

Population Status Review of Three Grouper Species in the U.S. Caribbean

Final Draft

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National Marine Fisheries Service**

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By

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1. INTRODUCTION

In 2007, a student contracted by NOAA Fisheries' Caribbean Field Office compiled a list of restaurants purchasing locally caught seafood in Puerto Rico and USVI as part of a larger grouper conservation project. Of the 218 seafood restaurants surveyed, 81 (37.2 %) serve grouper in their menus provided by local fishermen (Fig. 1). While the species of grouper served was not specified by the restaurants, it is clear that such demand greatly influences local fishermen who supply grouper to restaurants.

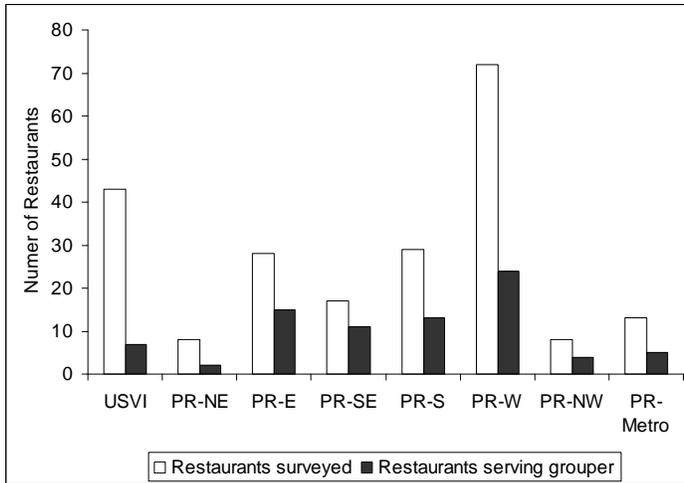


Figure 1. Seafood restaurants surveyed in Puerto Rico and U.S. Virgin Islands.

Legend: USVI =U.S. Virgin Islands, PR= Puerto Rico, Metro = metropolitan area, NE = Northeast, E = east, SE=southeast, S = south, W = west, NW = northwest.

Source: Caribbean Field Office, National Marine Fisheries Service

In spite of current regulations protecting goliath and Nassau grouper permanently in Puerto Rico and USVI federal and state waters, and red hind during their reproductive season in waters of Puerto Rico and certain federal waters in the Caribbean Exclusive Economic Zone (EEZ), the lack of knowledge in the general population regarding the protection status of these species as well as the demand from potential consumers (tourists, restaurants, hotels, fish markets, and the general public) directly fuels illegal fishing. Red hind are not protected throughout the Caribbean EEZ nor in USVI waters with some exceptions (See "Risk assessment and protection status" section).

The present report concerns the following species: goliath grouper (*Epinephelus itajara*), Nassau grouper (*E. striatus*) and red hind (*E. guttatus*). Sadovy & Eklund (1999) compiled the most comprehensive biological review of both goliath and Nassau grouper to date. Biological reviews for red hind can be found in Sadovy (1990) and Matos-Caraballo et al. (2004). It is not the aim of this report to repeat the information contained in the biological reviews cited, but rather to compile information on the current population status and other relevant information that will be summarized in bilingual information sheets (English and Spanish) for the purpose of grouper conservation outreach in Puerto Rico and USVI. The specific target population for the outreach activities will be commercial fishermen, tourists, hotels, restaurants, and fish markets.

2. LIFE HISTORY

Goliath and Nassau grouper and red hind are extremely vulnerable to overfishing due to a combination of life history traits typical in large serranid fish of the genera *Epinephelus*, *Mycteroperca* and *Plectropomus*. These traits are slow growth, long life, late sexual maturity, strong site fidelity, and formation of spawning aggregations (Levin & Grimes 2002). Additional life history traits also contribute to extinction vulnerability such as their dependence on tropical and subtropical habitats that are among the most vulnerable to alteration and loss due to human activities, including coastal development and pollution, and their general acclimation to divers (Table 1).

Table 1. Life history traits of goliath grouper, Nassau grouper and red hind that are strongly linked to their vulnerability to overfishing.

Life history trait	Goliath Grouper	Nassau Grouper	Red Hind
Longevity:			
Maximum size	250 cm TL	120 cm TL	72 cm TL
Maximum age	> 40 y	> 30 y	22 y
Maximum weight	400 kg	27 kg	20 kg
Sexual Maturity:			
Size at maturity	110-120 cm TL	40-45 cm TL	25 cm TL
Age at maturity	5 y males; 8 y females	4-7 y	3.4 y
Reproduction Type	Gonochoristic *	Gonochoristic *	Protogyny
	Broadcast spawner	Broadcast spawner	Broadcast spawner
	Spawning aggregation	Spawning aggregation	Spawning aggregation
	August-September (Florida)	May-August, July peak (Florida)	December-February—literature notes these are typically from Jan-March, although regulations protect SPAGs from Dec-Feb
	July-August (Caribbean)	December-February, January peak (Caribbean)	
Essential Fish Habitat			
Juveniles	Fringing red mangrove	Seagrass, patch reef	Coral reef
Adults	Coral reefs, reef ledges	Coral reef	Coral reef
Other Characteristics:			
Diet	Mostly invertebrates	Piscivorous	Piscivorous
Behavior	Strong site attachment	Strong site attachment	Some site attachment
	Adults and large juveniles curious and unafraid of divers	Adults may acclimate to diver presence	Do not approach divers

(* *Gonochoristic* means individuals develop as either males or females as opposed to the expected sequential hermaphrodites observed in other grouper species where individuals first develop as females and later in life switch sex to males (*protogyny*). In both Goliath and Nassau grouper, data are more consistent with a gonochoristic rather than an hermaphrodite reproduction strategy (Sadovy & Eklund 1999).

Source: Bullock et al. (1992), Sadovy et.al. (1992), Luckhurst et al. (1992), Heemstra & Randall (1993), Eggleston (1995); Sadovy & Eklund (1999), Nemeth (2005), Frias-Torres (2006); Frias-Torres (2007).

Spawning aggregations occur around the time of the full moon during the spawning season. Therefore, actual spawning events are limited to only a few days of each month within the spawning season, in very specific geographic locations. The narrow window of spawning in both time and space further increases the vulnerability to overfishing and limits recovery after overfishing or extinction of the aggregation has occurred. During the spawning aggregation events, fish behavior is focused on

courtship and reproduction; this renders individuals susceptible to any kind of fishing gear: nets, hand-lines, hook-and-line, traps, and spearfishing (Sadovy & Eklund 1999, Levin & Grimes 2002).

Outside the spawning aggregations, fish behavior determines gear vulnerability. Goliath and Nassau grouper are particularly vulnerable to spear fishing due to being mostly curious and unafraid of divers (Table 1) and are also easily caught by hook-and line (Sadovy & Eklund 1999). Red hind are particularly vulnerable to hand-lines and fish traps (see “Population status” section).

3. RISK ASSESSMENTS AND PROTECTION STATUS

Several risk assessments have been completed for goliath and Nassau grouper throughout their distribution area, but none for red hind (Table 2). The International Union for the Conservation of Nature (IUCN) is the world’s oldest and largest global environmental and conservation professional network. IUCN conducts assessments worldwide to determine the relative risk of extinction of species, and the evaluations are listed in the IUCN red list. Based on IUCN evaluation, **goliath grouper** is **critically endangered**: facing an extremely high risk of extinction in the wild due to actual or potential levels of exploitation which have caused an observed and inferred population size reduction equal to or greater than 80 % over the last 10 years. **Nassau grouper** is **endangered** according to the IUCN: facing a very high risk of extinction in the wild due to direct observation of actual and potential levels of exploitation, which have caused an observed and inferred population size reduction of $\geq 50\%$ over the last 10 years. **Red hind** has not yet been evaluated by IUCN (<http://www.iucnredlist.org>).

The American Fisheries Society (AFS) is the oldest association of fisheries professionals worldwide. AFS has conducted several risk assessments for marine fish (Musick 1999, Musick et al 2000 a,b) concluding that **goliath grouper** is both **endangered** throughout its distribution area (at high risk of extinction in the wild in the immediate future, within years) and **conservation dependent** in the U.S. Atlantic and Gulf of Mexico (the population is significantly reduced but stabilized or recovering under a continuing conservation plan). **Nassau grouper** is **threatened** (not endangered but facing a risk of extinction in the near future, within decades). **Red hind** was not listed in the AFS study.

Table 2. Risk assessments and protection status.

Legend: IUCN = International Union for the Conservation of Nature; AFS= American Fisheries Society; SPAGs = Spawning aggregations. Sources: IUCN red list (<http://www.iucnredlist.org>), Hudson & Mace (1996), Sadovy & Eklund (1999), Nemeth (2005), Musick et al 2000b

Risk Assessments	Goliath Grouper	Nassau Grouper	Red Hind
(International) IUCN red list *	Critically Endangered	Endangered	Not evaluated
AFS risk level	Conservation dependent Endangered	Threatened	Not included
Protection status			
Fishing moratoriums	Gulf of Mexico and Florida State (1990) US Atlantic (1990) Caribbean Council (1993) USVI territorial waters (1993)	Dominican Republic (mid 1980s) *** US Caribbean (1990) US Atlantic (1991) Bermuda (1996) US Gulf of Mexico (1997)	SPAGs St. Thomas (1989) SPAGs W Puerto Rico (1996) SPAGs all Puerto Rico (2005) SPAG, E St. Croix (2005)

Table Notes:

* IUCN red listing does not carry legal status to ensure protection, however, member countries are required by international law (UN Law of the Sea) to ensure the conservation of marine habitats and species in their Exclusive Economic Zone and international waters as treaties dictate.

** In 2006, the goliath grouper continental U.S. population or distinct population segment (DPS) was removed from the U.S. National Marine Fisheries Service “species of concern” list (NMFS 2006)

*** The moratorium prohibited catch or sale of ripe females during the spawning season

Current protection status for the three species is derived exclusively from fishing moratoriums (Table 2). Goliath and Nassau grouper are protected in Florida and U.S. federal waters through the moratoriums established by the Fishery Management Plans (FMP) of the South Atlantic, Gulf of Mexico and Caribbean Fishery Management Councils. Red hind fishing moratoriums have resulted from the Puerto Rico Fisheries Law during the spawning season and in federal waters in the U.S. Caribbean, including the Red Hind Bank Marine Conservation District (MCD) in St. Thomas where fishing is prohibited at all times, federal waters west of Puerto Rico during the spawning season and waters east of St. Croix on Lang Bank during the spawning season.

4. CURRENT POPULATION STATUS

Goliath Grouper

In the late 1980s, goliath grouper reached commercial extinction, and a fishery moratorium was implemented in U.S. federal and state waters in 1990, while other moratoriums followed for the species (see table 2). Data on commercial fishery landings in this species are only found for the state of Florida, USA (Fig. 2). A precipitous decline in the fishery started around the late 1970s when the spawning aggregations were targeted.

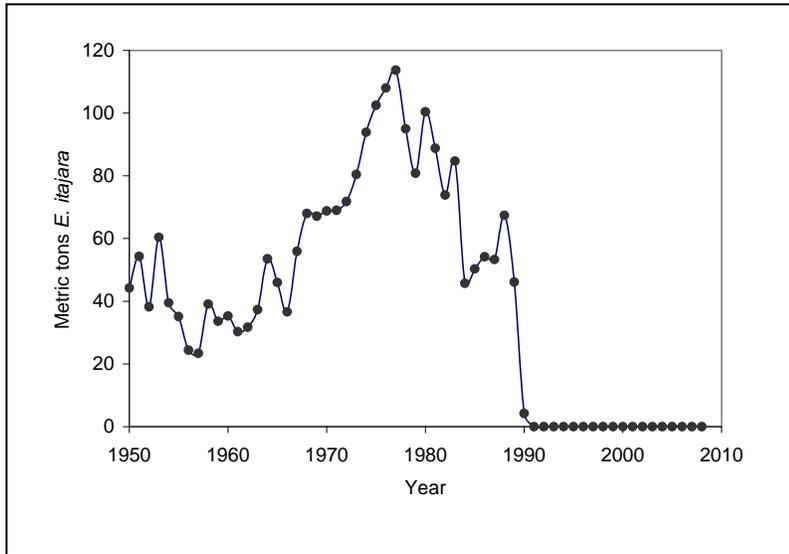


Figure 2. Goliath grouper commercial landings reported in Florida. The onset of commercial extinction is observed in the late 1970s, when spawning aggregations were targeted. The fishing moratorium was initiated and implemented in 1990. Source: NOAA Fisheries Statistics <http://www.st.nmfs.gov>

The most recent goliath grouper population status report (NMFS 2006) estimates that full population recovery will occur by 2020 or later. However, several problems in the report invalidate such projections:

- 1) An adult population census has not been completed. Fishery independent data collected during the moratorium are scarce.
- 2) The tendency of population increase has been observed only in juveniles. According to IUCN standards, the term “population recovery” can only be used when the adult reproductive population has increased in numbers. Such evidence (of increase in reproductive population) is lacking.
- 3) The Florida grouper population is identified as a DPS (Distinct Population Segment). However, there is a lack of genetic or oceanographic evidence to support such statement. The DPS classification was used to de-list the species from the U.S. Candidate Endangered Species list.
- 4) The stock assessment models and projections assume zero mortality, ignoring illegal take (poaching), red tide kills, cold snap kills, and diminishing juvenile habitat due to poor water quality and loss of habitat in Florida mangrove watersheds.

According to NOAA (2005) goliath grouper are still classified as overfished, and currently there is not enough information to determine the parameters required for a complete stock assessment.

Nassau Grouper

In the late 1980s, Nassau grouper reached commercial extinction, and a fishery moratorium was implemented in U.S. federal and state waters in the 1990s (see details in table 2). Data on commercial fishery landings in Florida and the U.S. Atlantic reveal fishing continued despite initial moratoriums (Fig 3).

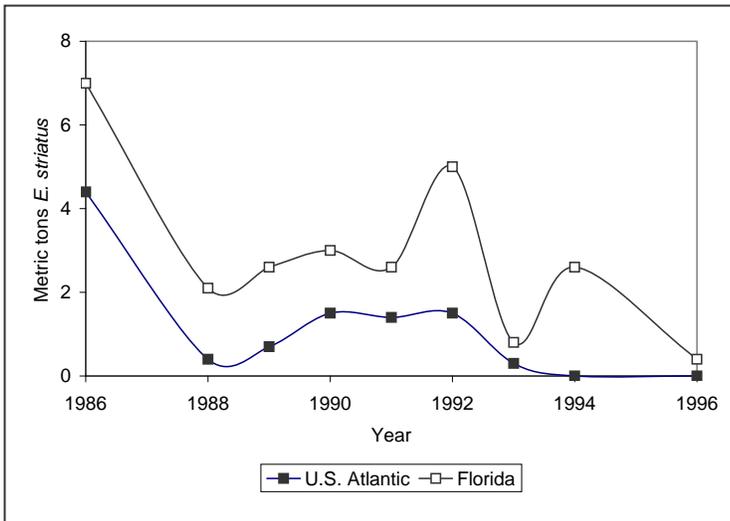


Figure 3. Nassau Grouper commercial landings reported for the U.S. Atlantic and the state of Florida. The fishing moratorium was initiated and implemented in 1991. A final peak in fish landings can be seen in Florida, in 1994. Source: NOAA Fisheries Statistics <http://www.st.nmfs.gov>

In Puerto Rico, Nassau grouper landings continued well after the fishing moratorium of 1990 in federal waters. Implementation of the moratorium was apparently initiated in 2002 based on the landings data indicating fishing of these animals up to 2002 (Fig. 4). It may also be that species are misreported as different regions around Puerto Rico have regional common names for species and the common name “mero cherna” is used to refer to both Nassau grouper and red hind. In addition, the Puerto Rico Fishing Regulations were published in 1998 and went into full force in 2002, which may also account for declines in catch corresponding to enforcement of federal and local regulations.

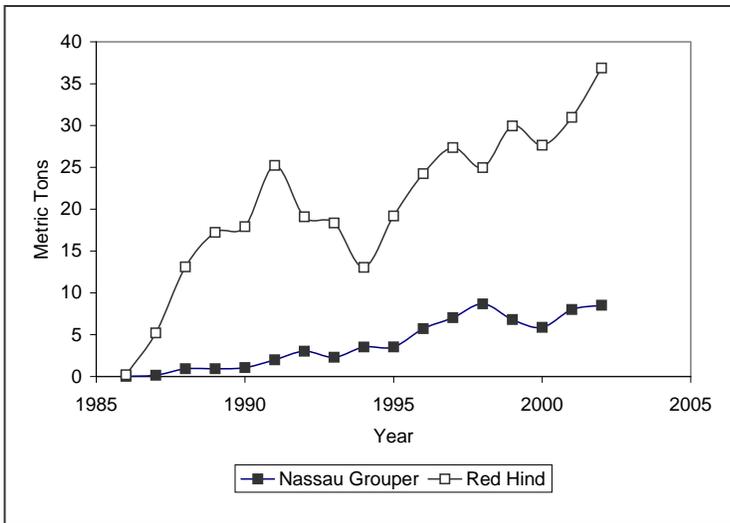


Figure 4. Annual landings statistics for Nassau grouper and red hind for all fishing centers in Puerto Rico. The data series ends in 2002. Refer to table 2 for fishing moratoriums in the region for both species. Source: SEDAR 4 (2003).

According to NOAA (2005) Nassau grouper are still classified as overfished, and currently there is not enough information to determine the parameters required for a complete stock assessment.

Red Hind

There are no statistics on red hind landings in the continental USA, as the species is most abundant in the Caribbean (NOAA Fisheries Statistics <http://www.st.nmfs.gov>).

SEDAR 4 (2003) provides annual landing statistics for red hind in Puerto Rico (see Fig. 4, comparing with Nassau grouper landings). A slight upward trend is observed for the 1985-2002 period. These statistics must be treated with caution due to the possibility that the use of the same or similar common name affected the landings data in terms of distinguishing species. In part due to this problem, the new Puerto Rico Fishing Regulations fishery statistics reporting requirements have become stricter in terms of species identification.

In Puerto Rico and USVI, red hind are extremely vulnerable to all types of fishing gear, especially hand-lines and fish traps, as the ranking of the species with the highest catch rates show (Table 3)

Table 3. Red hind ranking within the top 20 species with the highest catch rates (number per 1,000 hours fished). Source: SEDAR 4 (2003)

Location	Ranking	Gear	Mean catch rate	Standard Error
Puerto Rico	1st	Hand-lines	1032.31	41.30
	1st	Fish Traps	36.40	2.40
U.S. Virgin Islands	2nd	Hand-lines	212.07	33.88
	4th	Fish Traps	24.29	3.24

Red hind seasonal closures prohibiting take and possession of fish during their spawning aggregation season have been shown to increase the mean size of reproductive individuals (Nemeth 2005). The red hind population status is not yet classified as “overfished” (a biomass level below 20 % of the

spawning potential ratio), but trends indicate an “overfishing” status (harvesting occurs to a rate conducive to reach an overfished status) (SEDAR 4, 2003). Current seasonal closures in Puerto Rico and USVI (Table 2) can potentially improve the population status, but increases in fishing pressure (Fig. 4) and vulnerability to fishing gears (Table 3) require cautious assessment of current and future management and conservation activities.

5. CURRENT THREATS THROUGHOUT DISTRIBUTION AREA

Distribution area

Goliath grouper is found in the tropical and subtropical latitudes of the eastern and western Atlantic and eastern Pacific oceans. In the Atlantic, this species is found from Florida to Brazil (to Sao Paulo), throughout the Gulf of Mexico, in the Caribbean, and along the western African coast from Senegal to Congo. In the Pacific, this species is found from the Gulf of California to Peru (Heemstra & Randall 1993, Sadovy & Eklund 1999). However, the effective area occupied by the species is more limited, due to the strong dependence of juveniles on fringing red mangrove shorelines, where recruitment and juvenile growth occurs, and adults on coral reef and rocky substrate habitat (Sadovy & Eklund 1999). During the last 20 years, extensive human-induced habitat destruction of watershed, coastal mangroves, and coral reefs in the tropical western Atlantic have greatly reduced the essential fish habitat for the species (Gilmore & Snedaker 1993, Serafy et al 1997, Serafy et al 2003, Frias-Torres 2006).

Nassau grouper is found in tropical latitudes of the western Atlantic Ocean from Florida to Bermuda and the Caribbean Sea down to southern Brazil. It is rare or transient in the Gulf of Mexico (Heemstra & Randall 1993). It is mostly a shallow water insular species, preferring clear water with high relief coral reefs or rocky substrate (Sadovy & Eklund 1999). Therefore habitat degradation in coral reefs, as in the case of goliath grouper, greatly reduces the essential fish habitat for the species.

Red hind is found in the tropical western Atlantic, from Florida to Bermuda, in the Bahamas, the Caribbean Sea, and the Gulf of Mexico. The species is mostly found associated with coral reefs and hard bottom (Heemstra & Randall 1993). The distribution of the species is limited by habitat quality.

Marked differences in juvenile versus adult critical habitat is present in all three species. Such change of shift in habitat as the individual grows and matures (ontogenetic habitat shifts) also produces dietary shifts. Table 1 shows the different requirements of juvenile versus adults in all three species. Habitat and dietary shifts must be considered in management and conservation strategies (Levin & Grimes 2002)

Current threats

There is historical evidence of large grouper populations in the Caribbean Sea (Jackson 1997). Some species, such as Nassau grouper, have long been a mainstay in the diet of Caribbean coastal communities. However, the life history characteristics of these species discussed previously and continuing increases in fishing pressure have resulted in the collapse of most, if not all, grouper stocks in the tropical western Atlantic (Jackson et al 2001). The overfishing trend targets initially the largest species then smaller species as populations of large fish decline. In the case of the groupers discussed in this report, fishing pressure moved from goliath to Nassau grouper to red hind. While red hind is not yet classified as vulnerable by IUCN or AFS (Table 2), landings for this species have declined sharply since the late 1970s (NMFS, 1999), and the largest sizes collected during red hind spawning aggregations in the Marine Conservation District in St. Thomas is 25 % less (54.6 cm TL for males, Nemeth 2005) than the maximum size attainable by the species (72 cm TL, Table 1). It is possible that a detailed evaluation by IUCN will reveal the vulnerable status of red hind populations due to current levels of exploitation.

In November 2006, the Gulf and Caribbean Fisheries Institute (GCFI) hosted two dedicated workshops on goliath and Nassau grouper and a general grouper fisheries and management session. The consensus resulting from the expert meetings reveals that, in spite of existing fisheries management and conservation strategies (including protection of spawning aggregations and marine protected areas), all groupers in the region, and in particular goliath and Nassau grouper and red hind, are still in rapid decline. As Russ (1991) already concluded, the high market value and demand for grouper result in inadequate or nonexistent protection. The GCFI experts concluded that the most pressing threats for goliath, Nassau and red hind groupers are, in order of priority:

(1) Overfishing and/or extinction of spawning aggregations during the reproductive season.

The narrow window in both time and space for spawning aggregations has been discussed earlier. Research indicates that overfishing during the aggregations might cause sperm limitation and behavioral changes in courtship that limit the reproductive potential of the species (Levin & Grimes 2002). Once a spawning aggregation has been fished out (extinct), recovery rarely occurs, at least not at the same location or with a significantly reduced number of individuals (Sadovy & Vincent 2002)

(2) Overfishing of reproductive adults traveling to and from the spawning aggregation site.

(3) Overfishing of juveniles and adults during the non-reproductive season.

In relation to (2) and (3), when conservation initiatives are in place, fishing moratoriums often target spawning aggregations, leaving the individuals unprotected when they move to and from the spawning aggregation site and during the non-reproductive season. A comprehensive recovery and conservation plan must take a holistic approach and consider habitat and life history traits of these species.

(4) Habitat destruction of mangroves and coral reefs.

The need for particular habitat types in groupers makes them particularly vulnerable to habitat destruction. For example, the persistence of a goliath grouper population in Florida once the fishery moratorium was implemented has been attributed mostly to the existence of extensive fringing red mangrove nurseries in southwest Florida, which provided a refuge to juveniles even as commercial extinction occurred in the late 1980s (Frias-Torres 2006). The lack of such extensive fringing red mangrove coverage in Puerto Rico and USVI might limit or delay goliath grouper recovery in that region. Groupers are closely associated with structurally complex habitats (Levin & Grimes 2002). Therefore, reduction in coral reef complexity and habitat quality due to pollution, bleaching or physical destruction can limit juvenile and adult habitat for Nassau grouper and red hind (Levin & Grimes 2002, Nemeth 2005).

A new and pervasive threat results from the expansion of the live reef fish trade. This type of trade involves the capture of fish that are kept alive until consumption in high-end restaurants. The main clients are located in Hong-Kong, and other expensive cities in China and Japan. Species targeted in this kind of trade are large fish, mostly groupers and wrasses. As traditional supply areas in the Indo-Pacific are being depleted, the high-priced markets in Asian countries are now targeting grouper populations worldwide, both at spawning aggregations and as juveniles. The detachment of the consumers from the product source, the potential for high returns, and an exponential increase in value as the species and larger individuals become rare fuel uncontrolled exploitation and prevent adequate management (Sadovy & Vincent 2002). During the next decade, as Asian countries continue their economic development and more people can access luxury items, the live reef fish trade might become the next window of opportunity to commercial extinction for goliath and Nassau grouper and red hind.

LITERATURE CITED

- Bullock LH, Murphy MD, Godcharles MF, Mitchell ME (1992) Age, growth, and reproduction of jewfish, *Epinephelus itajara*, in the eastern Gulf of Mexico. *Fish Bull* 90:243–249
- Eggleston DB (1995) Recruitment of Nassau grouper *Epinephelus striatus*: post-settlement abundance, microhabitat features and ontogenetic habitat shifts. *Mar Ecol Prog Ser* 124:9–22
- Frias-Torres S (2006). Habitat use of juvenile goliath grouper *Epinephelus itajara* in the Florida Keys, USA. *Endangered Species Research Vol. 2*: 1–6.
- Frias-Torres S, Barroso P, Eklund AM, Schull J, Serafy J. (2007). Activity patterns of three juvenile goliath grouper *Epinephelus itajara*, in a mangrove nursery. *Bull, Mar, Sci* :80(3): 587-594
- Gilmore RG, Snedaker SC (1993) Mangrove forests. In: Echternacht AC (ed) *Biodiversity of the Southeastern United States: lowland terrestrial communities*. John Wiley & Sons, New York, p 165–198
- Heemstra PC, Randall JE (1993) *FAO species catalogue: 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 Fish Synop* 125 (16):1-382
- Hudson EJ, Mace GM (1996) Marine fish and the IUCN Red List of Threatened Animals. In: Hudson EJ, Mace GM (eds) *Report of the IUCN-WWF Workshop at the Zoological Society of London, April 29-May 1, 1996*, p 1–26
- Jackson JBC. 1997. Reefs since Columbus. *Coral Reefs* 16, Suppl.: S23-S32.
- Jackson et al. 2001. Historical Overfishing and the Recent Collapse of Coastal Ecosystems. *Science* 293: 629-638
- Levin PS, Grimes CB. (2002). Reef fish ecology and grouper conservation and management. Pp 377-389. In: Peter F. Sale (Ed) *Coral Reef Fishes: Dynamics and Diversity in a Complex Ecosystem*. Academic Press, San Diego ,549 p.
- Luckhurst BE, Barnes J, Sadovy Y (1992) Record of an unusually large red hind, *Epinephelus guttatus* (Serranidae), from Bermuda with comments on its age. *Bull Mar Sci* 51: 267–270
- Matos-Caraballo D, Cartagena-Haddock M, Peña-Alvarado N. 2004. Portrait of the Fishery of Red Hind, *Epinephelus guttatus*, in Puerto Rico during 1988-2001. *Proceedings of the Gulf and Caribbean Fisheries Institute* 57:343-356.
- Musick JA. (1999). Criteria to Define Extinction Risk in Marine Fishes: The American Fisheries Society Initiative. *Fisheries* 24 (12): 6-13.
- Musick JA et al. (2000a). Protection of Marine Fish Stocks at Risk of Extinction. *Fisheries* 25 (3): 6-8.
- Musick JA et al. (2000b). Marine, Estuarine, and Diadromous Fish Stocks at Risk of Extinction in North America (Exclusive of Pacific Salmonids). *Fisheries* 25 (11): 6-30.
- Nemeth RS (2005) Population characteristics of a recovering US Virgin Islands red hind spawning aggregation following protection. *Marine Ecology Progress Series* 286: 81–97.

NMFS (1999). Our Living Oceans. Report on the Status of U.S. Living Marine Resources, 1999. NOAA Tech. Memo NMFS-F/SPO-4. U.S. Department of Commerce, Washington DC.

NMFS. (2006). Status report on the continental United States distinct population segment of the goliath grouper (*Epinephelus itajara*). January 12, 2006. 49 pp.

NOAA (2005). Stock assessment and fishery evaluation report for the snapper-grouper fishery of the South Atlantic. South Atlantic Fishery Management Council, November 18, 1005 [Internet download]

Russ, GR. (1991). Coral reef fisheries: effects and yields. IN: P. F. Sale (ed) *The Ecology of Fishes on Coral Reefs*. Pp. 601-635. Academic Press, San Diego, CA.

Sadovy, Y. (1990). Grouper Stocks of the Western Central Atlantic: The Need for Management and Management Needs. *Proceeding of the Gulf and Caribbean Fisheries Institute* 43: 43-64

Sadovy Y, Eklund AM (1999) Synopsis of biological information on the Nassau grouper, *Epinephelus striatus* (Bloch 1792) and the jewfish, *E. itajara* (Lichtenstein 1822). NOAA Tech Rep NMFS 146

Sadovy Y, Vincent A (2002). Ecological issues and the trades in life reef fishes. Pp. 391-420. In: Peter F. Sale (Ed) *Coral Reef Fishes: Dynamics and Diversity in a Complex Ecosystem*. Academic Press, San Diego ,549 p.

Sadovy Y, Figueroa M, Roman A (1992) Age and growth of red hind, *Epinephelus guttatus* in Puerto Rico and St. Thomas. *Fish Bull Fish Wildl Serv US* 90:516–528

SEDAR (2003). Caribbean Deepwater Snapper-Grouper Data Report: Atlantic and Caribbean. Southeast Data Assessment and Review, SEDAR 4-SAR2. NMFS/SEFSC. [Internet Download]

Serafy JE, Lindeman KC, Hopkins TE, Ault JS (1997) Effects of freshwater canal discharge on fish assemblages in a subtropical bay: field and laboratory observations. *Mar Ecol Prog Ser* 160:161–172

Serafy JE, Faunce CH, Lorenz JJ (2003) Mangrove shoreline fishes of Biscayne Bay, Florida. *Bull Mar Sci* 72(1):161–180

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Appendix: Extended Literature List

**Submitted to the
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- Aguilar-Perera A. (2006). Disappearance of a Nassau grouper spawning aggregation off the southern Mexican Caribbean coast. *Marine Ecology Progress Series* 327: 289–296.
- Beets J, Friedlander A. (1989). Stock Analysis and Management Strategies for Red Hind, *Epinephelus guttatus* in the U.S. Virgin Islands. *Proceedings of the Gulf and Caribbean Fisheries Institute* 42: 66-79.
- Bullock LH, Murphy MD, Godcharles MF, Mitchell ME (1992) Age, growth, and reproduction of jewfish, *Epinephelus itajara*, in the eastern Gulf of Mexico. *Fishery Bulletin* 90:243–249
- Carter J, Marrow GJ, Pryor V. (1990). 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.
- Chiappone M, Sluka R, Sullivan-Sealy KM, Schmitt E, Bustamante G, Kelly J, Vega M, Pugibet E, Gerald FX, Torres RE. (1997). Comparison of Grouper Assemblages in Northern Areas of the Wider Caribbean: A Preliminary Assessment. *Proceedings of the Gulf and Caribbean Fisheries Institute* 50: 427-451.
- Colás-Marrufo TE, Tuz-Sulub A, Brulé T. (2000). Observaciones Preliminares sobre la Pesquería de Meros (Serranidae:Epinephelinae) en el Parque Marino Nacional "Arrecife Alacranes", Yucatán, México. *Proceedings of the Gulf and Caribbean Fisheries Institute* 53: 430-445
- Coleman FC, Koenig CC, Eklund AM, Grimes CB. (1999). Management and conservation of temperate reef fishes in the grouper-snapper complex of the southeastern United States. Pp. 233-242 IN J.A. Musick (ed.) *Life in the slow lane: ecology and conservation of long-lived marine animals*. American Fisheries Society Symposium 23, Bethesda, Maryland
- Colin PL. (1990). Preliminary Investigations of Reproductive Activity of the Jewfish, *Epinephelus itajara* (Pisces: Serranidae). *Proceedings of the Gulf and Caribbean Fisheries Institute* 43: 138-147.
- Dahlgren CP, Eggleston DB. (2000). Ecological processes underlying ontogenetic habitat shifts in a coral reef fish. *Ecology* 81 (8): 2227-2240.
- Eklund A.M. (2005). Habitat Affinities of Juvenile Goliath Grouper to Assess Estuarine Conditions. Chapter 25 Pp. 393-407. In: S.A. Bortone (ed.). *Estuarine Indicators*. CRC Press. Boca Raton, Florida.
- Eggleston DB (1995) Recruitment of Nassau grouper *Epinephelus striatus*: post-settlement abundance, microhabitat features and ontogenetic habitat shifts. *Marine Ecology Progress Series* 124:9–22
- Frias-Torres S (2006). Habitat use of juvenile goliath grouper *Epinephelus itajara* in the Florida Keys, USA. *Endangered Species Research* Vol. 2: 1–6.
- Frias-Torres S, Barroso P, Eklund AM, Schull J, Serafy J. (2007). Activity patterns of three juvenile goliath grouper *Epinephelus itajara*, in a mangrove nursery. *Bulletin of Marine Science* :80(3): 587-594
- Gilmore RG, Snedaker SC (1993) Mangrove forests. In: Echnacht AC (ed) *Biodiversity of the Southeastern United States: lowland terrestrial communities*. John Wiley & Sons, New York, p 165–198

- Gilmore RG, Bullock LH, Berry FH. (1978). Hypothermal mortality in marine fishes of southcentral Florida, January 1977. *Northeast Gulf Science* 2(2): 77-97.
- Gobert B, Berthou P, Lopez E, Lespagnol P, Turcios MDO, Macabiau C, Portillo P. (2005). Early stages of snapper–grouper exploitation in the Caribbean (Bay Islands, Honduras). *Fisheries Research* 73: 159–169.
- Grover JJ, Olla BL, Wicklund RI (1989). Food Habit of Nassau Grouper (*Epinephelus striatus*) Juveniles in Three Habitats in the Bahamas. *Proceedings of the Gulf and Caribbean Fisheries Institute* 42: 247-247
- Heemstra PC, Randall JE (1993) FAO species catalogue: 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* 125 (16):1-382
- Heyman W. (2004). Test of Multi-Species Spawning Aggregations. *Proceedings of the Gulf and Caribbean Fisheries Institute* 55: 521-529.
- Hudson EJ, Mace GM (1996) Marine fish and the IUCN Red List of Threatened Animals. In: Hudson EJ, Mace GM (eds) Report of the IUCN-WWF Workshop at the Zoological Society of London, April 29-May 1, 1996, p 1–26
- Jackson JBC. 1997. Reefs since Columbus. *Coral Reefs* 16, Suppl.: S23-S32.
- Jackson et al. 2001. Historical Overfishing and the Recent Collapse of Coastal Ecosystems. *Science* 293: 629-638
- Koenig CC, Coleman FC, Eklund AM, Schull J, Ueland J. (2007). Mangroves as essential nursery habitat for goliath grouper (*Epinephelus itajara*). *Bulletin of Marine Science* 80(3): 567-586.
- Levin PS, Grimes CB. (2002). Reef fish ecology and grouper conservation and management. Pp 377-389. In: Peter F. Sale (Ed) *Coral Reef Fishes: Dynamics and Diversity in a Complex Ecosystem*. Academic Press, San Diego ,549 p.
- Luckhurst, B.E. (1997). Site Fidelity and Homing Behaviour of Tagged Red Hind (*Epinephelus guttatus*) to Spawning Aggregation Sites at Bermuda. *Proceedings of the Gulf and Caribbean Fisheries Institute* 50: 750-763.
- Luckhurst BE, Barnes J, Sadovy Y (1992) Record of an unusually large red hind, *Epinephelus guttatus* (Serranidae), from Bermuda with comments on its age. *Bulletin of Marine Science* 51: 267–270
- Matos-Caraballo D. (1996). Status of the Groupers in Puerto Rico, 1970-1995. *Proceedings of the Gulf and Caribbean Fisheries Institute* 49: 340-353.
- Matos-Caraballo, D. (1998). Overview of Puerto Rico's Small-scale Fisheries Statistics, 1994-1997. *Proceedings of the Gulf and Caribbean Fisheries Institute* 51: 215-231.
- Matos-Caraballo D. (2000). Portrait of the Commercial Fishery of the Red Hind, *Epinephelus guttatus*, in Puerto-Rico During 1992 - 1999. *Proceedings of the Gulf and Caribbean Fisheries Institute* 53: 446-459.

- Matos-Caraballo D. (2004). Overview of Puerto Rico's Small-Scale Fisheries Statistics 1998-2001. Proceedings of the Gulf and Caribbean Fisheries Institute 55: 103-118.
- Matos-Caraballo D, Cartagena-Haddock M, Peña-Alvarado N. (2004). Portrait of the Fishery of Red Hind, *Epinephelus guttatus*, in Puerto Rico during 1988-2001. Proceedings of the Gulf and Caribbean Fisheries Institute 57:343-356.
- Musick JA. (1999). Criteria to Define Extinction Risk in Marine Fishes: The American Fisheries Society Initiative. Fisheries 24 (12): 6-13.
- Musick JA et al. (2000a). Protection of Marine Fish Stocks at Risk of Extinction. Fisheries 25 (3): 6-8.
- Musick JA et al. (2000b). Marine, Estuarine, and Diadromous Fish Stocks at Risk of Extinction in North America (Exclusive of Pacific Salmonids). Fisheries 25 (11): 6-30.
- Nemeth RS (2005) Population characteristics of a recovering US Virgin Islands red hind spawning aggregation following protection. Marine Ecology Progress Series 286: 81–97.
- NMFS (1999). Our Living Oceans. Report on the Status of U.S. Living Marine Resources, 1999. NOAA Tech. Memo NMFS-F/SPO-4. U.S. Department of Commerce, Washington DC.
- NMFS. (2006). Status report on the continental United States distinct population segment of the goliath grouper (*Epinephelus itajara*). January 12, 2006. 49 pp.
- NOAA (2005). Stock assessment and fishery evaluation report for the snapper-grouper fishery of the South Atlantic. South Atlantic Fishery Management Council, November 18, 1005 [Internet download]
- Porch C, Eklund AM, Scott GS. (2006). A catch-free stock assessment model with application to goliath grouper (*Epinephelus itajara*) off southern Florida. Fishery Bulletin. 104:89–101.
- Russ, GR. (1991). Coral reef fisheries: effects and yields. IN: P. F. Sale (ed) The Ecology of Fishes on Coral Reefs. Pp. 601-635. Academic Press, San Diego, CA.
- Sabat AM, Hernández-Delgado EA, Toledo CG. (1998). Demographic Analysis of the Effect of Fishing Mortality on the Population Dynamics of the Red Hind (*Epinephelus guttatus*). Proceedings of the Gulf and Caribbean Fisheries Institute 51: 169-181.
- Sadovy, Y. (1990). Grouper Stocks of the Western Central Atlantic: The Need for Management and Management Needs. Proceeding of the Gulf and Caribbean Fisheries Institute 43: 43-64
- Sadovy Y. (1992). 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, Domeier M. (2005). Are aggregation-fisheries sustainable? Reef fish fisheries as a case study. Coral Reefs 24: 254–262.
- Sadovy Y, Eklund AM (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

Sadovy Y, Vincent A (2002). Ecological issues and the trades in life reef fishes. Pp. 391-420. In: Peter F. Sale (Ed) *Coral Reef Fishes: Dynamics and Diversity in a Complex Ecosystem*. Academic Press, San Diego ,549 p.

Sadovy Y, Figueroa M, Roman A (1992) Age and growth of red hind, *Epinephelus guttatus* in Puerto Rico and St. Thomas. *Fishery Bulletin of the Fish and Wildlife Service US* 90:516–528

Sala E, Ballesteros E, Starr RM. Rapid Decline of Nassau Grouper Spawning Aggregations in Belize: Fishery Management and Conservation Needs. *Fisheries* 26(10): 23-30

SEDAR (2003). Caribbean Deepwater Snapper-Grouper Data Report: Atlantic and Caribbean. Southeast Data Assessment and Review, SEDAR 4-SAR2. NMFS/SEFSC. [Internet Download]

SEDAR 2004. Complete Stock Assessment Report of SEDAR 6: Goliath Grouper. SEDAR6 Assessment Report 1 SEDAR6-SAR1. SEDAR/SAFMC. 17 p.

Serafy JE, Lindeman KC, Hopkins TE, Ault JS (1997) Effects of freshwater canal discharge on fish assemblages in a subtropical bay: field and laboratory observations. *Marine Ecology Progress Series* 160:161–172

Serafy JE, Faunce CH, Lorenz JJ (2003) Mangrove shoreline fishes of Biscayne Bay, Florida. *Bull Mar Sci* 72(1):161–180