believe there is not enough information at this time to determine how climate change is affecting the extinction risk of Nassau grouper now or in the foreseeable future.

The ERAG also considered threats from aquaculture to Nassau grouper under Factor E and determined that aquaculture was a ''very low'' risk threat to Nassau grouper. Experiments to determine the success rate of larval Nassau grouper culture (Watanabe *et al.* 1995a, 1995b) and survival of released hatchery-reared juveniles have been conducted and feasibility of restocking reefs has been tested (Roberts *et al.* 1995) in St. Thomas, U.S.V.I. However, the potential of Nassau grouper stock enhancement, as with any other grouper species, has yet to be determined (Roberts *et al.* 1995). Serious concerns about the genetic consequences of introducing Nassau grouper raised in facilities, possible problems of juvenile habitat availability, introduction of maladapted individuals, and the inability of stocked individuals to locate traditional spawning locations, continue to be raised. Given the number of concerns with aquaculture and the fact that some spawning aggregations remain, we believe that it is unlikely that Nassau grouper aquaculture will develop further. Therefore we agree with the ERAG that aquaculture presents a very low extinction risk to Nassau grouper and is not contributing to the species' current status.

Demographic factors of abundance, population growth rate/productivity and diversity were also considered by the ERAG under Factor E. Each ERAG member considered whether the species is likely to be able to maintain a sustainable population size and adequate genetic diversity. They also considered whether the species is at risk due to a loss in the breeding population, which leads to a reduction in survival and production of eggs and offspring. Trends or shifts in demographic or reproductive traits were considered when assessing the ranking of threats by each ERAG member to identify a decline in population growth rate. The ERAG scores indicated that abundance of Nassau grouper was a ''moderate risk,'' growth rate/productivity was an ''increasing risk,'' and that diversity was a ''moderate risk.'' We agree with these rankings and believe they are supported by the declining number and size of spawning aggregations, which affects growth rate/productivity and diversity.

NMFS's Conclusions From Threats Evaluation

The most serious threats to Nassau grouper are fishing at spawning aggregations and inadequate law enforcement. These threats, considered under Factors B and D, were rated by the ERAG as ''high risk'' threats to the species. We agree with the ERAG's assessment that these threats are currently affecting the status of Nassau grouper, putting it at a heightened risk of extinction. A variety of other threats were identified by the ERAG as also impacting the status of this species. Growth rate/productivity (Factor E), spatial structure/connectivity (Factors A and E), and effectiveness of foreign regulations (Factor D) were identified by the ERAG as ''increasing risks.'' Artificial selection (Factor B), abundance (Factors B and E), diversity (Factor E), commercial harvest (Factors B and D), and effectiveness of state and territory regulations (Factor D) were determined to be ''moderate risks.'' NMFS concurs that these threats have the potential to adversely affect the status of Nassau grouper over the foreseeable future.

Extinction Risk Analysis

We must assess the ERA results and make a determination as to whether the Nassau grouper is currently in danger of extinction, or likely to become so within the foreseeable future. We first evaluated the current status of the Nassau grouper in light of the four demographic factors. Based on our assessment of the ERA in regards to these demographic factors (abundance, growth rate/productivity, spatial structure and connectivity, and diversity) we do not believe the Nassau grouper is currently in danger of extinction. Each of these demographic factors was ranked by the ERAG as a moderate or increasing risk to the species' current status.

We acknowledge that the abundance of Nassau grouper has been dramatically reduced in relation to historical records, but we do not believe abundance is currently so low that the species is at risk of extinction from stochastic events, environmental variation, anthropogenic perturbations, lack of genetic diversity, or depensatory processes. Although the reduced abundance of Nassau grouper has diminished the size and number of spawning aggregations, spawning is still occurring and abundance is increasing in some locations (*e.g.* Cayman Islands and Bermuda) where adequate protections are effectively being implemented. The abundance of Nassau grouper is now patchily distributed throughout the Caribbean with areas of higher abundance correlated with those areas with effective regulations. We believe the abundance of Nassau grouper in these protected areas is large enough to sustain the overall population and limit extinction risk. However, we also believe that further regulations will be necessary in other countries to counteract past population declines and ultimately recover the population of Nassau grouper throughout the Caribbean.

Abundance is closely related with the other three demographic factors. Growth rate/productivity, spatial structure and connectivity, and diversity are all negatively affected by decreased abundance associated with overexploitation. Historical overfishing has led to a decreased average length and earlier age at maturity in exploited populations, which affects the species' ability to maintain the population growth rate above replacement level. Reductions in the number and distribution of spawning aggregations has the potential to affect larval and juvenile dispersal. This can further affect genetic diversity within the population. However, we don't believe that any of these demographic factors have been adversely affected to the point that Nassau grouper is currently in danger of extinction. As described previously, the species continues to occupy its current range, spawning is still occurring in several locations thus continuing to deliver new recruits to the population, and recovery of spawning aggregations has been documented in locations with adequate regulatory mechanisms and enforcement. The size of Nassau grouper is also increasing in areas where protections are in place (*e.g.,* Belize and U.S.V.I.), indicating that current abundance is not adversely affecting growth rate and productivity at these locations.

After considering the current status of Nassau grouper based on the four demographic factors, we next assessed how the identified threats are expected to affect the status of the species, including its demographic factors, over the foreseeable future. The ERAG identified a variety of threats that have the potential to impact Nassau grouper. The ERAG ranked and we agreed that several threats (habitat alteration, disease, aquaculture, and U.S. federal regulations) ranked as ''very low'' or ''low'' risk, will have little to no effect on the extinction risk of Nassau grouper within the foreseeable future. Several other threats (commercial harvest, artificial selection, foreign regulations within jurisdictional waters, and regulations of the U.S. and its territories), were ranked as moderate or increasing risks to the status of Nassau grouper. We agree that collectively these threats could cause Nassau grouper to become in danger of extinction within the foreseeable future.

Finally, the ERAG identified three threats that present a ''high'' risk to the status of Nassau grouper over the foreseeable future. We agree with the ERAG's assessment that fishing of spawning aggregations combined with inadequate law enforcement is currently adversely affecting the status of Nassau grouper as discussed above, but disagree with the ERAG's ranking of historic harvest as a high risk. These high risk threats will continue to elevate the extinction risk of Nassau grouper over the foreseeable future. Both threats directly affect the current abundance of the species, its ability to maintain population growth rate, the population structure of the species, and its diversity in terms of genetics and overall ecology.

As previously described, the ERAG analyzed inadequate law enforcement as a standalone threat under Factor D, inadequacy of existing regulatory mechanisms, and ranked it as a ''high risk'' threat. We agree that existing regulations, and enforcement of existing regulations, are inadequate to control the threat posed by fishing on spawning aggregations, and thus this threat under Factor D is contributing to the extinction risk and status of Nassau grouper.

Based on the information in the Biological Report and the results from the ERA, we conclude that ESA Factors B (overutilization for commercial, recreational, scientific, or educational purposes), D (inadequacy of regulatory mechanisms), and E (other natural or manmade factors) are contributing to a threatened status for Nassau grouper. Overutilization in the form of historical harvest has reduced population size and led to the collapse of spawning aggregations in many locations. While some countries have made efforts to curb harvest, fishing at spawning aggregation sites remains a ''high risk'' threat. Further contributing to the risk of Nassau grouper extinction is the inadequacy of regulatory control and law enforcement, which leads to continued overutilization (low abundance), reduced reproductive output, and reduced recruitment. If growth and sexual recruitment rates cannot balance the loss from these threats, populations will become more vulnerable to extinction over the future (Primack 1993).

Protective Efforts

Section 4(b)(1)(A) of the ESA requires the Secretary, when making a listing determination for a species, to take into consideration those efforts, if any, being made by any State or foreign nation to protect the species. To evaluate the efficacy of domestic efforts that have not yet implemented or that have been implemented, but have not yet demonstrated to be effective, the Services developed a joint ''Policy for Evaluation of Conservation Efforts When Making Listing Decisions'' (''PECE''; 68 FR 15100; March 28, 2003).

The PECE is designed to ensure consistent and adequate evaluation on whether domestic conservation efforts that have been recently adopted or implemented, but not yet proven to be successful, will result in recovering the species to the point at which listing is not warranted or contribute to forming the basis for listing a species as threatened rather than endangered. The PECE is expected to facilitate the development of conservation efforts by states and other entities that sufficiently improve a species' status so as to make listing the species as threatened or endangered unnecessary.

The PECE establishes two overarching criteria to use in evaluating efforts identified in conservations plans, conservation agreements, management plans or similar documents: (1) The certainty that the conservation efforts will be implemented; and (2) the certainty that the efforts will be effective. While section 4(b)(1)(A) requires that we evaluate both domestic and foreign conservation efforts, it does not set out particular criteria for doing so. While the particular framework of the PECE policy only directly applies to consideration of domestic efforts, we have discretion to evaluate foreign efforts using a similar approach and find that it is reasonable to do so here. In our discretion, we evaluated foreign conservation efforts to protect and recover Nassau grouper that are either underway, but not yet fully implemented, or are only planned, using these overarching criteria.

Conservation efforts with the potential to address identified threats to Nassau grouper include, but are not limited to, fisheries management plans, education about overfishing and fishing of spawning aggregations, and projects addressing the health of coral reef ecosystems. These conservation efforts may be conducted by countries, states, local governments, individuals, NGOs, academic institutions, private companies, individuals, or other entities. They also include global conservation organizations that conduct coral reef and/or marine environment conservation projects, global coral reef monitoring networks and research projects, regional or global conventions, and education and outreach projects throughout the range of Nassau grouper.

The Biological Report summarizes known conservation efforts, including those that have yet to be fully implemented or have yet to demonstrate effectiveness. Conservation efforts that we considered that are yet to be fully implemented include Mexico's 2012 proposed management plan, Antigua-Barbuda's 2008 closed season proposal, and Guadeloupe and Martinique's plans to protect the species. Because these proposed plans are several years old with no updates or known implementation, we find that there is not a sufficient basis to conclude that there is a reasonable certainty of implementation or effectiveness. We also considered the marine protected areas implemented by Jamaica in 2011, though based on Jamaica's historic overfishing and difficulty in enforcing existing regulations, we find that there is not a sufficient basis to conclude that these marine protected areas present a reasonable certainty of effectiveness in reducing threats that contribute to Nassau grouper's extinction risk. We carefully considered the other conservation efforts summarized in the Biological Report and acknowledge that time is required to see the benefit of mature adults in the spawning aggregations; however, the continued decline in number and size of Nassau grouper spawning aggregations indicates the effectiveness of those conservation efforts is currently unknown and thus there is insufficient basis to conclude there is a reasonable certainty of effectiveness. While some conservation efforts have been partially successful on localized scales, Nassau grouper appear to still be overutilized and at heightened risk of extinction based on the ERA. After taking into account these conservation efforts, our evaluation of the section 4(a)(1) factors is that the conservation efforts do not reduce the risk of extinction of Nassau grouper to the point at which listing is not warranted.

Significant Portion of Range

There are two situations under which a species is eligible for listing under ESA: A species may be endangered or threatened throughout all of its range or a species may be endangered or threatened throughout only a ''significant portion of its range'' (SPOIR). Although the ESA does not define ''SPOIR,'' NMFS and the U.S. Fish and Wildlife Service (USFWS) published a final policy clarifying their interpretation of this phrase (79 FR 37577; July 7, 2014). Under the policy, if a species is found to be endangered or threatened throughout only a significant portion of its range, the entire species is subject to listing and must be protected everywhere. A portion of a species' range is ''significant'' if ''. . . the species is not currently endangered or threatened throughout its range, but the portion's contribution to the viability of the species is so important that, without the members in that portion, the species would be in danger of extinction, or likely to become so in the foreseeable future, throughout all of its range.'' Thus, if the species is found to be threatened or endangered throughout its range, we do not separately evaluate portions of the species' range.

Although the SPOIR Policy had yet to go into effect during our status review of Nassau grouper, we considered the interpretations and principles contained in the 2014 Draft Policy with regards to the Nassau grouper and completed an assessment of potential ''SPOIR,'' which is documented in the ERA. However, throughout the status review process NMFS determined threats and risks to the status of Nassau grouper are affecting the species over the entirety of its range. Because the threats and risks are widespread throughout the entire range of this species, there is no portion of the range that can be considered ''significant.''

Listing Determination

Based on the Biological Report, the Threats Evaluation, the Extinction Risk Analysis, and Protective Efforts we determined that the Nassau grouper warrants a threatened status under the ESA. We summarize the results of our comprehensive status review as follows: (1) The species is made up of a single population over a broad geographic range, and its current range is indistinguishable from its historical range; (2) the species possesses life history characteristics that increase vulnerability to unregulated harvest; (3) historical harvest greatly diminished the population of Nassau grouper and the species has yet to recover from this overexploitation; (4) spawning aggregations have drastically declined in size and number across the species' range; (5) there are two threats the ERAG rated as ''high risk,'' that we agree are affecting the current status of the species and will continue to do so over the foreseeable future—fishing at spawning aggregations and inadequate law enforcement; and (6) historical harvest has abated, though existing regulatory mechanisms and law enforcement have not been effective in preventing fishing at many spawning aggregation sites. Conservation efforts in some nations (U.S., Puerto Rico, U.S.V.I., and Belize) have almost certainly prevented further declines. Given the life history characteristics of Nassau grouper, more time will be needed to determine if these protective measures are successful in recovering the population. Collectively, the information obtained during the status review indicates the species is not currently in danger of extinction (though reduced in number, the species maintains its historical range and still forms spawning aggregations at some sites), but it is likely to become endangered within the foreseeable future (based on continued risk of harvest, especially at spawning aggregation sites inadequately controlled by regulations and law enforcement). Accordingly, we have determined that the Nassau grouper warrants listing as a threatened species under the ESA.

Effects of Listing

Conservation measures provided for species listed as endangered or threatened under the ESA include recovery plans (16 U.S.C. 1533(f)), critical habitat designations (16 U.S.C. 1533(a)(3)(A)), Federal agency consultation requirements (16 U.S.C. 1536), and protective regulations (16 U.S.C. 1533(d)). Recognition of the species' status through listing promotes conservation actions by Federal and state agencies, private groups, and individuals, as well as the international community. Both a recovery program and designation of critical habitat could result from this final listing. Given its broad range across the Caribbean Sea, a regional cooperative effort to protect and restore Nassau grouper is necessary. We anticipate that protective regulations for Nassau grouper will also be necessary for the conservation of the species. Federal, state, and the private sectors will need to cooperate to conserve listed Nassau grouper and the ecosystems upon which they depend.

Identifying ESA Section 7 Consultation Requirements

Section 7(a)(2) of the ESA and NMFS/FWS regulations require Federal agencies to consult with us on any actions they authorize, fund, or carry out if those actions may affect the listed species or designated critical habitat. Based on currently available information, we can conclude that examples of Federal actions that may affect Nassau grouper include, but are not limited to, artificial reef creation, dredging, pile-driving, military activities, and fisheries management practices.

Critical Habitat

Critical habitat is defined in section 3 of the ESA (16 U.S.C. 1532(5)) as: (1) The specific areas within the geographical area occupied by a species, at the time it is listed in accordance with the ESA, on which are found those physical or biological features (a) essential to the conservation of the species and (b) that may require special management considerations or protection; and (2) specific areas outside the geographical area occupied by a species at the time it is listed upon a determination that such areas are essential for the conservation of the species. ''Conservation'' means the use of all methods and procedures needed to bring the species to the point at which listing under the ESA is no longer necessary. Critical habitat may also include areas unoccupied by Nassau grouper if those areas are essential to the conservation of the species.

Section 4(a)(3)(A) of the ESA (16 U.S.C. 1533(a)(3)(A)) requires that, to the maximum extent prudent and determinable, critical habitat be designated concurrently with the listing of a species. Pursuant to 50 CFR 424.12(a), designation of critical habitat is not determinable when one or both of the following situations exist: Data sufficient to perform required analyses are lacking; or the biological needs of the species are not sufficiently well known to identify any area that meets the definition of ''critical habitat.'' Although we have gathered information through the status review and public comment periods on the habitats occupied by this species, we currently do not have enough information to determine what physical and biological features within those habitats facilitate the species' life history strategy and are thus essential to the conservation of Nassau grouper, and may require special management considerations or protection. To the maximum extent prudent and determinable, we will publish a proposed designation of critical habitat for Nassau grouper in a separate rule. Designations of critical habitat must be based on the best scientific data available and must take into consideration the economic, national security, and other relevant impacts of specifying any particular area as critical habitat. Once critical habitat is designated, section 7 of the ESA requires Federal agencies to ensure that they do not fund, authorize, or carry out any actions that are likely to destroy or adversely modify that habitat. This requirement is in addition to the section 7 requirement that Federal agencies ensure that their actions do not jeopardize the continued existence of listed species.

Identification of Those Activities That Would Constitute a Violation of Section 9 of the ESA

Because we are proposing to list Nassau grouper as threatened, the ESA section 9 prohibitions do not automatically apply. Therefore, pursuant to ESA section 4(d), we will evaluate whether there are protective regulations we deem necessary and advisable for the conservation of Nassau grouper, including application of some or all of the take prohibitions. If protective regulations are deemed necessary, a proposed 4(d) rule would be subject to public comment.

Policies on Peer Review

In December 2004, the Office of Management and Budget (OMB) issued a Final Information Quality Bulletin for Peer Review establishing minimum peer review standards, a transparent process for public disclosure of peer review planning, and opportunities for public participation. The OMB Bulletin, implemented under the Information Quality Act (Pub. L. 106–554) is intended to enhance the quality and credibility of the Federal government's scientific information, and applies to influential or highly influential scientific information disseminated on or after June 16, 2005. To satisfy our requirements under the OMB Bulletin, we obtained independent peer review of the Biological Report. Five independent specialists were selected from the academic and scientific community, Federal and state agencies, and the private sector for this review (with three respondents). All peer reviewer comments were addressed prior to dissemination of the final Biological Report and publication of this final rule.

Solicitation of Information

We are soliciting information on features and areas that may support designation of critical habitat for Nassau grouper. Information provided should identify the physical and biological features essential to the conservation of the species and areas that contain these features. Areas outside the occupied geographical area should also be identified if such areas themselves are essential to the conservation of the species. Essential features may include, but are not limited to, features specific to the species' range, habitats, and life history characteristics within the following general categories of habitat features: (1) Space for individual growth and for normal behavior; (2) food, water, air, light, minerals, or other nutritional or physiological requirements; (3) cover or shelter; (4) sites for reproduction and development of offspring; and (5) habitats that are protected from disturbance or are representative of the historical, geographical, and ecological distributions of the species (50 CFR 424.12(b)). ESA implementing regulations at 50 CFR 424.12(h) specify that critical habitat shall not be designated within foreign countries or in other areas outside of U.S. jurisdiction. Therefore, we request information only on potential areas of critical habitat within waters in U.S. jurisdiction.

For features and areas potentially qualifying as critical habitat, we also request information describing: (1) Activities or other threats to the essential features or activities that could be affected by designating them as critical habitat, and (2) the positive and negative economic, national security and other relevant impacts, including benefits to the recovery of the species, likely to result if these areas are designated as critical habitat.

References

A complete list of the references used in this final rule is available at: (*http://sero.nmfs.noaa.gov/protected_resources/listing_petitions/species_esa_consideration/index.html*).

Classifications

National Environmental Policy Act

The 1982 amendments to the ESA, in section 4(b)(1)(A), restrict the information that may be considered when assessing species for listing. Based on this limitation of criteria for a listing decision and the opinion in *Pacific Legal Foundation* v. *Andrus,* 675 F. 2d 825 (6th Cir. 1981), NMFS has concluded that ESA listing actions are not subject to the environmental assessment requirements of the National Environmental Policy Act (See NOAA Administrative Order 216–6).

Executive Order 12866, Regulatory Flexibility Act and Paperwork Reduction Act

As noted in the Conference Report on the 1982 amendments to the ESA, economic impacts cannot be considered when assessing the status of a species. Therefore, the economic analysis requirements of the Regulatory Flexibility Act are not applicable to the listing process. In addition, this final rule is exempt from review under Executive Order 12866. This final rule does not contain a collection-of-information requirement for the purposes of the Paperwork Reduction Act.

Executive Order 13132, Federalism

In keeping with the intent of the Administration and Congress to provide continuing and meaningful dialogue on issues of mutual state and Federal interest, the proposed rule was provided to the relevant agencies in each state in which the subject species occurs, and these agencies were invited to comment. We did not receive comments from any state agencies.

Executive Order 12898, Environmental Justice

Executive Order 12898 requires that Federal actions address environmental justice in the decision-making process. In particular, the environmental effects of the actions should not have a disproportionate effect on minority and low-income communities. This final rule is not expected to have a disproportionately high effect on minority populations or low-income populations.

List of Subjects in 50 CFR Part 223

Endangered and threatened species, Exports, Transportation.

Dated: June 21, 2016.

Samuel D Rauch, III,

Deputy Assistant Administrator for Regulatory Programs, National Marine Fisheries Service.

For the reasons set out in the preamble, we amend 50 CFR part 223 as follows:

PART 223—THREATENED MARINE AND ANADROMOUS SPECIES

■ 1. The authority citation for part 223 continues to read as follows:

Authority: 16 U.S.C. 1531–1543; subpart B, § 223.201–202 also issued under 16 U.S.C. 1361 *et seq.;* 16 U.S.C. 5503(d) for § 223.206(d)(9).

■ 2. In § 223.102, amend the table in paragraph (e) by adding an entry under the ''Fishes'' subheading for ''Grouper, Nassau'' in alphabetical order to read as follows:

§ 223.102 Enumeration of threatened marine and anadromous species.

* * * * *

(e) * * *

Species [1]			Citation(s) for listing determination(s)	Critical habitat	ESA rules
Common name	Scientific name	Description of listed entity			
*	*	*	* *	*	*
FISHES					
*	*	*	* *	*	*
Grouper, Nassau	*Epinephelus striatus*	Entire species	*[Insert **Federal Register** citation],* June 29, 2016.	NA	NA
*	*	*	* *	*	*

[1] Species includes taxonomic species, subspecies, distinct population segments (DPSs) (for a policy statement, see 61 FR 4722, February 7, 1996), and evolutionarily significant units (ESUs) (for a policy statement, see 56 FR 58612, November 20, 1991).

* * * * *

[FR Doc. 2016–15101 Filed 6–28–16; 8:45 am]

BILLING CODE 3510–22–P

DEPARTMENT OF COMMERCE

National Oceanic and Atmospheric Administration

50 CFR Part 600

[Docket No. 111014628–6513–02]

RIN 0648–BB54

Magnuson-Stevens Fishery Conservation and Management Act Provisions; Implementation of the Shark Conservation Act of 2010

AGENCY: National Marine Fisheries Service (NMFS), National Oceanic and Atmospheric Administration (NOAA), Commerce.

ACTION: Final rule.

SUMMARY: This final action updates agency regulations consistent with provisions of the Shark Conservation Act of 2010 (SCA) and prohibits any person from removing any of the fins of a shark at sea, possessing shark fins on board a fishing vessel unless they are naturally attached to the corresponding carcass, transferring or receiving fins from one vessel to another at sea unless the fins are naturally attached to the corresponding carcass, landing shark fins unless they are naturally attached to the corresponding carcass, or landing shark carcasses without their fins naturally attached. This action amends existing regulations and makes them consistent with the SCA.

DATES: Effective July 29, 2016.

ADDRESSES: Copies of the Environmental Assessment (EA)/Regulatory Impact Review (RIR)/Final Regulatory Flexibility Analysis (FRFA) prepared for this action can be obtained from: Erin Wilkinson, National Marine Fisheries Service, 1315 East-West Highway, Room 13437, Silver Spring MD 20910. An electronic copy of the EA/RIR/FRFA document as well as copies of public comments received can be viewed at the Federal e-rulemaking portal: *http://www.regulations.gov/* (Docket ID: NOAA–NMFS–2012–0092).

FOR FURTHER INFORMATION CONTACT: Erin Wilkinson by phone at 301–427–8561, or by email: *erin.wilkinson@noaa.gov* or *sca.rulemaking@noaa.gov.*

SUPPLEMENTARY INFORMATION:

I. Overview of the Shark Conservation Act

Background information and an overview of the Shark Conservation Act can be found in the preamble of the proposed rule published on May 2, 2013 (78 FR 25685). Copies are available from NMFS (see **ADDRESSES**), or can be viewed electronically at the Federal E-Rulemaking portal for this action: *http://www.regulations.gov.*

II. Major Components of the Final Action

Retaining a shark fin while discarding the shark carcass (shark finning) has been prohibited in the United States since the 2000 Shark Finning Prohibition Act. The 2010 SCA included provisions that amended the Magnuson-Stevens Fishery Conservation and Management Act (MSA) to prohibit any person from: (1) Removing any of the fins of a shark (including the tail) at sea; (2) having custody, control, or possession of a fin aboard a fishing vessel unless it is naturally attached to the corresponding carcass; (3) transferring a fin from one vessel to another vessel at sea, or receiving a fin in such transfer, unless the fin is naturally attached to the corresponding carcass; or (4) landing a fin that is not naturally attached to the corresponding carcass, or landing a shark carcass without its fins naturally attached. For the purpose of the SCA and these regulations, ''naturally attached,'' with respect to a shark fin, means to be attached to the corresponding shark carcass through some portion of uncut skin.

This action amends NMFS' regulations consistent with these provisions of the SCA. Specifically, the rule amends regulations at 50 CFR part 600, subpart N, to prohibit the removal of shark fins at sea, namely, the possession, transfer and landing of shark fins that are not naturally attached to the corresponding carcass, and the landing of shark carcasses without the corresponding fins naturally attached. In the preamble to the proposed rule, NMFS noted that it interprets the prohibitions in subpart N as applying to sharks, not skates and rays, and solicited public comment on whether clarification was needed in the regulatory text on this issue. See 78 FR 25685, 25686 (May 2, 2013). NMFS received only one public comment on this point, which was supportive of this interpretation, and NMFS thus affirms in this final rule that the prohibitions do not apply to skates and rays.

This final rule also updates subpart N to be consistent with section 103(b) of the SCA regarding an exception for individuals engaged in commercial fishing for smooth dogfish. Interpretation of that exception was addressed in a rule finalized in November 2015, for Amendment 9 to the 2006 Consolidated Atlantic Highly Migratory Species Fishery Management Plan (November 24, 2015; 80 FR 73128). That final rule, among other things, allows for the at-sea removal of smooth dogfish fins provided that fishing occurs within 50 nautical miles of shore along the Atlantic Coast from Maine through the east coast of Florida; smooth dogfish fin weight does not exceed 12 percent of the carcass weight on board; smooth dogfish make up at least 25 percent of the total retained catch, by weight; and the fisherman/vessel holds both federal and state permits appropriate for the retention of smooth dogfish.

This final rule also combines the existing §§ 600.1203 and 600.1204 into one section. The text throughout 50 CFR part 600, subpart N, is amended to make it consistent with the provisions of the SCA.

The MSA authorizes the Secretary to regulate fisheries seaward of the inner boundary of the U.S. exclusive economic zone (EEZ), which is defined as a line coterminous with the seaward boundary of each U.S. coastal state. 16 U.S.C. 1802(11). Thus, as noted in the proposed rule, the SCA provisions apply to any person subject to the jurisdiction of the United States, including persons on board U.S. and foreign vessels, engaging in activities prohibited under the statute with respect to sharks harvested seaward of the inner boundary of the EEZ. See 78 FR 25685, 25686 (May 2, 2013). Federal regulations pertaining to the conservation and management of specific shark fisheries are set forth in parts 635, 648, and 660 of title 50 of the Code of Federal Regulations. For Atlantic highly migratory species fisheries, as a condition of its Federal permit, a vessel's fishing, catch, and gear are subject to federal requirements even when fishing in state waters. See 50 CFR 635.4(a)(10) (noting also that, when fishing within the waters of a state with more restrictive regulations, persons aboard the vessel must comply with those requirements). This rule amends 50 CFR part 600, subpart N, and does not supersede or amend any other federal regulation or requirement related to the conservation and management of sharks.

The SCA also amended the High Seas Driftnet Fishing Moratorium Protection Act, which provides for identification and certification of nations to address illegal, unreported, or unregulated fishing; bycatch of protected living marine resources; and, as amended by the SCA, shark catches. 16 U.S.C. 1826h–1826k. With regard to sharks, the High Seas Driftnet Fishing Moratorium

Spawning Aggregations Workshop Report

FIRST MEETING OF THE CFMC/WECAFC/OSPESCA/CRFM WORKING GROUP ON SPAWNING AGGREGATIONS

Miami, United States of America, 29–31 October 2013

Appendix C

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WESTERN CENTRAL ATLANTIC FISHERY COMMISSION

Report of the

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FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS
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PREPARATION OF THIS DOCUMENT

This is the report of the first meeting of the Caribbean Fisheries Management Council (CFMC), the Western Central Atlantic Fishery Commission (WECAFC), the Central American Organization of the Fisheries and Aquaculture Sector (OSPESCA), and the Caribbean Regional Fishery Mechanism (CRFM) Working Group on Spawning Aggregations, held in Miami, from 29 to 31 October 2013.

The joint Working Group was established by the fourteenth session of WECAFC in February 2012 and this first meeting was co-organized and sponsored by the CFMC of the United States Department of Commerce, WECAFC and FAO.

The FAO Secretariat to the meeting consisted of Dr Raymon van Anrooy, WECAFC Secretary. Administrative and logistical support was provided by CFMC, and coordinated by Mr Miguel Rolon, Executive Director of CFMC and convener of this Working Group, with assistance from Ms Diana Martino and Ms Maria de los Angeles Irizarry. Dr Yvonne Sadovy of the University of Hong Kong, technically coordinated and facilitated the meeting.

This report contains a summary of the presentations, discussions, conclusions and recommendations of the meeting. The conclusions adopted and recommendations made are presented in the form of a “Declaration of Miami” and a Recommendation to the fifteenth session of WECAFC on the establishment of a regional closed season for fisheries in the WECAFC area to protect spawning aggregations of groupers and snappers. The national summary reports presentenced at the meeting will be published separately with support from CFMC.

FAO Western Central Atlantic Fishery Commission. 2014.
Report of the first meeting of the CFMC/WECAFC/OSPESCA/CRFM Working Group on Spawning Aggregations, Miami, United States of America, 29–31 October 2013.
FAO Fisheries and Aquaculture Report. No. 1059. Bridgetown, Barbados, FAO. 29 pp.

ABSTRACT

The first meeting of the CFMC/WECAFC/OSPESCA/CRFM Working Group on Spawning Aggregations, was held in Miami, United States of America from 29 to 31 October 2013. The meeting brought together 23 experts working on spawning aggregations of fishes from all over the Western Central Atlantic region. The Working Group noted with concern the ongoing declines in stocks of many aggregating species and particularly groupers and snappers in the Wider Caribbean Region, the reduced numbers of their aggregations and the relatively smaller size of remaining aggregations. The Working Group also verified that the status of Nassau Grouper, Goliath Grouper (and several other species) stocks in the Wider Caribbean Region should be considered “overexploited”, and that some stocks can even be regarded as “depleted”. The Working Group further emphasized the high ecological and biological value of reef fishes that aggregate to spawn (including groupers and snappers) for the ecosystem and aquatic biodiversity in the region, as well as for achieving regional food security and livelihood objectives. The Working Group compiled information on the spawning fish aggregation management and conservation measures in place and examined their effectiveness. The meeting issued a “Declaration of Miami”, which included a recommendation to the fifteenth session of WECAFC on the establishment of a regional closed season for Nassau Grouper fisheries in the WECAFC area to protect spawning aggregations of this species.

CONTENTS

ABBREVIATIONS AND ACRONYMS

CFMC	Caribbean Fishery Management Council
CITES	Convention on International Trade in Endangered Species of Wild Fauna and Flora
CRFM	Caribbean Regional Fisheries Mechanism
EEZ	exclusive economic zone
ESA	Endangered Species Act (USA)
FSA	fish spawning aggregation
GCFI	Gulf and Caribbean Fisheries Institute
INPESCA	Institute for Fisheries and Aquaculture (Nicaragua)
IUCN	International Union for Conservation of Nature
MPAs	marine protected areas
MSC	Marine Stewardship Council
NGO	non-governmental organization
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration (USA)
OSPESCA	Central American Organization of the Fisheries and Aquaculture Sector
SAG	Scientific Advisory Group
SCRFA	Society for the Conservation of Reef Fish Aggregations
SIDS	Small Island Developing States
SPAW Protocol	Protocol Concerning Specially Protected Areas and Wildlife
STAC	Scientific Meeting and Technical Advisory Committee
Code	Code of Conduct for Responsible Fisheries (FAO)
USVI	United States Virgin Islands
WECAFC	Western Central Atlantic Fishery Commission

INTRODUCTION

1. Spawning Aggregations of reef fishes, particularly groupers, have been the focus of various regional meetings in the Caribbean. A Regional Workshop on Nassau grouper, which was coordinated by the Caribbean Fishery Management Council (CFMC) and the Western Central Atlantic Fishery Commission (WECAFC), was held on 20 and 21 October 2008, prior to the thirteenth session of WECAFC. The National Oceanographic and Atmospheric Administration (NOAA) and the National Marine Fisheries Service (NMFS) of the United States of America sponsored that workshop. Representatives from 17 countries attended the workshop. The two main items on the agenda were: a regional summary of the status of the Nassau grouper fishery in the region and the compilation of country status reports The Regional Workshop made various recommendations which were presented to WECAFC. These recommendations included:

a) a proposal for establishment of a WECAFC/CFMC ad hoc Working Group on Nassau Grouper;
b) that management of Nassau Grouper be more effective at the national level;
c) closed seasons are one of the most effective ways to protect spawning aggregations, when the species is more vulnerable to fishing; and
d) countries that do not have a closed season from December to February should establish one.

2. The thirteenth session of WECAFC (Colombia, October 2008) endorsed the recommendations and added that the main purpose of the Working Group is to foster regional cooperation in the management and conservation and restoration of Nassau grouper stocks in the WECAFC region; and to include coordination and harmonization of efforts for the management and conservation of the Nassau grouper. The thirteenth session recommended a regional coherent management approach, supported by national level implementation efforts.

3. Various Gulf and Caribbean Fisheries Institute (GCFI) annual conferences in recent years incorporated sessions or presentations on Spawning Aggregations or Nassau Grouper management and conservation. Moreover, the Society for Conservation of Reef Fish Aggregations (SCRFA) (later revised to Science and Conservation of Fish Aggregations) has been very active in raising awareness and building capacity on aggregations over the last decade. Numerous scientists, researchers, fishers and projects have been working on spawning aggregations and related issues lately.

4. At the fourteenth session of WECAFC, held in Panama City in February 2012, the Commission noted the limited activities of the Working Group on Nassau Grouper and Mr Miguel Rolon (CFMC) kindly offered to revive the working group as CFMC/WECAFC/OSPESCA/CRFM Working Group on Spawning Aggregations. The respective terms of reference were developed and endorsed by WECAFC (available in Appendix E) and funding was sought in support of Working Group activities. Mr Rolon called, as convener, the Working Group together to meet in Miami, United States of America. Moreover, Dr Sadovy compiled a status report on Nassau grouper which was delivered to the CFMC following the thirteenth session of WECAFC.

5. The principal objective of this first Working Group meeting was to bring together key experts to examine the available biological and socio-economic information from Caribbean countries involved in the fisheries of groupers and snappers and other species that aggregate to spawn. It was aimed to use the information to provide (as Working Group) advice on the management and implementation of regional strategies and regulations to protect spawning aggregations.

OPENING OF THE MEETING

6. The first meeting of the CFMC/WECAFC/OSPESCA/CRFM Working Group on Spawning Aggregations was held in Miami from 29 to 31 October 2013. The meeting was kindly hosted by the

Caribbean Fisheries Management Council (CFMC). Welcoming remarks were delivered by Mr Miguel Rolon on behalf of CFMC and as convener of the Working Group, and by Dr Raymon van Anrooy on behalf of FAO/WECAFC.

ATTENDANCE

7. The following countries and territories attended the meeting: Bahamas, Belize, Brazil, Caribbean Netherlands, Cayman Islands, Cuba, China (Hong Kong SAR), Mexico, Nicaragua, Puerto Rico, United States Virgin Islands and the United States of America. CMFC, CRFM, PEW and WECAFC/FAO, as well as various Spawning Aggregations experts were also in attendance. The list of 23 participants, including Working Group members and other participants, can be found in Appendix B.

ELECTION OF CHAIRPERSONS AND RAPPORTEURS

8. Dr Yvonne Sadovy was elected Chairperson of the Meeting. She was assisted by Dr Raymon Van Anrooy who also agreed to act as Rapporteur.

ADOPTION OF THE AGENDA

9. The Meeting adopted the agenda as shown in Appendix A.

GLOBAL PERSPECTIVE OF AGGREGATING SNAPPERS AND GROUPERS

10. Dr Yvonne Sadovy presented a “Global Perspective of Aggregating Snappers and Groupers”. The presentation covered what is known of the fish taxa that aggregate to spawn (mainly groupers and snappers according to the SCRFA database), the main habitats that spawning occurs globally, multispecies spawning, timing, relative to lunar phase, of spawning, and spawning behaviour. The talk covered the high importance of aggregating species within reef fisheries and hence their significance for food security and for earnings, with particular focus on groupers and snappers used both domestically and for exports. It was noted that export trade can drive particularly heavy focus on aggregating and migrating fish to fulfill the need to complete large shipments and catch large numbers of fish quickly (the cases of Honduras and Fiji were presented) which can contribute to overfishing of the species. Aggregating species are typically fished both during the aggregation season as well as outside of it and the case was presented to protect aggregations, the source of the next generation, and only fish outside of aggregations to ensure continuation of the fishery (of aggregating species) in the long term.

11. The status of aggregations globally was presented with most of known status found to be declining and little effective management in place. The case of the Nassau grouper throughout its geographic range was presented in detail for the lessons learned, as was the role of overfishing of aggregations in producing the threatened and near-threatened listings (International Union for Conservation of Nature [IUCN] Red List criteria) of several grouper species. Finally, the challenges and opportunities of management of aggregating species were presented highlighting particularly the issues of the value of aggregating species, the challenges of assessing their status (hyper-stability) from aggregation catches and the illusion of plenty that large number of fish gathered at one time and place can give. Management options were presented and statements of concern from various forums summarized.

12. The presentation triggered a lot of discussion on a wide range of issues. The importance of getting disaggregated trade data on grouper imports and exports, the potential impact of climate change and variability on reef fish species that aggregate to spawn, hyperstability issues of stocks of fishes that aggregate to spawn, the need for local fisherfolk participation in development and implementation of spawning aggregation conservation measures and the availability of and access to fisheries manuals and other awareness raising materials on spawning aggregations, were among the issues discussed. It was argued that there is an imbalance in terms of regulatory and management

measures in place for aquatic species, as lobster, queen conch and turtle are often covered by these measures, but groupers and other fishes that aggregate to spawn frequently (or even typically) are not. The Working Group agreed that the SCRFA website (www.scrfa.org), with its database and visibility and training materials could be used as repository for researchers/experts in the region who would like to share information on spawning aggregations.

HISTORICAL BACKGROUND OF WECAFC'S WORK ON SPAWNING AGGREGATIONS OF KEY SPECIES

13. Dr Van Anrooy made a presentation which covered the history, objectives and core activities of WECAFC, membership issues, and the work of the seven current working groups. Most information presented, as well as reports and publications of WECAFC working groups are available at the WECAFC website in three languages, accessible at: www.fao.org/fishery/rfb/wecafc/en. Dr Van Anrooy provided further some historical background to the Working Group on Spawning Aggregations and detailed (on behalf of the convener) the Terms of Reference of the Working Group. He also presented the data and information that FAO has on grouper landings in the WECAFC mandate area. In summary, the total landings of groupers in the WECAFC region were estimated in 2010 to be 16 400 tonnes and in 2011 some 14 400 tonnes. This is equivalent to 1.3 percent and 1 percent of total capture fisheries production in the region in these years. Mexico (51 percent), USA (28 percent), Venezuela (9 percent) and the Dominican Republic (5 percent) are the largest producers in terms of volumes of grouper harvested. The FAO data showed that since the 1980s there is a clear downward trend in landings of groupers. It was noted that the USA is the largest importer of grouper and grouper products from the region.

14. The discussion succeeding the presentation related to the role of non-coastal member states of WECAFC and how they could be incorporated better in regional fisheries management and to a perceived need to be able to make binding fisheries management recommendations in the region.

PRESENTATIONS OF NATIONAL STATUS REPORTS

15. National Summary Reports were prepared by expert participants from most countries attending the Working Group meeting. These summary reports and other research outcomes provided are made available in full in a separate report, along with an updated regional status overview. Also the representative of the CRFM provided an overview of the work of the Mechanism on aggregating species.

16. The presentations of the overviews were received with interest by the Working Group.

17. Summarized below are the presentations made by the experts and issues raised by participants during the discussions following the presentations.

18. **The United States Virgin Islands (USVI)**. Dr Richard S. Nemeth of the Center for Marine and Environmental Studies of the University of the Virgin Islands presented the status of spawning aggregations in the USVI.

19. In the United States Virgin Islands at least 20 species from five families (*Lutjanidae, Epinephelidae, Carangidae, Balistidae, Kyphosidae*) are known or suspected to form transient fish spawning aggregations (FSA). FSA's are important life history events characterized by very predictable locations and timing where the spawning adults are the primary source of annual reproductive effort. These characteristics make spawning aggregations very vulnerable to fishing which may severely deplete local populations: a scenario that has occurred repeatedly in the USVI and elsewhere in the Caribbean, especially the collapse of Nassau grouper (*Epinephalus striatus*) spawning aggregations.

20. Understanding the status of spawning aggregations is critical to their management. In the USVI, nearly all of the species that form transient spawning aggregations are either declining or have

insufficient information to evaluate their status, even though management regulations have been in place for five to ten years. These regulations include three US federal marine protected areas, three federal and local seasonal area closures and three areas with limited protection. Additional regulations include no-take for Nassau and Goliath grouper (*E. itajara*) and three endangered parrotfish (*Scarus guacamaia*, *S. coelestinus*, *S. coeruleus*) and seasonal catch restrictions on groupers (February to April) and snappers (April to June). In only one case has a species (red hind *E. guttatus* on St. Thomas) shown recovery due to protection of its spawning aggregation site. This is in stark contrast to the St. Croix red hind spawning population which has shown continuous decline for the past ten years in terms of size of males and females, sex ratios, population abundance and biomass even though it has received similar protection. A lack of basic biological information is hindering our understanding of these differences in response to management actions.

21. A minimum level of research is needed to provide Caribbean countries a baseline on which to establish FSA monitoring protocols (i.e. port surveys, underwater fish counts, bathymetric and habitat mapping). This basic information as well as more sophisticated studies can provide guidance for implementing precautionary management regulations. For example, a study in the USVI using acoustic telemetry to track grouper movements found that area requirements around spawning sites showed a strong positive relationship based on fish size. The largest species (yellowfin grouper, *Mycteroperca venenosa*) required 10–12 km^2, Nassau grouper required 5–6 km^2 and tiger grouper (*M. tigris*) 3–4 km^2. This information is broadly applicable to other countries and can be used to guide managers to define spatial and temporal closed areas and justify boundaries to stakeholders through a variety of outreach and informal education efforts.

22. The discussion which followed Dr Nemeth's presentation focused on the recommendations from the study, expressed a need to investigate the differences in effects of implementation of various management measures, and noted that the status of the stocks continued to decline.

23. **Puerto Rico**. Dr Michelle T. Schärer-Umpierre of the Department of Marine Sciences of the University of Puerto Rico presented the status of spawning aggregations in Puerto Rico.

24. Spawning aggregations of groupers and snappers have been confirmed for a handful of sites in the Puerto Rican archipelago. Various vulnerable, threatened and endangered species of grouper have been documented at some of these multi-species spawning sites with the aid of passive acoustic monitoring studies. Many of these species are extremely rare and hence they are not detected in fishery-independent studies; therefore the study of aggregations provides an efficient method to monitor their populations.

25. Of the spawning aggregation sites highlighted in Puerto Rico one is permanently protected from fishing year-round, three have seasonal protections and a three remain unprotected despite research documenting them. Current seasonal bans for some of the species that aggregate to spawn are applied island-wide, but differ in compatibility between local and federal regulations in the exclusive economic zone (EEZ). Compliance and enforcement efforts at sea are very limited and the effectiveness of seasonal bans is not perceived in local restaurants and markets and there is no export of these products to other locations.

26. Current fishery-dependent data available for these species is unsuitable for trends analyses. Difficulties associated with inconsistent data collection methods, lack of species-specific landings, misreporting from commercial fisheries and little or no information from the recreational sector make population evaluations problematic. The fishery-dependent recreational fishery data available is limited and contains high uncertainty due to the rarity of many of these species.

27. Questions asked after this presentation related to the effectiveness of management measures applied, occurrence of illegal fisheries, confiscation of illegally caught red hind, and why a buffer area around sites where fish aggregate to spawn is needed.

28. **Cayman Islands**. Mr Phillippe Bush, of the Marine Conservation Board of the Department of Environment of the Cayman Islands presented the “Historical and proposed future management of the Nassau grouper spawning aggregations of the Cayman Islands”.

29. Monitoring of the Nassau grouper spawning aggregation-based fishery of the Cayman Islands began in 1987, due to earlier complaints and reports from fishermen of decreasing catches and fish size. Fifteen years of data (1987–2001) from three main historical spawning aggregations showed declining trends in catch, size, and CPUE. In 2001 and 2002, approximately 4 000 fish were taken from a newly discovered spawning aggregation at the west end of Little Cayman, essentially halving a pre-fishing aggregation estimated at 7 000–8 000.

30. As a result of public outcry, 2003 saw the first (and only) “no-take” year based on “alternate year fishing” regulations, and a defined spawning season of November through March. Based on ageing and validation work done earlier, an 8 year (2004–2011) fishing ban prohibited the taking of Nassau grouper from any of the eight designated grouper spawning areas. In 2011, a second consecutive eight year ban (2012–2019) was implemented. In 2012, a conspicuous recruitment pulse of 1–2 year old juvenile Nassau grouper (total length ranging from 12–26 cm) occurred. This was the first time a recruitment of this magnitude was detected in ten years since the cessation of the fishery in 2003. Current frequent sightings of larger sub adults (30–40 cm) suggest much lower level recruitment events in prior years. This underpins importance of long term protection in maximizing chances of meaningful recruitment events. Thus, realistically, protection for depressed Caribbean stocks should therefore be in perpetuity.

31. The currently proposed legislation includes:

- Placing the species on protected status lists (i.e. prohibit the taking of the species anywhere in Cayman waters). Once recovered, the productivity of its population can provide a healthy non-spawning season fishery. (This is the most desirable option).
- Implement an annual closed season throughout Cayman waters for Nassau grouper from November through March.
- Impose a daily catch limit of two fish/person/day in open season.
- Impose a slot size limit of 45–60 cm.
- Ban the taking of Nassau grouper from all designated grouper spawning areas indefinitely.
- Change the current boundaries of designated grouper spawning areas to more realistically accommodate the potential shifting of spawning aggregations.

32. The discussion that succeeded the presentation revolved around the success of the eight year bans and why a permanent ban may be necessary, the proposed legislation and the question whether fishing should be allowed on recovered populations.

33. Dr Brice Semmens of the Scripps Institution of Oceanography of the University of California presented some work of the Grouper Moon research program in the Cayman Islands.

34. The Grouper Moon research program, a collaborative effort between the Reef Environmental Education Foundation (REEF) and the Cayman Islands Department of the Environment, uses a diverse array of field techniques in order to study the population and spatial biology of Nassau grouper (*Epinephalus striatus*). The Cayman Islands maintains a uniquely large (healthy) spawning aggregation of Nassau grouper (~4 000 fish), in addition to several heavily depleted spawning aggregations of the species. Acoustic tagging studies on both the healthy and depleted spawning aggregations indicate that all or nearly all reproductively mature individuals aggregate each year, and do not make abyssal migrations between islands. The acoustic data also suggest that individual grouper may visit multiple aggregation sites before ultimately coalescing at a single site. Finally, acoustic data revealed that larger (more fecund) fish aggregate longer than smaller fish, and that regardless of size, all fish appear to aggregate over a longer period of time at depleted spawning sites.

35. Taken together, these findings suggest a set of behavioral characteristics that present a mechanistic underpinning to the apparent hyper-stability in aggregating species; hyper-stability refers to the fact that catch per unit effort remains relatively constant despite steep declines in catch. The fact that hyper-stability is mediated by spawning behaviors suggests that efforts to harvest aggregating species during their spawning season will likely stymy traditional fisheries management and assessment approaches.

36. Questions after the presentation related to the size of the spawning aggregation and the time spent by fish on the aggregation site, the reason why catchability is higher in smaller populations, and the movement of fish to and from spawning aggregations.

37. **The Bahamas**. Mr Lester Gittens of the Department of Marine Resources of the Ministry of Agriculture, Marine Resources and Local Government presented the status of spawning aggregations in The Bahamas.

38. Though many fish species aggregate in The Bahamas, the Nassau grouper, Yellowfin grouper, Mutton snapper and Lane snapper have been targeted at spawning aggregations. Other than the iconic Nassau grouper, not much is known about the status of these resources either by species or by individual spawning aggregation. While quantitative evidence of management success is largely limited to a study that showed a greater diversity of groupers in the Exuma Cays Land and Sea Park, fishers also make anecdotal reports that there are greater numbers of small Nassau grouper. Nevertheless, despite the use of closed seasons in most years since the late 1990s (along with other older management measures) and abounding educational efforts led by non-governmental organizations (NGOs), the overall Nassau grouper fishery is estimated to range from fully exploited to overexploited. In addition, studies of a few individual Nassau grouper aggregations showed the disappearance of some aggregations and greatly reduced numbers in others.

39. Like regional counterparts, The Bahamas is challenged with finding the right combination of enforceable management measures that simultaneously facilitate food security, sustainability and the ability of fishers to right now earn a living. This can only be achieved by excising the current scourge of poaching (foreign and local) in addition to further embracing informed management decisions. Likewise, informed management implies that there is information to base decisions on. More resources must be contributed towards enhancing these sources of information including surveillance for enforcement purposes, accurate monitoring of landings, scientific research and stock assessments.

40. In the discussion that took place after the presentation the success of a closed season combined with a sales ban compared with a closed season without sales ban was an issue. The impact of the closed season on the stocks of Nassau grouper was discussed also and the need for a regional recommendation on the use of fish traps with biodegradable panels.

41. **Mexico.** Dr Alfonso Aguilar-Perera of the Universidad Autónoma de Yucatán presented the status of spawning aggregations in the Southern Gulf of Mexico and Mexican Caribbean.

42. In the Southern Gulf of Mexico and Mexican Caribbean, a lack of detailed knowledge prevails on the current conditions and fishery status of fish spawning aggregations (FSAs). Limited scientific documentation has revealed that grouper species (*Epinephelus striatus*, *E. itajara*, *E. guttatus*, *Mycteroperca bonaci*, *M. tigris*, *M. venenosa*) and snappers species (*Lutjanus analis*, *L. cyanopterus*, *L. synagris*, *L.jocu*, *Ocyurus chrysurus*) are opportunistically exploited during spawning aggregations. The practice of exploiting groupers, such as the Nassau and the Goliath, has been progressively fading because of population declines of these groupers. In fact, no fishermen community now strongly depends economically on fishing these aggregations.

43. There are no legal provisions by the Mexican Government for management of FSAs in the region. Most attention is paid to management of the red grouper, *E. morio* and the red snapper,

Lutjanus campechanus. The only regulation for grouper fishing is a one-month ban (February 15 to March 15 every year) established in 2005 for all grouper species (about 17). Also, a normative regulation (NOM-065-PESC-2007) established in 2010 provides complementary criteria to regulate the grouper fishing. None of these latter legal instruments consider the existence of FSAs. The equivalence of a Species Red List in Mexico is the NOM-059-SEMARNAT-2010, which only includes one commercially, marine, exploited teleost: *Totoaba macdonaldi* endemic to the Gulf of California.

44. The presentation contained a range of proposals to improve management, including introduction of co-management for FSAs. The subsequent discussion stressed the need for a regional coherent approach and that stock assessments should be conducted for more species.

45. **Cuba**. Mr Servando Valle of the Centre for Fisheries Research of Cuba presented, on behalf of Mr Rodolfo Claro, the status of spawning aggregations in Cuba.

46. Traditionally, the catches of reef-associated fin fishes in Cuba have shown strong seasonal trends, mainly associated with the reproductive periods of the most economically important species, among them snappers (*Lutjanidae*) and groupers (*Serranidae*). This seasonality in catch trends is determined by the increased vulnerability of aggregating species to fishing during the reproductive period and the resulting focus of fishing activity on spawning aggregations which yields a large proportion of annual catches of such species. Since the responses of aggregating species to fishing vary according to the biology of different targeted species, an understanding of the impacts of fishing and the consequences of management can only be understood by species-specific analyses in the context of the coastal fishery and its management history as a whole. The history of the coastal, reef-associated, fishery of Cuba is one of increasing and decreasing fishing pressure and variable management effectiveness that ultimately led to substantial declines in most key commercial species.

47. Snappers and the Nassau grouper are traditionally considered to be the major fin fish resources in Cuba, but many of these species have declined over the last four decades. The fishery of snappers and groupers typically concentrated on seasonal spawning aggregations. Twenty-two spawning aggregation sites were identified around the Cuban Shelf. Most of these sites are sequentially used by several species in different times. Some other sites may be found, but probably most important sites for massive spawning of targeted species are included.

48. Direct observations of spawning events have been rare in Cuba and more information on the population size of past and current spawning aggregations is needed. Active spawning aggregations due to their discrete nature and high productivity are clearly important resources. This emphasizes the need to validate aggregation information when available. Use of these spawning aggregation sites may vary temporally under natural conditions or be fully eliminated due to fishing pressure; therefore, efforts to confirm the existence of nominal aggregation sites and monitor their production through time will be essential to optimal reserve design and management.

49. Following the presentation the effects of a closed season were discussed as well as the identification of historical sites of Nassau grouper spawning aggregations. It was argued that the spawning aggregations in Cuba are often far at sea and that rough weather plus the distance to the site are not permitting the fishers to fish at many of these spawning aggregations.

50. **Belize**. Mr Mauro Gongora of the Fisheries Department presented the status of spawning aggregations in Belize.

51. Since 2003, the Government of Belize passed legislation to protect several commercially important fish species at 11 spawning aggregation sites distributed along the coast and in the three atolls of Belize. The major declines in the number of fish species, and in particular, the Nassau grouper (*Epinephelus striatus*) in the spawning aggregation sites, as demonstrated by studies done,

prompted the passing of Statutory Instrument numbers 161 and 162 of 2003 to protect the Nassau grouper and several other fish species.

52. Currently, seven spawning aggregation sites are monitored regularly. The monitoring teams are guided by the Reef Fish Spawning Aggregation Monitoring Protocol for the Mesoamerican Reef and Wider Caribbean. The inconsistency in spawning aggregation data collection as a result of the lack of resources has not helped the spawning aggregation working group to determine whether a particular fish species or more that aggregate to spawn in Belize have either recovered or have declined even further. It is clear that more resources are urgently needed to conduct additional field research and fisheries law enforcement activities at these sites to deter illegal fishing. This is a major challenge and needs to be addressed through a coordinated national and regional approach.

53. The presentation was followed by a discussion on the monitoring data, timing of monitoring, manpower available for monitoring and the concern about Nassau grouper aggregations moving between Belize and Mexico's EEZs, which requires subregional collaborative research.

54. **Nicaragua**. Mr Renaldy Barnuty Navarro of the Nicaraguan Institute for Fisheries and Aquaculture (INPESCA) made a presentation on the status of finfish fisheries in the Caribbean Sea of Nicaragua.

55. Finfish fisheries are the most important in Nicaragua in terms of volume landed and from the social point of view, because it is carried out mainly by artisanal fishermen. In Nicaragua finfish fisheries usually operate in environments dominated by multispecies landings comprising mainly snappers and groupers (*Lutjanidae* and *Serranidae*), snook (*Centropomus spp*), sharks (*Carcharhinidae, Triakidae*) and croakers (*Sciaenidae*). The highest landings of finfish originate from the Pacific and are clearly dominated by snappers. The boats used for fishing are mostly fiberglass boats with lengths between 5–10 m and outboard motors up to 75 HP. The crew of two to three people uses a variety of gears, such as gill nets, trammel nets, cast nets and lines with hooks.

56. In the case of finfish landings in the Caribbean Sea, the snappers (*Lutjanus spp*.) show a clear predominance followed by the snooks (*Centropomus spp*), and the group of other fish, followed by groupers (*Epinephelus spp*.) and sharks (*Carcharhinidae and Triakide*). For all species, there are growing trends in landings over the last five years.

57. The landings of snapper species in the Caribbean of Nicaragua are increasing and this is mainly due to the improvement of national and international market prices and an increased fishing effort mainly by the industrial fleet which is using traps. In the case of groupers, stability is observed in the landings over the last five years. The snapper and grouper landings in 2012 were equivalent to respectively USD2.4 million and 270 000 pounds round weight.

58. The trends of landings for the Caribbean groupers show that they were decreasing until 2009. After this period, there is a stabilization in the order of the thirty thousand pounds harvested per month. Major grouper species that are landed are the black grouper (*Mycteroperca bonaci*) Warsaw grouper (*Hyporthodus nigritus*) and yellow grouper (*Epinephelus flavolimbatus*). The monthly snappers landings showed an increasing trend, the main species that are landed is yellowtail snapper (*Ocyurus chrysurus*) with 71 percent, followed by 7 percent yellow eye snapper (*Lutjanus vivanus*) and the black end snapper (*Lutjanus buccanella*).

59. In Nicaragua there have been a few studies on the biology and dynamics population of finfish. INPESCA, responsible for the management and wise use of fishery resources of the country and as the competent authority for the application of Law 489, Law on Fisheries and Aquaculture and Regulations, established minimum sizes for fish species catches from the Caribbean Sea and the Pacific Ocean in Nicaragua. (Executive Resolution 003-2012). The minimum size is established based on studies and regulations established and conducted in other countries, such as Mexico, Jamaica and

the United States of America and by applying the precautionary principle and the Code of Conduct for Responsible Fisheries (the Code) of FAO.

60. Measures established to promote the use of the minimum size:

- Mesh size regulation for gill nets, traps and the size of hooks used in fishing - target fish by a Technical Standard Fishing Gear and Methods.
- Releasing live fish caught that are below the minimum size.
- Prohibition of fishing in breeding and nursery areas.
- Implementation of the Code.
- From 2012 onwards, monthly biological sampling of snappers in the Pacific Ocean.

61. In Nicaragua, closed seasons or quotas for finfish fisheries have not been established and today these fisheries are considered open-access fisheries. In the case of sharks, an indefinite closed season for species that penetrate inland waters exists.

62. The presentation was followed by some discussion on how minimum fish size regulations are enforced in practice. Examples of collaboration between the fishing authorities, navy, coast guard and police were given. The limited monitoring and few stock assessment studies being done were issues of concern raised.

63. **Caribbean Netherlands**. Mr Pieter Van Baren of the Rijksdienst Caribisch Nederland presented the status of spawning aggregations of commercially exploited aggregating species of the Caribbean Netherlands.

64. Various grouper and snapper species are exploited commercially. This is being done in an artisanal manner with hook and line and fish traps being used as gear. The status of FSA's in the Caribbean Netherlands is largely unknown. Currently, there is one known targeted multispecies (red hind and queen triggerfish) FSA off the coast of Saba. The red hind (*Epinephelus gattatus*) is being targeted commercially whereas the queen triggerfish (*Balistes vetula*) for recreational use. Red hind is being exported from Saba, mainly to St. Maarten.

65. In 2005, a study on the FSA was carried out of which the outcome was that the FSA was moderately exploited. Since then fishing pressure has increased tremendously and it is being presumed that the spawning aggregation is heavily overfished. As of 1st December 2013, the FSA will be closed during the months of December, January and February for the next five years. During this time the FSA will be monitored and after five years, the measure will be evaluated to see if prolonging is required and if additional measures are necessary.

66. On Bonaire and St. Eustatius there have been reporting's of FSA's in the past. Currently, there are no known FSA's near these islands.

67. The discussion that succeeded the presentation referred to a recommendation on Nassau grouper, which came out of the fourth Scientific Meeting and Technical Advisory Committee (STAC) of the SPAW protocol that discussed whether there was a need to protect marbled grouper and the threat of increased fishing pressure on FSAs following their identification through research efforts.

68. **Brazil**. Dr Athila Bertoncini, of the Federal University of the State of Rio de Janeiro made a presentation on reef fish aggregations in Southern Brazil: Pró-Arribada and Meros do Brasil Initiatives.

69. The presentation was followed by some questions that related to the incentives for fishers and other stakeholders to monitor goliath grouper sticks and FSAs, the type of environmental education and the focus of the research projects on dusky grouper and goliath grouper.

70. **USA – Atlantic Coast.** Dr Ken Lindeman of the Florida Institute of Technology presented an overview of "Snapper and Grouper Spawning Aggregation Information for the United States Atlantic Coast". His presentation summarized joint research work with G. Sedberry, M. Meadows, M. Burton, T. Kellison, N. Farmer, M. Reichert, D. DeMaria, C. Koenig, D. Morley, A. Acosta, C. Taylor, W. Heyman, S. Harter, and A. David.

71. They surveyed literature, unpublished data, and interviewed fishers to identify known and potential spawning aggregation sites for the snapper and grouper reef fish faunal complex of the United States Atlantic coast. Focal species included the 14 *lutjanid* and 18 *serranid* species (five and four genera, respectively) managed under the Snapper-Grouper Fishery Management Plan of the United States South Atlantic Fishery Management Council on diverse reef systems from the lower Florida Keys through North Carolina. Criteria were based on Domeier and Colin (1997) and use of local fisher information to supplement research data.

72. Nine snapper species have confirmed or potential spawning aggregation sites identified on the United States Atlantic coast. Mutton and cubera snapper had the most known spawning sites (13–15). There is considerable evidence of simple migratory spawning and some evidence of spawning aggregations for *L griseus*, *L campechanus* and five other species. In total, >40 confirmed or potential *lutjanid* spawning sites were identified. Confirmed and potential spawning aggregation sites were identified for seven grouper species with 20–30 total sites. Of these, at least nine goliath grouper aggregations have been confirmed by Koenig and Coleman (2013) in the Jupiter Inlet area of East Florida (27^{o} N).

73. The majority of known or potential aggregation sites for the southeast United States snapper-grouper reef fish complex are subject to few specific management measures to ensure aggregation sustainability; however where no-take areas are enforced, in situ data are positive for some aggregation sites. Monitoring and research have often been constrained by funding and few data to fully characterize potentially important spawning aggregations are available for the majority of sites.

74. The presentation was followed by discussion on the comparative effectiveness of spawning season closures. It was also noted that the Society for the Conservation of Reef Fish Aggregations had many outreach materials on its website and that fisher outreach should be scaled up through outreach campaigns as part of management measures.

75. The second day of the Working Group meeting started with summarizing the main findings and conclusions from the first day. A number of important additional observations were made related to the following issues:

- The multi-species, multi gear reef fisheries and aspects of fishing down the food web, given that many of the more vulnerable aggregating species are at the top of the food web.
- The public-value of aggregating species (food, tourism, earnings), along with ecological and biological values.
- The need to acknowledge as part of the ecosystem value that top predators contribute to the Caribbean marine ecosystem and the ecosystem role of groupers and other species that aggregate to spawn.
- The need to have a minimum standard regional closed-season for aggregating species, like there exists for lobster at the sub-regional level, given the dispersive larval phase of aggregating species and challenges for enforcing regulations, especially when there is international trade.
- The possibility to develop eco-tourism around spawning aggregations.
- The involvement of fishers in the management of spawning aggregations, as well as in spawning aggregation research and verification of spawning aggregations.

- The outreach and fishers exchange programmes that could contribute to increasing awareness and involvement of fishers in the management of spawning aggregations.
- The need to put in place threatened species legislation, as many countries in the region lack such legislation.
- The need for enforcement of existing regulations and monitoring of aggregating species.

76. Some additional questions were posed to the presenters of the national status reports. These questions related to the enforcement of fish size, catch and gear regulations, the ways to reduce fishing pressure and fleet capacity, the functioning of spawning aggregation working groups at national level (e.g. in Belize), alternative employment options for fishers during closed seasons, social development programmes that fishers can tap into, and the involvement of fishers in spawning aggregation monitoring programmes.

Biogeography of transient reef-fish spawning aggregations in the Wider Caribbean

77. Dr Shinichi Kobara of Texas A&M University presented a brief summary of the recently published review paper, "Biogeography of transient reef-fish spawning aggregations in the Caribbean: a synthesis for future research and management." The review evaluates all currently known and documented transient reef fish species and their spawning aggregation sites in the Wider Caribbean. In this region, 37 species of fish from ten families form transient FSAs and there are at least 108 geographically discrete transient FSA sites. Nassau grouper aggregations were the most commonly documented spawning aggregations (55 sites) and 32 sites had multispecies aggregations.

78. Dr Kobara emphasized the importance of bathymetric data collection in characterizing spawning aggregations. Even relatively crude bathymetric information can support site characterization and help design of appropriately sized marine protected areas (MPAs). Bathymetric information can also help in the understanding and modeling of hydrodynamics – water mass movement around the spawning site – and thus the influences on larval transport from the site. Finally, and perhaps most importantly, bathymetric data can be used to predict previously unknown spawning sites.

79. There are 18 multispecies sites that have bathymetric data available in this region. For every site, the spawning aggregation occurred at a shelf edge, adjacent to relatively deep water, and a reef promontory. Although it might not be applicable for every single-species spawning aggregation site (e.g. red hind spawning aggregation sites in Puerto Rico), the geomorphological approach has been used to predict and find a previously unknown multispecies spawning aggregation site in Belize. The approach might prove feasible in other locations as well.

80. Dr William D. Heyman of LGL Ecological Research Associates, Inc., continued the presentation on the research undertaken.

81. Many large groupers and snapper species can be considered as components of a snapper-grouper complex – a suite of species that share similar life history characteristics that are harvested as part of multi-species fisheries throughout the wider Caribbean. Many of these species are over-fished; some are threatened or endangered. Though many are considered data-poor species in that their status has not been successfully evaluated. These fishes are generally long-lived, late to reproductive maturity, and spawn in massive transient aggregations – all contributing to their vulnerability to over-exploitation.

82. Dr Heyman categorized research on aggregations into eight levels with increasing cost and sophistication. He identified the minimum data needed for management action: a site map and characterization using fisher interviews, fishery dependent surveys, and underwater visual counts and documentation with photos or video. He further documented that research can be conducted and sites

protected more efficiently by involving local aggregation fishermen in all aspects of the research and management process.

83. Dr Heyman offered support for the hypothesis that multi-species spawning aggregations occur predictably at the tips of reef promontories, at shelf edges in 15–60 m water depth, adjacent to deepwater (>200 m). This search image has been used to predict the location of multi-species spawning aggregations in Belize and Mexico, and may prove useful throughout the wider Caribbean and the Gulf of Mexico. He offered a vision of the future whereby a network of multi-species spawning aggregations are protected and monitored with a standard protocol, promoting recovery of the Wider Caribbean snapper grouper complex.

84. The discussion that succeeded the presentations focused on the interconnection of the grouper/snapper complex and the need to update a spawning aggregation monitoring manual.

ESA, CITES, SPAW PROTOCOL

85. Ms Stephania Bolden of the National Oceanic and Atmospheric Administration, National Marine Fisheries Service and Southeast Regional Office made a presentation on the regulatory tools: the Endangered Species Act (ESA), the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) and the Protocol Concerning Specially Protected Areas and Wildlife (SPAW).

86. The presentation outlined what CITES involves and does and discussed the CITES appendices. The benefits of CITES listing in an appendix were noted as well. An overview was given also of the United States ESA and the various ESA sections of relevance to the process of listing endangered marine aquatic species under ESA.

87. The Cartagena Convention, the only legally binding environmental treaty for the region, was discussed as well, with emphasis on the SPAW Protocol. Ms Bolden detailed that the SPAW Protocol assists governments in the Wider Caribbean region to:

- protect and recover certain species;
- protect areas and ecosystems;
- develop technical and scientific research on these areas and species, and exchange and coordinate information concerning research or monitoring programmes.

88. The SPAW Protocol establishes the principle of coordination of measures, criteria and guidelines corresponding to these different objectives. The Protocol includes three species lists to protect listed flora (Annex I), fauna (Annex II), and species of flora and fauna to be maintained at a sustainable level (Annex III). The Protocol became international law in 2000 and 16 countries have ratified; however SPAW ratification is not necessary for collaborative activities.

89. Ms Bolden added that at the fifth Meeting of the STAC to the Protocol Concerning Specially Protected Areas and Wildlife (SPAW) in the Wider Caribbean region, a report was submitted by the Government of Cuba with recommendations for listing of species under the SPAW Annexes, which given time limitations, could not be previously considered. That list included, amongst others, the Nassau grouper.

90. The Working Group took note of the three regulatory tools and recognized that CITES and SPAW listings are only useful if they receive follow-up from the countries. It was noted that CITES is not a management body as such and that all CITES decisions are to be carried out by the national governments. There was some resistance among various of the country delegates to have any of the grouper species listed under CITES. It was argued further that most Nassau grouper currently caught

ends up at domestic markets and that thus the CITES tool would not add much to the management of spawning aggregations.

91. In terms of ESA the ongoing process following the proposal for the listing of queen conch was explained. It was noted that ESA listing will have far reaching consequences and that any ESA related follow-up recovery plans are limited to the USA EEZ only; there is unlikely to be management support for other countries.

92. The listing of Nassau grouper under an appendix of the SPAW protocol was an option favoured by many experts in the Working Group. It was recognized that the distribution of Nassau grouper has dwindled at the regional level. While at the national level, in some cases, the stocks are not under threat it is a different situation when looking at the regional trends of landings of Nassau grouper by fisheries and occurrence of spawning aggregations. It was noted however that there are large gaps in terms of ratification of the SPAW protocol in the region and that the recommendations of it are non-binding, i.e. voluntary.

WORKING GROUP DISCUSSIONS

93. The meeting decided to split into three break-out working groups:

- Group 1: Importance of aggregating species for food and income and the need to manage/conserve them.
- Group 2: Research and monitoring of aggregating species
- Group 3: Educational and outreach – experiences and challenges

94. **Group 1** (Importance of aggregating species for food and income and the need to manage/conserve them) summary of the group discussions:

- It is a "no-brainer" that the aggregations that are commercially fished need to be protected or managed in order to have populations of fishes that form aggregations in the long term (includes most reef fishes such as parrotfish, surgeonfishes, snappers and groupers as well as pelagic sp. i.e. flying fish).
- Fisheries regulations regarding traps should be revised to make sure they do not impact the species that form spawning aggregations (timing, mesh size, biodegradable panels, etc.).
- It is important to highlight the cultural, economic and ecological value of the fish populations for the livelihood of many Caribbean communities.
- There was much discussion regarding the need for highlighting the importance of fish spawning aggregations for "food security" in some of these countries since many coastal communities depend on many different coral reef species which aggregate.
- The urgency of this matter was highlighted since we have been discussing among us for many years the need to protect FSA.
- It would be useful to develop a report card for the Caribbean countries, similar to "Reefs at Risk" to present which countries have FSAs and how they are doing.
- Fisheries management bodies haven't all incorporated the protection of FSA as a priority and this is worrisome, but perhaps due to short-term alternatives such as aquaculture that don't really shift effort but add to it.
- An effort has to be made to highlight the urgent need for protecting FSAs to fisheries managers and include the list of solutions that they can use to act, not leave it at "here is the problem and deal with it".

- The cascading benefits of protecting FSA due to ecological integrity i.e. improved coral reefs.
- The plight of FSAs needs to be encapsulated into a marketing campaign for which the information already exists (SCRFA) and the audience should be two-fold one bottom-up (public and constituency) and another top-down (government levels).
- We need to develop a marketing plan focused on the importance of FSAs for the fisheries species, then seek the support of NGOs and other partners to be able to implement across Caribbean and the Gulf of Mexico.
- Mexico could be a good pilot project for the implementation of this marketing plan.
- Some type of eco-label could be applied to products from sustainable "non" FSA fisheries.
- Perhaps some "earned media" coverage could be used to highlight the importance of protecting FSA.
- The message of the importance of FSAs should be transmitted through the voice of fishers, i.e. the 'Ambassadors' that can take the message to their government agencies and stakeholders.

95. The discussion that followed Group 1's presentation added that, for coastal communities' food security, and for long-term general food security, the management of FSAs is essential. It was noted that no new eco-label may be needed as there are so many around already and that some linkage with the Marine Stewardship Council (MSC) certification scheme may be an option.

96. **Group 2** (Research and monitoring of aggregating species) summarized its discussion in the following table:

	Realities/ current situation	**Needs/GAPS desired situation**	**Approaches to bridge gaps/ Action required and who to act**
Identification			
Issues: ongoing work	• Discovery based monitoring (detailed maps – occurrence) • Acoustic monitoring • Cuba has lengthy historical landing information	Know what is/are most important spawning sites regionally Know the migration patterns of each species – to inform management and conservation	In Turks and Caicos islands, no fishing for Nassau grouper, thus it would be opportunity to identify spawning sites.
Research			
Issues:	Countries fearful of other countries getting hands on data Researchers that collect data and information in other countries need to provide info/findings to these countries	• Effective data and info exchange at regional level • Raw level data can be kept internal; only aggregated data be shared • All Small Island Developing States (SIDS) should identify spawning aggregation sites • Socio-economic dependence on aggregations and perception related to conservation of aggregations	Website – database – digital library established. NGOs conservation community is needed to collect data. Transfer of technology and knowledge from south-east Asia may be useful

		• Ecological indicators • Reference points for management • Stock assessment methods for spawning aggregation species • Restocking of wild stocks might provide options in some cases • Threshold density for aggregating species? • Artificial fertilization – aquaculture – survival rate of larvae is low	
Monitoring			
Issues:	Shifts in aggregations are occurring (MPAs were established but now fish aggregate elsewhere – albeit nearby – in some cases) Difficult to find aggregations without fishers knowledge/information Allow a few cooperating fishers to fish on specific days (note that fish won't bite on actual spawning day) only – to ensure data/ information requirements are met, and only a small part of the fish is caught (use of single hook and line – one day per month -17 vessels – two fishers per vessel in Belize; estimated that 18–20% is caught). Limited access, rights based fisheries. Visual surveys are done additionally as well as cross-checking of info with exporters. NGO community has created public awareness and conservation efforts promotion.	Legislation + voluntary collaboration with fishers Monitoring manual to be updated and endorsed by WECAFC, CRFM, etc.	Fisherfolk cooperation is required to identify and monitor spawning aggregation sites May be needed to issue special permit to allow few fishers to fish site for limited time – in return for full collaboration/info from fishers Acoustic monitoring may include also vessels monitoring during aggregation events

97. The presentation of the above group discussion was followed by a plenary discussion in which the issue of identification of spawning sites got most attention. Some experts regarded it important not to reveal the spawning sites in cases where there are no management measures is in place to protect the spawning aggregation. Moreover, it was argued that there are often no immediate benefits for fishers to inform the government or researchers of existing spawning sites. Local institutional capacity is often too limited to monitor and manage spawning aggregation sites effectively and more remote aggregation sites are often difficult to protect/monitor due to the high costs related to doing so.

98. **Group 3** (Educational and outreach – experiences and challenges) summary of discussions:

99. What is the goal? We need to have people broadly understand, but also to ACT.
WHO DOES the OUTREACH? Fishermen

"Low Hanging Fruit"

1. Capture all of the existing outreach information in a single website that links to all existing education and outreach information.
   - SCRFA website
   - Project Goliath
   - TAMU Geography UTube
   - Reef resilience Website (TNC)
   - Exchange videos
   - Spawning aggregation working group site
   - REEF – kids programme in Cayman Islands, live uplink from aggregation

2. Support local fishermen leaders as spokespersons and Ambassadors
   - Awards for student paper
   - Award for best fishermen
   - Gladding Award Winner
   - Training fishermen on policies and public speaking
   - CFMC to pay for travel expenses for fishers to attend
   - Travel expenses for fishermen to attend GCFI

3. Messaging might be targeted for various audiences
   - Fishermen = value in supporting sustainable source of seafood
   - Divers – a great dive experience
   - Broad general public – anyone who knows about the sea should know
   - Decision makers/managers – protect multi-species aggregations year round

4. Tools to use:
   - Live Traveling educational shows
     - ✓ Mero-movil Grouper-mobile
     - ✓ Sailboat – educational boat
     - ✓ Carnival or travelling festival
     - ✓ Children's play
   - Fisher exchanges
   - Social media
     - ✓ YouTUBE
     - ✓ Facebook
     - ✓ iTunes University
   - Get companies who want to advertise to contribute and use the platforms for their own purpose of advertising.

5. Existing Television or Video outlets
   - Wild Krat's Episode
   - National Geographic Film

6. Certification of species – Work with MSC to have them consider whether a species aggregates to spawn and if a fish was caught outside time and location of spawning aggregations – as part of the certification process

7. Fishermen Ambassador Programme
   - Through GCFI
   - Gladding Award Winners

8. MESSAGE SHOUD COME FROM FISHERMEN
   - Videos of fishermen talking to fishermen
   - Fisher exchange videos
   - “At Sea Level”

9. Possible Donors: Ballard Foundation, watch leaders – Ocean Exploration Trust

10. Donors must also remember that regional bodies need support

11. Teacher training programme
    - Packages for interested schools – grouper day, curricula

100. In the discussion that followed Group 3’s presentation the CFMC Secretariat referred to the importance to have a teacher’s manual for educating school children on spawning fish aggregations.

GENERAL DISCUSSIONS

101. Following an example provided by the CFMC/WECAFC Working Group Secretariat, the participants were requested to complete overview tables of fisheries management measures for aggregating groupers and snappers in each of the participating countries. The overview table included input controls (e.g. closed areas, closed seasons, gear restrictions, method restrictions, effort restrictions, and licenses) as well as output controls (e.g. harvest restrictions, length limits, bag/catch limits, fish holding restrictions, sale/market restrictions, trade restrictions and landing requirements). The completed overview tables will be published in the updated regional status overview in a separate report.

102. Ms Elizabeth Mohammed of the Caribbean Regional Fisheries Mechanism (CRFM) Secretariat made a presentation on the work of CRFM in relation to fish spawning aggregations.

103. The CRFM is an inter-governmental organization which seeks to promote and facilitate the responsible utilization of the region's fisheries and other aquatic resources for the economic and social benefits of the population of the region. Currently the Mechanism comprises seventeen member States, of which spawning aggregations are documented thus far to be of importance to Jamaica, Belize, the Bahamas and Antigua and Barbuda.

104. Through the CRFM Reef and Slope Fish Resource Working Group, which meets at the CRFM Annual Scientific Meetings, data analyses have been conducted for several fisheries targeting snappers (*Lutjanus purpureus, L. synagris*), groupers (*Epinephelus guttatus, E. striatus*) and other reef and slope species. Management objectives do not focus specifically on fish spawning aggregations, except perhaps in the case of Belize and Jamaica, but address inter alia the need for long-term sustainability of the resource, application of the ecosystem approach, rebuilding depleted fish stocks in nearshore areas, protection of essential fish habitat, regulation of fishing effort, fishing areas and size of fish in the catch and control of the alien invasive species, *Pterois* spp. (Indo-Pacific lionfish).

105. Current management measures include, to varying degrees among member States, effort regulation through licensing systems, mesh size regulation, closed seasons, reduction in ghost fishing and establishment of marine protected areas. Weak monitoring, control and surveillance capability continues to impede effective management. Generally, stock assessment results have been inconclusive due to uncertainties regarding stock identification, distribution and level of sharing

among countries and inadequate catch, effort and biological data. Consequently, to improve the quality of stock assessments and management advice provided, future data collection and research efforts should focus in these areas as well as collection of industry socio-economic data; identification of spawning locations; consideration of environmental data in assessment modelling; biomass, ecological and economic evaluation of fish spawning aggregations, assessment of socio-economic impacts of management measures on fishing communities and examination of alternative livelihood options. Public awareness and education on the need to identify and protect spawning aggregations for long term sustainability of the resource should target decision-making bodies such as the CRFM Ministerial Council as well as direct stakeholders such as the Caribbean Network of Fisherfolk Organizations. The latter could be instrumental in acquiring local ecological knowledge on fish spawning aggregations to inform management.

106. In the discussion that followed the presentation questions were asked about the sub-regional flying fish management plan and when it would come into effect, the effects of fish aggregating devices (FADs) in fisheries, how the working group of CRFM relates to the joint working group with CFMC, OSPECA and WECAFC, and about the need to work jointly on public outreach to increase understanding on spawning aggregations.

PREPARATION AND ADOPTION OF THE REPORT TO WECAFC

107. The Working Group was presented by the meeting Secretariat with a draft declaration in which the main discussions, conclusions and recommendations from the meeting were combined. The draft declaration was discussed and modified by the Working Group. The final version of the Declaration of Miami, as approved by the Working Group, can be found in Appendix C. The Declaration contains an annex with the recommendation to the sixth session of the Scientific Advisory Group (SAG) of WECAFC and the fifteenth session of WECAFC on the “Establishment of a regional closed season for fisheries in the WECAFC area to protect spawning aggregations of groupers and snappers”. The sixth session of the SAG reviewed and endorsed the Recommendation on 3 November 2013. The Recommendation to the fifteenth session of WECAFC can be found in Appendix D.

CLOSURE OF THE MEETING

108. Mr Miguel Rolon, on behalf of CFMC, thanked the Working Group members and other meeting participants, the co-organizers, the members of the CFMC/WECAFC meeting Secretariat, chairperson and interpreters for their active participation and their contributions to the success of the meeting.

109. The meeting was declared closed by Mr Rolon, on Thursday 31 October 2013, at 13:00 hours.

APPENDIX A

Agenda

1. Opening of the meeting
2. Election of the Chairpersons and rapporteurs
3. Adoption of the agenda and arrangements for the meeting
4. Global perspective of aggregating snappers and groupers
5. Historical background of WECAFC's Work on Spawning Aggregations of key species
6. Presentations of national status reports by each of the participants
7. Biogeography of Transient Reef Fish Spawning Aggregations in the Caribbean
8. ESA, CITES, SPAW Protocol
9. Working Group Discussions
10. General discussions
11. Preparation and adoption of the report to WECAFC
12. Closure of the meeting

APPENDIX B

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APPENDIX C

Declaration of Miami

The Members of the CFMC/WECAFC/OSPESCA/CRFM Working Group on Spawning Aggregations:

Recalling the Terms of Reference of the joint Working Group, as established by the 14th session of the Western Central Atlantic Fishery Commission (Panama City, 6–9 February 2012);

Noting with concern the ongoing declines in stocks of many aggregating species and particularly groupers and snappers in the Wider Caribbean Region, the reduced numbers of spawning aggregations, the relatively smaller size of remaining aggregations and the resulting reduced economic and food opportunities;

Having verified with scientific methods and based on the information available that the status of Nassau Grouper, Goliath Grouper (and several other species) stocks in the Wider Caribbean Region should be considered "overexploited", and that some stocks can even be regarded as "depleted";

Stressing the high ecological and biological value of fishes that aggregate to spawn (including groupers and snappers) for the ecosystem and aquatic biodiversity in the region, and that fishing down the food web needs to be avoided;

Noting that the biological connectivity of both adults and larvae of some species of snapper and grouper are geographically extensive and hence cross national boundaries;

Mindful of the importance of groupers and snapper fisheries for local food security and of the social and economic value of these fisheries for coastal communities in the region;

Noting that the actual number of fishers targeting spawning aggregations (as opposed to species that have the aggregating habit) is low. Consequently, while management aimed to conserve spawning aggregations may reduce short-term profits for few fishers, it should enhance long-term sustainable fisheries for many other fishers that fish outside of aggregations. As such spawning aggregations are best considered as capital in a savings account that is guarded to allow provision of annual interest (more fish) to the fishery sector when conducted outside of the aggregation period;

Concerned about the increasing demand for grouper and snapper in the international market, which will almost certainly further increase fishing pressure on aggregating species in the region and is strongly implicated in illegal, unregulated and unreported trade;

Reiterating the recommendations from the CFMC/WECAFC Regional Workshop on Nassau Grouper (Cartagena, Colombia, October 2008), which called for a regional closed season and establishment of regional collaboration on grouper research and management;

Recognizing that in recent years, national level management and conservation efforts targeting spawning aggregations and aggregating species have shown mixed results in the Caribbean, and that introductions of closed seasons and/or site closures in some of the countries in the Wider Caribbean region and in other regions have proven successful in protecting aggregations, particularly when networks of such reserves are implemented by neighbouring countries or regionally. Simultaneous sales controls active fisherfolk involvement can also increase effectiveness;

Recognizing that fishers and their organizations have a key role in fisheries management and that there is a need for their active involvement in the research, conservation, and adaptive management of spawning aggregations of fishes;

Recognizing that many groupers and snappers spawn in multi-species spawning aggregations and that these aggregations are both extremely valuable and extremely vulnerable to overfishing in the absence of management;

Further recognizing the efforts at local, national and regional level to conserve aggregating fish species fisheries in line with the FAO Code of Conduct for Responsible Fisheries, the 1995 UN Fish Stocks Agreement, the precautionary approach and the Ecosystem Approach to Fisheries (EAF), the 2009 FAO Agreement on Port State Measures to Prevent, Deter and Eliminate Illegal, Unreported and Unregulated Fishing, the IUCN Red list, a Recommendation to better protect and manage fish spawning aggregations (adopted by the 4th IUCN World Fisheries Congress, 2004), the work of the Science and Conservation of Fish Aggregations (SCRFA), the Statement of Concern adopted by the second Inter-Tropical Marine Ecosystem Management Symposium in March 2003 on aggregations, and the recommendations of the 4th Scientific Meeting and Technical Advisory Committee (STAC) of the SPAW protocol;

Convinced that scientific research on aggregating species and spawning aggregations (e.g. local traditional knowledge, specific stock assessment methods, biology, ecology and life cycle, social and economic value, and reference points for conservation and management of aggregating fish species) should continue to inform fisheries decision makers on *inter alia* suitable input and output measures for fisheries management, appropriate harvesting strategies, consistent with the Ecosystem Approach to Fisheries as well as trade controls and measures to enhance capacities for enforcement and compliance;

Committed to individually and collectively taking measures and actions to further improve the management and conservation of fish aggregations and aggregating species in the Wider Caribbean Region;

1. RECOMMEND the endorsement and implementation of the enclosed draft Recommendation to the 6th WECAFC Scientific Advisory Group and 15th session of WECAFC on the establishment of a regional suit of harmonized closed seasons for specific species (starting with Nassau Grouper and adding others as appropriate) in the WECAFC area to protect spawning of overexploited aggregating species (see Annex A);

2. RECOMMEND that the range countries collect and share species specific national and international trade data for Nassau Grouper and other fish species that aggregate to spawn;

3. RECOMMEND that WECAFC members propose the listing of species that aggregate to spawn (in particular Nassau Grouper and Goliath Grouper) under Annex III[1] of the SPAW Protocol , to the Scientific and Technical Advisory Committee (STAC);

4. RECOMMEND that WECAFC, CFMC, CRFM and OSPESCA support the development of a regional plan for the management and conservation of fish species that aggregate to spawn (targeting groupers and snappers), in accordance with the best available scientific evidence to be presented to the 16th session of WECAFC in 2016 for review, consideration and regional adoption;

5. RECOMMEND that member countries assess the timing, location and status, of all known transient multi-species spawning aggregations. A list of sites should be prioritized for monitoring, conservation and management based on status and institutional capacity for management at each site;

[1] Containing threatened and endangered species of marine and coastal fauna that may be utilized on a sustainable basis, but for which management measures are necessary in collaboration with other range States.

6. FURTHER RECOMMEND that these assessments be conducted along with local fishers who are presently fishing those aggregations, in part to gather their support and in part to offer economic alternatives to fishing those aggregations;

7. SOLICIT the support for, and the direct and immediate implementation by the countries in the Wider Caribbean Region of the above listed recommendations; and

8. REQUESTS THE RESPECTIVE SECRETARIATS to present this declaration and its annexes for discussion and endorsement to the 15th Session of WECAFC, which is scheduled to be held in Trinidad and Tobago in March 2014, as well as to the next session of the Caribbean Fisheries Forum of CRFM and the next ministerial meeting of OSPESCA and communicate with the SPAW Secretariat for appropriate follow-up.

APPENDIX D

Annex A: Recommendation to the sixth WECAFC Scientific Advisory Group and fifteenth session of WECAFC

ON THE ESTABLISHMENT OF A REGIONAL CLOSED SEASON FOR FISHERIES IN THE WECAFC AREA TO PROTECT SPAWNING AGGREGATIONS OF GROUPERS AND SNAPPERS

The Western Central Atlantic Fishery Commission (WECAFC),

RECALLING that the objective of the Commission is to promote the effective conservation, management and development of the living marine resources within the area of competence of the Commission, in accordance with the FAO Code of Conduct for Responsible Fisheries, and address common problems of fisheries management and development faced by members of the Commission;

RECALLING the recommendations of the Regional Workshop on the Management of Nassau Grouper and the agreement of the 13th session of WECAFC (both held in Colombia, October 2008) with these recommendations on the management of Nassau Grouper;

REAFFIRMING its commitments, made at the 14th session, through establishing the CFMC/WECAFC/OSPESCA/CRFM Working Group on Spawning Aggregations with an aim to provide advice on the management and implementation of regional strategies and regulations to protect spawning aggregations and aggregating species;

RECOGNIZING the conclusions of the CFMC/WECAFC/OSPESCA/CRFM Working Group on Spawning Aggregations, which convened in Miami, USA, 29-31 October 2013, reviewed the status of some species that aggregate to spawn in the WECAFC Area and discussed a large variety of management and conservation options;

CONSIDERING that the Scientific Advisory Group (SAG) at its 6th Session assessed that several fish species that aggregate to spawn (in particular Nassau Grouper and Goliath Grouper) are overexploited, some with a high risk of collapse, and that sustainable management requires that measures aimed at limiting the fishing of spawning aggregations and aggregating species are implemented;

NOTING that both the Working Group and the SAG advise of the need to establish a harmonized regional closed season for commercial and recreational fisheries of fish species that aggregate to spawn;

NOTING that both the Working Group and the SAG advise the WECAFC members to establish year round no-take marine protected areas at known transient multi-species spawning aggregation sites;

RECOGNIZING that various WECAFC members have already established closed seasons for commercial grouper fishing and/or closed areas to protect spawning aggregations;

NOTING that many of the spawning aggregations of grouper and snapper in the Caribbean have seriously declined or disappeared in the last two decades and that immediate action is required to stop further reduction in spawning areas and depletion of the stocks;

CONSIDERING that current management and conservation efforts targeting spawning aggregations and addressing aggregating species have shown mixed results in the Caribbean, and that application of closed seasons in other regions has proven to be successful when implemented regionally, it is fundamental to limit the fishing effort in areas where adults of important species aggregate to spawn to allow these stocks to reproduce, and, in many cases to recover, thereby allowing for their sustainable exploitation and ongoing contribution to long-term food security and social and economic objectives of the governments in the WECAFC region;

CONSIDERING that more scientific information and research is needed with a view to better understanding the relevance of areas on the continental shelf and slope for the protection of spawners in known aggregations and sensitive habitats, as well as to better know the level and spatial distribution of the fishing effort exerted on aggregating species in general;

PENDING the delivery of this additional information by the Working Group and the SAG;

ADOPTS in conformity with the provision of Article 6 (h) of the Revised Statutes of the WECAFC the RECOMMENDATION that:

1. Members of WECAFC [shall] identify and monitor all known and exploited spawning aggregation areas of groupers and snappers and inform the SAG of any changes in these areas.

2. Members of WECAFC [shall] issue a regional seasonal closure for all commercial and recreational fishing activities of Nassau Grouper (*Epinephelus striatus*) in the identified areas for the period 1 December – 31 March.

3. For the fisheries restricted area referred to in paragraph 1 above, Members [shall] call the attention of the appropriate national and international authorities in order to protect spawning aggregations from the impact of any other human activity jeopardizing the spawning aggregation areas, and ensure enforcement of closed seasons during the reproductive period, if necessary by also implementing sales bans during the closed season.

4. Members of WECAFC [shall] not permit any export of Nassau grouper and Nassau grouper products (e.g. roe, fillets) for the duration of the regional seasonal closure.

5. Member shall conduct research to ascertain the ecological, social and economic impacts of the proposed management measures to inform future management decision-making.

6. Members [shall] prepare national grouper and snapper fisheries management and conservation plans.

7. Members [shall] communicate to the WECAFC Secretariat the measures taken to adhere to the above paragraphs.

8. The WECAFC Secretariat [shall], together with the Members, establish an outreach and communication campaign on the closed areas and regionally agreed closed season.

9. The WECAFC Secretariat [shall], together with the Members, seek to mobilize resources to assist the Members in the implementation of research, monitoring and management measures.

10. Boundaries of the identified spawning areas, spawning seasons and conditions to fish therein, as referred to in previous paragraphs may change on the basis of Working Group and SAG advice coming from additional knowledge.

11. WECAFC, CFMC, and as appropriate CRFM and OSPESCA, [shall] support the development of a regional plan for the management and conservation of fish species that aggregate to spawn (targeting groupers and snappers), in accordance with the best available scientific evidence to be presented to the 16th session of WECAFC in 2016 for review, consideration and regional adoption.

12. Members [shall] assess the timing, location and status, of all known transient multi-species spawning aggregations. A list of aggregations should be prioritized for monitoring, conservation and management based on status and institutional capacity for management at each site.

13. Members [shall] conduct assessments along with local fishers who are presently fishing those aggregations, in part to gather their support and in part to offer economic alternatives to fishing those aggregations.

14. Members [shall] solicit support for direct and immediate implementation by the countries in the Wider Caribbean Region of the above listed recommendations.

APPENDIX E

Terms of Reference of the CFMC/WECAFC/OSPESCA/CRFM Working Group on Spawning Aggregations

Convener: Miguel Rolón (CFMC)

The working group will carry out the following tasks:

- Compile and analyze data on spawning aggregations in the member countries and monitor any changes.
- Seek partnerships with other institutions that could provide assistance in the monitoring, evaluation, and recommendations for management for protection and conservation of spawning aggregations.
- Provide advice on the management and implementation of regional strategies and regulations to protect spawning aggregations.
- Report to the appropriate institutions at each session.

The first meeting of the CFMC/WECAFC/OSPESCA/CRFM Working Group on Spawning Aggregations, was held in Miami, United States of America, from 29 to 31 October 2013. The meeting brought together experts working on spawning aggregations of fish from all over Western Central Atlantic region. The Working Group noted with concern the ongoing declines in stocks of many aggregating species and particularly groupers and snappers in the Wider Caribbean Region, the reduced numbers of aggregations and the relatively smaller size of remaining aggregations. The Working Group also verified that the status of Nassau grouper, Goliath grouper (and several other species) stocks in the Wider Caribbean region should be considered "overexploited", and that some stocks can even be regarded as "depleted". The meeting issued a "Declaration of Miami", which included a recommendation to the fifteenth session of WECAFC on the establishment of a regional closed season for Nassau Grouper fisheries in the WECAFC area to protect spawning aggregations of this species.

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Proposal of the Kingdom of the Netherlands for listing of shark and ray species on the Annexes of the SPAW Protocol

Proposal of the Kingdom of the Netherlands for listing of shark and ray species on the Annexes of the SPAW Protocol

Executive Summary

The Kingdom of the Netherlands is proposing to list a number of species of Sharks and Rays on Annexes II and II of the SPAW Protocol.

For Annex II:

1. **Smalltooth Sawfish (*Pristis pectinata*),**
   qualified for listing on the SPAW Protocol Annex 2, according to:
   - criterion 1, due to evidence of decline and population fragmentation,
   - criterion 4, as the species is listed as critically endangered by IUCN (Wiley *et al.,* 2013),
   - criterion 5, due to the trade in the rostral saws and CITES listing on Appendix I and
   - criterion 6, as cooperation between countries is needed to protect the species during their seasonal migrations

   The Smalltooth Sawfish (*Pristis pectinata*) has been wholly or nearly extirpated from large areas of its former range in the Western Atlantic Ocean by fishing (trawl and inshore netting) and habitat modification. Negative records from scientific surveys, anecdotal fisher observations, and fish landings data over its historic range infer a population reduction ≥95% over a period of three generations (i.e., 1962 to present). The species of the family Pristidae (the Sawfishes) are the most threatened elasmobranchs globally

2. **Whale Shark (*Rhincodon* typus)**
   qualified for listing on the SPAW Protocol Annex 2, according to:
   - criterion 1, due to the population decline,
   - criterion 4, as it is listed by IUCN as globally endangered and its Atlantic population as vulnerable,
   - criterion 5, as the species is on Appendix II of CITES, and
   - criterion 6, since it qualifies for regional cooperative efforts due to the north-south seasonal migration path which spans many countries' jurisdictions.

the Whale Shark is a highly migratory species and is widespread in tropical-temperate seas Catches have declined and populations have apparently been depleted in several countries by harpoon fisheries targeting localized concentrations of this huge, slow-moving and behaviorally vulnerable species. The whale shark has shown an overall decline of 63% in the Indo-Pacific over the last 75 years (three generations). In the Atlantic, the overall population decline is considered to be lower at ≥30%, the overall global decline is inferred to be ≥50%.

3. **Oceanic Whitetip Shark (*Carcharhinus longimanus*)**
   qualified for listing on Annex 2 of SPAW based on:
   - Criterion 1, since its population has declined precipitously in the Northwest and Western Central Atlantic region
   - Criterion 4, as it is listed as Vulnerable by IUCN and in the Northwest and Western Central Atlantic as Critically Endangered because of the enormous declines that have
   - Criterion 5, as it is listed on CITES appendix II

– Criterion 6, as it is listed as a highly migratory species by UNCLOS

The Oceanic Whitetip shark is a highly migratory species which has declined more than 90% over a period spanning three of its generations. Because of its migratory nature, effective conservation of this species will require international cooperation.

For Annex III

1. **Manta rays (*Manta birostris*, *Manta alfredi* and *Manta* cf. *birostris*)**
   Qualified for listing on Annex III of SPAW based on:
   – Criterion 1, because of the decline and fragmentation of the populations
   – Criterion 4, because these species are all listed as Vulnerable by IUCN
   – Criterion 5, since they are lilsted on CITES Appendix II
   – Criterion 6, since they have been listed on Appendix I and II of CMS and on Annex I of the Shark MoU, requiring cooperation for their conservation

The giant Manta Ray Manta birostris and the reef Manta Ray Manta alfredi, with a third putative species endemic to the Caribbean region, Manta cf. birostris, are the largest genus of rays, making their life history especially conservative, and rendering them vulnerable to depletion. Moreover, despite evidence for long migrations, regional populations appear to be small, sparsely distributed, and fragmented, meaning localized declines are unlikely to be mitigated by immigration.

2. **Hammerhead sharks (Sphyrna *lewini, Sphyrna mokarran* and *Sphyrna zygaena*)**
   Qualified for listing on Annex III of SPAW based on:
   – Criterion 1, since there is proliferating evidence for declining populations in the West-Atlantic Ocean, they are vulnerable to overexploitation and have a low recovery potential due to a low intrinsic growth rate and slow reproduction, and there is a increasing targeted catch and bycatch in the Northwest and Western Central Atlantic ocean.
   – Criterion 2, a precautionary approach is warranted since the exact amount of fishing pressure and the corresponding mortality rate is obscure, species-specific inferences cannot easily be made because of the difficulties associated with the inability to distinguish between S. *zygaena, S. lewini,* and *S. mokarran*, and the conservation status of hammerhead sharks is dire situation
   – Criterion 4, since IUCN lists the conservation status of hammerhead sharks as Endangered for *S. mokarran* and *S. lewini* (both on a global scale and the Northwest and Western Central Atlantic subpopulation) and Vulnerable for *S. zygaena*.
   – Criterion 5, since the family of hammerheads is listed under Appendix II of CITES
   – Criterion 6, since Hammerhead sharks are listed on Annex I of the United Nations Convention on the Law of the Sea (UNCLOS) and thus require international cooperation for their conservation

The hammerhead sharks are circumglobal shark species residing in coastal warm temperate and tropical coastal seas. *S. lewini* has among the lowest recovery potential when compared to other species of sharks. Population growth rates determined for populations in the Pacific and Atlantic Ocean are low. Abundance trend analyses of catch-rate data have reported large declines in abundance ranging from 60-99% over recent years. A stock assessment using information on catch, abundance trends and biology specific to *S. lewini* from the northwest Atlantic Ocean indicate a decline of 83% from 1981-2005. Standardized catch rates from the U.S. pelagic longline fishery show declines in *Sphyrna spp*. of 89% between 1986 and 2000 and declines of 76% between 1992 and 2005. Hammerhead fins are highly valued and they are being increasingly targeted in some areas in response to increasing demand for shark fins. Hammerhead shark species *S. zygaena* and *S. lewini* were found to represent at least 4-5% of the fins auctioned in Hong Kong, the world's largest shark fin trading center. Fins from the Hong Kong SAR market can be genetically assessed and have been shown to originate from western Atlantic Ocean basins.

Proposal

Considering:

The need for protection of sharks and rays as evidenced by their exceptional vulnerability to overfishing and long lasting depletion due to their slow growth, late maturity, and small litters– Females do not reproduce until they are over a decade old and give birth to a small number of pups after a long pregnancy. Generation times for shark species can be as much as 50 years, which puts them in the FAO's lowest reproductive category;

That shark populations have been heavily fished and severely depleted all over the Atlantic Ocean – As reproductive females are the largest, most prized individuals these tend to be most heavily targeted in fisheries;

That globally sharks have become an important fishing commodity prized for their meat but mainly for their fins, the key ingredient for shark fin soup, a delicacy all across Asia – The large demand for shark products and sharks innate vulnerability to fishing pressure has led to steep decline in shark numbers worldwide, with some populations being reduced with more than 90%;

That the Caribbean Sea and Western Central Atlantic are the areas worldwide where there is the greatest uncertainty about the species and where the number of IUCN category Data Deficient species is highest (Dulvy *et al.*, 2014). This means that there is a high level of uncertainty about their status;

That most shark and ray species are migratory or have transboundary ranges and therefore cooperative protection and management between countries is needed to manage these species;

That the Kingdom of the Netherlands established the 'Yarari' Sanctuary for sharks and marine mammals in the waters of Bonaire and Saba;

Recalling:

Article 11 4. (a) of the Protocol;

Noting:

The required information listed in Art. 19.3;

The criteria and procedure for listing as adopted by the eighth Conference of parties (COP 8) in Cartagena, Colombia, December 2014;

The Kingdom of the Netherlands proposes the following species of Sharks and Rays for listing on the SPAW Annexes as indicated below:

For Annex II

1. Smalltooth Sawfish (*Pristis pectinata*)

Overview

The Smalltooth Sawfish qualifies for listing on the SPAW Protocol Annex 2, especially according to: criteria 1 due to evidence of decline and population fragmentation, criterion 4 as the species is listed as critically endangered by IUCN (Wiley *et al.,* 2013), criterion 5 due to the trade in the rostral saws and CITES listing on Appendix I and criterion 6 as cooperation between countries is needed to protect the species during their seasonal migrations

The Smalltooth Sawfish (*Pristis pectinata*) has been wholly or nearly extirpated from large areas of its former range in the Western Atlantic Ocean by fishing (trawl and inshore netting) and habitat modification. Negative records from scientific surveys, anecdotal fisher observations, and fish landings data over its historic range infer a population reduction ≥95% over a period of three generations (i.e., 1962 to present). While the population found in the United States appears to have stabilized with some evidence of increase, information from other areas is lacking. The remaining populations are inferred to be small and fragmented based on the lack of records. The species can only be reliably encountered in the Bahamas (where suitable habitat is available) and the United States (Georgia south to Louisiana). It is rare but present in Honduras, Belize, and Cuba. While historic threats to Smalltooth Sawfish have been reduced in places like the United States, threats still exist today from areas where Sawfish are unprotected and habitat modification and inshore netting still occurs. All species of the family Pristidae (the Sawfishes) are the most threatened elasmobranchs globally (Dulvy *et al.*, 2014).

Species information

a. Scientific and common names of the species

1.1. Class: Chondrichthyes, subclass Elasmobranchii
1.2. Order: Rajiformes
1.3. Family: Pristidae
1.4. Species: *Pristis pectinata* (Latham, 1974)
1.5. Scientific synonyms: *Pristis serra* (Bloch and Schneider 1801), *Pristis granulosa* (Bloch and Schneider 1801), *Pristis acutirostris* (Duméril 1865), *Pristis leptodon* (Duméril 1865), *Pristis megalodon* (Duméril 1865), *Pristis occa* (Duméril 1865), *Pristis woermanni* (Fischer 1884),*Pristis evermanni* (Fischer 1884), and *Pristis anandalei* (Chaudhuri 1908).
1.6. Common names:
English: Smalltooth Sawfish, Wide Sawfish
Spanish: Pejepeine, Pez Sierra, Espadachin, Espadon, Pejes sierra, Pez espada, Pez rastrillo
French: Poisson-scie, Requin-scie

b. Estimated population of species and its geographic ranges

Smalltooth Sawfish were widely distributed throughout the tropical and subtropical marine and estuarine waters of the Western Atlantic Ocean. They were found from Uruguay through the Caribbean and Central America, the Gulf of Mexico, and the Atlantic coast of the United States (Faria *et al.,* 2013). However, this range has contracted and the Smalltooth Sawfish has been likely extirpated from large areas of its former range. The species is currently known to occur in the southeastern United States, Bahamas, Cuba, Honduras, and Belize. Reports of Smalltooth Sawfish outside of the Atlantic Ocean are likely misidentifications of other Sawfish species (Faria *et al.*, 2013). In the United States, the Smalltooth Sawfish population appears to have declined dramatically during the middle and later parts of the 20th century (Simpfendorfer, 2002). Based on the contraction of the range and declines in landings, it is likely that the population in the United States at the end of the 20th century was less than 5% of its size at the time of European settlement (Simpfendorfer, 2002). Based on genetic sampling, estimates of the current effective population size range of the United States population of Smalltooth Sawfish were from 269.6–504.9 individuals (95% Confidence Interval 139.3–1,515; Chapman et al. 2011). Outside United States waters, no data on population size or trends in abundance exist and the only information on trends in the population can be inferred from capture records. While early records of this species include most countries throughout Central and South America, records and reports indicate the Smalltooth Sawfish can only be reliably encountered in the Bahamas where suitable habitat is available, and in Honduras, Belize, and Cuba (R. Graham pers. comm. 2012).

Using data from reported encounters from 1998 to 2008, Wiley and Simpfendorfer (2010) evaluated Smalltooth Sawfish habitat use patterns in the US. There was an inverse relationship between Sawfish size and extent of northern distribution, with animals less than 200 cm having a wider latitudinal distribution and occurring farthest north, and animals greater than 200 cm reported mostly in southern Florida (Wiley and Simpfendorfer, 2010). Most encounters occurred in estuarine and nearshore habitats, and their locations were not randomly distributed, having a positive association with inshore mangrove and seagrass habitats. While Sawfish were reported in depths to 73 m, there was a significant relationship between size and depth, with smaller animals occurring in shallower waters (Wiley and Simpfendorfer, 2010).

Data from acoustic telemetry and tag-recapture information indicates Smalltooth Sawfish (less than 100 cm) had the smallest home ranges, a low linearity of movement, and a preference for very shallow mud banks (Simpfendorfer *et al.*, 2010). Juveniles greater than 100 cm demonstrated larger home ranges, preference for shallow mud/sand banks, and remained close to mangrove shorelines. Tide was found to be the main factor influencing movement on short time scales. Sawfish <150 cm. STL spend the majority of their time in water <0.5 m deep, while larger juveniles spend most of their time in water 0.5–1.0 m. deep. Juveniles >130 cm had high levels of site fidelity for specific nursery areas for periods up to almost 3 months, but the smaller juveniles had relatively short site fidelity to specific locations (Simpfendorfer *et al.*, 2010). For adult Sawfish, unpublished data from pop-off archival satellite transmitting (PAT) tags indicate Smalltooth Sawfish spend the majority of their time in shallow waters (<10 m deep) and prefer temperatures between 22°C and 28°C (J.K. Carlson, unpublished data). The maximum-recorded depth for Smalltooth Sawfish is 88 m.

The population of Smalltooth Sawfish may have stabilized in the United States. Carlson and Osborne (2012) reported the relative abundance of Sawfish increased at an average rate of about 3–5% per year since 1989 based on of voluntary dockside interviews of sports fishers. Despite a low population size in the United States, the Smalltooth Sawfish population will probably retain >90% of its current genetic diversity over the next century (Chapman et al. 2011).

Faria *et al.* (2013) state that both morphology and genetics support the current specific status of the Smalltooth Sawfish (*Pristis pectinata*) and proposed a modification of the distribution of the species to an Atlantic only range. No geographical structure of Smalltooth Sawfish populations has been detected, but the Western and Eastern Atlantic populations of the Smalltooth Sawfish represent separate units for conservation purposes.

A recent paper by Dulvy *et al.* (2014) shows that all seven species of the family Pristidae are the most threatened elasmobranchs in the world, as a result of their high exposure to coastal shallow-water fisheries and their large body size.

c. Status of legal protection, with reference to relevant national legislation or regulation

International

Convention on the International Trade of endangered Species (CITES)
All Sawfish species are listed under Appendix I of CITES. This means that CITES recognizes that the species is threatened with extinction and that all international commercial trade in wild specimens is prohibited. See www.cites.org

Convention for the protection of Migratory Species (CMS) – Memorandum of Understanding (MOU) on the Conservation of Migratory Sharks

All sawfish species are listed on Annex 1 of the Memorandum of Understanding (MOU) on the Conservation of Migratory Species. The Shark MOU is the first global instrument for the conservation of migratory species of sharks. Signatories to the MOU commit to the objective of achieving and maintaining a favorable conservation status for migratory sharks based on the best available scientific information, in particular the sharks listed on Annex 1 of the MOU, recognizing that successful shark conservation and management require the fullest possible cooperation among governments, intergovernmental organizations, nongovernmental organizations, and all stakeholders

IPOA Sharks
Since the 1990s there are several shark protection plans, both internationally at intergovernmental and non-governmental level, as well as at national level by several nations in the Wider Caribbean region. Within the framework of the Code of Conduct for Responsible Fisheries, the FAO (Food and Agriculture Organization) developed the International Plan of Action for the Conservation and Management of Sharks (IPOA Sharks) in 1999. The objective of IPOA Sharks is to ensure the conservation and management of sharks and their long-term sustainable use. IPOA Sharks is voluntary and intends to give

states guidelines on how to establish a National Plan of Action (NPOA) through guiding principles and procedures for implementation.

National Protection

USA

The United States listed *Pristis pectinata* on the US Endangered Species Act in 2003, following earlier protection in the State waters of Florida and Louisiana and protection under the USA Atlantic & Gulf Coasts Fishery Management Plan since 1997. This remnant population in the Gulf of Mexico is considered to have survived because of the benefits of large marine and coastal protected areas, including the establishment of the Everglades National Park in 1947, and as a result of a number of conservation measures during the 1990s, including species protection in Florida and Louisiana and a ban on all forms of entangling fishing nets in Florida State waters (Simpfendorfer 2002). A Recovery Plan has been adopted for this species (NMFS, 2006). The decline in this population may have ceased as a result of these measures.

Outside United States waters, Nicaragua imposed a permanent ban on targeted Sawfish fishing in Lake Nicaragua. In Brazil, the Smalltooth Sawfish is protected by the Ministry of Environment and in Mexico, the take of all Sawfishes is banned.

Honduras

In June 2011 Honduras created the first shark sanctuary in America and declared all its marine waters in both the Pacific and Caribbean as a permanent shark sanctuary. This had been preceded in 2010 by a shark fishing moratorium and created the first shark sanctuary of the Americas amounting to about 240,000 km2 of national waters, most of which lie along the 700 km-long Caribbean coast of the nation.

Bahamas

The Bahamas have had a longline fishing ban since 1993 and consequently there has been no commercial shark fishing activity. This longline ban has effectively made the whole archipelago of the Bahamas a shark "no-take" zone. The last export of shark from the Bahamas was a lot of 2 metric tons in 2004. In July 2011 the Bahamas went a step further and legally banned all shark fishing. That law firmly turns all 630,000 sq km of Bahamian waters into a shark sanctuary17. The fines for shark fishing were raised from 3000 to 5000 USD per incident.

Venezuela

Towards implementing its Plan de Acción Nacional (PAN) de conservación for sharks, in June 2012 Venezuela joined the rest of the Americas in outlawing the finning of sharks in its waters and established a 3,730 km2 shark sanctuary surrounding the touristic archipelago of Los Roques. Recent research (e.g. Tavares 2005, 2008 2009) had demonstrated the importance of the shallow waters of Los Roques as a shark nursery area.

The Dominican Republic has, together with Belize and six other Central American countries, united under the name SICA (Central American Integration System), signed an agreement to prohibit shark finning. This ban is also applicable to fishing vessels in international waters under the flag of SICA member states. This arrangement OSP-05-11 entered into force in 1 January 2012.

Kingdom of the Netherlands

- ***St. Maarten***
  On the 12th of October 2011 the government of St. Maarten issued a temporary moratorium on shark fishing. The shark fishing moratorium prohibits the take and landing of sharks and requires immediate release of incidentally caught sharks, under penalty of a maximum of 500,000 Antillean Guilders or 3 months in prison.
- ***Caribbean Netherlands***
  In 2015, the Dutch government designated the Yarari sanctuary for sharks and marine mammals in the Economic Exclusive Zones of Saba and Bonaire, declaring that provisions will be considered and implemented as necessary to regulate activities that may have a negative impact on sharks.
- **Bonaire**
  In 2008 the island of Bonaire passed a nature ordinance providing full protection for a list of species of plants and animals. This list includes all sharks and rays

d. Ecological interactions with other species and specific habitat requirements

Little is published about the ecological role and trophic ecology of Sawfish. It is known that the sawfish is a high order predator in riverine environments, and while consuming a wide range of prey types, it predominantly feeds on bony fishes (Thorburn, 2006). Adults are likely to be important predators of teleost fish and peneaid prawns in coastal marine ecosystems. Bigelow and Schroeder (1953) reported that Sawfish in general predominantly prey on small schooling fish, such as mullets and clupeids. Bigelow and Schroeder also reported that they feed to some extent on crustaceans and other bottom dwelling inhabitants. They use their rostrum to stun schooling fishes with sideswipes of the snout.

e. Management and recovery plans for the species

Since the U.S. Smalltooth Sawfish population was listed as endangered in 2003, the commercial bycatch and recreational fisheries, as well as habitat loss have greatly decreased (some of the actions already existed before 2003). There has been a ban on inshore fishing nets in Florida waters for more than a decade and there are prohibitions and fines against intentionally capturing, harming or harassing Sawfish)[1].

f. Research programs and available scientific and technical publications relevant to the species

Currently the major aim of Sawfish research in the U.S. (Florida) is monitoring the Sawfish population to determine if the population is rebounding or at the very least stabilizing, in order to evaluate the effectiveness of protective measures. This monitoring information will provide important data about the ecology, reproduction and life history of the species, which will enable more effective conservation efforts to protect the Smalltooth Sawfish. It is important that this monitoring program continues well into the future as the recuperation of this species will take some time due to its life history characteristics (https://www.flmnh.ufl.edu/fish/Sawfish/conservation/about/).

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[1] https://www.flmnh.ufl.edu/fish/Sawfish/conservation/about/

In July of 2016, the annual Joint Meeting of Herpetologists and Ichthyologists will be about the biology and ecology of sawfishes, possibly facilitating new research opportunities and improving coordination of current research efforts.

g. Threats to the species, its habitats and associated ecosystems, especially threats which originate outside the jurisdiction of the Party

The principal threat to the Sawfishes is from target and utilized bycatch (or byproduct) fisheries. Their long tooth-studded saw makes them extraordinarily vulnerable to entanglement in any sort of net gear. Bycatch mortality in net fisheries was the major reason for the decline of *Pristis pectinata* in the United States (Seitz and Poulakis, 2006). There have been some large-scale target Sawfish fisheries: in Lake Nicaragua and possibly in Brazil from 1960s to 1980s (bycatch is still landed in this range State). Populations are now so depleted, however, that commercial targeting of Sawfish stocks is no longer economic. Most Sawfishes have been and still are killed in broad-spectrum commercial and artisanal fisheries, particularly set net and trawl fisheries that target a very wide range of fishes and invertebrates. Sawfishes are retained in these fisheries, just as they were in former target fisheries, because of the very high value of their products (particularly meat, fins and rostral saws, also liver oil and skin). They are also targeted or bycatch and retained opportunistically for the same reasons. Sawfish fins occur but are now extremely rare in the Asian dried shark fin trade and may have once had their own trade name given their value (D. Chapman pers obs). Trophy angling for very large specimens has been reported (Simpfendorfer, 2005; McClenachan, 2009). The Nicaraguan government imposed a temporary moratorium on targeted fishing for Sawfishes in Lake Nicaragua in the early 1980s (Thorson, 1982), after the population collapsed following intensive fishing in the 1970s. The aim was to allow the population to recover, but no such recovery has occurred (McDavitt, 2002). It appears that even bycatch mortality is sufficient to prevent population growth.

Sawfish are regularly used for their meat; however, most of the consumption is local and so they appear to be only occasionally traded beyond local markets (NMFS, 2009). The meat is white and tender, particularly in juveniles, and is one of the most valuable and preferred of all elasmobranchs (sharks and rays) sold in the city of Belém, Pará State, Brazil (Charvet-Almeida, 2002) and caught by Guinéan fishers (Doumbouya, 2004). A large individual can yield several hundred kg of valuable meat (Last and Stevens 1994). The rostral saws can be very valuable as curios (particularly those from the largest specimens). In North Brazil (Pará State) Charvet-Almeida (2002) reports that large saws (>1.5 m) are ordered by buyers before fishing starts and may be worth up to US$ 300 to the fisherman, depending upon size. There is a significant market in Chinese Taipei for Sawfish saws that are part of the ceremonial equipment/weapons of spirit mediums (there are an estimated 23,000 of these mediums in Taiwan). The small saws, from newborn and juvenile Sawfish, are sold as curios, or ground up as a local treatment for asthma (in Brazil), or exported for use in traditional Chinese medicine.

Habitat degradation and loss also threaten Sawfishes throughout their range (CITES, 2007). The Smalltooth Sawfish relies on a variety of specific habitat types including estuaries and mangroves; these are all affected by human development (CITES, 2007). Agricultural and urban development, commercial activities, dredge-and-fill operations, boating, erosion, and diversions of freshwater runoff as a result of continued coastal and catchment development has caused substantial loss or modification of these habitats (CITES, 2007).

The other significant problem is that the species are only protected by a very few range States. Any national conservation initiative intended to prevent these Critically Endangered species from being driven further towards extinction is unlikely to be successful if Sawfishes are not protected during their seasonal migrations through other range States' waters. This is a particular problem when the population is distributed along a coastline that is divided into a large number of small countries, as is the case in the Central Caribbean.

Sawfish rostra are often traded as curios, ceremonial weapons, or for use in traditional medicines, and artificial spurs for cock fights (NMFS, 2009). Rostra have long been a favorite marine curiosity (Migdalski, 1981), with large rostra commanding impressive prices (McDavitt 1996). These rostral teeth are mostly obtained from Brazil, Ecuador, Panama and various Caribbean countries (CITES, 2007). Sawfish skin has been used to produce leather, which, like shark leather, is considered of very high quality (NMFS, 2009). The leather is used to make belts, boots, purses, and even to cover books (NMFS, 2009).

2. Whale Shark (Rhincodon typus)

Overview

Little is known about the life history of the Whale Shark but it attains a maximum size of 15-20 m and is likely to live to up to 60-100 years (Van Beek *et al.,* 2014). It is a highly migratory species and is widespread in tropical-temperate seas (Debrot *et al.,* 2013). Catches have declined and populations have apparently been depleted in several countries by harpoon fisheries targeting localized concentrations of this huge, slow-moving and behaviorally vulnerable species. There is also incidental capture in other fisheries. Directed fisheries, high value in international trade, a K-selected life history, highly migratory nature, and low abundance make this species vulnerable to exploitation. The Whale Shark is endangered worldwide and vulnerable in the Atlantic, according to IUCN. The species qualifies for listing on SPAW Annex 2 according to: criterion 1 due to the population decline, criterion 4 due to the vulnerable IUCN status, criterion 5 as the species is on Appendix II of CITES, and it qualifies for regional cooperative efforts under criterion 6 due to the north-south seasonal migration path which spans several countries jurisdictions.

Species information

a. Scientific and common names of the species

1.1 Class: Chondrichthyes (subclass Elasmobranchii)
1.2 Order: Orectolobiformes
1.3 Family: Rhincodontidae
1.4 Species: *Rhincodon typus* (Smith 1828)
1.5 Scientific synonyms: Primarily variant spellings: *Rhiniodon typus*, *Rhineodon typus* Smith, 1828; Genus Rhinchodon Smith; Genus Rineodon Müller and Henle, 1838; Genus Rhineodon Müller and Henle, 1838; Genus Rhinodon and Rhineodon typicus Müller and Henle, 1839; Genus Rhiniodon Swainson, 1839; Genus Rhinecodon Agassiz, 1845; Genus Rhinodon Smith, 1849.
Other synonyms: *Micristodus punctatus* Gill, 1865. *Rhinodon pentalineatus* Kishinouye, 1901.
1.6 Common names:
English: Whale shark
French: Requin-baleine
Spanish: Tiburón ballena, pez dama (chequer-board fish)
Papiamentu: Tintorero

b. Estimated population of species and its geographic ranges;

Whale Sharks are found in all tropical and warm temperate seas except for the Mediterranean. They are occasionally recorded in oceanic waters but are most commonly reported in feeding aggregations close to the coast. Although widely distributed, they are generally infrequently recorded except in a few apparently favored coastal areas, where they are usually seen in relatively large numbers (tens to low hundreds) for only a few months of the year. The distribution records are characterized by highly seasonal appearances, with aggregations of Whale Sharks appearing for a few months in locations where their zooplankton food is abundant as a result of regular fish or invertebrate spawning events

(Fowler, 2000; Norman, in press; Heyman *et al.*, 2001). The species is certainly highly migratory, with satellite tracking of individuals demonstrating some very long-distance and long-term migrations, including a journey of over 2000 kilometers. Whether these migrations are solely driven by feeding events or linked to other aspects of their life history is yet to be determined. Genetic analysis showed little genetic differentiation on a global scale, although there is some genetic variance between the Atlantic, and the Indo-Pacific region.

Satellite tracking by Hueter *et al.* (2013) revealed movements of Whale Sharks into parts of the Caribbean Sea and the sharks' use of this tropical environment for up to several months. Accounts of Whale Sharks off Trinidad, Haiti, and the Bahamas are mentioned in the early literature but substantive, contemporary reports of *R. typus* in the eastern Caribbean Sea are lacking. However, the ECOCEAN database reports encounters from several islands in this area including Aruba, Dominica, Grenada, Puerto Rico, and the US Virgin Islands (as reviewed by Hueter *et al.* 2013). Compagno (2001) reported Whale Sharks off central Brazil, Colombia, Panama, and Venezuela. In a compilation of Whale Shark sightings over a 51-year period, Romero *et al.* (2000) reported 20 specimens of *R. typus* off Venezuela between the months of August and February with most sightings from a region of highly productive upwelled water. Debrot *et al.* (2013) documented 24 records of Whale Sharks for the Dutch Caribbean. Their results suggest a higher abundance of Whale Sharks in the southern, leeward part of the Dutch Caribbean, likely associated with seasonal upwelling-driven productivity known for the southeastern Caribbean area. A bimodal seasonal pattern as documented elsewhere for Venezuela was not pronounced in the Leeward Dutch islands and Whale Sharks were recorded in 9 months of the year. In the Windward Dutch islands all records so far were for the winter months of December-February.

There appears to be spatial and seasonal population segregation, with animals of similar size and largely the same sex often reported in the same area (Norman, 1999), while other age classes and a predominance of the other sex are found elsewhere (Eckert and Stewart, 2001; Graham, 2007). By analogy with other large migratory sharks, different age classes and sexes may undertake different migrations. Thus, juveniles may have different migration patterns from mature fish, and mature males and females may also have migration patterns of different lengths over different distances.

The global status of the Whale Shark is assessed as Endangered by IUCN (Pierce and Norman, 2016). They infer that approximately 75% of the global Whale Shark population occurs in the Indo-Pacific, and 25% in the Atlantic. In the Indo-Pacific, a population reduction of 63% is inferred over the last three generations (75 years), and in the Atlantic a population reduction of more than 30% is inferred. Combining data from both regions, it is likely that the global Whale Shark population has declined by >50% over the last 75 years.

Pierce and Norman (2016) base their inferred decline of ≥30% in the Atlantic subpopulation on data from tuna fleet observers off a likely center of abundance for this subpopulation. Between 1980 and 2010 there was a decline in sightings per unit effort (SPUE) off western Africa, with SPUE peaking in 1995 and declining thereafter (Sequeira et al. 2014; Table 1 in the supplementary material). In absolute terms, sightings decreased from about 500 during the 1990s to around 150 during the 2000s. Peak-month sightings also declined by approximately 50% over this time (Sequeira et al. 2014). At Gladden Spit in Belize, Whale Shark sightings declined from a mean of 4 to 6 sharks per day between 1998 and 2001 to less than 2 per day in 2003 (Graham and Roberts 2007), with reports from diving guides indicating that numbers have remained low until 2016 (Pierce and Norman, 2016).

Pierce and Norman (2016) note that for the Atlantic subpopulation size regional counts of identified sharks or modelled abundance estimates are available from many of the larger known aggregation or feeding areas. Ramírez-Macías et al. (2012) photo-identified 350 individual Whale Sharks from Holbox Island in Mexico between 2005 and 2008, and estimated that 521–809 sharks participate in this aggregation. Aerial surveys from this area and the adjacent Caribbean coast have counted up to 420 sharks in a single aerial survey (de la Parra Venegas et al. 2011). The largest-known aggregation as of February 2016 occurs seasonally off the Yucatan cost of Mexico, with over 1,100 identified sharks (Norman et al. submitted). Satellite-tagged sharks from this aggregation have been tracked to the northern Gulf of Mexico (Hueter et al. 2013), where aggregations of up to 100 sharks have been reported (Hoffmayer et al. 2005), south to Belize where 106 individual sharks were identified between 1998 and 2003 (Graham and Roberts 2007), and off the island of Utila, Honduras, where 95 sharks were identified between 1999 and 2011 (Fox et al. 2013).

There is no detailed study of Whale Shark life history; estimates of age at maturity range from 9 to over 20 or 30 years, generation time from 24 to over 60 years, and longevity from 60 to over 100 years (e.g. Wintner, 2000). Even if the most conservative (lowest) estimates are taken, this is a very low-productivity, low-resilience species. Calculating life history parameters using Fishbase (www.fishbase.org) and the 20 meter long shark reported by Chen *et al.* (1997) yields an estimate of 0.08/year intrinsic rate of population increase.

Gestation period and the interval between births are both unknown; only one litter of about 300 small near-term pups of 48-58 cm TL that grew rapidly in captivity has been reported (Joung *et al.*, 1996; Leu *et al.*, 1997). By analogy with the Nurse Shark *Ginglymostoma cirratum* (Castro, 2000), the only other Orectolobid shark for which detailed reproductive data are available, pregnancy may last for less than a year, but birth is likely followed by a long resting period and litters born only every two years. This strategy might explain the small number of pregnant females observed. The initial rapid growth of pups (Leu *et al.*, 1997) would explain the scarcity of records of very small Whale Sharks. Growth would slow rapidly at maturity (Pauly, 2002). A Whale Shark about 20m long and 34t in weight (as reported landed in Taiwan by Chen *et al.* 1997) could be over 100 years old.

There are several documented declines in seasonal catches by directed fisheries for the Whale Shark, with these declines having occurred in some areas over only a few years in relatively recent and short-lived intensive fisheries. Local populations have apparently declined drastically in some places, while fishing effort and price have greatly increased. Most of these fisheries are too recent and/or populations too poorly monitored to determine whether these declines would result in long-term (many decades) reductions in local populations even if closed. This may well be the case, by analogy with other large sharks, as a result of low productivity and rebound potential and a lack of migration into the area of unfished stocks from other sources. It is not known to what degree fishing in one area affects population(s) in other areas, although the fact that at least some of the sharks migrate long distances within ocean basins suggests that the effects may not be purely local. Thus, a fishery in one may affect numbers sighted in another area or even in a different region. There is increasing concern that unexplained declines in numbers sighted seasonally in apparently unfished areas such as Thailand and South Africa could be the result of fisheries impacting these populations elsewhere. The rapid collapse of localized fisheries for this widely distributed and apparently seasonally migratory species could be explained by the tendency for Whale Sharks to be philopatric and to return regularly to the same seasonal feeding locations. Despite their very wide-ranging nature, they are, therefore, effectively part of local stocks that are particularly vulnerable to depletion by fisheries activity.

c. Status of legal protection, with reference to relevant national legislation or regulation

International

Convention on the International Trade of endangered Species (CITES)
The Whale Shark is listed in Appendix II of the Convention on Trade in Endangered Species of Flora and Fauna (CITES). This means that all transboundary trade has to be licensed, based on an analysis of the effects of the removal from the wild, or culture of the species – a Non-Detriment Finding (www.cites.org).

Convention for the protection of Migratory Species (CMS) – Memorandum of Understanding (MOU) on the Conservation of Migratory Sharks

The whale shark is listed on Appendix II of the Convention on Migratory Species (CMS), and on Annex I of the Shark MoU, with the objective of achieving and maintaining a favorable conservation status for migratory sharks based on the best available scientific information, in particular the sharks listed on Annex 1 of the MOU, recognizing that successful shark conservation and management require the fullest possible cooperation among governments, intergovernmental organizations, nongovernmental organizations, and all stakeholders

United Nations Convention on the Law of the Sea (UNCLOS).
The Whale Shark is also listed on Annex I (Highly Migratory Species) of UNCLOS, requiring cooperation, directly or through appropriate international organizations, to ensure the conservation and sustainable use of such species.

***IPOA Sharks*:**
Since the 1990s there are several shark protection plans, both internationally at intergovernmental and non- governmental level, as well as at national level by several nations in the Wider Caribbean region. Within the framework of the Code of Conduct for Responsible Fisheries the FAO (Food and Agriculture Organization) developed the International Plan of Action for the Conservation and Management of Sharks (IPOA Sharks) in 1999. The objective of IPOA Sharks is to ensure the conservation and management of sharks and their long-term sustainable use. IPOA Sharks is voluntary and intends to give states guidelines on how to establish a National Plan of Action (NPOA) through guiding principles and procedures for implementation.

National Protection

National legislations in the Caribbean region applying to sharks (as reviewed by Van Beek *et al.,* 2014) is as follows:

US Caribbean Region:
NOAA fisheries service presented the amendment 4 to the 2006 Consolidated Atlantic Highly Migratory Species (HMS) Fishery Management Plan (FMP). The PowerPoint states that "in 2010, Puerto Rico reported approximately 11.8 mt of commercial shark landings and less than one megaton was reported by St. Thomas and St. John combined. These landings were not species specific and it is unknown if they were harvested from Federal or Territorial waters". Proposed management measures for small-scale HMS commercial fisheries include specific authorized gears and retention limits for sharks.

US Gulf of Mexico and (Caribbean) Florida:
Following years of declines in catches, and concern about the protection status of many shark species, in 1993 the USA established a Federal Management Plan for Shark Fisheries in the Atlantic Ocean, particularly directed at the coastal bottom long-line fishery. Since 1993 several amendments of the original plan have been implemented and local state governments have tied in by implementing complementary legislation. Measures included successively restrictive catch quotas, finning limitations, area closures, seasonal closures, adjustments of size limits, limits to retention in recreational fisheries, establishment of protected species lists, establish a shark research fishery and the use of regional and species specific quotas.

Honduras:
In June 2011 Honduras created the first shark sanctuary in America and declared all its marine waters in both the Pacific and Caribbean as a permanent shark sanctuary. This had been preceded in 2010 by a shark fishing moratorium and created the first shark sanctuary of the Americas amounting to about 240,000 km2 of national waters, most of which lie along the 700 km-long Caribbean coast of the nation.

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The Dominican Republic has, together with Belize and six other Central American countries, united under the name SICA (Central American Integration System), signed an agreement to prohibit shark finning. This ban is also applicable to fishing vessels in international waters under the flag of SICA member states. This arrangement OSP-05-11 entered into force in 1 January 2012.

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— **Bonaire**
  In 2008 the island of Bonaire passed a nature ordinance providing full protection for a list of species of plants and animals. This list includes all sharks and rays

d. Ecological interactions with other species and specific habitat requirements

The role of the Whale Shark in its ecosystem is unknown but, as a large plankton feeder, it may be similar to that of the smaller baleen whales. The Whale Shark is one of only three species of shark that filter feeds, the other two being the Megamouth (*Megachasma pelagios*) and Basking Shark (*Cetorhinus maximus*; Compagno, 1984). Unlike these two, the Whale Shark does not rely on forward motion for filtration, but is able to hang vertically in the water and suction feed by closing its gill slits and opening its mouth (Compagno, 1984). *R. typus* is believed to be able to sieve zooplankton as small as 1 mm in diameter through the fine mesh of their gill-rakers, and typically feeds on a variety of planktonic and nektonic prey, small crustaceans and schooling fishes and even occasionally ingesting small tuna and squid. Although the species occasionally feeds on eggs released by spawning aggregations of reef fish, this localized predatory activity is not considered likely to have a significant effect upon populations of the prey species (only a minute proportion of fertilized teleost eggs result in recruitment of adults to the population). Whale Sharks are known by traditional tuna fishermen to be associated with schools of tuna and have been used as natural 'fish aggregation devices' by tuna purse seiners in the Caribbean. Predators include killer whale, *Orcinus orca* and, for juveniles, blue marlin and blue shark.

e. Management and recovery plans for the species

National regulations are providing the strongest form of protection for Whale Sharks with total ban on fishing in Honduras in 1999, Belize and most recently in Mexico (as reviewed in Graham, 2007).

f. Research programs and available scientific and technical publications relevant to the species

Observations of the Whale Shark in the Leeward Dutch Caribbean have shown a Whale Shark feeding in tuna schools positioned in a stationary vertical stance by opening and closing its mouth at the water surface (Debrot *et al.,* 2013). It was surrounded by schools of 2-ft-long yellowfin tunas *Thunnus albacares*) that were preying on smaller baitfish which in turn sought protection in compact schools around the Whale Shark. This implies potential feeding benefit to the Whale Shark derived from the predatory activities of the tunas. Hoffmeyer *et al.* (2005) has remarked that the highest diversity of pelagic fish aggregations in the Gulf of Mexico are associated with Whale Sharks. It is proposed that the causal mechanism for this may be based on pelagic schools of baitfish seeking protection from (a diversity of) predators by schooling tightly around Whale Sharks. Colman (1997) and Hoffmayer *et al.* (2005) have similarly described Whale Sharks feeding from a stationary vertical stance, also referred to as "suction-feeding"(Hoffmayer *et al.,* 2005). However, the bulk of local observers indicate that most feeding behavior witnessed in the Dutch Caribbean concerned ram surface feeding (gill pumping movement) directed towards surface shoals of baitfish (Taylor, 2007).Other research suggests that Whale Sharks are gregarious and form seasonal aggregations in some coastal waters (De la Parra Venegas *et al.,* 2011). The authors describe an aggregation that occurs annually north of Cabo Catoche, off Isla Holbox on the Yucatán Peninsula of Mexico. Another, much denser aggregation of Whale Sharks (dubbed "the Afuera") is described as appearing to occur off to the east of the tip of the Yucatán Peninsula in the Caribbean Sea, with 420 Whale Sharks aggregating in an area 18 km^2 in 2009 (De la Parra Venegas *et al.*, 2011). The authors note that plankton studies indicated that the sharks were feeding on dense homogenous patches of fish eggs, identified as belonging to little tunny, *Euthynnus alletteratus*. This contrasts with the annual Cabo Catoche aggregation nearby, where prey consists mostly of copepods and scombrid shrimp. Increased sightings at the Afuera coincide with decreased sightings at Cabo Catoche, and both groups have the same sex ratio, implying that the same animals are likely involved in both aggregations; tagging data support this idea. With two Whale Shark aggregation areas, high coastal productivity and a previously unknown scombrid spawning ground, the northeastern Yucatán marine region is a critical habitat that deserves more concerted conservation efforts (De la Parra Venegas *et al.*, 2011).

g. Threats to the species, its habitats and associated ecosystems, especially threats which originate outside the jurisdiction of the Party

Small-scale harpoon and entanglement fisheries have taken place in various regions of the world, including India, Pakistan, Taiwan, the Philippines, and the Maldives. These took Whale Sharks primarily for their meat, liver oil, and/or fins. Liver oil was traditionally used for water-proofing boat hulls. The huge fins are low quality but of high value as restaurant "signboards" in East Asia, and the soft meat (known as "tofu shark") are in great demand in Taiwan (Province of China).

In the Caribbean, since there are no targeted fisheries, threats to Whale Sharks stem primarily from unregulated tourism, aquaria collections and boat collisions. Research on

Whale Shark behavior indicates that patterns of movement exist, most notably following the bathymetric contours of the Mesoamerican Barrier Reef . This north-south path coincides with an important shipping lane that links the United States with the Mesoamerican reef countries. The volume of shipping and more recently cruise boat traffic and its potential impact to the regional Whale Shark population is undetermined. Coastal Development, cruise ship tourism, rising oil and gas exploration and land-based sources of pollution may pose additional yet site-variable direct and indirect threats to the region's Whale Shark population (Graham, 2007).

3. Oceanic Whitetip Shark - *Carcharhinus longimanus*

Overview

The Oceanic Whitetip Shark qualifies for inclusion under Annex 2 of SPAW under Criterion 1 and 4. The global status of the species is assessed by IUCN as *Vulnerable*, but in the Northwest and Western Central Atlantic as *Critically Endangered* because of the enormous declines that have been reported (Baum *et al.,* 2015). Two estimates of trends in abundance from standardized catch rate indices were made from independent datasets. An analysis of the US pelagic longline logbook data between 1992 and 2000, which covers the Northwest and Western Central Atlantic regions, estimated declines of 70%. An analysis of the Gulf of Mexico, which used data from US pelagic longline surveys in the mid-1950s and US pelagic longline observer data in the late-1990s, estimated a decline of 99.3% over this forty year time period or 98% over three generations (30 years), although this may be an overestimation. Fishing pressure on this species must be considerably decreased through reduction in fishing effort, catch limits, measures to enhance chances of survival after capture and possibly also through the implementation of large-scale oceanic non-fishing areas. Because of its migratory nature, effective conservation of this species will require international cooperation. The Whitetip is listed under CITES Appendix II and listed as highly migratory under UNCLOS. This also makes it eligible for the SPAW listing under criterion 5.

Species information

a. Scientific and common names of the species;

1.1 Class: Chondrichthyes
1.2 Order: Carcharhiniformes
1.3 Family: Carcharhinidae
1.4 Species: *Carcharhinus longimanus* (Poey, 1861)
1.5 Scientific synonyms: *Pterolamiops longimanus* (Poey, 1861), *Carcharius obtusus* (Garman, 1881), *Carcharius insularum* (Zinder, 1904), *Pterolamiops magnipinnis* (Smith, 1958), and *Pterolamiops budkeri* (Fourmanoir, 1961).
1.6 Common names:
English: Oceanic Whitetip Shark, Brown Milbert's sand bar shark, brown shark, nigarno shark, whitetip, whitetip shark, white-tip shark, and whitetip whaler
French: Requin océanique
Spanish: Tiburón punta blanca oceánico, aletiblanco oceánico, cazón, galano

b. Estimated population of species and its geographic ranges

The Oceanic Whitetip Shark is a globally widespread shark, ranging across entire oceans in tropical and subtropical waters. It is an oceanic-epipelagic shark, usually found far offshore in the open sea in waters 200 m deep, between about 30°N and 35°S in all oceans; it is normally found in surface waters, although it has been recorded to 152 m. It has occasionally been recorded inshore but is more typically found offshore or around oceanic islands and areas with narrow continental shelves (Fourmanoir ,1961, Compagno, 2005, Last and Stevens, 1994). Temperatures of waters in which it regularly occurs are 18 to 28°C, with water above 20°C preferred. Although one whitetip was caught in water of 15°C it tends to withdraw from waters that are cooling below this, as in the Gulf of Mexico in winter

(Compagno, 2005.). The location of nurseries has not been reported, but very young Oceanic Whitetip Sharks have been found well offshore along the southeastern US, suggesting offshore nurseries over the continental shelves (Compagno, 2005).

Smith *et al*. (1998) investigated the intrinsic rebound potential of Pacific sharks and found that Oceanic Whitetips have a moderate rebound potential, because of their relatively fast growth and early maturation. The population dynamics and structure of this species are unknown. Distribution appears to depend on the size and sex and the nursery areas appear to be oceanic (Seki *et al*., 1998). Larger individuals are caught deeper than smaller ones and there is geographic and sexual segregation (Anderson and Ahmed, 1993).

Despite being initially described as the most common pelagic shark throughout the warm-temperate and tropical waters of the Atlantic (Mather and Day, 1954) and beyond the continental shelf in the Gulf of Mexico (Bullis, 1961), enormous declines are estimated to have occurred in the Northwest and Western Central Atlantic. Two estimates of trends in abundance from standardized catch rate indices have been made from independent datasets. An analysis of the US pelagic longline logbook data between 1992 and 2000, which covers the Northwest and Western Central Atlantic regions, estimated declines of 70% (Baum *et al*. 2003) and 57% from 1992 to 2005 (Cortés *et al*., 2007). An analysis of the Gulf of Mexico, which used data from US pelagic longline surveys in the mid-1950s and US pelagic longline observer data in the late-1990s, estimated a decline of 99.3% over this forty year time period (Baum and Myers, 2004). When trends in abundance from the former analysis are extrapolated back to the mid-1950s, they match the latter analysis almost exactly (99.8%). Over a period of three generations (30 years), the estimated decline is 98%. However, the latter study has recently been criticized because temporal changes in fishing gear and practices over the time period were not taken fully into account and the study may, therefore, have exaggerated or underestimated the magnitude of the declines (Burgess *et al*., 2005; Baum *et al*., 2005).

c. Status of legal protection, with reference to relevant national legislation or regulation

International

Convention on the International Trade of endangered Species (CITES)
The Oceanic Whitetip is listed under Appendix II of CITES in 2013. This means that although the species is not necessarily currently threatened with extinction, it may become so unless trade is strictly regulated to avoid utilization incompatible with their survival. International (commercial) trade is permitted but regulated through a licensing system (www.cites.org).

Convention for the protection of Migratory Species (CMS) – Memorandum of Understanding (MOU) on the Conservation of Migratory Sharks

Carcharinus longimanus is listed on Annex 1 of the Memorandum of Understanding (MOU) on the Conservation of Migratory Species. The Shark MOU is the first global instrument for the conservation of migratory species of sharks. Signatories to the MOU commit to the objective of achieving and maintaining a favorable conservation status for migratory sharks based on the best available scientific information, in particular the sharks listed on Annex 1 of the MOU, recognizing that successful shark conservation and management require the fullest possible cooperation among governments, intergovernmental organizations, nongovernmental organizations, and all stakeholders

IPOA Sharks

There are since the 1990s several shark protection plans, both internationally at intergovernmental and non- governmental level, as well as at national level by several nations in the Wider Caribbean region. Within the framework of the Code of Conduct for Responsible Fisheries the FAO (Food and Agriculture Organization) developed the International Plan of Action for the Conservation and Management of Sharks (IPOA Sharks) in 1999. The objective of IPOA Sharks is to ensure the conservation and management of sharks and their long-term sustainable use. IPOA Sharks is voluntary and intends to give states guidelines on how to establish a National Plan of Action (NPOA) through guiding principles and procedures for implementation.

National Protection

National legislations in the Caribbean region applying to sharks (as reviewed by Van Beek *et al.,* 2014) are as follows:

US Caribbean Region

NOAA fisheries service presented the amendment 4 to the 2006 Consolidated Atlantic Highly Migratory Species (HMS) Fishery Management Plan (FMP). The powerpoint states that "in 2010, Puerto Rico reported approximately 11.8 mt of commercial shark landings and less than one megaton was reported by St. Thomas and St. John combined. These landings were not species specific and it is unknown if they were harvested from Federal or Territorial waters". Proposed management measures for small-scale HMS commercial fisheries include specific authorized gears and retention limits for sharks.

US Gulf of Mexico and (Caribbean) Florida

Following years of declines in catches, and concern about the protection status of many shark species, in 1993 the USA established a Federal Management Plan for Shark Fisheries in the Atlantic Ocean, particularly directed at the coastal bottom long-line fishery. Since 1993 several amendments of the original plan have been implemented and local state governments have tied in by implementing complementary legislation. Measures included successively restrictive catch quotas, finning limitations, area closures, seasonal closures, adjustments of size limits, limits to retention in recreational fisheries, establishment of protected species lists, establish a shark research fishery and the use of regional and species specific quotas.

Honduras

In June 2011 Honduras created the first shark sanctuary in America and declared all its marine waters in both the Pacific and Caribbean as a permanent shark sanctuary. This had been preceded in 2010 by a shark fishing moratorium and created the first shark sanctuary of the Americas amounting to about 240,000 km2 of national waters, most of which lie along the 700 km-long Caribbean coast of the nation.

Bahamas
The Bahamas have had a longline fishing ban since 1993 and consequently there has been no commercial shark fishing activity. This longline ban has effectively made the whole archipelago of the Bahamas a shark “no-take” zone. The last export of shark from the Bahamas was a lot of 2 metric tons in 2004. In July 2011 the Bahamas went a step further and legally banned all shark fishing. That law firmly turns all 630,000 sq km of Bahamian waters into a shark sanctuary17. The fines for shark fishing were raised from 3000 to 5000 USD per incident.

Venezuela

Towards implementing its Plan de Acción Nacional (PAN) de conservación for sharks, in June 2012 Venezuela joined the rest of the Americas in outlawing the finning of sharks in its waters and established a 3,730 km2 shark sanctuary surrounding the touristic archipelago of Los Roques. Recent research (e.g. Tavares 2005, 2008 2009) had demonstrated the importance of the shallow waters of Los Roques as a shark nursery area.

The Dominican Republic has, together with Belize and six other Central American countries, united under the name SICA (Central American Integration System), signed an agreement to prohibit shark finning. This ban is also applicable to fishing vessels in international waters under the flag of SICA member states. This arrangement OSP-05-11 entered into force in 1 January 2012.

Kingdom of the Netherlands

- ***St. Maarten***
  On the 12th of October 2011 the government of St. Maarten issued a temporary moratorium on shark fishing. The shark fishing moratorium prohibits the take and landing of sharks and requires immediate release of incidentally caught sharks, under penalty of a maximum of 500,000 Antillean Guilders or 3 months in prison.
- ***Caribbean Netherlands***
  In 2015, the Dutch government designated the Yarari sanctuary for sharks and marine mammals in the Economic Exclusive Zones of Saba and Bonaire, declaring that provisions will be considered and implemented as necessary to regulate activities that may have a negative impact on sharks.
- **Bonaire**
  In 2008 the island of Bonaire passed a nature ordinance providing full protection for a list of species of plants and animals. This list includes all sharks and rays.

d. Ecological interactions with other species and specific habitat requirements

Oceanic Whitetip Sharks are high trophic-level predators in the open ocean, feeding mainly on teleosts and cephalopods (Backus, 1956), but some studies have also reported that they prey on sea birds and marine mammals, among others (Compagno, 1984). Based on the diet of the oceanic white shark, Cortés (1999) determined that its trophic level was 4.2 (maximum=5.0).

e. Management and recovery plans for the species

Conservation and management action are urgently required for this species; the only known conservation measure at present is a broad, multi-species pelagic shark quota for U.S. Atlantic waters. Specifically, fishing pressure on this species must be considerably decreased through reduction in fishing effort, catch limits, measures to enhance chances of survival after capture and possibly also through the implementation of large-scale oceanic non-fishing areas. Effective conservation of this species will require international cooperation. The Oceanic Whitetip is listed as a highly migratory species under the 1995 UN Agreement on the Conservation and Management of Straddling Fish Stocks and Highly Migratory Fish Stocks (UNFSA). The Agreement specifically requires coastal States and fishing States to cooperate and adopt measures to ensure the conservation of these listed species. To date, there is little progress in this regard. See United Nations Convention on the Law of the Sea for further details. Also of relevance is the FAO International Plan of Action for the Conservation and Management of Sharks (IPOA-Sharks) which specifically recommends that Regional Fisheries Organisations (RFO) carry out regular shark population assessments and that member States cooperate on joint and regional shark management plans. This is of particular importance for pelagic sharks such as *C. longimanus* whose stocks are exploited by more than one State on the high seas. Although steps are being taken by some RFOs to collect species-specific data on pelagic sharks, and to ban the practice of shark finning, to date no RFO has limited shark catches or drafted a "Shark Plan" as suggested in the IPOA-Shark guidelines (R. Cavanagh, pers. comm).

f. Research programs and available scientific and technical publications relevant to the species

Research is being carried out on the Oceanic Whitetip Sharks (*Carcharhinus longimanus*) in the western North Atlantic following severe declines in abundance and the identification of the need for conservation measures (Howey-Jordan *et al.,* 2013). The research brings to light the spatial and temporal distribution of the individuals and the potential interaction with fishing gear during their migrations. Individuals have been tagged with pop-up satellite archival tags near Cat Island in the central Bahamas 1–8 May 2011 to provide information about the horizontal and vertical movements of this species. The individuals remained within 500 km of the tagging area for about 30 days and then dispersed across 16,422 km2 of the western North Atlantic. Maximum individual displacement from the tagging site ranged from 290–1940 km after times at liberty from 30–245 days, with individuals moving to several different destinations (the northern Lesser Antilles, the northern Bahamas, and north of the Windward Passage). Many sharks returned to The Bahamas after ~150 days. Sharks spent 99.7% of their time shallower than 200 m and did not exhibit differences in day and night mean depths. All individuals made short duration (mean = 13.06 minutes) dives into the mesopelagic zone (down to 1082 m and 7.75°C), which occurred significantly more often at night. Ascent rates during these dives were significantly slower than descent rates, suggesting that these dives are for foraging. The sharks tracked appear to be most vulnerable to pelagic fishing gear deployed from 0–125 m depths, which they may encounter from June to October after leaving the protected waters of The Bahamas EEZ.

g. Threats to the species, its habitats and associated ecosystems, especially threats which originate outside the jurisdiction of the Party

Oceanic Whitetip Sharks have been caught in large numbers virtually everywhere they occur, particularly in pelagic longline and driftnet fisheries. This species was initially described as the most common pelagic shark beyond the continental shelf in the Gulf of Mexico (Wathne, 1959; Bullis, 1961), and throughout the warm-temperate and tropical waters of the Atlantic and Pacific (Mather and Day 1954, Strasburg 1957). In the Gulf of Mexico, for example, between 2 and 25 of these sharks were usually observed following the vessel during longline retrieval on the exploratory surveys in the 1950s and their abundance was considered as a serious problem because of the high proportion of tuna they damaged (Bullis and Captiva, 1955; Backus *et al.*, 1956; Wathne, 1959). Recent shark papers on the Gulf of Mexico have either not mentioned this species or have dismissed it as rare, not recognizing its former prevalence in the area (Baum and Myers 2004).

Few data are available on the catch rate of these sharks, and this is a serious hindrance to assessing the status of this species in regions other than the Northwest Atlantic and Eastern Central Pacific. According to Berkeley and Campos (1988), Oceanic Whitetip Sharks constituted 2.1% of the shark bycatch in the swordfish fishery along the east coast of Florida in 1981 to 1983. Information collected by at-sea scientific observers on U.S.-flagged longline vessels in the western North Atlantic Ocean indicates that Oceanic Whitetip is the 8th most abundant pelagic species caught. However, the low abundance of this species likely reflects the distribution of the fishery, as most U.S.-flagged vessels fish at the northernmost part of the range of the Oceanic Whitetip Shark (Beerkircher *et al.*, 2002). The United States reports that commercial fisheries land very few Oceanic Whitetip Sharks. Except for two peaks of about 1,250 and 1,800 sharks landed in 1983 and 1998, respectively, total catches never exceeded 450 individuals per year. However, the proportion of the catch of Oceanic Whitetip Shark increases in areas of the Atlantic Ocean that are more tropical than temperate. For example, Oceanic Whitetip Sharks were present in 4.72% of eastern tropical Atlantic French and Spanish tuna purse-seine sets (Santana *et al.*, 1997). Domingo (2004) reported that the Uruguayan longline fleet observer program in 1998-2003 recorded catch rates of 0.006 sharks/1,000 hooks in Uruguayan and adjacent high seas South Atlantic waters (latitude 26o-37o, 16-23oC) but catch rates increased to 0.09 sharks/1,000 hooks in international waters off western equatorial Africa. Only Brazil, Mexico, Spain, St. Lucia and the United States have reported catches to ICCAT and, as indicated by Clarke (2008), these data are likely inaccurate and therefore may under-represent the magnitude of catches in the Atlantic Ocean. This species has been recorded as part of the catch of oceanic longline industrial fisheries in the Colombian Caribbean, with mean catch sizes of 128 +/- 62.35 cm TL, which corresponds to juveniles and may be impacting likely development areas (Caldas and Correa, 2010).

For Annex III

1. Manta rays (Manta birostris, Manta alfredi, Manta cf. birostris)

Overview

The giant Manta Ray *Manta birostris* and the reef Manta Ray *Manta alfredi, with a third putative species endemic to the Caribbean region, Manta cf. birostris,* are the largest genus of rays, making their life history especially conservative, and rendering them vulnerable to depletion. Moreover, despite evidence for long migrations, regional populations appear to be small, sparsely distributed, and fragmented, meaning localized declines are unlikely mitigate by immigration. Both species of Manta Ray have recently been reassessed for the IUCN Red List, which looks at different species against a range of criteria to see what issues are of concern to the species survival. Both species of manta are considered to be 'Vulnerable' on this listing. Giant mantas have also recently been listed on Appendix I and II under the Convention on Migratory Species (CMS), and both species are listed in Appendix II of the Convention on International Trade of Endangered Species (CITES). Listing of the Manta Ray in Annex 3 of SPAW would thus be consistent with international agreements and would be compliant with criteria 4 (IUCN), 5 (CITES) and 6 (regional cooperation). Criterion 1 is met due to the decline and fragmentation of the populations.

Species information

a. Scientific and common names of the species

1.1 Class: Chondrichthyes (Subclass: Elasmobranchii)
1.2 Order: Rajiformes
1.3 Family: Mobulidae
1.4 Genus and species:
All species of Genus *Manta birostris* (Donndorff 1798), *Manta alfredi* (Krefft, 1868), *Manta* cf. *birostris* (putative) and any other putative *Manta* species.
1.5 1.5a. Scientific synonyms:
M. birostris: Manta hamiltoni (Hamilton & Newman 1849); Raja birostris (Donndorff, 1798)
M. alfredi: Deratoptera alfredi (Krefft, 1868); Manta fowleri (Whitney, 1936)
1.6 Common names:
M. birostris: English: Oceanic Manta Ray, Giant Manta Ray, Chevron Manta Ray, Pacific Manta Ray, Pelagic Manta Ray
Spanish: Manta Comuda, Manta Diablo, Manta Gigante, Manta Raya, Manta Voladora.
M. alfredi: English: Reef Manta Ray, Coastal Manta Ray, Inshore Manta Ray, Prince Alfred's Ray, Resident Manta Ray.

b. Estimated population of species and its geographic ranges

The Giant Manta Ray *M. birostris* occurs in tropical, sub-tropical and temperate waters of the Atlantic, Pacific and Indian Ocean. The reef Manta *M. alfredi* is found in tropical and subtropical waters (Marshall *et al.*, 2009; Kashiwagi *et al.*, 2011; Couturier *et al.*, 2012). A possible subspecies *Manta cf birostris* appears to be a regional endemic with a reported distribution throughout the Gulf of Mexico, the Caribbean, and along the eastern coast of the United States. *Manta birostris* are thought to be seasonal visitors along productive coastlines with regular upwelling, in oceanic island groups, and near offshore pinnacles and seamounts. They visit cleaning stations on shallow reefs, are sighted feeding at the surface inshore and offshore, and are also occasionally observed in sandy bottom areas and seagrass beds (Marshall *et al*., 2011). *M. alfredi* is commonly sighted inshore but is also observed around offshore coral reefs, rocky reefs, and seamounts. This species is often resident in or along productive near-shore environments, such as island groups, atolls, or continental coastlines, and may also be associated with areas or events of high primary productivity (e.g., upwelling; Homma *et al*., 1999; Dewar *et al*., 2008; Kitchen-Wheeler, 2010; Anderson *et al.,* 2011; Deakos *et al*., 2011; Marshall *et al.,* 2011a). *Manta cf birostris* exhibits similar habitat preferences to *M. alfredi.*

The Manta Ray is a migratory species, A global investigation of major aggregation sites revealed that the Giant Manta Ray may be a more oceanic and a more migratory species than the Reef Manta Ray (A. Marshall *et al.,* unpubl. data). Rare or seasonal sightings of the Giant Manta Ray at locations such as northern New Zealand (Duffy and Abbott, 2003), southern Brazil (Luiz *et al*., 2009) and Uruguay (Milessi and Oddone, 2003), the Azores Islands, the Similan Islands, Thailand (A. Marshall, unpubl. data) and the eastern coast of the United States (Bigelow and Schroeder, 1953), suggests that this species undergoes significant seasonal migrations.

Despite these data, preliminary satellite tracking studies and international photo-identification matching projects have suggested a high degree of fragmentation between regional populations of this species, suggesting that movements across ocean basins may be rare. Satellite tracking results have been able to reveal that the Giant Manta Ray is capable of large migrations (over 1,100 km straight line distance) and have monitored individual movements across international borders, across large bodies of water, and into international waters (A. Marshall *et al.,* unpubl. data; R. Rubin, pers. comm.). Satellite tracking studies using archival PAT tags have registered movements of the Giant Manta Ray from Mozambique to South Africa (a distance of 1,100 km), from Ecuador to Peru (190 km), from the Yucatan, Mexico into the Gulf of Mexico (448 km). This species is capable of deep dives and has been both seen at depth and tracked down to depths exceeding 1,000 meters (A. Marshall *et al*., unpubl. data), as reviewed by Marshall *et al.* (2011).

Despite the long distance migrations , it is believed that regional populations are rather small. Individuals demonstrated a degree of site fidelity to specific regions, as well as critical habitats within them. Because of the global nature of their individual distributions, absolute population sizes will always be difficult to assess. Currently, the overall total global population sizes of both Manta species are unknown, but subpopulations appear, in most cases, to be less than 1,000 individuals, as well as sparsely distributed, and highly fragmented. Also, limited interchanging between populations is suggested, likely due to their resource and habitat needs, meaning declines are not likely to be mitigated by immigration.. The degree of interchange of individuals between subpopulations is assumed to be low because there are currently no data that support such interchange, despite active efforts to do so (A. Marshall *et al.,* unpubl. data). The giant Manta Ray, unlike the reef Manta Ray, is not often encountered in schools of more than 30 fish when feeding. In general, they are less frequently observed than reef Manta Rays, despite having a larger distribution across the world.

Depletion has been documented in some monitored subpopulations in the Philippines, Indonesia, and Mexico. Fishermen and divers in Mozambique, Madagascar, Sri Lanka, Thailand, and Australia have offered much anecdotal evidence of population declines over the last decade as a result of increased fishing (TRAFFIC, 2013). Overall, the rate of population reduction appears to be high in several regions, up to as much as 80% over the last three generations (approximately 75 years), and globally a decline of >30% is strongly suspected.

c. Status of legal protection, with reference to relevant national legislation or regulation

International

Convention on the International Trade of endangered Species (CITES)
The genus of Manta Rays is listed in Appendix II of the Convention on International Trade in Endangered Species (CITES). This means that all transboundary trade has to be licensed, based on an analysis of the effects of the removal from the wild, or culture of the species – a Non-Detriment Finding (www.cites.org).

Convention for the protection of Migratory Species (CMS) – Memorandum of Understanding (MOU) on the Conservation of Migratory Sharks

Manta rays are listed under the Convention on Migratory Species (CMS) and in Annex 1 of the Shark MoU with the objective of international cooperation for their conservation. Signatories to the MOU commit to the objective of achieving and maintaining a favorable conservation status for migratory sharks based on the best available scientific information, in particular the sharks listed on Annex 1 of the MOU, recognizing that successful shark conservation and management require the fullest possible cooperation among governments, intergovernmental organizations, nongovernmental organizations, and all stakeholders

IPOA Sharks:
There are since the 1990s several shark protection plans, both internationally at intergovernmental and non- governmental level, as well as at national level by several nations in the Wider Caribbean region. Within the framework of the Code of Conduct for Responsible Fisheries the FAO (Food and Agriculture Organization) developed the International Plan of Action for the Conservation and Management of Sharks (IPOA Sharks) in 1999. The objective of IPOA Sharks is to ensure the conservation and management of sharks and their long-term sustainable use. IPOA Sharks is voluntary and intends to give states guidelines on how to establish a National Plan of Action (NPOA) through guiding principles and procedures for implementation.

National Protection

National legislations in the Caribbean region applying to sharks (as reviewed by Van Beek *et al.,* 2014) are as follows:

US Caribbean Region:
NOAA fisheries service presented the amendment 4 to the 2006 Consolidated Atlantic Highly Migratory Species (HMS) Fishery Management Plan (FMP). The PowerPoint states that "in 2010, Puerto Rico reported approximately 11.8 mt of commercial shark landings and less than one megaton was reported by St. Thomas and St. John combined. These landings were not species specific and it is unknown if they were harvested from Federal or Territorial waters". Proposed management measures for small-scale HMS commercial fisheries include specific authorized gears and retention limits for sharks.

US Gulf of Mexico and (Caribbean) Florida:
Following years of declines in catches, and concern about the protection status of many shark species, in 1993 the USA established a Federal Management Plan for Shark Fisheries in the Atlantic Ocean, particularly directed at the coastal bottom long-line fishery. Since 1993 several amendments of the original plan have been implemented and local state governments have tied in by implementing complementary legislation. Measures included successively restrictive catch quotas, finning limitations, area closures, seasonal closures, adjustments of size limits, limits to retention in recreational fisheries, establishment of protected species lists, establish a shark research fishery and the use of regional and species specific quotas.

Honduras:
In June 2011 Honduras created the first shark sanctuary in America and declared all its marine waters in both the Pacific and Caribbean as a permanent shark sanctuary. This had been preceded in 2010 by a shark fishing moratorium and created the first shark sanctuary of the Americas amounting to about 240,000 km2 of national waters, most of which lie along the 700 km-long Caribbean coast of the nation.

Bahamas:
The Bahamas have had a longline fishing ban since 1993 and consequently there has been no commercial shark fishing activity. This longline ban has effectively made the whole archipelago of the Bahamas a shark "no-take" zone. The last export of shark from the Bahamas was a lot of 2 metric tons in 2004. In July 2011 the Bahamas went a step further and legally banned all shark fishing. That law firmly turns all 630,000 sq km of Bahamian waters into a shark sanctuary17. The fines for shark fishing were raised from 3000 to 5000 USD per incident.

Venezuela:
Towards implementing its Plan de Acción Nacional (PAN) de conservación for sharks, in June 2012 Venezuela joined the rest of the Americas in outlawing the finning of sharks in its waters and established a 3,730 km2 shark sanctuary surrounding the touristic archipelago of Los Roques. Recent research (e.g. Tavares 2005, 2008 2009) had demonstrated the importance of the shallow waters of Los Roques as a shark nursery area.

The Dominican Republic has, together with Belize and six other Central American countries, united under the name SICA (Central American Integration System), signed an agreement to prohibit shark finning. This ban is also applicable to fishing vessels in international waters under the flag of SICA member states. This arrangement OSP-05-11 entered into force in 1 January 2012.

Kingdom of the Netherlands

Kingdom of the Netherlands

- ***St. Maarten***
  On the 12th of October 2011 the government of St. Maarten issued a temporary moratorium on shark fishing. The shark fishing moratorium prohibits the take and landing of sharks and requires immediate release of incidentally caught sharks, under penalty of a maximum of 500,000 Antillean Guilders or 3 months in prison.
- ***Caribbean Netherlands***
  In 2015, the Dutch government designated the Yarari sanctuary for sharks and marine mammals in the Economic Exclusive Zones of Saba and Bonaire, declaring that provisions will be considered and implemented as necessary to regulate activities that may have a negative impact on sharks.
- **Bonaire**
  In 2008 the island of Bonaire passed a nature ordinance providing full protection for a list of species of plants and animals. This list includes all sharks and rays.

d. Ecological interactions with other species and specific habitat requirements

The role of the *Manta spp.* in their ecosystem is not fully known but, as large plankton feeders, it may be similar to that of the smaller baleen whales. As large species which feed low in the food chain, *Manta spp.* can been viewed as indicator species for the overall health of the ecosystem. Studies have suggested that removing large, filter-feeding organisms from marine environments can result in significant, cascading species composition changes (Springer *et al.*, 2003).

e. Management and recovery plans for the species

Manta rays are protected under CITES Appendix II, meaning that the species is not necessarily currently threatened with extinction, but may become so unless trade is strictly regulated to avoid utilization incompatible with their survival. International (commercial) trade is permitted but regulated. See: www.cites.org

The reef manta (*Manta alfredi*) and giant manta (*Manta birostris*) are protected in all waters where EU fleets are allowed to fish according to the EU TAC and quotum regulation (EU 2016/71) which will be reformed during 2016.

f. Research programs and available scientific and technical publications relevant to the species

The spatio-temporal distribution of devil ray (*Manta birostri*) was studied using satellite tracking off the Yucatan peninsula in Mexico (Graham *et al.,* 2012). The authors describe that the Manta Rays were associated with seasonal upwelling events and thermal fronts off the peninsula, and made short-range shuttling movements, foraging along and between them. The majority of locations were received from waters shallower than 50 m deep, representing thermally dynamic and productive waters (Graham *et al.,* 2012).

The biology of elasmobranchs is among the most poorly known and least understood of all the marine vertebrate groups (Fowler, 2005). This is particularly so for the Caribbean region in specific. Within the Caribbean Sea, research efforts are made to assess distribution, habitat use, population structure, and trophic ecology of sharks using acoustic telemetry, satellite tagging methods, genetic analysis and stable isotope research. The occurrence and relative abundance of sharks are investigated using Baited Remote Underwater Videos (BRUVs). The skillful use of modern techniques such as genetic analyses, telemetry, and Baited Remote Video monitoring can help circumvent the often-low abundance (and low sampling) of many species, and should help develop powerful new insights and introduce new techniques to the region where capacity and technology have lagged behind.

g. Threats to the species, its habitats and associated ecosystems, especially threats which originate outside the jurisdiction of the Party

The main threat to both Manta species is fishing, both targeted and incidental. Manta rays are currently killed or captured by a variety of methods including harpooning, netting and trawling. These rays are easy to target because of their large size, slow swimming speed, aggregative behavior, predictable habitat use, and lack of human avoidance. Specifically for the Caribbean, exploitation rates are unknown because of lacking landings data from fisheries.

Manta ray products have a high value in international trade markets. Their gill rakers are particularly sought after and are used in Asian medicinal products. This market has resulted in directed fisheries for Manta Rays, which are currently targeting these rays in unsustainable numbers. Over 1,000 Manta Rays are caught per year in some areas (Alava *et al*., 2002; Dewar, 2002; White *et al*., 2006; Anderson *et al*., 2010). Artisanal fisheries also target both species for food and local products (White *et al*., 2006; Marshall *et al*., 2011).

Aside from directed fisheries, Manta Rays are also incidentally caught as bycatch in both large-scale fisheries and small netting programs such as shark control bather protection nets (Young 2001, C. Rose, pers. comm.).

As a result of sustained pressure from targeted fisheries and bycatch certain monitored subpopulations appear to have been rapidly depleted (e.g., Indonesia and the Philippines; Anon, 1997; Alava *et al*., 2002). Targeting either species of *Manta* at critical habitats or aggregation sites, where individuals can be caught in large numbers in a short time frame, is a particular threat. Regional populations of both species appear to be small, and localized declines are unlikely to be mitigated by immigration. This situation is exacerbated by the conservative life history of these rays, which constrain their ability to recover from a depleted state.

Cryptic threats such as mooring line entanglement and boat strikes can also wound Manta Rays, decrease fitness or contribute to unnatural mortality (Marshall *et al.,* 2011; Deakos *et al.*, 2011; F. McGregor pers. obs.). In Maui, Hawaii, 10% of the population has amputated or non-functioning cephalic fins, most likely caused from entanglement in monofilament fishing line (Deakos *et al.*, 2011). Many other threats have been postulated and identified such as habitat degradation, climate change, pollution (from oil spills), ingestion of micro plastics and irresponsible tourism practices.

Dive tourism involving this species is a growing industry and it has been demonstrated that sustainable tourism significantly enhances the economic value of such species in comparison to short-term returns from fishing (Anderson *et al.*, 2010). However, rapidly growing tourism (including in-water interactions and recreational boating traffic) if unmanaged, is likely to affect localized use of and visitation rates to critical cleaning and feeding habitats (Osada 2010; Deakos *et al.*, 2011). Their natural behavior can also be affected by excessive ecotourism (F. McGregor unpubl. data, A. Marshall unpubl. data).

2. Hammerhead sharks – Sphyrna lewini, Sphyrna mokarran, Sphyrna zygaena

Overview

Sphyrna lewini, Sphyrna mokarran and Sphyrna zygaena are circumglobal shark species residing in coastal warm temperate and tropical coastal seas. *S. lewini* have among the lowest recovery potential when compared to other species of sharks. Population growth rates determined for populations in the Pacific and Atlantic Ocean are low (r=0.08-0.10 yr-1) and fall under the low productivity category (r<0.14) as defined by Food and Agriculture Organization of the United Nations (FAO). Abundance trend analyses of catch-rate data specific to *S. lewini* and to a hammerhead complex of *S. lewini*, including *Sphyrna mokarran* and *Sphyrna zygaena*, have reported large declines in abundance ranging from 60-99% over recent years. A stock assessment using information on catch, abundance trends and biology specific to *S. lewini* from the northwest Atlantic Ocean indicate a decline of 83% from 1981-2005. Standardized catch rates from the U.S. pelagic longline fishery show declines in Sphyrna spp. of 89% between 1986 and 2000 and declines of 76% between 1992 and 2005. Hammerhead fins are highly valued and they are being increasingly targeted in some areas in response to increasing demand for shark fins. Hammerhead shark species *S. zygaena* and *S. lewini* were found to represent at least 4-5% of the fins auctioned in Hong Kong, the world's largest shark fin trading center. Fins from the Hong Kong SAR market can be genetically assessed and have been shown to originate western Atlantic Ocean basins.

The listing of the Sphyrnidae family to Annex III of SPAW is warranted by the proliferating evidence for declining populations in the West-Atlantic Ocean, their vulnerability to overexploitation and low recovery potential due to a low intrinsic growth rate and slow reproduction, and sustaining targeted catch and bycatch in the Northwest and Western Central Atlantic ocean. The exact amount of fishing pressure and the corresponding mortality rate is obscure, and especially species-specific inferences cannot easily be made, because of the difficulties associated with the inability to distinguish between *S. zygaena*, *S. lewini*, and *S. mokarran*. The precautionary approach should be taken because of these constraints, and the dire situation of the conservation status of hammerhead sharks, which is assessed by IUCN as Endangered for *S. mokarran* and *S. lewini* (both on a global scale and the Northwest and Western Central Atlantic subpopulation) and Vulnerable for *S. zygaena*. The family of hammerheads is listed under Appendix II of CITES and in Annex I of the United Nations Convention on the Law of the Sea (UNCLOS) and should therefore be subject to its provisions concerning fisheries management in international waters.

In summary, the three hammerhead species are eligible for listing under SPAW Annex 3 (III) according to the criteria 1 (decline in population), 4 (IUCN listing), 5 (CITES) and 6 (the importance of regional cooperation to protect the species).

Species information

a. Scientific and common names of the species

The family of Sphyrnidae, or hammerhead sharks, with primarily the following three species:

- Smooth hammerhead - *Sphyrna zygaena*
- Great hammerhead - *Sphyrna mokarran*

– Scalloped hammerhead - *Sphyrna lewini*

1. Class: Chondrichthyes (Subclass: Elasmobranchii)
2. Order: Carcharhiniformes
3. Family: Sphyrnidae

4. a Genus, species: *Sphyrna lewini* (Griffith and Smith, 1834)
5. a Scientific synonyms: Cestracion leeuwenii (Day 1865), Zygaena erythraea (Klunzinger 1871), Cestracion oceanica (Garman 1913), Sphyrna diplana (Springer 1941), Sphyrna couardi (Cadenat, 1951), Zygaena lewini (Griffith & Smith, 1834)
6. a Common names: English: scalloped hammerhead, bronze hammerhead shark, hammerhead, hammerhead shark, kidney-headed shark, scalloped hammerhead shark, and southern hammerhead shark,
French: requin marteau halicorne
Spanish: tiburón-martillo, cachona, cornuda común
Portuguese: tubarão martelo, tubarão-martelo-entalhado, cambeva, cambeva-branca, cambevota, vaca, vacota, panã
Papiamentu: tribon martin, krus

4. b Genus, species: *Sphyrna mokarran* (Rüppell, 1837)
5. b Scientific synonyms: *Zygaena mokarran* (Rüppell, 1837)
6. b Common names:
Great Hammerhead, Squat-headed Hammerhead Shark, Hammerhead Shark
French: Sorosena, Grand Requin-marteau, Marieau Millet, Poisson Pantouflier
Spanish: Cornuda, El Tiburon, Guardia Civil, Pez Martillo, Tiburon
Papiamentu: tribon martin, krus

4. c Genus, species: *Sphyrna zygaena* (Linnaeus 1758)
5. c Scientific synonyms:
6. c Common names: Smooth Hammerhead
French: Requin-marteau commun, Requin marteau lisse
Papiamentu: tribon martin, krus

b. Estimated population of species and its geographic ranges

Sphyrna lewini

S. lewini is a coastal and semi-oceanic hammerhead shark that is circumglobal in coastal warm temperate and tropical seas, from the surface and intertidal to at least 275 m depth. Although it is wide ranging, there is genetic evidence for multiple subpopulations, with a separate subpopulations in the Northwest and Western Central Atlantic. Where catch data are available, significant declines have been documented: both species-specific estimates for *S. lewini* and grouped estimates for Sphyrna spp. combined suggest declines in abundance of 50-90% over periods of up to 32 years in several areas of its range, including the northwest Atlantic. Interviews with fishermen also suggest declining trends. Similar declines are also inferred in areas of the species' range from which specific data are not available, but fishing pressure is known to be high. Estimates of trends in abundance are available from two long-term research surveys conducted on the U.S. east coast, both of which indicate this species has undergone substantial declines in this region (98% between 1972 and 2003, and an order of magnitude between 1975 and 2005). A third survey comparing catch rates between 1983/84 with those in 1993-95 showed a decline of two-thirds, while a survey beginning more recently showed increases in catch rates of juveniles. Standardized catch rates from the U.S. pelagic longline fishery show declines in Sphyrna spp. of 89% between 1986 and 2000 (according to the logbook data) and declines of 76% between 1992 and 2005 (according to observer data). The other information for this species from this region comes from Belize, where it has been heavily fished since the 1980s and fishermen have reported dramatic declines, which led to the end of the fishery. Guatemalan fishermen sustain fishing pressure in Belize (Baum *et al.,* 2007).

Recent studies indicate that the Northwest Atlantic, Caribbean Sea and Southwest Atlantic populations of this species are each genetically distinct from each other, and from Eastern Central Atlantic and Indo-Pacific populations (D. Chapman and M. Shivji, Nova, unpublished data). The boundaries between each population are not yet completely defined due to sampling constraints, but the "Caribbean Sea" population includes Belize and Panama and the "U.S. Gulf Of Mexico" sample covers from Texas to southwestern Florida, the boundary or transition zone will be in between Texas and Northern Belize (D. Chapman and M. Shivji, pers. comm.). Given the major declines reported in many areas of this species' range, increased targeting for its high value fins, low resilience to exploitation and largely unregulated, continuing fishing pressure from both inshore and offshore fisheries, this species is assessed by IUCN as Endangered globally, as well as in the Northwest and Western Central Atlantic (Baum *et al.*, 2007). Hayes *et al.* (2009) conducted an assessment in the Northwest Atlantic using two surplus production models. Population size in 1981 was estimated to be between 142,000 and 169,000 sharks, but decreased to about 24,000 sharks in 2005 (an 83-85% reduction). A new stock assessment by the NMFS for the northwestern Atlantic was released April 2011 Under the Magnuson Stevens Act. The stock assessment estimated that a total allowable catch (TAC) of 2,853 scalloped hammerhead sharks per year (or 69 percent of the 2005 catch) would allow a 70 percent probability of rebuilding to MSY in 10 years. Great hammerhead (*S. mokarran*) and smooth hammerhead (*S. zygaena*) are also part of the Atlantic Large Coastal Shark Complex, but are assessed at the complex level. The overfished and overfishing status of this complex is unknown as of the 4th quarter of 2011 (NMFS 4th Quarter 2011 stock status).

Sphyrna mokarran

S. mokarran ranges widely throughout the tropical waters of the world, from latitudes 40°N to 35°S. It is apparently nomadic and migratory, with some populations moving polewards in the summer, as off Florida and in the South China Sea. There is a pupping and nursery ground in a coastal mangrove estuarine area of southern Belize (R.T. Graham, pers. obs). The large, widely distributed, tropical hammerhead shark is largely restricted to continental shelves.

Although there is very little species-specific data available, the absence of recent records give cause to suspect a decline of at least 80% in the past 25 years. Fishing proceeds unmanaged and unmonitored, resulting in an assessment of Critically Endangered in the Eastern Atlantic. Although not targeted in the Northwest Atlantic and Gulf of Mexico it is taken as by-catch in several fisheries and suffers greater than 90% vessel mortality. Two time series data sets (pelagic logbook, large pelagic survey) have shown a decline in the catch of Sphyrna spp. since 1986. Difficulties in species identification and accurate recording make an assessment of this species very difficult, however low survival at capture makes it highly vulnerable to fishing pressure, whether directed or incidental. It is therefore assessed by IUCN as Endangered in the Northwest Atlantic and Gulf of Mexico, based on a suspected decline of at least >50% over the past 10 years. The decline is poorly documented and has not been curtailed (Denham *et al.,* 2007).

Sphyrna zygaena
Specific data on populations of this species are generally unavailable in many areas because hammerhead shark catches are often grouped to include several *Sphyrna* species. Furthermore, this species has sometimes been confused with the *S. lewini* in the Caribbean and these two species are probably misidentified with each other. *Sphyrna zygaena* is one of the larger hammerhead sharks, found worldwide in temperate and tropical seas, with a wider range than other members of its family. It is semi-pelagic and occurs on the continental shelf. Although few data are available on the hammerhead's life-history characteristics, it is a large hammerhead shark and presumably at least as biologically vulnerable as *S. lewini*. Few species-specific data are available to assess population trends because catches of hammerhead sharks are often grouped together under a single category. Very often these sharks are finned and the carcasses discarded. This species has sometimes been confused with *S. lewini* in the tropics and these two species are probably misidentified with each other in some areas. Time series data on population trends in hammerhead sharks, including *S. zygaena*, are available from the Northwest and Western Central Atlantic and the Mediterranean Sea. In the Northwest and Western Central Atlantic, where *S. zygaena* is outnumbered by *S. lewini* by about ten to one, analysis of U.S. pelagic longline logbook data estimated that Sphrynidae (including *S. lewini*, *S. mokarran* and *S. zygaena*) declined in abundance by 89% since 1986. In the Mediterranean Sea, where *S. zygaena* outnumbers *S. lewini*, compilation and meta-analysis of time series abundance indices estimated that Sphyrnidae (including *S. lewini*, *S. mokarran* and *S. zygaena*) declined by >99% in abundance and biomass since the early 19th century. The species is currently assessed by IUCN as Vulnerable (Casper *et al.,* 2005) and further investigation into threats, population trends, catches and life-history parameters throughout its range are required to determine whether it may warrant a higher category in the future.

c. Status of legal protection, with reference to relevant national legislation or regulation

International

Convention on the International Trade of endangered Species (CITES)
The hammerhead species *S. lewini*, *S. mokarran* and *S. zygaena* are all listed in Appendix II of the Convention on International Trade in Endangered Species (CITES). This means that all transboundary trade has to be licensed, based on an analysis of the effects of the removal from the wild, or culture of the species – a Non-Detriment Finding (www.cites.org)

United Nations Convention on the Law of the Seas (UNCLOS)
The family Sphyrnidae is listed on Annex I, Highly Migratory Species, of the UN Convention on the Law of the Sea. States are urged to cooperate over the management of these species. No such management yet exists.

Convention for the protection of Migratory Species (CMS) – Memorandum of Understanding (MOU) on the Conservation of Migratory Sharks

The Memorandum of Understanding on the conservation of migratory sharks (Sharks MoU) of the Convention on the Conservation of Migratory Species of Wild Animals (CMS) is a legally non-binding instrument of the CMS and the first global instrument for the conservation of migratory shark species. Signatories to the MOU commit to the objective of achieving and maintaining a favorable conservation status for migratory sharks based on the best available scientific information, in particular the sharks listed on Annex 1 of the MOU, recognizing that successful shark conservation and management require the fullest possible cooperation among governments, intergovernmental organizations, nongovernmental organizations, and all stakeholders

National Protection

National legislations in the Caribbean region applying to sharks (as reviewed by Van Beek *et al.,* 2014) are as follows:

IPOA Sharks

There are since the 1990s several shark protection plans, both internationally at intergovernmental and non- governmental level, as well as at national level by several nations in the Wider Caribbean region. Within the framework of the Code of Conduct for Responsible Fisheries the FAO (Food and Agriculture Organization) developed the International Plan of Action for the Conservation and Management of Sharks (IPOA Sharks) in 1999. The objective of IPOA Sharks is to ensure the conservation and management of sharks and their long-term sustainable use. IPOA Sharks is voluntary and intends to give states guidelines on how to establish a National Plan of Action (NPOA) through guiding principles and procedures for implementation. Caribbean countries with an IPOA are: Antigua and Barbuda (in draft), Costa Rica (2010 – not official), Bolivarian Republic of Venezuela (2013 – not official; FAO, 2016).

National Legislation

USA

In the U.S., *S. lewini, S. mokarran* and *S. zygaena* are included in the Large Coastal Shark complex management unit, on U.S. Highly Migratory Species Fishery Management Plan (National Marine Fisheries Service: Federal Fisheries Management Plan for Atlantic Tuna, Swordfish and Sharks). There are, however, no management measures specific to this species, and no stock assessments.

US Caribbean Region

NOAA fisheries service presented the amendment 4 to the 2006 Consolidated Atlantic Highly Migratory Species (HMS) Fishery Management Plan (FMP). The powerpoint states that "in 2010, Puerto Rico reported approximately 11.8 mt of commercial shark landings and less than one megaton was reported by St. Thomas and St. John combined. These landings were not species specific and it is unknown if they were harvested from Federal or Territorial waters". Proposed management measures for small-scale HMS commercial fisheries include specific authorized gears and retention limits for sharks.

Kingdom of the Netherlands

— ***St. Maarten***
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— **Bonaire**
In 2008 the island of Bonaire passed a nature ordinance providing full protection for a list of species of plants and animals. This list includes all sharks and rays.

US Gulf of Mexico and (Caribbean) Florida
Following years of declines in catches, and concern about the protection status of many shark species, in 1993 the USA established a Federal Management Plan for Shark Fisheries in the Atlantic Ocean, particularly directed at the coastal bottom long-line fishery. Since 1993 several amendments of the original plan have been implemented and local state governments have tied in by implementing complementary legislation. Measures included successively restrictive catch quotas, finning limitations, area closures, seasonal closures, adjustments of size limits, limits to retention in recreational fisheries, establishment of protected species lists, establish a shark research fishery and the use of regional and species specific quotas.

Honduras
In June 2011 Honduras created the first shark sanctuary in America and declared all its marine waters in both the Pacific and Caribbean as a permanent shark sanctuary. This had been preceded in 2010 by a shark fishing moratorium and created the first shark sanctuary of the Americas amounting to about 240,000 km2 of national waters, most of which lie along the 700 km-long Caribbean coast of the nation.

Bahamas
The Bahamas have had a longline fishing ban since 1993 and consequently there has been no commercial shark fishing activity. This longline ban has effectively made the whole archipelago of the Bahamas a shark “no-take” zone. The last export of shark from the Bahamas was a lot of 2 metric tons in 2004. In July 2011 the Bahamas went a step further and legally banned all shark fishing. That law firmly turns all 630,000 sq km of Bahamian waters into a shark sanctuary17. The fines for shark fishing were raised from 3000 to 5000 USD per incident.

Venezuela
Towards implementing its Plan de Acción Nacional (PAN) de conservación for sharks, in June 2012 Venezuela joined the rest of the Americas in outlawing the finning of sharks in its waters and established a 3,730 km2 shark sanctuary surrounding the touristic archipelago of Los Roques. Recent research (e.g. Tavares 2005, 2008 2009) had demonstrated the importance of the shallow waters of Los Roques as a shark nursery area.

The Dominican Republic has, together with Belize and six other Central American countries, united under the name SICA (Central American Integration System), signed an agreement to prohibit shark finning. This ban is also applicable to fishing vessels in international waters under the flag of SICA member states. This arrangement OSP-05-11 entered into force in 1 January 2012.

d. Ecological interactions with other species and specific habitat requirements

The diet of *Sphyrna mokarran* includes fish (mainly demersal species), other elasmobranchs, crustacea and cephalopods (Compagno in prep. b). Strong *et al.* (1990) observed a large (*ca* 4 m) Great Hammerhead feeding on a southern stingray *Dasyatis americana* (disc width 1.5 m). Adult *S. lewini* feed on mesopelagic fish and squids. In certain areas stingrays of the *Dasyatis* family are the preferred food. Pups and juveniles feed mainly on benthic reef fishes (e.g., scarids and gobiids), demersal fish and crustaceans. (Baum *et al.*, 2007). For *S. zygaena* less than 2 m in length from the waters off South Africa, Smale (1991) reported that the diet was dominated by inshore squid (mostly *Loligo v. reynaudii*), with teleosts such as hake, horse mackerel and ribbonfish also being important. Crustaceans and elasmobranchs have also been reported from stomach analyses (Bass *et al.*, 1975; Compagno, 1984; Smale 1991; Last and Stevens, 1994).

Sharks and rays are often predators feeding at a high trophic level and are therefore thought to exert a significant top-down control over the ecosystem. Both empirical studies and ecosystem modeling studies demonstrated that the decline of large coastal elasmobranch species could induce a trophic cascade, as well as decreased ecosystem functioning and resilience. Because of their large size they occupy ecological niches first occupied by large predatory reptilians and have likely played a critical role in the evolution of marine mammals as well as other predators and prey species (Ferretti *et al.*, 2010). Sharks are largely seen as feeding generalists and typically take a wide range of prey and therefore likely have limited effect on mortality rates in individual species (Ellis and Musick, 2007). They are typically wide ranging and interconnect food webs across wide geographic ranges (Musick *et al.*, 2000). The ecological role each species can play in this is likely influenced by their distribution across habitats. Most shark species (90%) are restricted to near-shore waters of the continental shelves whereas some species (e.g., hammerhead, tiger shark) migrate between the pelagic and near-shore habitats and only few are fully pelagic in habits.

We know very little about the specific roles of sharks in Caribbean coral reef ecosystems, and hammerheads are no exception, but current models and theories suggest that their loss causes multiple effects throughout local food webs and could lead to reef collapse. A study by Rezende *et al.* (2009) highlighted the importance of sharks for the organization, and potentially also for the stability and biodiversity of the Caribbean food webs. Modelling suggests that sharks are important regulators of grouper biomass on Caribbean reefs (Bascompte *et al.*, 2005) and potentially important for the biological control of the invasive lionfish *Pterois volitans* (Albins and Hixon, 2008; Arias-Gonzalez *et al.,* 2011). Other work suggests the role of sharks in regulating grouper biomass has an indirect positive effect on parrotfish biomass and grazing capacity (Chapman *et al.*, 2006). The model of Arias-Gonzalez *et al.* (2011) predicts that lionfish will replace sharks as apex predators as a result of a decrease in sharks due to overfishing throughout the region. The ecological effects of loss of sharks as top predators is difficult to understand and generally obscured by the fact that ecosystems have simultaneously been undergoing many other major changes. *S. lewini* is a high trophic level predator in coastal and open ocean ecosystems. It has a diverse diet, feeding on crustaceans, teleosts, cephalopods and rays (Compagno, 1984). An analysis of its stomach contents revealed that the males feed on 42% of *Ancistrocheirus lesueurii* (Orbigny 1842), a species of mesopelagic cephalopod (Klimley, 1987). On the other hand, females consumed 63% mesopelagic squid species, *Mastigoteuthis* sp and *Moroteuthis robusta* (Verril, 1876). Cortés (1999) determined the trophic level to be 4.1 (maximum=5.0) for *S. lewini,* based on diet information. Navia *et al.* (2010) propose that this is the second most topologically important species for the maintenance of the structure of the community in the central fishing zone in the Colombina Pacific.

e. Management and recovery plans for the species

See Van Beek et al. (2014) for a complete overview of Dutch national management and recovery plans.

There is a management plan in place in US waters, regulating catches from fishing and the scalloped hammerhead (*Sphyrna lewini*) population has stabilized since the plan was put into place in 1994 (Hayes *et al.*, 2009). Scalloped hammerheads, which are among the faster growing species in the complex, have a relatively high probability of recovering quickly. Despite its slow life history characteristics, this scalloped hammerhead population appears to have a 58% or greater probability of recovery within a decade if the 2005 catch is maintained or decreased (Hayes et al., 2009).

f. Research programs and available scientific and technical publications relevant to the species

The biology of elasmobranchs is among the most poorly known and least understood of all the marine vertebrate groups (Fowler, 2005). This is particularly so for the Caribbean region. Within the Caribbean Sea, research efforts are underway to assess distribution, habitat use, population structure, and trophic ecology of sharks using acoustic telemetry, satellite tagging methods, genetic analysis and stable isotope research. The occurrence and relative abundance of sharks are investigated using Baited Remote Underwater Videos (BRUVs). The skillful use of modern techniques such as genetic analyses, telemetry, and Baited Remote Video monitoring can help circumvent the often-low abundance (and low sampling) of many species, and should help develop powerful new insights and introduce new techniques to the region where capacity and technology have lagged behind.

g. Threats to the species, its habitats and associated ecosystems, especially threats which originate outside the jurisdiction of the Party.

Baum *et al.* (2003) have shown a a decline of 89% of hammerheads (primarily scalloped hammerheads (*Sphyrna lewini*)) in the northwestern Atlantic, including the Caribbean between 1986 and 2000.

For pelagic species, fishing is identified as the main threat, which is corroborated by studies that have demonstrated the extent of overfishing of large predators in the Caribbean (e.g. Bonfil, 1997; Stallings, 2009; Pandolfi *et al.,* 2003). Pelagic sharks are all found to be declining, albeit at different rates (Cortés *et al.*, 2007; Baum and Blanchard, 2010). A decadal dataset (1994–2003) of the Venezuelan longline fisheries recorded (by order of importance) landings of the Blue Shark (*Prionace glauca*), Night shark (*C. signatus*), Silky Shark, Great Hammerhead (*Sphyrna mokarran*), and the Shortfin Mako (*Isurus oxyrinchus*; Tavares and Arocha, 2008). A study after bycatch rates of the Venezuelan longline fleet showed a major bycatch of great, and smooth hammerhead (Arocha *et al.,* 2002).

Due to the distinctive head shape of this genus, it is typical for catches to be reported at the genus level, *Sphyrna* spp. Therefore, it is rare to find fisheries statistics that are specific to one species of hammerhead shark. Species identification (*S. mokarran* vs. *S. lewini*) is a large obstacle in the proper assessment of this species. Catches of Sphyrnidae have been reported only from the Atlantic Ocean since 1991 and these landings are undoubtedly under-reported. The catch was near 2,200 tons in 2004 (Maguire *et al.,* 2006). Only *S. zygaena* and *S. lewini* are reported as individual species in the Food and Agriculture Organisation (FAO) fisheries statistics, but hammerhead catches are often grouped in one category as, Sphyrna species, which makes identification of actual catches of *S. zygaena* difficult. The high at-vessel fishing mortality for hammerheads makes the threat of fishing even greater for these species. This species' fins are highly valued and they are being increasingly targeted in some areas in response to increasing demand for shark fins. Hammerhead shark species *S. zygaena* and *S. lewini* were found to represent at least 4-5% of the fins auctioned in Hong Kong, the world's largest shark fin trading center (Clarke *et al.*, 2006). Fins from the Hong Kong SAR market can be genetically assessed and have been shown to originate western Atlantic Ocean basins. In a study by Chapman et al. (2009) approximately 21% of the samples were sourced from the western Atlantic.

Hammerhead shark fins are generally high value compared to other species because of their high fin ray count (S. Clarke unpubl. data). It is estimated that between 1.3 and 2.7 million *S. zygaena* or *S. lewini* are represented in the shark fin trade each year or, in biomass, 49,000 to 90,000 mt (Clarke *et al.*, 2006). Longline fleets exert intense fishing pressure throughout the Northwest Atlantic (Baum *et al.,* 2003). Baum *et al.* (2003) estimated that hammerhead sharks (grouped data for *S. lewini*, *S. mokarran* and *S. zygaena*) have declined in abundance by 89% since 1986 (95% confidence interval (CI): 86 to 91%) in their analysis of U.S. pelagic longline logbook data. This group is primarily composed of *S. lewini*; in Virginia Institute of Marine Science sampling programs since 1973, *S. lewini* outnumbered *S. zygaena* by more than ten to one (Ha, 2006).

Recent research shows that large, oceanic sharks may actually depend on shallow coastal areas during part of their life cycle (e.g. Carrier and Pratt, 1998; Tavares, 2008; Clarke *et al.*, 2011; Daly-Engel *et al.,* 2012; Hammerschlag *et al.,* 2012). This makes many sharks vulnerable to habitat destruction in coastal areas, as caused by man (Jennings *et al.,* 2008) and possibly, on the long-term by climate change (Field *et al.*, 2009). The dependence of sharks on habitat quality has hardly been studied so far (Field *et al.,* 2009). One important dimension of habitat quality is that of food availability. Sharks are potentially affected by shortage of prey due to competition for the same resources by their largest piscivorous competitor, namely man, but this has received even less attention.

S. lewini

Sphyrna lewini is taken as both a target and bycatch by trawls, purse seines, gillnets, fixed bottom longlines, pelagic longlines and inshore artisanal fisheries. The latter catch large numbers of pups and juveniles in some regions. The species' aggregating habit makes them vulnerable to capture in large schools. This also means that they may appear more abundant in landings, where they are caught in high, localized concentrations. Intense fishing pressure can deplete regional stocks rapidly, and re-colonization of depleted areas from neighboring regions is expected to be a slow and complex process. This species is expected to have a low resilience to exploitation because of its life-history characteristics. Also, the aggregating habit of *S. lewini* makes it very vulnerable to capture. In the nursery zones (<10 m) south and southeast of Brazil the newborn are intensively fished through coast gillnets, prawn trawls and pair trawls, as well as recreational capture (Haimovici & Mendonça, 1996; Kotas 2004; Kotas *et al.*, 2005; Vooren *et al.*, 2005).

In the USA, this species is caught in both commercial coastal shark bottom longline and gillnet fisheries and the pelagic longline fishery, where it suffers high mortality (Piercy *et al.,* 2007). It is also taken in recreational shark fisheries. The USA pelagic longline fishery has operated since the 1960s and encompasses the entire range of this species in the Northwest and Western Central Atlantic, from the equator to about 50°N. Although this is quite a fecund shark, its late age at maturity in this region (15 years) will render it quite vulnerable to overexploitation, and limit its recovery potential.

Estimates of trends in abundance of *Sphyrna* spp. are available from standardized catch rate indices of the U.S.A. pelagic longline fishery, from logbook data between 1986 and 2000 and from observer data between 1992 and 2005. The area covered by this fishery, ranging from the equator to about 50°N, encompasses the range of this species in these two regions. Although this fishery will not sample individuals closest to the coast, the sample size of hammerheads recorded in the logbook data (the majority of which are thought to be *S. lewini*) is substantial, with over 60,000 recorded during this period. This subpopulation of Scalloped Hammerhead sharks is estimated from the logbook data to have declined by 89% over the 15 year time period, from 1986-2000 (Baum *et al.*, 2003), which is less than one generation. A more recent analysis of the pelagic longline observer data indicates that *Sphyrna* spp. declined by 76% between 1992 and 2005 (Baum *et al.*, in prep.). The pelagic longline fishery has operated in these regions since the 1960s, thus declines from 1986 were certainly not from virgin population abundance.

Off the Atlantic coast of Belize hammerheads were fished heavily by longline in the 1980s and early 1990s (R.T. Graham, pers. obs.). Hammerheads are a favored target species for their large fins. Interviews with fishermen indicate that the abundance and size of Sphyrnids has declined dramatically in the past 10 years as a result of over exploitation, leading to a halt in the Belize based shark fishery (R.T. Graham, pers. obs.). However, the pressure is still sustained by fishers driving into Belizean waters from Guatemala (R.T. Graham, pers. obs.). *Sphyrna lewini* is also taken in various fisheries along the Caribbean coast of South America. It is taken in artisanal gillnet fisheries targeting mackerel off Guyana, Trinidad and Tobago and in pelagic tuna fisheries of the eastern Caribbean (Chan A Shing, 1999).

S. mokarran

Sphyrna mokarran is taken by target and bycatch, fisheries (Dudley and Simpfendorfer, 2006; Zeeberg *et al.*, 2006) and is regularly caught in the Caribbean, with longlines, fixed bottom nets, hook-and-line, and possibly with pelagic and bottom trawls (Compagno, *in prep*). Hammerhead sharks, with *S. mokarran* in particular, have been noted as a favored target species due to the size of their fins (R.T. Graham, pers. comm). Fin prices are rising above US$50/lb in the neighboring countries of Guatemala, driven by Asian buyers, according to interviews (R.T. Graham, pers. obs). Bonfil (1994) gives an overview of global shark fisheries. This species is mentioned specifically with reference to fisheries in Brazil, East USA and Mexico, however *Sphyrna* spp. are mentioned in the majority of tropical fisheries cited.

This species is caught primarily as a bycatch in the pelagic longline, bottom longline and net fisheries along the northwest Atlantic and Gulf of Mexico. It is also caught in the recreational fishery. The species represents 0.7% of the species catch and suffers from greater than 90% at-vessel fishing mortality in the U.S. bottom longline fishery (Commercial Shark Fishery Observer Program unpubl. data). The U.S. pelagic fishery logbook data has shown a decline close to 90%, however this dataset is known for inaccurate data reporting (Beerkircher *et al.,* 2002). There is probably a lack of reporting of the catch of Great Hammerheads because this species is routinely finned and discarded, which is illegal in the US Atlantic Federal Waters (Commercial Shark Fishery Observer Program, unpub. data). Both the pelagic and bottom longline observer programs have recorded a 2 to 3:1 ratio for *S. Lewini* to *S. mokarran*. The meat is not valuable but the fins are high grade and bring in a good price, thus finning still occurs in the U.S. fishery.

There appear to be little data for landings and catch effort for this species in Central America and the Caribbean. Off the coast of Belize hammerheads were fished heavily by longline in the 1980s and early 1990s. Interviews with fishermen indicate that the abundance and size of Sphyrnids has declined dramatically in the past 10 years as a result of over exploitation, leading to a halt in the Belize based shark fishery (R.T. Graham, pers. obs). However, the pressure is still sustained by fishers driving into Belizean waters from Guatemala (R.T. Graham pers. obs). The Cuban directed shark fishery (longline) recorded between 1983 and 1991 *S. mokarran* (subadults and juveniles) as one of 23 species caught. Since 1992 small increases in mean sizes were noted, indicating partial recovery of the species. In Mexico between November 1993 and December 1994 (Tamaulipas, Veracruz, Tabasco, Campeche and Yucatan) 901 vessels were monitored every day. *Sphyrna mokarran* represented 86% of the total catch.

S. zygaena

Sphyrna zygaena is caught with a variety of gears, including with pelagic longlines, handlines, gillnets, purse seines and pelagic and bottom trawls (Bonfil, 1994; Compagno in prep; Maguire *et al.,* 2006). This shark is undoubtedly caught in shark fisheries in most parts of its range, but it is not always reported separately from other hammerhead species. Bonfil (1994) reported that this species is caught as bycatch in a number of non-shark fisheries, particularly pelagic longline and gillnet fisheries that operate close to temperate and subtropical continental shelves. The capture of *S. zygaena* in many of these fisheries is infrequent (Bonfil, 1994). Although size data are limited, catches in pelagic fisheries appear to be dominated by larger individuals, while juveniles are common in inshore shelf fisheries.

References

Alava, M.N.R., Dolumbaló, E.R.Z., Yaptinchay, A.A. and Trono, R.B. 2002. Fishery and trade of Whale Sharks and Manta Rays in the Bohol Sea, Philippines. Pp. 132-148. In: S.L. Fowler, T.M. Reed and F.A. Dipper (eds). Elasmobranch Biodiversity, Conservation and Management: Proceedings of the International Seminar and Workshop. Sabah, Malaysia, July 1997. Occasional paper of the IUCN Species Survival Commission No. 25.

Anderson, R., Adam, M., Kitchen-Wheeler, A. and Stevens, G. 2010. Extent and economic value of Manta Ray watching in Maldives. Tourism in Marine Environments 7: 15-27.

Anderson, R.C. and Ahmed, H. 1993. The shark fisheries in the Maldives. FAO, Rome, and Ministry of Fisheries, Male, Maldives.

Anderson, R.C., Adam, M.S., and Goes, J.I. 2011. From monsoons to mantas: seasonal distribution of Manta alfredi in the Maldives. Fisheries Oceanography, 20(2): 104-113.

Anon. 1997. Fisheries conservation crisis in Indonesia: Massive destruction of marine mammals, sea turtles and fish reported from trap nets in pelagic migratory channel. http://darwin.bio.uci.edu/~sustain/bio65/indonesia/indon97e.htm.

Backus, R.H., Springer, S. and Arnold Jr., E.L. 1956. A contribution to the natural history of thewhite-tip shark, Pterolamiops longimanus (Poey). Deep-Sea Research 3: 176–188.

Baum, J., Medina, E., Musick, J.A. & Smale, M. 2015. Carcharhinus longimanus. The IUCN Red List of Threatened Species 2015: e.T39374A85699641. http://dx.doi.org/10.2305/IUCN.UK.2015.RLTS.T39374A85699641.en.

Baum, J.K. and Myers, R.A. 2004. Shifting baselines and the decline of pelagic sharks in the Gulf of Mexico. Ecology Letters. 7(3): 135–145.

Baum, J.K., Kehler, D. and Myers, R.A. 2005. Robust estimates of decline for pelagic shark populations in the northwest Atlantic and Gulf of Mexico. Fisheries 30: 27–30.

Beerkircher, L.R., Cortés, E., and Shivji, M. 2002. Characteristics of Shark Bycatch Observed on Pelagic Longlines off the Southeastern United States, 1992–2000. Marine Fisheries Review, 64(4) 40–49.

Berkeley, S.A. and Campos, W.L. 1988. Relative abundance and fishery potential of pelagic sharks along Florida's east coast. Mar. Fish. Rev. 50(1): 9–16.

Bigelow, H.B. and Schroeder, W.C. 1953. Sawfish, guitarfish, skates and rays. In: Tee-Van (ed.), Fishes of the Western North Atlantic, Part 2. Sears Foundation for Marine Research, Yale University, New Haven, pp 508-514.

Bullis H.R.J. and Captiva, F.J. 1955. Preliminary report on exploratory long-line fishing for tuna in the Gulf of Mexico and the Caribbean sea. Commercial Fisheries Review 17: 1–20.

Bullis, H.R.J. 1961. Observations on the feeding behavior of white-tip sharks on schooling fishes. Ecology 42: 194–195.

Burgess, G.H., Beerkircher, L.W., Cailliet, G.M., Carlson, J.K., Cortes, E., Goldman, K.J., Grubbs, R.D., Musick, J.A., Musyl, M.K. and Simpfendorfer, C.A. 2005. Is the collapse of shark populations in the northwest Atlantic Ocean and Gulf of Mexico real? Fisheries 30: 10.

Caldas, J.P. and Correa, J.L. 2010. Captura de tiburones asociada a la pesca industrial com palangre oceânico en el mar Caribe colombiano. Libro de Resúmenes II Encuentro de Colombiano sobre Condrictios. Cali, Colombia. P 35.

Carlson, J.K. and Osborne, J. 2012. Relative abundance of smalltooth Sawfish (*Pristis pectinata*) based on the Everglades National Park Creel Survey. NOAA Technical Memorandum NMFS-SEFSC-626, 15 p.

Castro, J.I. 2000. The biology of the nurse shark, Ginglymostoma cirratum, off the Florida east coast and the Bahama Islands. Environmental Biology of Fishes 58(1): 1-22.

Chapman, D.D., Simpfendorfer, C.A., Wiley, T.R., Poulakis, G.R., Tringali, M., Carlson, J.K., and Feldheim, K.A. 2011. Genetic diversity despite population collapse in a critically endangered marine fish: the Smalltooth Sawfish (Pristis pectinata). Journal of Heredity 102(6): 643-652.

Charvet-Almeida, P. 2002. Sawfish trade in the North of Brazil. Shark News 14: 9. Newsletter of the IUCN Shark Specialist Group. Naturebureau, Newbury, UK.

Chen, C.T., Liu, K.M. and Joung, S.J. 1997. Preliminary report on Taiwan's Whale Shark fishery. TRAFFIC Bulletin 17(1): 53–57.

Clarke, S. 2008. Estimating historic shark removals in the Atlantic using shark fin trade data and Atlantic specific area, tuna catch and effort scaling factors. ICCAT SCRS 2008/139.

Colman, J.G. 1997. A review of the biology and ecology of the Whale Shark. Journal of Fish Biology 51:1219-1234.

Compagno L.J.V. (2001) Sharks of the World: An Annotated and Illustrated Catalogue of Shark Species Known to Date. Volume 2 Bullhead, Mackerel and Carpet Sharks (Heterodontiformes, Lamniformes and Orectolobiformes). Food and Agriculture Organization of the United Nations, species catalogue for fishery purposes, Rome, Italy.

Compagno, L.J.V. 1984. FAO species catalogue. Vol. 4. Sharks of the world. An annotated and illustrated catalogue of shark species known to date. FAO Fisheries Synopsis No. 125, Volume 4, Part 1.

Compagno, L.J.V. 1984. Sharks of the World. An annotated and illustrated catalogue of shark species to date. Part I (Hexanchiformes to Lamniformes). FAO Fisheries Synopsis, FAO, Rome.

Compagno, L.J.V. 2005. Checklist of living Chondrichthyes. In: Hamlett, W.C. (ed.) Reproductive biology and phylogeny of chondrichthyes: sharks, rays and chimaeras, Vol. 3. Endfield, USA: Science Publishers: 503-548.

Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). 2007. Proposal 17 Inclusion of all species of the family Pristidae in Appendix I of CITES. Fourteenth meeting of the Conference of the Parties The Hague (Netherlands), 3-15 June 2007. http://www.cites.org/eng/cop/14/prop/e14-p17.pdf.

Cortés, E. 1999. Standardized diet compositions and trophic levels of sharks. ICES Journal of Marine Science 56:707–17

Cortés, E., C. Brown, and L. R. Beerkircher. 2007. Relative abundance of pelagic sharks in the western North Atlantic Ocean, including the Gulf of Mexico and Caribbean Sea. Gulf Caribbean Research Report 19: 37-52.

Couturier, L.I.E., Marshall, A.D., Jaine, F.R.A., Kashiwagi, T., Pierce, S.J., Townsend, K.A., Weeks, S.J., Bennet, M.B., and Richardson, A.J. 2012. Biology, ecology and conservation of the Mobulidae. Journal of Fish Biology, 80: 1075-1119.

De la Parra Venegas, R., R. Hueter, J. González Cano, J. Tyminski, J. Gregorio Remolina, M. Maslanka, A. Ormos, L. Weigt, B. Carlson and A. Dove, 2011. An unprecedented aggregation of Whale Sharks, Rhincodon typus, in Mexican coastal waters of the Caribbean Sea. PLoS ONE 6(4):e18994.

Deakos, M., Baker, J., and Bejder, L. 2011. Characteristics of a Manta Ray (Manta alfredi) population off Maui, Hawaii, and implications for management. Marine Ecology Progress Series, 429: 245-260.

Debrot, A.O., Leon de, R., Esteban, N., Meesters, H.W.G. (2013) Observations on the Whale Shark (Rhincodon typus) in the Dutch Caribbean. Caribbean Journal of Science, Vol. 47 [2-3]: 344-349.

Dewar, H. 2002. Preliminary report: Manta harvest in Lamakera. Report from the Pfleger Institute of Environmental Research and the Nature Conservancy.

Dewar, H., Mous, P., Domeier, M., Muljadi, A., Pet, J., Whitty, J. 2008. Movements and site fidelity of the giant Manta Ray, Manta birostris, in the Komodo Marine Park, Indonesia. Marine Biology, 155, (2); 121-133.

Domingo, A. 2004. ¿Adónde fue el Longimanus?. Elasmovisor, Bol. SBEEL, July, Brazil, 6pp.

Doumbouya, F. 2004. Rapport sur la preparation du PAN-Requin Guinéen et le dossier de la raie Pristis. Report to the Sub-Regional Fisheries Commission from the Départment Pêche Artisanale, Ministere de la Pêche et de l'Aquaculture, Conakry, Republic de Guinée.

Duffy, C.A.J. and Abbott, D. 2003. Sightings of mobulid rays from northern New Zealand, with confirmation of the occurrence of Manta birostris in New Zealand waters. New Zealand Journal of Marine and Freshwater Research 37: 715-721.

Dulvy, N.K, Fowler, S.L., Musick, J.A., Cavanagh, R.D., Kyne, P.M., Harrison, L.R., et al. (2014) Extinction risk and conservation of the world's sharks and rays. eLife 2014;3:e00590

Eckert, S.A. and B.S. Stewart. 2001. Telemetry and satellite tracking of Whale Sharks, Rhincodon typus, in the Sea of Cortez, Mexico, and the north Pacific Ocean. Environmental Biology of Fishes 60: 299-308.

Faria, V.V., McDavitt, M.T., Charvet, P., Wiley, T.R., Simpfendorfer, C.A. and Naylor, G.J.P. 2013. Species delineation and global population structure of Critically Endangered Sawfishes (Pristidae). Zoological Journal of the Linnean Society 167: 136-164.

Fourmanoir, P. 1961. Requins de la Côte Ouest de Madagascar. Memoires de L'Institut Scientifique de Madagascar. Série F. Oceanographie. ORSTOM. Tome IV.

Fowler, S.L. 2000. Whale shark Rhincodon typus. Policy and research scoping study. Nature Conservation Bureau, Newbury, UK.

Fowler, S.L., Cavanagh, R.D., Camhi, M., Burgess, G.H., Cailliet, G.M., Fordham, S.V., Simpfendorfer, C.A. and Musick, J.A. (comp. and ed.). 2005. Sharks, Rays and Chimaeras: The Status of the Chondrichthyan Fishes. Status Survey. IUCN/ SSC Shark Specialist Group. IUCN, Gland, Switzerland and Cambridge, UK. x + 461 pp.

Graham, R.T. 2007. Behaviour and conservation of Whale Sharks on the Belize BarrierReef

Graham, R.T. and Roberts, C.M. 2007. Assessing the size, growth rate and structure of a seasonal population of whale sharks (Rhincodon typus Smith 1828) using conventional tagging and photo identification. Fisheries Research 84: 71-80.

Graham, R.T., Hickerson, E., Castellanos, D,W., Remolina, F., Maxwell, S. 2012. Satellite Tracking of Manta Rays Highlights Challenges to Their Conservation. PLoS ONE 7(5): e36834. Doi:10.1371/pournal.pone.0036834

Heyman, W., Graham, R., Kjerfve, B. and Johannes, R.E. 2001. Whale sharks Rhincodon typus aggregate to feed on fish spawn in Belize. Marine Ecology Progress Series 215: 275–282.

Hoffmayer, E. R., J. S. Franks, and J. P. Shelley. 2005. Recent Observations of the Whale Shark (Rhincodon typus) in the northcentral Gulf of Mexico. Gulf and Caribbean Research 17: 1-4.

Homma, K., Maruyama, T., Itoh, T., Ishihara, H., and Uchida, S. 1999. Biology of the Manta Ray, Manta birostris Walbaum, in the Indo-Pacific. In: Seret, B. and Sire, J.Y. (eds) Indo-Pacific fish biology: Proc 5th Int Conf Indo-Pacific Fishes, Noumea, 1997. Ichthyological Society of France, Paris, p 209–216.

Howey-Jordan LA, Brooks EJ, Abercrombie DL, Jordan LKB, Brooks A, Williams S et al (2013) Complex movements, philopatry and expanded depth range of a severely threatened pelagic shark, the oceanic whitetip (Carcharhinus longimanus) in the Western North Atlantic. PLoS One 8(2):e56588.

Hueter RE, Tyminski JP, de la Parra R (2013) Correction: Horizontal Movements, Migration Patterns, and Population Structure of Whale Sharks in the Gulf of Mexico and Northwestern Caribbean Sea. doi: info:doi/10.1371/annotation/491b9b6c-7f77-4fb0-b336-572078aec830

Joung, S.J., C.T. Chen, C. Eugenie, S. Uchida and W.Y.P. Huang. 1996. The Whale Shark Rhincodon typus is a livebearer: 300 embryos found in one 'megamamma' supreme. Environmental Biology of Fishes 46: 219–223.

Kashiwagi, T., Marshall, A.D., Bennett, M.B. and Ovenden, J.R. 2011. Habitat segregation and mosaic sympatry of the two species of Manta Ray in the Indian and Pacific Oceans, Manta alfredi and M. birostris. Marine Biodiversity Records 4: e53.

Kitchen-Wheeler, A. 2010. Visual identification of individual Manta Ray (Manta alfredi) in the Maldives Islands, Western Indian Ocean. Marine Biology Research, 6(4):351-363

Last, P.R. and Stevens, J.D. 2009. Sharks and Rays of Australia. Second Edition. CSIRO Publishing, Collingwood.

Leu, M.Y., Chang, W.B. and Fang, L.S. 1997. The success of keeping a baby Whale Shark from its fetal stage in Taiwan. Proceedings of the Fourth International Aquarium Congress, Tokyo, Japan, June 1996.

Luiz, O.J. Jr, Balboni, A.P., Kodja, G., Andrade, M. and Marum, H. 2009. Seasonal occurrences of Manta birostris (Chondrichthyes: Mobulidae) in southeastern Brasil. Ichthyological Research 56: 96-99.

Marshall, A., Bennett, M.B., Kodja, G., Hinojosa-Alvarez, S., Galvan-Magana, F., Harding, M., Stevens, G. & Kashiwagi, T. 2011a. Manta birostris. The IUCN Red List of Threatened Species 2011: e.T198921A9108067.

Marshall, A.D., Compagno, L.J.V. and Bennett, M.B. 2009. Redescription of the genus Manta with resurrection of Manta alfredi (Krefft, 1868) (Chondrichthyes; Myliobatoidei; Mobulidae). Zootaxa 2301: 1-28.

Marshall, A.D., Dudgeon, C. and Bennett, M.B. 2011. Size and structure of a photographically identified population of Manta Rays Manta alfredi in southern Mozambique. Marine Biology 158(5): 1111-1124.

Mather, F.J.I. and Day, C.G. 1954. Observations of pelagic fishes of the tropical Atlantic. Copeia 1954: 179–188.

McClenachan, L. 2009. Documenting loss of large trophy fish from the Florida Keys with historical photographs. Conservation Biology 23 (3), 636-643.

McDavitt, M. 1996. The cultural and economic importance of Sawfishes (family Pristidae). Shark News 8: 10–11.

McDavitt, M. T. 2002. Lake Nicaragua revisited: conversations with a former Sawfish fisherman. Shark News 14: 5. Newsletter of the Shark Specialist Group. Naturebureau, Newbury, UK.

Migdalski, E.C. 1981. Fish Mounts and Other Fish Trophies. John Wiley & Sons, New York.

Millessi, A.C. and Oddone, M.C. 2003. Primer registro de Manta birostris (Donndurff 1798) (Batouidea: Mobulidae) En el Rio de la Plata, Uruguay. Gayana 67: 127-130.

National Marine Fisheries Service (NMFS). 2009. Recovery Plan for Smalltooth Sawfish (Pristis pectinata). Prepared by the Smalltooth Sawfish Recovery Team for the National Marine Fisheries Service. Silver Spring.

Norman, B.M. 1999. Aspects of the biology and ecotourism industry of the Whale Shark Rhincodon typus in north-western Australia. MPhil. Thesis (Murdoch University, Western Australia).

Norman, B.M., Holmberg, J.A., Arzoumanian, Z., Reynolds, S., Wilson, R.P., Gleiss, A.C., Rob, D., Pierce, S.J., de la Parra, R., Galvan, B., Ramirez-Macias, D., Robinson, D., Fox, S., Graham, R., Rowat, D., Potenski, M., Levine, M., Mckinney, J.A., Hoffmayer, E., Dove, A., Hueter, R., Ponzo, A., Araujo, G., Aca, E., David, D., Rees, R., Duncan, A., Rohner, C.A., Hearn, A., Acuna, D., Berumen, M.L., Vazquez, A., Green, J., Bach, S.S., Schmidt, J.V. and Morgan, D.L. Submitted. Understanding constellations: 'citizen scientists' elucidate the global biology of a threatened marine mega-vertebrate. Bioscience.

Osada, K. 2010. Relationship of zooplankton emergence, Manta Ray abundance and SCUBA diver usage Kona, Hawaii. Masters Thesis, University of Hawaii.

Pauly, D. 2002. Growth and mortality of the basking shark Cetorhinus maximus and their implications for management of Whale Sharks Rhincodon typus. In: S.L. Fowler, T.M. Reed and F.A. Dipper (eds), Elasmobranch Biodiversity, Conservation and Management. Proceedings of the International Seminar and Workshop, Sabah, Malaysia, July 1997, pp. 199–208. IUCN SSC Shark Specialist Group. IUCN, Gland, Switzerland and Cambridge, UK.

Pierce, S.J. & Norman, B. 2016. Rhincodon typus. The IUCN Red List of Threatened Species 2016: e.T19488A2365291. Downloaded on 04 July 2016.

Ramírez-Macías, D., Meekan, M., de la Parra-Venegas, R., Remolina-Suárez, F., Trigo-Mendoza, M. and Vázquez-Juárez, R. 2012. Patterns in composition, abundance and scarring of whale sharks Rhincodon typus near Holbox Island, Mexico. Journal of Fish Biology 80: 1401-1416.

Romero, A., A. I. Agudo, S. M. Green, and G. Notarbartolo di Sciara. 2001. Cetaceans of Venezuela: Their distribution and conservation status. NOAA Technical Reports, NMFS 151:1-60.

Santana, J.C., A., Molina de Delgado, R., Molinda de Delgado, J. Ariz, J.M. Stretta, and G. Domalain. 1997. Lista faunistica de las especies asociadas a las capturas de atún de las flotas de cerco communitarias que faenan en las zones tropicales de los océanos Atlantico e Índico. ICCAT Collective Volume of Scientific Papers 48:129-137.

Seitz, JC & GR Poulakis. 2006. Anthropogenic effects on the Smalltooth Sawfish (Pristis pectinata) in the United States. Marine Pollution Bulletin 52:1533-1540.

Seki, T., Taniuchi, T., Nakano, H. and Shimizu, M. 1998. Age, growth, and reproduction of the Oceanic Whitetip Shark from the Pacific Ocean. Fisheries Science Tokyo 64: 14–20.

Sequeira, A.M.M., Mellin, C., Fordham, D.A., Meekan, M.G. and Bradshaw, C.J.A. 2014. Predicting current and future global distributions of whale sharks. Global Change Biology 20: 778-789

Simpfendorfer, C. A. 2005. Threatened fishes of the world: Pristis pectinata Latham, 1794 (Pristidae). Environmental Biology of Fishes 73: 20.

Simpfendorfer, C.A. 2002. Smalltooth Sawfish: The USA's First Endangered Elasmobranch? Endangered Species UPDATE 19: 45-49.

Simpfendorfer, C.A., Wiley, T.R., and Yeiser, B.G. 2010. Improving conservation planning for an endangered Sawfish using data from acoustic telemetry. Biological Conservation 143(6): 1460-1469.

Smith, S.E., Au, D.W., Show, C. 1998. Intrinsic rebound potentials of 26 species of Pacific sharks. Marine and Freshwater Research 49: 663–678.

Springer, A.M., Estes, J.A., van Vliet, G.B., Williams, T.M., Doak, D.F., Danner, E.M., Forney, K.A., and Pfister, B. 2003. Sequential megafaunal collapse in the North Pacific Ocean: An ongoing legacy of industrial whaling? PNAS, 100(21): 12223-12228.

Taylor, J. G. 2007. Ram filter-feeding and nocturnal feeding of Whale Sharks (Rhincodon typus) at Ningaloo Reef, Western Australia. Fish. Res. 84: 65-70.

Thorburn, D.C. 2006. Biology, ecology and trophic interactions of elasmobranchs and other fishes in riverine waters of Northern Australia. PhD thesis, Murdoch University.

Thorson, T.B. 1982. Life history implications of a tagging study of the large-tooth Sawfish, Pristis perotteti, in the Lake Nicaragua-Rio San Juan system. Environmental Biology of Fishes, 7(3): 207-228, figures 1-5.

TRAFFIC (2013) Fact sheet for the 16th Meeting of the Conference of the Parties (CoP16) to the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). http://www.sharkadvocates.org/cites_4sharks_manta_fact_sheet.pdf

Van Beek, I.J.M., Debrot, A.O., Walker, P.A., Kingma, I. (2014) Shark protection plan for the Dutch Caribbean EEZ. Imares, Report number C209/13.

Van Beek, I.J.M., Debrot, A.O., Walker, P.A., Kingma, I. (2014) Shark protection plan for the Dutch Caribbean EEZ. Imares, Report number C209/13.

Van Beek, I.J.M., Debrot, A.O., Walker, P.A., Kingma, I. (2014) Shark protection plan for the Dutch Caribbean EEZ. Imares, Report number C209/13.

Wathne F. 1959. Summary report of exploratory long-line fishing for tuna in Gulf of Mexico and Caribbean sea, 1954–1957. Commercial Fisheries Review 21: 1–26.

White, W.T., Giles, J., Dharmadi and Potter, I.C. 2006. Data on the bycatch fishery and reproductive biology of mobulid rays (Myliobatiformes) in Indonesia. Fisheries Research 82: 65-73.

Wiley, T., Carlson, J. & Smith, K. 2013. Pristis pectinata (Western Atlantic subpopulation). The IUCN Red List of Threatened Species 2013: e.T43398250A43398253. http://dx.doi.org/10.2305/IUCN.UK.2013-1.RLTS.T43398250A43398253.en.

Wiley, T.R. and Simpfendorfer, C.A. 2010. Using public encounter data to direct recovery efforts for the endangered Smalltooth Sawfish (Pristis pectinata). Endangered Species Research 12: 179-191.

Wintner, S.P. 2000. Preliminary study of vertebral growth rings in the Whale Shark, Rhincodon typus, from the east coast of South Africa. Environmental Biology of Fishes 59: 441–451.

Young, N. 2001. An analysis of the trends in by-catch of turtle species, angelsharks and batoid species in the protective gillnets off KwaZulu-Natal, South Africa. Thesis, University of Reading.

Criteria for SPAW listing

Criterion 1. Is the listing of the species warranted by the size of the population, evidence of decline, restrictions on its range of distribution, degree of population fragmentation, biology and behavior of the species, as well as other aspects of population dynamics, or other conditions clearly increasing the vulnerability of the species?

[If applicable] Criterion 2. Why is a precautionary approach necessary i.e., the lack of full scientific certainty about the exact status of the species is not to prevent the listing of the species on the appropriate annex?

Criterion 3. [In particular with respect to species proposed for Annex III], what are the levels and patterns of use and how successful are national management programs?

Criterion 4. Does the evaluation according to IUCN criteria, applied in a Caribbean context, i.e., the status of the population at the regional level, warrant listing of the species?

Criterion 5. Is the species subject to local or international trade, and is the international trade of the species regulated under CITES or other instruments?

Criterion 6. How important and useful are regional cooperative efforts for the protection and recovery of the species? [Include strengthening of existing cooperative efforts through global MEAs such as CMS]

Criterion 7. The species is not an endemic species [or there are specific reasons why cooperative action is important for its recovery].

Criterion 8. The species is not a sub-species.

Criterion 9. The status of the population at the regional level warrants listing, not only of a sub-population.

Criterion 10. Is the species essential to the maintenance of such fragile and vulnerable ecosystems/habitats, as mangrove ecosystems, seagrass beds and coral reefs and is the listing of the species felt to be an "appropriate measure to ensure the protection and recovery"?

Species Proposed

Cuba

A proposal is made to transfer the Cuban parrot (*Amazona leucocephala*) to Annex III.

***Amazona leucocephala* (Cuban parrot)**

The species is listed under the Vulnerable category and likely to become endangered; however, captive breeding is one management measure to conserve the species, which is why a proposal is made to **transfer it from Annex II to Annex III**. The Ministry of Agriculture's National Flora and Fauna Protection Company (ENPFF, for its Spanish acronym) has a Management and Development Plan in place for captive breeding and the potential for future marketing, with no impact on wild populations and taking into account the management plans of protected areas where the species lives, since one of the biggest threats consists of taking chicks from their nests for the illegal pet trade.

Characteristics:

The Cuban parrot, *Amazona leucocephala*, ranges over Cuba, Bahamas, and Cayman Islands. Four subspecies are currently recognized: *A. l. leucocephala*; *A. l. bahamensis*; *A. l. hesterna,* and *A. l. caymanensis* (Collar, 1997).

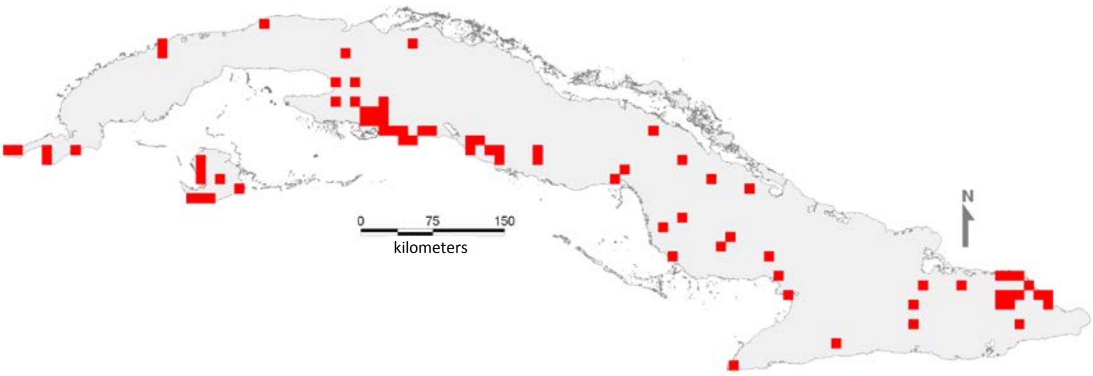
In Cuba this species is found throughout the country. Formerly, it was thought to be abundant and widely distributed, but now their flocks have been highly reduced in numbers. Habitats for this species include rainforests, evergreen cloud forests, evergreen swamp forests, pine forests, mangrove forests, and rocky coast vegetation clumps. While it is mostly found in natural and well-preserved habitats, *A. leucocephala* has an established population in Havana's urban environments, perhaps grown from caged birds that escaped (Berovides y Cañizares, 2004).

Many populations are now found in protected areas throughout Cuba, but only the population in "Los Indios" Ecological Reserve in the Island of Youth has been successfully managed for recovery (Berovides *et al*., 1995, 1996; Gálvez *et al*., 1998).

The Cuban parrot nests in abandoned woodpecker holes and natural cavities in virtually any tree species, depending on availability, although nests are much more often found in palm trees of the *Colpothrinax, Roystonea* and *Sabal* genera and in black mangrove (*Avicennia germinans*) tree trunks with holes. In spite of the fact there are such populations as the one in Los Indios reproducing in open savannas, it generally prefers dense and well-preserved forests with mature trees. Cuban parrot nests are usually located away from each other, and adults are very cautious and quiet in their nest surroundings. Nesting takes place from March to late May. Clutches are usually made up of 2–4 eggs, with a 26- to 28-day incubation period, and chicks remain in the nest for 56–60 days (Collar, 1997).

It feeds on a variety of flowers, fruits, and seeds from various plant species. González *et al*. (1987) recorded 18 plant species consumed by this parrot at Ciénaga de Zapata, and Gálvez *et al.* (1998) found 39 plant species consumed at Los Indios, Island of Youth. A recent study on this species dietary preferences in Alturas de Banao found that *A. leucocephala* uses trophic resources according to their availability in the environment (García, 2009).

It has national distribution, population size has declined, and its fragmented habitat has decreased 20% in the last 50 years (Berovides y Cañizares, 2004; Cañizares y Berovides, 2008).



Areas where the species has been recorded

Degree of Protection:

Name of Protected Area where the Species is Found	**Province**
Guanahacabibes National Park (NP)	Pinar del Río
Mil Cumbres Managed Resources Protected Area (MRPA)	Pinar del Rio
Los Indios Ecological Reserve (ER)	Island of Youth
Ciénaga de Zapata NP	Matanzas
Lomas de Banao ER	Sancti Spíritus
Tunas de Zaza Wildlife Reserve (WR)	Sancti Spíritus
Agabama Delta WR	Sancti Spíritus
Topes de Collantes Protected Natural Landscape (PNL)	Sancti Spíritus
Hanabanilla PNL	Villa Clara
Pico San Juan ER	Cienfuegos
North Ciego de Ávila Wetlands MRPA	Ciego de Ávila
Sierra de Najasa PNL	Camagüey
Sierra del Chorrillo MRPA	Camagüey
Sierra de Cubitas MRPA	Camagüey
Pico Cristal NP	Holguín
La Mensura, Pilotoss NP	Holguín
Desembarco del Granma NP	Granma
Cauto Delta WR	Las Tunas-Granma
Alejandro de Humboldt NP	Guantánamo-Holguín
Quibiján-Duaba ER	Guantánamo

Protected through Resolution 160/2011 in Appendix I as a species of special significance to the Republic of Cuba

Threat Category:
Cuba: VU A2(a,c,d); B1b(i,ii,iii). IUCN: NT.

Justification of Criteria:
Current international trade in *A. leucocephala* is legally prohibited; however, illegal traffic in this species at a regional scale is of the highest concern in Cuba. In a study carried out from 1998 through 2008 in Cuba's central region, where the parrot nests in both forest trees and limestone cliff holes (Pico San Juan), over 90% of recorded Cuban parrot nests had been looted. The low surviving percentage is basically the result of nest inaccessibility. Protection

measures for this species are entirely inefficient under current conditions, and the high price commanded by these birds in the black market become a strong incentive for illicit activities. Data from an inventory taken in several Havana municipalities on parrots kept as pets revealed that some 10% of homes keep these birds, a percentage increasing to over 30% in some residential areas like El Vedado (Patricia Rodríguez 2010, *pers*. *comm.*)

Although there are no accurate data available on the extent of Cuban parrot decline in the last few years, simultaneous counts taken in March 2009 in both natural and anthropic areas of central Cuba mountains estimated some 90–100 parrots in an area covering more than 200 km^2, which amounts to a very low population density (0.5 individuals/km^2).

The main threat against *A. leucocephala* is the looting of chicks for the illegal pet trade, which often results in nesting site destruction, although the species is also affected by habitat fragmentation and loss, deforestation, and hurricanes.

All populations of this species are threatened. Except for populations in the north of Cuba's eastern region, most are highly reduced and with a very low effective population size, thus resulting in high threats of local extinction.

Actions to be taken for conservation:

- Work should be done on managing habitats and wild populations, implementing monitoring programs and providing environmental education to the general public, as well as to communities living in the surroundings of the area where the species lives. Additionally, captive breeding is another option.
- The above mentioned data are based on censuses, field studies, informal field observations, and available literature.

References:

Berovides, V. y M. Cañizares. 2004. Diagnóstico del decline de los psitácidos cubanos y su posible solución. *Rev. Biol.* 18(2):109-112.

Cañizares, M. y V. Berovides. 2008. Distribución y abundancia de los bandos de psitácidos de Cuba Central. *Mesoamericana* 11(4):36-44.

Collar, N. J. 1997. Family Psittacidae (Parrots). En del Hoyo, J., A. Elliott y J. Sargatal (Eds.) *Handbook of the Birds of the World*. Vol. 4. Sandgrouse to Cuckoos. Lynx Ediciones. Barcelona.

Forshaw, J. M. 1989. *Parrots of the World.* Melbourne, Australia: Lansdowne Editions (3rd Ed.).

Gálvez, X., V. Berovides y J. Fernández..1996. *Aratinga euops*. Taller para la conservación, análisis planificado de una selección de especies cubanas. La Habana, Cuba: Zoológico de la Habana / Facultad de Biología, Universidad de la Habana / CITMA / Parque Zoológico Nacional / Flora y Fauna / UICN, 47-55.

García, L. 2009. Ecología trófica de los psitácidos en la reserva ecológica "Alturas de Banao", Sancti Spíritus. Tesis de Diploma. Facultad de Biología. Universidad de la Habana. 51 pp.

Garrido, O. H. y A. Kirkconnell. 2000. *Field guide to the birds of Cuba*. Cornell University press, Ithaca: 207-208.

González, H., D. Rodriguez y M. E.

PROPOSAL TO ADD THE FOLLOWING SPECIES TO ANNEX II:

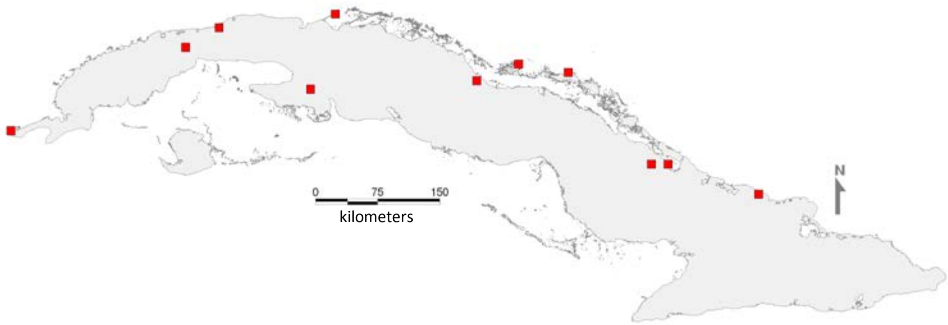
- *Passerina ciris (*Painted bunting*)*

Passerina ciris (Painted bunting)

This is a migratory bird species included as Vulnerable in Cuba's Red List of threatened species. Population decline has occurred as a consequence of indiscriminate profit-seeking capture to use it as an ornamental bird.

Characteristics:

The painted bunting has two separate reproductive populations. One living in the western states of Kansas, Oklahoma, Texas, Arkansas, Louisiana, and south of the Mexican states of Chihuahua, Coahuila, Nuevo León, and Tamaulipas, which spends winter in Central America. The other population, in eastern United States, breeds in the coastal areas of North and South Carolina, Georgia, and northeast Florida. This population spends winter in southeast Louisiana and Alabama, the Florida peninsula, Bahamas and Cuba (Íñigo-Elías *et al*., 2002; Rich *et al*., 2004). The species ranges throughout the Cuban territory, although is more common in the central eastern part of the country. It is ranked as a common transient and a rare winter dweller. It basically feeds on seeds, although it may consume fruits. It is quite commonly seen in secondary plant formations or in areas bordering grasslands. This species does not breed in Cuba (González *et al*., 1999; Garrido y Kirkconnell, 2000; Rodríguez, 2000).
It has a nation-wide distribution, population size in Cuba is unknown, and its fragmented habitat has declined in the last 30 years.



Areas where the species has been recorded

Degree of Protection:

Name of Protected Area where the Species is Found	Province
Guanahacabibes NP	Pinar del Río
Sierra del Rosario MRPA	Pinar del Río
Ciénaga de Zapata NP	Matanzas
Las Picúas-Cayo Cristo WR	Villa Clara
Lanzanillo-Pajonal-Fragoso	Villa Clara
North Ciego de Ávila Wetlands MRPA	Ciego de Ávila
Cayo Romano Wetlands MRPA	Camagüey
Río Máximo WR	Camagüey
Caletones ER	Holguín

Threat Category:
Cuba: Vu A1 (a, b, c d, e); B2 (iii). IUCN: NT.

Protected through Resolution 160/2011 in Appendix I as a species of special significance to the Republic of Cuba

Justification of Criteria:
The painted bunting has sustained a 55% effective population size decrease in the last 30 years. Causes of this decline include habitat loss in North American breeding areas, habitat loss in wintering zones, and the illegal trade in this species. The population inhabiting the southeastern United States and the Caribbean exhibits the highest population decline rate, at 3.9% annually (Íñigo-Elías *et al*., 2002; Rich *et al*., 2004).

In particular, tourist development taking place in Cuba's northern archipelago cays is leading to a major loss of habitats for painted buntings to feed and rest during their migration and winter residence. In addition, the booming wild bird trade in the last decade has had a negative impact on painted bunting populations. A 2001 study of three Cuban locations showed that over 400 individuals of this species are illegally traded per year (Ayón, 2001). Given this figure is biased by the number of locations covered, and according to recent conversations with bird dealers, the actual figure should be at least double the estimate made in said study.

Actions to be taken for conservation:

Work should be done on managing habitats, implementing monitoring programs and providing environmental education to the general public and, in particular, to poachers and people trading in this species.

The above mentioned data are based on censuses, field studies, informal field observations, and available literature.

References:

Ayón, X. 2001. Uso y comercio de las aves silvestres cubanas. Tesis para la obtención del Titulo de Master Sobre Gestión, Conservación y Control de Especies Sometidas a Comercio Internacional. Universidad Internacional de Andalucía, Sede Antonio Machado, Baeza, Jaén, España. 109 pp.

Garrido, O. H. y A. Kirkconnell. 2000. *Field guide to the birds of Cuba*. Cornell University press, Ithaca: 207-208.

González Alonso, H., A. Llanes Sosa, B. Sánchez Oria, D. Rodríguez Batista, E. Pérez Mena, P. Blanco Rodríguez, R. Oviedo Prieto y A. Pérez Hernández. 1999. Estado de las comunidades de aves residentes y migratorias en ecosistemas cubanos en relación con el impacto provocado por los cambios globales. 1989-1999. *Informe Final* depositado en el Inst. de Ecología y Sistemática. 111 pp.

Íñigo-Elías, E. E., K. V. Rosenberg y J. V. Wells. 2002. The Danger of Beauty. Birdscope, newsletter Summer 2002 Vol 16, no 3, of the Cornell Lab of Ornithology, Summer 2002. http://birds.cornell.edu/publications/birdscope.

Llanes A., H. González, B. Sánchez y E. Pérez 2002. Lista de las aves registradas para Cuba. Aves de Cuba, Ed. H. González. UPC Print, Vaasa, Finland. 147-155.

Llanes A., E. Pérez, H. González, A. Pérez. en prensa. *Wilsonia pussilla pileolata*, nueva subespecie para Cuba y adiciones a la ornitofauna a la Península de Guanahacabibes. *J. Carib. Ornithol*.

Raffaele, H., J. Wiley; O. H. Garrido; A. Keith y J. Raffaele 1998. *A guide to the birds of the West Indies*. Princeton University press. Princeton: 424-425.

Rich, T. D., C. J. Beardmore, H. Berlanga, P. J. Blancher, M. S. W. Bradstreet, G. S. Butcher, D. Demarest, E. H. Dunn, W. C. Hunter, E. Íñigo-Elías, J. A. Kennedy, A. Martell, A. Panjabi, D. N. Pashley, K. V. Rosenberg, C. Rustay, S. Wendt y T. Will. 2004. Partners in Flight North American Landbird Conservation Plan. Cornell Lab of Orithololgy. Ithaca, NY.

Rodríguez, D. 2000. Composición y estructura de las comunidades de aves en tres formaciones vegetales de Cayo Coco, Archipiélago de Sabana-Camagüey, Cuba. Tesis Doctorado, 99 Pp.

Author: Eneider Ernesto Pérez Mena.

ANNEX III. List of Protected Marine and Coastal Wildlidfe Species under Article 11(1)(c)

Proposal is made to transfer *Dendrocygna arborea* to Annex II.

WORKING GROUP ON REPTILES, AMPHIBIANS, AND MAMMALS

REPTILES
Proposal is made to transfer the following species to Annex III:

Crocodylus acutus
This species is widely distributed and there are CITES-approved wild population exploitation programs in place. It is not Critically Endangered, and populations are apparently stable in the Caribbean region. Proposal is made to transfer it from Annex II to Annex III.

MOLLUSK GROUP

Proposal is made to **INCLUDE** *Liguus fasciatus* (Müller, 1774) in ANNEX III
Found in Florida, Cuba.
Many taxa thus far considered as subspecies are coastal dwellers, suffering from habitat destruction and fragmentation (tree felling, charcoal production, crops, urban development, direct collection for handicraft purposes)
Example. Cuba *L. f. sanctamariae*, *caroli, caribbaeus, leonorae, goodrichi s.s*., etc.
Example. U.S. Subespecies of the L*. f. pictus* group in Florida Keys, *L. f. septentrionalis* and several varieties of *L. f. solidus*. It is vulnerable to climate change direct impacts.

a) ***Liguus fasciatus*** (Müller, 1774) Annex III

Synonyms:

Taxonomic Classification: Family Orthalicidae s.s., Superfamily Orthalicoidea, Sigmurethra, Stylommatophora, Pulmonata, Class Gastropoda, Phylum Mollusca.

b) Distribution: It is the only species in the genus with such a wide range , covering all Cuba, the Isles of Pines, and Florida. *L. virgineus* Linné is only found on the island of Hispaniola, while the other species inhabit only western Cuba. This species is able to produce discrete color pattern variations typical of small geographic areas, thus leading to over 100 subspecies having been wrongly described throughout its range, with several color morphs within subspecies.

Judging from its range it could be the species with the best adaptive capability, although several of these taxa are going through decline and extinction processes.

Taxonomic studies are needed first to define species, subspecies, and subordinate groups because different taxa do not usually exhibit identical ecological behaviors, and this should be taken into account in their conservation program. Additionally, their diversity should be quantified and data on population locations and ecological variables should be properly gathered. While there are information gaps concerning large land areas, some basic ecology information has been gathered in most of the publications listed below.

c) Despite being included as a protected species in Environmental Law Decree 160, Appendix 1 on total protection, harvesting still continues. Regardless of the fact this species has been overharvested and that some microgeographic races have been lost and others are threatened, **it is not included in CITES, or in IUCN Red List, or in Catalog of Life**. At the 2nd Conservation, Analysis, and Planned Management Workshop (CAMPII) on Cuban species, Fernández *et al*., 1997 proposed *L. fasciatus* to be included as an endangered species in CITES, and it had been considered as threatened by Kay in 1995.

Note: **None of the other 3 species of Cuban *Liguus* having a reduced range are in any of these.**

d) Requirements, ecological interactions, and threats: It is an arboreal species that feeds on fungi, algae, and lichens scraping them from the leaves and trunks of its favorite tree and shrub species. It only comes down to the ground to dig a hole where it lays eggs, provided there is a good leaf litter. It is found in patches or clusters in its range of population distribution, sometimes in much-reduced numbers (Fernandez,2000). It prefers semi-deciduous forests (Fernández y Berovides, 2000 and others) over rocks. Capable of feeding on other plant formations, it uses smooth-bark and thick trunk trees located at the inner side of vegetation, such as wild tamarind *Lysiloma latisiliquum*, gumbo limbo *Bursera simarouba*, Florida poisonwood *Metopium toxiferum* and black poisonwood *M.brownii,* mastic tree *Mastichodendrum foetidissimum,* fish fuddle *Piscidia piscipula,* pigeon plum *Coccoloba diversifolia,* black ironwood *Krugiodendron ferreum,* white stopper *Eugenia axilaris,* Panama tree *Sterculia apetala,* and ebony coccuswood *Brya ebenus*, among others. During winter they glue themselves to trunks and branches to hibernate at rather low heights ranging from a few centimeters to some 4 meters, but in summer they sometimes climb up to the 20-m high canopy. The species can be found on both leaves and branches, and their higher population density is associated with a good forest canopy. Their presence in high numbers is therefore an indicator of good forest health. Additionally, their class size frequency distribution is nearly Gaussian with no affected or absent age brackets and a presence of several color morphs, which is a typical behavior in this species. A smaller number of morphs is an indication of disturbance. The species is predated by birds, such as limpkin (*Aramus guarauna*), Cuban lizard-cuckoo (*Saurothera merlini*) and others, ants (the bite of one little fire ant *W. auropunctata* can kill an adult *L. fasciatus* in less than 12 hours, and depredation by tropical fire ant *S. geminata* has been recorded), spiders and other arthropods, large mollusk-eating giant anoles could feed on juveniles, the same as some snakes. In Florida they are also predated by raccoons and the rosy wolfsnail *Euglandina rosea*, a large voracious oleacinid gastropod. They are susceptible to disease and parasites, although this has not yet been studied. The species is affected by long drought spells and floods, as well as directly harmed by hurricanes that knock down many large host trees (sometimes over 50% of trees, such as in the case of Hurricane Andrew in Florida), natural fires, etc. But the most serious impact comes from human actions, i.e., forest fragmentation caused by felling trees for different purposes, intentional or accidental fires, mining, engineering works of all sorts (roads, diversion channels, rock-fills, urban development, etc.). Additional threats include the slash-and-burn and tilling practices to grow crops, invasion of dispersion-blocking herbaceous and other plants that compete with host plants and which are unsuitable as hosts. Introduced wild animals, as well as domestic and feral animals, take a toll on the species, i.e., rats, pigs, etc. Any anthropic toxic pollutant can be absorbed through this tree snail skin, and even smoke harms it.

Sexual maturity is reached at 3–4 years of age, mating takes place in July and August, and egg laying occurs after three to six weeks (Davidson, 1965). In November they go into their winter torpor on account of cold temperatures and absent precipitation. Juveniles emerge with April-May rains and adults come out of their hibernation. Population density fluctuations are not large, if undisturbed, but are contingent on the above mentioned processes. Partial self-fertilization ability has been recorded for the species (Hillis *et al*., 1987; Hillis, 1989; Hillis *et al*., 1991). The incubation period for Florida *L. fasciatus* is six months and clutch size varies from 8–14 eggs (Blackwell, 1940) up to two dozens, although Fernández y Berovides (2001) recorded higher values (18–41) with a 28.6-egg average and a longer incubation period (6.6–8 months). Microhabitat alterations were found to affect egg viability. Drought periods delay egg hatching in mollusks (Pollard 1975). Clutch size in other mollusks depends on individual age and environmental conditions.

f) **Research programs and scientific and technical publications on the species**

As part of the description of what are currently viewed as subspecies, Jaume in 1952 and 1954 provides data on the distribution of these and other known subspecies, as well as associated literature. He was also one of the first authors to write in 1943 about the concern over conserving the species, although he collected thousands of specimens in his description process in order to verify the alleged color morph stability.

Alvarez y Berovides 1989 in Cayo Romano estimate *L. fasciatus* density at 0.76–8 individuals/100m^2, finding it similar to other observed populations and seemingly normal, and assess the effect of 6 ecological variables on color pattern distribution. They observe mostly 1 individual/tree, preference for thick trees (+9 cm in diameter), good foliage cover, and resting at heights over 2 meters.

Berovides y Alfonso 1995 in S. Chorrillo Camagüey estimate the influence of depredation incidence on shell robustness and the distribution of 3 color morphs of *L. fasciatus*. They warn about how easy it would be for people to alter this species population size and genetic structure.

Fernández, I., L. Bidart, A. Fernández y V. Berovides, 1997 in the Report of the 2nd Conservation, Analysis, and Planned Management Workshop (CAMP II), Havana, present the fact sheet for the *Liguus fasciatus* taxon.

Concerning the ecology of *L. f. achatinus* in Holguín:

Fernández, A. y Berovides 91, Fernández, A. y Berovides,2000 in Yayal Holguín found densities of 0.12–0.17 animals/m^2 in areas not impacted by tree felling and near-extinction when the forest was felled. In 1995, the same authors determined densities of 0.09–0.31 with an average of 0.20 individuals/m^2 for the now extinct population in Pedernales.

Bidart, L. *et al*., 1992, González, et al, 1997.

A. Fernández's master's degree thesis determined aspects of vegetation composition and structure and other variables predicting *L. f. achatinus* spatial-temporal density changes in Yayal, Holguín and their usefulness as forest health indicators.

As to *L. f. sanctamariae* ecology, reference is made to Fernández I. *et al.* 1995 and Fernández y Perera, 1997, who make a potential connection between some environmental variables and the distribution of color morphs on Cayo Santa María.

Espinosa y Ortea in 1999 relate most species and subspecies of this genus, among other terrestrial mollusks, to some locations.

Also listed below are some publications on intraspecific taxa descriptions and a brief bibliography showing the species has been included in conservation and ecology studies in the last few years, some of them developed in Cuba.

Young 1951 and 1958, and Blackwell, 1940 explain the threats against this species in Florida, whereas Voss, 1976; Brown, 1978, and Bennetts *et al*., 2000 comment on mollusk-host relationships, particularly for *L. latisiliquum.*

Roth and Bogan, 1984 deal more with genetic and ecological issues, and Young 1960 covers shell color aleles, both studies carried out in Florida.

H. A. Pilsbury describes several subspecies in 1912 and 1946 and mentions some tree preferences in different Florida zones.

e) In Cuba there are no **implemented** management plans contributing to protection of the species, although there are proposals in unpublished documents, such as the above mentioned for *L. f. achatinus* by A. Fernández in Holguín and Maceira *et al.* 2011 in Granma, where they warn about species decline basically as a result of human actions. Said plans would include population monitoring, ex situ breeding, reforestation with primary vegetation, attempts at removing invasive plants and animals, ensuring work conditions for conservationists and providing environmental education to community members. In some of the visited protected areas, experts are aware of this species presence and of the need for preserving it, but means of transportation, communication, and local residents' attitude do not guarantee an effective surveillance.

The species has been bred in captivity in Florida and small colonies have been transferred and implanted with some success, although no in-depth study of potential consequences has been made. There are operational conservation and management plans in protected areas.