Status report on the continental United States distinct population segment of the goliath grouper (*Epinephelus itajara*)

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Cover: goliath grouper illustration courtesy of Diane Peebles.

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Abbreviations and Acronyms

ABC	acceptable biological catch
AP	advisory panel
BO	biological opinion
CPUE	catch per unit effort
CFR	Code of Federal Regulations
DPS	distinct population segment
DEIS	draft environmental impact statement
ESA	Endangered Species Act
EIS	environmental impact statement
EFH	essential fish habitat
EEZ	Exclusive Economic Zone
FR	Federal Register
FEIS	final environmental impact statement
FMP	fishery management plan
F	fishing mortality
GMFMC	Gulf of Mexico Fishery Management Council
IUCN	The World Conservation Union
MSFCMA	Magnuson-Stevens Fishery Conservation and Management Act
MMPA	Marine Mammal Protection Act
MRFSS	Marine Recreational Fisheries Statistics Survey
NEPA	National Environmental Policy Act
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
M	natural mortality rate
nm	nautical mile
ppm	parts per million
REEF	Reef Environmental Education Foundation
RIR	regulatory impact review
SAFMC	South Atlantic Fishery Management Council
SEDAR	Southeast Data, Assessment, and Review
SEFSC	Southeast Fisheries Science Center
SERO	Southeast Regional Office
SEIS	supplemental environmental impact statement
SFA	Sustainable Fisheries Act
SL	standard length
SPR	spawning potential ratio
TL	total length
USFWS	United States Fish and Wildlife Service

Summary

This status report provides a summary of information gathered for the continental United States distinct population segment (DPS) of the goliath grouper (*Epinephelus itajara*), which was formerly on the 1999 Endangered Species Act (ESA) candidate species list and currently is considered a species of concern. The purpose of this status report is to investigate the current status of goliath grouper relative to the criteria for including a species on the species of concern list, in light of updated information about the status of and threats to the continental U.S. DPS of the goliath grouper.

Goliath grouper is a long-lived and late-maturing serranid. The species depends on mangrove habitat during its early development, and recovery of the species may be impacted by habitat loss and degraded water quality along the coast. Because goliath grouper readily strike at a baited hook or a struggling fish and are easily approached by divers (i.e., spearfishermen), large juvenile goliath grouper and adults are susceptible to harvest. Additionally, goliath grouper aggregate to spawn and are particularly vulnerable to fishing during this period.

Historically, the distribution of the species within the continental U.S. stretched from North Carolina through Texas, with the center of abundance extending from the central east coast of Florida through the Gulf of Mexico to the Florida Panhandle. The population showed a decline in abundance and a truncation of range during the late 1970s and 1980s, primarily due to overutilization by the recreational and commercial fisheries.

Because of goliath grouper population declines, fishery regulations and eventual prohibitions were enacted to conserve and manage the population. Both the Gulf of Mexico Fishery Management Council (GMFMC) and the South Atlantic Fishery Management Council (SAFMC) prohibited the harvest and possession of goliath grouper in 1990. Likewise, the state of Florida prohibited the harvest and possession of goliath grouper from state waters in 1990, followed by all other coastal states from North Carolina through Texas.

The declines in abundance and occurrence of goliath grouper also prompted several organizations to recognize the species' uncertain status in an effort to provide additional consideration related to its management. NMFS identified the species as a candidate for possible listing as threatened or endangered under the ESA in 1991 for the entire range of the species within continental U.S. waters (56 FR 26797). In 1996, the World Conservation Union (IUCN) recognized the species as "critically endangered" throughout its range and distribution based on the conclusion that the species has been "observed, estimated, inferred, or suspected" of a reduction in abundance of at least 80 percent over the last 10 years or three generations (IUCN, 2005). The IUCN considers a species "critically endangered" if it appears to be at an "extremely high risk of extinction in the wild in the immediate future." Furthermore, in reports submitted to Congress under the Magnuson Stevens Fishery Conservation and Management Act (MSFCMA) on the status of fisheries in U.S. waters between 1999 and 2005, NMFS identified goliath grouper as "overfished," meaning the level of fishing mortality has jeopardized the capacity of the

fishery to produce the maximum sustainable yield on a continuing basis (i.e., the population is below a level considered healthy, requiring management action to achieve an appropriate level and rate of rebuilding). However, in 2000, the American Fisheries Society identified goliath grouper as being conservation dependent, which is a category that recognizes the species is reduced but stabilized or recovering under a continuing conservation plan (Musick et al., 2000).

In 2004, a Southeast Data, Assessment, and Review (SEDAR) assessment indicated that the goliath grouper stock in south Florida waters was recovering, but that full recovery to the MSFCMA management target might not occur until 2020 or later (SEDAR 2004). Based on the results of the assessment and due to inquiries from numerous stakeholders, NMFS proceeded to evaluate whether the continental U.S. population of goliath grouper still warranted species of concern status.

After evaluating the most up-to-date data, the NMFS assessment team concludes that the continental U.S. DPS of goliath grouper has undergone significant increases in abundance since its identification in 1991 as a candidate species under the ESA. The species has also become re-established throughout its historical range. Due to management actions implemented via the MSFCMA, extraction of goliath grouper by commercial and recreational fisheries is currently not a threat to the species. While the team is concerned about the rate of habitat loss and modification, in particular the loss of mangrove habitat, we do not feel the current habitat loss is a factor affecting the species' status at this time. Therefore, the team believes inclusion of goliath grouper on the NMFS' species of concern list is no longer warranted due to the fact that it no longer meets the definition of a species of concern.

Introduction

On June 11, 1991, NMFS identified goliath grouper (previously known as jewfish) as a candidate species under the ESA (56 FR 26797). On April 15, 2004, NMFS announced the establishment of a species of concern list, a description of the factors that it will consider when identifying species of concern, and revision of the ESA candidate species list (69 FR 19976). NMFS transferred 25 candidate species, including goliath grouper, to the species of concern list.

As appropriate, NMFS may initiate a status review or prepare a status report for any species of concern, and the public may petition to list any species under the ESA. A SEDAR assessment (2004) indicated the stock in south Florida waters was recovering, but a full recovery to the management target might not occur until 2020 or later.

Based on the results of the assessment and due to inquiries from numerous stakeholders, NMFS deemed it prudent to produce a status report on the species at this time. This status report is expected to determine if the goliath grouper should be removed from the NMFS species of concern list, or retained on that list.

This report first provides background on the ESA and the species of concern list, including a summary of species of concern listing criteria. The report next analyzes whether it is appropriate to evaluate the continental U.S. population of goliath grouper as a distinct population segment relative to the species of concern factors, since this is the population that has been the focus of previous concern and management. Next, the report describes in detail the taxonomy and species description, life history characteristics, and exploitation history of goliath grouper. After assessing threats to the species, in conjunction with the species of concern listing criteria, the report finally evaluates whether goliath grouper still meets the criteria for inclusion on the species of concern list.

The Endangered Species Act

The purposes of the ESA are to provide a means to conserve ecosystems upon which endangered species and threatened species depend, to provide a program for the conservation of endangered and threatened species, and to take appropriate steps to recover a species. The U.S. Fish and Wildlife Service (USFWS) and NMFS share responsibility for administering the ESA; NMFS is responsible for determining whether marine, estuarine or anadromous species, subspecies, or DPS are threatened or endangered under the ESA.

Generally, species are considered for listing under the ESA if they meet the definition of an endangered or threatened species and that status is the result of one or any combination of the following factors: (1) The present or threatened destruction, modification, or curtailment of its habitat or range; (2) overutilization for commercial, recreational, scientific, or educational purposes; (3) disease or predation; (4) the inadequacy of existing regulatory mechanisms; or (5) other natural or manmade factors affecting its continued existence.

The ESA provides the following definitions:

> *"the term **species** includes 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."*
>
> *"**endangered species** is defined as "any species which is in danger of extinction throughout all or a significant portion of its range."*
>
> *"**threatened species** is defined as "any species which is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range."*

When a species is listed as endangered under the ESA, it is afforded all protections of the ESA, including the development and implementation of recovery plans, requirements that federal agencies use their authorities to conserve the species, and prohibitions against certain practices, such as taking individuals of the species. Under NMFS policy, when a species is listed as threatened, the prohibitions for take are not automatically afforded; however, all other sections of the ESA apply. These prohibitions must be specifically afforded to a threatened species through a special rule (section 4(d) of ESA). The prohibitions of section 9 of the ESA, in part, make it illegal for any person subject to the jurisdiction of the U.S.: to take (i.e., to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture or collect, or to attempt to engage in any such conduct); to import into, or export from, the U.S.; to ship in interstate or foreign commerce in the course of commercial activity; or to sell or offer for sale in interstate or foreign commerce any endangered wildlife. To possess, sell, deliver, carry, transport, or ship, endangered wildlife that has been taken illegally is also prohibited. Section 10 of the ESA provides NMFS with the authority to grant exemptions to the section 9 taking prohibitions for scientific research, enhancement, and incidental take permits. The ESA provides some exceptions to the prohibitions, without permits, for certain antique articles and species held in captivity at the time of the listing.

NMFS identified goliath grouper as an ESA candidate species in 1991 due to declines in abundance resulting from fishing effort (i.e., overutilization) in both the recreational and commercial fishing sectors (GMFMC, 1989; SAFMC, 1990).

Candidate Species/Species of Concern Listing

In 2004, NMFS established a species of concern list in addition to its candidate species list. NMFS recognized that using the broader candidate species term may give an inaccurate impression that all species on that list were being considered for listing under the ESA. NMFS (69 FR 19975) distinguished the species to be included on each list as follows:

> *A "**candidate species**" refers to (1) species that are the subject of a petition to list and for which NMFS has determined that listing may be warranted pursuant to ESA section 4(b)(3)(A), and (2) species for which NMFS has determined, following a status review, that listing is warranted (whether or not they are the subject of a petition).*
>
> *A "**species of concern**" identifies species about which NMFS has some concerns regarding status and threats, but for which insufficient information is available to indicate a need to list the species under the ESA.*

NMFS believes placing organisms on the species of concern list will achieve the following: (1) Identify species potentially at risk; (2) increase public awareness about the species; (3) identify data deficiencies and uncertainties in species' status and threats; (4) stimulate cooperative research efforts to obtain the information necessary to evaluate species status and threats; and (5) foster voluntary efforts to conserve the species before listing becomes warranted. NMFS hopes that these effects may reduce the future need to list such species as threatened or endangered under the ESA. NMFS established a species of concern website (*http://www.nmfs.noaa.gov/pr/species/concern*) that includes a detailed explanation of the factors to be considered in evaluating whether a species warrants inclusion on the list.

Consistent with the NOAA 2004 policy, goliath grouper was transferred from the candidate species list to the species of concern list because it was not under active consideration for listing under the ESA, but there was still considered to be insufficient information to fully determine its status.

Species of Concern Criteria

Several demographic and diversity vulnerability criteria are considered when evaluating whether a species should be added or retained on, or removed from the species of concern list. These criteria include: species abundance and productivity; distribution; and life-history characteristics.

Factors related to a species abundance and productivity include magnitude of decline, both recent and historical; natural rarity, applicable to species known only from a small number of specimens due to ecological or evolutionary factors; and endemism, which is applicable to species native to only a specific geographic location. As goliath grouper are not naturally rare, nor are they endemic to any discrete location, those criteria will not be evaluated further. Goliath grouper abundance and productivity is discussed within the life history characteristics section of this report. Information germane to the historical decline of goliath grouper is included in a section discussing the species exploitation in both the commercial and recreational fisheries. Since the harvest and possession of goliath grouper has been prohibited since 1990, resulting in the recent recovery of the species, generally, only the historical decline is discussed in this section. The inclusion

of goliath grouper on the species of concern list was due to declines in abundance resulting from overfishing in the commercial and recreational sectors during the 1980s.

Distribution of the species needs to be considered as well. This may also include a discussion on the connectivity of populations, as the number and distribution of populations may affect a species' resilience to environmental variability. This is especially pertinent to endemic species and species with a limited geographic range, which are especially vulnerable in this regard. However, as goliath grouper are not geographically isolated or endemic, connectivity is not a factor impacting the demographics or genetic diversity of goliath grouper. Goliath grouper distribution is discussed within the life history characteristics section of this report.

Life history characteristics include various biological factors such as age and growth, reproductive maturity, natural maturity, fecundity, diet, etc., all of which may affect the vulnerability of a species to certain threats. These characteristics are discussed extensively following an introductory section on goliath grouper taxonomy and a brief species description.

A summary of threats to the species follows the discussion on the aforementioned demography and diversity vulnerability criteria to assist with the determination on whether the species should be added or retained on or removed from the species of concern list. These threats are extraction, habitat degradation/loss, disease and predation, and other natural or man-made factors. These factors, in isolation or in concert with information gleaned from the demographic and diversity criteria, may indicate that a species should be added or retained on, or removed from the species of concern list.

Geographic Scope of the Status Report

The goliath grouper was originally identified as a candidate species under the ESA on June 11, 1991 (56 FR 26797). In a later modification to the candidate species list published on July 14, 1997 (62 FR 37560), the area of concern for goliath grouper was identified as the Atlantic Ocean from North Carolina southward into the Gulf of Mexico (i.e., North America). While goliath grouper are found in the eastern Atlantic Ocean, throughout the Caribbean, and along portions of coastal South America (Figure 1), this status report was commissioned to evaluate only the status of the species in the continental United States due to information about the recent increases in abundance of this population. Therefore, the team first evaluated whether this limited review was supportable by determining whether the continental U.S. population meets the criteria for designation as a DPS.

There are two criteria applicable to identifying a DPS for the purposes of listing, delisting, and reclassifying species under the ESA (61 FR 4722): (1) The discreteness of the population segment in relation to the remainder of the species to which it belongs; and (2) the significance of the population segment to the species to which it belongs.

A population segment of a vertebrate species may be considered discrete if it satisfies either one of the following conditions: (1) It is markedly separated from other populations of the same taxon as a consequence of physical, physiological, ecological, or behavioral factors; or (2) it is delimited by international governmental boundaries within which differences in control of exploitation, management of habitat, conservation status, or regulatory mechanisms exist that are significant in light of section 4(a)(1)(D) of the ESA.

The continental U.S. goliath grouper population is geographically distinct from other goliath grouper populations, primarily due to the influence of the Gulf Loop and Gulf Stream currents. The current center of abundance of goliath grouper is thought to be the Ten Thousand Islands region of southwest Florida (Koenig et al., in review). The continental U.S. population does not depend on larval input from other areas, and larvae produced within this segment are most likely largely retained or potentially carried to fringe areas such as Bermuda. There is no evidence of population interaction between western and eastern Atlantic Ocean populations of goliath grouper. Recent genetics work indicates major, drastic genetic differences between the continental U.S. population and goliath grouper in the Caribbean (Chapman, pers. comm.). Goliath grouper are largely a solitary species with high site fidelity; there is no information to suggest the species is highly migratory.

When a population is considered discrete, such as the continental U.S. goliath grouper population, its biological and ecological significance is then considered. This consideration may include, but is not limited to, the following: (1) Persistence of the DPS in an ecological setting unusual or unique for the taxon; (2) evidence that loss of the DPS would result in a significant gap in the range of a taxon; (3) evidence that the DPS represents the only surviving natural occurrence of a taxon that may be more abundant elsewhere as an introduced population outside its historic range; or (4) evidence that the DPS differs markedly from other populations of the species in its genetic characteristics.

The continental U.S. goliath grouper population is significant for several reasons. The team believes the loss of the continental U.S. goliath grouper population would represent a significant gap in the range of the species, as the coastline along which goliath grouper occurs extends throughout the Gulf of Mexico to Cape Hatteras, North Carolina, a length of approximately 4,500 km. The loss of the goliath grouper, a high trophic level predator within marine communities, would represent a direct loss of species diversity and could potentially present significant, yet unforeseeable, ecological ramifications (e.g., changes within existing predator-prey relationships). Therefore, the continental U.S. goliath grouper population is considered biologically and ecologically significant.

Because the continental U.S. goliath grouper population is both discrete and significant as outlined above, it represents a DPS for the purposes of evaluation under the ESA. Therefore, this status report will focus solely on the continental U.S. goliath grouper DPS.

Taxonomy and Species Description

Taxonomic Description

Phylum Chordata
Class Osteichthyes
Superorder Acanthopterygii
Order Perciformes
Suborder Percoidei
Family Serranidae
Subfamily Epinephelinae

Goliath grouper belong to the genus *Epinephelus*, which includes a number of large to very large sea basses that are the most common top-level predators on coral reefs. The following characteristics of the genus *Epinephelus* (Bloch, 1793) come largely from Heemstra and Randall (1993):

Species within the genus *Epinephelus* typically have an elongate body that is robust (subcylindrical), oblong, or deep and compressed; body depth is 2.3 to 3.7 times in standard length (SL); body width 1.8 to 2.8 in depth. Head length is 2.1 to 2.8 times in SL; preorbital depth 6.7 to 15 times in head length; preopercle rounded or angular, the posterior edge serrate, with the serrae at the angle more or less enlarged; a few species with small serrae (mostly covered by skin) on the ventral edge; canines present at front of jaws, but they may be small in some species; no distinctly enlarged canine teeth at midside of lower jaw; teeth present on palatines; maxilla of adults without a distinct bony knob on ventroposterior corner, but there may be an abrupt step or hook-like process (covered by the upper lip) on the distal part of the ventral edge; supramaxilla well developed. Dorsal fin usually possesses 11 spines and 12 to 19 rays, the fin origin above the opercle; length of base of soft-rayed part of dorsal fin not more than base of spinous part; anal fin with 3 distinct spines and 7 to 10 rays; pectoral fin rounded, the middle rays longest; caudal branched ray and 7 to 10 procurrent rays in lower part. Scales on body are ctenoid or smooth. Two supraneural bones; dorsal and anal fins without trisegmental pterygiophores; rear edge of first dorsal pterygiophore with or without excavation for tip of second neural spine; one to 10 epipleural ribs on vertebrae. The diversity of cranial morphology of the many species assigned to *Epinephelus* makes it difficult to recognize diagnostic cranial characteristics for the genus.

The following are characteristics of *Epinephelus* larvae (Leis, 1986): pelvic-fin spines with 4 ridges; supraocular ridge with a single strong spine; spines on lower limb of preopercle serrate; posterior 1 or 2 dorsal-fin spines develop first as soft rays and all spines are present in larvae of 13.5 to 16 mm; all anal-fin spines are present prior to settlement at a length of 16 to 18 mm SL. The larvae are kite-shaped, with the second dorsal-fin spine and pelvic fin spines greatly elongated and a pigment spot at the cleithral symphysis (Johnson and Keener, 1984).

General Species Description

Goliath grouper, *Epinephelus itajara* (Lichtenstein, 1822), was formerly known as the jewfish. The American Fisheries Society changed the name from jewfish to goliath grouper in July 2004, on the basis of the Society's Principle 9, which states: "Names shall not violate the tenets of good taste" (Nelson et al., 2001).

Goliath grouper is the largest of the western Atlantic Ocean groupers, reaching a maximum length of 2,500 mm total length (TL) and a maximum weight of approximately 400 kg (884 lb) (FAO, 2005). Other characteristics include their nearly cylindrical shape, short dorsal spines, short canine teeth, small eyes, broad head, and distinct coloration. The body color is brownish yellow, grey or greenish (FAO, 2005). Black spots appear on the dorsal part of the head, body, and fins. Fish 87 mm SL and larger are generally greenish or tawny, have 3 to 4 faint, irregular, subvertical dark bars posteriorly on body and another covering rear half of caudal peduncle (Sadovy and Eklund, 1999). Five irregular bars are displayed on fish less than 1 m in length, and juveniles typically have a more vivid coloration and have relatively longer spines than adults.

Life History Characteristics

Habitat

Goliath grouper larvae, similar to the larvae of other Serranids (e.g., Nassau grouper, *Epinephelus striatus*), are likely pelagic. Specific habitat requirements of goliath grouper larvae are unknown (Sadovy and Eklund, 1999).

Mangrove habitat is thought to be the primary habitat for juvenile goliath grouper (to 1,000 mm TL). Juveniles exhibit high site fidelity to mangrove habitat where undercuts create a swift tidal flow (Koenig et al., in review). Many reef fish species, including goliath grouper, utilize mangrove habitat during their juvenile life stage. Studies have shown the structural complexity of mangrove habitat offers shelter from predators, increases prey availability, and provides shade (Laegdgaard and Johnson, 2001; Cocheret de la Morinière et al., 2004).

Three species of mangroves occur in Florida: red, white, and black. Red (*Rhizophora mangle*) and white mangrove (*Laguncularia racemosa*) are found as far north as Cedar Key in the Gulf of Mexico and Ponce de Leon Inlet on the east coast of Florida. Black mangrove (*Avicennia germinans*) is found farther north to Jacksonville on the east coast and along the Panhandle in the Gulf due to its ability to grow from undestroyed roots after a freeze. Red mangrove, which can reach 25 m in height, has distinctive prop roots that tangle and stick out of the water, and is typically found the closest to the waterline. White mangrove is the shortest (maximum height of 15 m) and the most inland of Florida mangroves. It is also the most susceptible to the effects of freezing, and is therefore commonly found in the southern part of Florida. Black mangrove has shallow cable-like roots that emanate outward from the tree with small vertical shoots that stick above the soil for purposes of aeration. Because of the zonation of both white and black mangrove

further inland and away from the water's edge compared to red mangrove, and due to the limited size and structure of their root systems, white and black mangrove only offer meager goliath grouper habitat. The range of the various species of mangrove has remained much the same over the past 50 years, though significant changes have occurred in the form of density and continuity.

Availability of mangrove habitat may be a bottleneck to goliath grouper abundance (Koenig et al., in review). Secondary and tertiary juvenile goliath grouper habitat areas include seagrass beds, oyster reefs, etc. Cass-Calay and Schmidt (2003) noted that early juveniles (to 30 mm SL) settled in salt marsh/mangrove salt ponds with rich organic sediment. Small young-of-the-year fish (46 to 88 mm SL) appear in grass beds and estuaries off the west coast of Florida from November through January, indicating a summer spawning period (Bullock and Smith, 1991).

Adult goliath grouper occur either as solitary individuals or in groups of up to 100 specimens. Adults are often found on artificial and natural reefs, overhangs, bridges, piers, and shipwrecks (Heemstra and Randall, 1993). While goliath grouper may be found on low-relief coral reef habitat, they typically are not found in great numbers (Heemstra and Randall, 1993). In general, goliath grouper prefer areas such as deep crevices, holes, and overhead structures that likely act as shelter and protection. Large goliath grouper are relatively sedentary and exhibit little movement within reefs; Smith (1976) observed the same individuals for more than a year at specific reef sites off Florida. Notable exceptions to this site fidelity include movement during presumed spawning (M. Barnette, NMFS, pers. obs.) and during low temperature events in nearshore and estuarine waters (Gilmore et. al., 1978) where specimens may migrate offshore to warmer waters.

The past two decades have witnessed an increase in artificial reef development in the state of Florida (Figure 2). Florida artificial reefs have been deployed in water shallower than 2 m and as deep as 135 m, though the vast majority of reefs deployed to date rest between 7-45 m and the average depth of all deployed artificial reefs is 21 m (Mille, 2005). These structures likely provide additional habitat to the species as individuals are often seen on these sites; however, there is no evidence that adult habitat is limiting.

Depth Range

Goliath grouper are generally a shallow-water species, typically found in less than 50 m of water (Heemstra and Randall, 1993); however, solitary specimens have been observed as deep as 80 m in the Gulf of Mexico and in the Atlantic Ocean off Florida (M. Barnette, NMFS, pers. obs.). Juveniles appear to prefer shallow estuarine waters 0 to 3 m in depth (Bullock and Smith, 1991; Koenig et al., in review). While larvae are pelagic, their exact depth distribution is unknown.

Distribution

The goliath grouper is present in both the Atlantic and Pacific Oceans (Figure 1). In the western Atlantic Ocean this species ranges from Bermuda and the Carolinas (though rarely) down through the coast of Brazil, including the Gulf of Mexico and the Caribbean Sea. In the eastern Atlantic Ocean, goliath grouper is found rarely from Senegal to Congo and the Canary Islands. They have also been found off the coast of Mexico in the eastern Pacific, including the Gulf of California to Peru (Smith, 1971; Heemstra and Randall, 1993).

The goliath grouper was historically found in coastal waters of all states along the Gulf of Mexico. Archival newspaper accounts of goliath grouper catches in Texas help to document the notable presence the species may have historically had in coastal waters. An article published in the *New York Times* on July 28, 1895, noted an "unusually large run of jewfish." It documented a fishing party catching 14 fish totaling approximately 5,000 lb, with the largest apparently topping the scales at 954 lb. The article also mentioned the exceptional catch of a "1,500-pound giant" in early May by a seine off Corpus Christi. A July 13, 1939, article in the *Port Arthur News* detailed the story of a 600-pound goliath grouper that was run over by a small vessel in the ship channel near the Gulfport shipyard.

While goliath grouper was found in the Atlantic Ocean northward to Cape Hatteras, North Carolina, based on historical catch data and anecdotal observations, specimens north of Florida likely represent the historical fringe of the goliath grouper distribution in the Atlantic (SAFMC, 1998). Historical accounts of divers and spearfishermen in the 1970s and 1980s reflect this apparent difference in density between the west Florida shelf and the Atlantic, especially off North Carolina. Divers first exploring newly discovered wrecks off North Carolina in the early 1980s would typically see only one specimen on a wreck, and the presence/absence of goliath grouper was spotty and inconsistent amongst wreck sites (M. Barnette, NMFS, pers. comm.).

The current center of abundance for the Gulf of Mexico population of goliath grouper is thought to be in the Ten Thousand Islands region off southwest Florida, where extensive mangrove habitat exists (Bullock and Smith, 1991; Koenig et al., in review). Radiating outwards from the Ten Thousand Islands area into the Gulf of Mexico, the majority of the goliath grouper population appears to be bounded by the Florida Keys, to the south and the Florida Panhandle to the north. This northern delineation also roughly corresponds to the northern range of mangroves in the Gulf. While goliath grouper stretch further west along the Gulf of Mexico coastline, the density of the species appears to be focused along the aforementioned area of the west Florida shelf. The remainder of specimens found off the Florida Panhandle and west towards Texas is likely the fringe of the species' distribution in the Gulf of Mexico.

The goliath grouper is one of the few grouper species that can live in brackish water, though low salinity is documented to negatively influence densities of juvenile goliath grouper (Koenig et al., in review). Low dissolved oxygen levels, in concert with low

salinity, negatively influence juvenile goliath grouper densities (Koenig et al., in review). However, small individuals have been caught alive in poorly oxygenated upland canals in Tampa Bay, Florida (Lindall et al., 1975).

Juvenile goliath grouper emigration to offshore waters occurs at the age of 5 or 6 years, probably at the onset of maturity that likely occurs when they approach 1,000 mm TL (Koenig et al., in review). There is no evidence that they respond to the sort of local environmental cues (e.g., temperature change) that trigger egress in other groupers, such as gag, *Mycteroperca microlepis* (Koenig and Coleman, 1998; Koenig et al., in review).

While there are numerous large artificial reefs and shipwrecks that offer ideal habitat for adult goliath grouper on the east coast of Florida in the Atlantic Ocean, the abundance and density of goliath grouper seemingly is not as high as that found in the Gulf of Mexico, particularly off southwest Florida. As discussed by Koenig et al. (in press), this is likely due to the lack of abundant mangrove habitat on the east coast due to coastal development. Lack of mangrove habitat may be a limiting factor for juvenile goliath grouper. The origin of these large, typically solitary adult goliath grouper that have taken up residence on the various shipwrecks and artificial reefs off southeast Florida and to the north in the past few years is unknown.

Another potential explanation for the differences in distribution of goliath grouper in Florida noted above might be the natural habitat limitations on the east coast of Florida compared to the west Florida shelf. The bathymetric contours along southeastern Florida north to Cape Canaveral is longitudinally compressed. Since water depth increases dramatically in close proximity to shore, the amount of adult goliath grouper habitat bounded by its depth range is significantly less than that of the west coast of Florida. This naturally limiting factor may be compounded by anthropogenic impacts occurring in the Florida Keys and South Florida, such as coastal development (i.e., juvenile habitat loss) and degradation of coastal water quality.

Abundance and Productivity

As discussed before, goliath grouper are historically documented to occur from Cape Hatteras, North Carolina, to Mexico in the Gulf of Mexico. In the South Atlantic, the fringe of the species' distribution occurs in north Florida (SAFMC, 1998). Based on current abundance and distribution from the Reef Environmental Education Foundation's (REEF) data (Table 1) and anecdotal observations from fishermen, the fringe of the Gulf of Mexico population appears to occur west of the Florida Panhandle. Therefore, the current bulk of the species' abundance appears to exist from approximately the Palm Beach area through the Florida Keys, and along the west coast of Florida.

In the Gulf of Mexico, historical (e.g., early 1950s) accounts indicate goliath grouper were relatively abundant in many areas along the west coast of Florida, such as in Charlotte Harbor and Tampa Bay. Likewise, goliath grouper were found in many shallow areas throughout the Florida Keys from the 1940s through the 1960s. Numerous juvenile goliath grouper could be found in large numbers around channel markers,

bridges, docks, wharfs, and other structures. In the Florida Keys, adult goliath grouper were also found under bridges and docks. Newspaper articles from the 1920s through the 1950s documented anglers who landed 50-450 lb goliath grouper in the Lower Keys. A June 18, 1931, article published in the *Key West Citizen* documented 14 goliath grouper caught from the Porter Dock Company's wharf weighing from "only a few pounds," to adult specimens of 350 pounds. The aforementioned newspaper articles from Texas only detailed catches of large, adult goliath grouper.

In the Atlantic, historical reports indicate that goliath grouper were also fairly common off the central east coast of Florida. Many of the catches reported appeared to have originated from under bridges or in the vicinity of area inlets. The *New Smyrna News* reported numerous catches of goliath grouper by anglers in the 1920s and 1930s, and implied that a few fishermen specialized in catching the species from area waters. For example, on May 7, 1920, the *New Smyrna News* reported that two goliath grouper were caught during the week, one of which was pulled in by "Mr. Calkins, the champion jewfish catcher."

As noted by the GMFMC (1990) and the SAFMC (1990), fishing pressure on goliath grouper throughout the 1970s and 1980s impacted the abundance and density of the species in both the Gulf of Mexico and the South Atlantic; total U.S. commercial goliath grouper landings are presented in Table 2. Commercial landings in the Atlantic Ocean peaked in 1977 with 72,000 pounds (Table 3). In the Gulf of Mexico, commercial landings increased in the late 1970s, and continued to increase until their eventual decline in the mid- to late-1980s (Tables 4-6). Because of fishing pressure in the commercial and recreational sectors, the abundance and density of goliath grouper significantly decreased throughout its range. In many cases, the species was completely eradicated from areas such as North and South Carolina for over a decade.

Porch et al. (2003) summarized interviews with fishermen and divers who had been active in southern Florida since the 1960s or earlier. Specifically, the nine interviewees were asked their perception on the reduction in goliath grouper populations from the time they first started fishing to the time of the harvest prohibition in 1990. The average percent reduction reported was 86 percent, with a standard deviation of approximately 13 percent (Porch et al., 2003).

Following the decline of the species in the 1980s and early 1990s, recent anecdotal reports from fishermen and divers suggest that goliath grouper numbers have increased in U.S. waters (Cass-Calay and Schmidt, 2003), particularly in the Gulf of Mexico. Numerous sightings are also being reported in other states such as North and South Carolina (M. Barnette, NMFS, pers. obs.), though typically only solitary specimens. Divers have also observed solitary residents, almost all of which are adults greater than 1,000 mm TL, on several artificial reefs off Charleston in 12 to 34 m of water, as well as high-relief ledge and livebottom areas in 24 to 30 m of water (R. Harding, pers. comm.). The increase is attributed to the closing of the fishery in 1990. Since traditional fishery dependent data are of little use inasmuch as they extend back only a few years prior to the closure and are probably inaccurate (SEDAR, 2003), two visual surveys were used as a

proxy for more traditional stock assessment techniques: the personal observations of Don DeMaria, a commercial spearfishermen who maintained a logbook during his dives, and a volunteer fish monitoring program administered by REEF. The Everglades National Park creel survey provides an additional source of data to help determine trends in the species. Figure 3 represents the trends in relative abundance amongst these three data sets, though both the DeMaria and Everglades National Park data sets are regionally limited in their scope (i.e., southwest Florida).

The center of abundance for the U.S. goliath grouper population is presumed to be southwest Florida, particularly the Ten Thousand Islands area. Trap captures indicate juvenile goliath grouper are found associated with mangrove shoreline habitat, clustering in areas with heterogeneous characteristics such as mangrove overhangs, scoured undercuts, tangles of debris, and benthic depressions (Eklund and Schull, 2001; Koenig et al., in review). Offshore adult abundance based on visual surveys in the REEF database (Table 1) demonstrates a strong positive relationship to the quantity of mangrove shoreline along the Florida coast (Koenig et al., in review). With the exception of the Florida Panhandle where there is no red mangrove and only patchy areas of small black mangrove (Anderson, 1985), the lowest adult goliath grouper abundances in Florida occur off the east coast (Koenig et al., in review).

Koenig et al. (in press) estimated absolute abundance of juvenile goliath grouper (20 – 1,000 mm TL) found in mangrove habitat in southwest Florida; there were 15,740 juveniles (95 percent CL = 3,060 – 28,569) in the Ten Thousand Islands and Everglades National Park rivers; 54,553 juveniles (95 percent CL = 10,137 – 99,121) in the Ten Thousand Islands mangrove island habitat; and 1,115 juveniles (95 percent CL = 0 – 4,664) in the mangrove habitat in Florida Bay. Koenig et al. (in press) conclude the relatively lower abundance of juvenile goliath grouper in Florida Bay is likely associated with poor water quality (as reported in Kruczynski, 1999). By determining the relationship between absolute abundance and CPUE, Koenig et al. (in press) could estimate absolute abundance based on CPUE calculations. CPUE in the Ten Thousand Islands study area is demonstrating a positive trend (Figure 4).

Reproduction

Goliath grouper exhibit no definitive sexual dimorphism on body shape or color (Bullock et al., 1992), though Colin (1994) noted a presumed spawning pattern on males. Initially the entire *Epinephelus* genera was classified as protogynous hermaphrodites by Smith (1965). This initial presumed protogynous mode of Epinephelinae reproduction was prematurely assessed for both the goliath grouper and the Nassau grouper (*E. striatus*) as it was based on few criteria and small sample size (Shapiro, 1987). Since then, examination of both population and gonadal structure of 481 goliath grouper (Bullock and Smith, 1991) did not provide sufficient evidence to confirm hermaphroditism or discount gonorchorism pursuant to criteria established by Sadovy and Shapiro (1987): testes with a lumen and peripheral sperm-collecting sinuses were found as well as small mature males.

Reproductive maturity is reached late (~5-6 years) and at a large size (~1,000 mm TL) due to the slow growth rate of the species (Bullock et al., 1992). Males mature at a smaller size and somewhat younger age than females. Males less than 1,150 mm TL are immature with 50 percent mature by 5-6 years of age. All males larger than 1,155 mm TL and older than 7 years are mature. Female goliath grouper first mature at 1,200 to 1,350 mm TL and 6-7 years of age; all females larger than 1,225 mm TL and older than 6 years are mature (Bullock et al., 1992). In the eastern Gulf of Mexico, Bullock et al. (1992) observed a sex ratio of 1.75:1 (female:male).

Goliath grouper are thought to spawn between June and October; however, it likely varies with geographic location. Erdman (1976) examined 14 goliath grouper from the northeastern Caribbean and found both males and females with ripe (stage IV) gonads during the months of July and August. Goliath grouper in the Gulf of Mexico contained ripe gonads from June through September, with peak activity occurring from July through September (Bullock et al., 1992). Presumed courtship behavior was observed in southwestern Florida around the full moons of August and September, although no spawning was observed (Colin, 1994). During this display, the presumed males displayed a pale-colored head with a darker-colored body, while presumed females did not change coloring during the courtship period (Figure 5). Goliath grouper are likely dispersal spawners, whereby the females release eggs and males release sperm that are then mixed in open offshore waters. After the gametes are released into the water column, pelagic larvae spend weeks to months in the water column before subsequently settling into suitable benthic habitat.

As noted previously, goliath grouper may form large aggregations of up to 100 individuals offshore on isolated reef patches, shipwrecks, and artificial reefs at depths of 30 to 45 m. Females at a documented aggregation site had advance vitellogenic oocytes and males contained running milt, indicating recent or imminent spawning (Carlos A. Bohorquez, cited in Colin, 1989). An aggregation that historically formed off West Palm Beach in the 1970s disappeared during the late 1980s (SAFMC, 1990) and the 1990s, but has recently been re-established with greater than 50 individuals (W. Parks, pers. comm.). The only other documented spawning aggregation site is in the Gulf of Mexico on a shipwreck northwest of the Dry Tortugas (C. Koenig, FSU, pers. comm.).

Fecundity

Based on two females (1,322 mm and 1,397 mm), Bullock and Smith (1991) estimated batch fecundities of 38,922,168 ± 1,518,283 and 56,599,306 ± 1,866,130 oocytes, respectively.

Larvae and Juvenile Phases

To date, little work has been done on larval goliath grouper, and no work has been done on the embryonic stage. Based on conspecifics, pelagic larvae are thought to spend weeks to months in the water column, subsequently settling into benthic habitats (Powell and Tucker, 1992).

Age and Growth

Goliath grouper are a long-lived and late-maturing species that grows to an unusually large size. Bullock et al. (1992) aged goliath grouper (n=383) from the eastern Gulf of Mexico caught between November 1977 and January 1990 using sectioned otoliths. Opaque rings were found to form once a year between April and August. Bullock and Smith (1991) determined goliath grouper longevity of more than 35 years, and Smith (1971) determined their maximum weight could exceed 700 lb. Because the mean size at age of males and females were similar, Bullock et al. (1992) pooled all individuals to estimate growth, and using the von Bertalanffy growth model, predicted growth rate as:

$$TL = 2006 * (1-e^{-0.126*(t+0.49)}), \text{ where "TL" is total length and "t" is age.}$$

Empirical and predicted lengths at age from the Bullock et al. (1992) study are provided in Figure 6 and Table 7.

In an effort to age juvenile goliath grouper using non-lethal methods, Brusher and Schull (in review) examined scales, dorsal fin-rays, and dorsal fin-spines as aging structures, and compared these structures to otoliths. Spines from fish were collected from the Ten Thousand Islands area off southwest Florida between 1997 and 2003. They found that spines could be used for aging and were able to validate the annual periodicity of ring formation. Translucent rings were used for aging and were deposited once annually between August and December.

Ages of juvenile goliath grouper examined by Brusher and Schull (in review) ranged from 1 to 6 years (n=1,114). Mean empirical lengths were smaller than those reported by Bullock et al. (1992) (Table 7 and Figure 6). It is unknown why the mean length estimates determined by Brusher and Schull (in review) were smaller than those reported for the same ages by Bullock et al. (1992).

Growth rates average 100 mm (4 in) per year until age six, where growth then declines to approximately 30 mm (1.2 in) per year until age 15, and then 10 mm (0.4 in) per year after 25 years of age (Bullock et al., 1992). Growth between the sexes does not appear to vary significantly.

Diet

Goliath grouper are typically opportunistic, slow-moving predators with general diets. Their canine teeth support a mainly crustacean diet, although they will consume a variety of fish species. Goliath grouper are known to forage on invertebrates, including spiny lobsters (*Panulirus argus*), shrimp, and crabs. They have also been known to feed on stingrays, hardhead catfish (*Arius felis*), spadefish (*Chaetodipterus faber*), scrawled cowfish (*Acanthostracion quadricornis*), parrotfish (Family Scaridae), gastropods (*Fasciolaria tulipa*), octopus (*Octopus* spp.), and young sea turtles; juveniles feed on shrimp, xanthid crab (*Rhithropanopeus harrisii*), and hardhead catfish (*Arius felis*) (Odum, 1971; Bullock and Smith, 1991; Bullock, pers. comm.). They also exhibit

ambush predatory behavior, where food is attained by a quick rush and snap of the jaws (Bullock and Smith, 1991). Goliath grouper have been observed to utilize this tactic when feeding on round herring (*Etrumeus teres*) (C. Koenig, pers. comm.).

As the abundance of goliath grouper has increased in recent years, many fishermen now perceive the species as a nuisance or competition. Aside from their natural feeding behavior, goliath grouper are also opportunistic predators (Sadovy and Eklund, 1999). They will readily strike at a struggling fish on a line and feed on numerous species in this fashion including snapper, grouper, snook, amberjack, and even small sharks. Furthermore, spearfishermen have noted that, in some areas, goliath grouper follow divers and attempt to steal fish off stringers or a spear.

Recreational fishers often state their belief that goliath grouper are reducing the number of other fish through predation. However, available literature (e.g., Bullock and Smith, 1991) does not support the assertion that goliath grouper naturally feed on snapper and grouper, and the absence of other target species is likely the result of fishing pressure.

While goliath grouper feed on spiny lobster, the association between the two species (i.e., abundance) is still unclear. Some fishermen feel the increased abundance of goliath grouper has negatively impacted the abundance and harvest of spiny lobster. Figure 7 (Frias-Torres, unpublished study) demonstrates the relatively consistent commercial trend since goliath grouper were fished down to low abundance in the 1980s, and does not illustrate any significant increase in lobster landings during this time frame. It should be noted that Figure 7 does not include recreational landings, which represent 20-30 percent of the total continental U.S. spiny lobster harvest.

Parasites and Sources of Mortality

According to Bullock et al. (1992), parasites associated with the goliath grouper include:

> Trematoda: *Lecithochirium microstomum, Prosorhynchus promicropsi*, and *Stephanostomum promicropsi*;
> Nematoda: *Heterotyphlum eurycheilum* and *Hysterothylacium sp.*;
> Hirudinea: *Trachelobdella sp.*;
> Isopoda: *Excorallana tricornis, Nerocila acuminata*, and *Rocinela signata*; and
> Copepoda: *Grandiungus promicrops* and *Tuxophorus caligodes*

Goliath grouper can be susceptible to red tide events. A *Ft. Pierce News-Tribune* article published on April 4, 1954, detailed a red tide event with associated mortalities of several goliath grouper during March and April of that year; the event extended from Ft. Myers to Sarasota. In June 2005, at least 20 goliath grouper carcasses washed ashore in the Tampa Bay area that were presumed to be red tide related mortalities (J. Schull, NMFS, pers. comm.). Goliath grouper mortality has also been associated with red tide events in February 2005 and March 2003 off southwest Florida (J. Schull, NMFS, pers. comm.). Figure 8 illustrates the size of goliath grouper from 2003 and 2005 red tide-associated

mortalities (n=26). Currently, there is insufficient information to determine the significance of red tide events on goliath grouper.

Goliath grouper may be susceptible to other marine episodes such as the black water event that occurred off southwest Florida in early 2002. A plume of dark brown water originated off Everglades City and eventually was transported by wind and currents through the Florida Keys and into the Florida Straits. Marine life within this plume was largely absent, and some impacts to corals were noted. A similar phenomenon was documented in a *New York Times* article published on December 15, 1878. The dark water was reported to also originate from the Everglades area. This event was apparently more extensive, as it impacted not only coastal waters but extended over 150 miles into the Gulf of Mexico and out past the Dry Tortugas. Turtles, sharks, and fish, including goliath grouper, were found floating on the surface.

From 1989 to 1991, eight large goliath grouper from southwestern Florida and the Florida Keys were found to have average mercury concentrations exceeding the U.S. Food and Drug Administration's action level of 3.3 ppm for total mercury concentration, with a trend that larger individuals have a higher concentration (Henderson, 1992).

Predators

Known predators of juvenile goliath grouper include large fish such as sharks, barracuda, and other grouper species. The ichthyology department of the Florida Museum of Natural History states that the sandbar shark (*Carcharhinus plumbeus*) and the hammerhead shark (*Sphyrna mokarran*) are known to feed on goliath grouper. Sharks have been observed feeding on hooked juvenile goliath grouper near shoreline mangrove areas off southwest Florida in the Gulf of Mexico (A.M. Eklund, NMFS, pers. comm.). Due to the large size of adults, they likely have very few predators.

Natural Mortality

Instantaneous natural mortality rate (M) estimates for goliath grouper range from 0.04 to 0.19, based on the species' perceived life span of 40 to 80 years (Legault and Eklund, 1998). Using Hoenig's (1984) method, based on a maximum age of 37 years, M equals 0.11. When the fishery was still open, the estimated natural mortality rate was 0.15, while the instantaneous rate of total mortality (Z) was estimated at 0.85 for fish over 11 years (GMFMC, 1990). These values indicate a low natural mortality rate compared to the high fishing mortality rate the species experienced prior to the fishery closure.

As outlined above, goliath grouper are a relatively shallow water species and can be found in close proximity to shore. As such, the depth most goliath grouper are likely caught by anglers (e.g., < 25 m), particularly in the directed catch-and-release fishery, is not believed to introduce a significant level of release mortality. This assumption is supported by the fact that tagged animals have been captured repeatedly (Eklund and Schull, 2001). However, fishermen report fish caught in deeper water (> 30 m) often suffer from barotrauma.

Red tide, black- and cold-water events are a source of natural mortality, though the significance of these events and the impact on the goliath grouper population are unknown.

Exploitation History of Goliath Grouper

Both commercial and recreational goliath grouper landings have occurred since at least the 1800s. This species had been caught traditionally by hook and line, speargun, and as bycatch from traps and trawls (GMFMC, 1990). The majority of commercial and recreational goliath grouper landings were reported during the species' reproductive season (August-September).

Commercial Fishery

Commercial goliath grouper landings data exist from 1950 until 1990, at which point the moratorium took effect. Landings were both over- and under-reported, did not capture all commercial landings, and overall have limited relevance to the current state of the species. However, they do provide loose corroborative evidence for the trend in the species decline.

While the commercial fishery did not significantly expand until the 1970s, goliath grouper were consistently harvested to some extent from the 1930s until the fishery was closed in 1990, as evidenced by advertisements in the *Key West Citizen* (June 11, 1932) for "jewfish steaks" at $0.15/lb (i.e., retail price), or "jewfish with bone" at $0.10/lb. Further, Lowe's Fish Company in Key West advertised that they specialized in "young jewfish" (*Key West Citizen*, October 9, 1931).

Commercial goliath grouper landings are presented in Tables 3-7 and Figure 9. Handlines accounted for the majority of commercial landings until the mid-1980s, when spearguns became more prevalent; from 1986-1990, spearguns averaged approximately 41 to 42 percent of the Florida commercial landings originating from the Gulf of Mexico and Atlantic, respectively (Sadovy and Eklund, 1999).

In the early- to mid-1900s, Gulf of Mexico goliath grouper were harvested only incidentally in the red snapper fishery, and later in the developing reef fish fishery. Although annual Gulf commercial landings of goliath grouper occasionally exceeded 200,000 lb in the 1960s, most of the catch was incidental to the snapper fishery operating off the Yucatan Peninsula, Mexico. From 1964 through 1969, snapper boats operating out of Alabama landed 53 to 70 percent of the entire Gulf of Mexico goliath grouper harvest.

Little information exists on the Atlantic Ocean goliath grouper fishery; however, similar to the early Gulf of Mexico fishery, harvest of goliath grouper was likely incidental to the South Atlantic snapper grouper fishery. According to the Snapper Grouper FMP (SAFMC, 1983a), approximately 50 divers from North Carolina to the Florida Keys were commercially spearfishing deepwater snapper grouper species in 1982. None apparently

derived a significant portion of their income from goliath grouper (SAFMC, 1990). Landings reported in the Snapper Grouper Source Document (SAFMC, 1983b) indicated a decrease in the Atlantic Ocean goliath grouper harvest from 68,000 lb in 1968 to approximately 13,000 lb in 1988.

Overall fishing effort began to increase when locations of goliath grouper aggregations became well known and publicized, better navigational equipment was employed in the fishery, and the economic value of the species increased. In the 1980s the demand and price for the species increased, thereby increasing effort. The average price per pound for Gulf of Mexico goliath grouper rose from $0.39/lb in 1979 to $0.74/lb in 1987; in Key West, the price increased from $0.50-$0.60/lb in 1979 to $1.25/lb in 1987 (GMFMC, 1990); Atlantic Ocean ex-vessel price increased from $0.56/lb in 1979 to $1.02/lb in 1987 (SAFMC, 1990). Anecdotal information indicates the commercial sector also utilized goliath grouper harvested with spearguns (i.e., powerheads) for bait on shark longline trips; this harvesting practice does not appear in the landings data. Anecdotal information presented during the SEDAR process reported goliath grouper were regularly sold directly to restaurants during the 1980s and these fish were not reflected in any landings data (DeMaria, pers. comm.). The advent of LORAN-C allowed greater accuracy and repeatability in locating isolated shipwrecks and reefs where goliath grouper resided. The period between intensive fishing in the 1980s and population decline was relatively short, especially given the number of fishery participants, suggesting that goliath grouper are easily overexploited (DeMaria, 1990).

Recreational Fishery

Similar to the commercial fishery, anglers have caught goliath grouper since at least the late 1800s. As cited earlier, an article published in the *New York Times* on July 28, 1895, documented a Texas fishing party catching 14 fish totaling approximately 5,000 lb.

Recreational catch data are presented in Table 9. The data in Table 9 represents total catch, which includes all goliath grouper that were landed (A), discarded (B1), or released alive (B2). The proportional standard error (PSE), which is a measure of the data's precision, is extremely high for all states until approximately 1997 when the accuracy of the data improved. Even then, it only significantly improved for the Florida catch data. Therefore, the MRFSS data should be used cautiously.

An interesting feature of the MRFSS data in Table 9 is the apparent spike in catch observed for Florida after 1999. This spike can be partially explained by the emergence of a popular catch-and-release fishery, with increasing numbers of fishermen targeting goliath grouper. Due to their predictable presence on artificial reefs, as well as the strong fight the fish is capable of presenting to an angler, fishermen may frequently stop off on the return to the dock from fishing offshore to allow for an additional fishing experience. In many instances, the same goliath grouper may be caught and released numerous times throughout the year.

A large fraction of the recreational landings of the goliath grouper appear to have been from the Ten Thousands Islands area in southwest Florida (Cass-Calay and Schmidt, 2003), which is not surprising given that is the reported center of the species abundance in the Gulf of Mexico. Most catches in the Atlantic Ocean were off reefs and wrecks (SAFMC, 1990). Although most recreational catch occurred in Florida, other Gulf states reported some catch (Table 9). Only occasionally are goliath grouper caught by headboats in the Gulf of Mexico.

From 1973 to 1981, approximately 26 percent of the sport fishing trips included in an analysis conducted by Cass-Calay and Schmidt (2003) reported the capture of one or more goliath grouper. In 1981, Florida's goliath grouper landings totaled 19,000 lb, which represented a great decline from the 70,000 lb landed annually during 1974 through 1977 (SAFMC, 1983). Landings declined further from 1982 to 1992. However, as noted above, due to recent increases in abundance, catch-and-release of goliath grouper has become more common in some areas of Florida, particularly in the Florida Keys and southwest Florida.

Management History

Prior to 1985, there were no applicable regulatory measures related to the harvest and possession of goliath grouper. While there was a historical recreational and commercial fishery for the species, effort was relatively limited due to the gear requirements to land and properly prepare large and/or numerous specimens.

The goliath grouper fishery expanded quickly and dramatically through the 1980s, which required the introduction of conservation and management measures for the species. The SAFMC prohibited the spearing of goliath grouper in March 1983 (SAFMC, 1983a). In 1985, the state of Florida implemented an 18-inch minimum size limit for goliath grouper to help prevent the harvest of juvenile fish. However, the rapid increase in fishing effort for goliath grouper followed by a subsequent decline in catches also led to regulatory measures by the GMFMC for federal waters (i.e., > 9 nm offshore) in the Gulf of Mexico. In 1989, the GMFMC implemented a 50-inch (1,270-mm) TL minimum size limit for goliath grouper (GMFMC, 1989). This measure was originally considered conservative enough to restore the stock. However, additional information revealed the stock was more depleted than previously thought, so in March 1990 the GMFMC prohibited the harvest and possession of goliath grouper in federal waters of the Gulf of Mexico (GMFMC, 1990). Likewise, the SAFMC prohibited the harvest and possession of goliath grouper from federal waters (i.e., > 3 nm offshore) off North Carolina southward through Florida in November 1990 (SAFMC, 1990).

The state of Florida followed suit and prohibited the harvest and possession of goliath grouper from state waters (i.e., = 3 nm offshore in the Atlantic Ocean and = 9 nm offshore in the Gulf of Mexico) in 1990. Eventually, all other coastal states from North Carolina to Texas implemented regulations to prohibit the harvest or possession of goliath grouper.

Threats Assessment

In establishing its species of concern list, NMFS determined that factors related to the demography and diversity vulnerability of a species will be evaluated to determine whether the species represents a species of concern. NMFS developed the following factors to be considered in evaluating demographic and diversity vulnerability: (1) Abundance and productivity, or magnitude of decline (in terms of recent and historical rates); (2) natural rarity and endemism; (3) distribution; and (4) life history characteristics.

In summary, the previous section of the report outlined that goliath grouper abundance declined in the 1980s, primarily due to overfishing; however, prohibitions on the harvest and possession of goliath grouper implemented in 1990 in both the Gulf of Mexico and Atlantic have allowed the species to rebuild, and there have been documented increases in species abundance. Goliath grouper are not naturally rare, nor are they endemic to any discrete location. Goliath grouper are found in the Atlantic Ocean off Florida, northward to Cape Hatteras, North Carolina, though specimens north of Florida likely represent the historical fringe of the goliath grouper distribution in the Atlantic (SAFMC, 1998). The goliath grouper was historically found in coastal waters of all states along the Gulf of Mexico. The current center of abundance for the Gulf of Mexico population of goliath grouper is thought to be in the Ten Thousand Islands region off southwest Florida, where extensive mangrove habitat exists (Bullock and Smith, 1991; Koenig et al., in review). Radiating outwards from the Ten Thousand Islands area into the Gulf of Mexico, the majority of the goliath grouper population appears to be bounded by the Florida Keys to the south and the Florida Panhandle to the north. While a comprehensive overview of the species' life characteristics can be found in the previous section of the status report, it is important to note that goliath grouper are long-lived and late to mature. The species depends on mangrove habitat during its early development. Additionally, goliath grouper aggregate to spawn and are particularly vulnerable to fishing during this period. This information, and in particular the up-to-date data on trends in abundance and the DPS' range, do not suggest that the continental U.S. DPS of goliath grouper is at risk due to demographic or genetic diversity concerns.

Information on the threats to a species, in isolation or in concert with information on the aforementioned demographic and diversity factors, should also be evaluated to determine whether they indicate a species is at risk and should be added to the species of concern list. These threats are: (1) Extraction; (2) habitat degradation/loss; (3) disease and predation; and (4) other natural or man-made factors.

Extraction

Based on historical reports, landings data, and anecdotal evidence, fishing pressure in both the recreational and commercial sectors was the single most significant factor responsible for the decline of goliath grouper in both the Atlantic Ocean and Gulf of Mexico. Due to the species historical abundance, proximity to shore, predictable habitat preferences, and ease to catch, fishermen were able to land large numbers of goliath

grouper year-round. Further, a significant portion of the fishery was likely targeting juvenile fish due to the fact they were easier to catch and prepare as compared to a large, adult fish. Without size or possession limits, and with the increase in value of the species, overfishing of goliath grouper occurred. Extraction of the species may have also been facilitated by the lack of adequate (i.e., in terms of time and scale) landings data. Had the data been available in time to reveal the true scope of the fishery, more effective management measures might have been implemented.

Goliath grouper is classified as overfished throughout the Gulf of Mexico and Atlantic Ocean according to the most recent NMFS report to Congress on the status of U.S. fisheries (NMFS, 2004). In March 2003, a SEDAR workshop was held to review available goliath grouper data. The workshop concluded catch data were not adequate for an assessment (Anon., 2003). However, a subsequent SEDAR Review Panel (SEDAR, 2003) concluded that "not conducting an assessment on this occasion had likely been an incorrect decision" and suggested the use of assessment models that could operate in a data-poor arena. An assessment of goliath grouper was prepared by Porch et al. (2003) and presented to an Assessment Review Panel (SEDAR, 2004) in January 2004. The review panel, after making a few minor changes to the assessment (detailed in Porch, 2004), found the assessment models used were "appropriate for the available data, and adequately addressed questions of exploitation and relative abundance, within the limits of the data."

The assessment model tracked the goliath grouper population from an assumed pristine state in 1950, through increasing fishing mortality, declining population levels, and implementation of a moratorium on harvest in 1990. The three indices of abundance used to condition the model all suggest recent increases in goliath grouper abundance (Figure 3). The model indicated the goliath grouper population in south Florida waters had been increasing since the moratorium. The biomass of goliath grouper in 2002 was estimated to be 31-36 percent of the pristine population biomass, which is less than the management target of about 45 percent (the level associated with a 50 percent spawning potential ratio). The Review Panel concluded that, as of 2003, goliath grouper remained overfished relative to the management target, but was unable to determine if overfishing was occurring. The Review Panel believed overfishing was unlikely given the present moratorium, but noted the extent of illegal harvest and release mortality was unknown. Forecasts of future biomass were sensitive to this source of uncertainty (SEDAR, 2004). The Review Panel recommended the use of post-moratorium fishing mortality rates ranging from 1 to 10 percent of fishing mortality rates prior to the moratorium. Based on the assumed effectiveness of the moratorium in reducing fishing mortality, the population was estimated to have a 50 percent chance of recovering between 2005 and 2009, and an 80 percent chance of recovering between 2009 and 2015 (Figure 10). However, one sensitivity run suggested a full recovery to the management target may not occur until 2020 or later (Porch, 2004).

Habitat Degradation/Loss

The modification and destruction of goliath grouper habitat, notably elimination of juvenile mangrove habitat, may currently have an impact on the species' abundance to some extent. Mangroves are essential fish habitat for post-larval and juvenile goliath grouper (GMFMC, 2004). Over the past 100 years, there has been a reduction in the amount of mangrove habitat acreage in Florida. In some areas, in particular southeast Florida and the Florida Keys, coastal development has dramatically reduced the amount of available mangrove habitat. The reduction of mangrove habitat, coupled with degraded water quality, may potentially have a negative impact on goliath grouper. Mangroves are abundant near the current center of abundance (Ten Thousand Islands, Florida), but have significantly declined in other areas. The destruction or modification of mangrove habitat in these areas may limit the rate goliath grouper become re-established throughout their historical range, because it offers less suitable habitat for juveniles to reside. Areas outside the "center of abundance" (e.g., southeast Florida; northwest Florida) are therefore likely dependent on adults emigrating from southwest Florida.

Of the estimated 693,360 acres of mangroves in the United States, 96 percent occur in Florida (Mendelssohn and McKee, 2000). A recent study by Ueland (2005) determined there were an estimated 512,842 acres of mangrove in the 14 southernmost coastal counties of Florida in 2000. In one of the few studies that investigated long-term changes in mangrove systems, Ueland (2005) determined that the 2000 estimate represented a 9.0 percent total loss in mangrove habitat from his 1987 estimate of 563,388 acres. In terms of total acres amongst the 14 counties encompassed within the study, Monroe County lost the largest amount of mangrove area (37,031 acres; 12.2 percent decline), while Charlotte County showed an increase of 1,229 acres (5.9 percent increase) during the 13-year period (Table 10).

Though natural events such as hurricanes can result in mangrove loss, over the past six decades, habitat modification and coastal development in Florida have resulted in dramatic reductions in mangrove habitat. The Everglades has lost approximately 22 percent of mangrove/marsh habitat since 1927, primarily due to habitat modification for agricultural purposes (Foster and Smith, 2001). On Florida's east coast, the Indian River Lagoon system from St. Lucie Inlet north to Satellite Beach has less than 8,000 acres of mangroves, but only 1,900 are available as fisheries habitat because of mosquito impoundments; a total of 86 percent of the mangrove areas have been lost to fisheries since the 1940s (FL DEP, 2003). Lake Worth Lagoon near West Palm Beach has experienced an 87 percent decrease of its mangrove acreage over the past 40 years (FL DEP, 2003). Mangroves appear to have been replaced by the Australian Pine and/or urbanization (FL DEP, 2003).

While habitat destruction and modification may have some impact on the abundance of the goliath grouper, it is unlikely that it presents a significant impact that would threaten or endanger the species, unless extensive juvenile habitat loss occurs near the population's "center of abundance." Despite extensive habitat modification in Florida,

the species has been increasing in number over the past 15 years. The construction of artificial reefs in both the Atlantic Ocean and Gulf of Mexico during the past 20 years may have had a beneficial impact on the species by presenting additional shelter and forage opportunities for adult goliath grouper.

Disease and/or Predation

Goliath grouper do not demonstrate significant susceptibility to any particular pathogen or predator that appear to be measurably affecting the species' abundance and productivity. While goliath grouper are susceptible to red tide events, these harmful algae blooms are not thought to jeopardize the species locally or regionally.

Other Natural or Manmade Factors

The team could identify no other known factors that have or could contribute to the decline of the continental U.S. DPS of goliath grouper.

Conclusion

The team recognizes the continental U.S. DPS of goliath grouper is highly "conservation-dependent," and can be particularly affected by fishing pressure and habitat loss. This point was also made by the SEDAR panel, which noted any fishery could risk rapidly depleting the population, and would require careful monitoring. However, based on the current status of the continental U.S. DPS of goliath grouper, the team believes the goliath grouper should be removed from the NMFS' species of concern list.

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Table 1. Visual surveys of goliath grouper (REEF data, generated 06/08/05).

CODE	ZONE	SIGHTING FREQUENCY	DENSITY SCORE	SPECIES RANK (TOTAL SPECIES)	NUMBER OF SURVEYS
2101	West Florida Panhandle (FL)	8.3%	1.2	41 (233)	268
2201	Pasco County (FL)	14.6%	1.1	37 (105)	41
2202	Citrus County (FL)	20%	2	22 (29)	5
2203	NW Florida (FL)	46.1%	2	14 (41)	13
2301	Pinellas County (FL)	30.6%	1.7	28 (230)	261
2302	Manatee County (FL)	22.5%	1.5	14 (90)	34
2303	Sarasota County (FL)	20.8%	1.4	31 (106)	26
2304	Charlotte County (FL)	73.6%	2.2	3 (63)	19
2305	Lee County (FL)	72%	1.8	7 (193)	537
2306	Collier County (FL)	51.6%	1.5	6 (130)	93
2307	West Everglades NP (FL)	50%	1.3	33 (58)	6
2402	Flower Gardens (TX)	0.05%	1	251 (261)	2,018
2403	Sonnier Banks (TX)	1.8%	1	127 (134)	54
3101	St. Mary's River to Cape Canaveral (FL)	19.1%	1.4	25 (210)	172
3201	Cape Canaveral to Jupiter Light (FL)	8.1%	1.4	94 (312)	773
3301	Jupiter Light to Key Biscayne (FL)	3.8%	1.3	154 (452)	4,454
3302	Biscayne NP (FL)	2.9%	1.2	145 (234)	242
3403	Key Largo (FL)	2.5%	1.1	158 (384)	6,884
3404	Islamorada (FL)	2.2%	1.3	162 (340)	1,858
3405	Marathon (FL)	4.1%	1.2	142 (314)	1,331
3406	Looe Key NMS (FL)	22.3%	1.3	61 (240)	292
3407	Long Key (FL)	1.6%	2	135 (173)	124
3408	Key West (FL)	5.1%	1.2	130 (334)	2,370
3409	Marquesas Keys (FL)	5.3%	1.8	154 (210)	131
3410	Dry Tortugas (FL)	11.1%	1.2	94 (317)	1,724
9301	South Carolina (SC)	1.5%	1	88 (90)	63
9302	Gray's Reef NMS (GA)	3.1%	1.3	78 (164)	260

Table 2. Total U.S. (Gulf of Mexico and Atlantic Ocean) commercial goliath grouper landings, 1950-1990 (SEFSC data).

YEAR	POUNDS
1950	98,159
1951	185,368
1952	170,119
1953	283,744
1954	115,356
1955	82,187
1956	54,888
1957	58,519
1958	114,130
1959	118,076
1960	96,492
1961	102,329
1962	89,800
1963	139,700
1964	241,200
1965	670,400
1966	182,600
1967	200,100
1968	265,800
1969	200,800
1970	231,400
1971	196,100
1972	238,405
1973	242,125
1974	236,582
1975	248,861
1976	253,993
1977	272,953
1978	76,958
1979	51,933
1980	60,331
1981	69,846
1982	66,020
1983	89,344
1984	83,204
1985	124,630
1986	120,317
1987	119,032
1988	152,726
1989	101,868
1990	11,807

Table 3. South Atlantic goliath grouper commercial landings and value information for 1967-1987 (SAFMC, 1990).

	NMFS ACCUMULATIVE MONTHLY LANDINGS						SNAPPER GROUPER SOURCE DOCUMENT (1983)			
YEAR	GEORGIA		FLORIDA EAST COAST		SOUTH ATLANTIC		FLORIDA EAST COAST		SOUTH ATLANTIC	
	POUNDS	DOLLARS	POUNDS	DOLLARS	POUNDS	DOLLARS	POUNDS	DOLLARS	POUNDS	DOLLARS
1967							71,000		71,000	
1968							68,000	$8,160	68,000	$8,160
1969							54,000	$8,200	54,000	$8,200
1970							31,000	$4,666	31,000	$4,666
1971							17,000	$2,205	17,000	$2,205
1972							23,000	$3,871	23,000	$3,871
1973							35,000	$8,455	35,000	$8,455
1974							66,000	$18,600	66,000	$18,600
1975							56,000	$15,799	56,000	$15,799
1976							59,000	$19,671	59,000	$19,671
1977			50,803	$20,708	50,803	$20,708	72,000	$29,610	72,000	$29,610
1978			17,185	$8,156	17,185	$8,156	39,000	$8,156	39,000	$8,156
1979			18,064	$10,166	18,064	$10,166	29,000	$10,166	29,000	$10,166
1980			19,423	$11,059	19,423	$11,059	23,000	$12,789	23,000	$12,789
1981	1,154	$695	12,397	$8,678	13,551	$9,373	19,000	$12,664	19,000	$12,664
1982	177	$94	6,131	$4,449	6,308	$4,543				
1983			12,293	$8,304	12,293	$8,304				
1984	191	$114	11,440	$9,687	11,631	$9,801				
1985	548	$729	9,367	$8,452	9,915	$9,181				
1986			10,492	$9,877	10,492	$9,877				
1987			17,911	$18,307	17,911	$18,307				
1988										

Table 4. Gulf of Mexico commercial goliath grouper landings and value data by geographic region: 1) S FL – Monroe County; 2) SW FL – Charlotte, Collier, and Lee Counties; 3) W FL – Hillsborough, Manatee, Pasco, Pinellas, and Sarasota Counties; 4) NW FL – Bay, Citrus, Dixie, Escambia, Franklin, Gulf, Hernando, Jefferson, Levy, Okaloosa, Santa Rosa, Taylor, Wakulla, and Walton Counties; and 5) AL-TX – Alabama, Louisiana, Mississippi, and Texas. Pounds and value calculations represent totals for each combination of region and year, whereas price/lb is an average value (GMFMC, 1990).

Geographic Region	Category	Year									
		79	80	81	82	83	84	85	86	87	Year Totals
1 S.FL	Pounds	19964	15764	26800	22008	22939	14521	22632	22978	26246	193853
	Value,$	7297	5767	11242	8913	9348	6893	16660	26226	23979	116325
	Price/lb,$	0.45	0.43	0.48	0.49	0.51	0.56	0.83	1.10	0.92	0.66
2 SW.FL	Pounds	4495	12640	8844	15955	28050	32292	60784	70004	52851	285714
	Value,$	1214	4131	3538	6534	12728	14718	26999	39945	31126	140933
	Price/lb,$	0.33	0.39	0.43	0.44	0.50	0.51	0.53	0.56	0.61	0.51
3 W.FL	Pounds	8189	12074	17117	10901	16891	22865	23812	15628	19730	147207
	Value,$	1973	3762	6682	4214	7218	13460	16765	11112	15517	80703
	Price/lb,$	0.30	0.35	0.45	0.46	0.52	0.65	0.91	0.73	0.76	0.59
4 NW.FL	Pounds	1458	1315	2189	1030	735	696	126	342	713	8605
	Value,$	403	617	909	528	326	1033	41	237	615	4707
	Price/lb,$	0.43	0.54	0.51	0.63	0.57	1.30	0.30	0.69	0.79	0.60
5 AL-TX	Pounds	2690	2887	6062	14101	14327	7240	13176	873	1581	62937
	Value,$	876	1011	2425	6987	5331	2771	5349	564	995	26309
	Price/lb,$	0.33	0.32	0.38	0.50	0.45	0.30	0.49	0.64	0.64	0.43
Gulf Total	Pounds	36797	44478	61012	63995	82942	77614	120531	109825	101121	698315
	Value,$	11763	15288	24796	27176	34949	38875	65814	78084	72232	368977
	Price/lb,$	0.39	0.40	0.45	0.48	0.51	0.55	0.70	0.76	0.74	0.58

Table 5. Gulf of Mexico commercial goliath grouper landings and value data by state for 1979-1987. Alabama, Mississippi, Louisiana, and Texas data were combined to protect confidentiality of statistics (GMFMC, 1990).

State Group	Category	Years									
		79	80	81	82	83	84	85	86	87	All Years
AL,MS,LA,TX	Pounds	2690	2887	6062	14101	14327	7240	13176	873	1170	62526
	Value,$	876	1011	2425	6987	5331	2771	5349	564	683	25997
	Price/lb,$	0.33	0.32	0.38	0.50	0.45	0.30	0.49	0.64	0.63	0.42
W. Florida	Pounds	34107	41591	54950	49894	68615	70374	107355	108952	99951	635789
	Value,$	10887	14277	22371	20189	29618	36104	60465	77520	71549	342980
	Price/lb,$	0.40	0.40	0.46	0.47	0.51	0.58	0.71	0.76	0.75	0.59
Gulf Total	Pounds	36797	44478	61012	63995	82942	77614	120531	109825	101121	698315
	Value,$	11763	15288	24796	27176	34949	38875	65814	78084	72232	368977
	Price/lb,$	0.39	0.40	0.45	0.48	0.51	0.55	0.70	0.76	0.74	0.58

Table 6. Commercial goliath grouper monthly landings and value data for all Gulf of Mexico states combined, 1979-1987. Data from NMFS landings data files (GMFMC, 1990).

Months	Category	Years									All Years
		79	80	81	82	83	84	85	86	87	
Jan	Pounds	2126	2397	5759	6846	7148	2572	3682	4992	3559	39081
	Value,$	610	840	2154	2999	3839	1159	2423	2832	2270	19126
	Price/lb,$	0.34	0.41	0.40	0.47	0.53	0.57	0.84	0.64	0.68	0.56
Feb	Pounds	3872	2443	13669	5057	3508	3528	12774	8417	8614	61881
	Value,$	1311	880	5923	1980	1904	2243	7314	6365	5656	33576
	Price/lb,$	0.41	0.43	0.47	0.50	0.52	0.60	0.79	0.95	0.60	0.62
Mar	Pounds	4635	3020	6926	4074	2107	4079	8482	7231	6857	47411
	Value,$	1256	981	2912	1674	966	2041	6239	4824	4642	25535
	Price/lb,$	0.29	0.39	0.50	0.50	0.57	0.57	0.82	0.82	0.82	0.61
Apr	Pounds	3693	2892	5723	4772	5075	8466	12693	11612	8274	63201
	Value,$	1291	838	2364	1994	2485	4865	6358	7984	6494	34673
	Price/lb,$	0.54	0.35	0.47	0.48	0.56	0.60	0.60	0.69	0.83	0.59
May	Pounds	4583	4190	4153	4956	5166	5937	12003	11000	12514	64503
	Value,$	1589	1400	1429	2152	2243	2623	6348	7205	10229	35218
	Price/lb,$	0.39	0.36	0.43	0.51	0.51	0.51	0.73	0.73	0.79	0.58
Jun	Pounds	2745	7991	5678	4429	9411	6177	12746	10920	8173	68271
	Value,$	814	2630	2148	1993	3780	2616	6252	8315	5192	33740
	Price/lb,$	0.37	0.41	0.46	0.49	0.46	0.55	0.56	0.84	0.65	0.55
Jul	Pounds	2634	6727	5004	6667	13335	6443	11277	8825	12919	73831
	Value,$	930	2049	2130	2634	5075	2989	5836	6654	8740	37037
	Price/lb,$	0.43	0.38	0.45	0.42	0.50	0.55	0.62	0.73	0.65	0.54
Aug	Pounds	4625	3435	3158	11667	11933	10160	19255	14672	18868	97773
	Value,$	1486	1264	1265	4877	4426	5252	9641	14296	12219	5472-
	Price/lb,$	0.39	0.41	0.44	0.45	0.47	0.56	0.56	0.97	0.75	0.5
Sep	Pounds	2549	4362	2497	6186	12099	8668	19067	14685	8459	785 –
	Value,$	823	1729	963	3115	4906	4251	10969	9308	6396	42460
	Price/lb,$	0.43	0.42	0.44	0.51	0.50	0.50	0.80	0.79	0.81	0.62
Oct	Pounds	2117	3100	1616	3452	6914	11941	2839	7396	2950	42325
	Value,$	680	1183	639	1605	2670	6079	1535	4442	2204	21037
	Price/lb,$	0.36	0.38	0.44	0.51	0.48	0.48	0.79	0.70	0.74	0.54
Nov	Pounds	1488	2028	3154	3493	3480	4780	3620	7598	3147	32788
	Value,$	482	739	1405	1261	1342	2395	1862	4338	2270	16094
	Price/lb,$	0.34	0.42	0.48	0.44	0.47	0.58	0.63	0.60	0.75	0.55
Dec	Pounds	1730	1893	3674	2394	2767	4863	2094	2477	6787	28679
	Value,$	491	755	1464	892	1313	2362	1037	1521	5920	15755
	Price/lb,$	0.36	0.46	0.44	0.42	0.54	0.57	0.65	0.61	0.82	0.55
Year Total	Pounds	36797	44478	61012	63995	82942	77614	120531	109825	101121	698315
	Value,$	11763	15288	24796	27176	34949	38875	65814	78084	72232	368977
	Price/lb,$	0.39	0.40	0.45	0.48	0.51	0.55	0.70	0.76	0.74	0.58

Table 7. Number of goliath grouper, empirical total lengths (TL) at age, and predicted TL at age for goliath grouper from the eastern Gulf of Mexico. Mean empirical lengths from Bullock et al. (1992) were pooled over males, females, and unknown sex fish and predicted lengths are derived from a von Bertalanffy growth curve.

	Bullock et al. (1992)			Brusher and Schull (in review)	
Age	n	Empirical TL (mm)	Predicted TL (mm)	n	Empirical TL (mm)
0	5	204		30	236
1	3	517	344	276	306
2	6	716	541	429	276
3	10	756	714	237	495
4	8	951	867	101	697
5	11	1083	1002	37	801
6	9	1124	1121	4	795
7	9	1365	1226		
8	12	1426	1318		
9	16	1376	1400		
10	20	1504	1471		
11	30	1565	1535		
12	39	1620	1590		
13	41	1643	1640		
14	24	1745	1683		
15	20	1790	1721		
16	15	1803	1755		
17	9	1867	1785		
18	12	1773	1811		
19	6	1833	1834		
20	13	1865	1854		
21	12	1886	1872		
22	11	1855	1888		
23	4	1938	1902		
24	9	1934	1914		
25	6	1566	1925		
26	6	1898	1935		
27	5	1938	1943		
28	3	1982	1951		
29	1	2090	1957		
30	1	2040	1963		
33	2	1820	1977		
34	2	2024	1980		
36	1	1908	1986		
37	1	1970	1988		

Table 8. Percent distribution of commercial goliath grouper landings by year and fishing gear type. Data from NMFS General Canvas files (GMFMC, 1990).

State group	Gear type	YEAR									All
		79	80	81	82	83	84	85	86	87	Years
AL,MS,LA,TX	Unk./Misc.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.1	0.0
	Trawl	0.0	25.3	8.0	1.6	4.9	3.4	0.2	75.6	0.0	4.6
	Handline	100.0	74.7	92.0	91.8	95.1	96.6	99.8	24.4	97.9	93.9
	Longline/Buoy	0.0	0.0	0.0	6.6	0.0	0.0	0.0	0.0	0.0	1.5
	All Gear	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
W. Florida	Unk./Misc.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0
	Trawl	7.3	1.1	1.3	0.8	1.0	0.7	0.1	1.8	1.7	1.9
	Handline	87.2	87.8	81.1	69.8	64.4	67.6	39.7	40.4	39.1	69.0
	Longline/Buoy	0.0	7.1	11.2	21.1	26.2	20.7	31.4	20.0	14.5	15.7
	Speargun	5.4	4.1	6.4	8.3	8.4	11.1	28.8	37.8	44.3	13.5
	All Gear	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Gulf Total	Unk./Misc.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0
	Trawl	7.2	1.3	1.5	0.9	1.2	0.8	0.1	2.4	1.7	2.0
	Handline	87.4	87.6	81.3	71.3	66.4	69.5	45.6	40.2	39.7	70.0
	Longline/Buoy	0.0	7.0	10.9	20.1	24.5	19.3	28.3	19.8	14.4	15.1
	Speargun	5.4	4.1	6.2	7.7	7.8	10.4	26.0	37.5	43.8	13.0
	All Gear	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Table 9. Recreational goliath grouper catch, in numbers of fish, all modes (A + B1 + B2) combined (MRFSS data).

YEAR	FL	GA	SC	NC	AL	LA	TX
1981	24,044						
1982	7,869					1,774	
1983	120						
1984	5,350				1,289	629	1,516
1985	8,992						
1986	1,339					4,988	
1987	4,349					120	
1988	3,212						
1989	8,380						
1990	1,928						
1991	5,722						
1992	3,062						
1993	5,316						
1994	4,404						
1995	13,883						
1996	2,442					159	
1997	8,242						
1998	7,867		438				
1999	8,055				171		
2000	33,294						
2001	41,393						
2002	30,895			87			
2003	49,354						
2004	55,447	964					

Table 10. Changes in mangrove habitat area (in acres) of 14 southern counties in Florida (Ueland, 2005).

COUNTY	1987 ESTIMATE	2000 ESTIMATE	% CHANGE
Broward	550	765	39.1
Charlotte	20,810	22,039	5.9
Collier	84,973	82,251	-3.2
Hillsborough	7,938	6,294	-20.7
Indian River	6,084	4,393	-27.8
Lee	44,537	44,235	-0.7
Manatee	6,282	3,866	-38.5
Martin	5,546	3,951	-28.8
Miami-Dade	68,019	66,393	-2.4
Monroe	303,549	266,518	-12.2
Palm Beach	1,616	652	-59.7
Pinellas	4,579	4,229	-7.6
Sarasota	1,260	828	-34.3
St. Lucie	7,646	6,428	-15.9
TOTALS	**563,388**	**512,842**	**-9.0**

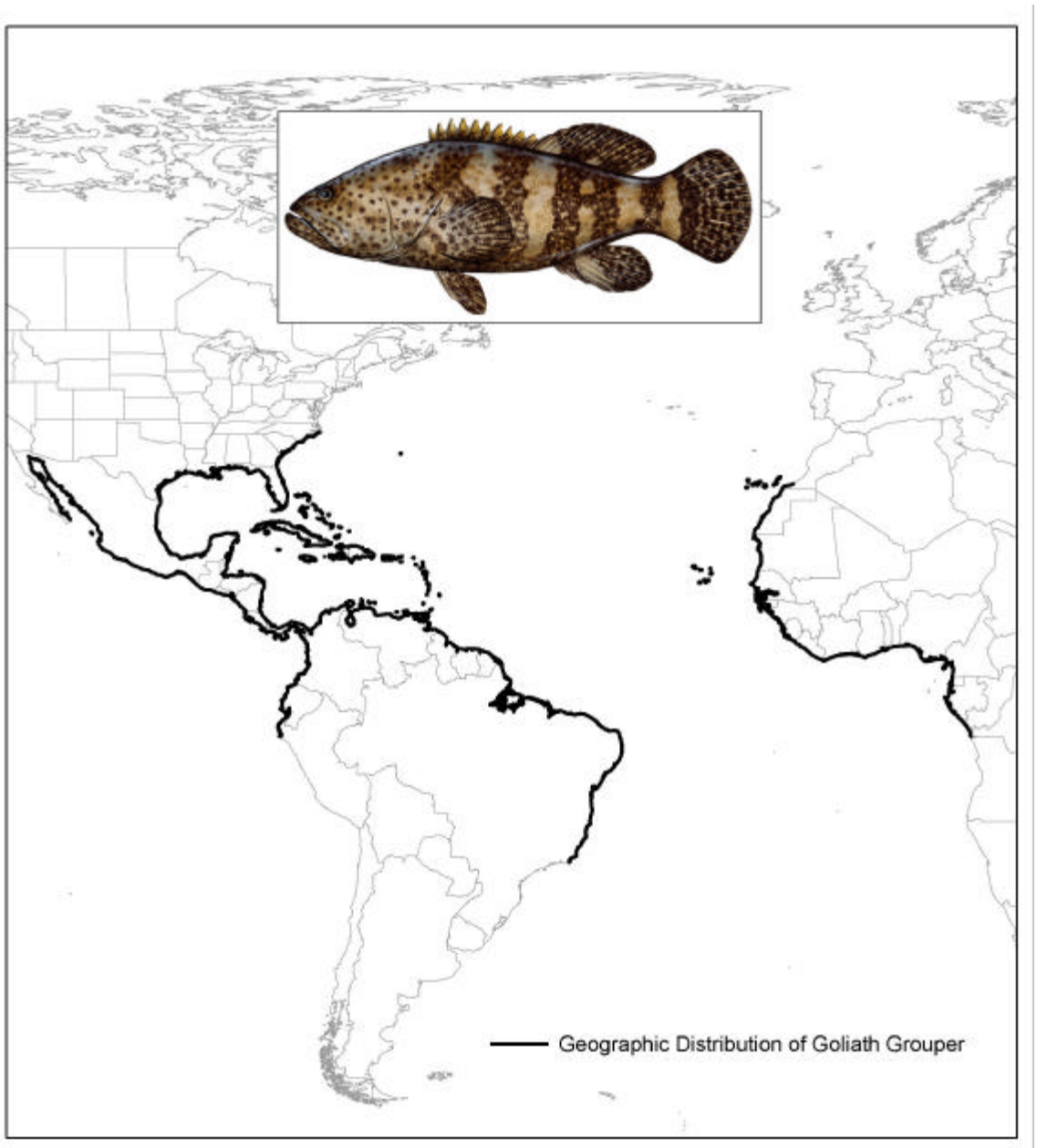

Figure 1. Goliath grouper distribution (goliath grouper illustration courtesy of Diane Peebles).

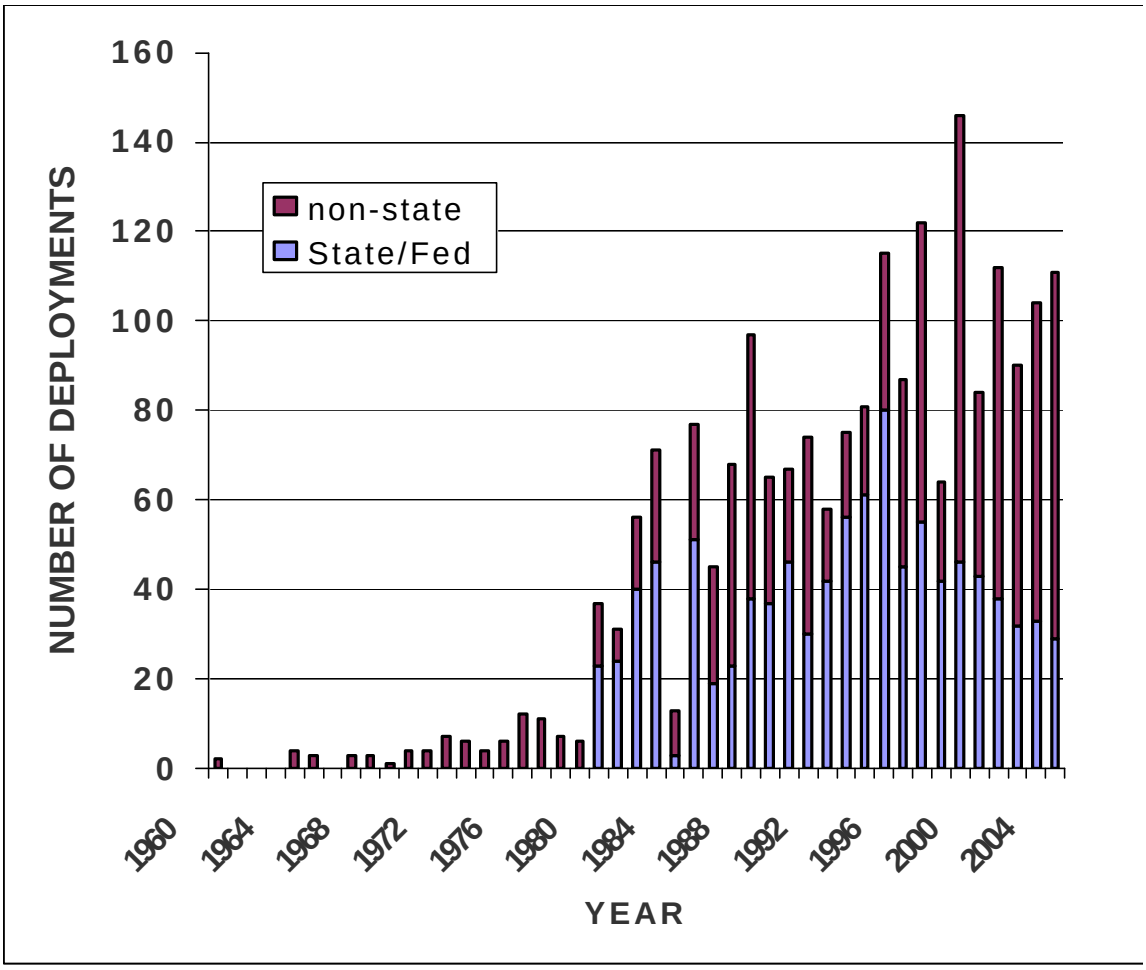

Figure 2. Number of artificial reefs deployed annually in Florida (K. Mille, Florida Fish and Wildlife Conservation Commission).

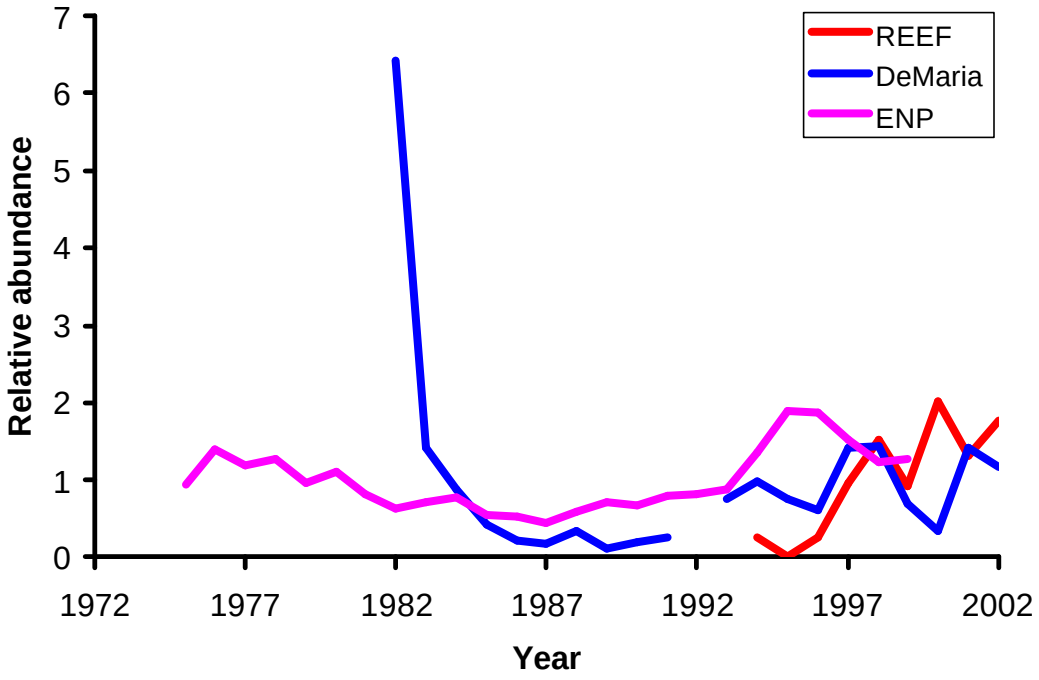

Figure 3. Trends in relative abundance of adult goliath grouper indicated by standardized REEF and DeMaria visual surveys (Porch and Eklund, 2004) compared with the trends for juvenile goliath grouper indicated by the standardized creel survey from Everglades National Park (Cass-Calay and Schmidt, in press).

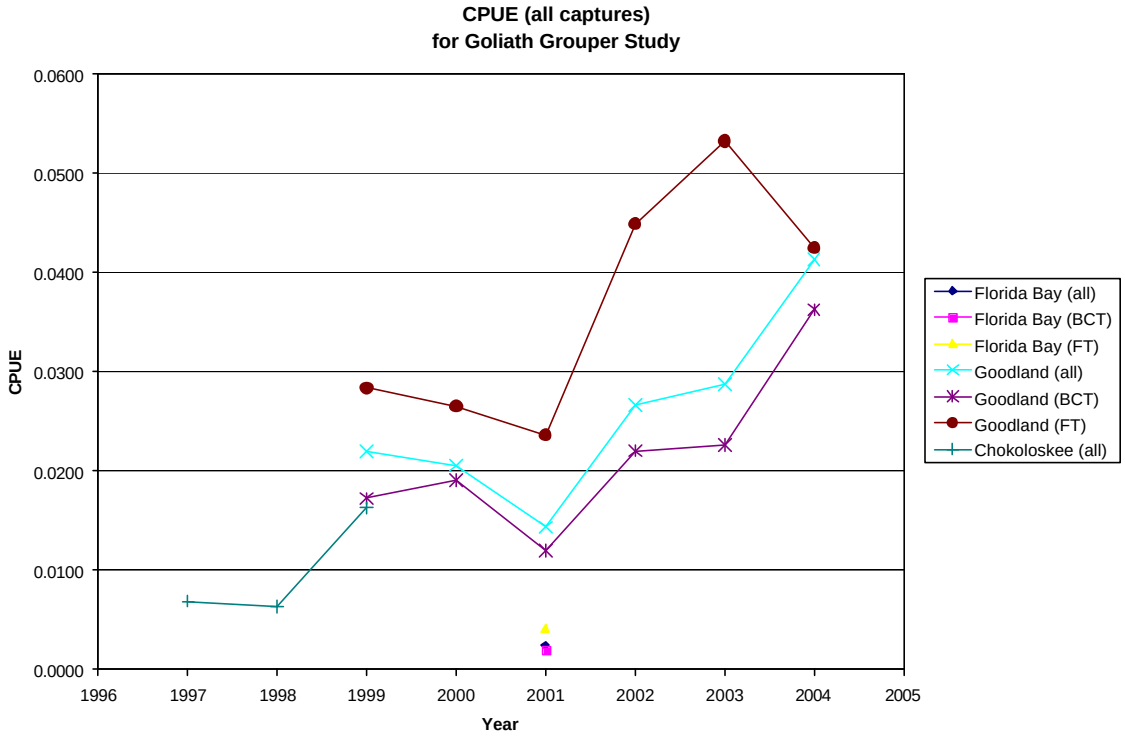

Figure 4. Catch per unit effort (CPUE) for annual monitoring of goliath grouper distribution and abundance in Southwest Florida from 1997 to 2004. For Florida Bay and Goodland sites, CPUE was calculated by dividing number of captures by number of trap days. CPUE was calculated for all traps combined, blue crab traps only, and fish traps only. For the Chokoloskee study (utilizing set lines), CPUE was calculated by dividing total number of captures by number of soak hours (J. Schull, NMFS, unpublished data).

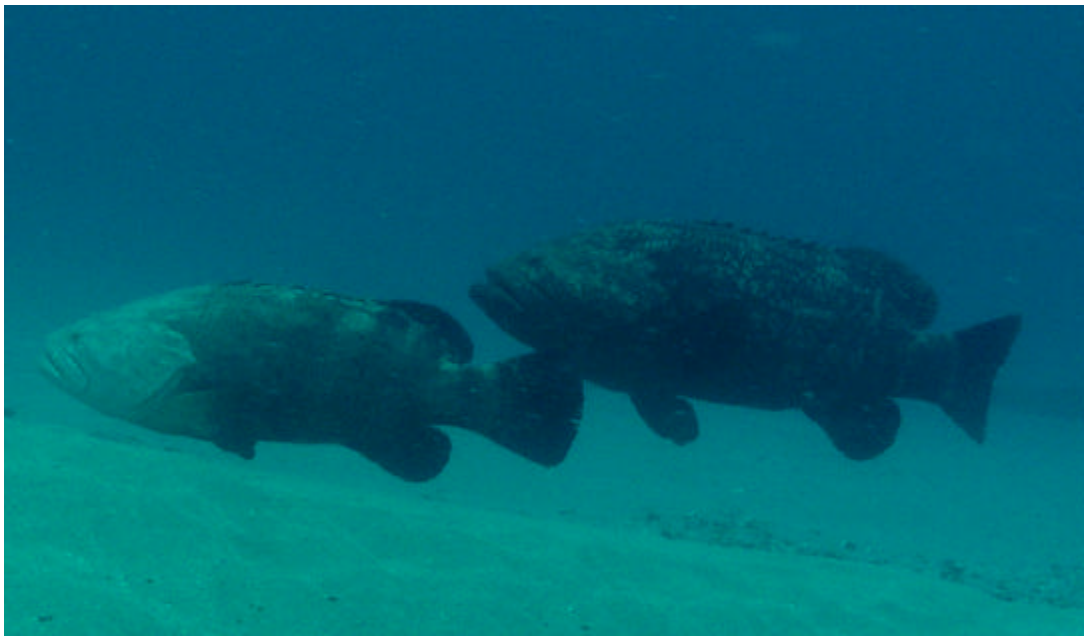

Figure 5. Presumed goliath grouper spawning coloration pattern (M. Barnette, NMFS).

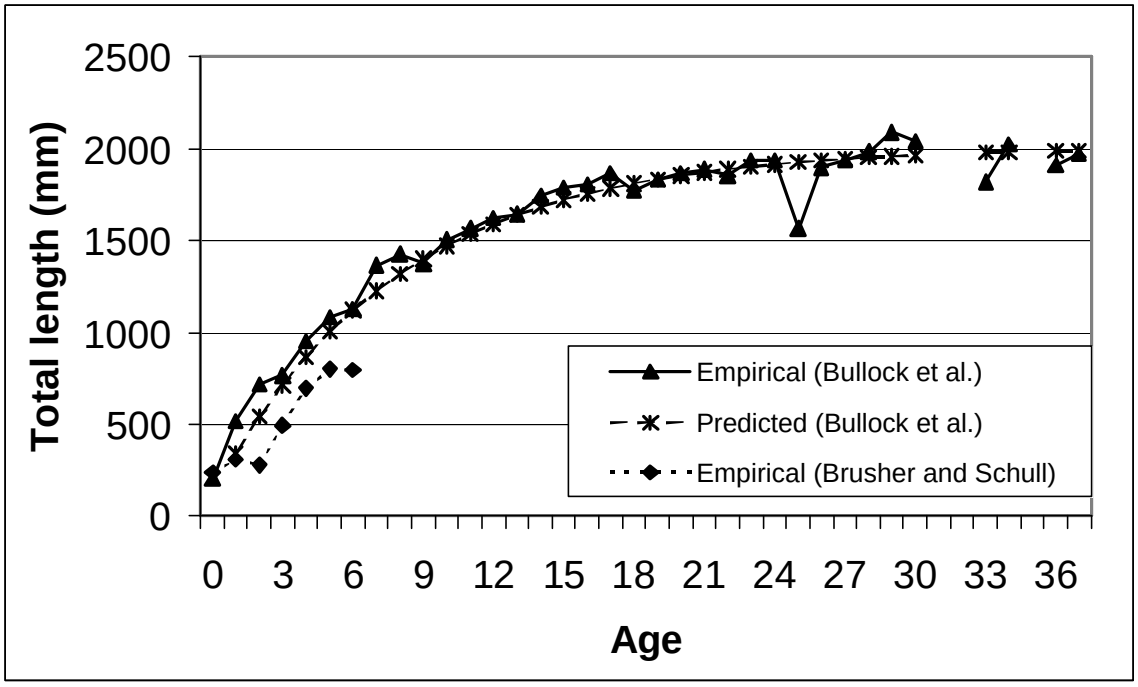

Figure 6. Empirical and predicted total lengths (TL) at age for goliath grouper from the eastern Gulf of Mexico. Mean empirical lengths from Bullock et al. (1992) were pooled over males, females, and unknown sex fish and predicted lengths are derived from a von Bertalanffy growth curve.

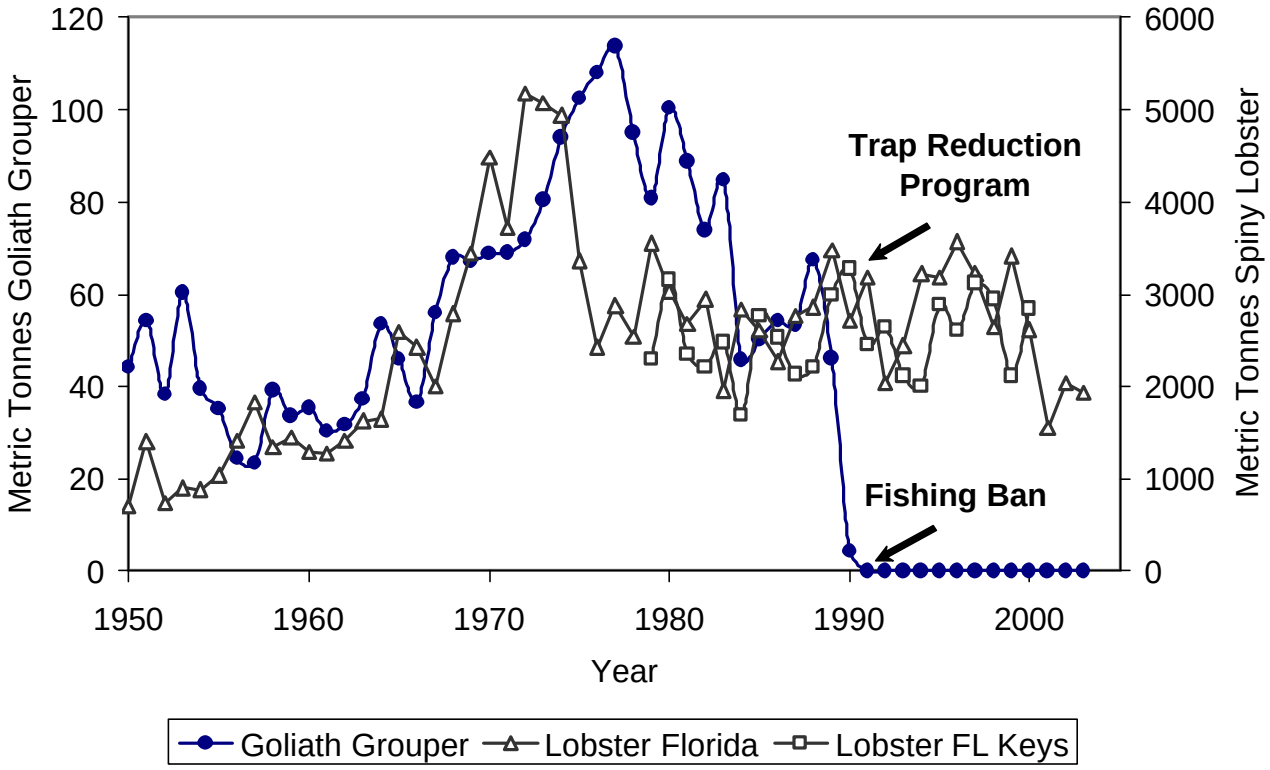

Figure 7. Commercial landings of goliath grouper and spiny lobster (Frias-Torres, unpublished study). Commercial landings and relevant regulations were obtained from several sources (1,2). When necessary, data were transformed from pounds to metric tones. The Trap Reduction Program (1992) dramatically reduced the use of sub-legal sized spiny lobsters to bait traps in the commercial fishery. However, recreational landings estimated for the two-day sport season in late July and for the period between August 6 and Labor Day, indicate that from 1987 to 2000, recreational landings were 23.7 percent (SE 0.95) of commercial landings in the Florida Keys, and such amount should be added to ascertain the total fishing pressure in spiny lobster.

1. NOAA Fisheries Statistics, http://www.st.nmfs.gov/st1

2. R.G. Muller, W.C. Sharp, T.R. Matthews, R. Bertelsen, J.H. Hunt, Spiny Lobster Stock Assessment, Florida Fish and Wildlife Conservation Commission (2000)

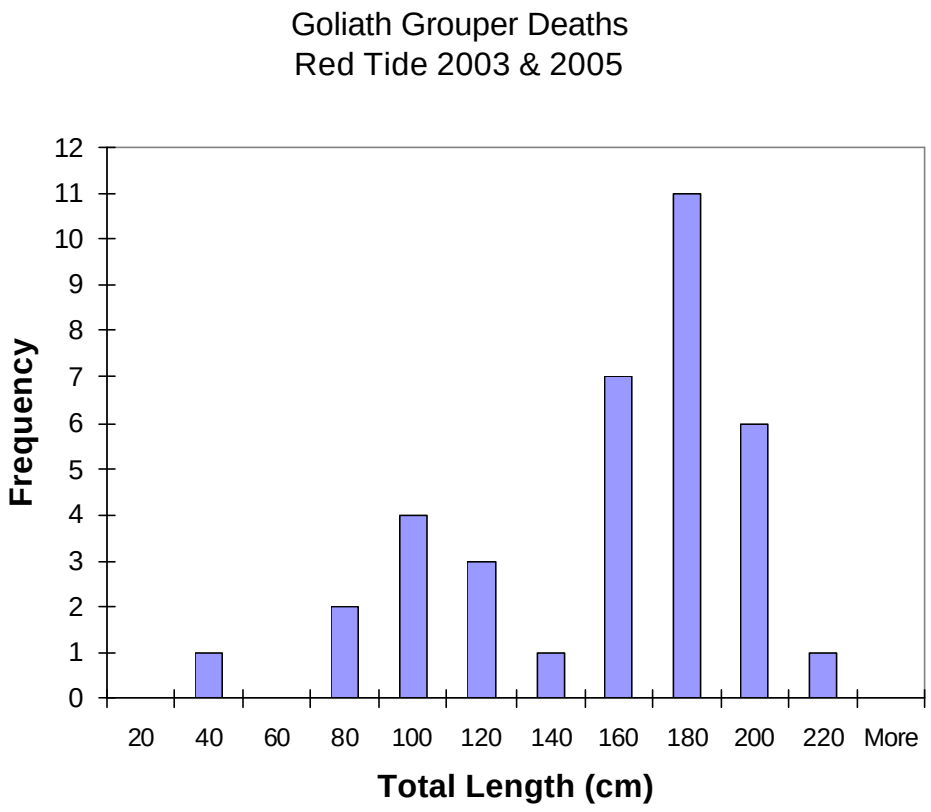

Figure 8. Size distribution of goliath grouper collected during Florida red tide events in 2003 and 2005 (n=26) (J. Schull, NMFS, pers. comm.).

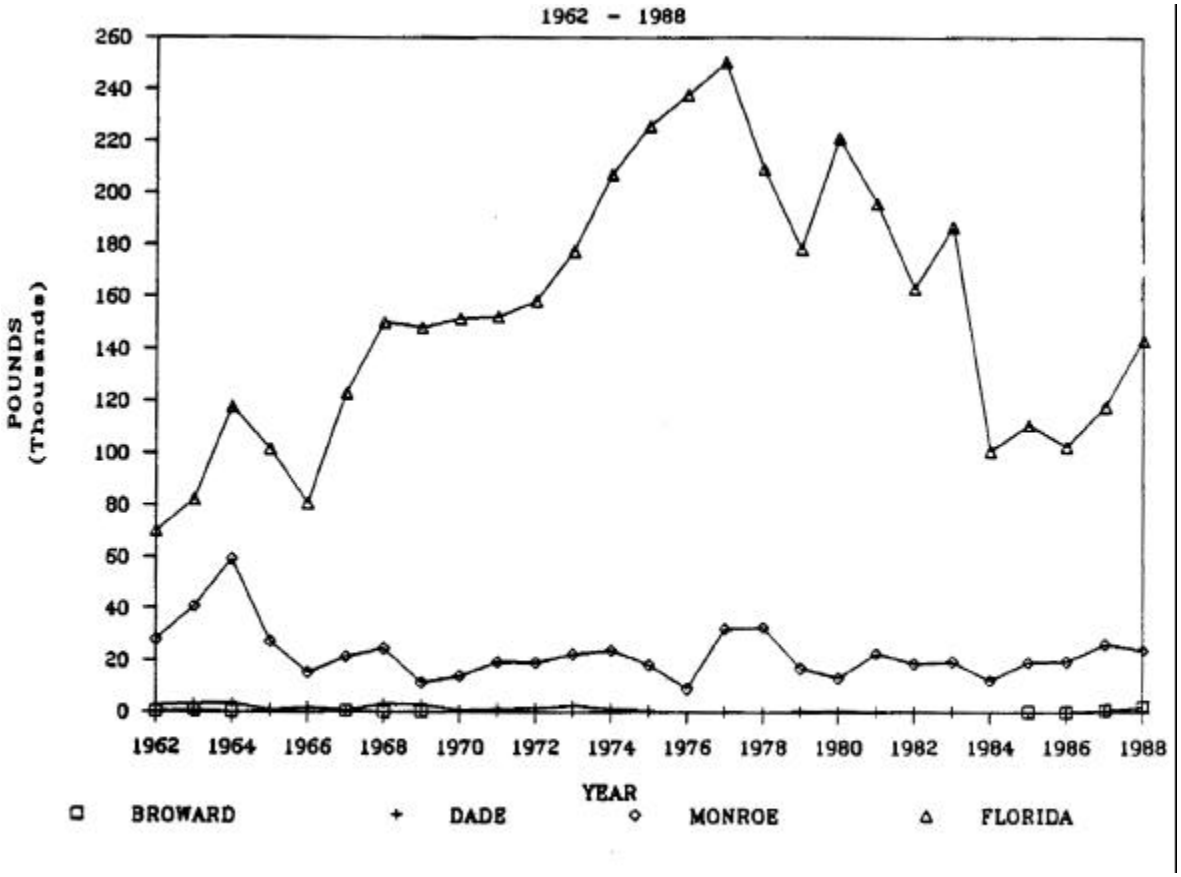

Figure 9. Florida commercial landings of goliath grouper (SAFMC, 1990).

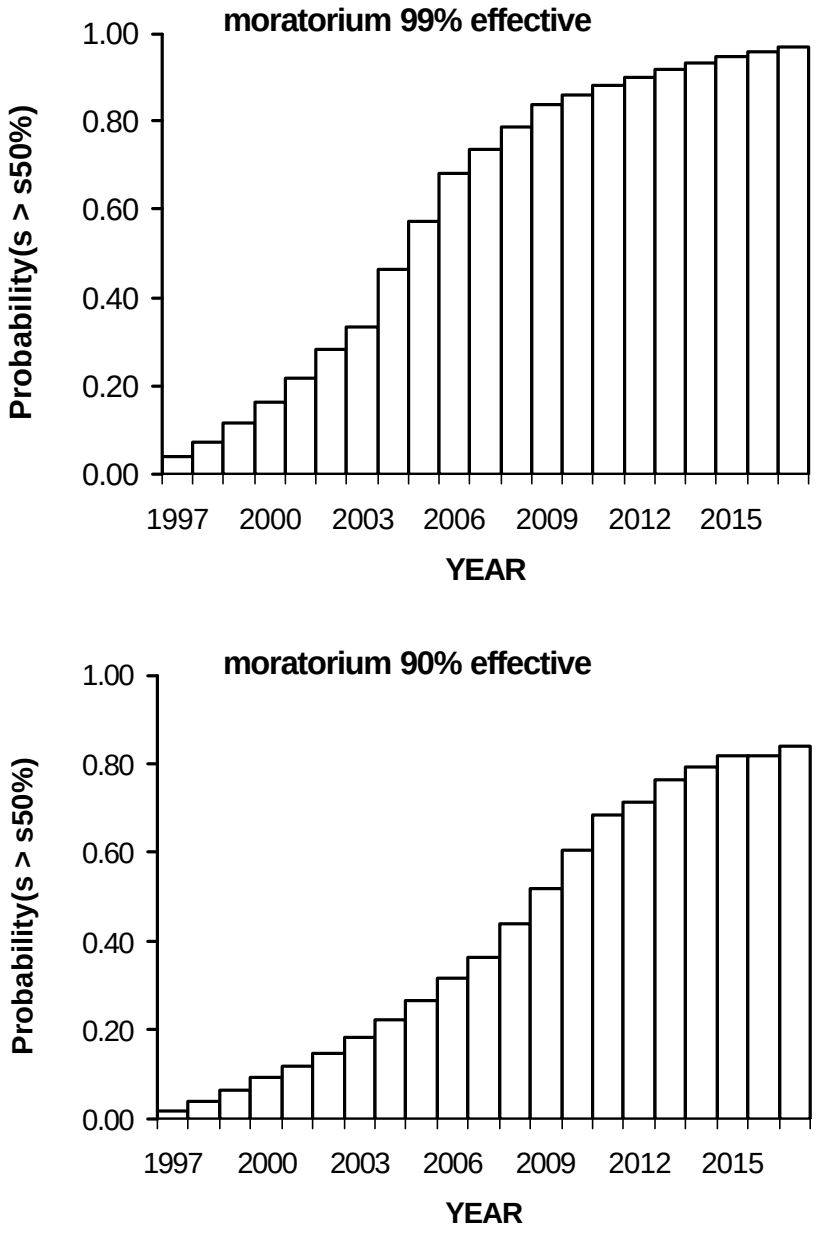

Figure 10. Probability stock will recover to spawning biomass levels corresponding to a 50 percent SPR assuming the moratorium on harvest is 99 percent effective (top panel) or 90 percent effective (bottom panel) (Porch, 2004).