SEDAR

Southeast Data, Assessment, and Review

Complete Stock Assessment Report
of
SEDAR 6

Goliath Grouper

SEDAR6
Assessment Report 1

SEDAR6-SAR1

2004

SEDAR/SAFMC
One Southpark Circle #306
Charleston, SC 29414
(843) 571-4366

CONTENTS

I. Introduction

Goliath grouper stocks in the South Atlantic, Gulf of Mexico, and Caribbean were initially considered for assessment during SEDAR 3 in March, 2003. The SEDAR 3 Data Workshop recommended that available data were insufficient to conduct a quantitative stock assessment, and therefore an assessment was not pursued. However, survey data were discovered subsequent to the Data Workshop which led the SEDAR 3 Review Panel to suggest that an assessment be considered for Goliath Grouper. The SEFSC followed the Review Panel suggestion and prepared an assessment of Goliath Grouper.

Hogfish Snapper in South Florida were assessed through an FMRI contract to the University of Miami that was initiated prior to formation of the SEDAR process. Since the species is managed by the South Atlantic and Gulf of Mexico Fishery Management Councils, Florida offered the final assessment for review by SEDAR.

SEDAR 6 differs from the standard SEDAR process in that it includes only a Review Workshop. This Workshop was convened to specifically address the review of stock assessments for Goliath grouper and hogfish snapper.

The SEDAR 6 Review Workshop convened in Tampa, Florida, January 27 – 30, 2004.

SEDAR 6. Goliath Grouper and Hogfish Snapper

Review Workshop

TERMS OF REFERENCE

The task of the SEDAR Assessment Review Panel is to review the goliath grouper and hogfish stock assessments as to completeness, correctness, and adequacy under the Sustainable Fisheries Act. Do the assessments use the best available scientific information and techniques, both within the constraints of available time and manpower provided for the assessments? The Panel should also make recommendations for improvements in future data collection and assessments. The Review Panel will provide two reports to accompany the stock assessment report. The first is a consensus summary of the stock assessment that addresses the Terms of Reference and includes the peer review comments on the assessment, the Panel's findings on stock and fishery status, and recommendations biological benchmarks and status determination criteria necessary for management under SFA guidelines. The second is an Advisory Report that summarizes the status of the stock.

1. Evaluate the adequacy and appropriateness of fishery-dependent and fishery-independent data used in the assessment (i.e., are the input data scientifically sound and up to date?).

2. Evaluate the adequacy, appropriateness, application and results of models used to assess goliath grouper and hogfish stocks (e.g., measures of exploitation, abundance, and biomass).

3. Evaluate the adequacy, appropriateness, application, and results of models used to estimate population benchmarks and Sustainable Fisheries Act status determination criteria (e.g., MSY, F_{msy}, B_{msy}, MFMT, MSST, and OY).

4. Evaluate the adequacy, appropriateness, and application of models used for rebuilding analyses where appropriate, and estimate, to the extent possible, generation time and rebuilding time in the absence of fishing mortality.

5. Develop recommendations for improving data collection and assessment and future research (both field and assessment).

6. Prepare a Consensus Summary report summarizing the peer review panel's evaluation of the goliath grouper and hogfish assessments and addressing the Terms of Reference. (Drafted during the Review Workshop, final report due two weeks later - February 12, 2004).

7. Prepare an Advisory Report on Stock Status, including summaries of fishery and population status and recommendations for biological benchmarks and SFA parameters. (Drafted during the Review Workshop, final report due two weeks later - February 12, 2004).

Each individual panelist will receive the stock assessments and other appropriate documents on these species for review approximately 10 days before the Panel meets.

The Panel's primary duty is to review the existing assessments. In the course of this review, the Chair may request a reasonable number of sensitivity runs, additional details of the existing assessments, or similar items from technical staff. However, the Review Panel is neither authorized to conduct or review an alternative assessment, nor to request an alternative assessment from the technical staff present. To do so would invalidate the transparancy of the SEDAR process. If the Review Panel determines that the assessment models and results are not adequate and appropriate, then the Panel shall outline in its report the remedial measures that the Panel proposes to rectify those shortcomings.

Goliath Grouper Data Workshop Report

Introduction

The goliath grouper SEDAR Data Workshop was held from 8:30 AM March 5 through 11AM March 6, 2003. Stu Kennedy of Florida Fish and Wildlife Commission's Florida Marine Research Institute (FWC-FMRI) was the convener; the participants are listed in Appendix 1. Stephania Bolden and Anne-Marie Eklund served as rapporteurs for the first and second days respectively.

The terms of reference for the workshop were to determine the quality and appropriateness of data available for an assessment. The participants agreed to place all data needed for an assessment on a CD, which would be provided to the Gulf of Mexico, South Atlantic, and Caribbean Fishery Management Councils and to the NOAA-Fisheries stock assessment team at the Southeast Fisheries Science Center in Miami. Anne-Marie Eklund agreed to collect the data files and reports for that CD.

The working group reviewed the available data and concluded that they were not adequate for an assessment; although since the meeting, a new data-source has been identified that may be useful for assessment purposes (see section E). In general, goliath grouper data are limited as all harvest for goliath grouper has been prohibited since 30 August 1990. In addition, the working group found several problems with the historical fishery-dependent data. The working group developed a prioritized list of information that it believed would be required to develop adequate estimates of stock status.

A. Biology and Life History

Felicia Coleman made a general presentation on life history based on multiple years of research conducted by herself, Anne-Marie Eklund, Chris Koenig, Jennifer Schull and other colleagues. That presentation will be placed on the CD with explanations of the information on each slide. Subsequent discussion reviewed the various research topics in greater detail.

Stock structure

Coleman reported on preliminary results of genetic analyses of goliath grouper from Belize and southwest Florida (conducted by Bob Chapman of South Carolina Department of Natural Resources) which indicate that the fish in those two areas are discrete stocks. Coleman and Chapman are working on size/age of fish from which genetic samples were taken. It was stated that the fish from Florida were small (juveniles) but the size of the fish from Belize was not known.

Age and Growth

Bullock *et al.* (1992) published information on goliath grouper age and growth.

More than 1000 dorsal spines and a small number of otoliths from juvenile goliath grouper in mangrove habitat have been examined (John Brusher and Jennifer Schull from SEFSC). Edge analysis indicates that the observed annuli in spines are formed once a year between July and December (with peak annulus formation from August-November). A comparison of spine and otolith ages from a small number of fish indicates that there are differences of up to one year between the two hard parts. These differences are thought to be due to the different times of year that the two hard parts appear to lay down annuli. Schull and Brusher are currently analyzing the data and adjusting the ageing for date and time of annulus formation.

Study of goliath grouper in mangrove creeks and tidal passes indicates that those caught by crab traps and fish traps and by hooks were primarily ages 1-6 years old (having 1-6 annuli present on otoliths and fin spines). Most of those fish were less than 100 cm TL, while fish from wrecks and reef habitats were greater than 150 cm TL. It was therefore assumed that most of the fish on wrecks and reefs were at least 6 years old. These data on individual fish and comparisons between age readers will be put on the CD.

The panel recommended continued work on ageing. Ages should be standardized to a calendar year, so that information on a year class is treated consistently throughout the year. Corroborative studies between the current research group (Schull and Brusher) and those with previously published age and growth work (Lew Bullock - FMRI) should be continued.

Reproduction

Bullock *et al.* (1992) published information on goliath grouper reproductive biology. They collected ripe fish between July-September and found no indication of sex change in any of the fish collected. Fish were mature between the ages 4 to 7.

Habitat

Felicia Coleman and colleagues (Anne-Marie Eklund, Chris Koenig, Jennifer Schull at meeting) reported that goliath grouper found in mangrove creeks and tidal passes are immature, and mature goliath grouper were thought to be associated with both artificial and natural reef structure, including piers, bridges, artificial reefs, wrecks and natural reefs. They have caught goliath grouper from about 2-100 cm TL (from young-of-the-year to age 6) in mangrove habitat. Those researchers and fishermen (Don DeMaria, Eddie Toomer) reported that fish of about 150 cm TL and larger are usually found around structure such as wrecks, artificial reefs and natural habitat with relief and overhangs. Another fisherman (Peter Gladding) reported that large goliath grouper have been observed on sand bottom in shallow water, beneath vessels.

Felicia Coleman further reported that there are indications that the amount of mangrove habitat in Florida has declined over time, thereby potentially reducing nursery habitat. There is a student at FSU working on a project to compare historical coastal mangrove coverage to present-day coverage. A student at the University of Florida is evaluating the relative impact of sea-level rise on mangrove distribution. It was noted that black mangrove habitat is newly developing along the Louisiana coast. Although our studies indicate that goliath grouper use primarily red mangrove habitat, goliath grouper occur and have historically occurred along the coasts of Louisiana and Texas; what habitat is used by juvenile goliath grouper in those areas is not known. (NB – during the last day of the workshop, two Texas Fishermen, Matt Murphy and Mike Nugent, reported that goliath grouper are frequently seen under docks off central Texas).

In the southeastern Gulf of Mexico, adult goliath grouper are often observed on offshore wrecks. Information on their distribution and abundance on natural habitat is more limited, possibly because these sites are visited less frequently by many of the dive groups that make and report observations. Goliath grouper may be concentrated around wrecks (isolated areas of high relief) and more spread out on low-relief natural habitat. The number of offshore wrecks has increased over time, thereby potentially increasing the amount of available offshore habitat available for the fish, or simply concentrating the fish on isolated structures. Eddie Toomer presented some interesting footage of goliath grouper on shallow, inshore sites and has offered to take the goliath grouper research team to visit these sites in summer 2003.

Distribution

Most of the current observations of goliath grouper are on wrecks off Charlotte and Lee Counties in southwest Florida. Don DeMaria pointed out that there were aggregations of goliath grouper off the southeast coast of Florida, near Jupiter, in the 1950s. These aggregations were fished-out soon after discovery, and the goliath grouper had not been reported from that area for several decades. However, in 2002, an apparent aggregation of 50 individuals was observed in that same area. Reports of fish in the northeastern Gulf of Mexico and northeast coast of Florida are beginning to come in through the FWC tagging hotline. No spawning aggregations from these northern sites are known.

Movement

Tagging of juvenile goliath grouper in southwest Florida mangrove habitat (mainly in the Ten Thousand Islands) indicates limited movement. Tagging of adults (Koenig *et al.* unpublished data) primarily during the spawning months on presumed spawning sites has shown that a high proportion (>40%) of recaptures occurred at the original tagging site. Analysis of acoustic tagging information at four sites in the Gulf of Mexico (Eklund *et al.* unpublished data) might provide additional quantitative information, but the analyses have not yet been conducted. Information gathered from that study might provide some indication of motility and site fidelity. The acoustic data from the juvenile tagging study in the Ten Thousand Islands area and from offshore tagging will be put on the CD.

Concern was expressed that if the fish do not move much, then the estimates of abundance would be only estimates of a local population and would, therefore, have only limited value in estimating the size of the population at large. Don DeMaria reported that he observed new fish on wrecks within months after removal of fish via spear fishing. This observation was true earlier in his fishing experience, but later, as the overall population was thought to have declined, replacement of removed fish occurred much more slowly. Jim Cowan suggested that it was possible that motility could be directly related to fish density, and as the overall population declined and density decreased, the motility of the fish might also have declined.

Predation

Sharks are the only known natural predator on adult or larger juvenile goliath grouper.

Natural Mortality

It was noted that the estimates of mortality provided from Jolly-Seber analyses of mark/recapture of juveniles (see power point presentation by Felicia Coleman on the CD) are confounded with emigration and gear selectivity. The investigators did not use those estimates of mortality and do not recommend using them. Jim Cowan recommended that alternative analytical methods (MARK software) be considered for use in estimating abundance and particularly the natural mortality rate.

B. Catch

Landings

Landings data from NOAA Fisheries were presented for 1950-1990; the moratorium on goliath grouper landings was imposed on August 30, 1990 [55 FR 25310]. The reliability of the landings data was discussed.

FWC reported that landings prior to 1985 or 1986 from a dealer on the west coast of Florida were substantially inflated for all species. With the advent of the Florida trip ticket system in 1986 this problem was identified, and FWC personnel developed revised catch statistics. It is possible that the NOAA Fisheries data are not corrected for that problem; a noted decrease in the goliath grouper landings in the mid-1980s could be associated with a transition from inflated to actual landings statistics. Josh Bennett will work with Stu Kennedy and Joe O’Hop to determine whether NOAA Fisheries landings data have been corrected or need revision.

Several fishermen reported that goliath grouper catches frequently were not sold through dealers. Prior to the early to mid-1980s, prices were very low (on the order of $0.10 / lb) and a substantial fraction of the catch was thought to have been sold directly to restaurants rather than to dealers. Apparently, in about 1984, prices began to increase and the proportion of the landings sold through fish houses increased. Some goliath grouper continued to be sold directly to restaurants, even after the imposition of the Florida trip ticket system in 1986. One fisherman from Key West reported that he had caught one to five goliath grouper per trip over many years but had never sold them to a dealer, whereas another Key's fisherman reported that he had always sold fish through dealers. If the proportion of sales of goliath grouper to fish houses increased in the mid-1980's, then the decline in reported landings may actually be an underestimate of the actual decline in catch. It was recommended that estimates of the proportions of sales of goliath grouper to restaurants be made from Florida trip ticket data if possible.

Another concern was that goliath grouper larger than about 150 lbs. were sold without the head. Because NOAA Fisheries landings records historically record whole weight, landings of headed and gutted fish would have been converted to whole weight using a standard set of conversion factors.

One fisherman (Eric Schmidt) estimated that in the Fort Myers, FL area, about 75% of the goliath grouper landings were made by recreational fishermen.

Current (catch and release) mortality

Several fishermen reported that they thought fishing mortality was currently occurring when goliath grouper are caught (when other species are targeted) and when fishermen target (some repeatedly) goliath grouper for catch-and-release. Generally, the goliath grouper population is thought to have increased, but mortality continues as a result of probable release mortality (especially adult specimens brought from depth) and unreported illegal catch.

C. Size and Age Composition

A small number of individual sizes were recorded for goliath grouper in the NOAA Fisheries TIP database (n = 102 total, 28 from the Caribbean area and 74 for mainland US). Investigation of the mainland US records after the Data Workshop revealed that at least 66 of the records were mis-identified gag and snowy grouper (Josh Bennett), thus at most 8 size observations are available in the TIP data base.

Fishery-independent sampling for age and size composition is continuing (1997-present) (Schull and Brusher and other colleagues). Bullock and Smith (1991) and Bullock et al. (1992) also present data on age and size composition from opportunistic sampling during the late 1980s.

D. Effort

Effort directed at goliath grouper reportedly increased during the 1980s (see Amendment 2 to the Gulf of Mexico Reef Fish Fishery Management Plan).

E. Indices of Abundance

Everglades National Park has conducted a survey of recreational fishermen since 1974 (or possibly before), and goliath grouper is likely to have been recorded in the data set. Apparently the survey collects information not only on landings, but also releases, and should be useful for developing an index of abundance. Anne-Marie Eklund will review that data to determine if goliath grouper landings are recorded with sufficient frequency to develop an index.

A relatively short time-series of catch and effort information exists in the Florida trip ticket data for the mid-1980s to August 1990 when the prohibition of harvesting was imposed. These data would be available for analysis if required.

Catch rates have been recorded from 1997-present in the juvenile tagging study conducted in the Ten Thousand Island/ Florida Bay area. The low motility of some of those fish (approx. 40% recaptured, many fish several times) was thought to limit the usefulness of that data as an index for the entire population. These data will be put on the CD.

The Florida Marine Research Institute conducted a trap survey in 2000-2002 along the Southeast Coast; no goliath grouper were caught.

Scott Nichols reported that SEAMAP had recorded only one goliath grouper in many years of sampling with multiple gears.

<u>Diver observations</u>

A series of observations by one diver (Don DeMaria) from 1981 to present at four wrecks from depths of 100-130 feet in the eastern Gulf of Mexico was presented as a possible index of abundance. Don DeMaria was a spear fisherman in the 1970s and 1980s. His written log lists the number of goliath grouper observed on each dive. DeMaria noted that during the earlier part of his log he probably underestimated numbers, because it was difficult to see all of the fish present when there were so many of them. Thus, his earlier numbers would be less precise; the counts in the mid to late 1980s likely included all of the fish observed because far fewer fish were present. It was noted that the pattern in the observations was similar to the pattern of commercial landings. The data and a description of the sampling protocol are provided on the CD.

Several questions were raised about the utility of the time-series for use as an index of abundance. In response to a question about the consistency of the effort, Don DeMaria reported that he thought it was consistent due to limits on dive time at such depths. In response to a question about whether the high number of goliath grouper recorded when a site was first visited (1982 for three of the sites) was accurately representing the number of fish on the wrecks, Don DeMaria responded that he thought the wrecks had not been exploited before he first visited them (they were in deep water and spear fishing had been limited to the shallower inshore wrecks) and that the observations did represent the number of fish present. It was noted that the wrecks might deteriorate over time and their suitability as habitat for goliath grouper might diminish. One wreck was small and deteriorating; another was a large shipwreck from WWII and was not visibly changing.

The group discussed whether the data from these four small areas could reflect total population trends. Don Demaria noted that inshore wrecks generally were not repopulated after being fished-out while offshore wrecks appeared to repopulate. However, tagging data from 1998-present indicate that fish often continue to be observed at their tagging locale. It was recommended that the tagging data be further examined for indications of site fidelity. There was some discussion that these offshore wrecks might be associated with spawning sites. If they were spawning sites and goliath grouper actually migrate to them, then they might be more reflective of the population in a broader area. There are no data on spawning migrations, however; and acoustic data from Eklund suggest that the majority of the acoustically-tagged fish remain on-site for several months after tagging.

The Florida Marine Research Institute has conducted an underwater visual survey on selected reef tracts in the Florida Keys since 1999. One goliath grouper was seen in 1999, two in 2000, none in 2001, and three in 2002.

The Reef Fish Visual Census information collected by NOAA Fisheries in Miami (and in recent years in cooperation with the University of Miami) consists of replicated observations by pairs of divers in the Florida Keys and extends from 1978 to present. A total of 8 goliath grouper are noted in the data set through 2001. However, there are several more observations in the 2002 data (not analyzed yet). The panel decided that the limited number of goliath observations would likely be of little value so this data will not be included on the CD.

Some time series of observations by recreational divers might be considered for developing indices of abundance. The Reef Educational and Environmental Foundation (REEF) has collected information from recreational divers from 1993-present from sites in Florida and in the Caribbean. Abundance is recorded in the following categories: one, few, several and many. Size of fish is not recorded. Anne-Marie Eklund will request the data from REEF and if obtained will include it on the CD unless the numbers of goliath grouper observations are very low. A time series of observations from dive clubs diving artificial reefs in Florida has been collected by Bill Horn (Florida Fish and Wildlife Conservation Commission, Marine Fisheries Division). Felicia Coleman and Chris Koenig have that data and will attempt to determine whether the data set contains useful effort measures. Without a good measure of effort, the increase in the number of goliath grouper observations is confounded with increases in diving effort and number of artificial reefs placed in Florida waters over time.

F. Estimates of Abundance

Estimates of abundance have been made from juvenile mark-recapture data in the inshore mangrove areas of the Ten Thousand Islands and Florida Bay (Coleman, Koenig and Eklund, in review). Jolly-Seber methods were utilized to estimate population size. It was recognized that these would be estimates of local abundance because of the limited geographic range of the tagging and the low movement rates exhibited (gear selectivity also confounds information on age-class abundance). These data will be included on the CD. Mark-recapture abundance estimates of adult abundance throughout the Florida shelf (east and west coast) have not yet been finalized (Koenig et al.).

G. Estimates of abundance relative to the unexploited condition

Steve Turner (SEFSC) presented a paper by Porch and Scott (2001) detailing a method of estimating time of stock recovery given information or assumptions on the status of spawning stocks relative to the unexploited condition. The group discussed the possibility of using information from fishermen who had fished for goliath grouper in the 1950s or 1960s through the 1980s to provide perspectives on stock biomass decline between a relatively lightly exploited period and the time of the closure of the fishery. The group expressed concern that the results would be so highly variable that they would be unreliable for producing meaningful estimates. Steve Atran reported that the Gulf Council had conducted surveys of opinions about the relative status of goliath grouper in the early 1990s. Anne-Marie Eklund has that information from the Council and will include it on the CD. Several people recommended that log books would provide more reliable estimates than oral history.

H. Population information which might be useful in monitoring future stock status

The group expressed concern that the existing information available for estimating stock status might not be sufficient. The group discussed the types of information which might be useful for monitoring stock rebuilding. Research issues were discussed and categorized into eight research topics. They were then prioritized based on their short term value for assessing goliath grouper stocks Gulf-wide. There was also a request to the Gulf Council and NMFS (Tom McIlwain) to include this research in the next round of grant RFPs.

The top four research topics were:

1**. Estimation of population size** - Estimates of population size were considered to be of highest importance for future management. It was noted that because of the apparent restricted home ranges and high site fidelity, sampling throughout the geographic range would probably be important. Tag/recapture studies were mentioned as a potential monitoring tool. (NB – to better define their geographic distribution, the State of Alabama (http://www.dcnr.state.al.us/mr/goliath_grouper.htm) and the State of Mississippi (http://www.dmr.state.ms.us/Misc/Species-of-concern/) recently put up hotline notices on their websites. Louisiana plans to add a link to their site, and Texas should follow suit).

2. **Demographics** - Monitoring the demographics of the population, particularly age composition, could provide valuable information (as it has for red drum in the Gulf of Mexico).

3. **Reproductive Biology** - Developing further understanding of the reproductive biology of goliath grouper was considered quite important. Identifying spawning locations, duration and periodicity could be very useful for identifying sites to conduct population surveys.

4. **Historical Abundance** - Obtaining information on historical abundance, perhaps via old logbooks, was also considered important.

Four other research topics were also considered, but it was thought that they were either less important, or less likely to be completed:

1. It could be very useful to have estimates of unrecorded mortality from accidental or intentional sources, but obtaining such information would be very difficult.

2. Additional information on stock structure was considered important.

3. Some thought that it would be useful to have a greater understanding of goliath grouper bioenergetics and trophic relationships. Others asked how that information would assist in a stock assessment.

4. Information identifying the changes in mangrove abundance and distribution, thereby changing available nursery habitat, could assist in developing predictions of future abundance.

Literature Cited

Bullock, L.H and G.B.Smith 1991. Seabassess (Pisces:Serranidade).Florida Mar. Res. Inst. Memoirs of the Hourglass Cruises. 8(2), 243p.

Bullock, L.H., M.D.Murphy, M.F. Godcharles and M.E.Mitchell. 1992. Age, growth and reproduction of jewfish, *Epinephelus itajara*, in the eastern Gulf of Mexico. Fish. Bull. 90: 243-249.

Coleman, FC, CC Koenig, and AM Eklund. In review. Density, survival and movement patterns of juvenile goliath grouper (Epinephelus itajara) in mangroves. Ecological Applications.

Porch, C.E. and G.P. Scott. 2001. Rebuilding times for Nassau and goliath grouper. NOAA Fisheries, Miami, manuscript 6p.

Appendix 1: Participants and email addresses
Goliath Grouper E-mail List

Atran, Steven	steven.atran@gulfcouncil.org
Barbieri, Luiz	luiz.barbieri@fwc.state.fl.us
Barnette, Mike	michael.barnette@noaa.gov
Bennett, Josh	joshua.bennett@noaa.gov
Bergmann, Charlie	charles.bergmann@noaa.gov
Blough, Heather	heather.blough@noaa.gov
Bolden, Stephania	stephania.bolden@noaa.gov
Bullock, Lew	lew.bullock@fwc.state.fl.us
Calay, Shannon	shannon.calay@noaa.gov
Chih, Ching-ping	ching-ping.chih@noaa.gov
Coleman, Felicia	coleman@bio.fsu.edu
Cowan, Jim	jhcowan@lsu.edu
Cufone, Marianne	mcufone@oceanconservancyFL.org
De Maria, Don	dondemaria@aol.com
Eklund, Anne Marie	anne.marie.eklund@noaa.gov
Garcia-Moliner, Graciela	graciela@coqui.net
Goode,Tim	timothy.goode@gulfcouncil.org
Holiman, Stephen	stephen.holiman@noaa.gov
Hood, Paul	phood1@tampabay.rr.com
Jensen, Jill	hms.consulting@prodigy.net
Kennedy, Stu	stu.kennedy@fwc.state.fl.us
Koenig, Chris	koenig@bio.fsu.edu
McIlwain, Tom	tom.mcilwain@noaa.gov
Muller, Bob	robert.muller@fwc.state.fl.us
Nichols, Scott	scott.nichols@noaa.gov
Poffenberger, John	john.poffenberger@noaa.gov
Rosario, Aida	lipdrna@coqui.net
Schmidt, Eric	capter@earthlink.net
Schull, Jennifer	jennifer.schull@noaa.gov
Shipp, Bob	rshipp@jaguar1.usouthal.edu
Steele, Phil	phil.steele@noaa.gov
Strelcheck, Andy	andy.strelcheck@fwc.state.fl.us
Toomer, Eddie	toomer@comcast.net
Toomer, Jane	toomer@comcast.net
Turner, Steve	steve.turner@noaa.gov
Uwate, Roger	ruwate@vitelcom.net
Williams, Kay	hkaywilliams@hotmail.com

Gladding, Peter - no e-mail address – 305-296-2821

STANDARDIZED VISUAL COUNTS OF GOLIATH GROUPER OFF SOUTH FLORIDA AND THEIR POSSIBLE USE AS INDICES OF ABUNDANCE

by

Clay E. Porch and Anne Marie Eklund

National Marine Fisheries Service, Southeast Fisheries Science Center,
Sustainable Fisheries Division, 75 Virginia Beach Drive, Miami, FL, 33149-1099, USA

Sustainable Fisheries Division Contribution SFD-2003-0017

Introduction

Goliath grouper, *Epinephelus itajara*, is the largest grouper in the western North Atlantic and one of the largest groupers in the world (Heemstra and Randall 1993). It is an unwary species that congregates predictably on artificial wrecks and reefs, making it especially vulnerable to fishing. Not surprisingly, it was overfished through the 1980s. All harvest of goliath grouper was prohibited in the U.S. Gulf of Mexico by emergency rule in 1990 (GMFMC 1990). Harvest was also banned in U.S. Atlantic and Caribbean waters in 1990 and 1991, respectively (Sadovy and Eklund 1999). The recovery of goliath grouper has been slow due to its long-life span and low reproductive rate (Sadovy and Eklund 1999). Nonetheless, anecdotal reports from fishers and divers suggest populations are increasing in U.S. waters.

The NOAA-Fisheries Southeast Fisheries Science Center is currently assessing the status of the goliath grouper stock and developing estimates of its recovery time. Traditional fishery-dependent data are of little use in this endeavor inasmuch as they extend back only a few years prior to the closure and are probably inaccurate (SEDAR 2003). There are, however, two visual surveys that may prove more helpful: the personal observations of a professional spearfisher (DeMaria[1]) and a volunteer fish-monitoring program administered by the Reef Education and Environmental Foundation (REEF 2000).

Sadovy and Eklund (1999) constructed an index of abundance from the DeMaria survey but did not account for the unbalanced design of the sampling procedure. An inspection of the data revealed that the counts of goliath grouper differed among locations (Figure 1) as well as with the onset of the spawning season in late summer/early fall (Figure 2). When coupled with uneven sampling, either situation could bias the overall trend. A similar situation occurs with the

[1] DeMaria, Don. P.O. Box 420975, Summerland Key, FL 33042.

REEF data, but the matter is complicated further by the fact that the observations of 3 to 10 fish are recorded only as 2 or more. In this paper we standardize both surveys by use of generalized linear models (GLM) that compensate for the unbalanced design of each survey and, in the case of the REEF data, account for the fact that the data are censored at 2.

Methods

Field data collection: DeMaria Survey

The protocol adopted by Mr. DeMaria was to count the total number of goliath grouper he encountered on specific sites during SCUBA dives that would typically last 25 minutes (due to diver-depth limitations). Prior to 1990, he was spearfishing and he recorded the number of fish observed as well as the number speared. After the moratorium began in 1990, he continued to visit these sites with researchers and recorded the number of fish seen on his dives. Due to the size of the fish (1-2 m in length) and the discrete area of artificial sites (all of the reef fish, including the goliath grouper, typically are concentrated at the structures and not found for the most part in the adjacent sand areas), it was not difficult for him to count all fish on a particular site, particularly if there were fewer than 50 individuals. Researchers diving with Mr. DeMaria found that his counts differed little from their own. However, Mr. DeMaria has stated that the numbers recorded during the early years may underestimate the actual number on each site since there were many more fish to count at that time.

The specific locations included in Mr. DeMaria's survey are indicated in Figure 3. They include (1) the wreck of the Baja California, a WWII merchant marine ship sunk 40 miles north of Key West in about 36 m of water, (2) the wreck of a small shrimp boat approximately 90 miles north of Key West at a depth of 34 m, (3-4) the stern and bow sections of a Patrol Boat about 2 miles north of site 2 in 40 m and (5) a Navy navigation tower about 2 miles from site 1 in 30 m of water. Sites 1 and 5 are well known and frequently visited by divers and fishers. Sites 2, 3 and 4, on the other hand, were seldom visited by other fishers or divers. Several dives were made on each site during most years, particularly early in the time series.

Field data collection: REEF Survey

The REEF database has been constructed from a compilation of the observations of volunteer divers trained in the roving diver technique (Pattengill-Semmens and Semmens 1998, Jeffrey et al. 2001). Essentially, divers swim freely about a dive site within a 100 m radius of the starting point, recording every species that they can positively identify. After the dive they assign an abundance category to each species: (1) a single fish, (2) 2-10 fish, (3) 11-100 fish or (4) > 100 fish. The dive location, dive duration, depth, bottom temperature, visibility, habitat type and experience level of the diver are also recorded.

The data provided to us included 15890 surveys conducted at 903 dive sites from June 1993 through 2002. Sites where goliath grouper were never observed and sites visited in fewer than 6 different years were culled from the analysis, leaving a total of 5246 surveys at 32 sites (see Table 1). Most of the sites that made the cut are located in the Florida Keys, the rest being located along the Florida east coast (Figure 3). The primary habitat types recorded for these sites were: (1) mixed, meaning a variety of individual habitats; (2) high profile reef, where coral structures rise > 1.3 m off the bottom; (3) low profile reef, where coral structures rise < 1.3 m off the bottom and (4) artificial structures, including ship wrecks and other dumped debris. On a few occasions some of these sites were also reported as rubble, sloping dropoffs, ledges, or shear dropoffs. In such cases rubble and sloping dropoffs were counted as mixed habitats while ledges and shear dropoffs were counted as high profile reefs.

Statistical modeling: DeMaria survey

The number of goliath grouper spotted on a given dive (N_i) at location L during year Y and season S was assumed to be lognormally distributed such that

(1) $\ln(N_i + c) = \alpha + \beta_Y + \beta_S + \beta_L + \beta_{YS} + \beta_{YL} + \beta_{SL} + \varepsilon_i$

where c is a small constant (1.0) added to allow for occasional zero counts, ε is a normally-distributed error term, α is the intercept parameter, and the β are categorical variables that represent the main effects and second-order interactions corresponding to each year, season and location. There were insufficient data to estimate a third order interaction (β_{YSL}). The categorical variable for season included two levels; one for observations made during the warm season (June – October) and the other for observations made during other times (there were insufficient observations to subdivide this further and the designation June–October provided the best fit to the data).

A stepwise approach was used to build a parsimonious statistical model. The procedure was initiated by constructing competing GLM's (SAS 1993) each consisting of a base model (the year main effect alone) plus one of the remaining categorical variables. The variable that most reduced the deviance per degree of freedom was then added to the original base model, provided it was statistically significant according to the sample-size-corrected version Akaike's information criteria (AICc, Hurvich and Tsai 1995). This process of adding factors one at a time and updating the model with the categorical variable that most reduced the deviance per degree of freedom was repeated until no factor (main effect or interaction) met the criteria for incorporation into the final model. After the final model was identified, it was fit to the proper response variables using the SAS macro GLIMMIX (c/o Russ Wolfinger, SAS Institute Inc.). All main effects and interactions were treated as fixed effects except year interactions, which were treated as random effects, so that annual indices of abundance could be constructed with variances that appropriately reflect the added uncertainty expected when significant year interaction effects are present.

The standardized measure of visual counts for year Y was computed as

(2) $$N_Y = \exp\{\, \alpha + \beta_Y + (d+1)(\, s^2_R - s^2_{ln(\alpha\beta)}\,)/2d \,\} - c$$

where the values used for $\alpha + \beta_Y$ are the GLM estimates (see Bradu and Mundlak 1970, Gavaris 1980). The terms s^2_R, d, and $s^2_{ln(\alpha\beta)}$ are the estimated residual variance, the degrees of freedom for the residual variance, and the estimated variance of $\alpha + \beta_Y$, respectively.

Statistical modeling: REEF survey

The relative rarity of goliath grouper in the REEF samples coupled with the fact that observations of multiple animals are recorded as “2” suggests that the count data are unlikely to follow a lognormal distribution. One alternative is to treat the series as presence-absence data and model the proportion of surveys with positive counts, but this method would ignore some of the information content in the data. Instead, we model the counts using the censored Poisson distribution:

(3) $$p(N) = \begin{cases} \dfrac{e^{-\mu}\mu^N}{N!} & x = 0, 1, \ldots, Z-1 \\ 1 - \displaystyle\sum_{k=0}^{Z-1} \dfrac{e^{-\mu}\mu^N}{N!} & x \geq Z \end{cases}$$

where Z is the censor point and μ is the expected count of goliath grouper. In the present case the censor point is 2, therefore maximum likelihood estimates for the parameters α and β may be obtained by minimizing the negative loglikelihood expression

(4) $$L = \sum_{N_i=0} \mu_i + \sum_{N_i=1} (\mu_i - \ln \mu_i) - \sum_{N_i=2} \ln\left(1 - (1+\mu_i) e^{-\mu_i}\right)$$

The expectation for a given dive, μ_i, was modeled as

(5) $$\ln\mu_i = \gamma_t + \alpha + \beta_Y + \beta_S + \beta_L + \beta_E + \beta_V + \beta_H$$

where the γ_i is the offset covariate (dive duration) and the β are categorical variables representing the main effects of year, season, location, experience level, visibility and habitat type, respectively. There were two levels for season (June–October, November-April), three levels of visibility (poor, fair and good), two levels of experience (novice or experienced) and four levels of habitat (described above). The most parsimonious combination of main effects was identified by use of the AICc criteria. Interaction effects were not estimated owing to the sparseness of the observations at many of the sites.

All model fits (negative loglikelihood minimizations) were accomplished using the utilities provided in the software package AD Model Builder[2]. Standardized measures of visual counts for each year were constructed as

(6) $$N_Y = \exp\{ \alpha + \beta_Y \}.$$

Confidence limits for N_Y were obtained by the likelihood profile method.

[2] AD Model Builder Version 6.0.2. Otter Research Ltd., Box 2040, Sidney, B.C. V8L 3S3, Canada.

Results

DeMaria survey

The main effects associated with year, location and season were all statistically significant; accounting for 27%, 22% and 2% reductions in deviance per degree of freedom, respectively. The year/location interaction term was also statistically significant and therefore was included as a random effect. The log-scale residuals followed closely those of a normal distribution with constant variance (Fig. 4), verifying the underlying lognormal error assumption of the final model.

The standardized index of goliath grouper counts is similar to the time series of annual means (Table 2, Fig. 5). The wide error bars are largely a result of the high variability and low replication, but also reflect the significant year/location interaction. Nevertheless, the initial decline and post-1990 increase in goliath grouper counts is statistically significant.

REEF survey

The main effects associated with year, location, and season proved statistically significant. There was no discernible relationship between the number of goliath grouper counted and dive duration; incorporating dive duration as a covariate significantly degraded the model fit according to the AICc. The fit of the model was poor, accounting for only about 7 percent of the variation in the data. Accordingly, the standardized index is very similar to the time series of annual means (Table 2, Fig. 6). As was true for the DeMaria survey, the wide error bars are largely a result of the high variability and low replication. Nevertheless, the estimated increase in abundance is statistically significant.

Discussion

The most important factors in standardizing the DeMaria and REEF data were the year and location. The seasonal effect was also statistically significant, but it had relatively little impact on the percent of the variation explained by either model because most of the dives in any given year were conducted during the ‘warm’ season. In the case of the DeMaria survey, the estimates for the seasonal effects suggest that the abundance of goliath grouper on the five artificial reefs is about 50% higher during the ‘warm’ season than during the ‘cold’ season. Anecdotal observations (Sadovy and Eklund 1999) as well as the recent results from an acoustic tag study (Figure 7) appear to support this conclusion. However, exactly the opposite trend is estimated from the REEF survey data; goliath grouper appear to be about 50% less abundant during the warmer months. It is possible that the reversed trend in the REEF data is spurious owing to the present scarcity of goliath grouper observations in those areas. Nonetheless, it is possible that the opposing trends reflect summer movements related to spawning or seaward migrations during the cold winter months.

The large size and generally unwary nature of goliath grouper makes them easy to spot, even under relatively poor visibility. Hence, it is not surprising that visibility and diver experience were not significant factors in the analysis of the REEF data. Furthermore, inasmuch as the range examined by each diver is limited by design to a 100 m radius, conspicuous fish like goliath grouper are likely to be seen shortly into the dive, which explains why the number counted was independent of dive duration.

The standardized DeMaria and REEF surveys can be used as measures of the relative abundance of goliath grouper off southern Florida. In the case of the DeMaria index such extrapolations are somewhat tenuous owing to the relatively restricted geographic area surveyed and the apparently limited movements of adult goliath grouper (Smith 1976). Mr. DeMaria and others assert that these offshore sites were the last of the known goliath grouper aggregations to be exploited and had not been subjected to the decades of fishing pressure that inshore area had experienced (DeMaria, pers. comm., Gladding pers. comm., SEDAR report). In other words, the high abundance of goliath grouper on these artificial sites in the early 1980's did not reflect the overall depleted state of the rest of the resource. Moreover, the rapid declines observed at sites 1, 2 and 4 in the early 1980's were largely due to heavy fishing pressure exerted at about the time the survey began (DeMaria[1]). Since as these wrecks were easily relocated, once they had been discovered, and harbored high concentrations of goliath grouper, they probably received proportionately more fishing pressure than the population as a whole. Hence, it is likely that the initial decline indicated by the index is more precipitous than that of the overall population.

The REEF survey includes many more sampling locations (32) and is spread over a much broader area than the DeMaria survey; therefore it is probably a reasonably good index of the relative abundance of goliath grouper along the southeast coast. Unfortunately, the center of abundance of the goliath population is along the southwest coast (as evidenced by the very low numbers seen at all REEF sites). The REEF and DeMaria surveys both indicate a substantial increase since the 1990 moratorium on harvest, but the increase in the REEF survey does not begin until several years later (Figure 8). This delay in recovery along the east coast, relative to the increase in the west coast, may be to a lack of nursery habitat along Atlantic shores or a concentration effect on artificial structures in the Gulf of Mexico. Anecdotal reports reveal that this species was historically observed frequently along both coasts of southern Florida (Eklund 1994; DeMaria 1996).

Despite the above misgivings, the surveys in question are the only such time series available for adult goliath grouper. As such, they are invaluable to any attempt at assessing the status of the resource. In this regard, the counts made after the harvest moratorium imposed in 1990 should prove especially useful as an indicator of the rebuilding potential of the stock. The most troubling aspect, the very rapid initial decline in the DeMaria index associated with local depletion, may be handled simply by ignoring the data prior to 1984.

Literature Cited

Aitkin, M., Anderson, D., Francis, B., and Hinde, J. 1989. Statistical modeling in GLIM. Oxford Science Publications. Oxford

Bradu, D., and Y. Mundlak. 1970. Estimation in log-normal linear models. Journal of the American Statistical Association 65:198-211.

DeMaria, K.K. 1996. Changes in the Florida Keys marine ecosystem based upon interviews with experienced residents. The Nature Conservancy and Center for Marine Conservation Special Report. The Nature Conservancy, Key West, FL.

Eklund, A.M. 1994. (editor) Status of the stocks of Nassau grouper, *Epinephelus striatus*, and jewfish, *E. itajara* - Final Report. SEFSC report Miami Lab. Contrib. No. MIA-94/95-15.

Gavaris, S. 1980. Use of a multiplicative model to estimate catch rate and effort from commercial data. Canadian Journal of Fisheries and Aquatic Sciences 37:2272-2275.

Gulf of Mexico Fishery Management Council (GMFMC). 1990. Amendment Number 2 to the Fishery Management Plan for the Reef Fish Fishery of the Gulf of Mexico, 31 p.

Heemstra, P.C., and J.E. Randall. 1993. FAO Species Catalogue. Groupers of the world (Family Serranidae, Subfamily Epinephelinae). An annotated and illustrated catalogue of the grouper, rockcod, hind, coral grouper and lyretail species known to date. FAO Fisheries Synopsis 16 (125), 382 p.

Hurvich, C. M., and Tsai, C. 1995. Model selection for extended quasi-likelihood models in small samples. Biometrics **51**: 1077-1084.

Jeffrey, C. F. G., Pattengill-Semmens, C., Gittings, S., and Monaco, M. E. 2001. Distribution and sighting frequency of reef fishes in the Florida Keys National Marine Sanctuary. Marine Sanctuaries Conservation Series MSD-01-1. U.S. Dept. Commerce, Nat. Oceanic and Atmospheric Administration, Marine Sanctuaries Division, Silver Spring, MD. 51 pp.

McCullagh, P., and Nelder, J. A. 1989. Generalized linear models. Chapman and Hall. London.

Pattengill-Semmens, C. V. and B. X. Semmens. 1998. Fish census data generated by non-experts in the Flower Garden Banks National Marine Sanctuary. J. Gulf Mexico Sci (2): 196-207.

SAS. 1993. SAS/STAT Software: the GENMOD procedure. SAS Technical Report P-243. SAS Institute Inc. SAS Campus Drive, Cary, NC 27513. 88 pp.

Sadovy, Y. and A-M. Eklund 1999. Synopsis of biological data on the Nassau grouper, *Epinephelus striatus* (Bloch, 1792), and the jewfish, *E. itajara* (Lichtenstein, 1822). NOAA Tech. Report NMFS 146. 65 p.

Southeast Data, Assessment and Review (SEDAR). 2003. Goliath grouper data workshop report. Gulf of Mexico Fishery Management Council. 10 p.

Smith, G. B. 1976. Ecology and distribution of eastern Gulf of Mexico reef fishes. Fla. Mar. Res. Publ. No. 19. 78 pp.

Table 1. Sites in the Reef Education and Environmental Foundation database used for this analysis, with the number of surveys conducted at each site between 1994 and 2002 and the total number of goliath grouper observed (observations of "2 or more" were counted as 2).

Location	REEF Geozone	Number of goliath grouper	Number of surveys	Number of years
Juno Ledge	33010005	2	15	7
Opal Tower	33010038	4	47	6
Delray Ledge	33010042	2	15	6
Anchor Chain	34030001	1	152	9
South Ledge	34030003	1	117	9
Grecian Rocks	34030004	2	295	9
Key Largo Dry Rocks	34030005	1	296	9
Carysfort Reef	34030006	1	145	8
South Carysfort Reef	34030007	1	75	8
French Reef	34030008	3	374	9
Molasses Reef	34030009	24	942	9
Benwood Wreck	34030011	7	172	9
City of Washington	34030014	3	134	9
Horseshoe Reef	34030018	9	67	9
NN Dry Rocks	34030023	1	175	9
The Elbow	34030031	4	82	9
Alligator Reef	34040002	1	131	6
Conch Reef	34040004	4	207	9
Tennesse Reef	34040008	2	93	7
Sombrero Reef	34050001	6	192	9
Samantha's Ledge	34050002	2	113	8
Looe Key Reef East	34050005	10	183	7
Looe Key Reef	34050006	5	75	7
Western Sambo	34080001	9	297	9
Eastern Sambo	34080002	6	108	8
Rock Key	34080003	3	129	9
Sand Key	34080004	2	195	9
Middle Sambo	34080005	1	99	8
Western Dry Rocks	34080018	1	123	7
Texas Rock	34100004	7	100	7
Pulaski	34100005	2	76	6
Windjammer site	34100015	11	22	6

Table 2. Relative standardized count index for goliath grouper from two diver surveys in southern Florida waters.

YEAR	RELATIVE INDEX	LCI	UCI	CV
		DeMaria survey		
1982	4.43	2.30	8.51	0.34
1983	0.99	0.50	1.96	0.35
1984	0.87	0.47	1.61	0.32
1985	0.45	0.26	0.78	0.29
1986	0.23	0.12	0.44	0.33
1987	0.19	0.09	0.40	0.37
1988	0.35	0.18	0.69	0.35
1989	0.13	0.06	0.27	0.40
1990	0.22	0.09	0.53	0.45
1991	0.27	0.12	0.62	0.44
1992				
1993	1.18	0.40	3.43	0.58
1994	1.13	0.54	2.34	0.38
1995	0.89	0.47	1.69	0.33
1996	0.77	0.42	1.38	0.30
1997	1.52	0.76	3.07	0.36
1998	1.83	0.80	4.14	0.43
1999	0.91	0.47	1.76	0.34
2000	0.41	0.15	1.11	0.53
2001	1.63	0.83	3.20	0.35
2002	1.63	0.77	3.43	0.39
		REEF survey		
1994	0.26	0.04	0.49	0.46
1995	0.00	0.00	0.01	0.46
1996	0.25	0.00	0.81	0.99
1997	0.95	0.38	1.64	0.30
1998	1.51	0.69	2.47	0.26
1999	0.93	0.32	1.57	0.32
2000	2.02	1.14	2.86	0.19
2001	1.31	0.77	1.83	0.19
2002	1.77	1.14	2.41	0.16

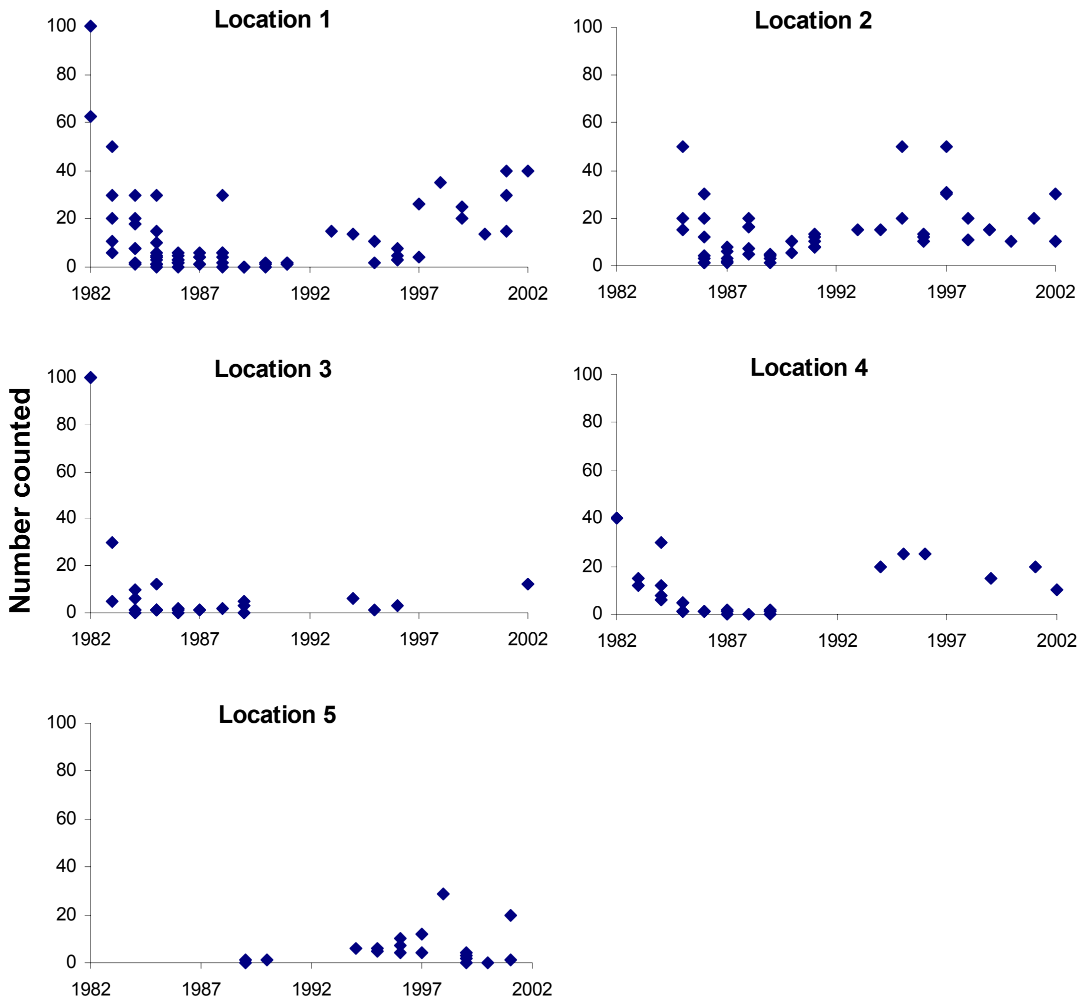


Figure 1. Number of goliath grouper observed at each of five artificial reefs in the eastern Gulf of Mexico, from 1982 to 2002.

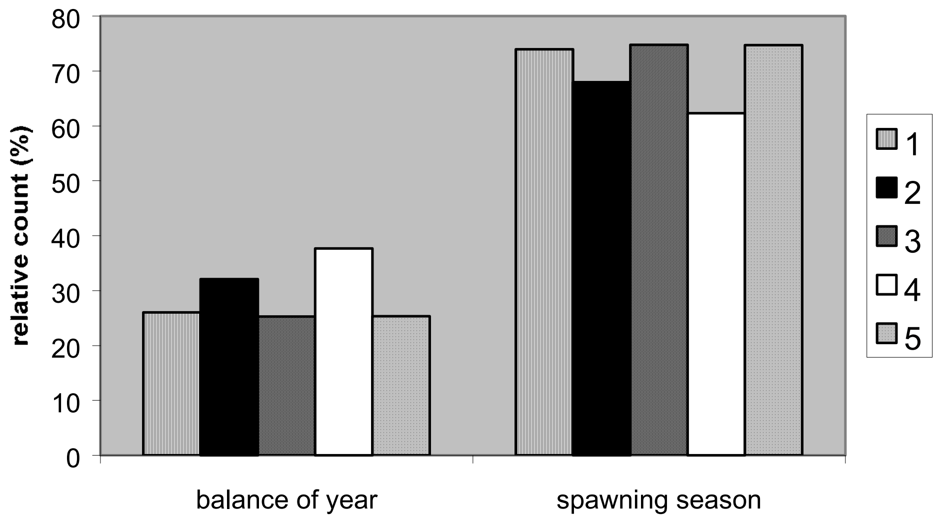


Figure 2. Relative number of goliath grouper counted during and outside the spawning season, broadly represented from June-October, each of five artificial reefs in the eastern Gulf of Mexico from 1982-2002. Only those years (N=5) that had observations in both seasons were included.

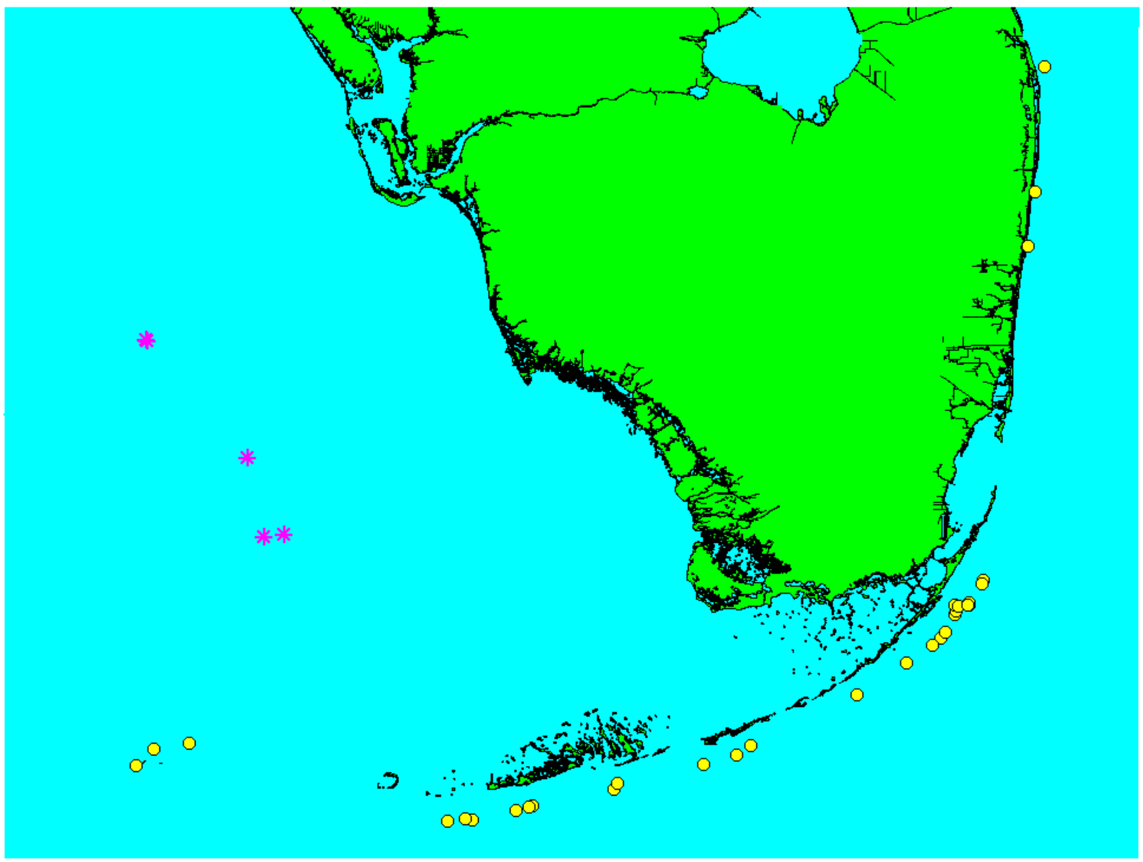


Figure 3. Survey locations for two diver censuses: * = artificial structures in the eastern Gulf of Mexico where goliath grouper were observed from 1982-2002; o = locations where the Reef Education and Environmental Foundation's volunteer divers observed goliath grouper from 1994-2002.

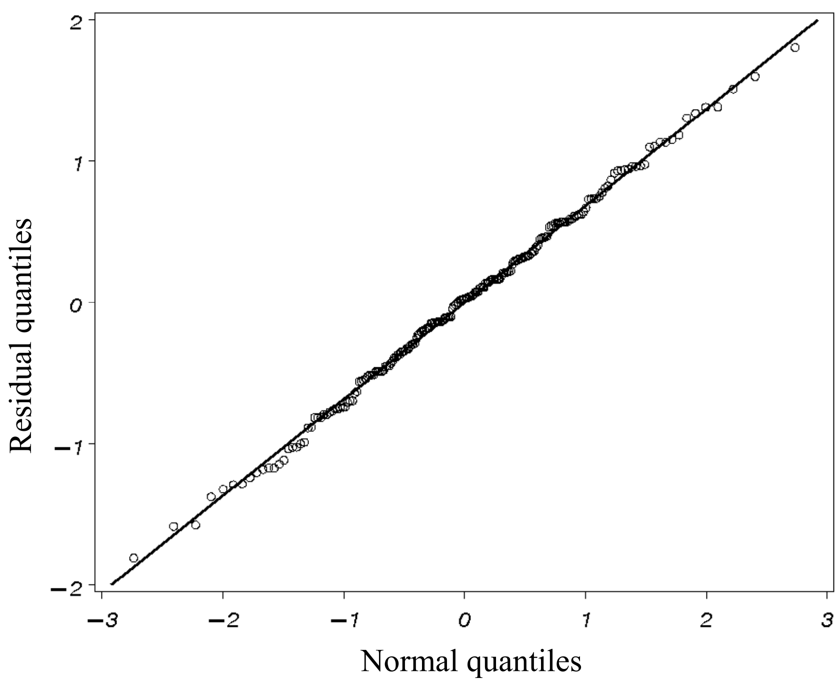


Figure 4. Quantile-quantile plot of the residuals from the GLM fit to the DeMaria count data (circles) compared with a normal distribution with mean zero and standard error 0.685 (line).

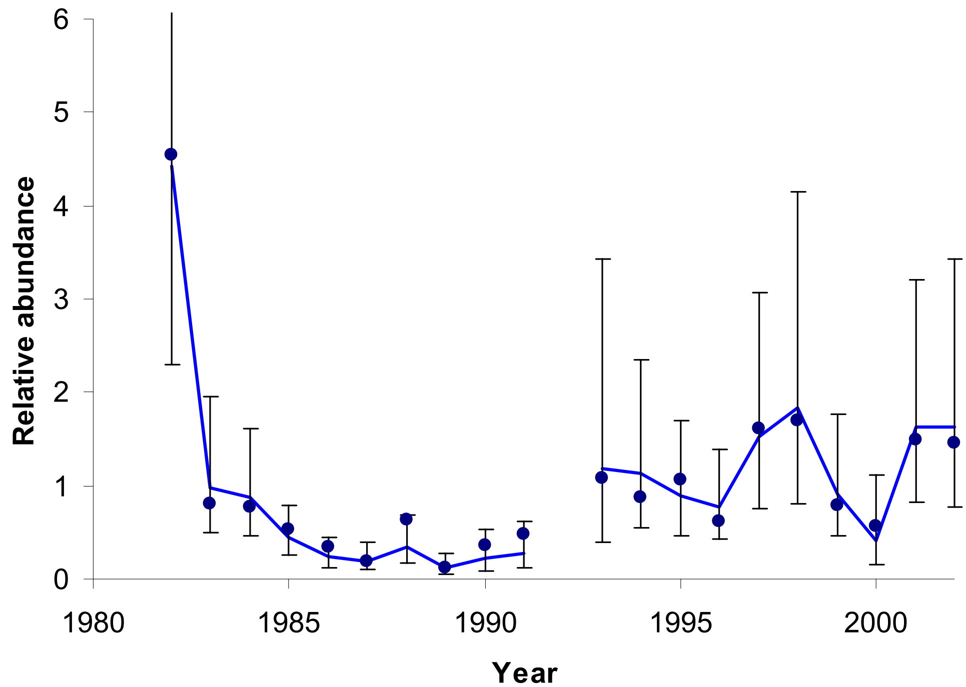


Figure 5. Relative standardized counts of goliath grouper (line) with approximate 95% confidence intervals compared with the corresponding nominal index (circles) from Captain DeMaria's logbook of goliath grouper observations at four artificial structures in the eastern Gulf of Mexico from 1982-2002.

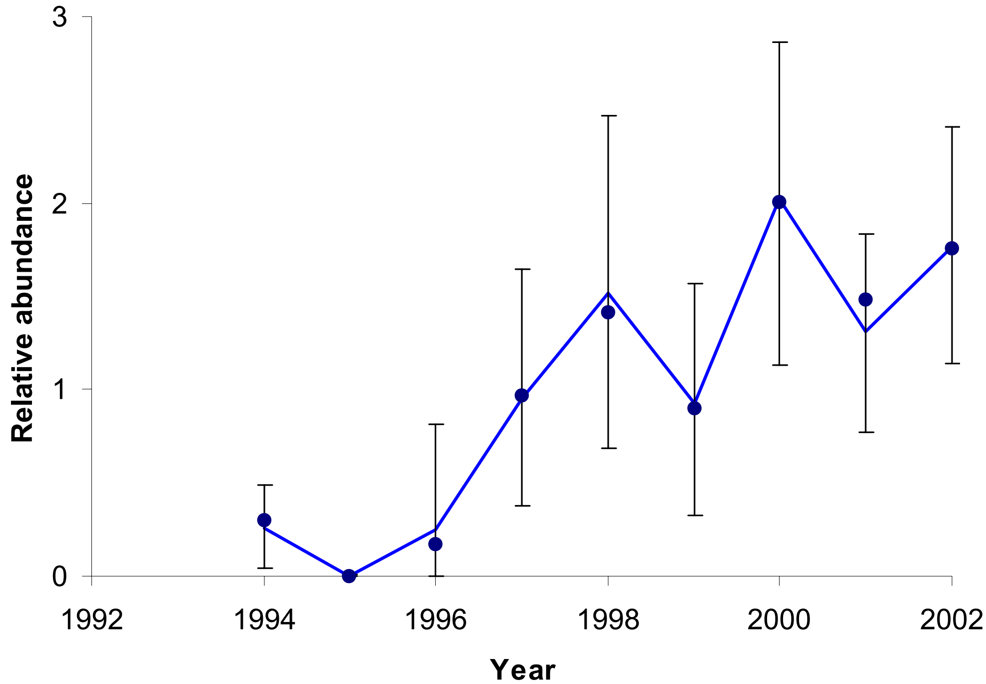


Figure 6. Relative standardized counts of goliath grouper (line) with approximate 95% confidence intervals compared with the corresponding nominal index (circles) from the REEF database of diver observations of goliath grouper in Florida, U.S.A., from 1994-2002.

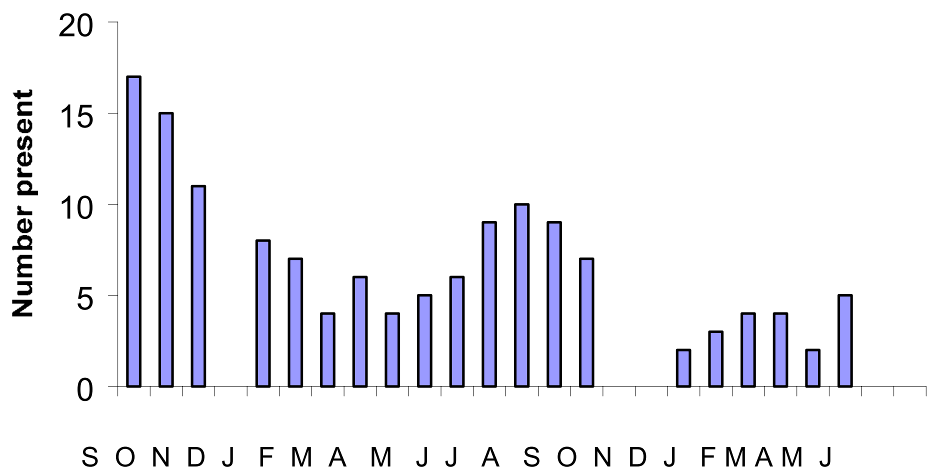


Figure 7. Number of acoustic-tagged goliath grouper detected each month on the Baja California wreck in the eastern Gulf of Mexico (September 2000 to June 2002).

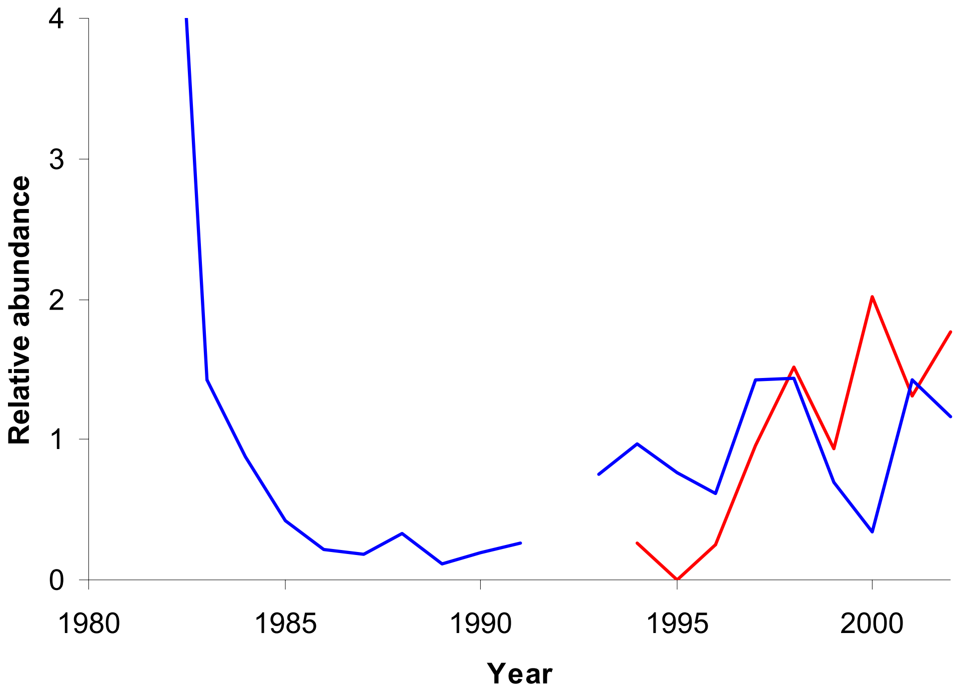


Figure 8. Comparison of standardized counts of goliath grouper from DeMaria's logbook and the REEF database normalized to the 1994-2002 means. Note that both indices are presented relative to their respective annual means. The number of goliath grouper counted on the DeMaria sites is typically an order of magnitude greater than on most of the REEF sites.

STANDARDIZED CATCH RATES OF JUVENILE GOLIATH GROUPER, *EPINEPHELUS ITAJARA*, FROM THE EVERGLADES NATIONAL PARK CREEL SURVEY, 1973-1999

by

Shannon L. Cass-Calay[1] and Thomas W. Schmidt[2]

[1]National Marine Fisheries Service, Southeast Fisheries Science Center,
Sustainable Fisheries Division, 75 Virginia Beach Drive, Miami, FL, 33149-1099, USA
Shannon.Calay@noaa.gov

[2]National Park Service, South Florida Ecosystem Office,
950 North Krome Avenue, 3rd Floor. Homestead, FL 33030
Tom_Schmidt@nps.gov

Sustainable Fisheries Division Contribution SFD-2003-0016

ABSTRACT

Juvenile goliath grouper (*Epinephelus itajara;* Lichtenstein, 1822) are generally found in shallow mangrove habitat. Their historical center of abundance is the Ten Thousand Islands area of southwest Florida. Detailed catch and effort data are available from this region from 1973-1999. The data were collected by Everglades National Park (ENP) during voluntary dockside interviews of sport fishermen. Interviewers record landings and releases. Using this data, a standardized index of abundance was created for juvenile goliath grouper. The delta-lognormal index was constructed by combining two general linear models, a binomial model fit to the proportion of positive trips, and a lognormal model fit to catch rates. As expected, the index shows a substantial decline in abundance during the late 1970s and early 1980s. Since that time, recovery is evident. Relative abundance is very high in 1995 and 1996, suggesting that strong year classes have recently occurred in ENP. These results support recent anecdotal reports of increasing populations of goliath grouper in U.S. waters.

INTRODUCTION

Goliath grouper occur in tropical areas of the western Atlantic Ocean, from Florida south to Brazil, including the Gulf of Mexico and the Caribbean Sea (Heemstra and Randall, 1993). They are the largest of the western north Atlantic groupers, reaching a size of 2.0 to 2.5 m TL (Heemstra and Randall 1993) and 320 kg (Smith, 1971). Adults are typically found in shallow, inshore waters at depths less than 40 m (Sadovy and Eklund, 1999). They generally occupy limited home ranges near areas of refuge such as caves, shipwrecks, and rocky ledges (Nagelkerken, 1981). Goliath grouper are slow to mature and long-lived. According to Bullock et al. (1992) females reach sexual maturity at 1.2 to 1.35 m TL and 6-7 years of age while males are often mature at 1.15 m TL and 5-6 years of age. The maximum recorded age from an exploited population of goliath grouper is 37 years (Bullock et al., 1992).

Goliath grouper may be unusually susceptible to overfishing due to their unwary behavior, conspicuous size, apparent site specificity and relatively long life span. Inshore populations began to decline in the 1950s, likely due to fishing on spawning aggregations and spearfishing of adults (Sadovy and Eklund, 1999). During the late 1970s and 1980s, fishing effort on goliath increased rapidly, while subsequent catches decreased. By 1989, substantial reductions in the number and size of spawning aggregations were noted (DeMaria[1]; Sadovy and Eklund, 1999). These observations led to strict regulatory measures. In 1990, the Gulf of Mexico Fisheries Management Council (GMFMC) prohibited the landing of goliath grouper in Gulf of Mexico federal waters (GMFMC, 1990). Identical moratoria were enacted in 1990 by the South Atlantic Fisheries Management Council (SAFMC) and the State of Florida. In 1993, the Caribbean Fisheries Management Council (CFMC) and the territorial government of the U.S. Virgin Islands expanded the moratorium to federal and territorial waters of the U.S. Caribbean.

Recent anecdotal reports from U.S. fishers and divers suggest that goliath grouper populations are increasing in U.S. waters. Due, in part, to these reports, in 2003, the GMFMC requested an assessment of goliath grouper to develop estimates of current status and recovery time. The assessment was completed at the NOAA Fisheries Southeast Fisheries Science Center, Miami Laboratory, and is described by Porch et al. (2003). This effort required the development of at least one index of abundance. This document summarizes the creation of one such index, a standardized index of abundance for juvenile goliath grouper. Additional indices developed for the 2003 assessment of goliath grouper are reported in Porch and Eklund (2003).

The current center of abundance for Gulf populations of goliath grouper is the Ten Thousand Islands area of southwestern Florida (Sadovy and Eklund, 1999). Here, extensive estuarine, and swamp mangrove habitats exist, ideal for juvenile goliath grouper (Bullock and Smith, 1991). The Ten Thousand Islands area is located near Chokoloskee and Everglades City, Florida, and is predominantly contained within the borders of Everglades National Park (ENP; Fig. 1). Thus, fisheries data provided by the park may be useful for the development of a standardized abundance index of juvenile goliath grouper.

ENP was established in 1947, and is located in southern Florida. Systematic collection of fisheries data commenced within the park in 1958 (Davis and Thue, 1979). The evolution of the monitoring procedures are detailed by Davis and Thue (1979) and Schmidt et al. (2002). During the first ten years (1958-1969) the program was conducted by the University of Miami's Institute of Marine Science, and evaluated only the sport fishery. Estimates of catch and catch per unit effort (CPUE) were recorded only for specific species (not including goliath grouper) landed by sport fishermen operating out of Flamingo. In 1972, the National Park Service expanded the monitoring program to include daily trip ticket reports from commercial permit holders, and park-wide monitoring of sport fishing and commercial catch and effort. At this time, the species list was expanded to include all species typically landed within ENP. Fish length measurements were collected as of 1974 and, in 1980, routine monitoring of the Chokoloskee-Everglades City boat ramps began.

[1] DeMaria, Don. P.O. Box 420975, Summerland Key, FL 33042.

MATERIAL AND METHODS

Data Collection

ENP data were provided by the National Park Service, South Florida Ecosystem Office[2]. Detailed descriptions of ENP data collection and recording formats include Higman (1967), Davis and Thue (1979) and Tilmant et al. (1986). To summarize, sport fishermen are interviewed by ENP personnel at the Flamingo and Chokoloskee-Everglades City boat ramps upon completion of their trip. Data routinely recorded includes trip origin, area fished (Fig. 1), number of fish kept and released by species, number of anglers, hours fished, species preference, angler residence, type of fisherman (skilled, family, novice, sustenance). When possible, fish length measurements are also recorded.

Since 1990, landings of goliath grouper have been prohibited in all U.S. Federal and State of Florida waters. However, goliath grouper continue to be captured and released by sport fishermen in ENP. Therefore, ENP records, which include fish kept and released, can be used to develop a standardized abundance index. For each trip, we calculated catch per unit effort using Eq. 1.

(1) $$CPUE = \frac{Goliath\,Kept + Goliath\,Released}{Anglers * Hours\ Fished}$$

Defining Species Associated with Goliath Grouper

The ENP dataset contains useful information from 165,734 sport fishing trips that took place during 1973-1999. Trips were excluded if essential fields were missing or unfeasible. Commonly landed species include spotted seatrout (*Cynoscion nebulosus*), crevalle jack (*Caranx hippos*) gray snapper (*Lutjanus griseus*) and red drum (*Sciaenops ocellatus*). These species were observed on 44%, 38%, 33% and 28% of the trips, respectively. In contrast, goliath grouper were captured on only 1.8% of the trips. Due to variations in fishing location, depth, bait and gear choice, we believe that many fishing trips that targeted these common species had low probability to capture a goliath grouper. In the absence of detailed and reliable data regarding fishing location, bait choice, etc., we used an association statistic to attempt to identify trips with a higher probability of catching goliath grouper. The association statistic (Eq. 2) was developed

(2) $$Association\ Statistic = \frac{Trips\ with\ Goliath + Species\ X}{Trips\ with\ Goliath} \Bigg/ \frac{Trips\ with\ Species\ X}{Total\ Trips}$$

---

[2] Schmidt, Tom. National Park Service, South Florida Ecosystem Office, 950 North Krome Avenue, 3rd Floor. Homestead, FL 33030

using the species composition of the catch, as proposed by Heinemann[3], and previously described by Cass-Calay and Bahnick (2002). Species preference was rejected as a method to restrict the data for two reasons. First, very few fishermen report targeting goliath grouper since the 1990 moratorium. Second, there is concern that fishermen are less likely to report targeting a species if they failed to land that species.

We calculated the association statistic for all species reported by 100 or more sport fishing trips during 1973-1999. We assumed that a species was associated with goliath grouper if the association statistic was =2.0. If a trip kept or released a goliath grouper, or a species identified as an associate, that trip was included in the dataset used to estimate standardized CPUE.

Index Development

In order to develop a well balanced sample design, it was necessary to construct the following categorical variables. The factor PARTY refers to the skill level of the fishing party. Two levels were considered.

"Skilled" = Fishers identified as "skilled" by ENP.
"Other" = Fishers identified as "family", "novice" or "sustenance" by ENP.

The factor SEASON was constructed from MONTH to create three periods generally reflective of water temperatures and rainfall in the shallow waters of ENP. Those periods were:

MONTH = (Nov, Dec, Jan, Feb) then SEASON = 1
MONTH = (Mar, Apr, May, Jun) then SEASON = 2
MONTH = (Jul, Aug, Sept, Oct) then SEASON = 3

The factor TARGET was defined using the reported species preference. If the species preference listed was goliath grouper, TARGET = "Goliath". If not, TARGET = "Other".

The factor AREA was constructed using the ENP definitions (Fig. 1) with one exception, areas 1 and 2 were combined in order to obtain sufficient observations of goliath grouper. Although the areas were constructed by ENP to delimit different habitats, we felt areas 1 and 2 were sufficiently alike to permit combination.

We used the delta lognormal model approach (Lo et al. 1992) to develop the standardized index of abundance. This method combines separate generalized linear modeling (GLM) analyses of the proportion of successful trips (trips that kept or released a goliath grouper) and the positive catch rates on successful trips to construct a single standardized CPUE index. Parameterization of each model was accomplished using a GLM procedure (GENMOD; Version 8.02 of the SAS System for Windows © 2000. SAS Institute Inc., Cary, NC, USA).

[3] Heinemann, Dennis. The Ocean Conservancy, 1725 DeSales Street, Suite 600, Washington, D.C. 20036

Factors considered as possible influences on the proportion of successful trips included YEAR, SEASON, AREA, PARTY and TARGET. During this GLM procedure, we fit a type-3 model, assumed a binomial error distribution, and selected the logit link. The response variable was proportion positive trips. We examined the same factors during the analysis of catch rates on positive trips. In this case, a type3 model assuming lognormal error distribution was employed. The linking function selected was "normal", and the response variable was ln(CPUE).

For each GLM, we used a stepwise approach to quantify the relative importance of the factors. First the null model was run. These results reflect the distribution of the nominal data. Next we added each potential factor to the null model one at a time, and examined the resulting reduction in deviance per degree of freedom. The factor that caused the greatest reduction in deviance per degree of freedom was added to the base model if the factor was significant based upon a Chi-Square test ($p<0.05$), and the reduction in deviance per degree of freedom was =1%. This model then became the base model, and the process was repeated, adding factors and interactions individually until no factor or interaction met the criteria for incorporation into the final model.

The final delta-lognormal model was fit using a SAS macro, GLIMMIX (glmm800MaOB.sas: Russ Wolfinger, SAS Institute). All factors were modeled as fixed effects except interaction terms containing YEAR (e.g. YEAR*AREA). These were modeled as random effects. To facilitate visual comparison, a relative index and relative nominal CPUE series were calculated by dividing each value in the series by the mean value of the series.

RESULTS AND DISCUSSION

ENP records include length measurements for 420 goliath grouper landed within the park from 1974-2001 (Fig. 2). The mean total length reported is 605 mm (SD±192 mm). Unexpectedly, a secondary mode occurs at 950-1000 mm because ENP technicians record length only to 999 mm. Therefore, all goliath grouper larger than 1 m are included in this length bin (26 of 420 observations). However, as goliath grouper do not mature until they are in excess of 1 m (Bullock et al., 1992), it is apparent that the majority of individuals captured within ENP are juveniles.

Species classified as associates of goliath grouper, and their relevant association statistics are summarized in Table 1. It is important to emphasize that the defined assemblage does not require, or suggest strict biological association. An association statistic equal to 1.0 implies that a given species is captured as frequently in association with goliath grouper as random chance would predict. Values >1.0 indicate that a given species is found more often in association with goliath grouper than expected. The maximum value of the association statistic depends on the rarity of the "target" species. Of the 165,734 interviewed trips, 14,026 landed goliath grouper, or a species with an association statistic =2.0. Only these trips were included in the data set used to develop the standardized index of abundance.

The stepwise construction of the binomial model of the probability of catching goliath grouper is summarized in Table 2. The final model was ***PROPORTION POSITIVE TRIPS =***

TARGET + YEAR. Annual variations in the proportion of positive trips are shown in Figure 3. From 1973-1981, approximately 26% of the sport fishing trips included in the analysis reported the capture of one or more goliath grouper. This percentage declined to ~12% from 1982-1992. During the most recent years, 1993-1999, substantial recovery is noted. During this period, ~26% of trips included in the analysis captured goliath. Diagnostic plots were examined to evaluate the fit of the binomial model. The distribution of the chi-square residuals (Fig. 4) indicates an acceptable fit, although some outliers were noted. These occurred in strata containing few observations, and were not unexpected. The frequency distribution of the proportion of positive trips, by year and target was also acceptable (Fig. 5).

The stepwise construction of the lognormal model of catch rates on positive trips is summarized in Table 3. The final model was ***ln(CPUE) = YEAR + PARTY + AREA + YEAR*AREA.*** Annual values of nominal CPUE on positive trips are shown in Figure 6. CPUE was lowest during the 1980s and early 1990s. A rapid increase in nominal CPUE occurs after 1993 with the highest catch rates on record occurring during 1995 and 1996. Diagnostic plots created to assess the fit of the lognormal model were acceptable. The residuals were distributed evenly around zero (Fig. 7), although the range was narrower during the middle of the time series. This is due, in part, to substantially fewer "positive" trips during those years. Also as expected, the frequency distribution of ln(CPUE), by year, party and area, approximated a normal distribution (Fig. 8). In summary, all diagnostic plots met our expectations, and supported an acceptable fit to the selected models.

The delta-lognormal abundance index, with 95% confidence intervals, is shown in Figure 9. To allow quick visual comparison with the nominal values, both series were scaled to their respective means. The index statistics can be found in Table 4. No index estimate was possible for the year 1974 because only one positive trip was reported. The standardized abundance index is quite similar to the nominal CPUE series. These results suggest that within ENP, captures of juvenile goliath grouper have increased substantially since 1992, and that one or more large year classes were present during 1995 and 1996.

LITERATURE CITED

Bullock L. H. and G. B. Smith. 1991. Seabasses (Pices: Serranidae). Memoirs of the hourglass cruises. 8(2), 243 p.

Bullock, L. H. M. D. Murphy, M. F. Godcharles, and M. E. Mitchell. 1992. Age, growth and reproduction of jewfish, Epinephelus itajara in the eastern Gulf of Mexico. Fish. Bull. 90:243-249.

Cass-Calay, S. L. and M. Bahnick. 2002. Status of the yellowedge grouper fishery in the Gulf of Mexico: Assessment 1.0. Sustainable Fisheries Division Contribution SFD-02/03-172. Southeast Fisheries Science Center, 75 Virginia Beach Drive, Miami, Florida 33149.

Davis, G. E. and E. B. Thue. 1979. Fishery data management handbook. Rept. T-546. Everglades National Park, SFRC, P. O. Box 279, Homestead, FL. 33030.

GMFMC. 1990. Amendment Number 2 to the Fishery Management Plan for the Reef Fish Fishery of the Gulf of Mexico. Tampa, Florida.

Heemstra, P. C. and J. E. Randall. 1993. FAO species catalog: Groupers of the world (Family Serranidae, Subfamily Epinephelinae). An annotated and illustrated catalogue of the grouper, rockcod, hind, coral grouper and lyretail species known to date. FAO Fisheries Synopsis 16(125), 382 p.

Higman, H. B. 1967. Relationships between catch rates of sport fish and environmental conditions in Everglades National Park, Florida. Proc. Gulf Carib. Fish. Inst. 19:129-140.

Lichtenstein, M. G. G. 1822. Die Werke von Marcgrave und Piso uber die Naturgeschichte Brasiliens, erlautert aus den wieder aufgefundenen Originalzeichnungen. Abbildungen. IV. Fische. Abh. K. Akad. Wiss. Berlin (1820-1821): 267-288.

Lo, N.C., L.D. Jackson, J.L. Squire. 1992. Indices of relative abundance from fish spotter data based on delta-lognormal models.

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

Porch, C. E., and Eklund, A-M. 2003. Standardized visual counts of Goliath grouper off South Florida and their possible use as indices of abundance. Sustainable Fisheries Division Contribution SFD-2003-0017. Southeast Fisheries Science Center, 75 Virginia Beach Drive, Miami, Florida 33149.

Porch, C. E., A-M.. Eklund and G. P. Scott. 2003. An assessment of rebuilding times for goliath grouper. Sustainable Fisheries Division Contribution No. SFD-2003-0018. Southeast Fisheries Science Center, 75 Virginia Beach Drive, Miami, Florida 33149.

Sadovy, Y. and A-M. Eklund 1999. Synopsis of biological data on the Nassau grouper, Epinephelus striatus (Bloch, 1792), and the jewfish, E. itajara (Lichtenstein, 1822). NOAA Tech. Report NMFS 146. 65 p.

Schmidt, T. W., J. Osborne, J. Kalafarski, and C. Greene. 2002. Year 2001 annual fisheries report, Everglades National Park. USNPS/ SFNRC/ENP, 40001 State Road 9336, Homestead, FL 33034 (Online at http://www.nps.gov/ever/current/fisheries_report_2001.pdf)

Smith, C. L. 1971. A revision of the American groupers: Epinephelus and allied genera. Bull. Amer. Mus. Nat. Hist. 146:69-241.

Tilmant, J. T., E. S. Rutherford, R. H. Dawson, and E. B. Thue. 1986. Impacts of gamefish harvest in Everglades National Park. Pro. Conf. Sci. in Nat'l Parks. pp. 75-103.

.

Table 1. Results of the calculations used to identify species associated with goliath grouper. Species were assumed to be associated with goliath grouper if the association statistic was ≥ 2.0. Shaded rows indicate associated species.

Species X Common Name	Species X Scientific name	ENP Species Code	Trips with Goliath and Species X	Trips with Species X	Assoc. Stat.
Goliath grouper	*Epinephelus itajara*	8815	2988	2988	55.47
Schoolmaster	*Lutjanus apodus*	5804	15	110	7.56
Nurse shark	*Ginglymostoma cirratum*	6901	106	976	6.02
Misc Sawfishes	Pristidae	8000-8002	7	69	5.63
Bull Shark	*Carcharhinus leucas*	1905	14	141	5.51
Gag	*Mycteroperca microlepis*	8837	270	2846	5.26
Misc. Serranids	Serranidae	8800	246	3799	3.59
Cobia	*Rachycentron canadum*	8101	53	864	3.40
Black grouper	*Mycteroperca bonaci*	8835	34	555	3.40
Toadfish	Batrachoididae	1200	12	205	3.25
Misc Mullets	Mugilidae	6100	26	478	3.02
Mutton snapper	*Lutjanus analis*	5803	7	139	2.79
Lane snapper	*Lutjanus synagris*	5811	30	619	2.69
Permit	*Trachinotus falcatus*	1823	19	500	2.11
Tripletail	*Lobotes surinamensis*	5601	45	1250	2.00
Atlantic spadefish	*Chaetodipterus faber*	4101	2	57	1.95
Gray snapper	*Lutjanus griseus*	5808	1732	53999	1.78
Blacktip Shark	*Carcharhinus limbatus*	1906	113	3634	1.72
Greater amberjack	*Seriola dumerili*	1818	2	65	1.71
Unid. Cichlid spp.	Cichlidae	2413	9	296	1.69
Red Grouper	*Epinephelus morio*	8816	12	401	1.66
Snook	*Centropomus undecimalis*	2204	794	26953	1.63
Lookdown	*Selene vomer*	1817	3	102	1.63
Misc. Stingrays	Dasyatididae	3500	53	1849	1.59
Spanish mackerel	*Scomberomorus maculatus*	8611	123	4316	1.58
Tarpon	*Megalops atlanticus*	3902	118	4431	1.48
Misc. Sea catfish	Ariidae	800	223	8908	1.39
Oscar	*Astronotus ocellatus*	2402	4	165	1.34
Lemon shark	*Negaprion brevirostris*	1917	7	291	1.33
Bluestriped grunt	*Haemulon sciurus*	7714	15	628	1.32
Misc. Snappers	Lutjanidae	5800	23	1007	1.27
Misc. L/E Flounders	Bothidae	1500	49	2156	1.26
Misc. Jacks and Pompanos	Carangidae	1800	12	537	1.24
Gafftopsail catfish	*Bagre marinus*	802	422	18948	1.24
Sheepshead	*Archosargus probatocephalus*	9001	528	23734	1.23
Black drum	*Pogonias cromis*	8521	266	12016	1.23
Bluefish	*Pomatomus saltatrix*	7801	19	869	1.21
Stone crab	*Minippe mercenaria*	2740	2	94	1.18
Red drum	*Sciaenops ocellatus*	8522	962	46478	1.15

Table 1. (continued)

Misc. Porgies	Sparidae	9000	3	146	1.14
Blue runner	*Caranx crysos*	1803	30	1474	1.13
Southern flounder	*Paralichthys lethostigma*	1522	5	254	1.09
Misc Gars	Lepisosteidae	5500	2	102	1.09
Pufferfish	Tetradontidae	9600	113	6032	1.04
Crevalle jack	*Caranx hippos*	1804	1134	62923	1.00
Pinfish	*Lagodon rhomboides*	9012	45	2522	0.99
Sea catfish	*Arius felis*	801	793	45349	0.97
Great hammerhead	*Sphyrna mokarran*	9202	7	406	0.96
Great barracuda	*Sphyraena barracuda*	9101	29	1706	0.94
Misc Grunts	Haemulidae	7700	64	3934	0.90
Misc. remoras	Echeneidae	3700	3	191	0.87
Ladyfish	*Elops saurus*	3901	614	39494	0.86
Spiny lobster	*Panulirus argus*	1211	1	65	0.85
Lizardfishes	Synodontidae	9500	26	1693	0.85
Southern puffer	*Sphoeroides nephelus*	9606	4	262	0.85
Misc. Requiem Sharks	Carcharhinidae	1900	83	5578	0.83
Florida pompano	*Trachinotus carolinus*	1822	19	1349	0.78
Spotted Seatrout	*Cynoscion nebulosus*	8506	1030	73709	0.78
Yellowtail snapper	*Ocyurus chrysurus*	5813	3	215	0.77
Bonnethead	*Sphyrna tiburo*	9203	53	3923	0.75
Cichlids	Cichlidae	2400	1	83	0.67
Grass porgy	*Calamus arctifrons*	9003	1	86	0.64
Blue crab	*Callinectes sapidus*	2532	33	3278	0.56
Leatherjacket	*Oligoplites saurus*	1815	1	106	0.52
Cero	*Scomberomorus regalis*	8612	1	108	0.51
White mullet	*Mugil curema*	6103	2	221	0.50
Misc. Needlefish	Belonidae	1300	3	339	0.49
Inshore lizardfish	*Synodus foetens*	9504	2	263	0.42
Sand seatrout	*Cynoscion arenarius*	8505	7	946	0.41
Sailors choice	*Haemulon parra*	7712	1	143	0.39
Silver perch	*Bairdiella chrysura*	8503	1	156	0.36
Largemouth bass	*Micropterus salmoides*	2126	7	1389	0.28
Gulf kingfish	*Menticirrhus littoralis*	8517	2	462	0.24
Sand perch	*Diplectrum formosum*	8810	3	912	0.18
Striped mullet	*Mugil cephalus*	6102	1	466	0.12
Pigfish	*Orthopristis chrysoptera*	7716	0	129	0.00
Yellow jack	*Caranx bartholomaei*	1802	0	85	0.00
Florida gar	*Lepisosteus platyrhincus*	5504	0	79	0.00
Bonefish	Abulidae	200/201	0	61	0.00
Misc. Hammerhead sharks	Sphyrnidae	9200, 9204, 9201	0	61	0.00

Table 2. A summary of formulation of the binomial model. Factors were added to the model if PROBCHISQ < 0.05 and %REDUCTION in DEV/DF = 1.0% (bold blue font). The final model was SUCCESS = TARGET + YEAR.

There are no explanatory factors in the base model.

FACTOR	DEGF	DEVIANCE	DEV/DF	%REDUCTION	LOGLIKE	CHISQ	PROBCHISQ
BASE	13556	14287.7	1.0540		-7143.9		
SEASON	13554	14191.8	1.0471	0.66	-7095.9	95.95	0.00000
PARTY	13555	14170.7	1.0454	0.81	-7085.3	117.06	0.00000
AREA	13552	14151.5	1.0442	0.92	-7075.8	136.22	0.00000
YEAR	13531	13777.3	1.0182	3.39	-6888.6	510.45	0.00000
TARGET	13555	13473.4	0.9940	5.69	-6736.7	814.34	0.00000

The explanatory factors in the base model are: TARGET

FACTOR	DEGF	DEVIANCE	DEV/DF	%REDUCTION	LOGLIKE	CHISQ	PROBCHISQ
BASE	13555	13473.4	0.9940		-6736.7		
SEASON	13553	13417.1	0.9900	0.40	-6708.6	56.28	0.00000
PARTY	13554	13379.4	0.9871	0.69	-6689.7	93.99	0.00000
AREA	13551	13366.6	0.9864	0.76	-6683.3	106.80	0.00000
YEAR	13530	12885.0	0.9523	4.19	-6442.5	588.38	0.00000

The explanatory factors in the base model are: TARGET YEAR

FACTOR	DEGF	DEVIANCE	DEV/DF	%REDUCTION	LOGLIKE	CHISQ	PROBCHISQ
BASE	13530	12885.0	0.9523		-6442.5		
SEASON	13528	12845.6	0.9496	0.29	-6422.8	39.39	0.00000
PARTY	13529	12834.4	0.9487	0.39	-6417.2	50.65	0.00000
AREA	13526	12803.9	0.9466	0.60	-6401.9	81.13	0.00000

The explanatory factors in the base model are: TARGET YEAR

FACTOR	DEGF	DEVIANCE	DEV/DF	%REDUCTION	LOGLIKE	CHISQ	PROBCHISQ
BASE	13530	12885.0	0.9523		-6442.5		
YEAR*TARGET	13509	12837.5	0.9503	0.21	-6418.7		

Table 3. A summary of formulation of the lognormal model. Factors were added to the model if PROBCHISQ < 0.05 and %REDUCTION in DEV/DF = 1.0% (bold blue font). The final model was log(CPUE) = YEAR + PARTY + AREA +YEAR*AREA.

There are no explanatory factors in the base model.

FACTOR	DEGF	DEVIANCE	DEV/DF	%REDUCTION	LOGLIKE	CHISQ	PROBCHISQ
BASE	2982	1641.8	0.5506		-3342.0	.	.
TARGET	2981	1641.6	0.5507	-0.02	-3341.9		
SEASON	2980	1633.1	0.5480	0.49	-3334.1	15.78	0.00037
PARTY	2981	1606.2	0.5388	2.16	-3309.4	65.32	0.00000
AREA	2978	1593.9	0.5352	2.81	-3297.9	88.31	0.00000
YEAR	2957	1569.2	0.5307	3.63	-3274.6	134.78	0.00000

The explanatory factors in the base model are: YEAR

FACTOR	DEGF	DEVIANCE	DEV/DF	%REDUCTION	LOGLIKE	CHISQ	PROBCHISQ
BASE	2957	1569.2	0.5307		-3274.6		
TARGET	2956	1563.1	0.5288	0.35	-3268.8	11.59	0.00066
SEASON	2955	1561.0	0.5283	0.46	-3266.8	15.70	0.00039
AREA	2953	1543.2	0.5226	1.53	-3249.7	49.97	0.00000
PARTY	2956	1544.6	0.5225	1.54	-3251.0	47.19	0.00000

The explanatory factors in the base model are: YEAR PARTY

FACTOR	DEGF	DEVIANCE	DEV/DF	%REDUCTION	LOGLIKE	CHISQ	PROBCHISQ
BASE	2956	1544.6	0.5225		-3251.0		
TARGET	2955	1541.4	0.5216	0.17	-3248.0	6.11	0.01348
SEASON	2954	1538.1	0.5207	0.36	-3244.7	12.67	0.00177
AREA	2952	1518.6	0.5144	1.55	-3225.7	50.68	0.00000

The explanatory factors in the base model are: YEAR PARTY AREA

FACTOR	DEGF	DEVIANCE	DEV/DF	%REDUCTION	LOGLIKE	CHISQ	PROBCHISQ
BASE	2952	1518.6	0.5144		-3225.7		
SEASON	2950	1514.0	0.5132	0.24	-3221.2	9.04	0.01089
TARGET	2951	1514.5	0.5132	0.24	-3221.6	8.11	0.00441

The explanatory factors in the base model are: YEAR PARTY AREA

FACTOR	DEGF	DEVIANCE	DEV/DF	%REDUCTION	LOGLIKE	CHISQ	PROBCHISQ
BASE	2952	1518.6	0.5144		-3225.7		
AREA*PARTY	2948	1509.1	0.5119	0.49	-3216.4	18.69	0.00090
YEAR*PARTY	2833	1443.4	0.5095	0.95	-3150.0		
YEAR*AREA	2858	1453.6	0.5086	1.13	-3160.5	130.48	0.00765

The explanatory factors in the base model are: YEAR PARTY AREA YEAR*AREA

FACTOR	DEGF	DEVIANCE	DEV/DF	%REDUCTION	LOGLIKE	CHISQ	PROBCHISQ
BASE	2858	1453.6	0.5086		-3160.5		
YEAR*PARTY	2833	1443.4	0.5095	-0.17	-3150.0		
AREA*PARTY	2854	1449.1	0.5077	0.17	-3155.8	9.30	0.05398

Table 4. The relative nominal CPUE, proportion positive trips, relative abundance index, and confidence intervals and coefficients of variance associated with the relative abundance index for juvenile goliath grouper captured in Everglades National Park, 1973-1999.

YEAR	Relative Nominal CPUE	Positive Trips	Proportion Positive Trips	Relative Index	Lower 95% CI (Index)	Upper 95% CI (Index)	CV (index)
1973	1.049	109	0.311429	1.112	0.852	1.451	0.134
1974	N/A	1	0.002	N/A	N/A	N/A	N/A
1975	0.757	106	0.187611	0.937	0.700	1.254	0.147
1976	1.354	189	0.319797	1.386	1.112	1.726	0.110
1977	1.306	186	0.309484	1.184	0.950	1.474	0.110
1978	1.349	150	0.268817	1.276	0.993	1.640	0.126
1979	1.000	66	0.226804	0.966	0.677	1.379	0.179
1980	1.341	117	0.259424	1.107	0.847	1.447	0.134
1981	0.994	93	0.216783	0.816	0.599	1.111	0.155
1982	0.698	53	0.119639	0.623	0.409	0.948	0.212
1983	0.609	66	0.142857	0.719	0.500	1.033	0.183
1984	0.646	60	0.149626	0.785	0.532	1.157	0.196
1985	0.478	35	0.104478	0.542	0.322	0.913	0.265
1986	0.434	38	0.101333	0.525	0.315	0.874	0.259
1987	0.349	30	0.089552	0.437	0.249	0.766	0.287
1988	0.420	31	0.113139	0.578	0.346	0.966	0.261
1989	0.597	73	0.182957	0.705	0.494	1.005	0.179
1990	0.481	60	0.117188	0.675	0.467	0.973	0.185
1991	0.507	50	0.121655	0.795	0.536	1.180	0.199
1992	0.525	65	0.134298	0.819	0.583	1.152	0.172
1993	0.676	99	0.162562	0.879	0.661	1.170	0.144
1994	1.341	240	0.269663	1.354	1.118	1.641	0.096
1995	2.259	210	0.320611	1.897	1.572	2.289	0.094
1996	2.489	329	0.339876	1.875	1.579	2.226	0.086
1997	1.604	246	0.265946	1.513	1.248	1.835	0.096
1998	1.304	146	0.223926	1.232	0.979	1.551	0.116
1999	1.433	136	0.230118	1.263	0.999	1.597	0.118

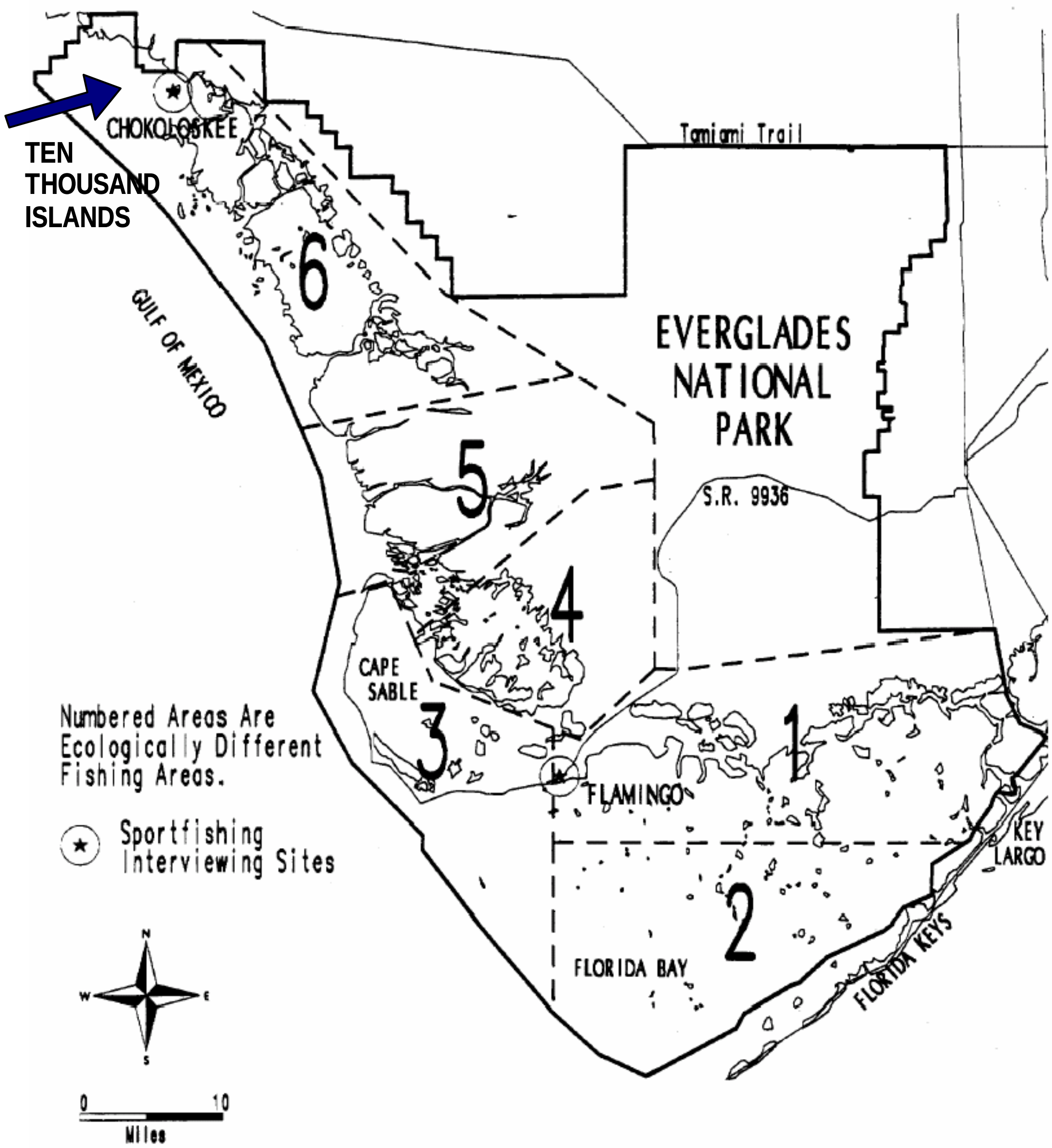


Figure 1. A map of Everglades National Park depicting the defined fishing areas. The Ten Thousand Islands area is located to the northwest, within Area 6. (Reprinted from Schmidt et al. 2002).

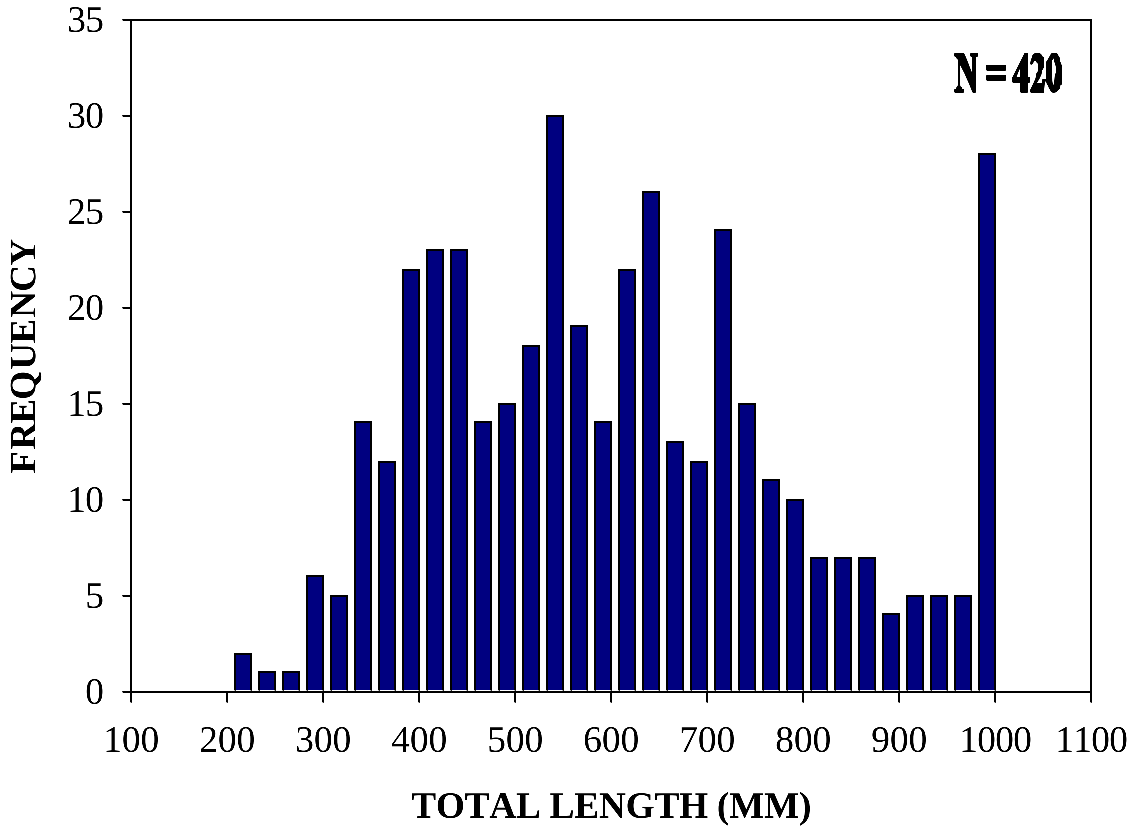


Figure 2. The length frequency distribution of goliath grouper captured in ENP from 1974-2001.

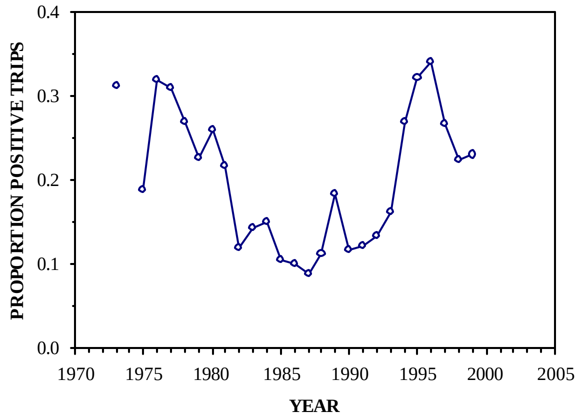


Figure 3. The proportion of positive trips (trips that kept or released a goliath grouper), by year.

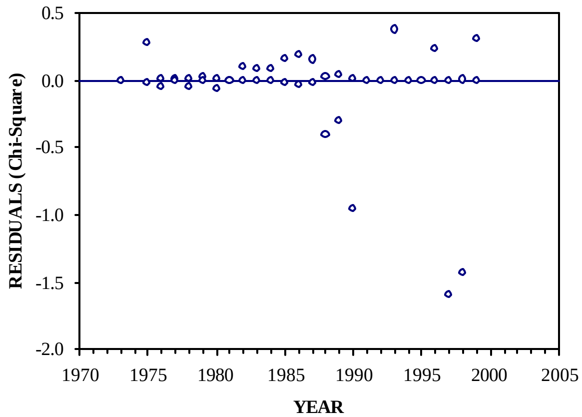


Figure 4. Chi-square residuals for binomial model on proportion positive trips, by year and target.

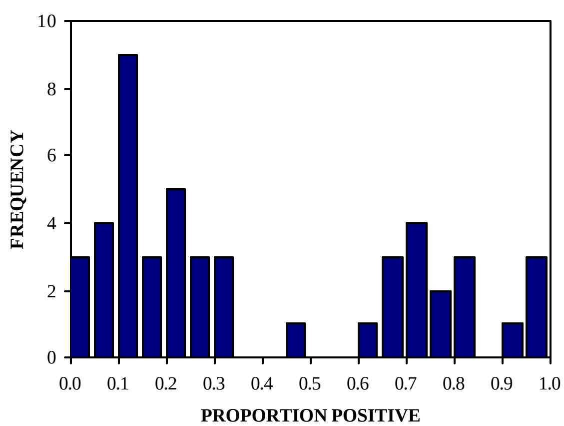


Figure 5. Frequency distribution of proportion positive trips by year and target.

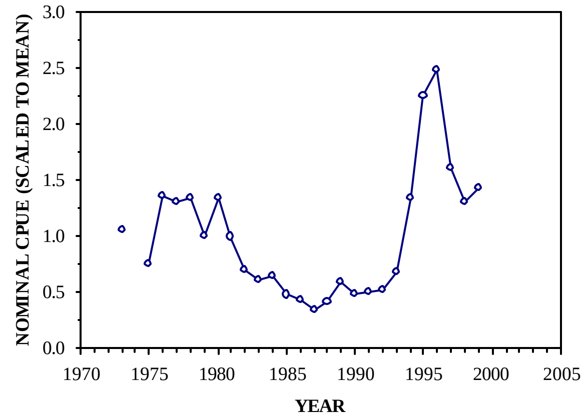


Figure 6. Annual variations in nominal CPUE on positive trips.

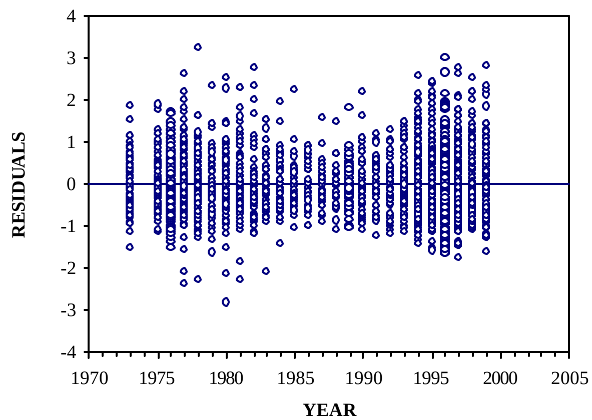


Figure 7. Residuals for the lognormal model on positive catch rates.

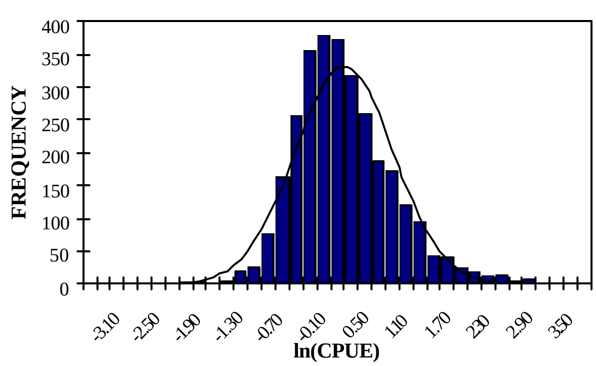


Figure 8. Frequency distribution of ln(CPUE) by year, party and area. The solid line is the expected normal distribution.

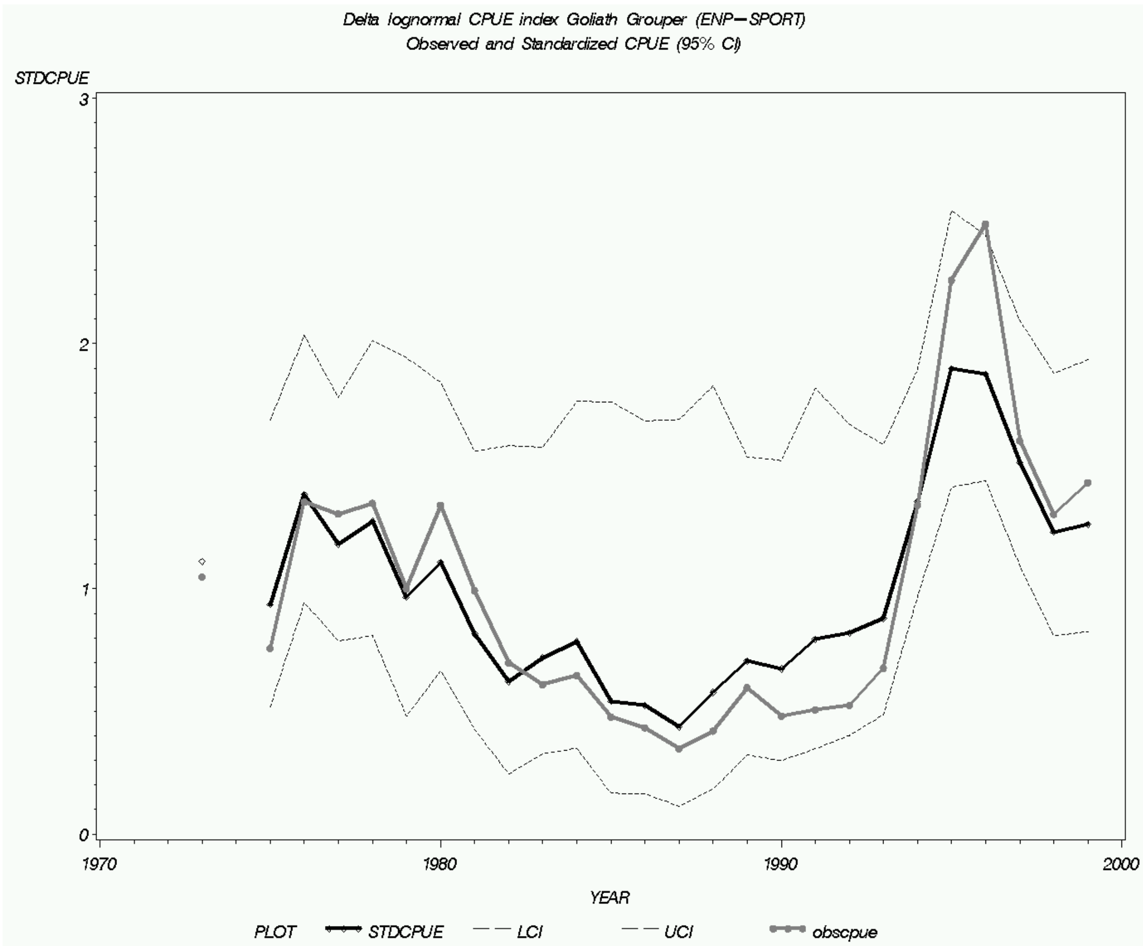
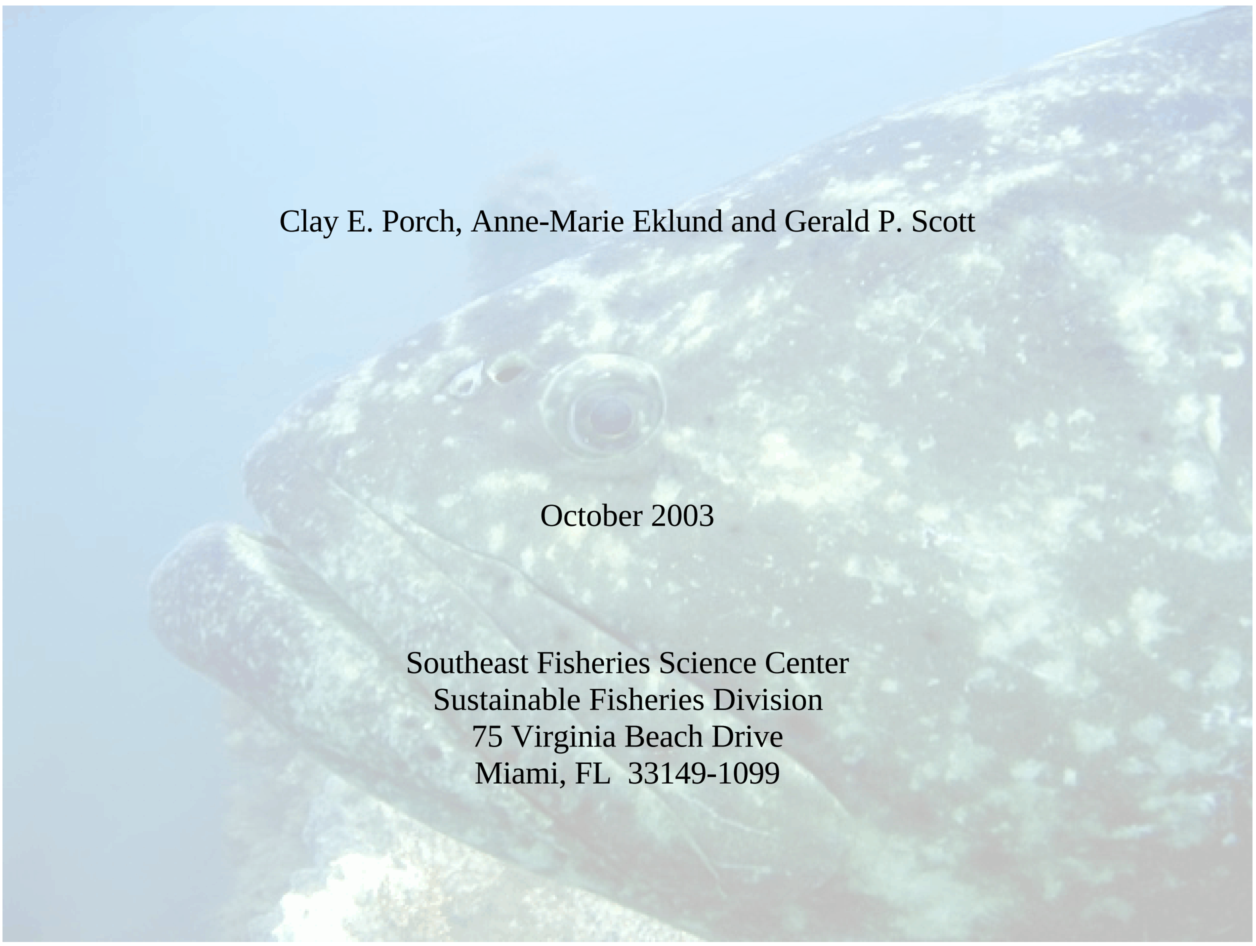


Figure 9. Nominal CPUE (solid gray), standardized CPUE (solid black) and upper and lower 95% confidence limits of the standardized CPUE estimates (dotted).

AN ASSESSMENT OF REBUILDING TIMES FOR GOLIATH GROUPER



Clay E. Porch, Anne-Marie Eklund and Gerald P. Scott

October 2003

Southeast Fisheries Science Center
Sustainable Fisheries Division
75 Virginia Beach Drive
Miami, FL 33149-1099

Sustainable Fisheries Division Contribution No. SFD-2003-0018

Introduction

The goliath grouper, *Epinephelus itajara*, is the largest grouper in the western North Atlantic and one of the largest in the world (Sadovy and Eklund 1999). This species grows to approximately 2 meters and lives to at least 37 years (Bullock et al. 1992). It reaches reproductive maturity at a large size (one meter) and late age (4-7 years). This life history strategy, along with a curious and unwary behavior, make it highly vulnerable to overexploitation (Sadovy and Eklund 1999). Its range includes both sides of the Atlantic Ocean and along the coast of Mexico in the eastern Pacific, although it may have been extirpated from that area. Along the western Atlantic, the species ranges from the Carolinas, into the Gulf of Mexico, the Caribbean and down the coast of Brazil (Sadovy and Eklund 1999).

The Gulf of Mexico and the South Atlantic Fishery Management Councils closed the fishery for goliath grouper in 1990, by emergency rule, due to concerns of overfishing The Caribbean Fishery Management Council followed by closing the fishery in 1993. No harvest has been allowed in federal waters since that time. A SEDAR data workshop[1] was convened in early 2003 to examine the data available for determining the status of the goliath grouper stock. During the meeting, several fisherman reported that goliath grouper sales had often been to buyers other than dealers (dealers are the source of federal commercial landings statistics) and that the proportion of the catch sold through dealers may have changed over time. Based on this testimony, the SEDAR participants concluded that the catch statistics were unreliable and that a meaningful assessment was not possible for goliath grouper.

Most stock assessment approaches do indeed require reliable catch data, however a number of *ad hoc* methods have been developed to accommodate ‘data-poor’ situations. For example, an approach that is often taken when research surveys or other indices of abundance are available is to set the minimum stock size threshold (MSST) equal to some fraction of the survey values observed during an earlier portion of the time series when the stock was presumably close to pre-exploitation or MSY levels. Such ‘model free’ approaches have the advantage of assuming relatively little about the recovery rate of the stock, but cannot be used to estimate many of the reference points stipulated by the Magnuson-Stevens Act. Moreover, there may be other types of information about the fishery that could influence the perception of the status of the stock and it would be useful to integrate that information formally into the assessment.

The purpose of this paper is to assess the status of the goliath grouper stock in U.S. waters (principally southern Florida) by use of an estimation framework developed specifically for data-poor situations. The model recasts the canonical age-structured equations in terms relative to pre-exploitation levels, thus eliminating the need for catch information. A Bayesian estimation scheme is adopted to allow the incorporation of pertinent auxiliary information such as might be obtained from meta-analyses of similar stocks or anecdotal observations.

[1]Anon. SEDAR Goliath Grouper Data Workshop Report, March 2003. 11 pp.

Methods

Population dynamics

The stock was assumed to be near virgin levels in 1950, such that the relative abundance N of each age class a at the beginning of 1950 is given by

$$N_{a,1950} = \begin{cases} 1 & \{\text{for } a = a_r\} \\ N_{a-1,1950}\, e^{-M_a} & \{\text{for } a_r < a \leq A\} \end{cases} \quad . \tag{1}$$

where a_r is the age when the animal first recruits to the fishery, A is the maximum age attainable, and M is the natural mortality rate. The relative abundance at the beginning of subsequent years (y) is modeled by the recursion

$$\begin{gathered} N_{a,y} = \begin{cases} r_y = \Psi(s_{y-a_r})\, e^{e_y} & (a = a_r) \\ N_{a-1,\,y-1}\, e^{-F_{y-1} v_{a-1} - M_{a-1}} & (a_r < a \leq A) \end{cases} \\ s_y = \sum_{a=a_r}^{A} E_a\, e^{-(F_y v_a + M_a) t_s}\, N_{a,y} \Big/ \sum_{a=a_r}^{A} E_a\, e^{-M_a t_s}\, N_{a,1} \end{gathered} \tag{2}$$

The vector v represents the relative vulnerability of each age class to the fishery, which implicitly includes factors such as gear selectivity, size limit regulations, and the fraction of the stock exposed to the fishery. The variable F represents the fishing mortality rate on the most vulnerable age class. In this regard the model distinguishes three time periods: a 'historical' period (1950-1979) during which the fishing mortality rate is assumed to have increased linearly through time, a 'modern' period (1980-1989) when the fishing mortality rate was relatively constant, and a 'moratorium' period (1990 onwards) during which the fishing mortality rate is assumed to be negligible.

The variable r is the recruitment relative to virgin levels expressed as a function Ψ of the spawning stock relative to virgin levels s, which in turn is expressed as a function of an index of the per-capita number of eggs produced by each age class (E) and the fraction of the year elapsed at the time of spawning (t_s). In this case Ψ is assumed to be of the Beverton and Holt type expressed in terms of the maximum lifetime reproductive rate α (see derivation in Appendix 1):

$$\Psi(s) = \begin{cases} s\alpha^{1-s} & \text{Ricker} \\ \dfrac{\alpha s}{\left(1 + s(\alpha - 1)\right)} & \text{Beverton and Holt} \end{cases} \tag{3}$$

The shapes of these two curves are essentially the same as the conventional Ricker or Beverton and Holt relationships, however their domain is implicitly limited to the interval $0 \leq s \leq 1$. Deviations in recruitment (e_y) from the expectation $\Psi(s)$, ostensibly due to fluctuations in the environment, are modeled as a first-order, lognormal autoregressive process,

(4)
$$
\begin{aligned}
r_y &= \Psi(s_{y-a})\, e^{e_y} \\
e_y &= r e_{y-1} + h_y
\end{aligned}
\quad ,
$$

where r is the correlation coefficient (here 0.5) and h is a normal-distributed random variate having mean 0 and standard deviation σ_r (here 0.4 on a log-scale).

Reference points

The set of equations 1-4 describe the relative dynamics of a population apart from its absolute abundance. As such they are most suited for developing management plans where the fishing mortality rate is controlled directly (e.g., by reducing effort) and the biomass reference points are expressed on a relative scale. When the virgin spawning biomass itself is used as the reference point, the estimated value of s_y is a direct measure of the status of the stock. For example, if the management goal is to maintain spawning biomass at or above 50% of the virgin level, then estimates of s below 0.5 might trigger some action to reduce fishing pressure.

A related reference point is the equilibrium spawning potential ratio (Goodyear, 1993), defined as the expected lifetime fecundity per recruit at a given F (f_F) divided by the expected lifetime fecundity (maximum spawning potential) in the absence of fishing (f_0):

(5)
$$
\begin{aligned}
p &= \frac{f_F}{f_0} \\
f_F &= \sum_{a=0}^{A} E_a e^{-(F_a + M_a)t_s}\, e^{-\sum_{i=0}^{a-1} F v_i + M_i}
\end{aligned}
$$

where E is relative egg production by each age class and t_s is the time of spawning. As shown in Appendix 2, the corresponding equilibrium spawning biomass (relative to the virgin level) may be computed as

(6)
$$
\tilde{s}_p = \begin{cases} 1 + \dfrac{\log_e p}{\log_e a} & \text{Ricker} \\[2ex] \dfrac{ap - 1}{a - 1} & \text{Beverton and Holt} \end{cases} .
$$

Thus, management actions may be triggered when the estimates of s fall below the estimate of $\tilde{s}_p$.

Other management plans employ reference points such as F_{max} or $F_{0.1}$, which are based on the yield per recruit statistic

(7) $$\left(\frac{Y}{R}\right) = \sum_{a=0}^{A} w_a F v_a \, \frac{1 - e^{-(Fv_a + M_a)}}{Fv_a + M_a} \, e^{-\sum_{i=0}^{a-1} Fv_i + M_i} ,$$

where w_a is some measure related to the average weight of the catch. Inasmuch as there are no terms involving the absolute abundance of the stock, the calculation of such statistics poses no special problems for the relative framework presented here. The corresponding values of p (and therefore $\tilde{s}_p$) may be calculated via equation (5).

Prescriptions based on maximum sustainable yield (*MSY*) are slightly more complicated because equilibrium yield is the product of equilibrium recruitment $\tilde{R}$ and equilibrium yield per recruit:

(8) $$\tilde{Y} = \tilde{R}_F \sum_{a=0}^{A} w_a F v_a \, \frac{1 - e^{-(Fv_a + M_a)}}{Fv_a + M_a} \, e^{-\sum_{i=0}^{a-1} Fv_i + M_i} ,$$

However, the fishing mortality rate that maximizes (8) also maximizes (8) divided by the virgin recruitment R_0 (a constant). Thus, F_{MSY} may be obtained from

(9) $$\max_F \left\{ \frac{F\tilde{s}_p}{p} \sum_{a=0}^{A} w_a v_a \, \frac{1 - e^{-(Fv_a + M_a)}}{Fv_a + M_a} \, e^{-\sum_{i=0}^{a-1} Fv_i + M_i} \right\} .$$

where $\tilde{s}_p \,/\, p$ has been substituted for $\tilde{R} \,/\, R_0$ (from equation A.4 in Appendix 1). Inasmuch as the absolute abundance is not estimable, the absolute value of MSY may not be calculated directly.

Bayesian estimation

The equations above include numerous 'unknowns' representing the processes of reproduction, mortality and growth. In the case of "data-poor" stocks like Goliath grouper, there are insufficient data to estimate all of these unknown parameters with an acceptable level of precision. However, it is often possible to increase the precision of the estimates through the use of Bayesian prior probability densities constructed to reflect anecdotal information or the results from meta-analyses involving similar species (Gelman et al. 1995, Liermann and Hilborn 1997).

The Bayesian approach to estimation seeks to develop a 'posterior' probability density for the parameters Q that is conditioned on the data D, P(Q | D). By application of Bayes rule it is easy to show that

(10) $$\mathrm{P}(\Theta | \mathrm{D}) \propto \mathrm{P}(\mathrm{D} | \Theta)\, \mathrm{P}(\Theta) .$$

where P(D | Q) is the sampling density (likelihood function) and P(Q) is the prior density (the analyst's best guess of the probability density for Q). Estimates for Q may be obtained from (9) by integrating the posterior (classical Bayes moment estimator)

(11) $$\hat{q}_i = \int q_i \, \mathrm{P}(\mathrm{D} | \Theta)\, \mathrm{P}(\Theta) dq_i \quad , \qquad q_i \in \Theta \quad .$$

or by minimizing its negative logarithm (highest posterior density estimator)

$$\min_{\Theta} \{-\log_e \mathrm{P}(\mathrm{D}\,|\,\Theta) - \log_e \mathrm{P}(\Theta)\} \qquad (12)$$

In the present model, a prior needs to be specified for the parameters reflecting recruitment (α, ρ, s_r and e), mortality (M, F, v), fecundity (E) and growth in weight (w). It is here assumed that the parameters are statistically independent with respect to prior knowledge such that the joint prior is merely the product of the marginal priors for each parameter. The lone exceptions are the parameters for the annual recruitment deviations e_y, which are assumed to be autocorrelated lognormal variates such that

$$-\log \mathrm{P}(e) = \frac{1}{2s_r^2}\left[e_1^2 + \sum_{y=1}^{w-1}(e_{y+1} - r e_y)^2\right] + w \log s_r \qquad (13)$$

where w is the last year in the simulation, r_r is the correlation coefficient (here 0.5) and s_r^2 is the variance of $\log_e h$ (for stability reasons, it is assumed that $e_0 = 0$).

It is possible, at least in principle, to conduct an assessment based on prior specifications alone. However, it may be difficult to develop sufficiently informative priors for some of the parameters, particularly the fishing mortality rates. The preferred approach is to condition the estimates on data. For example, visual counts of goliath grouper have been conducted at several fixed locations since 1982. To the extent that changes in the abundance at these locations (n) are proportional to changes in the abundance of the population as a whole (N), the visual counts (c) may be modeled as:

$$\begin{aligned} c_{i,y} &= q_i \sum_a v_{i,a} N_{a,y} e^{-(F_y v_a + M_a)t_i} e^{x_{i,y}} \\ x_{i,y} &\sim Normal(0, s_i) \end{aligned} \qquad (14)$$

where i indexes the location, q is the proportionality coefficient scaling the number counted to the relative abundance of the population, $v_{i,a}$ is the relative vulnerability (availability) of each age class at the survey site, t_i is the fraction of the year elapsed at the time of the survey, and s_i is the standard deviation of the fluctuations in $\log_e c_i$ owing to observation errors or changes in the distribution of the stock. The corresponding negative logarithm of the sampling density is

$$-\log \mathrm{P}(c|\Theta) = \sum_y \left\{\frac{1}{2s_i^2}(\log_e c_{i,y} - q_i \sum_a v_{i,a} N_{a,y} e^{-(F_y v_a + M_a)t_i})^2 + \log s_i\right\} \qquad (15)$$

An alternative to the use of data is to construct priors relating to auxiliary information such as anecdotal perceptions of the abundance of the resource relative to virgin levels (n). In such cases an appropriate model might be

$$n_y = \frac{\sum_a l_a N_{a,y} e^{-\left(F_y v_{i,a} + M_a\right)d}}{\sum_a l_a e^{-M_a d} e^{-\sum_{i=0}^{a-1} M_i}} e^{z_y} \tag{16}$$

$$z_{i,y} \sim Normal(0, s_n)$$

where $l_{,a}$ is the relative contribution of each age class in forming the perception of total abundance (e.g., fishermen may never encounter very young fish), d is the time of the year most reflective of the period upon which the perceptions were based (e.g., the peak of the fishing season), and s_n is the standard deviation of the fluctuations in $\log_e n_y$ owing to errors in perception. Note that such auxiliary priors are mathematically equivalent to sampling densities and we do not here distinguish between them.

The model was implemented using the nonlinear optimization package AD Model Builder (Otter Research Ltd.[2]), which provides facilities for estimating the mode and shape of the posterior distribution (equation 10).

Application to goliath grouper

The retention of goliath grouper is currently prohibited by law, but status determination criteria have not been defined nor has the duration of the moratorium been specified. The Caribbean Fishery Management Council (CFMC, 2001) postulated that the biomass of the populations under their jurisdiction were so much lower than any reasonable MSST that recovery would be unlikely to occur within 10 years. They therefore set the allowable rebuilding period equal to 10 years plus one generation time, where the generation times were estimated by Legault and Eklund[3] to be between 15 to 40 years for goliath grouper. The CFMC preferred the lower end of the range because it is more ‘precautionary’ in the sense that managers are under greater compunction to prohibit harvest when they are constrained to rebuild over a short time frame.

Natural mortality

Legault and Eklund[2] developed estimates for M ranging from 0.04 to 0.19 for goliath grouper based on its perceived life spans. Estimates from Hoenig’s (1984) method based on a maximum observed age of 37 years (Sadovy and Eklund 1999) suggests an expected value of 0.11. An examination of the range of plausible values from Legault and Eklund[2] suggested a lognormal prior with median 0.11 and CV about 0.4.

---

[2]Otter Research Ltd. 2001. An introduction to AD MODEL BUILDER Version 4.5. Box 2040, Sidney B.C. V8L 3S3, Canada. 141 p.

[3]Legault, C.M. and Eklund, A.-M. 1998. Generation times for Nassau grouper and jewfish with comments on M/K ratios. Sustainable Fisheries Division Contribution SFD-97/98-10A. Southeast Fisheries Science Center, 75 Virginia Beach Drive, Miami, Florida 33149.

Stock-recruitment relationship

As far as we are aware, there is no reliable information on the nature of the spawner-recruit relationship for any goliath grouper populations (or, for that matter, any subtropical serranid). Myers et al (1999) examined over 700 spawner-recruit series (none of them serranids) with a broad spectrum of a values ranging between 1.4 and 123.5. Rose et al. (2000), however, have subdivided this data set according to three general life history strategies: opportunistic, periodic and equilibrium. Of these, the 'periodic' strategy (larger, highly fecund fishes with long life spans) appears most descriptive of Goliath grouper. Accordingly, we developed a prior for a by fitting a lognormal distribution to the frequency histogram of values corresponding to the periodic strategists represented in the Myers et al (1999) data set (Figure 1).

Fecundity and growth

To date there are insufficient data for estimating a fecundity-at-age relationship. We follow Legault and Eklund[2] and substitute the weight at age relationship:

(17)
$$E_a = \begin{cases} 0 & a < 6 \\ w_a = 1.31 \times 10^{-5} l^{3.056} & a \geq 6 \end{cases},$$

$$l = 200.6(1 - e^{-0.126(a + 0.49)})$$

where w is weight in kg and l is length in cm expressed as a von Bertalanffy function of age (see Bullock et al., 1992). Uncertainty in these parameters was reflected by imposing a normal prior on the asymptotic length with a 6% CV and a lognormal prior on k with log-scale variance equal to 0.204.

Historical vulnerability to fisheries

There is little quantitative information on the vulnerability (v) of goliath groupers to the fishery that existed prior to the moratorium. A large fraction of the recreational landings of goliath grouper appear to have been from the ten thousand islands area, where most of the animals observed to date are between the ages of one and four. However, large animals were often targeted by commercial and recreational fishers in other areas. Thus it is unclear how the overall vulnerability of goliath grouper changes with age. We assume the vulnerability of goliath grouper generally increased with age according to the sigmoid-shaped logistic curve:

(18)
$$v_a = \frac{1}{1 + e^{-(a - a_{50})/d}}$$

where a_{50} is the age of 50% relative vulnerability for fleet and d is the dispersion coefficient controlling the slope of the curve at a_{50} (values of d less than 0.2 effectively imply knife-edge selection). In order to estimate the parameters a_{50} and d, we converted length composition data collected during the course of a creel survey in the Ten Thousand Islands area (courtesy T. Schmidt[4]) into age composition data by use of an age-length key derived from experimental trap and trot-line catches (Brusher and Schull[5]). We then fitted a logistic vulnerability curve (weighted by cumulative mortality) to the observed frequency of ages 0 to 5 (older age classes appear to migrate out of the area but are caught elsewhere). The estimated values of $a_{50\%}$ and d are 2.51 and 0.525, respectively (see Figure 2). Uncertainty was incorporated via normal priors on $a_{50\%}$ with 10% CV's.

Survey information
Porch and Eklund (2003) have developed relative indices of abundance from two visual surveys: the personal observations of a professional spearfisher (DeMaria[6]) and a volunteer fish-monitoring program administered by the Reef Education and Environmental Foundation (REEF 2000). In addition, Cass-Calay and Schmidt (2003) have standardized catch rate data collected in the Ten Thousand Islands area by the Everglades National Park (ENP). We assume the two visual surveys reflect the abundance of ages 6 and older and that the ENP index reflects the relative abundance of ages 1 to 5 according to the dome-shaped gamma function (normalized to a maximum of 1):

(19) $$v_a = \left(\frac{a}{a_{100\%}} e^{1-a/a_{100\%}} \right)^{g^{-2}-1}$$

where $a_{100\%}$ is the most vulnerable age and g is the coefficient of variation. Uncertainty was incorporated via a normal prior on $a_{100\%}$ with a 10% CV. Estimates for $a_{100\%}$ (3.47) and g (0.34) were obtained by fitting the cumulative mortality-weighted gamma curve to the frequency of ages 0 -7 in age-converted ENP data described above (see Figure 2).

Anecdotal impressions of stock status
Johannes et al. (2000) point out that local fishers often disagree with the conclusions drawn by scientists in data-poor situations and that many times additional data will prove the fishers correct. As mentioned earlier, expert judgements about the relative abundance of a stock can be treated as data and represented by a 'prior' (e.g., Punt and Walker, 1998; other examples). We developed a prior for the value of s at the time moratoriums began (1990) by interviewing fishers and divers who had been active in southern Florida during the 1960's or earlier (nine such individuals have so far been identified). Specifically, interviewees were asked to state their perception of the percent reduction in Goliath grouper populations from the time they began diving to the time the moratorium on catch was imposed (1990). The average percent reduction reported was 86% with a standard deviation of about 13%.

---

[4]Schmidt, T. W. Everglades National Park, U. S. National Park Service

[5]J. Brusher and J. Schull, in prep.

[6] DeMaria, Don. P.O. Box 420975, Summerland Key, FL 33042.

Results

The base model assumes the fishing mortality rate is nearly zero in 1950, increases linearly through 1979, is relatively constant between 1980 and 1989, and then drops off to near-zero from 1990 onwards owing to the moratorium. The model fit to the data is shown in Figure 3. As the Gulf of Mexico Fishery Management Council has recommended using benchmarks associated with an SPR of 50% as proxies for MSY benchmarks for Goliath grouper, statistics relative to this measure are reported herein. The estimated trends in spawning biomass relative to the equilibrium level corresponding to an SPR of 50% ($\tilde{s}_{50\%}$) and estimated fishing mortality rates are shown in Figure 4. The estimated probabilities that the population will have recovered to a level at or above $\tilde{s}_{50\%}$ are shown in Figure 5.

Numerous sensitivity runs were made examining (1) the effect of dropping one or more of the indices, (2) changing the youngest age assumed to be represented by the REEF and DeMaria indices from 6 to 10, (3) extending the historical period back to 1940, and (4) changing the years when the fishing mortality rate was assumed to be constant (1976-89 or 1984-89). None of these resulted in any substantial departure from the results presented in Figures 3-5 except when the ENP index was dropped from the analysis, in which case the estimated recovery rate was somewhat less optimistic (Figures 6 and 7).

An additional run was made allowing for large interannual deviations in F between 1980 and 1989 rather than assuming it was relatively constant (as might occur with fluctuations in demand and price) and allowing for moderate deviations in estimated recruitment from the Beverton and Holt relationship (as discussed in the methods section). The fit to the ENP index was substantially improved (Figure 8), but at the expense of highly imprecise estimates for F and *s* (Figure 9). The estimated probability distribution of the time of recovery derived from the posteriors for the relative biomass trend suggests that there is a 60% chance that the population has already recovered (Figure 10). However, we have little confidence that these probabilities are correct owing to the poor behavior of the solution surface. The likelihood profile routine used by ADMB crashed while calculating the posterior distributions for many of the parameters of interest and the posteriors calculated by the MCMC algorithm used by AD Model Builder were poorly behaved with modes that were sometimes quite different from the HPD estimates (even with 5,000,000 samples).

Discussion

One issue that merits further investigation is the choice of reference points. In the present paper we have adopted $\tilde{s}_{50\%}$, which is the equilibrium spawning biomass associated with a spawning potential ratio of 50% under the historical vulnerability pattern, as a proxy for the biomass at MSY. In the present framework, it also is possible to directly compute the equilibrium spawning biomass associated with MSY ($\tilde{s}_{MSY}$). Strictly speaking, this would be obtained by heavily exploiting a single optimal age class, but this is impossible to achieve for most stocks. The classical alternative is to define MSY as the maximum sustainable yield when the vulnerability is constant for all ages above some optimal age. In some cases, however, the definition of MSY is conditioned on the historical vulnerability pattern (which we will denote MSY|*v*). Reference points based on MSY|*v* ($\tilde{s}_{MSY|v}$ and $F_{MSY|v}$) are often more risky than those based on classical approach because they are conditioned on fisher behavior. One can imagine, for example, a situation where fishers might focus on very young juveniles for the live animal trade, in which case $\tilde{s}_{MSY|v}$ might be much lower than $\tilde{s}_{MSY}$ and the stock more prone to collapse. Moreover, the reference points ($F_{MSY|v}$ and $\tilde{s}_{MSY|v}$, but $F_{MSY|v}$ moreso) have the unsettling tendency to change through time as fisher behavior changes, whereas $\tilde{s}_{MSY}$ and F_{MSY} do not.

The $\tilde{s}_{50\%}$ proxy used here, like $\tilde{s}_{MSY|v}$, depends on the assumed historical vulnerability vector. The MSY|*v* calculations, however, are likely to be doubly sensitive to mis-specifications of this vulnerability vector because the vulnerability vector is used to compute potential yield in addition to *s*. Inasmuch as the historical vulnerability of goliath grouper is poorly known, and apt to change if the fishery is reopened after more than a decade of closure, we recommend the $\tilde{s}_{50\%}$ proxy over $\tilde{s}_{MSY|v}$. If MSY-based measures are desired for reference points, then we recommend measures that are independent of fisher behavior such as the maximum sustainable yield under knife-edge selection after some optimal age.

We believe the best advice at present for managing the U.S. goliath grouper population should be predicated on the results of the base model (Figures 4 and 5). These indicate that there is about a 50% chance that the population will have recovered to $\tilde{s}_{50\%}$ by 2006 and about a 95% chance that it will recover by 2012. It is important to consider, however, that the three indices of abundance considered each focus on a relatively small portion of the potential range of goliath grouper (see Porch and Eklund 2003). It is believed that the center of abundance for the population in U.S. waters is southern Florida, particularly the Ten Thousand Islands area, but goliath grouper are known to have occurred throughout the coastal waters of Gulf of Mexico and along the east coast of Florida, and on up through the Carolinas. Inasmuch as goliath grouper are not highly migratory, it is possible it may take some additional time for the species to fully occupy its historical range, thus delaying the overall recovery of the stock.

There is perhaps some evidence of a delay in range expansion in a comparison of the REEF and DeMaria indices: The DeMaria index, which is based on sites adjacent to the Ten Thousand Islands area, indicates a noticeable recovery by 1994 while the REEF index, which is based on sites located along the southeast Florida Coast, indicates the increase began about 3 years later. However, it is also possible that the delay is attributable to the difference in habitat, the DeMaria index coming from isolated wreck sites and the REEF index coming from more continuous, natural reef habitats. Recent surveys (Eklund, pers. obs.) suggest that artificial reefs may be artificially concentrating goliath grouper and may not reflect their distribution and abundance on natural habitat. This concentration effect is well-known in artificial reef literature. In any case, we agree with the conclusions of the SEDAR stock assessment review panel[7] that sampling throughout the geographic range would probably be important in ascertaining stock status, owing to the restricted home ranges and high site fidelity of these animals.

Somewhat less optimistic results were obtained when the ENP index was excluded from the analysis, in which case there is about a 50% chance that the population will have recovered to $\tilde{s}_{50\%}$ by 2008 and about an 80% chance that it will recover by 2012. Inasmuch as the ENP index is the

[7] Anon. 2003. SEDAR Peer Review of Yellowtail Snapper Assessment, with comments on Goliath Grouper. Tampa, Florida. July 28-31, 2003. 12 pp.

longest and probably most representative time series, we feel it is inappropriate to exclude it in favor of the DeMaria index (based on only five sites) or REEF index (mostly based on sites along the fringes of the range of Goliath grouper). However, a caveat to keep in mind is that the ENP index is based on catch rate data, where declining trends are often somewhat masked by the ability of fishers to find local concentrations of fish. Moreover, the ENP data were collected from the Ten Thousand Islands area, where it is believed the species was the least impacted by changes in fishing pressure over time. Outside the Ten Thousand Islands, the decline in juvenile abundance may have been more rapid owing to increased fishing pressure as human population levels increased in southern Florida and recent technological advances (LORAN and GPS) that enabled fishers to consistently locate productive reefs and offshore wrecks. For these reasons, it may be that the historical decline in overall juvenile abundance was more precipitous than indicated by the ENP index. Within the context of the model, relatively flat trends in a juvenile index in concert with a dramatic increase in an adult index suggest a productive stock capable of rapid recovery. Thus, if the trends indicated by the ENP index are indeed flatter than for the overall juvenile population, then the base model results will likely be too optimistic.

The assessment herein also needs to be seen in light of the fact that the relationship between fecundity and age is unknown. We used weight-at-age as a proxy for the relative fecundity-at-age in our analysis, but it is often the case that fecundity increases with age faster than weight. If this is true for goliath grouper, than our projections would be too optimistic. Furthermore, although the results were not especially sensitive to our assumptions about the vulnerability coefficients for the REEF and DeMaria surveys, the same is not likely to be true of our assumptions about the vulnerability coefficients for the fishery. Information on the age composition of the historical catch is needed to estimate these coefficients, but at present none is available. There have been recent data collected on size estimates of goliath grouper on the sites used in the DeMaria index, and there may be some data mining through older video-surveys that may be available in the future.

Finally, we wish to reiterate that the methodology employed here cannot provide a direct estimate of the equilibrium catch level associated with any particular reference point such as MSY. This is because, in the absence of historical catch data, one is relegated to estimating the abundance of the stock relative to unexploited levels rather than absolute abundance. The situation could be ameliorated by obtaining estimates of absolute abundance from a comprehensive short-term survey covering the entire range of the animal. Alternatively, a long-term monitoring program at select sites located throughout the range could be established to detect changes in relative abundance under various closely monitored trial levels of catch.

Acknowledgments

S. Cass-Calay and T. Schmidt secured the length composition data from the Everglades National Park creel survey; J. Brusher and J. Schull provided the age-length data from their sampling program in the Ten Thousand Islands area; D. DeMaria provided the data for the ‘DeMAria index; and theReef Environmental Education Foundation provided the data for the REEF index. Steve Turner gave helpful comments on the manuscript. Cover photo from Fish Base by Athila Andrade Bertoncini, Centro de Ciências Exatas e da Natureza, Departamento de Sistemática e Ecologia, Universidade Federal da Paraíba, João Pessoa - Paraíba, Brasil.

Literature cited

Bullock, L. H., M. D. Murphy, M. F. Godcharles, and M. E. Mitchell. 1992. Age, growth, and reproduction of jewfish *Epinephelus itajara* in the eastern Gulf of Mexico. Fish. Bull. 90:243-249.

Cass-Calay, S. L. and Schmidt, T. W. 2003. Standardized catch rates of juvenile goliath grouper, *Epinephelus itajara*, from the Everglades National Park Creel Survey, 1973-1999.Sustainable Fisheries Division Contribution SFD-2003-0016. Southeast Fisheries Science Center, 75 Virginia Beach Drive, Miami, Florida 33149.

Gelman, A., Carlin, J. B., Stern, H. S., Rubin, D. B. 1995. Bayesian data analysis. Chapman and Hall.

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

Johannes, R. E., Freeman, M. M. R., and Hamilton, R. J. 2000. Ignore fishers' knowledge and miss the boat. Fish and Fisheries 1: 257-271.

Liermann, M., and Hilborn, R. 1997. Depensation in fish stocks: a hierarchic Bayesian meta-analysis. Can. J. Fish. Aquat. Sci. 54: 1976-84.

Punt, A. E. and Walker, T. I. 1998. Stock assessment and risk analysis for the school shark (*Galeorhinus galeus*) off southern Australia. Mar. Freshwater Res. 49: 719-31.

Porch, C. E., and Eklund, A.-M. 2003. Standardized visual counts of Goliath grouper off South Florida and their possible use as indices of abundance. Sustainable Fisheries Division Contribution SFD-0017. Southeast Fisheries Science Center, 75 Virginia Beach Drive, Miami, Florida 33149.

Restrepo, V. R., Thompson, G. G., Mace, P. M., Gabriel, W. L., Low, L. L., MacCall, A. D., Methot, R. D., Powers, J. E., Taylor, B. L., Wade, P. R., and Witzig, J. F. 1998. Technical guidance on the use of precautionary approaches to implementing National Standard 1 of the Magnuson-Stevens Fishery Conservation and Management Act. NOAA Technical Memorandum NMFS-F/SPO-31. 54 p.

Rose, K. A., Cowan, J. H., Winemiller, K. O., Myers, R. A. and Hilborn, R. 2001. Compensatory density dependence in fish populations: importance, controversy, understanding and prognosis. Fish and Fisheries 2: 293-327.

Sadovy, Y. and A-M. Eklund 1999. Synopsis of biological data on the Nassau grouper, *Epinephelus striatus* (Bloch, 1792), and the jewfish, *E. itajara* (Lichtenstein, 1822). NOAA Tech. Report NMFS 146. 65 p.

Appendix 1: Reparameterized spawner-recruit relationships

The number of young fish recruiting to a population is often related to the aggregate fecundity of the spawning stock using one of two functional forms:

$$\text{(A.1)} \qquad R = \begin{cases} aSe^{-bS} & \text{Ricker} \\ \dfrac{abS}{b+S} & \text{Beverton and Holt} \end{cases} .$$

The parameter a is the slope of the curve at the origin and the parameter b controls the degree of density dependence. Notice that the domain of both functions extends from zero to infinity, whereas in practice there must be some limitation on S even in the absence of fishing owing to environmental constraints. This being so, we obtain

$$\text{(A.2)} \qquad a\frac{S_0}{R_0} = \begin{cases} e^{bS_0} & \text{Ricker} \\ 1 + S_0/b & \text{Beverton and Holt} \end{cases}$$

The ratio S_0/R_0 represents the maximum expected lifetime fecundity of each recruit and a represents the survival of recruits in the absence of density dependence. Accordingly, the product $\alpha = aS_0/R_0$ may be interpreted as maximum possible number of spawners produced by each spawner over its lifetime (Myers et al. 1998).

The dimensionless character of α makes it useful for interspecies comparisons, or for borrowing values from species with similar life history strategies. Solving for b in terms of α one obtains

$$\text{(A.3)} \qquad b = \begin{cases} \log_e \alpha \,/\, S_0 & \text{Ricker} \\ S_0 \,/\, (1-\alpha) & \text{Beverton and Holt} \end{cases}$$

Substituting (A.3) into (A.1) gives

$$\text{(A.4)} \qquad R = \begin{cases} aS\alpha^{-S/S_0} & \text{Ricker} \\ \dfrac{aS_0}{1+(\alpha-1)S/S_0} & \text{Beverton and Holt} \end{cases}$$

and, since $a = \alpha R_0/S_0$,

$$\text{(A.5)} \quad R = \begin{cases} R_0 \dfrac{S}{S_0} a^{\,1-S/S_0} & \text{Ricker} \\ R_0 \dfrac{aS/S_0}{1+(a-1)S/S_0} & \text{Beverton and Holt} \end{cases} .$$

Dividing through by R_0 and defining $s = S/S_0$ gives equation (3).

Appendix 2: Formula for equilibrium spawning biomass

The spawning potential ratio (p) is defined as the number of spawners produced by each recruit at equilibrium with a given fishing mortality rate F divided by the number of spawners per recruit under virgin conditions (F=0). This may be written

$$\text{(A.6)} \qquad p = \frac{f_F}{f_0} = \frac{\tilde{S}_F / \tilde{R}_F}{\tilde{S}_0 / \tilde{R}_0} = \frac{\tilde{S}_F / \tilde{S}_0}{\tilde{R}_F / \tilde{R}_0} = \tilde{s} / \tilde{r}$$

where the tilde signifies equilibrium values. At equilibrium we also obtain from equation (4)

$$\text{(A.7)} \qquad \tilde{r} = \begin{cases} \tilde{s}\, a^{1-\tilde{s}} & \text{Ricker} \\ \dfrac{a\tilde{s}}{\left(1+\tilde{s}(a-1)\right)} & \text{Beverton and Holt} \end{cases}$$

Dividing both sides of (A.7) by $\tilde{r}$, substituting (A.6) and solving for $\tilde{s}$ gives equation (6).

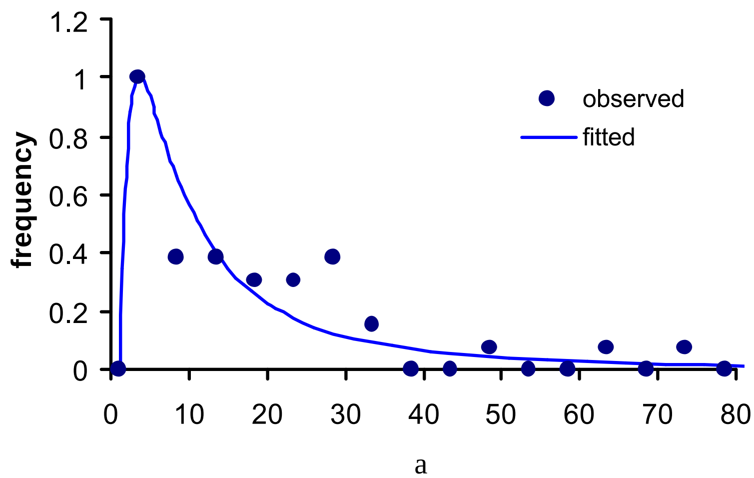


Figure 4. Prior for the maximum lifetime fecundity parameter (α). derived from the values in Myers et al. (1999) that correspond to species categorized as periodic strategists by Rose et al. (2000). The lognormal density was fitted to the values of α-1 in Myers et al. (1999) corresponding to species classified as periodic strategists by Rose et al. (2000). The fitted distribution (with median 9.8 and log-scale variance 1.31) was then shifted 1 unit to provide a prior for α.

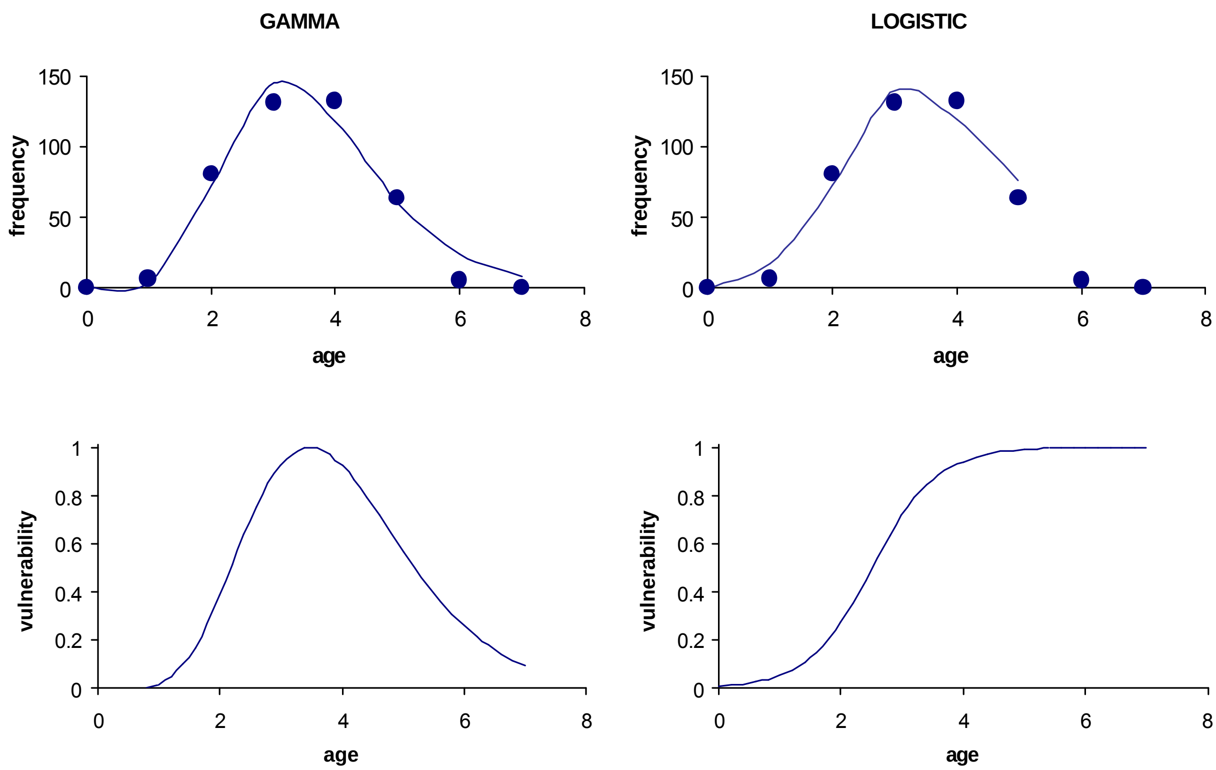


Figure 2. Gamma and logistic vulnerability curves derived by fitting to age-converted length composition data obtained from the Everglades National Park. Top panels show the fit of the expected frequencies at age to the observed values and the bottom panels show the predicted relative vulnerability curves.

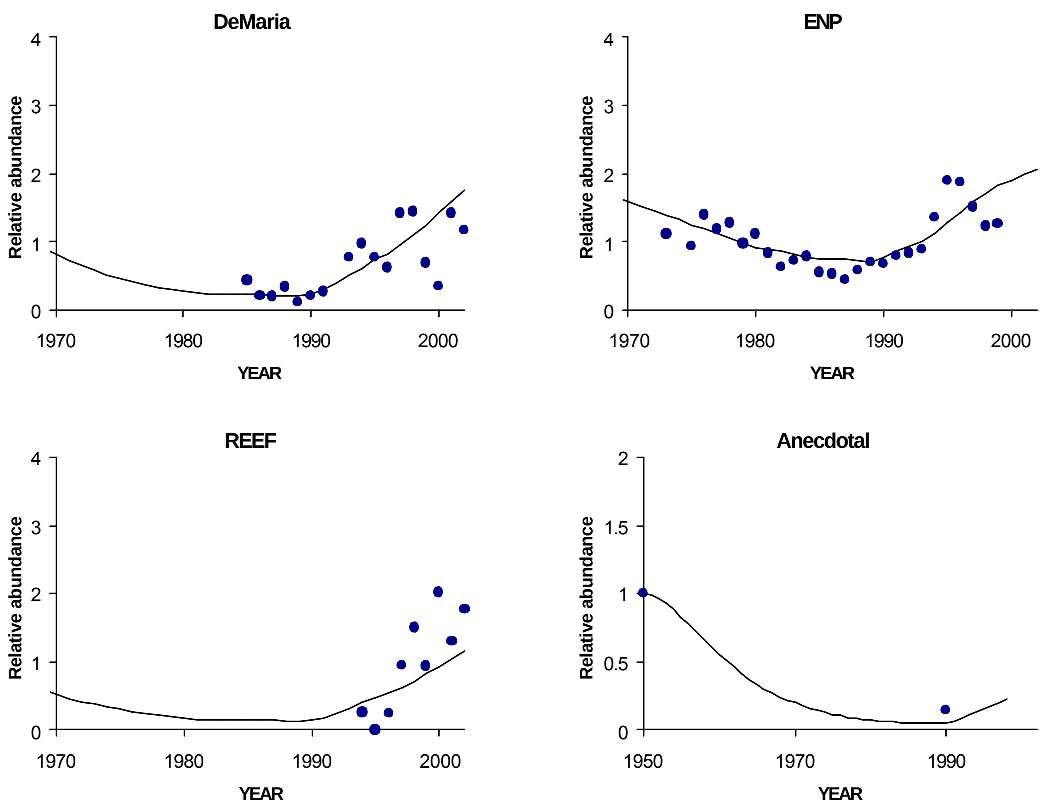
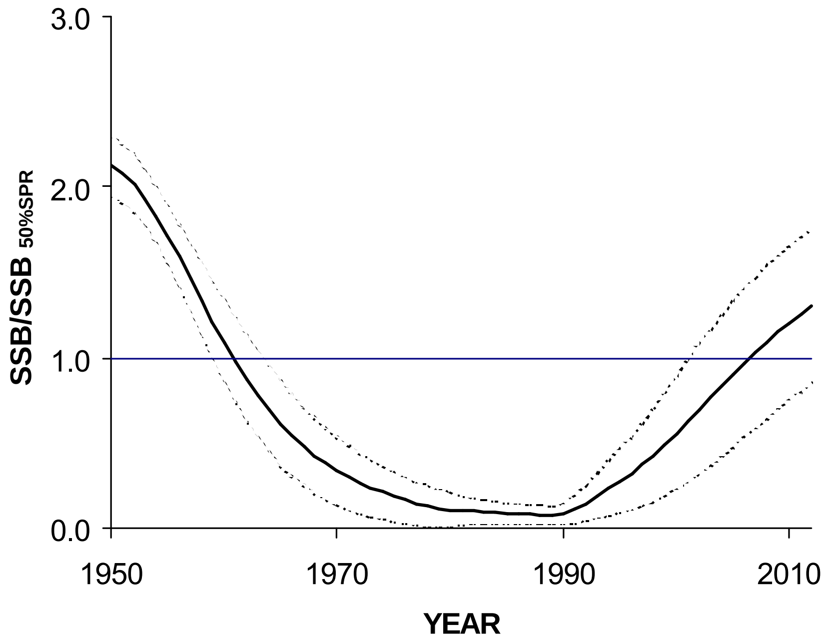


Figure 3. Base model fit to the four indices of abundance.



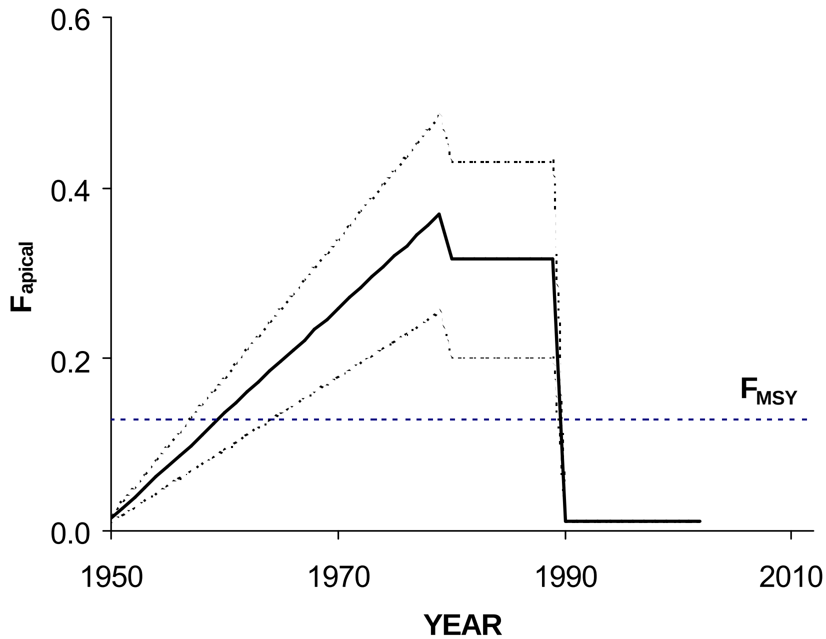


Figure 4. Base model predictions of relative spawning biomass and fishing mortality rate with approximate 80% confidence limits.

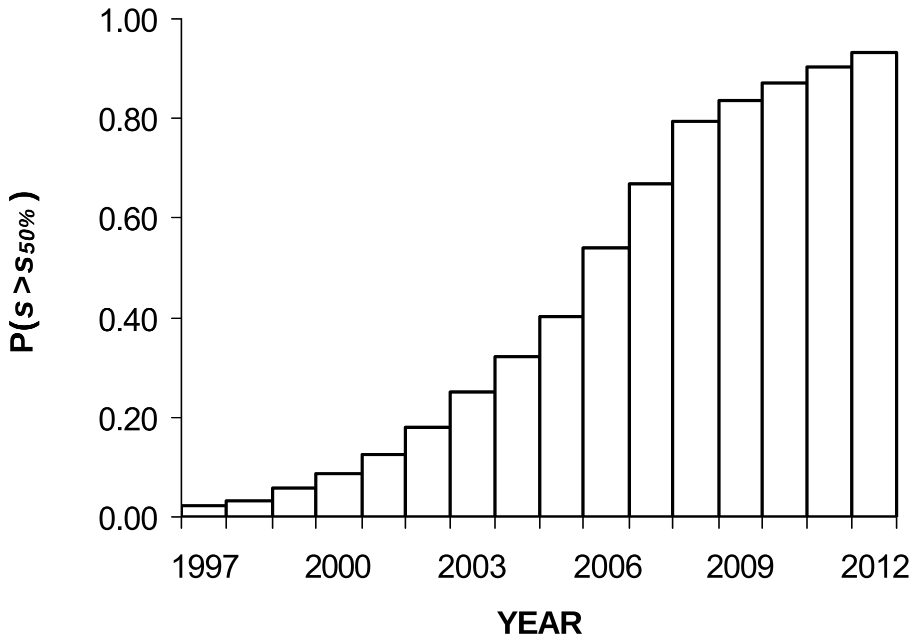


Figure 5. Probability stock will have recovered to spawning biomass levels corresponding to a 50% SPR by year for the base model

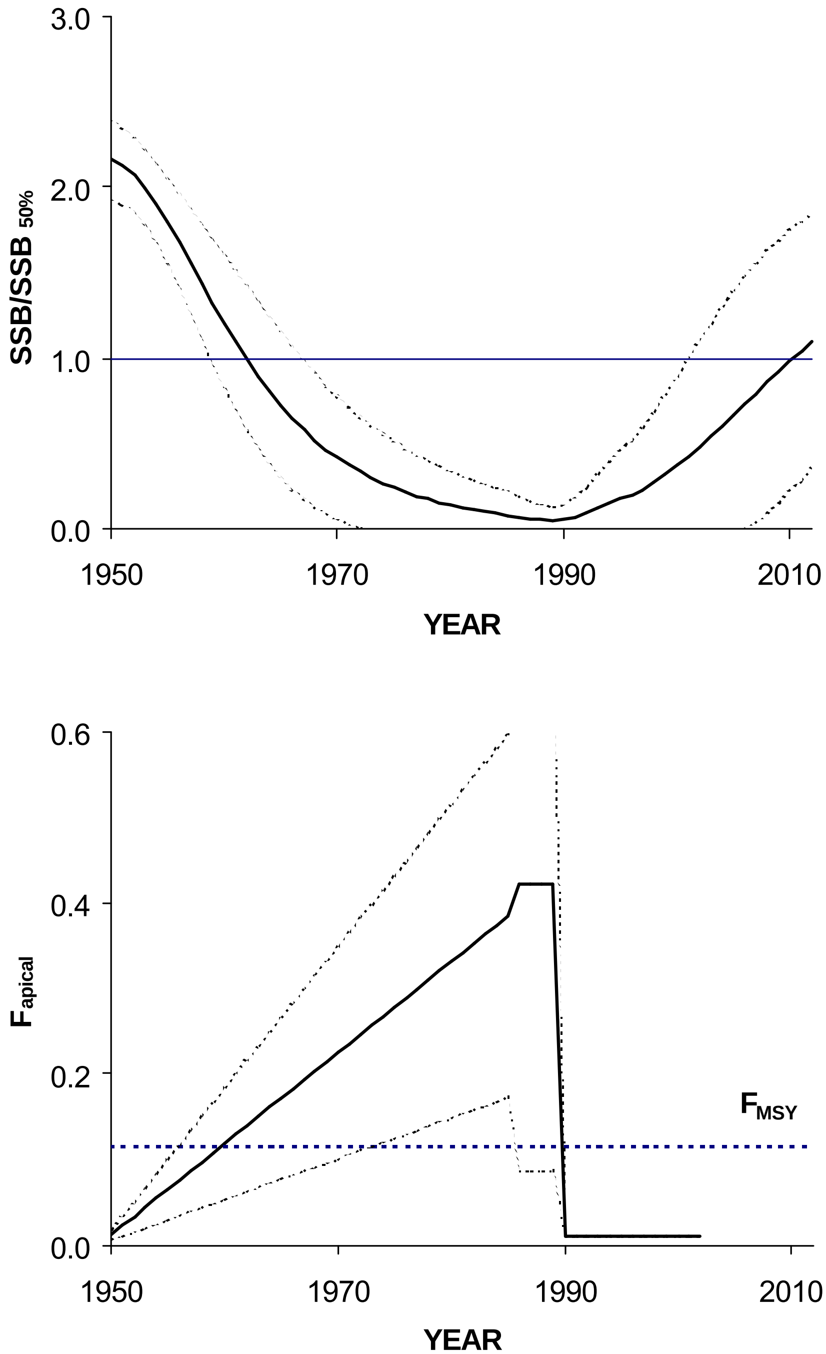


Figure 6. Predictions of relative spawning biomass and fishing mortality rate resulting when base model is applied without the ENP index on juveniles.

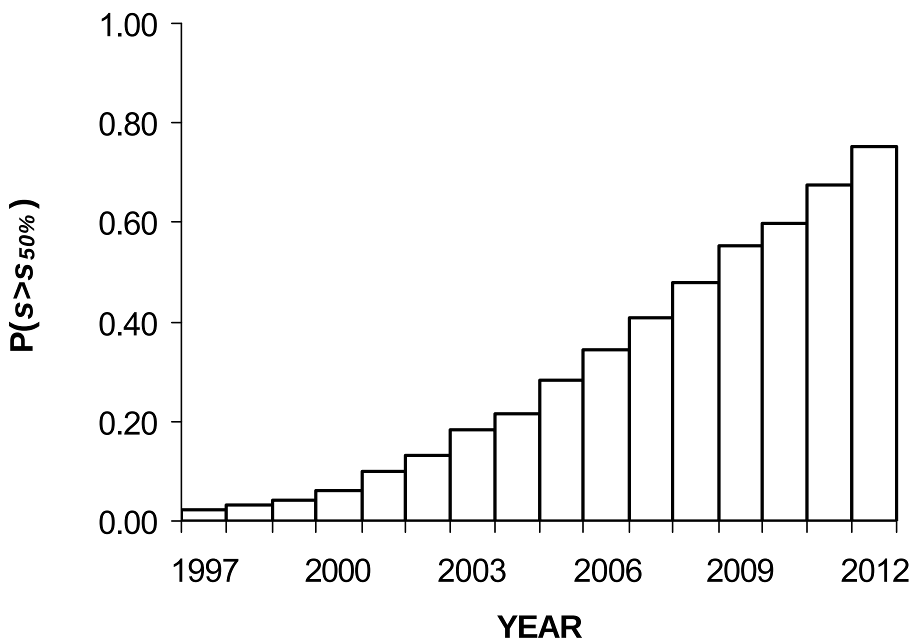


Figure 7. Probability stock will have recovered to spawning biomass levels corresponding to a 50% SPR by year for the base model without the ENP index

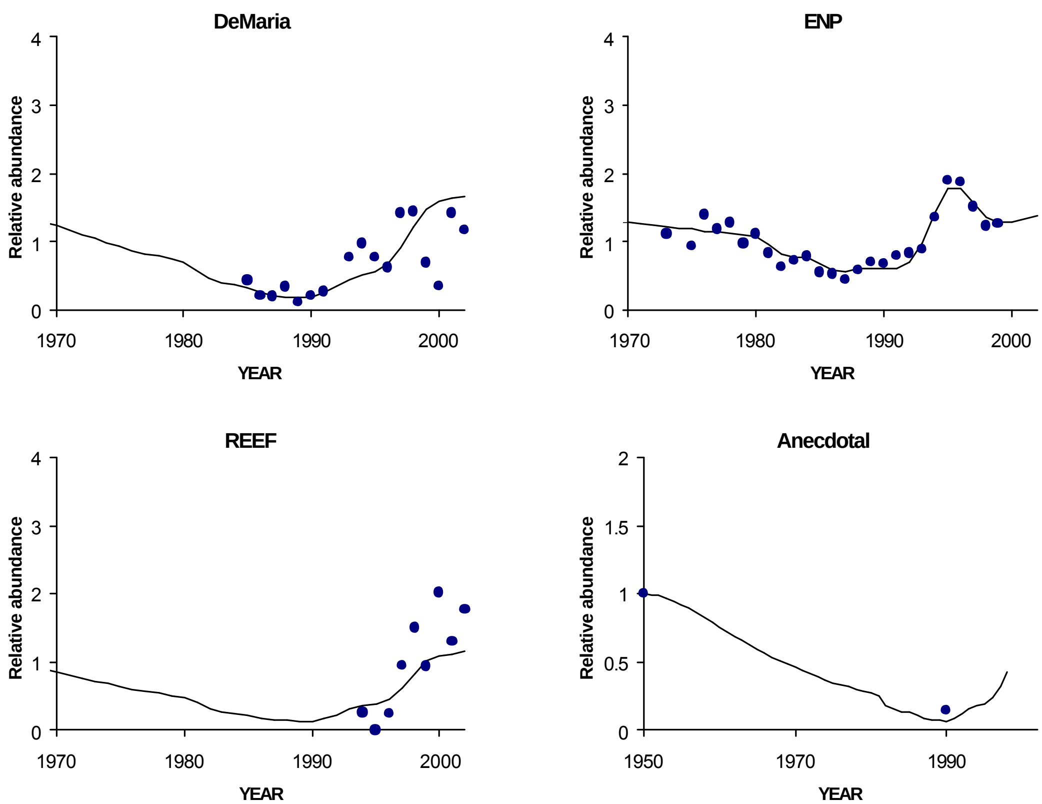


Figure 8. F-deviation model fits to the four indices of abundance.

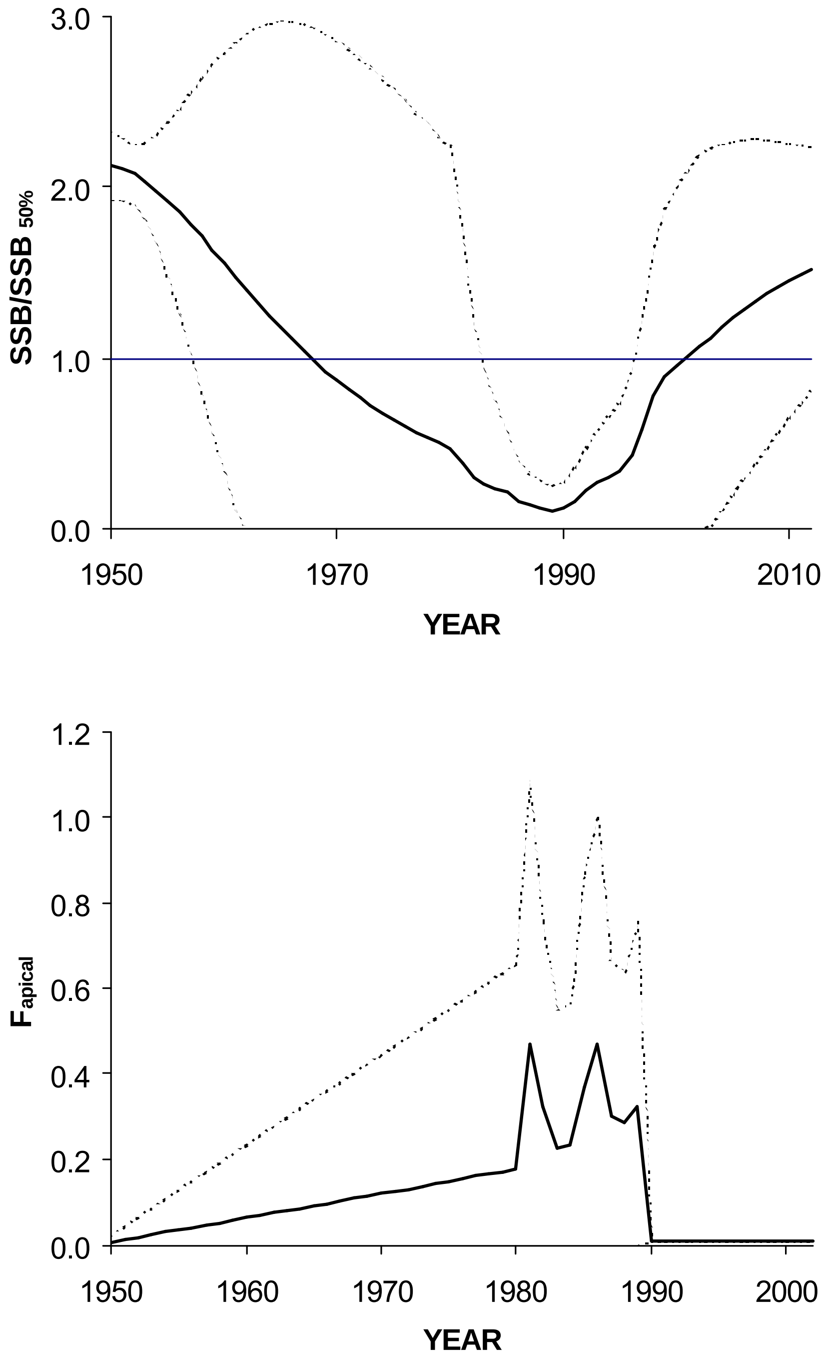


Figure 9. F-deviation model predictions of relative spawning biomass and fishing mortality rate with approximate 80% confidence limits.

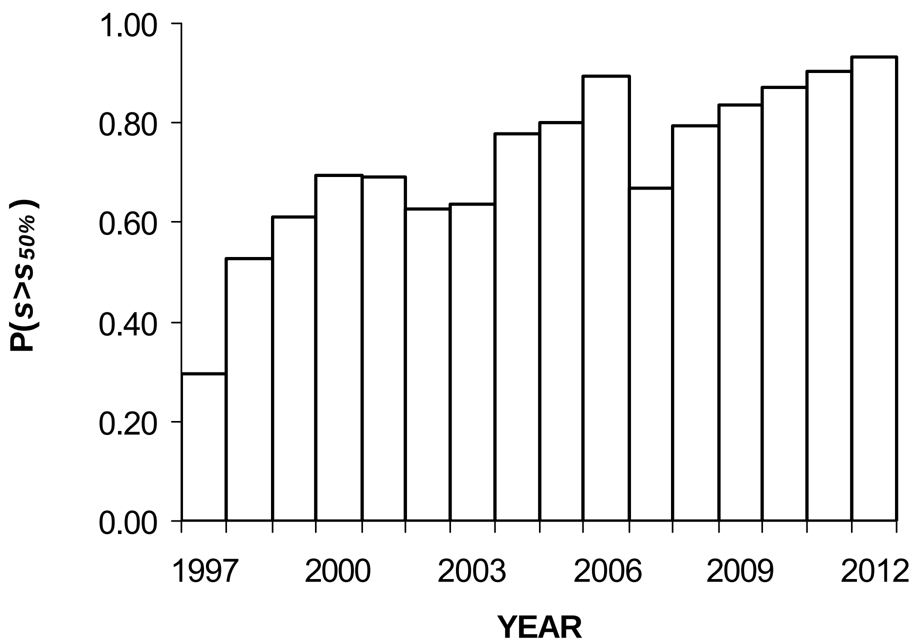
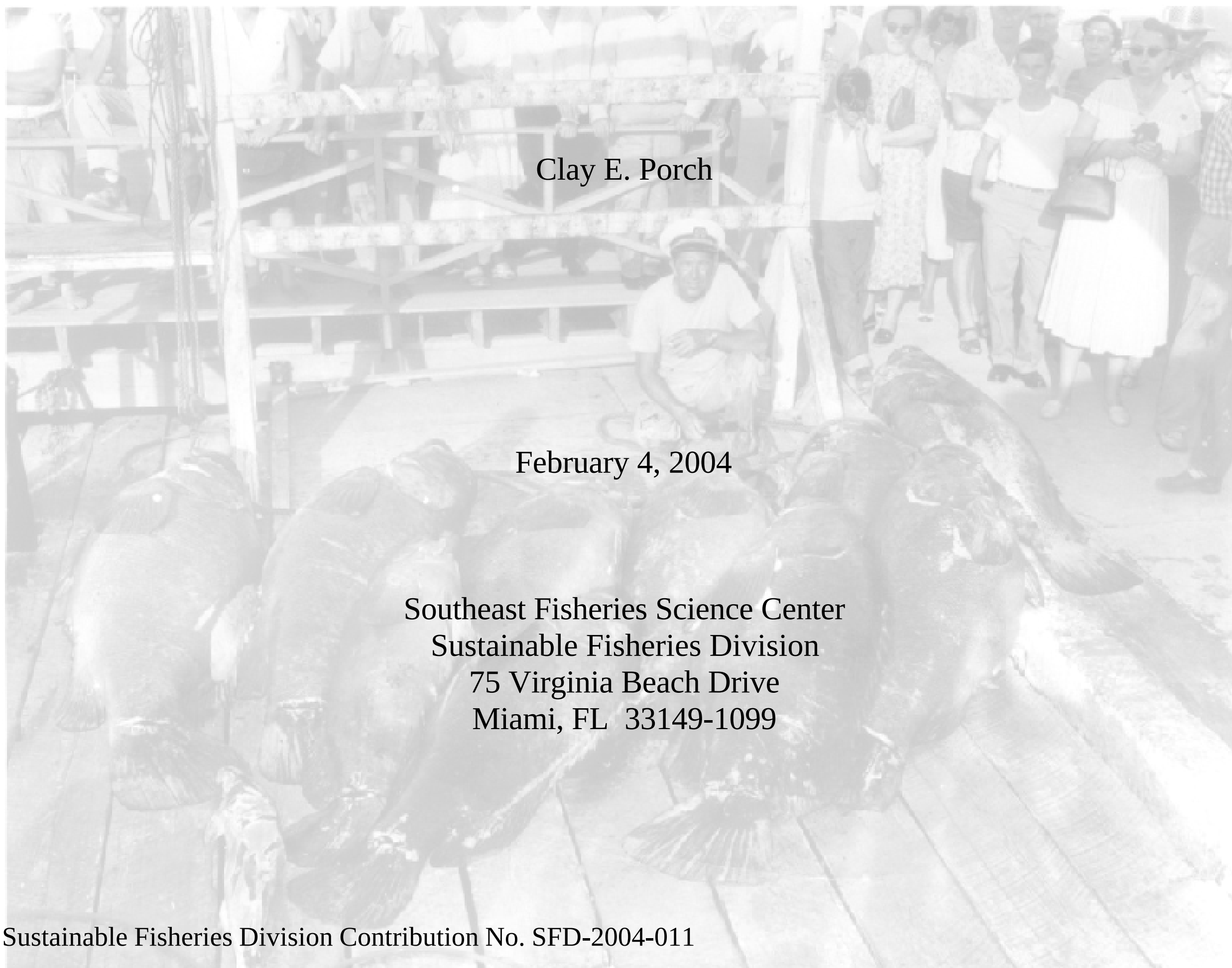


Figure 10. Probability stock will have recovered to spawning biomass levels corresponding to a 50% SPR by year for the F-deviation model

A REASSESSMENT OF REBUILDING TIMES FOR GOLIATH GROUPER WITH MODIFICATIONS SUGGESTED BY THE SEDAR REVIEW PANEL



Clay E. Porch

February 4, 2004

Southeast Fisheries Science Center
Sustainable Fisheries Division
75 Virginia Beach Drive
Miami, FL 33149-1099

Sustainable Fisheries Division Contribution No. SFD-2004-011

This paper updates the previous assessment of goliath grouper (Porch et al. 2003) by incorporating two changes in model structure and two changes recommended by the SEDAR stock assessment review panel[1] related to the input data. Apart from these changes, described below, the model and data are as described in Porch et al. (2003) and summarized here in Table 1.

Methods

Changes in the way fishing mortality is modeled
The fishing mortality rate on the most vulnerable age class is now modeled by a two-line function,

$$(1) \qquad F_y = \begin{cases} F_1 + \dfrac{F_{\text{modern}} - F_1}{y_{\text{modern}} - y_1}(y - y_1) & y_1 \le y < y_{\text{modern}} \\ F_{\text{modern}} & y_{\text{modern}} \le y < 1990 \end{cases}$$

where the parameter F_1 represents the fishing mortality rate in the first year of the time series (y_1 = 1950) and F_{modern} represents the average fishing mortality rate during the 'modern period' (here y_{modern} = 1980). The earlier formulation differed from (1) in that $F_y = F_1 + my$ for $y_1 \le y < y_{modern}$, where m is a slope parameter independent of the values of F_{modern}. The new formulation avoids the artificial discontinuity at y_{modern} (Figure 1) while at the same time eliminating m (a nearly superfluous parameter) and improving the overall precision of the estimates.

The fishing mortality rate from 1990 forward was originally set by Porch et al. (2003) to an arbitrary low value (0.01 yr^{-1}) to reflect the effect of the harvest moratorium. The SEDAR panel was divided as to whether the actual fishing mortality rate was higher or lower than this. They suggested bracketing this value by assuming the moratorium was probably not more than 99% effective at reducing F, but at least 90% effective. Given that the estimated average mortality rate immediately prior to the moratorium was on the order of 0.3 yr^{-1}, the two scenarios are roughly equivalent to assuming 0.3 to 3 percent of the goliath grouper population is killed each year by human activities (e.g., poaching and release mortality).

Changes in the way the variance of the indices of abundance are modeled
In the case of survey data, the variances associated with sampling variability are often estimated extraneous to the population model (e.g., during the standardization procedure). However, there may be additional variance owing to fluctuations in the distribution of the stock relative to the survey area (IWC 1994). Previously, to accommodate such possibilities, the log-scale variances were modeled as

---

[1]Anon. Goliath Grouper Stock Assessment Workshop Report, Southeast Data, Assessment and Review (SEDAR). January 2003. xx pp.

(2)
$$s^2_{c,i,y} = \log\left((c_{c,i,y}CV)^2 + 1\right)$$
$$s^2_{n,y} = \log\left((c_{n,y}CV)^2 + 1\right)$$

where $c_{c,i,y}$ and $c_{n,y}$ are relative coefficients of variation (estimated outside the model and scaled by the maximum value in the time series) and CV is a coefficient of variation that reflects some overall process variance (estimated within the model). The new model assumes the variances of the logged quantities are additive such that

(3)
$$s^2_{c,i,y} = c^2_{c,i,y} + \log(\mathrm{CV}^2 + 1)$$
$$s^2_{n,y} = c^2_{n,y} + \log(\mathrm{CV}^2 + 1)$$

where the $c^2_{c,i,y}$ and $c^2_{n,y}$ are now the annual observation variances for the logarithms of the count data and anecdotal reports of relative abundance (again, estimated outside the model). Besides being more intuitively appealing, the additive model produced more realistic process CV's (about 60% compared with over 300% in the previous model) and stabilized the likelihood profiling algorithm provided in the AD Model Builder package.

Other changes

The SEDAR review panel did not reject any of the model inputs per se, however it did question why the early data points (1982-1984) of the DeMaria index were excluded from the fitting procedure. It was generally agreed that the drastic decline from 1982 to 1983 was attributable to heavy fishing pressure applied when the sites were first discovered and probably did not reflect the trend of the goliath grouper population as a whole. Nevertheless the panel suggested that this problem may have been less severe in subsequent years and recommended that the 1983 and 1984 points be included.

Another point of contention was the point when the population was assumed to be near virgin levels (i.e., when substantive fishing began), with some members of the panel indicating that the date should be pushed back to as early as 1900. This was done as a sensitivity analysis.

Results and discussion

The base model assumes the fishing mortality rate is nearly zero in 1950, increases linearly through 1979, is relatively constant between 1980 and 1989, and then drops off from 1990 onwards to 1% or 10% of the 1980-89 level owing to the moratorium. The model fits to the data are statistically identical under both post-moratorium levels of F shown (Figure 2). Neither model was able to reconcile the rapid increase in relative abundance indicated by the REEF survey with the more gradual trends indicated by the other surveys (the same was true of the runs reported on in Porch et al, 2003).

The key parameters affecting the estimated recovery rate of the stock are the maximum lifetime fecundity parameter a and natural mortality rate M. The data appear to be sufficiently informative to influence the estimates of the latter, but have almost no effect on the former (figure 3). Thus the prior for the natural mortality rate must be regarded as highly influential in regards to the point estimates. The model that assumes a 90% effective moratorium estimates a greater value of a than the model with a 99% effective moratorium in order to reconcile the higher presumed mortality rates with the increase in abundance indicated by the surveys. Nevertheless, the estimated increase in productivity is offset by the increased fishing mortality rates so that the trends in spawning biomass and fishing mortality rates under the two scenarios are almost identical until about 1998. After that, the trends obtained with the 90% effective moratorium become increasingly less optimistic compared to the results with the 99% effective moratorium. As a result, the probability that the population will have recovered to a level at or above are the equilibrium level corresponding to an SPR of 50% ($\tilde{s}_{50\%}$) is lower for any given year (Figure 4). For example, under the 99% effective scenario it is estimated that there is a 50% chance the population will recover by 2005 and an 80% chance that it will recover by 2009. Under the 90% effective scenario, however, these dates are pushed back to 2009 and 2015.

The sensitivity runs where nearly pristine conditions were assumed to occur in 1900 are less optimistic than the runs above (Figures 5 and 6). They suggest a 50% chance of recovery by 2009 or 2015 with the 99% and 90% effective moratoriums, respectively. In both cases the 80% probability level is not reached until after 2020. It should be noted, however, that several member of the SEDAR review panel felt the results might be overly pessimistic because the fishing mortality rate was not likely to have increased linearly over the entire time period from 1900 to 1980 (more likely it continued at a relatively low level until about 1950 and them began increasing more rapidly).

It is important to reiterate that the data considered focus on a relatively small portion of the potential range of goliath grouper (see Porch and Eklund 2003). It is believed that the center of abundance for the population in U.S. waters is southern Florida, particularly the Ten Thousand Islands area, but goliath grouper are known to have occurred throughout the coastal waters of Gulf of Mexico and along the east coast of Florida, and on up through the Carolinas. Inasmuch as goliath grouper are not highly migratory, it is possible it may take some additional time for the species to fully occupy its historical range, thus delaying the overall recovery of the stock.

Acknowledgments

I thank the members of the SEDAR stock assessment review panel for their helpful suggestions. Cover photo from the web site sponsored by the Institute of Fisheries Research and Ecology, Florida State University (http://www.bio.fsu.edu/ifre/ifre_jewfish_threatspage.html).

Literature cited

Porch, C. E., and Eklund, A.-M. 2003. Standardized visual counts of goliath grouper off South Florida and their possible use as indices of abundance. Sustainable Fisheries Division Contribution SFD-0017. Southeast Fisheries Science Center, 75 Virginia Beach Drive, Miami, Florida 33149.

Porch, C. E., A.-M. Eklund, and G. P. Scott. 2003. An assessment of rebuilding times for goliath grouper. Sustainable Fisheries Division Contribution SFD-0018. Southeast Fisheries Science Center, 75 Virginia Beach Drive, Miami, Florida 33149.

Table 1. Summary of likelihood and prior components of log-posterior distribution. Note that CV refers to the estimated ‘overall’ coefficient of variation.

Component	distribution	median	standard deviation
Prior for a-1	lognormal	2.65	$s_{\ln a}$ = 1.14
Prior for M	lognormal	0.095	$s_{\ln M}$ = 0.4
Prior for F_1	normal*	0.1	s_{F_1} = 0.2
Prior for F_{modern}	normal*	0.3	$s_{F_{\mathrm{modern}}}$ = 0.3
Prior for catchabilities q	normal*	0.5	s_q = 1.0
Prior for CV	normal	0.5	s_{CV} = 0.25
Prior for recruitment devs.	lognormal	0	$s_{\ln r}$ = 0.4, r = 0.5
Likelihood for surveys	lognormal	model expectation	$s^2_{c,i,y} = c^2_{c,i,y} + \log(\mathrm{CV}^2 + 1)$
Likelihood for anecdotes	lognormal	model expectation	$s^2_{n,y} = c^2_{n,y} + \log(\mathrm{CV}^2 + 1)$

*relatively uninformative priors.

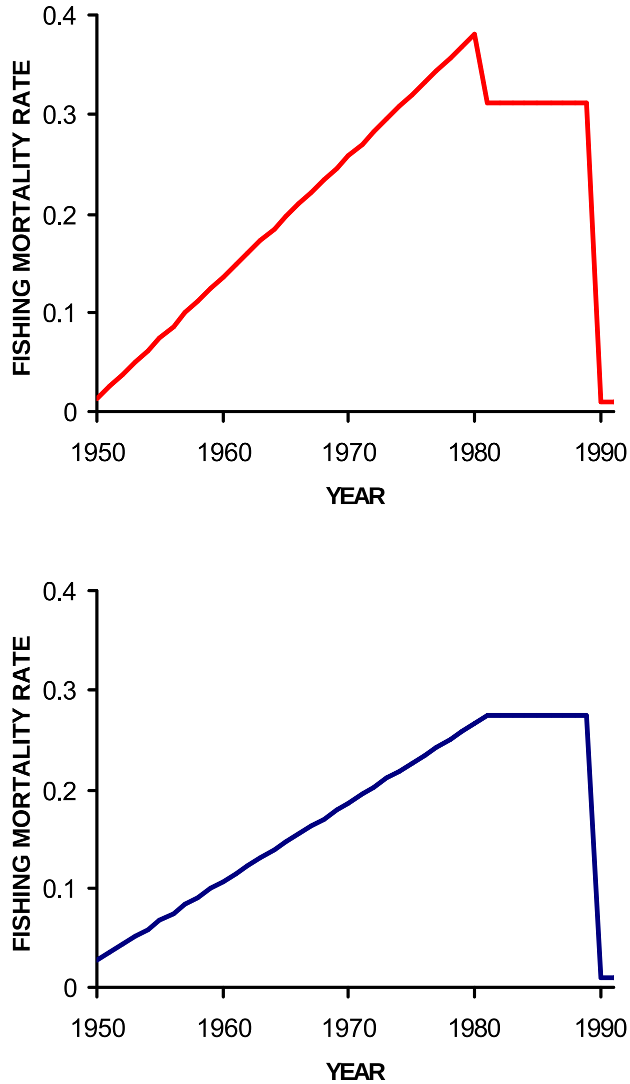


Figure 1. Estimated patterns of fishing mortality rate under the old (top) and new (bottom) formulations.

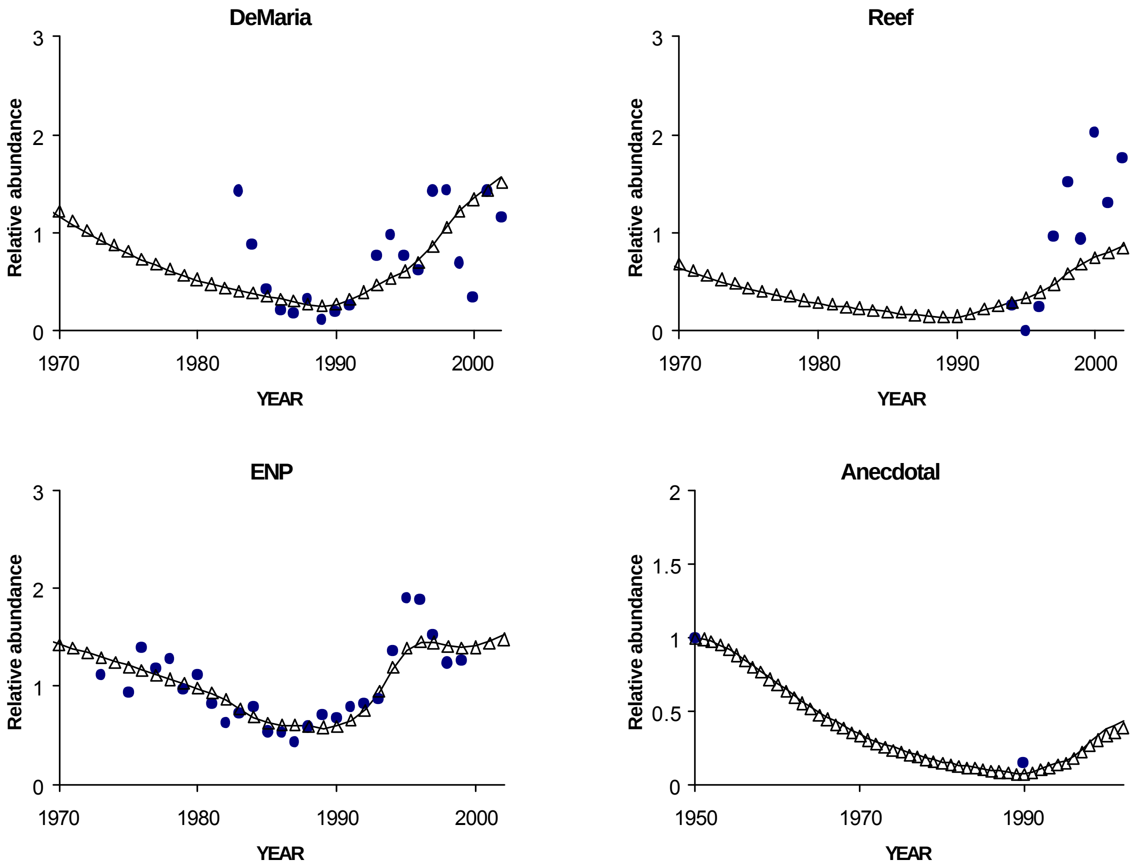


Figure 2. Model fits to the four indices of abundance. Lines denote predicted values with a 99% effective moratorium and triangles denote predicted values with a 90% effective moratorium.

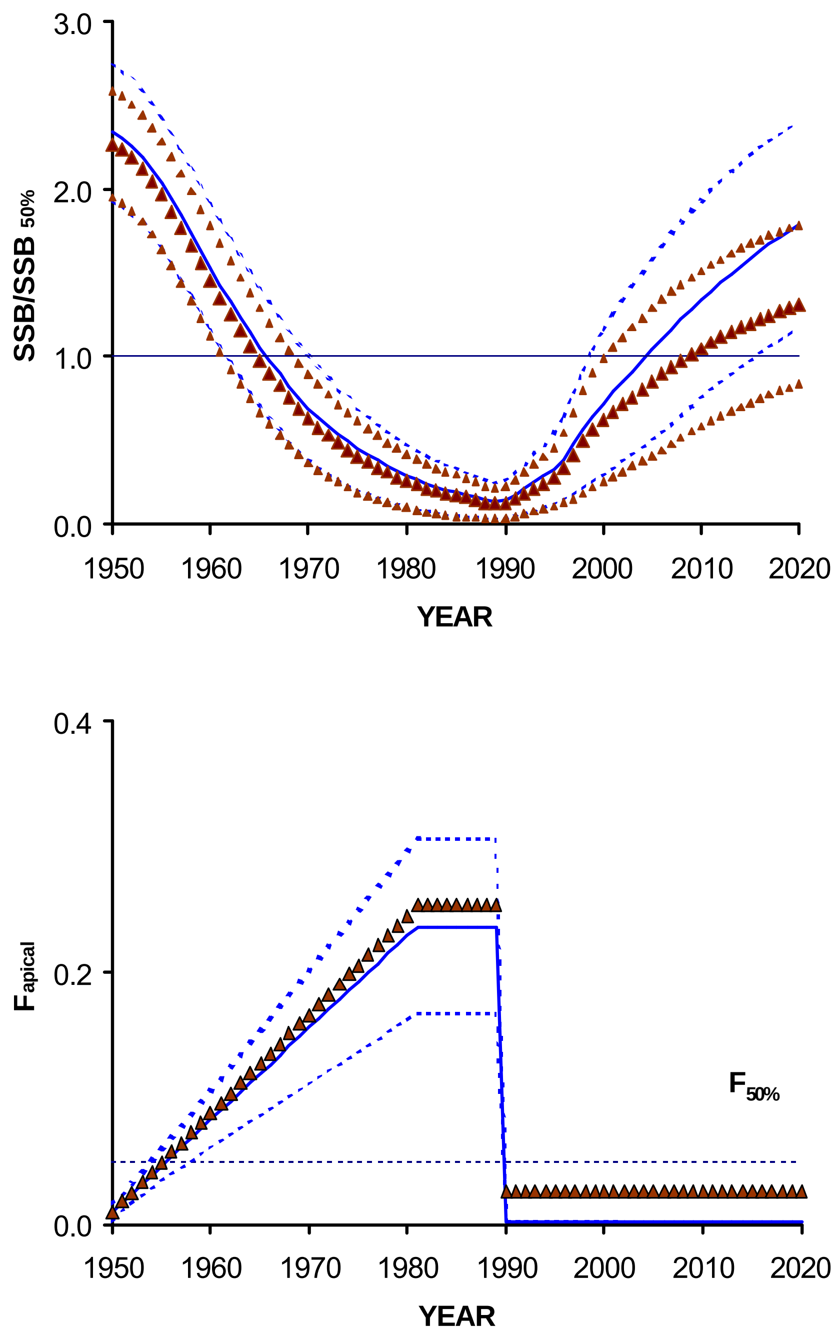


Figure 3. Predictions of relative spawning biomass and fishing mortality rate with approximate 80% confidence limits from the models assuming the moratorium was 99% effective (lines) or 90% effective (triangles).

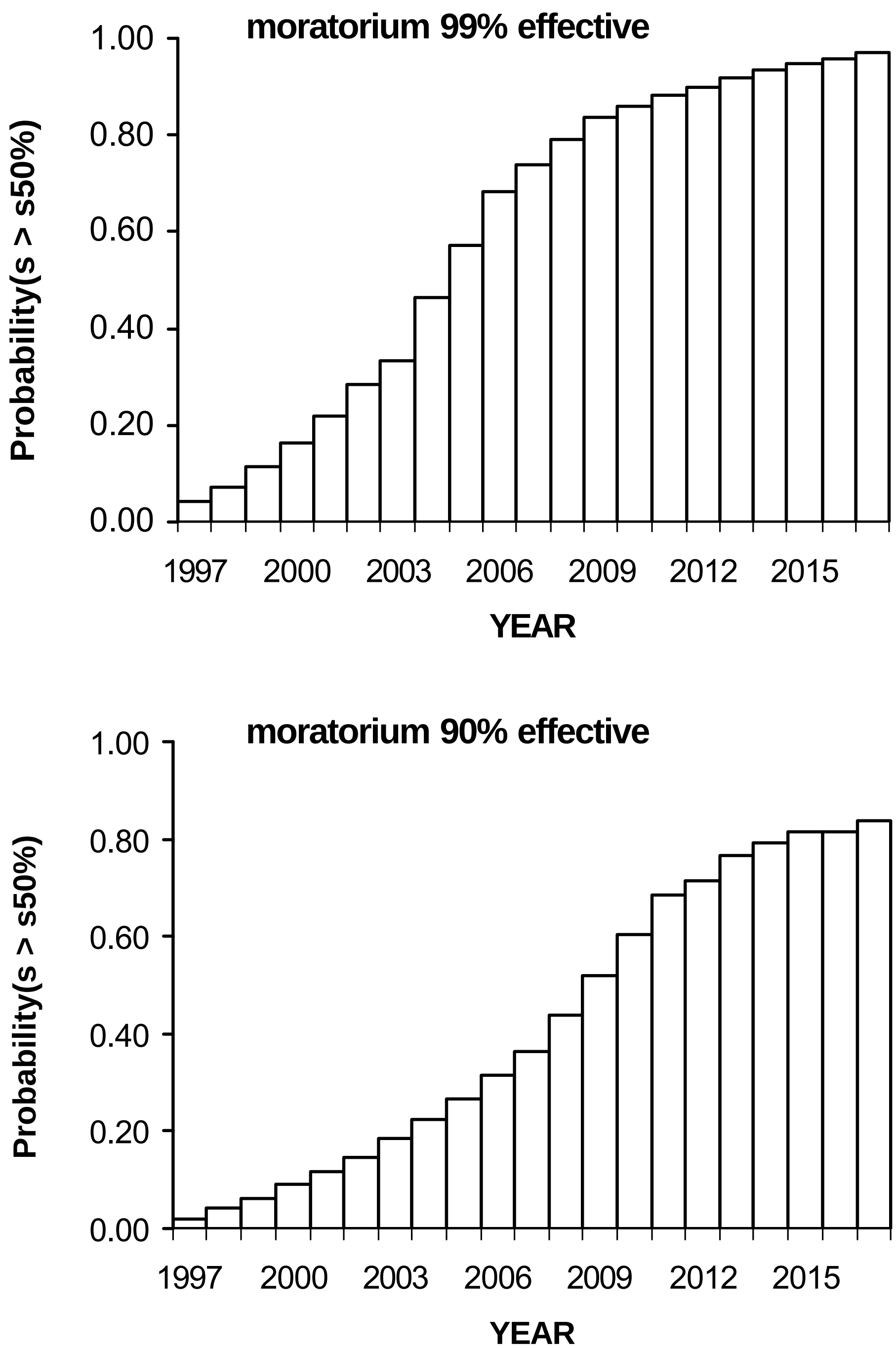


Figure 4. Probability stock will have recovered to spawning biomass levels corresponding to a 50% SPR assuming the moratorium was 99% effective (top panel) or 90% effective (bottom panel).

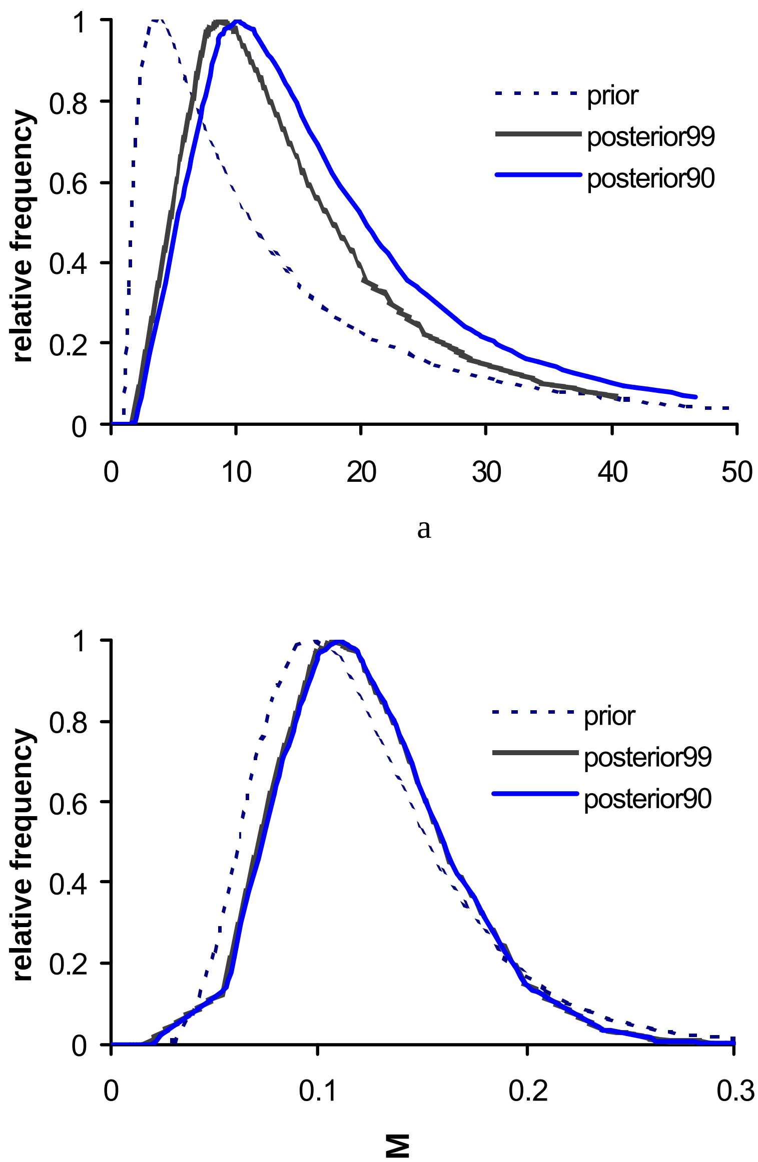


Figure 5. Prior and posterior distributions for the maximum lifetime fecundity parameter (α) and natural mortality rate (M) obtained when the moratorium was assumed to be 99% or 90% effective in reducing F.

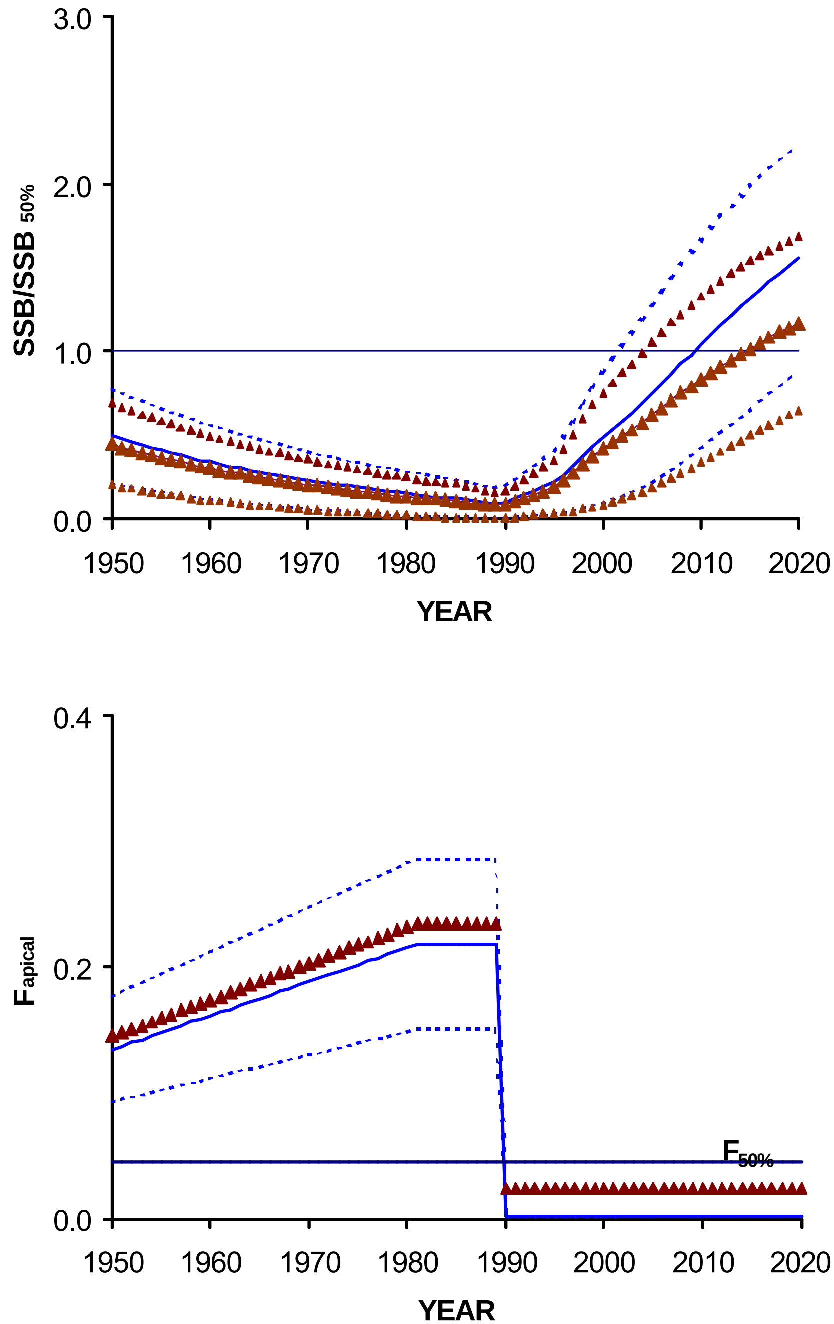


Figure 6. Predictions of relative spawning biomass and fishing mortality rate resulting when substantive exploitation is assumed to begin in 1900 rather than 1950.

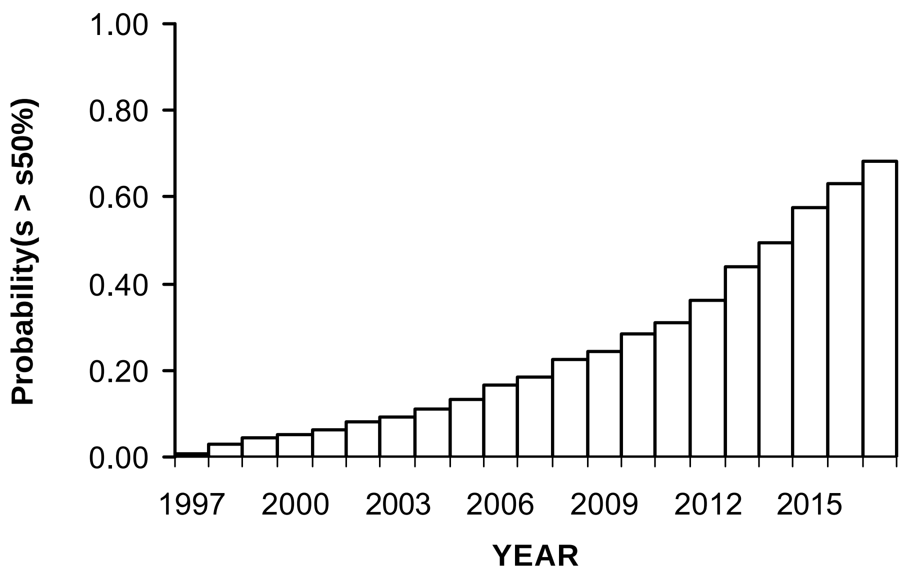


Figure 7. Probability stock will have recovered to spawning biomass levels corresponding to a 50% SPR when substantive exploitation is assumed to begin in 1900 and the moratorium is 90% effective.

The Goliath Grouper in Southern Florida: Assessment Review and Advisory Report

Report prepared for the
South Atlantic Fishery Management Council
Gulf of Mexico Fishery Management Council
National Marine Fisheries Service

Edited by Michael C.S. Kingsley for the
Southeast Data and Assessment Review

February 2004

Kingsley, M.C.S., ed. 2004. The Goliath Grouper in southern Florida: assessment review and advisory report. Report prepared for the South Atlantic Fishery Management Council, the Gulf of Mexico Fishery Management Council, and the National Marine Fisheries Service. Southeast Data and Assessment Review. vii + 17 pp.

CONTENTS

PREFACE

Summary of the SEDAR review process

The South Atlantic Fishery Management Council, the Gulf of Mexico Fishery Management Council, and the Caribbean Fishery Management Council, in conjunction with NOAA Fisheries, have adopted the Southeast Data, Assessment and Review (SEDAR) process, a multi-step method for determining the status of fish stocks. SEDAR is structured around three workshops: 1) Data Workshop, 2) Stock Assessment Workshop and 3) Review Workshop. Participants in Data Workshops review input data, including catch statistics, fishery sampling and population monitoring data, and species life history. Participants in Assessment Workshops develop stock assessment models, estimate values for population parameters and stock status benchmarks, and project future population conditions. At Review Workshops an independent peer review panel provides a technical review of the data and of the assessment methods. The relevant Council committees, such as the Science and Statistics Committees, must then certify the final assessment report before it can become eligible for use in developing management actions. The goal of SEDAR is to provide an open and transparent process for developing and reviewing scientific information that is critical to management of species in the Southeastern United States, including the South Atlantic, Gulf of Mexico, and Caribbean. The SEDAR process includes data collectors, biologists, fishermen, environmental representatives, database managers, stock assessment scientists and Council members and staff.

The Goliath Grouper (*Epinephelus itajara*) has been identified as a species of concern, and was proposed for SEDAR Assessment. A workshop on the data available for the Goliath Grouper was held on 5-6 March 2003[1]. The participants concluded, from a review of the data presented to them, that the data available on the species were not adequate to support a full assessment even in waters restricted to southern Florida, and still less adequate for the entire range of the species. However, as the report of the workshop mentions, another data set was identified *after* the meeting that might contribute to an assessment.

---

[1] Anon. n.d. [2003.] Goliath Grouper data workshop report. SEDAR3-DW-1. 11 pp.

A subsequent SEDAR Review Panel[2] revisited the question of an assessment of the Goliath Grouper and considered that "not conducting an assessment on this occasion had likely been an incorrect decision. It was suggested that the assessment option for Goliath Grouper be revisited at an early opportunity, initially looking specifically at assessment models that could operate in a data-poor arena."

This recommendation was acted upon and an assessment document was prepared[3]; however, no assessment workshop was held at which the assessment could be examined or other models compared with the one that was used. Instead, the assessment document was presented to an Assessment Review Panel, normally the third and last stage of the SEDAR process, at a meeting in Tampa, Fla on 27–30 January 2004. The present document reports the results of that meeting. It does not present the assessment itself, but the Review Panel's views on the validity and limitations of both the assessment and the data upon which it was based. An Advisory Report, prepared by the Review Panel, and based on the conclusions it could draw from the assessment as to the current state of the stock and forecasts for its future, is appended.

Purpose of the Terms of Reference and Advisory Report

The 'Terms of Reference Report' provides a brief review of the stock assessment and the underlying data, with the SEDAR Assessment Review Panel's conclusions about the adequacy and appropriateness of both. The report does not repeat the detailed results of the assessment. An 'Advisory Report' on stock status and possible and appropriate management for the stock in accordance with SFA prescription is appended; however, as the Panel is specifically enjoined not to conduct an alternative assessment, the Advice that can be formulated is bounded by the adequacy of the assessment(s) that is (are) reviewed.

Acknowledgments

Thanks are due to the members of the SEDAR Assessment Review Panel who participated in the review—Ralph Allen (GMFMC Advisory Panel; Independent), Luiz Barbieri (GMFMC Scientific and

[2] SEDAR Peer Review of Yellowtail Snapper Assessment, with comments on Goliath Grouper (Tampa, Florida, 28–31 July, 2003).

[3] Porch, C.E., A.-M. Eklund and G.P. Scott. 2003. An assessment of rebuilding times for Goliath Grouper. SEDAR6-RW-3. Contribution SFD-2003-0018, Sustainable Fisheries Div., SE Fisheries Science Center, National Marine Fisheries Service, Miami, Fla. 25 pp.

Statistical Committee; Florida Fish and Wildlife Conservation Commission), Jon Brodziak (Reviewer; Northeast Fisheries Science Center, NMFS), Marianne Cufone (Reviewer; The Ocean Conservancy), Don DeMaria (SAFMC Advisory Panel; Independent), Michael Kingsley (Chairman; Center for Independent Experts), Debra Murie (GMFMC Finfish Assessment Panel; University of Florida), Michael Murphy (GMFMC Finfish Assessment Panel; Florida Fish and Wildlife Conservation Commission), Julie A. Neer (Reviewer; Southeast Fisheries Science Center, NMFS), Jay Rooker (GMFMC Finfish Assessment Panel; Texas A&M University), Richard Taylor (GMFMC Reviewer; Independent), Eddie Toomer (GMFMC Advisory Panel; Independent) and John Wheeler (Reviewer; Center for Independent Experts). We thank the presenters and other scientific staff for their work beforehand and for their presentations at the meeting, and the members of the public, the fishermen, divers, and others, for cooperative and constructive input to the review meeting. We thank the staff of the Fishery Management Councils, the National Marine Fisheries Service and other organisations for their contributions to the running of the meeting and for their input to the Review Panel's deliberations.

BACKGROUND ON THE GOLIATH GROUPER.

The Goliath Grouper (*Epinephelus itajara*) is a long-lived reef fish that grows to unusually large size: fish weighing several hundred pounds are not unusual. Outside the spawning season, adults are typically solitary, sedentary, and territorial, unafraid and somewhat inquisitive; these characteristics make them an easy target for spearfishing. The species takes hooks easily, so is also vulnerable to angling. The large size it can reach makes it impressive as a trophy, but also makes it difficult to handle with the care necessary to ensure its survival on release. These factors combined to create an overfishing situation that depleted numbers in southern Florida and elsewhere, and the Fishery Management Councils imposed a moratorium on landings in 1990. Since then, anecdotal accounts and quantitative survey data agree that numbers of both adults and juveniles have increased, although a subjective consensus appears to be that pristine stock levels have not been reached. Prevailing comment on the state of the stock ranges from concern over the still-depleted numbers and reported continuing mortality from poaching and other fishing—mortality of released fish whether caught intentionally or as by-catch is reported to be high—to irritation at the effect of an increasing abundance of large territorial adults in restricting both the numbers, and the availability to divers, of other reef species.

I TERMS OF REFERENCE FOR THE REVIEW OF THE GOLIATH GROUPER ASSESSMENT.

Evaluate the adequacy and appropriateness of fishery-dependent and fishery-independent data used in the assessment (i.e., are the input data scientifically sound and up to date?).

The fishery-independent data comprised two time series consisting of visual-survey counts of adult fish carried out by divers[4]. The first series (made by Mr D. DeMaria) had the following characteristics: few (5) sites, all relatively distant from the coast in the eastern Gulf of Mexico; all observations were made by one observer; a 21-year series (1982–2002; although not at all sites were surveyed over the entire period). The second, made by the Reef Educational and Environmental Foundation (REEF), was a nine-year series covering 1994–2002. It had many sites, all relatively close to land in the reef tract off the east coast of Florida and the southern edge of the Florida Keys. Observations were made by many different observers but the methods were standardized, and all the counts were censored at a maximum of

[4] Porch, C.E., and A.-M. Eklund. 2003. Standardized visual counts of goliath grouper off south Florida and their possible use as indices of abundance. Contribution SFD-0017, Sustainable Fisheries Division, SE Fisheries Science Center, NMFS, Miami, Fla.

two fish sighted. Both series were census-type surveys. There was no mention of the collection in the course of either survey of other data, such as estimated length.

The first series was questioned with respect of how well it reflects the abundance or density of the species over its entire range in south Florida waters. The fact that a single observer collected the data was considered a strength of the series, but its limited coverage of a small set of similar sites in a restricted area remained a concern. It was not clear whether these sites represent the predominant range for the species in the long term: observations were cited of historical aggregations near shore in shallow water in many locations around the coast. However, anecdotal observations were advanced that indicated broadly similar trends in other areas of western Florida further north, and it was also observed that the overall trend of the series is supported by that of the Everglades National Park creel survey series. It was concluded that the data series was acceptable for the assessment.

The inclusion of the data from 1982 and 1983 in the DeMaria series was also questioned. The assessment that was presented had omitted both these years on the grounds that large reductions in numbers observed from 1982 to 1984 reflected intensive fishing subsequent to, and consequent on, discovery of these sites and may therefore represent a localized effect. This decision was questioned. One of the arguments for including those two points was that the sites might have been fished before the survey was begun in 1982. Additionally, fishery landings data, which had been excluded at the data workshop, signaled a 40% drop in landings at the same time. However, the commercial landings were subject to problems of both over- and under-reporting, and therefore such a drop in commercial landings was not considered to be a reliable indicator of a corresponding reduction in overall stock abundance. Furthermore, including the 1982 data impaired the agreement between this series and the others. The Review Panel's final recommendation was to include the 1983 data, but to exclude the 1982 data from the assessment.

The REEF diver survey along the Florida reef tract was accepted for use in the assessment with little discussion. The censoring of the data at 2 fish per survey station was considered unlikely to be significant in terms of the assessment, since the numbers of observed Goliath Grouper in this survey were overall very small. The inclusion of a data series from a geographical fringe of the distribution was considered an advantage, because it might help the aggregated data to track the trend of the species in more of its range.

Another set of data consisted of subjective estimates of the decline in stock size between 1950 and 1990 obtained by telephone interviews with 9 experienced fishermen and divers who were active over the whole period. The Panel considered these estimates acceptable for the assessment.

The fishery-dependent data available consisted of a single creel-survey series from the Everglades National Park (ENP)—where coastal mangroves are principally considered habitat for juveniles—covering 1973–1999 and reporting catch and effort from a total of 165,734 trips[5]. The data were restricted to 14,026 trips that reported catching Goliath Grouper or species deemed, from analysis of the total set, 'associated' with Goliath Grouper. This restricted set was used to calculate a catch:effort series as an index of abundance of the sub-adult segment of the stock. Effort per observation was estimated.

The restriction method used on the ENP data series was discussed. Among the points raised were that some of the associations determined by the association analysis were biologically unconvincing, and suggestions were made both that the association threshold should be made more stringent and that it should be relaxed[6]. No consensus was reached for changing the assigned value either way, and the threshold was left unchanged. It was pointed out that the restriction was a numerical exercise to avoid gross biases due to time trends in the proportion of trips that were directed completely away from Goliath Grouper habitat. There was discussion on the effect of including all trips that caught Goliath Grouper, regardless of the presence of associated species, in the restricted set, but no consensus was reached that it induced a bias that would be significant to the assessment.

The Review Panel considered that this data series, and the treatment to standardize the catch: effort ratios, were acceptable for the assessment. There was a question about whether the relationship between catch: effort ratios and density would be different before the fishery was closed from after, but it was pointed out that even after the moratorium on landings of Goliath Grouper was instituted, a directed catch-and-release fishery continued. There were additional discussions on whether the skill of fishermen

---

[5] Cass-Calay, S.L., and T.W. Schmidt. 2003. Standardized catch rates of juvenile Goliath Grouper, *Epinephelus itajara*, from the Everglades National Park Creel Survey, 1973-1999. SEDAR6-RW-2. Contribution SFD-2003-0016, Sustainable Fisheries Div. SE Fisheries Science Center, National Marine Fisheries Service, Miami, Fla. 17 pp.

[6] It transpired after the Review Panel meeting that Cass-Calay and Schmidt had in fact tested the effect of different values of the association criterion. A more stringent value, excluding more species and more trips, gave trends in catch:effort ratios that were almost identical with those used. A lower, more inclusive, value gave trends that were somewhat more exaggerated—faster decrease at the beginning, faster increase at the end—but not very different.

in continuing to find fish, even when becoming scarce, could cause catch: effort ratios to be a non-linear indicator of average density.

By means of an existing age-length curve[7], the ENP data were also used to calculate age-specific vulnerabilities to the fishery before the moratorium, and age-specific relative abundance after the moratorium for age classes within this stock segment (ages 0 to 5). The Review Panel questioned whether vulnerability in the pre-moratorium fishery might have reached asymptote as late as 9 or 10 yrs, and the sensitivity of the assessment to such a change was investigated. However, the study that suggested this hypothesis was not available to the Panel for review, nor designed to get this type of information. The Panel concluded to retain the vulnerability curve originally proposed.

Landings data from NOAA Fisheries exists for 1950–1990. This series ended with the imposition of the moratorium. The series had problems with both over- and under-reporting and is of limited relevance in the current state of the stock and the fishery, but might provide loose corroborative evidence for the trend of the population decline. Some catch-rate, and possibly mark-recapture, data exist from a tagging study on juveniles in the Ten Thousand Islands and Florida Bay area. These two data series were not used in the assessment.

Other life-history data were used in stock-dynamics modeling. Natural mortality estimates in the literature were used together with estimates derived from published longevity to generate a prior distribution for natural mortality[8,9,10]. It was pointed out that the longevity estimate was obtained from an exploited population and could possibly underestimate the true natural longevity. Additional methods of determining longevity were discussed but no definite recommendations were made. Existing age-length and length-weight curves were used to generate a surrogate for age-specific fecundity. Metadata from

---

[7] Bullock, L.H., M.D. Murphy, M.F. Godcharles and M.E. Mitchell. 1992. Age, growth and reproduction of jewfish *Epinephelus itajara* in the eastern Gulf of Mexico. Fish. Bull. 90: 243-249.

[8] Legault, C.M., and A.-M. Eklund. 1998. Generation times for Nassau grouper and jewfish with comments on M/K ratios. Contribution SFD-97/98-10A, Sustainable Fisheries Division, Southeast Science Center, National Marine Fisheries Service, Miami, Fla.

[9] Hoenig, J. 1984. Empirical use of longevity data to estimate mortality rates. Fish. Bull. 81(4): 898–903.

[10] Sadovy, Y., and A.-M. Eklund. 1999. Synopsis of biological data on the Nassau grouper, *Epinephelus striatus* (Bloch, 1792), and the jewfish, *E. itajara* (Lichtenstein, 1822). NOAA Tech. Report NMFS 146. 65 pp.

other 'periodic strategist' fishes was used to generate prior distributions for parameters of the stock-recruitment relationship[11,12].

Overall, the Review Panel considered that the data used were scientifically sound. However, the data sets available were very limited, and restricted the type of assessment model that could be built, and therefore the conclusions that could be drawn from it.

Evaluate the adequacy, appropriateness, application and results of models used to assess stocks (e.g., measures of exploitation, abundance, and biomass).

The stock to be considered was not defined. The data available were limited to southern Florida waters. The relationship between stocks, or sub-stocks, in these different areas appears not to be well known. The meeting therefore considered that it was reviewing an assessment covering all Goliath Grouper in waters off Florida south of 26°N. Conclusions from the assessment are restricted to the areas covered by the data.

Visual surveys to count adults (DeMaria and REEF surveys) were standardized using a stepwise approach to build general linear models of logged counts, so that year effects could be isolated. In addition to year, location and season effects were statistically significant. The diagnostic statistics of the model fits were satisfactory, and visual surveys were thought to give valid indices of abundance for adults. Catch rates of juveniles from creel survey data were standardized with sequential fitting of models to proportion successful trips and to catch per unit of effort (CPUE) of successful trips. Retained factors in the proportion of successful trips were whether trips targeted Goliath Grouper or not and year. Retained factors from the analysis of the CPUE of successful trips included year, skill level of the fishing party, fishing area, and an interaction between year and area. Diagnostic statistics were again satisfactory.

The Review Panel considered that these treatments of the series of abundance indices were acceptable.

---

[11] Rose, K.A., J.H. Cowan, K.O. Winemiller, R.A. Myers and R. Hilborn. 2001. Compensatory density dependence in fish populations: importance, controversy, understanding and prognosis. Fish and Fisheries 2: 293–327.
[12] Myers, R.A., and G. Mertz. 1998. Reducing uncertainty in the biological basis of fisheries management by meta-analysis of data from many populations: a synthesis. Fish. Res. 37: 51–60.

It was remarked in the report of the data workshop and in assessment documents that no measures of absolute abundance exist for any stock segment, and no data from which any such measure could be based. Therefore, all deductions on abundance from assessment modeling are relative to a pristine stock state; deductions on fishing mortality are, by contrast, absolute.

An assessment model was built to trace stock trajectory from an assumed pristine state in 1950 through increasing fishing mortality to low stock levels, the moratorium in 1990 and subsequent increasing indices of abundance. Stock levels in the model were expressed relative to pristine. Stock structure was governed by age-specific natural mortality and age-specific vulnerability to year-specific fishing mortality. Vulnerability was assumed to follow an increasing logistic. Recruitment was governed by weight at age in the spawning stock and pre-recruitment mortality.

The model was fitted to data using Bayesian methods, and ancillary information was sought to create informative priors, including stock-recruitment relationships. Under the assumption of a linear increase in fishing mortality from 1950 through 1979, the stock structure was tracked back to its pristine state. The stock trajectory fitted the series of standardized abundance indices reasonably well.

Three sensitivity trials were carried out. 1) 1950 was replaced by 1900 as the year for which the stock state was assumed pristine. The result of this sensitivity trial showed that recovery was lengthened by several years under the altered assumption. It was recommended to retain the 1950 starting point. 2) When the age of full selectivity in the model was increased from 6 years to about age 10 years, rebuilding would already have occurred, with 50% probability, by 2002. 3) The model showed that predictions of rebuilding time were very sensitive to the assumed on-going fishing-induced mortality after the moratorium was imposed. When it was assumed that the moratorium only reduced fishing mortality to 20% of its pre-moratorium level (i.e. 80% effective), the model suggested that the stock would be unlikely to recover.

The Review Panel recognised the importance of estimating the present mortality in trying to predict rebuilding times. However, even after much discussion, and considering anecdotal evidence of on-going mortality, the Panel could not reach a single conclusion on its magnitude for lack of data. By consensus, it was agreed that it would be reasonable to bracket a range at end-points of 10% and 1% of pre-moratorium fishing mortality in order to provide an illustrative range of rebuilding-time predictions[13].

The Review Panel considered that the models used were appropriate for the available data, and adequately addressed questions of exploitation and relative abundance, within the limits of the data.

Evaluate the adequacy, appropriateness, application, and results of models used to estimate population benchmarks and Sustainable Fisheries Act status determination criteria (e.g., MSY, F_{msy}, B_{msy}, MFMT, MSST, and OY).

In the absence of estimates of biomass, it was not possible to estimate all standard stock benchmarks. MSY and other benchmarks referencing absolute biomass could not be estimated. An MSST relative to pristine stock state could be estimated.

The model, and the available data, are together adequate for estimating fishing mortality reference points, such as fishing mortality corresponding to any percentage SPR, and a wide range of other fishing mortality benchmarks. F_{msy} could not be reliably estimated on account of concerns over selectivity and the exact stock-recruitment relationship.

The Review Panel used a proxy for F_{msy}, $F_{50\%SPR}$, in accordance with the Gulf Council's selection of that proxy in its generic SFA Amendment. $F_{50\%SPR}$ was also the proxy for F_{OY} used by the South Atlantic Council, which in Amendment 11 to its FMP for the snapper/grouper complex had selected $F_{40\%SPR}$ as its proxy for F_{msy}.

The Review Panel considered that OY, which depends on socio-economic and other inputs, is outside its scope.

---

[13] After the meeting, two members of the panel expressed reservations about the use of a value of 90% as an 'ineffective' endpoint of the illustrative range, considering it likely that the moratorium had been even less effective than this would imply. (See also 'Stakeholder Comments' below.)

Evaluate the adequacy, appropriateness, and application of models used for rebuilding analyses where appropriate, and estimate, to the extent possible, generation time and rebuilding time in the absence of fishing mortality.

The Review Panel reviewed the assessment model as a device for predicting rebuilding times for this stock, and considered the model to be adequate for estimating rebuilding times for any level of F. The Panel did not consider a scenario in which current and future fishing mortality is zero. The Panel did not review the available information on generation time[8] as it was not part of the current assessment.

Develop recommendations for improving data collection and assessment and future research (both field and assessment).

The Review Panel concurs with the recommendations of the data workshop that the following topics be pursued in research programs on the Goliath Grouper. It recommended the following rough priority listing, as determined by the difficulty encountered in treating these topics in the course of this review:

Estimation of population size: Estimates of population size were considered to be of highest importance for future management. It was noted that because of the apparently restricted home range and high site fidelity characteristic of adults, sampling throughout the geographic range would be important. Tag/recapture studies were mentioned as a potential monitoring tool.

Estimates of on-going mortality: The issue of ongoing mortality was of critical concern to the Review Panel. Anecdotal information with regard to various sources of this mortality was presented. These sources included longline by-catch, post-release mortality, and illegal harvest. It is extremely important that these sources of ongoing mortality be identified and the magnitude of this mortality estimated.

Investigations of stock structure: This question was repeatedly raised. The assessment reviewed by the Panel was of necessity limited to south Florida owing to the geographic coverage of the data and the absence of data concerning the stock structure.

Demographics: Monitoring the demographics of the population, particularly age composition, could provide valuable information.

Reproductive biology: Developing further understanding of the reproductive biology of Goliath Grouper was considered important.

Historical abundance and exploitation: Obtaining information on historical abundance was also considered important.

Survey data. While the Review Panel considered it in the highest degree important to continue the current surveys, it recommended that data collection could be improved by extending survey efforts to better cover the full historical range of the stock.

ADDITIONAL COMMENTS

There were none.

III STAKEHOLDER COMMENTS

From Ralph Allen: 'The fact that adult Goliath Grouper heavily aggregate at a small number of well known and easily located sites would make them extremely vulnerable to rapid depletion in the event that a directed fishery were ever opened.'

From Marianne Cufone and Don DeMaria: 'We are uncomfortable with the assumed values of post-moratorium fishing mortality on Goliath grouper. The discussion was difficult to follow and keep in perspective, as it ranged back and forth between the panel and the audience and discussion of assumptions regarding mortality rates, mortality reductions, moratorium effectiveness, and the number of fish killed per 100 in the population. Upon further consideration and reviewing the final assumed values, assuming the moratorium is 90-99% effective might be overly optimistic. The mathematics of these stock assessments is quite impressive, but we fail to see how unknown parameters such as human nature and environmental conditions can be factored into an equation. Considering the slow growth and long life of Goliath grouper, the number of dead Goliath grouper observed, and reports of fish being intentionally killed, we feel more comfortable erring on the side of conservation and not attempting to estimate moratorium effectiveness.'

From Dennis O'Hern of Largo, Fla, recreational angler, diver, spearfisher and representative for the Florida Skin Divers Association (FSDA) whose numbers represent over 500 divers: 'Goliath Grouper populations in our area of West Central Florida, roughly north of the 26 degree latitude line, are large, growing and becoming increasingly aggressive toward divers. Examples of the over-population abound, with local anglers and divers reporting goliath encounters on every wreck in the area. Even small, natural ledges are holding one or two medium to large fish. A small wreck will hold 6 fish at least, with the *Mexican Pride* (a popular local wreck) having 25 or more that appear to exceed 300 #. Many local divers, including myself, have been bumped aggressively and had fish taken from them by these large grouper.

'There are no scientific estimates or ideas of total jewfish population whatsoever. A value needs to be determined for virgin stock levels or even 1950s stock levels. Responsibility for the definition of a specific value continues to be passed from one entity to another. Without the value, there is no way to declare the Goliath population recovered. In the meantime, the goliath population is growing rapidly and unchecked at an admittedly unknown rate. This species's over-protection must be having some detrimental effects on other species' populations. By their sheer numbers, goliaths are consuming large quantities of shellfish and fish. No consumption data is currently available.

'All data used seemed to revolve around one of the nursery areas for goliaths, along with a few sites in the southwestern gulf. The data from the Gulf sites are the anecdotal observations of one individual.

'The non-natural mortality rate discussion considered what percentage of the population was poached or killed unnaturally, with no quantitative data being presented. The figure of one percent was discussed. That is ten thousand poached fish per million, a figure that is way too high. Even a thousand fish per million is too high. .There is simply no evidence of poaching or non-natural mortality that would make one percent even close to a reasonable estimate. This one value can swing the goliath from being considered recovered today, to not being recovered for at least 15 more years.'

From Richard Taylor: 'Extensive visual evidence by the 60 members of the St. Petersburg Underwater Club (SPUC) shows a dramatic increase in Goliath Grouper populations occurring west of the Tampa Bay Peninsula. Goliath Grouper are being observed in all age sizes and locations. Many solitary fish are being observed at the area's numerous local ledges and outcroppings. Larger structures often hold a dozen or more Goliaths. The incidence of non-natural mortality was debated at length during the SEDAR workshop. SPUC members strongly believe that the incidence of non-natural mortality occurring is miniscule compared to the overall population and statistically insignificant. SPUC members have not seen nor heard of any unlawful incidents with regard to Goliath Grouper and no evidence of a high rate of non-natural mortality was presented during the SEDAR workshop.'

RECOMMENDATIONS FOR THE CONDUCT OF FUTURE WORKSHOPS

The review would have been facilitated if the assessment had been examined by an assessment workshop. It would have been helpful to have the authors of all the relevant documents available to make presentations and answer questions.

Advisory Report
Goliath Grouper

Stock Identification and Distribution: The stock is not defined and the current distribution of the species is not completely known. The conclusions of this assessment are applicable to Goliath Grouper within the limited area covered by the available data.

State of Stock: Goliath Grouper in south Florida (south of latitude 26° N) are overfished, and overfishing may or may not be occurring, depending on the effectiveness of the moratorium, which is unknown. Fishing-related mortality is known to occur, but lack of data prevents estimation of rates. If the moratorium has been at least 90% effective in reducing fishing mortality, overfishing is unlikely, and biomass in 2003 could be estimated as 76% of the target biomass, taken to be that corresponding to 50% SPR. If the moratorium had been 99% effective, biomass in 2003 would be predicted to lie at about 91% of the target biomass. Indications from the assessment were that the biomass has continuously increased since imposition of the moratorium.

Status Table: Goliath Grouper relative biomass and estimated fishing mortality, 1993–2002 with maximum, minimum, and mean for 1950–2002. (Catch was considered unreliable and was not included in the stock assessment.)

	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	max[1]	min[1]	mean[1]
	Moratorium 90% effective[2]												
B/B_{ref}[3]	0.22	0.25	0.28	0.34	0.41	0.49	0.56	0.62	0.67	0.72	2.27	0.12	0.78
F[4](/yr)	0.026	0.026	0.026	0.026	0.026	0.026	0.026	0.026	0.026	0.026	0.254	0.010	0.124
	Moratorium 99% effective[5]												
B/B_{ref}[3]	0.25	0.29	0.33	0.39	0.48	0.57	0.65	0.72	0.79	0.85	2.34	0.14	0.84
F[4](/yr)	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.237	0.002	0.111

[1] Statistics based on estimates for entire period 1950-2002.
[2] I.e. fishing-induced mortality under the moratorium has been set for illustrative purposes at 10% of estimated pre-moratorium (1979–1990) fishing mortality.
[3] B_{ref} is taken to be $B_{50\%SPR}$
[4] F for 1990–2002 is the stated proportion (10% or 1%) of the estimated pre-moratorium F.
[5] I.e. fishing-induced mortality under the moratorium has been set for illustrative purposes at 1% of estimated pre-moratorium (1979–1990) fishing mortality

Management Advice: The moratorium should be maintained at least until a future assessment shows that the biomass achieves the rebuilding target. Any fishery could risk rapidly depleting the stock, and would require careful monitoring.

Forecasts: Forecasts of future biomass were critically dependent upon the level of fishing mortality during the moratorium, but were also associated with large uncertainties due to imprecise fits of the model to available data. When these two sources of uncertainty are combined, the year by which the biomass in south Florida waters can be expected (with 80% confidence) to be rebuilt is estimated to lie between 1999 and sometime beyond 2020 (Figure 1).

Forecast Table: Forecast point estimates of biomass relative to MSST, 2003-2012, for two illustrative values of moratorium effectiveness.

	Moratorium Effectiveness	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
B/B_{ref}	90%	0.76	0.81	0.85	0.89	0.93	0.97	1.01	1.05	1.08	1.11
	99%	0.91	0.98	1.04	1.10	1.16	1.22	1.28	1.34	1.39	1.45

Catches: The stock is under moratorium. There are data on catch and release, mostly of juveniles, but no data on associated mortality and no data on poaching or other directed takes, or on by-catch. Catch data prior to the moratorium are considered unreliable.

Data and Assessment: An age-structured production model was fitted to visual count data from offshore south Florida in the eastern Gulf of Mexico, catch and effort data from inshore mangrove habitat in Everglades National Park, and visual count data from the Florida Atlantic Reef Tract (Figure 2). The model assumed a pristine stock in 1950, fishing mortality increasing linearly with time until 1979, and stable fishing mortality from 1980 until 1990 when the moratorium was imposed. Assessment runs were made under suppositions that the moratorium had been 90% or 99% effective. No data were available to support either supposition. No reliable catch data were available to tune the model, which therefore provided a trajectory of relative biomass.

Biological Reference Points: Absolute values of biological reference points related to biomass (MSY, OY) are not available. Point estimates of F_{msy} range between 0.083/yr and 0.093/yr. The point estimate of $F_{50\%SPR}$ is 0.095/yr. MSY is assumed to occur at $F_{50\%SPR}$ based on the current generic SFA Amendment adopted by the Gulf of Mexico Fishery Management Council, and at $F_{40\%SPR}$ based on Amendment 11 to the South Atlantic Fishery Management Council FMP for the snapper-grouper complex. Given the life history and low natural mortality of Goliath Grouper, the Review Panel recommends that the MSST proxy be $(1\text{-}M)*B_{msy}$.

Biological Reference Points Table. Goliath Grouper in South Florida, for two illustrative levels of moratorium effectiveness.

	Effectiveness of Moratorium ($(F_{before} - F_{after})/F_{before}$)			
	90%		99%	
	Estimate	SE	Estimate	SE
Fmsy (/yr)	0.09	0.0174	0.08	0.0190
$F_{50\%\ SPR}$ (/yr)	0.05	0.0158	0.05	0.0159
$F_{40\%\ SPR}$ (/yr)	0.07	0.021	0.07	0.021

Fishing Mortality: The assessment model assumed fishing mortality to increase linearly from a low value in 1950 to a plateau in 1979. Estimated maximum annual fishing mortality was around F=0.25/yr, experienced from 1979-1989. The moratorium is known to be imperfect. Assessment runs were made under suppositions that it had reduced the fishing mortality by 90% or 99% of the maximum. No data were available to support either supposition.

Recruitment: No estimates of recruitment are available.

Stock Biomass: The assessment was limited to southern Florida waters. Only relative measures of biomass are available. Relative biomass has increased steadily since the moratorium was imposed in 1990, at which time it appears that biomass had fallen to around 5% of the pristine level. 2002 biomass is estimated to be 31% of pristine if the moratorium were 90% effective, and 36% of pristine assuming 99% moratorium effectiveness. Three independent surveys indicated that biomass has increased since the early 1990s (Fig. 2).

Special Comments: The panel noted that it is difficult to infer stock status owing to a lack of reliable catch data and to the limited geographic range of available survey data. A stock definition combined with expanded monitoring efforts to cover the stock range would benefit future assessment efforts.

Sources of Information:

Porch, C.E. and A.-M. Eklund. 2003. Standardized visual counts of goliath grouper off south Florida and their possible use as indices of abundance. SEDAR6-RW1, 25pp.

Cass-Calay, S.L. and T.W. Schmidt. 2003. Standardized catch rates of juvenile goliath grouper from the everglades national park creel survey, 1973-1999. SEDAR6-RW2. 17pp.

Porch, C., A.-M. Eklund and G.P. Scott. 2003. An assessment of rebuilding times for goliath grouper. SEDAR6-RW3. 23pp.

Anon. n.d. [2003]. Goliath grouper data workshop report. SEDAR3-DW1. 11 pp.

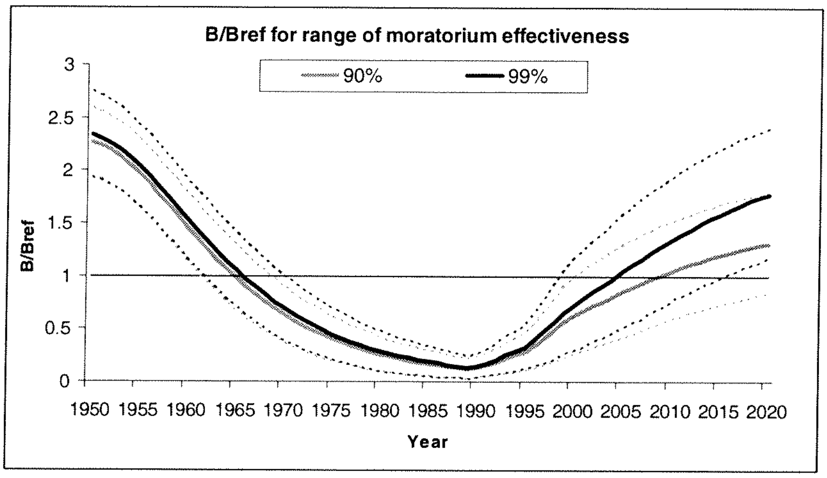


Figure 1. Estimated trend in biomass relative to the reference biomass from 1950 to 2020 for two assumed levels of moratorium effectiveness.

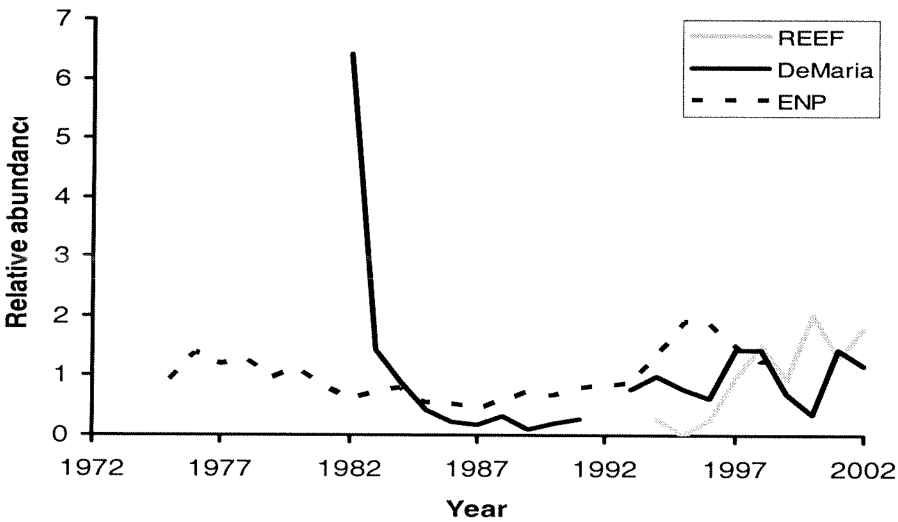


Figure 2. Trends in relative abundance for 3 surveys of Goliath Grouper.

ANNEX II: GLOSSARY AND ABBREVIATIONS

B	stock biomass level
B_{msy}	value of B capable of producing MSY on a continuing basis
B_{ref}	value of B used as a proxy to represent B_{msy}
$B_{50\%\ SPR}$	value of B corresponding to 50% of the spawning potential in an unfished stock
CPUE	catch per unit of effort
ENP	Everglades National Park
GMFMC	Gulf of Mexico Fishery Management Council
F	(instantaneous) fishing mortality
F_{msy}	fishing mortality to produce MSY under equilibrium conditions
$F_{50\%\ SPR}$	fishing mortality that will result in $B_{50\%\ SPR}$ under equilibrium conditions
M	(instantaneous) natural mortality
MFMT	maximum fishing mortality threshold, a value of F above which overfishing is deemed to be occurring
MSST	minimum stock size threshold, a value of B below which the stock is deemed to be overfished
MSY	maximum sustainable yield (equals F_{msy} times B_{msy})
NMFS	National Marine Fisheries Service
NOAA	National Oceanographic and Atmospheric Administration
OY	optimum yield
REEF	Reef Educational and Environmental Foundation
SAFMC	South Atlantic Fishery Management Council
SEDAR	Southeast Data, Assessment and Review
SFA	Sustainable Fisheries Act of 1996
SPR	spawning potential ratio, stock biomass relative to an unfished state of the stock