SEDAR

Southeast Data, Assessment, and Review

SEDAR 23
Stock Assessment Report

South Atlantic and Gulf of Mexico

Goliath Grouper

March 2011

SEDAR
4055 Faber Place Drive, Suite 201
North Charleston, SC 29405

THIS PAGE WAS LEFT BLANK INTENTIONALLY

Table of Contents

THIS PAGE WAS LEFT BLANK INTENTIONALLY

SEDAR

Southeast Data, Assessment, and Review

SEDAR 23

South Atlantic and Gulf of Mexico Goliath Grouper

SECTION I: Introduction

SEDAR
4055 Faber Place Drive, Suite 201
North Charleston, SC 29405

1. SEDAR PROCESS DESCRIPTION

SouthEast Data, Assessment, and Review (**SEDAR**) is a cooperative Fishery Management Council process initiated in 2002 to improve the quality and reliability of fishery stock assessments in the South Atlantic, Gulf of Mexico, and US Caribbean. SEDAR seeks improvements in the scientific quality of stock assessments and the relevance of information available to address fishery management issues. SEDAR emphasizes constituent and stakeholder participation in assessment development, transparency in the assessment process, and a rigorous and independent scientific review of completed stock assessments.

SEDAR is managed by the Caribbean, Gulf of Mexico, and South Atlantic Regional Fishery Management Councils in coordination with NOAA Fisheries and the Atlantic and Gulf States Marine Fisheries Commissions. Oversight is provided by a Steering Committee composed of NOAA Fisheries representatives: Southeast Fisheries Science Center Director and the Southeast Regional Administrator; Regional Council representatives: Executive Directors and Chairs of the South Atlantic, Gulf of Mexico, and Caribbean Fishery Management Councils; and Interstate Commission representatives: Executive Directors of the Atlantic States and Gulf States Marine Fisheries Commissions.

SEDAR is organized around three workshops. First is the Data Workshop, during which fisheries, monitoring, and life history data are reviewed and compiled. Second is the Assessment workshop, during which assessment models are developed and population parameters are estimated using the information provided from the Data Workshop. Third and final is the Review Workshop, during which independent experts review the input data, assessment methods, and assessment products. The completed assessment, including the reports of all 3 workshops and all supporting documentation, is then forwarded to the Council SSC for certification as 'appropriate for management' and development of specific management recommendations.

SEDAR workshops are public meetings organized by SEDAR staff and the lead Council. Workshop participants are drawn from state and federal agencies, non-government organizations, Council members, Council advisors, and the fishing industry with a goal of including a broad range of disciplines and perspectives. All participants are expected to contribute to the process by preparing working papers, contributing, providing assessment analyses, and completing the workshop report.

SEDAR Review Workshop Panels consist of a chair, 3 reviewers appointed by the Center for Independent Experts (CIE), and three reviewers appointed from the SSC of the Council having jurisdiction over the stocks assessed. The Review Workshop Chair is appointed by the Council from their SSC. Participating councils may appoint additional representatives of their SSC, Advisory, and other panels as observers.

2. MANAGEMENT OVERVIEW

2.1 *FISHERY MANAGEMENT PLAN AND AMENDMENTS*

The following summary describes only those management actions that likely affect goliath grouper fisheries and harvest

Original SAMFC FMP

The Fishery Management Plan (FMP), Regulatory Impact Review, and Final Environmental Impact Statement for the Snapper-Grouper Fishery of the South Atlantic Region, approved in 1983 and implemented in August of 1983, establishes a management regime for the fishery for snappers, groupers and related demersal species of the Continental Shelf of the southeastern United States in the fishery conservation zone (FCZ) under the area of authority of the South Atlantic Fishery Management Council and the territorial seas of the states, extending from the North Carolina/Virginia border through the Atlantic side of the Florida Keys to 83o W longitude. In the case of the sea basses, the management regime applies only to south of Cape Hatteras, North Carolina. Regulations apply only to Federal waters.

SAFMC FMP Amendments affecting goliath grouper

Description of Action	FMP/Amendment	Effective Date
4” Trawl mesh size and 12” TL minimum size limit	Snapper Grouper FMP	8/31/1983
Prohibited harvest of goliath grouper in SMZs	Regulatory Amendment #1	3/27/1987
Prohibit trawls	Snapper Grouper Amend 1	1/12/1989
Prohibited harvest/possession of goliath grouper in or from the EEZ	Snapper Grouper Amend 2	10/30/1990
Established artificial reef at Key Biscayne, FL as SMZ. Fish trapping, bottom longlining, spear fishing, and harvesting of Goliath grouper prohibited in SMZ.	Regulatory Amendment #3	11/2/1990
Required permit to fish for, land or sell snapper grouper species	Snapper Grouper Amend 3	1/31/1991

Prohibited gear: fish traps except bsb traps north of Cape Canaveral, FL; entanglement nets; longline gear inside 50 fathoms; bottom longlines to harvest wreckfish; powerheads and bangsticks in designated SMZs off S. Carolina. Established 20" TL minimum size and a 10 snapper/person/day bag limit, excluding vermilion snapper, and allowing no more than 2 red snappers.	Snapper Grouper Amend 4	1/1/1992
Oculina Experimental Closed Area.	Snapper Grouper Amend 6	6/27/1994
Limited entry program; transferable permits and 225 lb non-transferable permits.	Snapper Grouper Amend 8	12/14/1998
Vessels with longline gear aboard may only possess snowy grouper, warsaw grouper, yellowedge grouper, misty grouper, golden tilefish, blueline tilefish, and sand tilefish.	Snapper Grouper Amend 9	2/24/1999
Approved definitions for overfished and overfishing. MSST = [(1-M) or 0.5 whichever is greater]*B_{MSY}. MFMT = F_{MSY} MSY proxy for Goliath grouper is 40% static SPR; OY proxy is 50% static SPR	Snapper Grouper Amend 11	12/2/1999
Extended for an indefinite period the regulation prohibiting fishing for and possessing snapper grouper species within the *Oculina* Experimental Closed Area.	Snapper Grouper Amend 13A	4/26/2004

Original GMFMC FMP

The Fishery Management Plan for reef Fish Fisheries of the Gulf of Mexico was initially published in 1981 and implemented in 1984. Goliath grouper (then called jewfish) were included as a species in the management unit; however, there were no specific goliath grouper regulations. General regulations affecting reef fish included a stressed area within which the use of fish traps, roller trawls, and powerheads for the taking of reef fish was prohibited, specifications for the construction and making of fish traps, and a prohibition on the use of poison or explosives for the taking of reef fish. The amendment also established reporting requirements.

GMFMC FMP Amendments affecting goliath grouper

Description of Action	FMP/Amendment	Effective Date
Size limit = 50 in TL, part of the recreational 5 grouper bag limit; no commercial quota	Amendment 1	February 21, 1990
Permanently prohibited harvest	Amendment 2	August 30, 1990
NMFS identified goliath grouper as a candidate under ESA species	Endangered Species Act	July 11, 1991
Goliath grouper removed from species of concern following a NMFS status review		February 10, 2006

2.2. Emergency and Interim Rules

<u>Gulf of Mexico</u>

Emergency Rule: March 2, 1990, Prevent harvest of goliath grouper in the Gulf EEZ

The Emergency Rule was extended in June 1990.

2.3. Management Program Specifications

Table 2.3.1. General Management Information

South Atlantic

Species	Goliath Grouper (*Epinephelus itajara*)
Management Unit	Southeastern US
Management Unit Definition	All waters within South Atlantic Fishery Management Council Boundaries
Management Entity	South Atlantic Fishery Management Council
Management Contacts SERO / Council	Jack McGovern/Myra Brouwer
Current stock exploitation status	Not Overfishing

Current stock biomass status	Unknown

Gulf of Mexico

Species	Goliath Grouper (*Epinephelus itajara*)
Management Unit	Gulf of Mexico
Management Unit Definition	All waters within the Gulf of Mexico Fishery Management Council boundaries. Defined as the economic zone (EEZ), 200 miles from state boundary line.
Management Entity	Gulf of Mexico Fishery Management Council
Management Contacts SERO / Council	Peter Hood/Karen Burns
Current stock exploitation status	Not undergoing overfishing
Current stock biomass status	Unknown

Table 2.3.2. Specific Management Criteria

South Atlantic

Criteria	Current		Results from SEDAR 23	
	Definition	Value	Definition	Value
MSST	MSST = [(1-M) or 0.5 whichever is greater]*B_{MSY}	Unknown	MSST = [(1-M) or 0.5 whichever is greater]*B_{MSY}	TBD
MFMT	F_{MSY}	Not specified	F_{MSY}	TBD
MSY	Yield at F_{MSY}	Not Specified	Yield at F_{MSY}	TBD
F_{MSY}	$F_{40\%SPR}$	Not specified	F_{MAX}	TBD
OY	Yield at F_{OY}	Not Specified	Yield at F_{OY}	TBD
F_{OY}	$F_{50\%SPR}$	Not specified	F_{OY} = 65%,75%, 85% F_{MSY}	TBD
M	n/a	0.061* 0.04-0.19 **	M	TBD

*Amendment 11 to the Fishery Management Plan for the Snapper Grouper Fishery of the South Atlantic Region.

** Based on a 40-80 yr lifespan (1998 estimate) point estimate of 0.11 suggested

Gulf of Mexico

Criteria	Gulf of Mexico - Current		Gulf of Mexico - Alternative	
	Definition	Value	Definition	Value
MSST	0.8(Bmsy)		MSST = [(1-M) or 0.5 whichever is greater]*B_{MSY}	SEDAR 23
MFMT	Fmsy = F50%SPR		F_{MSY}	SEDAR 23
MSY			Yield at F_{MSY}	SEDAR 23
F_{MSY}			F_{MSY}	SEDAR 23
OY			Yield at F_{OY}	SEDAR 23
F_{OY}	0.75Fmsy	No definition	F_{OY} =65%, 75%, 85% F_{MSY}	SEDAR 23
M		0.04-0.19 *		SEDAR 23

* Based on a 40-80 yr lifespan (1998 estimate) point estimate of 0.11 suggested

There has been no assessment of goliath grouper in the Gulf of Mexico EEZ since 2003. The fishery was closed1990 due to concerns of overfishing. An MSY and Yield at 50%SPR were proposed but were rejected in 1999 so there are no official definitions.

NOTE: "Proposed" columns are for indicating any definitions that may exist in FMPs or amendments that are currently under development and should therefore be evaluated in the current assessment. "Current" is those definitions in place now. Please clarify whether landings parameters are 'landings' or 'catch' (Landings + Discard). If 'landings', please indicate how discards are addressed.

Stock Rebuilding Information

South Atlantic

In the past, goliath grouper was listed as overfished. As such, Amendment 4 (regulations effective January 1992) implemented a 15-year rebuilding plan beginning in 1991. Amendment 2 (regulations effective October 1990) prohibited harvest and possession of goliath grouper in or from the South Atlantic EEZ. The overfished determination of this stock has been changed to unknown to better reflect the current knowledge of its status. The previous pre-SFA overfished determination was based on qualitative data, not a biomass-based stock assessment. Although a pre-SFA definition of overfished based on SPR was approved prior to the SFA amendments, it has since been rejected by the Secretary of Commerce because it is not biomass-based and therefore does not meet criteria specified in the SFA. A biomass-based assessment for goliath grouper (Gulf and Atlantic) was completed in June 2004. A review of the assessment stated "In the absence of biomass, it was not possible to estimate all standard stock benchmarks. MSY and other benchmarks referencing absolute biomass could not be estimated. A MSST relative to pristine stock state could not be estimated." The South Atlantic has defined MSST = 1-M(0.5)B_{MSY} for goliath grouper. Therefore, goliath grouper overfished status is unknown in the South Atlantic.

Gulf of Mexico

Porch and Scott (2001) suggested a rebuilding time under F = 0 ranging from 20 – 95 years.

Table 2.3.3. Stock projection information.

(This provides the basic information necessary to bridge the gap between the terminal year of the assessment and the year in which any changes may take place or specific alternative exploitation rates should be evaluated

South Atlantic

Requested Information	Value
First Year of Management	2012
Projection Criteria during interim years should be based on (e.g., exploitation or harvest)	Fixed Exploitation; Modified Exploitation; Fixed Harvest*
Projection criteria values for interim years should be determined from (e.g., terminal year, avg of X years)	Average of previous 3 years. Zero harvest in interim years.

*Fixed Exploitation would be $F=F_{MSY}$ (or $F<F_{MSY}$) that would rebuild overfished stock to B_{MSY} in the allowable timeframe. Modified Exploitation would be allow for adjustment in $F<=F_{MSY}$, which would allow for the largest landings that would rebuild the stock to B_{MSY} in the allowable timeframe. Fixed harvest would be maximum fixed harvest with $F<=F_{MSY}$ that would allow the stock to rebuild to B_{MSY} in the allowable timeframe.

Gulf of Mexico

Requested Information	Value
First Year of Management	2012
Projection Criteria during interim years should be	Fixed explotation rate at $F_{rebuild}$ or F_{oy} if $F_{oy}<F_{rebuild}$ where $F_{rebuild}$

based on (e.g., exploitation or harvest)	time is either 10 years or T_{min} + 1 generation time
Projection criteria values for interim years should be determined from (e.g., terminal year, avg of X years)	Zero harvest in interim years

First year of Management: Earliest year in which management changes resulting from this assessment are expected to become effective

interim years: those between the terminal assessment year and the first year that any management could realistically become effective.

Projection Criteria: The parameter which should be used to determine population removals, typically either an exploitation rate or an average landings value or a pre-specified landings target.

Table 2.3.4. Quota Calculation Details

If the stock is managed by quota, please provide the following information

South Atlantic

Quota Detail	Value
Current Quota Value	0
Next Scheduled Quota Change	Not scheduled
Annual or averaged quota ?	0
If averaged, number of years to average	0
Other?	0

Gulf of Mexico

Quota Detail	Value
Current Quota Value	0
Next Scheduled Quota Change	Not scheduled
Annual or averaged quota ?	0
If averaged, number of years to average	0
Does the quota include bycatch/discard ?	0

2.4. Management and Regulatory Timeline

The following tables provide a timeline of Federal management actions by fishery.

Table 2.4.1. Annual Goliath Grouper Regulatory Summary – South Atlantic

	Commercial Fishery Regulations				Recreational Fishery Regulations				
Effective Date	Size Limit	Trip Limit	Season	Catch Limit	Size Limit	Possession Limit	Season	Catch Target	Both/Other
3/27/1987	Prohibited harvest of goliath grouper in SMZs								
10/30/1990	Commercial and recreational harvest and possession prohibited								
11/2/1990	Established artificial reef at Key Biscayne, FL as SMZ. Fish trapping, bottom longlining, spear fishing, and harvesting of Goliath grouper prohibited in SMZ.								

Table 2.4.2. Annual Goliath Grouper Regulatory Summary – Gulf of Mexico

	Commercial Fishery Regulations				Recreational Fishery Regulations				
Effective Date	Size Limit	Trip Limit	Season	Catch Limit	Size Limit	Possession Limit	Season	Catch Target	Both/Other
2/21/1990	Recreational and commercial size limit of 50 in TL; part of 5 grouper aggregate person/day for recreational								
3/2/1990	Commercial and recreational harvest prohibited (via emergency rule)								
6/1/1990	Extension of emergency rule harvest prohibition for both commercial and recreational								
8/30/1990	Permanently prohibited commercial and recreational harvest								

Table 5. State Regulatory History

Goliath Grouper minimum size limits - State of Florida

* Goliath grouper have a convex rounded tail, therefore fork length=total length

Measurement	inches	mm
FL	12	304.8
FL	18	457.2

Florida regulatory date	Year	Florida Commercial ATL	Florida Commercial Gulf	Florida Recreational ATL	Florida Recreational Gulf
7/1/1977[a]	1977	12" FL	12" FL	12" FL	12" FL
	1978	12" FL	12" FL	12" FL	12" FL
	1979	12" FL	12" FL	12" FL	12" FL
	1980	12" FL	12" FL	12" FL	12" FL
	1981	12" FL	12" FL	12" FL	12" FL
	1982	12" FL	12" FL	12" FL	12" FL
	1983	12" FL	12" FL	12" FL	12" FL
	1984	12" FL	12" FL	12" FL	12" FL
7/29/1985[b]	1985	18" FL	18" FL	18" FL	18" FL
	1986	18" FL	18" FL	18" FL	18" FL
	1987	18" FL	18" FL	18" FL	18" FL
	1988	18" FL	18" FL	18" FL	18" FL
	1989	18" FL	18" FL	18" FL	18" FL
2/1/1990[c]	1990	*	*	*	*
	1991	*	*	*	*
	1992	*	*	*	*
	1993	*	*	*	*
	1994	*	*	*	*
	1995	*	*	*	*
	1996	*	*	*	*
	1997	*	*	*	*
	1998	*	*	*	*
	1999	*	*	*	*
	2000	*	*	*	*
	2001	*	*	*	*
	2002	*	*	*	*
	2003	*	*	*	*
	2004	*	*	*	*
	2005	*	*	*	*
	2006	*	*	*	*

2007	*	*	*	*
2008	*	*	*	*
2009	*	*	*	*
2010	*	*	*	*

[a] - Florida Statutes, 1977. Chapter 370.11 (2)8. Fish; regulation, effective 7/1/1977.

[b] - Florida Administrative Code, Chapter 46-14, Reef Fish, effective 12/11/1986

[c] - Florida Administrative Code, Chapter 46-14, Reef Fish, effective 2/1/1990

* - harvest prohibited

References:

Florida Administrative Code, 1986-2010. Chapter 46-14 Reef Fish (interlibrary loans by year, 1986-1999). Chapter 68B-14 Reef Fish (1999-2009). Current regulations: https://www.flrules.org/default.asp

Florida Fish and Wildlife Conservation Commission, Division of Marine Fisheries Management. Evolution of each saltwater regulation (1985-2010). Prepared by Lee Schlesinger (revised February 24, 2010). http://www.MyFWC.com/RULESANDREGS/SaltwaterRules_history.htm

Florida Statutes, 1977-2009. Chapter 370.11 (2)8. Fish; regulation. (1997-2009 available online; interlibrary loans by year, 1969-1985; note: these regulations superseded by Florida Marine Fisheries Commission rules in F.A.C Chapter 46-14 in 1986). Current statutes (transferred to Chapter 379): http://www.leg.state.fl.us/statutes/

All Gulf coast states currently prohibit harvest of goliath grouper.

Texas: verbatim message from Mark Fisher:

“Before the no-take rule was implemented September 1, 1991, there were no bag or size limits in Texas waters for goliath grouper. They were unregulated.”

Louisiana: verbatim message from Harry Blanchet:

“The LA Wildlife and Fisheries Commission established the no-take rule for goliath in December, 1990. Prior to that time, there were no state-specific rules for harvest of any grouper species.”

Mississippi: verbatim message from Buck Buchanan:

"We adopted a no possession limit in February of 1995. Before that there were no size and possession limits in MS"

Alabama: waiting for response on past management practices

GA, SC, NC state regulations: Not provided

References

NMFS, 2006. Status Report on the Continental United States Distinct Population Segment of the Goliath Grouper (*Epinephelus itajara*). January 12, 2006. 49 pp.

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. 26 pp.

Porch,C.E. and Scott, G. P. 2001. Rebuilding Times for Nassau Grouper and Goliath Grouper. Sustainable Fisheries Division Contribution No. SFD-01/02-171. Southeast Fisheries Science Center, 75 Virginia Beach Drive, Miami, Florida 33149. 8 pp.

SAFMC (South Atlantic Fishery Management Council). 1983. Fishery Management Plan, Regulatory Impact Review and Final Environmental Impact Statement for the Snapper Grouper Fishery of the South Atlantic Region. South Atlantic Fishery Management Council, 1 Southpark Circle, Suite 306, Charleston, South Carolina, 29407-4699.

SAFMC (South Atlantic Fishery Management Council). 1988. Amendment Number 1 and Environmental Assessment and Regulatory Impact Review to the Fishery Management Plan for the Snapper Grouper Fishery of the South Atlantic Region. South Atlantic Fishery Management Council, 1 Southpark Cir., Suite 306, Charleston, S.C. 29407-4699. 63 pp.

SAFMC (South Atlantic Fishery Management Council). 1991. Amendment Number 4, Regulatory Impact Review, Initial Regulatory Flexibility Analysis and Environmental Assessment for the Fishery Management Plan for the Snapper Grouper Fishery of the South Atlantic Region. South Atlantic Fishery Management Council, 1 Southpark Cir., Suite 306, Charleston, S.C. 29407-4699. 200 pp.

SAFMC (South Atlantic Fishery Management Council). 1993. Amendment Number 6, Regulatory Impact Review, Initial Regulatory Flexibility Analysis and Environmental Assessment for the Fishery Management Plan for the Snapper Grouper Fishery of the South Atlantic Region. South Atlantic Fishery Management Council, 1 Southpark Cir., Suite 306, Charleston, S.C. 29407-4699. 155 pp.

SAFMC (South Atlantic Fishery Management Council). 1997. Amendment Number 8, Regulatory Impact Review, Social Impact Assessment, Initial Regulatory Flexibility Analysis and Supplemental Environmental Impact Statement for the Fishery Management Plan for the Snapper Grouper Fishery of the South Atlantic Region. South Atlantic Fishery Management Council, 1 Southpark Cir., Ste 306, Charleston, S.C. 29407-4699. 124 pp.

SAFMC (South Atlantic Fishery Management Council). 1998a. Amendment Number 9, Final Supplemental Environmental Impact Statement, Initial Regulatory Flexibility Analysis/Regulatory Impact Review, and Social Impact Assessment/Fishery Impact Statement for the Fishery Management Plan for the Snapper Grouper Fishery of the South Atlantic Region. South Atlantic Fishery Management Council, 1 Southpark Cir., Suite 306, Charleston, S.C. 29407-4699. 246 pp.

SAFMC (South Atlantic Fishery Management Council). 1998b. Comprehensive Amendment Addressing Sustainable Fishery Act Definitions and Other Required Provisions in Fishery Management Plans of the South Atlantic Region (Amendment 11 to the Snapper Grouper Fishery Management Plan). South Atlantic Fishery Management Council, 1 Southpark Cir., Suite 306, Charleston, S.C. 29407-4699. 151 pp.

SAFMC (South Atlantic Fishery Management Council). 2007. Final Amendment Number 14, Final Environmental Impact Statement, Initial Regulatory Flexibility Analysis/Regulatory Impact Review, and Social Impact Assessment/Fishery Impact Statement for the Fishery Management Plan for the Snapper Grouper Fishery of the South Atlantic Region. South Atlantic Fishery Management Council, 4055 Faber Place, Ste 201, North Charleston, S.C. 29405.

SAFMC (South Atlantic Fishery Management Council). 2008. Amendment Number 16, Final Environmental Impact Statement, Initial Regulatory Flexibility Analysis/Regulatory Impact Review, and Social Impact Assessment/Fishery Impact Statement for the Fishery Management Plan for the Snapper Grouper Fishery of the South Atlantic Region. South Atlantic Fishery Management Council, 4055 Faber Place, Ste 201, North Charleston, S.C. 29405. 375 pp.

3. ASSESSMENT HISTORY AND REVIEW

Catches of goliath grouper in the Caribbean have been noted in various historical accounts dating back at least to 1679 (Gould and Atz 1996), but information on the biology of this species useful for stock assessment was published only recently by Bullock et al. (1992). Some parameters were presented in that work, but catch information and parameters useful for describing catches (e.g., catch-at-age, fishery selectivities, catch by sector and gear, etc.) were deemed to be unreliable or poorly known (GMFMC 1990, SAFMC 1990) for typical assessment models. The next attempt at assembling the data and other information for an assessment occurred during SEDAR 3. The conclusion at the Data Workshop was that there was some information available that might be useful for a formal assessment to proceed (SEDAR 3, 2003). Following that effort, Porch et al. (2003) constructed a “catch-free” stock assessment model for SEDAR 6 which was based upon biological parameters derived from studies of goliath grouper, meta-analyses of other species of fish with reasonably similar life histories, expert opinion on the effectiveness of the moratorium on harvest in reducing fishing mortality since 1990, indices of abundance drawn from catch surveys and underwater observations, and interviews with fishermen who had fished in south Florida since the 1950’s, and some limited catch information to derive vulnerability curves. The conclusions from SEDAR 6 were that the population of goliath grouper in southern Florida waters was overfished and overfishing in the past had occurred, but that a significant reduction in fishing mortality had been achieved with the moratorium on harvest and the abundance of goliath grouper was increasing. Projections of the population status were conditional on the incomplete knowledge of the maximum age of goliath grouper and the effectiveness of the moratorium. The conclusions were that either the population may surpass the spawning stock biomass (SSB) at the fishing mortality rate (F) corresponding to the 50% spawning potential ratio (SPR) (the SAFMC’s optimum yield definition at that time) sometime near 2005 (Porch 2004), or if more pessimistic assumptions about the reductions in F were used, overfishing was still occurring and the population would have less than a 50% chance of recovery to the $SSB_{F\ at\ 50\%SPR}$ benchmark before 2015 (Porch 2004). Porch et al. (2006), in a later set of analyses, estimated that F in their base model run was reduced by more than 50% but less than 90% which lead to a prediction of less than a 40% chance that the population would recover to the $SSB_{F\ at\ 50\%SPR}$ benchmark by 2020. The conclusions of these analyses show how crucial the underlying assumption of the moratorium effectiveness is to determining the current and projected population status for goliath grouper. If the moratorium was more than 90% effective, the chances for recovery were relatively larger. If the moratorium was less than 90% effective, the chances for recovery were relatively smaller.

References:

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

Gould, R. G. and Atz, J. W. 1996. The trouble with “jewfish”, or what’s in a name? Tropical Fish Hobbyist 44: 172-182.

Gulf of Mexico Fishery Management Council. 1990. Amendment 2 to the Fishery Management Plan for Reef Fish, February 1990. Tampa, FL.

Porch, C. E. 2004. A reassessment of rebuilding times for goliath grouper with modifications suggested by the SEDAR Review Panel. NOAA Fisheries, Sustainable Fisheries Division Contribuition No. SFD-2004-0011. SEDAR 6-SAR1.

Porch, C.E., Eklund, A.M., and Scott, G.P. 2003. An assessment of rebuilding times for goliath grouper. NOAA Fisheries, Sustainable Fisheries Division Contribuition No. SFD-2003-0018. SEDAR 6-RW-3.

Porch, C.E., Eklund, A.M., and Scott, G.P. 2006. A catch-free stock assessment model with application to goliath grouper (*Epinephelus itajara*) off southern Florida. Fishery Bulletin 104: 89-101.

SEDAR 3. 2003. Goliath grouper data workshop report. S3-DW-01 Goliath grouper data report.

South Atlantic Fishery Management Council. 1990. Amendment 2 to the Fishery Management Plan for the Snapper Grouper Fishery

4. REGIONAL MAPS

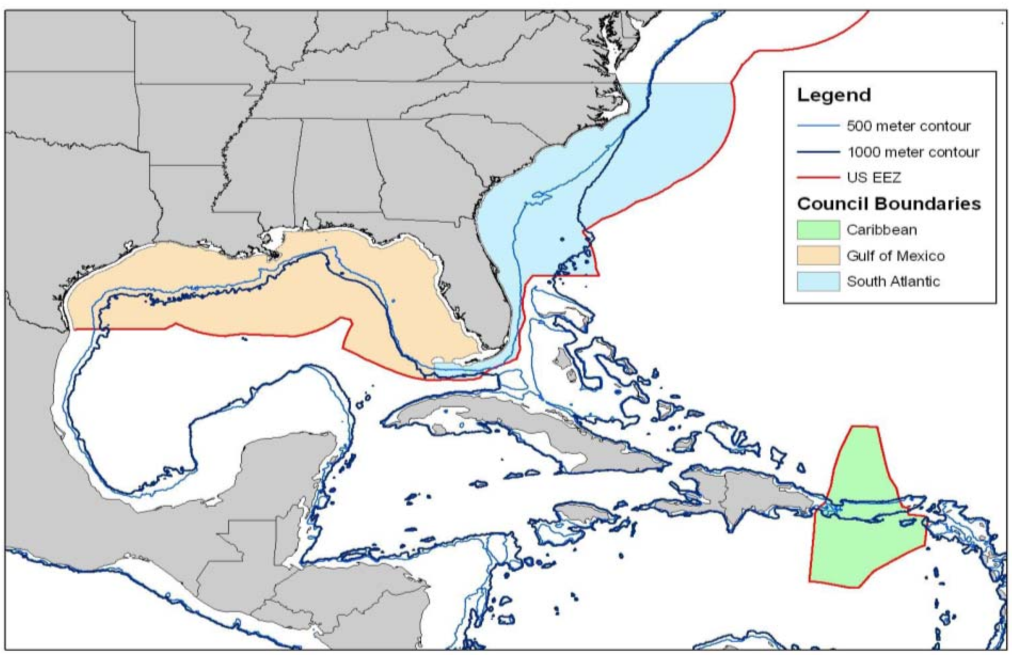


Figure 4.1. Southeast Region including Council and EEZ Boundaries

5. **ASSESSMENT SUMMARY**

The Summary Report provides a broad but concise view of the salient aspects of the stock assessment. It recapitulates: (a) the information available to and prepared by the Data Workshop; (b) the application of those data, development and execution of one or more assessment models, and identification of the most reliable model configuration as the base run by the Assessment Process (AP); and (c) the findings and advice determined during the Review Workshop.

Review Panel Executive Summary

The stock assessment of goliath grouper presented by the SEDAR 23 Assessment Workshop (AW) provided the Review Panel with thorough descriptions of the data available for assessing goliath grouper, information about the life history of this species, as well as outputs and results from the catch-free model developed for this stock by Porch et al. (2006). The panel felt the proposed base model parameterization as presented was inappropriate to provide information on goliath grouper stock status or benchmarks as it does not reflect appropriate stock dynamics. Further, the panel felt that the output of the model is unlikely to represent real changes in the F trajectories because some model assumptions were thought to be heavily influencing the model output, and the recruitment pattern did not appear realistic with respect to expected patterns of recruitment for a long-lived species.

Stock Identification and Management Unit:

Goliath grouper has been managed in the US as separate Atlantic and Gulf of Mexico stock units with the boundary essentially being U.S. Highway 1 in the Florida Keys west to the Dry Tortugas.

Species Distribution:

In the US, goliath grouper are known from North Carolina to Texas and the US Caribbean (PR and USVI), with the current center of abundance located in south Florida. Adult goliath grouper have a patchy distribution related to high-relief habitat (artificial or natural), while juveniles have a high affinity for estuarine and fringing red mangrove habitat.

Stock Life History:

- Goliaths groupers are aggregation spawners, with spawning occurring typically from August to October.

- Reproductive maturity is reached late (~5 – 7 years) and at a large size (1100 -1200 mm TL) due to the slow growth rate of the species.
- Maximum validated age is 37 years for one female of 1,970 mm total length (TL); the DW Life History Working Group agrees that maximum age for this species is probably much older.

Assessment Methods:

The Review Panel felt the choice of the catch-free model is logical given the types of available data as the catch is not fully known after the implementation of the moratorium and catch and landings are highly uncertain prior to that. In addition, the available age data is too sparse to develop an explicit age-based assessment to estimate cohort strength. However, its appropriateness to management as currently implemented by the Council is questionable given that it is essentially a method that only provides estimates of relative fishing mortality and abundance. To obtain relative levels of abundance the model is scaled, in this case by assuming the biomass at the beginning of the time series equaled the unexploited equilibrium biomass, an assumption unlikely to be appropriate given the historical landings record of goliath grouper.

Catch Trends:

Preliminary commercial and recreational Goliath grouper catch information was compiled by the Data Workshop (see Data Workshop Report) but it was deemed highly uncertain.

Fishing Mortality Trends:

Goliath grouper have been under a harvest moratorium since 1990. As such, fishing mortality trends were not examined during this assessment.

Stock Abundance and Biomass Trends:

While it was not possible for the Review Panel to recommend abundance or biomass estimates, it felt some qualitative statements could be made about abundance, biomass and exploitation, and stock status, based solely on data. Whilst interpretation of indices is not straightforward, all indices suggest that abundance and biomass have increased since 1990 when the moratorium was implemented. The extent of that increase is difficult to gauge given the nature of the indices which all suggest faster rates of increase, and in some cases variability, than seem plausible given the biology of the species. There are also clear indications from indices representative of younger fish that recent recruitment may be less than in the preceding years. It is difficult to interpret the degree of previous stock decline as the perceived status in 1990 is strongly driven by the way the assessment must interpret the limited DeMaria index information.

Projections

Although the Review Panel believed the methods used to project future population status were implemented correctly, due to the underlying issues in the assessment model, estimates of future stock condition cannot be made at this time.

Scientific Uncertainty

This is a data-poor species, and there is much uncertainty over the most basic life history parameters. Fishing mortality rates are difficult to estimate with any certainty, and the effectiveness of the moratorium on harvest since 1990 is unknown but estimated with a prior. The catch-free model uses Bayesian approaches to provide likely bounds on several parameters to develop model estimates, and MCMC simulations were used to examine uncertainty in the parameter estimates and projections. The impact on the perception of relative stock status of two critical parameters (maximum age/natural mortality and moratorium effectiveness) was examined using sensitivity runs.

Summary Comments:

Without a better understanding of longevity in goliath grouper, it may be prudent to treat the current known maximum age (37 years) as an estimate that may be modified if older animals are ever found. It would not be difficult to imagine that goliath grouper may live 40-50 years in unfished or lightly fished populations. Likewise, without a better understanding of historical harvests including recreational harvest (average sizes or weights, especially), it will be difficult to develop management benchmarks for yields and F in any terms other than relative ones. A fisheries-independent survey that is sufficiently designed to estimate absolute abundances throughout the range of this species may allow the calculation of management benchmarks by scaling the results from the catch-free model. An alternative would be the long-term monitoring of an experimental fishery to detect changes in relative abundance. Lastly, it is important to consider whether goliath groupers have increased sufficiently in population in all portions of their historical range. This assessment has focused on data from south Florida out of necessity since there is very little information from other states in the southeastern U.S. There is a lack of knowledge of historical abundances of goliath grouper throughout its historical range, so it will be difficult to devise meaningful criteria for this aspect of population recovery.

Sources of Information:

All information was copied directly or generated from the information available in the final Stock Assessment Report for SEDAR 23: South Atlantic and Gulf of Mexico Goliath Grouper.

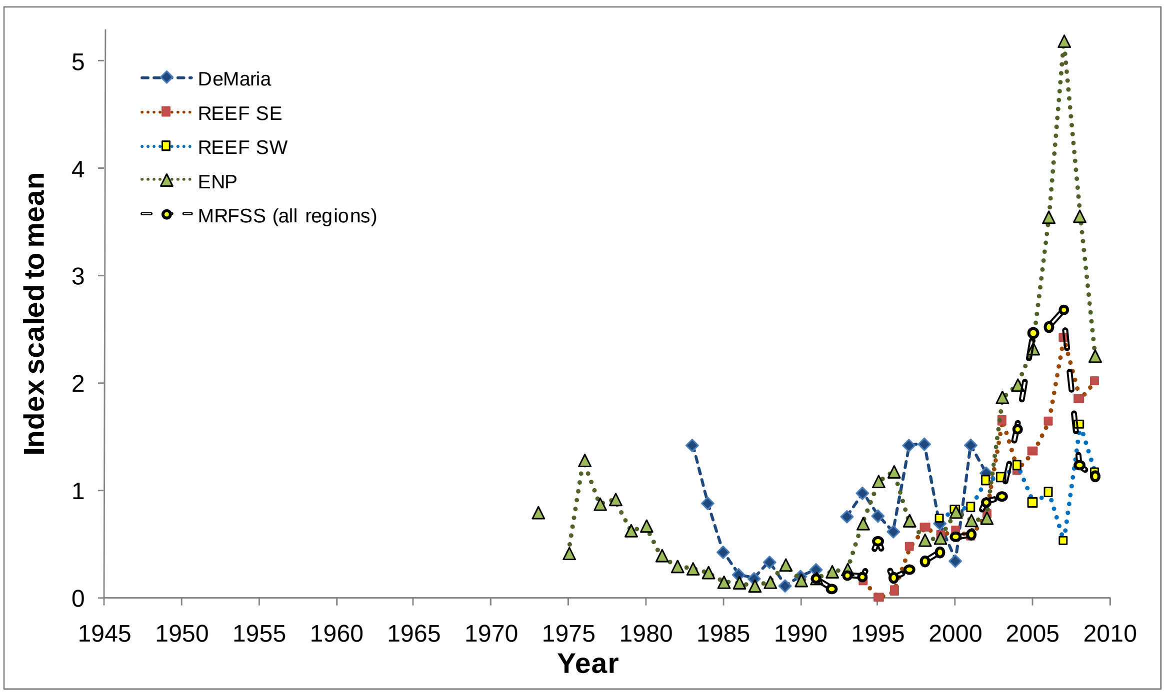


Figure 1: Indices of abundance included in SEDAR 23 proposed base model run and sensitivity runs. (Figure 3.3.3b in the Assessment Workshop Report).

6. SEDAR ABBREVIATIONS

ABC	Allowable Biological Catch
ACCSP	Atlantic Coastal Cooperative Statistics Program
ADMB	AD Model Builder software program
ALS	Accumulated Landings System; SEFSC fisheries data collection program

ASMFC	Atlantic States Marine Fisheries Commission
B	stock biomass level
BMSY	value of B capable of producing MSY on a continuing basis
CFMC	Caribbean Fishery Management Council
CIE	Center for Independent Experts
CPUE	catch per unit of effort
F	fishing mortality (instantaneous)
F_{MAX}	fishing mortality that maximizes the average weight yield per fish recruited to the fishery
F_{MSY}	fishing mortality to produce MSY under equilibrium conditions
F_{OY}	fishing mortality rate to produce Optimum Yield under equilibrium
$F_{XX\%\ SPR}$	fishing mortality rate that will result in retaining XX% of the maximum spawning production under equilibrium conditions
F_0	a fishing mortality close to, but slightly less than, Fmax
FL FWCC	Florida Fish and Wildlife Conservation Commission
FWRI	(State of) Florida Fisheries and Wildlife Research Institute
GA DNR	Georgia Department of Natural Resources
GLM	general linear model
GMFMC	Gulf of Mexico Fishery Management Council
GSMFC	Gulf States Marine Fisheries Commission
GULF FIN	GSMFC Fisheries Information Network
M	natural mortality (instantaneous)
MARMAP	Marine Resources Monitoring, Assessment, and Prediction
MFMT	maximum fishing mortality threshold, a value of F above which overfishing is deemed to be occurring
MRFSS	Marine Recreational Fisheries Statistics Survey; combines a telephone survey of households to estimate number of trips with creel surveys to estimate catch and effort per trip
MRIP	Marine Recreational Information Program
MSST	minimum stock size threshold, a value of B below which the stock is deemed to be overfished
MSY	maximum sustainable yield
NC DMF	North Carolina Division of Marine Fisheries
NMFS	National Marine Fisheries Service

NOAA	National Oceanographic and Atmospheric Administration
OY	optimum yield
SAFMC	South Atlantic Fishery Management Council
SAS	Statistical Analysis Software, SAS Corporation
SC DNR	South Carolina Department of Natural Resources
SEDAR	Southeast Data, Assessment and Review
SEFSC	Fisheries Southeast Fisheries Science Center, National Marine Fisheries Service
SERO	Fisheries Southeast Regional Office, National Marine Fisheries Service
SPR	spawning potential ratio, stock biomass relative to an unfished state of the stock
SSB	Spawning Stock Biomass
SSC	Science and Statistics Committee
TIP	Trip Incident Program; biological data collection program of the SEFSC and Southeast States.
Z	total mortality, the sum of M and F

SEDAR

Southeast Data, Assessment, and Review

SEDAR 23

Gulf of Mexico and South Atlantic Goliath Grouper

SECTION II: Data Workshop Report

SEDAR
4055 Faber Place Drive, Suite 201
North Charleston, SC 29405

Table of Contents

1. INTRODUCTION

1.1. *WORKSHOP TIME AND PLACE*

The SEDAR 23 Data Workshop was held April 26 - 29, 2010 in Tampa, Florida.

1.2. *TERMS OF REFERNCE*

1. Characterize stock structure and develop a unit stock definition. Provide maps of species and stock distribution.

2. Review, discuss and tabulate available life history information (e.g., age, growth, natural mortality, reproductive characteristics); provide appropriate models to describe growth, maturation, and fecundity by age, sex, or length as applicable. Evaluate the adequacy of available life-history information for conducting stock assessments and recommend life history information for use in population modeling.

3. Provide measures of population abundance that are appropriate for stock assessment. Consider and discuss all available and relevant fishery dependent and independent data sources. Document all programs evaluated, addressing program objectives, methods, coverage, sampling intensity, and other relevant characteristics. Provide maps of survey coverage. Develop CPUE and index values by appropriate strata (e.g., age, size, area, and fishery); provide measures of precision and accuracy. Evaluate the degree to which available indices adequately represent fishery and population conditions. Recommend which data sources are considered adequate and reliable for use in assessment modeling.

4. Characterize commercial and recreational catch, including both landings and discard, in pounds and number. Provide estimates of discard mortality rates by fishery and other strata as appropriate or feasible. Evaluate and discuss the adequacy of available data for accurately characterizing harvest and discard by species and fishery sector. Provide length and age distributions if feasible. Provide maps of fishery effort and harvest.

5. Provide recommendations for future research in areas such as sampling, fishery monitoring, and stock assessment. Include specific guidance on sampling intensity (number of samples including age and length structures) and appropriate strata and coverage.

6. Develop a spreadsheet of assessment model input data that reflects the decisions and recommendations of the Data Workshop. Review and approve the contents of the input spreadsheet by June 1.

7. Prepare the Data Workshop report providing complete documentation of workshop actions and decisions (Section II. of the SEDAR assessment report). Develop a list of tasks to be completed following the workshop.

1.3. LIST OF PARTICIPANTS

Workshop Panel

Adam Pollack.. NMFS Pascagoula
Alejandro Acosta ....FWRI
Angela Collins ....FWRI
Bill Lindberg..Univ. of Florida
Bob Zales II..GMFMC AP/ North Florida
Chris Koenig .... USF
Clay Porch..NMFS Miami
Don DeMaria .... SAFMC AP – Florida Keys
Gregg DeBrango ....SAFMC AP
Jennifer Schull ....NMFS
Joe O'Hop ....FWRI
Joseph Munyandorero..FWRI
Kevin McCarthy..NMFS Miami
Luiz Barbieri .... FWRI
Monica Lara .... FWRI
Rich Taylor ....
Sarah Frias-Torres.. Ocean Research & Conservation Association
Walter Ingram .... NMFS Pascagoula

Council Representation

Ben Hartig..SAFMC
Ed Sapp ....GMFMC

Staff

Julie Neer .... SEDAR
Karen Burns ....GMFMC Staff
Rachael Lindsay.. SEDAR
Tyree Davis..NMFS Miami

1.4. LIST OF DATA WORKSHOP WORKING PAPERS AND REFERNCE DOCUMENTS

Document #	Title	Authors
Documents Prepared for the Data Workshop		
SEDAR23-DW-01	Bottom longline fishery bycatch of Goliath Grouper (*Epinephelus itajara*) from observer data	Loraine Hale

SEDAR23-DW-02	Monitoring changes in the catch rates and abundance of juvenile goliath grouper using the ENP creel survey, 1973-2009	Shannon L. Cass-Calay
SEDAR23-DW-03	Goliath grouper surveys and samples: A summary of recent work by the Fish and Wildlife Research Institute (2006 -2010)	Angela Collins & Luiz Barbieri
SEDAR23-DW-04	Calculated Goliath grouper discards from commercial vertical line and longline fishing vessels in the Gulf of Mexico and US South Atlantic	Kevin McCarthy
Reference Documents		
SEDAR23-RD01	Age, growth, and reproduction of jewfish, *Epinephelus itajara* in the eastern Gulf of Mexico	L.H. Bullock, M.D. Murphy, M.F. Godcharies, and M.E. Mitchell
SEDAR23-RD02	Monitoring changes in the catch rates and abundance of juvenile goliath grouper using the ENP creel survey, 1973-2006	Shannon L. Cass-Calay and Thomas W. Schmidt
SEDAR23-RD03	How many species of goliath grouper are there? Cryptic genetic divergence in a threatened marine fish and the resurrection of a geopolitical species	M. T. Craig, R. T. Graham, R. A. Torres, J. R. Hyde, M. O. Freitas, B. P. Ferreira, M. Hostim-Silva, L. C. Gerhardinger, A. A. Bertoncini, D. R. Robertson
SEDAR23-RD04	Habitat affinities of juvenile goliath grouper to assess estuarine conditions	Anne-Marie Eklund
SEDAR23-RD05	A stepwise approach to investigating the movement patterns and habitat utilization of goliath grouper, *Epinephelus itajara*, using conventional tagging, acoustic telemetry and satellite tracking	Anne-Marie Eklund and Jennifer Schull
SEDAR23-RD06	Activity patterns of three juvenile goliath grouper, *Epinephelus itajara*, in a mangrove nursery	Sarah Frias-Torres, Pedro Barroso, Anne-Marie Eklund, Jennifer Schull, and

		Joseph E. Serafy
SEDAR23-RD07	Mangroves as essential nursery habitat for goliath grouper (*Epinephelus itajara)*	Christopher C. Koenig, Felicia C. Coleman, Anne-Marie Eklund, Jennifer Schull, and Jeffrey Ueland
SEDAR23-RD08	Early life history stages of goliath grouper *Epinephelus itajara* (Pisces: Serranidae) from Ten Thousand Islands, Florida	Monica R. Lara, Jennifer Schull, David L. Jones, Robert Allman
SEDAR23-RD09	Goliath grouper *Epinephelus itajara* sound production and movement patterns on aggregation sites	David A. Mann, James V. Locascio, Felicia C. Coleman, Christopher C. Koenig
SEDAR23-RD10	Documenting Loss of Large Trophy Fish from the Florida Keys with Historical Photographs	Loren McClenachan
SEDAR23-RD11	Status report on the continental United States distinct population segment of the goliath grouper (*Epinephelus itajara*)	NMFS
SEDAR23-RD12	A catch-free stock assessment model with application to goliath grouper (Epinephelus itajara) off southern Florida	Clay E. Porch, Anne-Marie Eklund, and Gerald P. Scott
SEDAR23-RD13	A Preliminary Discussion of Acceptable Harvest Levels for Scientific Sampling of Goliath Grouper in the U.S. South Atlantic and Gulf of Mexico	Clay E. Porch and Luiz R. Barbieri
SEDAR23-RD14	Range-wide status and conservation of the goliath grouper *Epinephelus itajara*: Introduction	Kevin L. Rhodes and Rachel T. Graham
SEDAR23-RD15	Synopsis of biological data on the Nassau grouper, *Epinephelus striatus* (Bloch, 1792), and the jewfish, *E. itajara* (Lichtenstein, 1822)	Yvonne Sadovy and Anne-Marie Eklund
SEDAR23-RD16	Complete Stock Assessment Report of SEDAR 6 - Goliath Grouper	SEDAR 3 DW participants/ SEDAR 6 RW participants
SEDAR23-RD17	Habitat use of juvenile goliath grouper *Epinephelus itajara* in the Florida Keys, USA	Sarah Frias-Torres
SEDAR23-RD18	Standardized visual counts of goliath grouper off south Florida and their possible use as indices of	Clay E. Porch and

	abundance	Anne-Marie Eklund
SEDAR23-RD19	Population density, demographics, and predation effects of adult goliath grouper	Christopher C. Koenig and Felicia C. Coleman
SEDAR23-RD20	The role of dispersal and demography in determining the efficacy of marine reserves	Gerber LR, Heppell SS, Ballantyne F, Sala E.
SEDAR23-RD21	Spawning aggregations and reproductive behavior of reef fishes in the Gulf of California	Sala E, Aburto-Oropeza O, Paredes G, Thompson G.
SEDAR23-RD22	American Fisheries Society Position Statement. Long-lived reef fishes: the grouper-snapper complex	Coleman, F.C., C.C. Koenig, G.R. Huntsman, J.A. Musick, A.M. Eklund, J.C. McGovern, R.W. Chapman, G.R. Sedberry, and C.B. Grimes
SEDAR23-RD23	Preliminary Investigations of Reproductive Activity of the Jewfish, Epinephelus itajara (Pisces: Serranidae)	Colin, P.L.
SEDAR23-RD24	Grouper Stocks of the Western Central Atlantic: The Need for Management and Management Needs	Sadovy, Y.
SEDAR23-RD25	Hypothermal mortality in marine fishes of southcentral Florida	Gilmore RG, Bullock LH, Berry FH
SEDAR23-RD26	Evaluation of finrays as a non-lethal ageing method for protected goliath grouper *Epinephelus itajara*	Murie DJ, Parkyn DC, Koenig CC, Coleman FC, Schull J, Frias-Torres S.
SEDAR23-RD27	Mercury concentrations in the goliath grouper of Belize: an anthropogenic stressor of concern	Evers DC, Graham RT, Perkins CR, Michener R, Divoll T.

2. LIFE HISTORY

2.1. *OVERVIEW*

2.1.1. 2.1.1. Group Membership

Bill Lindberg	University of Florida, GMFMC SSC, WG Leader and Editor
Alejandro Acosta	FWRI
Jennifer Schull	NMFS
Angela Collins	FWRI
Chris Koenig	Florida State University
Sarah Frias-Torres	ORCA
Monica Lara	St. Petersburg College
Luiz Barbieri	FWRI, GMFMC SSC

2.1.2. 2.1.2. Issues

Issues discussed by the Life History Working Group for Goliath grouper included: population distribution and stock definition; known spawning aggregations, ontogenetic habitat shifts, habitat quality/distribution, movements and geographic expansion from a center of abundance; cautions about interpreting fish density without also incorporating habitat quality; growth characteristics, new size-at-age data and uncertainty about maximum age; reproductive characteristics; natural mortality, episodic mortality and poaching. Issues remaining at the end of the Data Workshop were related to the write-up of natural mortality and release mortality, and the editing and review of the Life History Working Group report.

2.2. *REVIEW OF WORKINGPAPERS*

Three working papers were submitted for the SEDAR 23 Data Workshop. Hale (S23-DW-01) reported Goliath bycatch from the NMFS bottom longline observer program from 2005 to 2009; of 47 Goliath incidentally caught, 46 were alive when captured of which 43 were released alive. Such data are pertinent to Section 2.4.2 Release Mortality. Collins and Barbieri (S23-DW-03) summarized 367 Goliath surveys (depths 7-48m) and opportunistic biological samples (105 for DNA, 60 for otoliths, 23 for gonad histology) by the Florida Fish and Wildlife Research Institute between May 2006 and April 2010. These data are pertinent to Section 2.5 Age and Growth and Section 2.6 Reproduction. Cass-Calay (S23-DW-03) reviewed the results of an ongoing creel survey within Everglades National Park (1973-2009), which indicate a strong increase in juvenile abundance through 2007. These data are relevant to Section 2.7.1. EFH, Habitat Quality and Ontogenetic Shifts.

2.3. *STOCK DEFINITION AND DESCRIPTION*

The taxonomy of Goliath grouper is as follows:

Kingdom: Animalia (animals)

Phylum: Chordata (organisms with a notochord)

Subphylum: Vertebrata (animals with backbones)

Class: Actinopterygii (ray-finned fishes)

Order: Perciformes

Family: Serrranidae (sea basses and groupers)

Genus: Epinephelus

Species: itajara (Lichtenstein 1822)

Common name: Goliath Grouper (formerly Jewfish, English)

2.3.1. Population Genetics

There is empirical and anecdotal evidence that the South Atlantic and Gulf of Mexico stocks should be treated as a unit. Documented range-wide stock differentiation exists between Belize and SW Florida; and Brazil and Florida (Craig et al. 2009, Chapman pers. comm.). The population structure of US Caribbean goliath grouper populations is unclear.

2.3.2. Tagging

Tagging studies show that goliath grouper are capable of long-distance movements but are typically limited in their movements (Figure 1; Koenig and Coleman 2009). One juvenile goliath grouper, tagged in the Ten Thousand Islands of southwest Florida, was recaptured off southeast Florida near the Indian River Lagoon (Figure 2; Koenig and Coleman 2009). In the literature, the maximum distance traveled by an adult was 203 km (Collins and Barbieri 2010). Most long-distance movements by adults are thought to be to and from spawning sites and feeding sites (Koenig and Coleman 2009).

2.3.3. Larval Transport/Connectivity

Florida populations of goliath grouper appear to be self-recruiting. The center of abundance for goliath grouper is southwest Florida (Sadovy and Eklund 1999). Southern GOM spawning aggregations are the major contributor of larval recruits into southwest Florida estuaries. The known oceanographic circulation patterns in the GOM are sufficient to explain the observed distribution of goliath grouper (and their expansion) in Florida (Lee et al. 1994). The reformation of spawning aggregations in the SA may be contributing larvae to the SA; however, limits to settlement (e.g. timing of spawning coincident with favorable hydrographic conditions) and availability of suitable nursery habitats (e.g. mangrove dominated estuaries with high quality water) may be limiting factors. Extent and characterization of settlement and nursery habitat in the SA are unknown outside of the Indian River Lagoon (Gilmore pers. comm.).

2.3.4. Distribution

In the US, goliath grouper are known from North Carolina to Texas and the US Caribbean (PR and USVI). Based on historical catch data, Reef Environmental Education Foundation (REEF) data, and anecdotal reports, it is likely that areas north and west of Florida represent the fringe of the goliath grouper population (NMFS 2006). They are known to be very sensitive to low temperatures (Sadovy and Eklund 1999; Koenig and Coleman 2009). Information used in the early 1990s to describe the decline of goliath grouper stocks included region-wide declines in distribution and abundance, a restriction in range, and the extirpation of known spawning aggregations.

Adult goliath grouper have a patchy distribution related to high-relief habitat (artificial or natural) in the southern region of Florida, including the Tortugas, with more sparse distribution in the Florida Keys. This patchy distribution of adults is a contributing factor to the difficulty of assessing the status of the stock. Additionally, adult goliath grouper move to participate in spawning aggregations during the months of August – October, with the largest documented distance being 175km (Koenig and Coleman 2009) (Figure 3). Recent observations (Collins 2009) indicate that smaller size classes of goliath grouper (<100cm TL) occupy presumed "adult" habitat, which may be an indicator of ongoing recovery of the stock.

While adult goliath grouper appear to be more generalist with regards to habitat requirements, juveniles have a high affinity for estuarine and fringing red mangrove (Rhizophora mangle) habitat (Koenig et al. 2007). Within the mangrove habitat, juvenile goliath grouper show site fidelity to high complexity sites, microhabitats within the larger mangrove shoreline (undercuts, overhangs, solution holes and dead submersed trees) with a patchy distribution, resulting also in a patchy occurrence of juveniles (Frias-Torres 2006). Quantifying the total juvenile population remains difficult. The lack of such high quality mangrove habitat may be a population bottleneck for goliath grouper (Frias-Torres 2006; Koenig et al 2007). Furthermore, larval dispersal potential may be governed by larval duration (~30-45 days) (Lara et al. 2009), and a limited number of known, geographically isolated spawning aggregations centered in the SA and southern GOM are potentially a source of these larvae.

2.4. *MORTALITY*

2.4.1. Natural Mortality (including episodic mortality)

Legault and Eklund (1998) suggested a plausible range of natural mortality (M) values for goliath grouper of 0.04 yr^{-1} to 0.19 yr^{-1} (midpoint 0.11) based on an analysis of the fraction surviving to various maximum ages. After evaluating a number of alternative methods the DW Life History Working Group recommends the use of Hoenig's method of estimating M based on maximum age (Hoenig 1983). The oldest goliath grouper collected and aged to date was 37 years old (Bullock et al 1992) but this may underestimate maximum age for this species (See Section 2.5.2. Maximum Age, below). Using Hoenig's equation this corresponds to an average lifetime M of approximately 0.12 yr^{-1}. Consistent with what was done in previous SEDAR assessments [e.g., SEDAR 10 (South Atlantic and Gulf of Mexico gag), SEDAR12 (Gulf of Mexico red grouper), and SEDAR19 (South Atlantic and Gulf of Mexico black grouper)] as well as recommendations from the SEDAR 12 Review Panel this average lifetime M value (0.12 yr^{-1}) was scaled over goliath grouper ages 4-37 (ages fully-selected to the fisheries) to generate age-specific M estimates (Table1) using the Lorenzen method (Lorenzen 1996, 2005). Insufficient information is available to estimate generation time (Sadovy & Eklund 1999).

Episodic natural mortality events (caused by red tides, cold kills, etc.) were also discussed. Episodic events kill selectively determinate life history phases. Red tides caused by the dinoglagellate *Karenia brevis* kill mostly adults (57 % of carcasses recovered during the 2003 and 2005 red tides were larger than 1200 mm TL; Frias-Torres unpub. data). Cold kills triggered by weather fronts kill mostly juveniles (e.g. 2008 and 2010), as the inshore mangrove nursery habitats are the first to experience low water temperatures for longer periods. It is recommended that the Assessment Panel evaluate the potential role of these events on goliath grouper stocks in the southeastern US by inspecting indices of abundance (e.g., ENP, MRFSS, REEF, etc.) and model fits (similar to what was done for the 2009 SEDAR Assessment Updates for Gulf of Mexico gag and red grouper).

The LH Working Group acknowledges the high uncertainty in goliath grouper natural mortality estimates and recommends that the assessment use a prior distribution for M (a lognormal prior with a median of 0.12 and CV of 0.4) as described in Porch et al. (2006).

2.4.2. Release mortality

There are no experimental or field-based studies of goliath grouper release mortality. Several Data Workshop participants observed that goliath grouper in the southeastern US (i.e., South Atlantic and Gulf of Mexico waters) are subject to unknown but significant levels of release mortality, especially adult specimens brought up from depth. Fishing mortality due to release mortality also occurs when goliath grouper are caught as incidental catch (i.e., when other species are targeted) and when fishers target (some repeatedly) goliath grouper for catch-and-release fishing.

Since the catch-free model being considered as the base model for this assessment (Porch et al. 2006; the same model used for the last goliath grouper assessment) does not require a formal release mortality estimate, the LH Working Group recommends that release mortality be treated as part of the overall uncertainty in goliath grouper fishing mortality as described in Porch et al. (2006).

2.5. *AGE AND GROWTH*

2.5.1. Available Age Data and Alternative Procedures

As mentioned during the previous SEDAR 6 (2004) and NMFS status report (2006), a large number of juveniles were sampled for alternative hard parts for ageing comparison with traditional otolith ageing methods. Non-lethal, alternative ageing methods have been validated for both fin spines (Brusher and Schull 2009) and fin rays (Murie et al. 2009), at least for younger fish (to 18 years). Annual annuli deposition has been confirmed experimentally (OTC injection; Murie et al 2009; Brusher and Schull 2009). Brusher and Schull (2009) collected dorsal fin spines and dorsal fin rays from fish ranging 180 – 1000 mm TL and 0 – 7 years. Murie et al. (2009) collected fin rays from fish ranging 320 – 2070 mm and 0 – 18 years (n=22; 71% overall agreement). Brusher and Schull found highest agreement between otoliths and fin spines (n=1207, 86% agreement vs. only 48% agreement for fin rays, n=66). Murie et al. (2009) suggest that rays may be better than spines for older fish (> 7 y). Murie et al. (2009) recommend more extensive age and growth studies to evaluate fin ray ageing in older fish due to concerns regarding decreasing validity of fin rays and spines in old fish (erosion of annuli around the core, particularly worrisome for fin spines). These two papers provide support for the application of non-lethal techniques for ageing, at least for fish to 18 years. It is our opinion from these recent projects that otoliths are still the most accurate method, followed by spines for young (0-7y) fish, and rays for older fish (>7y). It has been concluded that scales are not an optimal ageing method. Additionally, potential age information may be also available for goliath grouper in Belize (from market samples; see Graham et al. 2009).

Opportunistic collection of otoliths (and other hard parts) has been ongoing since 2003 from mortality events (red tides, cold kills, bridge explosions, etc.; n=81). Fish sizes ranged 112 – 2070 mm and ages 1 -16 years (Frias-Torres unpub. data, Collins and Barbieri, 2010).

The SEDAR23-DW-Life History Working Group recommends the Von Bertalanffy be re-run with new age data since SEDAR 6 (Brusher and Schull 2009; Murie et al. 2009; FWC data, see Collins and Barbieri 2010).

2.5.2. Maximum Age

Maximum validated age is 37 years for one female of 1,970 mm total length (TL) (Bullock et al. 1992); the group agrees that maximum age for this species is probably much older. Bullock et al. used sectioned otoliths to age fish. Opaque rings were found to form once a year between April and August.

Minimal data is available for large, old fish and no fish older than 37 years have been collected and aged at this point. Bullock et al. 1992 samples were collected at a time when the fishery was already undergoing overfishing towards commercial extinction, so their data likely do not represent the oldest and largest potential growth range for this species. The maximum adult size reported in the literature is 2500 mm TL (Heemstra & Randall 1993), and the age of this specimen may be beyond the oldest reported in the published literature (37 years old; Bullock et al. 1992) based on the asymptotic rate of growth present in teleost fish after they have reached maturity. It is possible that the maximum age of 37 years reported in the Bullock study most likely represents a truncated maximum age (from a juvenesced population) since the species was fished to commercial extinction in the 1980's, and that a majority of the population in US waters now are likely a product of the fishing ban instituted in the 1990s (~20 years of age). Length data for adults continues to be limited in quantity, but may provide some indication of size structure of the stock. More data on distribution and abundance of size classes are necessary.

2.5.3. Growth

The existing parameter values from Bullock et al. (1992) are: L_∞ = 2006 mm, K=0.126/y, t_0=0.49 y (Figure 4)).

Bullock et al. (1992) estimated growth rate as > 100 mm/y until age 6; then reduces to 30 mm/y by age 15, and levels off to < 10 mm/y after age 25. The growth rate established for younger fish in Bullock et al. is similar to findings for fin spine ages in Brusher and Schull and fin rays in Murie et al. (2009). Comparisons of early (< 6 y) growth rates (Koenig et al. 2007; Brusher and Schull 2009; Koenig and Coleman 2009; Murie et al. 2009; Collins and Barbieri, 2010) should be made to Bullock et al. (1992) to determine regional differences or changes in growth rates since Bullock's study. Koenig et al. (2007) found higher growth rates around mangrove islands than in rivers, indicating habitat specific differences in growth rates. Koenig et al.'s growth rate estimations for adults via laser measurement during underwater visual surveys (or recaptures) may be available. Lara et al. (2009) also presents growth rates for larvae/new recruits to up 87 mm (100 days) that settle anywhere from 30 – 80 days of age. These data sets provide the most recent information available for age and growth. Figure 6 in NMFS 2006 could be modified to include new data (Brusher and Schull 2009, Koenig et al. 2009, Murie et al. 2009, FWC).

Detailed information is available for age/length/growth rates for juvenile and early adult fish (< 6y); however more detailed information is needed for large adults.

Additional review should be considered to compare growth rates calculated in Bullock et al. 1992 with growth rates available from new recapture data (Koenig et al. 2009; Brusher and Schull 2009).

2.5.4. Additional Considerations

The growth performance index phi-prime (ø) facilitates the intra and interspecific comparison of growth performance (Pauly and Munro 1984). Estimates of this parameter for several large grouper species may provide useful comparisons considering the lack of data available for Goliath grouper. This index was calculated by the equation of Pauly and Munro (1984): phi (ø) = $\text{Log}_{10} K + 2 \text{Log}_{10} (L\infty)$ where *K* is the growth constant and L_∞ is the asymptotic length derived from the von Bertalanffy growth curve.

Population parameters from the von Bertalanffy growth curves for several grouper species are listed in Table 2. Comparison of growth curves for Goliath grouper using phi (ø) showed close agreement with other species of grouper. Goliath grouper presented a phi (ø) =3.705, versus a mean phi (ø) =3.121 other grouper species investigated. The growth rates of goliath grouper are within the range of those estimated for other members of the family in tropical and temperate waters. Even though differences can be observed between the population parameters, the similarity of the phi (ø) values indicates the existence of a similar growth pattern. This result supports the statement of Sparre et al. (1989) that the phi (ø) values must be similar in members of the same family. Estimates of M for goliath grouper are in line with the trend for Serranids which in general have low rates of natural mortality (e.g., Manooch, 1987).

Evers et al. (2009) indicate that mercury (Hg) may inhibit growth and reduce reproductive success in Belize. Hg samples have been taken opportunistically by FWC and these data can be made available for fish collected in Florida.

McClenachan (2009a) provides photographic size data from recreational charters in the Florida Keys and these indicate significant declines in maximum size for fish catches over time (1923 - 1990). These data should be examined closely for additional information on maximum length.

Conversion criteria are available for weight/length relationships as well as length/age in Bullock et al. (1992), but these are limited to relatively small sample sizes for the largest, oldest fish. Brusher and Schull (2009) also have abundant raw data from which updated weight/length relationships could be derived.

2.6. *REPRODUCTION*

2.6.1. Reproductive Characteristics

Goliaths are assumed to be gonochorists, however there is insufficient data to rule out hermaphrodism (in both Bullock et al. 1992 and Collins and Barbieri S23-DW-03 the youngest and oldest fish were female). Goliath grouper are aggregation spawners - there is no evidence of them spawning outside of the aggregations. While there is no external sexual dimorphism in goliath grouper, changes in coloration during aggregation activity has been documented (Sadovy and Eklund 1999). Reproductive data is available from Bullock et al 1992, and the Collins and Barbieri report 2010.

Collins and Barbieri (2010) reported that sex was confirmed through gonad histology for 23 fish (Table 3). Confirmed females (n=14) ranged 644-1650 mm TL and 2-11 years, and males (n=9) ranged 790 – 1750 mm TL and 4 – 10 years (Figure 5). Three of the males exhibited primary growth oocytes scattered throughout the gonad. This character is not a reliable feature for discounting gonochorism (Shapiro, 1987; Bullock et al., 1992); however, together with the presence of a central lumen and the lamellar structure of the testicular tissue, it does provide further support for protogyny (Shapiro, 1987; H. Grier, pers. comm.).

2.6.2. Spawning Season

Goliath grouper are aggregation spawners known to spawn in the late summer through early fall (Sadovy & Eklund 1999). Spawning in southern Florida is from August to October, as determined from night-time chorusing by spawning adults (Mann et al. 2009), although Bullock et al. 1992 reported collecting ripe fish as early as June.

2.6.3. Age/Size at Maturity

As stated in NMFS (2006), reproductive maturity is reached late (~5 – 6 years) and at a large size (1100 -1200 mm TL) due to the slow growth rate of the species (Bullock et al., 1992). Bullock et al. (1992) found that males mature at a smaller size and somewhat younger age than females. Males mature between 1100 – 1150 mm TL (4-6 y). All males larger than 1155 mm TL and older than 7 years are mature. Female goliath grouper mature between 1200-1350 mm TL (6-7 y); all females larger than 1,225 mm TL and older than 6 years are mature.

2.6.4. Fecundity

Based on two females (1322 mm and 1397 mm), Bullock and Smith (1991) estimated batch fecundities of 38,922,168 ± 1,518,283 and 56,599,306 ± 1,866,130 oocytes, respectively.

2.6.5. Sex ratio

In the eastern Gulf of Mexico, Bullock et al. (1992) observed a sex ratio of 1.75:1 (female: male).

2.6.6. Distribution and Characterization of Spawning Aggregations

Spawning aggregations were almost completely extirpated from US waters by the late 1980s. Since the fishing moratorium in US waters (1990), a few confirmed spawning aggregations have been located. These aggregations are on artificial structure in the GOM, and on a mix of artificial and natural structure in the SA. One SA sight in Palm Beach County was a known SPAG in the 1970s and has recently reformed (Figure 6).

Goliath grouper do not follow the typical epinepheline aggregation strategy of -winter/spring spawning, at dusk, on or directly following the full moon. Only recently, Koenig and Coleman (MARFIN report) confirmed timing of spawning (~Midnight – 3AM) by collecting goliath grouper eggs in the late evening and early morning downstream from spawning aggregations during the last quarter moon in the Atlantic and during the new moon in the Gulf. Goliath grouper spawn was confirmed from the SA and GOM using genetic verification of the collected eggs.

Goliath grouper migrate over large distances to spawn. Koenig and Coleman (2009) confirmed a 175 km migration of a tagged fish to a known spawning aggregation.

2.7. *HABITAT AND MOVEMENTS*

2.7.1. EFH, Habitat Quality and Ontogenetic Shifts

The Magnuson-Stevens Act of 1996 mandates identification of essential fish habitat (EFH) for managed species, and requires measures to conserve and enhance the habitat needed by fish to carry out their life cycles (http://www.nmfs.noaa.gov/sfa/magact/magnuson_stevens2007.htm).

Goliath grouper have very specific habitat requirements throughout their life history, from juvenile to adults. The availability of fringing red mangrove (*Rhizophora mangle*) nursery habitat is a bottleneck for population recovery in goliath grouper; limited availability also limits population recruitment and juvenile growth (Frias-Torres 2006; Koenig et al. 2007). The quality of the mangrove habitat is also critical. Juvenile goliath grouper show a preference for highly structured, erosional, old mangrove sites, specifically undercuts, overhangs, submerged dead trees and limestone solution holes adjacent to fringing red mangrove shorelines (Frias-Torres 2006). After ontogenetic migration from the juvenile inshore habitat to the adult offshore habitat, adult goliath grouper show a preference for high relief habitat, either reef ledges or artificial reefs, but rarely coral reefs (Figure 7, Koenig and Coleman 2009). Site fidelity is found in both juveniles (Frias-Torres et al 2007) and adults (Sadovy and Eklund 1999) and for adult spawning aggregation sites (Sadovy and Eklund 1999).

Microhabitat preferences and site attachment have major implications on population estimates, because both juvenile and adult goliath grouper are not evenly distributed throughout mangrove shorelines or reef habitat respectively. Instead they show a clumped or contagious distribution, reflecting the landscape-level distribution of high quality mangrove habitat and high relief reef habitat. Therefore, density values (as number of individuals per unit area or length of coastline) should be used with caution in population estimates and modeling. It is essential to contrast densities in high quality habitats versus low quality habitats, and not use a single density value which could result in over-estimates of total population levels.

Habitat requirements are limited by water quality as well as structure. Preliminary research shows goliath grouper are strongly affected by decreases in water quality, specifically low dissolved oxygen (DO < 3 mg/L) (Koenig et al 2007).

Juveniles can tolerate a wide range of salinities (Smith 1971), but are limited by very low salinities (< 5 ppt). Both juvenile and adult goliath groupers are extremely sensitive to low temperatures, and will die during severe cold weather events (Gilmore et al. 1978). Due to the nearshore life history of goliath grouper, knowledge of water quality in estuarine and coastal waters is critical if we want to comply with all the EFH monitoring and protection requirements of the Magnuson-Stevens Act.

Very little is known about the characteristics of the settlement habitat (nursery areas) of larvae goliath grouper. No estimates of larval mortality are available nor is there an understanding of conditions necessary for high settlement vs. low settlement rates.

The British Petroleum (BP) Deepwater Horizon oil spill has the potential to impact negatively both juvenile and adult stages of goliath grouper. Through a combination of ocean currents (Loop Current, Florida Current, frontal eddies) and cross-shelf transport, the oil spill (in the form of surface or subsurface oil sheen, tar balls, oil+ dispersant) could contaminate all known primary mangrove juvenile habitat of goliath grouper (Ten Thousand Islands in SW Florida, mangroves of the Florida Keys, and mangroves along Florida’s east coast) and adult reef habitat.

For example, studies of oil spills on Florida and Caribbean red mangrove shorelines (Burns and Yelle-Simmons 1994, Burns et al. 1993, Burns et al. 1994; Garrity et al. 1994, Duke et al. 1997, Proffitt and Devlin 1998) show that oil contact results in immediate death of sessile organisms attached to the mangrove prop roots, killing about 30 % to 74 % of mangrove trees, and stunted growth and seed deformities in almost 100 % of the remaining living mangroves. This results in the elimination of filtering capabilities of mangrove shoreline (loss of sessile filter feeders), elimination of food sources for fish and invertebrates that use mangroves as a nursery, and destruction of the mangrove shoreline itself (collapse of dead trees). Further, low oxygen conditions on most mangrove sediment delays natural microbial oxygen-dependent biochemical reactions that digest and eliminate oil and its derivatives. Oil permanence in mangrove sediments can last for 20 years or longer, allowing for continuous re-oiling and chronic death events. Bioaccumulation of the whole range of alkylated polynuclear aromatic hydrocarbons (PAHs) is detected even 5 years after oil contamination occurs. We can speculate that if the critical goliath grouper mangrove nursery habitats are impacted by the BP oil spill, they will no longer fulfill that role. This potential loss of essential fish habitat should be considered, if possible, when evaluating the status of the goliath grouper population.

2.7.2. Movements and Migrations

Mangroves have been shown to be primary nursery habitat for goliath grouper (Koenig et al. 2007). Koenig et al. (2007) used both telemetry tags and internal anchor tags (~2500 tagged) in their study of juvenile movement patterns within the Ten Thousand Islands of SW Florida. Using telemetry tags they found over a 2-year period that movement was restricted in the mangrove islands (mean home range = 170 m), but was considerably greater in the mangrove-lined rivers (mean home range = 586 m), which they assumed was due to the more variable water quality of the rivers, causing the fish to move in response to periodic lower salinity and dissolved oxygen conditions. Some internal-anchor-tagged juveniles, observed over a much longer time period, showed greater variability in distances travelled, both within and outside of the Ten Thousand Islands. One moved northwest to an area off Tampa, over 200 km away from the nursery. Most moved west or south, but one moved around the tip of the Florida peninsula and was recaptured on the east coast near Indian River Lagoon (Figure 2).

Goliath grouper adults move about very little (Koenig and Coleman 2009). Eighty-two percent of recaptured adults (<170 out of 2100 tagged) moved less than 1 km in their time at liberty (Figure 1). There was no clear pattern between time at liberty and distance traveled (Figure 8). Some fish recaptured after years at liberty were either on the same site or not far from it. The maximum distance traveled by an adult was 175 km. Movements greater than about 1 km appear to be related mostly to migrations to and from spawning sites and a presumed feeding site in Charlotte Harbor (Figure 3).

2.8. *COMMENTS ON ADEQUACY OF DATA FOR ASSESSMENT ANAYLSES*

The Life History Working Group judged the following data and information as adequate for use in the assessment: stock definition; natural mortality estimation and release mortality; aging criteria, characterization of growth and maximum age; the characterization of reproduction; and habitat requirements. The LH Working Group deemed as inadequate the data available for age-based or spatially explicit assessment approaches. While available information is adequate for assessment, the LH Working Group recognized substantial room for improvement and makes several recommendations in Section 3.1, below.

2.9. *LITERATURE CITED*

Brusher. J.H and J. Schull. 2009. Non-lethal age determination for juvenile goliath grouper *Einephalus itajara* from southwest Florida. Endang Species Res. Vol. 7: 205-212, doi: 10.3354/esr00158.

Bullock, L. H., and G. B. Smith. 1991. Seabasses (Pisces: Serranidae). Pages 1-243 Memoirs of the Hourglass Cruises. Florida Marine Research Institute, Department of Natural Resources, St. Petersburg, FL.

Bullock LH, 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.

Bullock, L. H., and M. D. Murphy.1994. Aspects of the life history of the yellowmouth grouper, *Mycteroperca interstitialis*, in the eastern Gulf of Mexico. Bull. Mar. Sci. 55(1):30–45.

Bullock, L. H., M. F. Godcharles, and R. E. Crabtree.1996. Reproduction of yellowedge grouper *Epinephelus fl avolimbatus*, from the eastern Gulf of Mexico. Bull. Mar.Sci. 59(1):216–224.

Burns KA, S.D Garrity, and S.C. Levings. 1993. How Many Years Until Mangrove Ecosystems Recover from Catastrophic Oil Spills? Marine Pollution Bulletin, 26(5): 239-248.

Burns KA, and L. Yelle-Simmons. 1994. The Galeta oil spill IV. Relationship between sediment and organism hydrocarbon loads. Estuarine, Coastal & Shelf Science 38: 397-412.

Burns KA, S.D. Garrity, D. Jorissen, J. MacPherson, M. Stoelting, J. Tierney, and L. Yelle-Simmons. 1994. The Galeta oil spill. II. Unexpected persistence of oil trapped in mangrove sediments. Estuarine, Coastal & Shelf Science 38: 349-364.

Claro R., A. García-Cagide, L.M. Sierra, y J.P. García-Arteaga. 1990a. Características biológicopesqueras de la cherna criolla *Epinephelus striatus* (Bloch) (Pisces:Serranidae) en la plataforma cubana. *Cienc. Biol*. 23: 23-43.

Collins, A.B. 2009. A preliminary assessment of the abundance and size distribution of goliath grouper *Epinephelus itajara* within a defined region of the central eastern Gulf of Mexico. Proceedings of the 61st Gulf and Caribbean Fisheries Institute: 184-190.

Collins, A.B. and L.R. Barbieri. 2010. Goliath surveys and samples: A summary of recent work by the Fish and Wildlife Research Institute (2006 -2010). Goliath Grouper SEDAR Data Workshop, April 27-29, 2010, St. Petersburg, FL.

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

Craig, M. T., R. T. Graham, R. A. Torres, J. R. Hyde, and e. al. 2009. How many species of goliath grouper are there? Cryptic genetic divergence in a threatened marine fish and the resurrection of a geopolitical species Endangered Species Research **7**:167-174.

Duke NC, Z.S. Pinzon, and M.C. Prada. 1997. Large-Scale Damage to Mangrove Forests Following Two Large Oil Spills in Panama. Biotropica 29(1): 2-14.

Evers. D.C, R.T. Graham, C.R. Perkins, R. Michener, and T. Divoll. 2009. Mercury concentrations in the goliath grouper of Belize: an anthropogenic stressor of concern. Endang Species Res. Vol. 7: 249–256, doi: 10.3354/esr00158.

Frias-Torres S. 2006. Habitat use by juvenile goliath grouper, *Epinephelus itajara*, in the Florida Keys, USA. Endangered Species Research 2: 1-6.

Frias-Torres S, P. Barroso, A-M. Eklund, J. Schull, J. Serafy. 2007. Activity patterns of juvenile goliath grouper, *Epinephelus itajara*, in a mangrove nursery. Bulletin of Marine Science 80: 587-594.

Garrity SD, S.C. Levings and K.A. Burns. 1994. The Galeta oil spill I. Long-term effects on the physical structure of the mangrove fringe. Estuarine, Coastal & Shelf Science 38: 327-348.

Gilmore RG, L.H. Bullock and F.H. , Berry FH. 1978. Hypothermal mortality in marine fishes of south central Florida, January 1977. Northeast Gulf Sci 2(2): 77-97

Grandcourt, 2005. Demographic characteristics of selected Epinepheline groupers (family: serranidae; subfamily: Epinephelinae) from Aldabra atoll, Seychelles. Atoll Research Bulletin. No. 539.

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

Hoenig, J.M. 1983. Empirical use of longevity data to estimate mortality rates. Fish. Bull. 82: 898-903.

Hood, P. B., and R. C. Schlieder. 1992. Age, growth and reproduction of gag, *Mycteroperca microlepis*, in the eastern Gulf of Mexico. Bull. Mar. Sci. 51(3):337–352.

Keener, P. 1984. Age, growth, and reproductive biology of the yellowedge grouper, *Epinephelus flavolimbatus*, off the coast of South Carolina. M.S. thesis, College of Charleston, Charleston, SC, 65 p.

Koenig CC, F.C.Coleman. Eklund. A.M., Schull. J, Ueland. J. 2007. Mangroves as essential nursery habitat for goliath grouper, Epinephelus itajara. Bull Mar Sci. 80:567–586.

Koenig, C.C. and Coleman, F.C. 2009. Population density, demographics and predation effects of adult goliath grouper. MARFIN Project (NA05NMF4540045) NOAA/NMFS Final Report. 79 pp.

Lara, M. R., J. Schull, D. L. Jones, and R. Allman. 2009. Early life history stages of goliath grouper *Epinephelus itajara* (Pisces: Epinephelidae) from Ten Thousand Islands, Florida. Endangered Species Research **7**:221–228.

Lee, T.N., M.E. Clarke, E. Williams, A. Szmant, and F. T. Berger. 1994. Evolution of the Tortugas Gyre and its influence on recruitment in the Florida Keys. Bull Mar Sci. 54(3):621-646 (26).

Lesher and Sedberry, SEDAR 10-DW-06 Analysis of Prelminary Results for the Release of Satellite-Tracked Drifters over Gag Spawning Sites

Lombardi-Carlson, L. C. Palmer, C. Gardner and B. Farsky. 2006 Temporal and spatial trends in red grouper (*Epinephelus morio*) age and growth from the northeastern Gulf of Mexico: 1979-2005. Panama City Laboratory Contribution 2006-09**.**

Lorenzen, K. 1996. The relationship between body weight and natural mortality in juvenile and adult fish: A comparison of natural ecosystems and aquaculture. Journal of Fish Biology 49: 627-647.

Lorenzen, K. 2005. Population dynamics and potential of fisheries stock enhancement: practical theory of assessment and policy analysis. Philosophical Transactions of the Royal Society of London B 360: 171-189.

Manickchand-Heileman, S.C., and D.A. Phillip. 2000. Age and growth of the yellow edge grouper, *Epinephelus flavolimbatus*, and the yellowmouth grouper, *Mycteroperca interstitialis*, off Trinidad and Tobago. *Fisheries Bulletin* 98:290-298.

Mann, D. A., J. V. Locascio, F. C. Coleman, and C. C. Koenig. 2009. Goliath grouper (*Epinephelus itajara*) sound production and movement patterns on aggregation sites. Endangered Species Research **7**:229-236.

Manooch, C.S. and M. Haimovici. 1978. Age and growth of the gag *Mycteroperca microlepis* and size-age composition of the recreational catch off the southeastern United States. Trans. Am. Fish. Soc. 107: 234-240.

Manooch, C.S. and Mason DL 1987. Age and growth of the Warsaw grouper and black grouper from the southeast region of the United States. Northeast Gulf Sci. 9:65-75.

McClenachan, L. 2009. Documenting Loss of Large Trophy Fish from the Florida Keys with Historical Photographs. Conservation Biology 23:636-643.

McClenachan, L. 2009. Historical declines of goliath grouper populations in South Florida, USA. Endang Species Res 7: 175–181.

Moore, C.M and R.F. Labisky. 1984. Population Parameters of a Relatively Unexploited Stock of Snowy Grouper in the Lower Florida Keys. *Tran. of the American. Fish. Soc.* 1984; 113: 322-329

Murie, D.J. D.C. Parkyn, C.C. Koenig, F.C. Coleman, J. Schull, and S. Frias-Torres. 2009. Evaluation of finrays as a non-lethal ageing method for protected goliath grouper *Epinephelus itajara*. Endang Species Res. Vol. 7: 213–220, doi: 10.3354/esr00146.

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

2006. NMFS, St.Petersburg, FL. http://sero. nmfs.noaa.gov/pr/pdf/Final_Status_Report_on_the_Goliath_Grouper.pdf

Pauly, D. and L. Munro. – 1984. Once more on growth comparison in fish and vertebrates. *Fishbyte,* 2(1): 21.

Pears, R.J. 2005 Comparative demography and assemblage structure of serranid fishes: implications for conservation and fisheries management. Ph.D. thesis, James Cook University, Townsville.

Pears, R.J., J.H. Choat, B.D. Mapstone, and G.A. Begg. 2006. Demography of a large grouper, *Epinephelus fuscoguttatus* from the Great Barrier Reef: implications for fishery management. Mar. Ecol. Prog. Ser. 307-259-272.

Porch, C. E., A-M. Eklund and G. P. Scott. 2006. A catch-free stock assessment model with application to goliath grouper (*Epinephelus itajara*) off southern Florida. Fish. Bull. 104:89-1001.

Proffitt CE, and D.J. Devlin. 1998. Are there cumulative effects in red mangroves from oil spills during seedling and sapling stages? Ecological Applications, 8(1): 121-127.

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

SEDAR. 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. vi + 15 pp.

Shapiro, D.Y. 1987. Differentiation and evolution of sex change in fishes. Bioscience 37: 490-497.

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

Sparre, P., E. Ursin and S. Venema. – 1989. Introduction to tropical fish stock assessment. Part 1 Manual. *FAO Fish. Tech. Pap.*, 306 (1): 1-337.

2.10. *TABLES*

Table 1: Lorenzen age-specific natural mortality (M) estimates scaled to Hoenig's estimate (0.12 yr^{-1}) over goliath grouper ages 4-37 (ages fully-selected to the fisheries).

Age	TL (mm) mid-year	W (grams)	M
0	235.3	232.1	0.624
1	444.9	1627.0	0.387
2	629.7	4704.3	0.291
3	792.6	9504.2	0.239
4	936.3	15811.2	0.207
5	1062.9	23298.9	0.185
6	1174.6	31615.3	0.169
7	1273.0	40430.0	0.157
8	1359.8	49456.8	0.148
9	1436.3	58461.9	0.141
10	1503.7	67263.5	0.135
11	1563.2	75727.0	0.130
12	1615.6	83758.7	0.126
13	1661.8	91298.5	0.123
14	1702.6	98313.3	0.120
15	1738.5	104790.8	0.118
16	1770.2	110734.4	0.116
17	1798.1	116158.9	0.114
18	1822.7	121087.2	0.113
19	1844.4	125547.0	0.111
20	1863.5	129569.4	0.110
21	1880.4	133186.7	0.109
22	1895.3	136431.6	0.109
23	1908.4	139336.1	0.108
24	1919.9	141931.0	0.107
25	1930.1	144245.6	0.107
26	1939.1	146307.0	0.106
27	1947.0	148140.8	0.106
28	1954.0	149770.2	0.106
29	1960.2	151216.7	0.105
30	1965.6	152499.8	0.105
31	1970.4	153637.0	0.105
32	1974.6	154644.3	0.105
33	1978.3	155536.0	0.104
34	1981.6	156325.0	0.104

35	1984.5	157022.9	0.104
36	1987.0	157639.8	0.104
37	1989.3	158185.1	0.104

Table 2: Comparison of growth parameters and mortality rates for grouper species. * Note: as the model has been constrained through the origin, $t_0 = 0$. SE: standard error

Species	Area	Method	Mortality yr^{-1}	Growth parameters				Age/Size		Source
				t_0 (years)	K	L∞ (cm)	phi	Max Age	Mean Age	
Epinephelus itajara (Goliath grouper)	USA	finrays						18		Murie, et al, 2009
	USA	otoliths		-0.49	0.126	200.6	3.705	37		Bullock, et al, 1992
Hypothordus nigritus (Warsaw grouper, Craig and Hastings 2007)	USA			3.616	0.115	153.2	3.431	41		Mannoch and Mason, 1987.
Epinephelus fuscoguttatus (Marble grouper)	Australia	otoliths	0.11		0.16	80.7	3.018	42	11.8	Pears, 2005
	Australia		0.14	0*	0.20	76.7	3.071			Grandcourt, 2005
Hypothordus flavolimbatus (Yellowedge grouper Craig and Hastings 2007)	Trinidad and Tobago	otoliths		-0.08	0.099	96.3	2.963	35		Manickchand-Heileman, S.C., and D.A. Phillip. 2000
	USA	otoliths			0.191	83.1	3.120	27		Bullock et al 1996
	USA	otoliths			0.163	89.1	3.112	15		Keener, 1984
Mycteroperca interstitialis (Yellowmouth grouper)	Trinidad and Tobago	otoliths		-4.6	0.057	93.4 (TL) 85.4 (FL)	2.619 2.697	41		Manickchand-Heileman, S.C., and D.A. Phillip. 2000
	USA				0.076	82.2	2.711	28		Bullock and Murphy, 1994
Mycteroperca bonaci (Black grouper)	USA	otoliths	0.13	-0.902	0.143	133.42	3.406	33		SEDAR19-DW-02.Data workshop report
Mycteroperca microlepis (gag grouper)	USA	otoliths		-0.62	0.166	119	3.371	22		Hood and Sclieder, 1992.
	USA			-1.127	0.121	129	3.304	13		Manooch and Haimovici, 1978
Epinephelus morio (Red grouper)	USA	otoliths		-0.91	0.16	85.4	3.067	29	7.53	Lombardi-Carlson et al., 2006
Epinephelus niveatus (Snowy grouper)	USA (FL)	otoliths		-1.013	0.087	132	3.181	15		Moore and Labisky, 1984
Epinephelus striatus Nassau grouper)	Cayman Islands							29		Bush, 1996

	Cuba	otoliths		-3.27	0.063	94	2.746			Claro, et al. 1990
Mean							**3.121 SE:0.762**			

Table 3: Number of specimens sampled by FWRI staff for DNA, otoliths, and/or gonads (2006-2010). (Collins and Barbieri 2010).

year	sample (n)	aged (n)	gonad histology (n)
2006	7	7	0
2007	4	4	1
2008	17	17	2
2009	7	0	0
2010	70	32	20
Total	**105**	**60**	**23**

2.11. *FIGURES*

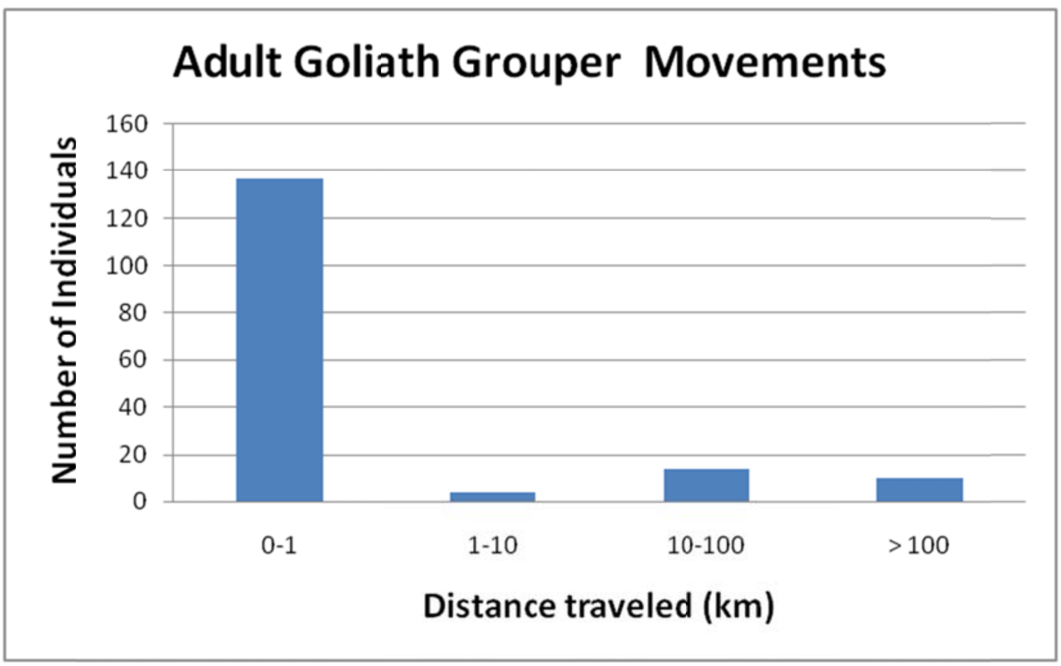


Figure 1. Distance traveled by tagged adult goliath grouper recaptured off southwest Florida.

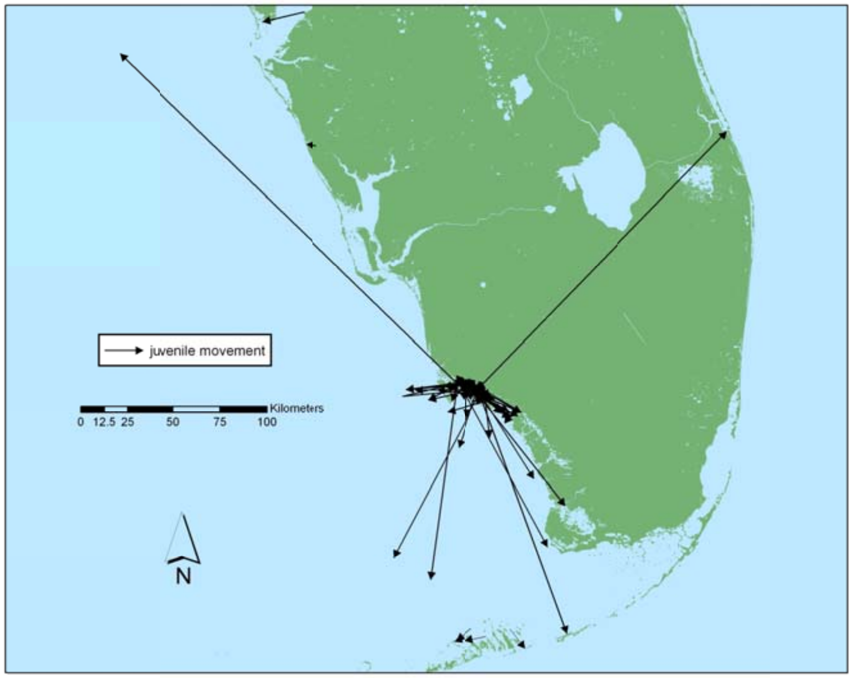


Figure 2. Movement of juvenile goliath grouper from the Ten Thousand Island area to offshore adult locations (Koenig and Coleman 2009)

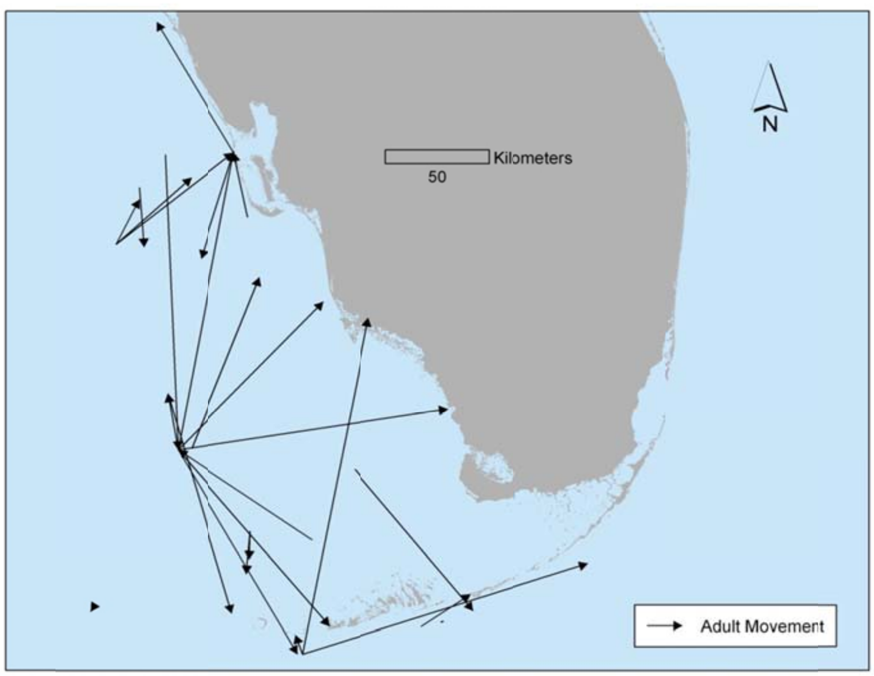


Figure 3. Long-range movements of adult goliath grouper in the vicinity of a spawning site (SW of Charlotte Harbor) and a feeding site in Charlotte Harbor off southwest Florida (Koenig and Coleman 2009).

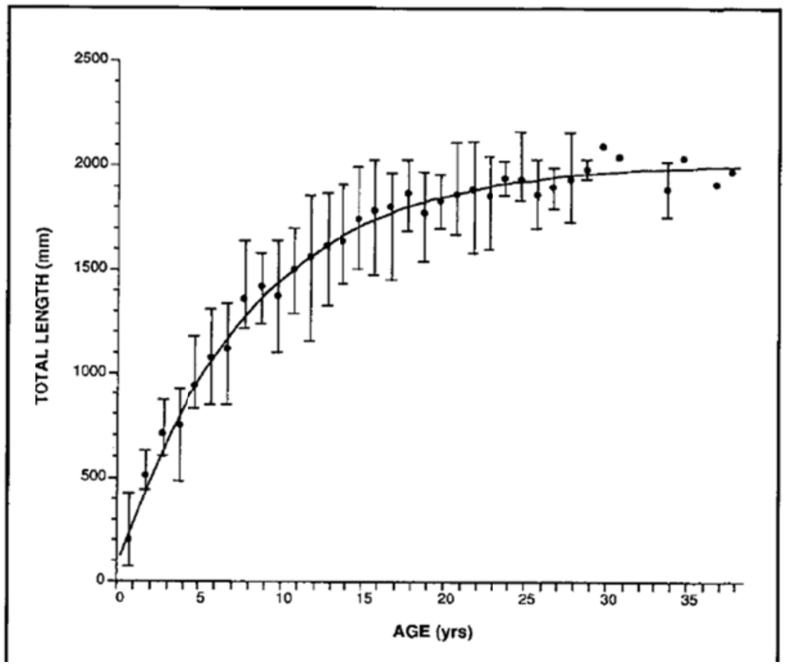


Figure 4. Age and length data for goliath grouper (n=384). From Bullock et al. 1992.

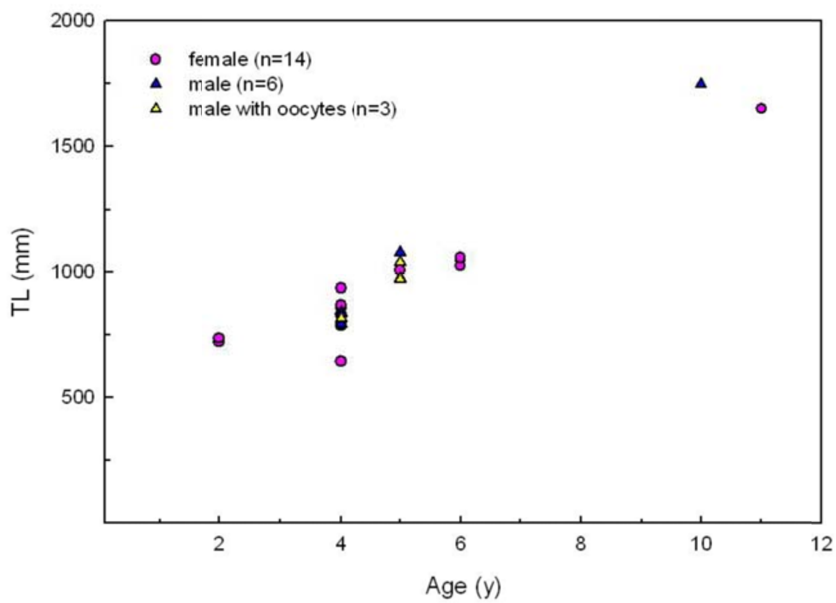


Figure 5. Size – age data for goliath grouper whose sex was confirmed through histology (n=23). From Collins and Barbieri 2010.

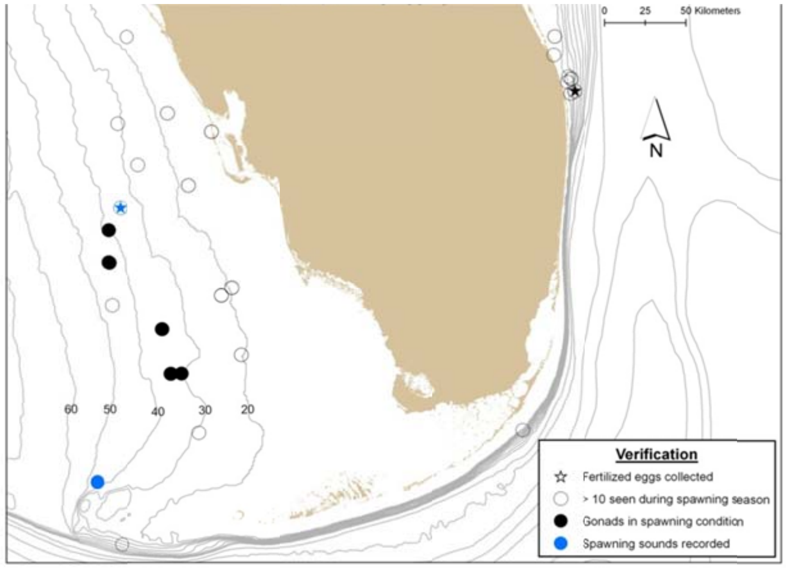


Figure 6. Goliath grouper aggregation sites offshore of South Florida (each having > 10 individuals [illegible] med spawning s[illegible] Caves (Atlantic si[illegible] nd production [illegible]

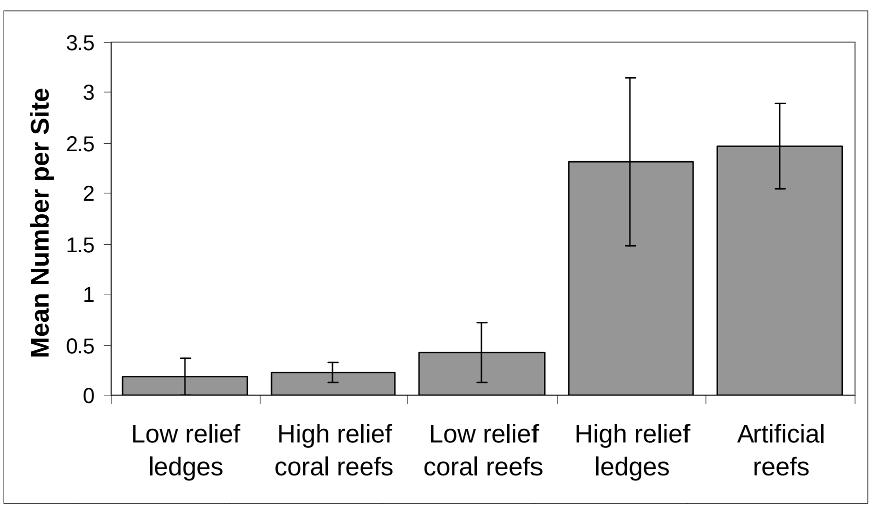


Figure 7. Comparison of adult goliath grouper densities on offshore structured habitat types from dives made by FSU researchers in all coastal regions of Florida (from Koenig and Coleman 2009).

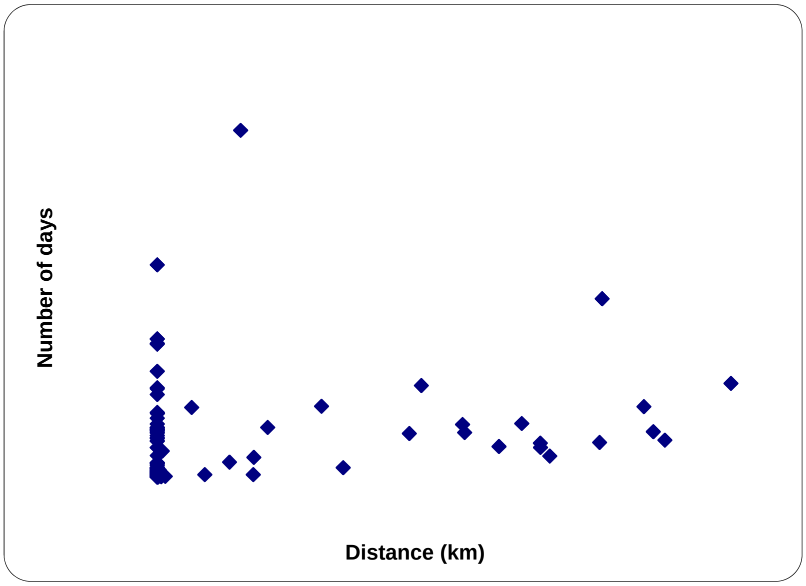


Figure 8. Distance traveled by adult goliath grouper relative to days at liberty.

3. COMMERCIAL STATISTICS

3.1. *OVERVIEW*

3.1.1. Group Membership

Chair: Benjamin C. Hartig (SAFMC representative), Richard Taylor (St. Petersburg Dive Club), Bob Zales (GMFMC AP), Gregg DeBrango (SAFMC AP), Don DeMaria (SAFMC AP), Joseph Munyandorero (FWC; presenter and editor), Joe O'Hop (FWC, draft preparation). Additional consultations on certain matters (frequency of catches noted in commercial log books, released fish condition, depth of catches, general released fish condition, and recaptures of tagged fish) occurred with Kevin McCarthy (NOAA SEFSC), Jennifer Schull (NOAA SEFSC), and Angela Collins (FWC).

3.1.2. Issues

Historical commercial landings data for goliath grouper were explored to address issues such as accuracy (non-reporting, over-reporting, under-reporting), potential for misidentification in the landings records, commercial discards, discard mortality, and research needs.

3.2. *REVIEW OF WORKING PAPERS*

3.2.1. Bycatch of goliath grouper observed from the bottom longline fishery.

Title: Bottom longline fishery bycatch of goliath grouper (*Epinephelus itajara*) from observer data. (Hale, L.F. 2010)

Author: Loraine Hale (NOAA Fisheries/SEFSC, Panama City)

Abstract: Observations of the shark-directed bottom longline fishery in the Atlantic Ocean and Gulf of Mexico have been conducted since 1994 (e.g. Hale and Carlson 2007, Hale et al. 2007, Morgan et al. 2009, Hale et al. 2009, Hale et al. 2010). From 1994 through 2001, observer coverage was conducted on a voluntary basis. Beginning with the 2002 fishing season, observer coverage of the shark directed bottom longline fishery became mandatory under the current federal management plan for highly migratory species [50 CFR 635.7, National Marine Fisheries Service (NMFS) 2003]. Observer coverage from 1994 through the first trimester season of 2005 was coordinated by the Commercial Shark Fishery Observer Program (CSFOP), Florida Museum of Natural History, University of Florida, Gainesville, FL. Starting with the 2nd trimester season of 2005, responsibility for the fishery observer program was transferred to the NMFS, Southeast Fisheries Science Center (SEFSC), Panama City Laboratory. This report describes the bycatch of goliath grouper (*Epinephelus itajara*) on observed trips from 2005 through 2009.

There were 47 goliath grouper incidentally caught in 36 hauls on 32 trips. The majority of the sets targeted sharks (95.7%) while the remainder (4.3%) targeted groupers and snappers. Goliath groupers ranged in size from 57 to 219 cm total length (average 132.3 cm TL); however, most lengths (68.1%) were estimated due to the difficulty of boating large goliath groupers. The average depth of sets when groupers were caught was 57.3 m, ranging from 3.5 to 275 m deep. The depths were recorded by the vessels' depth finder and represent the depth at the beginning and end of the set of gear, but may not reflect variations in depth between the two points.

Of the 47 goliath groupers, 46 (97.9 %) were alive when captured and of those, the majority (93.5 %) were released alive. Goliath groupers were vented by the crew and were coded as alive by the observer only if the fish swam down in the water column after release. The one goliath grouper that came up dead was caught at 13 m average depth (no predation noted), while three goliath groupers that were released dead after being caught alive were caught at 203 m average depth (102.5 m to 275 m depth range).

3.2.2. Bycatch of goliath grouper reported in commercial fishermen's logbooks from the vertical line and bottom longline gears.

Title: Calculated goliath grouper discards from commercial vertical line and longline fishing vessels in the Gulf of Mexico and US South Atlantic. (McCarthy, 2010)

Author: Kevin McCarthy (NOAA Fisheries/SEFSC, Miami)

Abstract: In August 2001, the Southeast Fisheries Science Center (SEFSC) initiated a program to collect discard data from commercial fishing vessels landing federally managed species in the Gulf of Mexico and US South Atlantic. A reporting form was developed as a supplement to the mandatory coastal logbook forms for commercial vessels with Federal fishing permits (Poffenberger and McCarthy, 2004). Discard data from the SEFSC coastal fisheries logbook program were used to calculate the number of Goliath grouper that were discarded from commercial fishing vessels during the period January 1, 2002 through December 31, 2009.

Data collection for the discard logbook program involves, each year, a 20% sample of vessels with Federal fishing permits. To assure that the sample was representative of permitted vessels, the universe of those vessels was stratified by region and gear fished. A random sample, weighted by vessel effort reported the previous year, was selected from each stratum. Region was defined as the Gulf of Mexico (Gulf-side of the Florida Keys-Dry Tortugas to the Texas-Mexico border) and the South Atlantic (which extends from the North Carolina-Virginia border to the ocean-side of the Florida Keys-Dry Tortugas). Fishing gear strata included handline, electric reel (bandit rig), trolling, longline, trap, gillnet, and diving. The selected fishers were instructed to complete a supplemental discard form for every fishing trip that they made. Trips with no discards were reported as such.

Reported data included the numbers of discards by species, estimated condition of the fish when released, reason for release (due to regulations or unmarketable/unwanted), and the fishing area where the animal was discarded. There were six options for the condition of released fish: all animals are dead, majority of the animals are dead, all animals are alive when released, majority of animals are alive, the fish are kept but not sold, and the condition of the animals is unknown. To calculate species specific discard rates, discard data were matched to the effort data reported to the coastal logbook program.

During this period (2002-2009), discard forms were submitted for 450 longline trips fishing in areas 2-6 in the Gulf of Mexico (total in the filtered data set). There were 11,390 vertical line trips reported to the discard logbook program from the areas included in these analyses. Goliath grouper discards were reported from 89 (0.8%) vertical line and 53 (11.8%) longline trips during 2002-2009. There were 5,804 longline trips in areas 2-6 and 110,096 vertical line trips in the areas included in these analyses that reported to the coastal logbook program during 2002-2009.

Calculated total discards for each gear and year (2002-2009) were provided for commercial fishing trips deploying longline and vertical line gear, respectively. Calculated discards (those developed using standardized discard rates from the delta-lognormal model) were almost always lower than the median calculated discards estimated from bootstrapping. The proportion of trips reporting goliath grouper discards was included in the calculation of discard rate when using the delta-lognormal standardization model, accounting for the lower total discards calculated using that method. Coefficients of variation of delta-lognormal calculated discard rates were often high and ranged from 0.45-1.6 for longline discard rates and from 0.31-1.17 for vertical line discard rates.

Vertical line calculated discards (using model generated standardized discard rates) were usually below the 5th percentile of bootstapped total discards. Longline calculated discards were higher than the 5th percentile of bootstrapped total discards. Longline calculated discards were highest during the period 2002-2004 with another, smaller, peak in 2007. During the 2002-04 period, the highest variability (as defined by the 5th and 95th percentiles of bootstrapped values) was also found. Total discards calculated from vertical line data was less than 1,000 fish per year except for the years 2006-07 and 2009. Variability in the vertical line calculated discards (as determined by bootstrap estimated discards) was generally consistent among years and did not have the wide range found during the initial years of the longline time series.

The release condition of discarded goliath grouper is reported in the logbooks. There were more than 261 longline and 110 vertical line goliath grouper discards reported to the coastal logbook discard program. Overall, 30% of discarded goliath grouper from longline vessels were reported as “all dead” or “majority dead” and 70% of discards were reported as “all alive” or "majority alive." Greater than 95% of vertical line goliath grouper discards were reported as "all alive" or "majority alive" during each year, 2002-2009. Nearly all goliath grouper discards were, not surprisingly, reported as "due to regulatory restrictions", except for a small percentage where the reason for discarding the fish was unreported. No estimate of delayed mortality was possible with these data.

The number of trips reporting goliath grouper discards in the US South Atlantic and Gulf of Mexico was very low. Goliath grouper discards were reported on 15 or more trips during only two years from either longline or vertical line vessels. During six years, five or fewer longline trips reported Goliath grouper discards; however, five or fewer vertical line trips reporting Goliath grouper occurred in only two years. Discard totals, calculated from such relatively rare events, should be used cautiously.

3.3. *COMMERCIAL LANDINGS*

3.3.1. Historical perspective on U.S. commercial landings information.

Originally, Lichtenstein (1822) published a description of goliath grouper from a Brazilian specimen and named it *Serranus itajara*, which in more recent years has been reclassified as *Epinephelus itajara* (Lichtenstein 1822*)*. Other ichthyologists, sometimes in different parts of the world, described this species under names such as *Serranus guasa*, *S. galeus*, *S. mentzelii*, *Promicrops ditobo*, and *P. esonue* which were later synonymized with *E. itajara* [see Eschmeyer and Fricke 2010]. A misspelling of *itajara* occurred as *itaiara*, causing a little more confusion. Goliath grouper [as *P. guasa* (Poey)] was listed in Jordan and Gilbert's (1882) treatise on fishes found in North America, Jordan (1884) used the name *E. itaiara* for goliath grouper in the Florida Keys, Jordan's (1887) catalogue of fishes in North America used *P. itaiara*, and Jordan and Eigenmann (1890) applied the name *P. guttatus* to a goliath grouper specimen from the St. John's River, FL. Irrespective of the taxonomic uncertainty and litany of scientific names used by different workers at different times, goliath grouper were known by fishermen and scientists at that time under the common names (with or without hyphens) "jewfish", "spotted jewfish", "gigantic jewfish", "guasa", "merou", and "Jacob Evertzen." *S. quiquefasciatus* Bocourt 1868 was formerly considered a synonym of *E. itajara*, but is now a synonym for *E. quinquefasciatus* (Bocourt 1868) and considered a valid name for goliath groupers living in the Eastern Pacific based upon genetic analyses (Craig et al. 2009). Nelson et al. (2001) recommended for immediate adoption the change in common name for *E. itajara* to goliath grouper and adopted this change for the American Fisheries Society's sixth edition of the Common and Scientific Names of Fishes from the United States, Canada, and Mexico (Nelson et al. 2004).

The earliest descriptions of some U.S. commercial landings occurred in 1887 (U.S. Bureau of Fisheries 1887) with a brief note on the printing of the results of the Fishery Census of 1880. These descriptions of U.S. fishery landings included all states in the southeastern U.S. and Gulf of Mexico. The 1887 and 1888 surveys (U.S. Bureau of Fisheries, 1892) showed some landings of goliath grouper in Texas but nowhere else from North Carolina (NC) to Louisiana (LA). The surveys did not regularly include all southeastern and gulf states until the 1897 (U.S. Bureau of Fisheries, 1900) and 1902 (U.S. Bureau of Fisheries, 1905) surveys, and it is possible that those surveys did not include goliath grouper as a regular reporting category in all states (unless there really were none caught, which was unlikely). For example, over several weeks in 1883, Jordan (1884) observed fishing in the Florida Keys and noted that goliath grouper (and other large reef fishes) are caught by larger vessels and that most are usually taken alive to Havana rather than sold in Key West. Stevenson (1893) mentioned a fish caught in Texas' bays and coastal fisheries during 1891 which Mexican fishermen called "guasa" that was of large size (occasionally 500 pounds or more) and that came from Aransas Bay (where, in 1890, a jewfish weighing 597 pounds was recorded). Stevenson (1893) thought that this fish was another large grouper (*Epinephelus nigritus* or warsaw grouper) which was also called "jewfish" and "black jewfish" at that time in Pensacola and noted that it was called '"warsaw, doubtless a corruption of "guasa."' However, because of its large size and occurrence of large individuals near shore, this fish was undoubtedly goliath grouper. In Texas, this fish was also known as "junefish" because it was more plentiful at that time of the year.

Evermann and Bean (1897) in their 1895-1896 investigation of fish and fisheries in Florida's Indian River Lagoon and adjacent marine waters noted that four specimens of young goliath grouper (as "*Promicrops guttatus*", lengths from 1 5/8"-3") were captured, and that this species was "probably not uncommon" to the Indian River area though Wilcox (1897) did not list them as components of the commercial fishery there. Brice's (1897) account of the coastal fish and "principal fishing centers" of Florida (Indian River, Lake Worth, Biscayne Bay, Key West, Tampa, Tarpon Springs, Apalachicola, Carrabelle, Pensacola, and others) conducted during 1895-1896 noted that goliath grouper (as "*P. guttatus*") caught are usually 100-250 pounds, with a maximum of 400 or 500 pounds, but that those over 250 pounds "do not sell well". He also noted that, in 1895, dealers in Key West reported purchasing 10,000 pounds ($425) of goliath grouper from local fishermen. A separate reporting category for goliath grouper in statistical reports by state did not appear until 1897, but may not have been reliably used (possibly goliath groupers were lumped into a "grouper" category) by dealers for reporting until the 1918 survey (U.S. Bureau of Fisheries, 1921) and continued to be used regularly in later surveys.

Schroeder (1924) provided an updated description of Key West fisheries, and noted that the first large-scale ice-making and cold-storage plant was built to store excess catches of fish. In 1919, there were severe losses to the fishing industry when the one small ice-making plant in the city became disabled. The fishing fleet consisted of small boats which had sails, gasoline engines, or both, which seldom traveled very far from shore and fished at the numerous near-by reefs, and a few locally-owned larger vessels along with "a number of [larger] vessels… from the east and west coast of Florida [that came] to fish at Key West during the winter." It was not unusual for Cuban vessels to fish near Key West and sell their catch to Key West seafood dealers. Fishing for reef fish, particularly the larger reef fish, required vessels to have live wells since ice was only used to preserve species like mullet, kingfish, or Spanish mackerel. The larger reef fish were usually fished farther offshore and by larger vessels (ranging from 30-75 feet in length) using hand lines. Schroeder (1924) noted that a portion of the catch was sold locally in Key West, but that a much greater portion was sold in Cuba and to other U.S. cities. Fish were brought in alive, and were packed in ice for shipment to Cuba or elsewhere.

Goliath grouper (as "*Promicrops itaiara*") were not numerous in catches, but because of their large size accounted for a little more commercial importance in Key West. Larger goliath groupers were known to prefer "moderately deep water with rocky or coral bottom", and smaller ones (1-10 pounds) were "frequently taken in shallow water close to shore" (Schroeder 1924). Schroeder (1924) wrote that "During the six weeks of July and August of 1918, 74 jewfish, ranging in weight from 35 to 350 pounds, with a mean average of 125 pounds," nearly all of which were taken off Knight's Key[1] (about 40 miles above Key West). Goliath grouper were

[1] Knight's Key (near Marathon) was the site of a long, deep water dock built in 1906 to support the building of the Seven Mile bridge for Henry Flagler's Key West Extension of the Florida East Coast Rail System (http://www.keyshistory.org/KKD-Knights-Key-Dock.html). It was burned to the waterline in 1912 leaving only pilings. These structures provided habitat that may have attracted goliath grouper.

brought to Key West's market alive, and kept in live cars until sold, selling for about 20 cents per pounds. Schroeder (1924) wrote that a catch of goliath grouper "always finds a ready sale, the entire catch being consumed locally."

There is little information available about the commercial landings of goliath grouper in more recent years. Commercial harvests were generally by hand lines early in the century, and more recently bandit rigs (hydraulic and electric reels) as well as traditional hand lines were used. Divers used spearguns to harvest individuals, and long lines (GMFMC 1990; Hale 2010; DeMaria 1989), gill nets, and trawls occasionally catch some individuals (DeMaria 1989). Most goliath grouper were taken incidentally in the red snapper fishery at first, and later in the grouper/snapper fishery in the Gulf of Mexico (GMFMC 1990). It is likely that some goliath grouper landed from the snapper fishery came from the Campeche Bank (Fig. 3.1; Yucatan Peninsula, Mexico) and show up in the Alabama landings during the 1960s (GMFMC 1990). Landings of goliath groupers are not available in the FAO statistics data base, so the amount of goliath grouper harvested in other countries is unknown. Goliath grouper were still harvested to a small extent in the Mexican fishery on the Campeche Bank (Colás-Marrufo et al. 1998).

By at least the 1880s, U.S. fishermen knew that the Campeche Bank had abundant and commercially valuable fish populations, particularly red snapper. Stevenson (1893) noted that one schooner in December 1890 fished there and in two days with seven men harvested 22,000 pounds of red snapper weighing on average about 10 pounds. Commercial fishing operations to these fishing grounds faced very challenging logistics, and the markets at that time in Galveston were not ready for such large catches. As a result, the catch was not sold at a good price. In January 1891, this schooner made another trip to the Campeche Bank, and caught 15,000 pounds of fish. Another fisherman, with a market in Corpus Christi, told Stevenson (1893) that he had fished the Campeche Banks and had caught 16,000 pounds of red snapper in five hours. Stevenson (1893) noted in his report (for the 1889-1891 period) that he believed that the Campeche Bank fishery could be developed and that they would be profitable.

Experimental fishing on the Campeche Bank occurred in 1892 (Smith 1895), and the success of these trials led to a regular fishery there beginning in 1893. The "principal fishes" taken there were red snapper, warsaw (and perhaps black grouper), and jewfish. Warsaw and jewfish (specimens up to 300 pounds) "constantly figured in the catch, but were noted as being of little commercial value (Smith 1895). The depths fished typically were 40 to 60 fathoms, and the fish harvested from these depths did not do well in live wells and were packed whole in ice. The snapper fishery expanded to the Campeche Banks in 1895, and the highest production of red snapper occurred over the 1895-1929 period (Bortone et al., 1997). With the low selling price of goliath grouper compared to red snapper, lengthy transit time to the Campeche Banks and the need for live wells or ice which was not in great supply (Bortone et al., 1997), it is unlikely that goliath grouper were retained as part of the catches by snapper vessels fishing the Campeche Banks in this earlier time period. Low commercial value would have kept goliath grouper from being harvested and landed to any great extent from the Campeche Banks by commercial fishermen from the southeastern U.S. during these early years, though there probably would have been discards.

3.3.2. Preliminary landings and discussion of methods

The commercial landings statistics began including a reporting category for goliath grouper in 1902, but it may not have been regularly used by seafood dealers until the 1918 survey (Table 3.1). Several agencies through the time period had the responsibility for collecting and reporting these data, and often the process was a joint state-federal cooperative effort. The U.S. Bureau of Fisheries collected landings data in the southeastern U.S. (NC-TX) using annual surveys of seafood dealers in some years and regions from 1902 to 1936 after which the U.S. Fish and Wildlife Service (USFWS) began collecting these data and publishing them in their Statistical Digest series from 1939 to 1967. The Florida State Board of Conservation (FL SBC) also collected commercial landings data using annual surveys of seafood dealers in Florida from 1939 to 1948, and these data are contained in their Biennial Report series. Beginning in 1949, The FL SBC began using monthly surveys of seafood dealers to get information on commercial landings, and these data were tabulated and shared with the USFWS. The Department of Commerce's NMFS took over the responsibility of collecting commercial fishery landings information in 1970, publishing these data for 1968 to the present. Thompson (1984) reviewed the relative completeness of the commercial landings data by region and year from 1880 to 1977.

The data for goliath grouper landings from 1902 to 1949 were obtained from the aforementioned published (printed) reports. Data for 1950 to 2008 were retrieved from commercial landings data found at NOAA Fisheries commercial fishery landings web page (http://www.st.nmfs.noaa.gov/st1/commercial/) and from the Florida Fish and Wildlife Conservation Commission's web page containing commercial fishery data collected using trip tickets (http://research.myfwc.com/features/view_article.asp?id=19224) from 1986-2009 and compared in Table 3.2. Electronic data were also available from NMFS Accumulated Landings System (ALS; collected by port agents) by year, month, county for 1950-1977, and also by dealer for the 1978-1986 period (Josh Bennett, SEFSC, personal communication). Comments regarding commercial fishery landings data and the exaggerated reporting of goliath grouper landings by one dealer for the 1978-1984 period from Amendment 2 to the Gulf of Mexico Reef Fish Management Plan (GMFMC 1990) and Amendment 2 to the South Atlantic Snapper-Grouper Fishery Management Plan (SAFMC 1990) were discussed during the data workshop. In addition, comments from SEDAR 3 (Yellowtail Snapper and Goliath Grouper) regarding the under-reporting of goliath grouper landings in Monroe County due to unreported direct sales of this species to restaurants were discussed during the data workshop.

Upon inspection of the printed commercial landings series[2] from the U.S. Bureau of Commercial Fisheries from 1902 to 1936, the USFWS Statistical Digests for the years 1939-1967, NOAA Fisheries commercial fisheries landings web page, and the FL SBC Biennial Reports, some decisions on which values for commercial landings in some years would have to be made. There was some overlap between the USFWS landings series and the FL SBC for 1939-1959, and the FL SBC recorded commercial landings in more years than the USFWS (Table 3.1). The FL SBC data were chosen to use in place of the USFWS data for the 1939-1949 period because it is more complete than landings compiled by the USFWS. During 1949, the FL SBC began collecting commercial landings using monthly surveys of seafood dealers and sharing those data with the USFWS, so it seems likely that starting in 1949, the FL SBC and the USFWS printed landings should be similar since they were presumably based upon the same surveys. There may be minor differences due to dates of printing and revisions to the data that may have occurred after printing. Some minor differences between the NOAA web page landings for 1950-2008 and the ALS data were noted in 1950 and 1958-1960, and those appeared to be related to the adjustment between landed weight (most reef fish were gutted) and whole weight (Table 3.2), though it is possible that there were revisions to the commercial landings data after the ALS data were compiled and sent. A similar problem was noted in 1986 between Florida trip ticket and ALS data, and it appeared that the ALS data were not corrected for the

[2] See Figure 3.2 for an explanation of the division of Florida commercial landings by coast used in these published reports.

conversion between gutted weight and whole weight, but the NOAA web page was very similar to the Florida trip ticket data beginning in 1986.

It was suspected that one southwest Florida seafood dealer, which was in business since 1937, had inflated landings of goliath grouper (and other reef fish) at least during 1978 to 1984 and possibly from 1965 to 1984. Both Amendment 2 to the GMFMC's Reef Fish Management Plan (GMFMC 1990) and Amendment 2 to the South Atlantic Snapper-Grouper Fishery Management Plan (SAFMC 1990) addressed the over-reporting issue by deleting the commercial landings reported by this southwest Florida seafood dealer (which was believed not to be a major processor of reef fish) from the landings series for 1978-1984. Commercial landings by dealer were not available for the 1950 to 1977 period, but landings at the county level were available from the ALS (Josh Bennett, NOAA Fisheries SEFSC, personal communication).

An alternative approach is to adjust this dealer's landings based upon an estimate of the proportion of this dealer's landings to the county landings of goliath grouper during a period of time when the reported landings were likely to be more reliable. Landings of goliath grouper reported by this dealer declined in June of 1984 and continued at a lower level through 1986 in marked contrast to their reported landings of this species from 1978 to May of 1984. It may be likely that the latter period represents a time of more reliable reporting than the former period. The ratio of this dealer's average monthly landings from June of 1984 to December 1986 to its average monthly landings from January 1978 to May 1984 was 0.072 (i.e., the dealer's reported monthly purchases from the 6/84-12/86 period were 7.2% of the monthly purchases from 1/78-5/84). The amounts reported by this dealer for January 1978- May 1984 were multiplied by 0.072 to produce a new landings series for this dealer for this period. The county landings (Table 3.2) were recalculated by subtracting the originally reported landings for this dealer and adding the adjusted landings. The FL West Coast and statewide landings were re-calculated by subtracting the old values and adding the adjusted values (Table 3.2).

The 1965-1977 period was suspected to have been inflated also (GMFMC 1990, SAFMC 1990), but the reported landings by dealer were not available for examination and neither of the Council's amendments addressed this time period. The average annual reported landings of the dealer who inflated goliath grouper landings represented 98.0-98.9% (average 98.5%) of the county landings from 1978-1981 (other dealers in this county began purchasing increasing amounts of goliath grouper in 1982, so it seemed reasonable to derive the ratio for the inflated reporting using only the 1978-1981 time period). The county landings for the 1968-1977 were multiplied by 0.985 to estimate the fraction of the assumed inflated county landings that may have been reported by this dealer for 1968-1977. The estimated inflated landings of goliath grouper by this dealer were multiplied by 0.072 to obtain an adjusted amount of this dealer based upon the proportion observed from June 1984 to December 1986 (see preceding paragraph). To make a smoother transition of landings for years prior to 1968, the county landings for 1965-1967 were multiplied by 0.823 (the proportion of county landings represented by this dealer from January to May of 1984), and the estimated inflated landings were multiplied by 0.072 to obtain the estimated landings for this dealer and the newly calculated county, FL west coast and statewide values (Table 3.2). These are highly uncertain estimates of goliath grouper landings for this dealer, and it is not known if there are data from which to make better estimates because this seafood dealer went out of business in 2003 and the original owner passed away over two decades ago. These adjustments greatly alter the reported commercial landings time series in Florida for goliath grouper (Tables 3.2, 3.3, Figs. 3.3- 3.6) but may be more reasonable than the reported landings series for 1965-1984 given the concerns over inflated landings of goliath grouper regarding this seafood dealer.

Another concern with the commercial landings were the issues of unreported purchases of goliath grouper by seafood dealers and direct sales to restaurants by commercial and sport fishermen that were unreported. The issue of “backdoor sales” and non-reporting has existed since the beginning of the commercial landings reports by the U.S. Bureau of Fisheries and continues to the present day. In the Tenth Biennial Reports of the FL SBC for 1951-1952, special mention was made regarding the lack of knowledge of the level of harvest by sport fishermen, the ability of some sport fishermen to turn a profit from their “recreational” harvests by selling to dealers and restaurants, and the potential of these activities to compete with commercial fishing and result in increasing tensions between sport and commercial fishermen. DeMaria (1989; see Appendix A) and comments made during SEDAR 3 mentioned this same concern over unreported sales of goliath grouper in the Florida Keys. There was no consensus by the DW Commercial and Recreational landings workgroup over potential adjustments that could be made to the commercial landings for these unreported sales in a county or for Florida. The recommendation of this workgroup was to leave the reported landings unadjusted for unreported sales.

With the adjustments (Tables 3.2, 3.3) made to the commercial landings series (primarily to the 1965-1984 period, but also adding in the annual values for 1939-1949 from the FL SBC), landings of goliath grouper in Florida likely reached the highest levels of harvest in the 1940s and declined subsequently (Figs. 3.4, 3.6). An earlier peak and decline after 1927 (Figs. 3.4, 3.6) may have been associated with the general decline in business activity during the Depression years after 1929. Landings (as adjusted) along the Florida West Coast increased somewhat during the 1980s (though not at the levels observed during the 1940s) and fell after the prohibition on harvest enacted by the Florida Marine Fisheries Commission in state waters in early 1990 and later in federal waters by the GMFMC and SAFMC.

3.3.3. Recommendations on commercial landings

At the time of the DW, commercial landings had not been compiled, nor had they been compiled for SEDAR 3 (and, in fact, no assessment of goliath grouper was attempted) or SEDAR 6, and in fact were unnecessary for the catch-free assessment model (Porch et al., 2006). Documentation of the existing landings information and recommendations on aspects of the landings series are appropriate, however, even if these data are unnecessary for the assessment model. The commercial and recreational landings workgroup discussed the need for adjusting the landings series for the inflated landings by a seafood dealer in Lee County and agreed in principle that adjustments were necessary. The workgroup agreed not to adjust for unreported or under-reported commercial landings in Monroe County because of the lack of an objective criterion to make this adjustment. Following these recommendations, the landings data (compiled after the DW) in Tables 3.2 and 3.3 are proposed as the recommended commercial landings series for goliath grouper until such time that further improvements to the historical landings can be made.

3.4. *COMMERCIAL DISCARDS AND RELEASE MORTALITY*

3.4.1. Logbook discards

The commercial and recreational catch workgroup discussed commercial observer program discards (see Hale 2010) and commercial logbook discards that had been analyzed using the commercial reef fish logbooks. There were very few trips (32 out of 273 observed trips) on which goliath grouper were caught from 2005-2009, one of the forty-seven individuals caught were dead when brought to the boat, and three of forty-seven (6.5%, including the fish that was dead when brought to the boat) goliath groupers were released dead. Most (32 of 47) of these fish were caught in water depths less than 40 meters, though sets on which groupers were caught ranged from 3.5 to 275 meters in water depth. The length of goliath groupers caught averaged 132.3 cm (range 57 to 219 cm).

Similarly, Scott-Denton (1995) examined observer data from reef fish fishery trips in the eastern Gulf of Mexico. No goliath groupers were observed from fish traps pulled from December 1993 to February 1995 (13 trips), none were observed from long line gear during the same period (12 trips), and two were noted from bandit gear used off of Florida (nine trips, both goliath groupers released alive) from January through July of 1995. No goliath grouper were observed from bandit gear trips off of Louisiana (seven trips) from January through July of 1995. Goliath groupers were not observed in earlier studies using fish traps (Taylor and McMichael 1983, Sutherland and Harper 1983).

Limited observer studies of shrimp trawl bycatch noted no catches of goliath grouper from roller frame trawls (for bait shrimp) over seagrass beds in Tampa Bay (Meyer et al. 1991), and more extensive observer studies of shrimp trawl bycatch in the roller frame and otter trawl shrimp fishery in and around several bay systems on Florida's west and east coasts found no bycatch of goliath grouper (Coleman et al. 1992, Steele and Levitt 1999a, Steele and Levitt 1999b). However, there have been several specimens of small (<100 mm TL) goliath grouper taken in commercial bait shrimp trawls over seagrass beds during December and January from Florida's west coast (Bullock, personal communication). Commercial landings data notes a small amount of goliath grouper from otter trawls for shrimp (NOAA Fisheries commercial landings web page), so it is likely that the observer studies were conducted with trawls used over bottom habitats or during a time of the year that goliath grouper were less likely to be encountered, that sample sizes may have been insufficient for a species which is infrequently encountered by this gear, or (for roller frame trawls only) that the fish were too large to enter through the frame in the mouth of the net. It is also possible that some of the landings of goliath grouper listed from commercial shrimp trawls may have resulted from hook and line fishing by the crews during the day.

The commercial reef fish and shark long line discard logbook data were summarized and verbally presented to the commercial and recreational catch workgroup by Kevin McCarthy (NOAA Fisheries, SEFSC) and provided after the DW as SEDAR-DW-04. There were some observations of goliath grouper from these logbooks (McCarthy 2010 for an overview of the methods), though too few vessels reported goliath grouper discards in 2004 (vertical line vessels) and 2005 (bottom longline vessels) to allow for presentation of the results. The number of trips on which goliath grouper were noted was low in both fisheries, and it is difficult to make a precise estimate of the number of discarded fish (McCarthy 2010). The estimated median for annual discards of goliath grouper from the longline fishery ranged from 47 to 4,514, and 976 to 10,435 fish in the vertical line fishery (McCarthy 2010). In five of the eight years of the discard logs from the longline fishery and in seven of the eight years in the vertical line fishery, most of the goliath grouper reported in the discard logbooks from both the vertical line fishery and the longline fishery were reported to have been released alive. Over the 2002-2009 period, bottom longline vessels reported that 30% of the goliath groupers were released dead (either all or the majority were dead) from bottom longline gear. For the vertical hook and line vessels (e.g., bandit rigs, hydraulic or electric reels), 95% of the goliath groupers were reported to be released alive (either all alive or the majority were alive). The observed mortality reported in these logbooks is, of course, the “immediate or acute” mortality and no studies on delayed mortality or total release mortality have been conducted for goliath groupers.

From the observer studies and the logbook program data, it appears that goliath grouper are not frequently caught by commercial fishermen, and of the ones that are caught most are released alive. Release mortality appears to be higher in the bottom longline fishery than from the vertical line fishery. Research studies on juvenile goliath grouper in shallow water show that those smaller fish encountering fishing gear have a reasonably good chance of survival if they are released. Brusher and Schull (2009) used trot lines, blue crab traps, and fish traps to sample and tagged 1,683 juvenile goliath grouper in the Ten Thousand Islands area of the Florida Everglades. Of those individuals, they sampled 1,144 for hard parts (fin rays, spines, scales) and of these they recaptured 667 fish with 275 recaptured two or more times. So it appears that for juvenile goliath grouper, release mortality may be relatively low at least at shallow depths.

3.4.2. Recommendations on commercial discards and release mortality

The commercial and recreational catch statistics workgroup were presented with information from the commercial reef fish and shark long line fishery logbooks which indicated that the level of incidental bycatch was relatively low for long line and vertical hook and line commercial fisheries. The immediately observed release mortality of goliath grouper from the logbooks varied by sector, with a 30% release mortality for long line fishery and 5% for the vertical hook and line fishery. The release mortality rate from trips where observers were aboard also supported a relatively low release mortality rate for goliath grouper. The workgroup recommended that a 30% release mortality rate be used for the commercial long line fishery, and a 5% release mortality rate be used for the commercial vertical hook and line fishery. These point estimates could be bracketed for sensitivity runs. There were no specific recommendations on the ranges for sensitivity runs for release mortality estimates from the commercial and recreational catch workgroup. The behavior of the computer model to changes in assumptions on release mortality could be important, and a suggested range on release mortalities should be used to examine the sensitivity of the model to different levels of release mortalities. For example, a range of release mortalities for the long line release mortality rate of 25-40% with a mid-point of 30% could be used for sensitivity runs. Likewise, a range for the vertical hook and line release mortality could be from 5% to 15%.

3.5. *COMMERCIAL EFFORT*

There was no separate analysis of commercial fishing effort for goliath grouper presented during the DW.

3.6. *BIOLOGICAL SAMPLING*

There is little information available on sizes and weights of goliath grouper from commercial catches prior to the prohibitions on harvest in 1990. The most information available is from Bullock et al (1992), and some of those specimens, collected for age and growth information, may not be appropriate for use in average weight and size calculations. A few specimens are available from the Trip Interview Program (SEDAR 3 2003), but not enough to generate size frequencies in the catch. Few otoliths or other structures appropriate for ageing purposes have been collected from commercial catches other than those in the Bullock et al (1992) study. With the prohibition on harvest of this species, nearly all size and age information from any source (commercial, recreational, fishery independent) became unavailable after 1989. Typically, data after 1989 on size and age of goliath grouper comes from specimens killed by red tide or cold winter temperatures and from special studies such as those in the Ten Thousand Islands of the Everglades (e.g., Brusher and Schull 2009).

3.6.1. Adequacy for characterizing catch and for assessment analyses

Characterizing size and age frequency in commercial catches for goliath grouper will be challenging and problematic both before and after 1990. The information on landings by gear is minimal for the 1950-1990 period, and is probably only suitable for landings by sector (commercial). There is no discard data for goliath grouper available for the commercial fishery before 1994 (Scott-Denton 1995), and there were no discards of goliath grouper in that limited data set. Some limited size information is available from commercial catches on observed trips (Hale 2010). At present, the modeling approach (Porch et al 2006) does not require these types of data inputs. The landings data may be suitable for Stock Reduction Analysis (see Quinn and Deriso 1999) if some assumptions are made about release mortality and if commercial or recreational catches can be converted to some common unit (either numbers or weight). Without size frequency information for individuals in the catch by fishery and given that goliath groupers can grow to very large size, it will be difficult to develop adequate conversions for commercial catches in pounds to numbers of fish or to convert recreational catches in numbers to pounds. Some of the data collected by Bullock et al. (1992) may be of use to develop conversions, but because of the limited scope of these collections the conversions may not be representative of year-to-year variations.

3.7. *LITERATURE CITED*

Bortone, S.A., R. N. Besser, C. R. McNeil. 1997. The importance of Silas Stearns (1859-1888) and the Pensacola red snapper fishery to North American Ichthyology. Collection Building in Ichthyology and Herpetology. Chap. 25, pp 459-467. American Society of Ichthyologists and Herpetologists.

Colás-Marrufo, T., T. Brulé, and C. Déniel. 1998. Análisis preliminar de las capturas de meros realizadas a través de unidades de la fl ota mayor en el sureste del Golfo de México. Proc. Gulf Caribb. Fish. Inst. 50:780−803.

Brusher, J. H. and J. Schull. 2009. Non-lethal age determination for juvenile goliath grouper *Epinephelus itajara* from southwest Florida. Endang. Species. Res. 7: 205-212.

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.

Brice, J. J. 1897. The fish and fisheries of the coastal waters of Florida. Part 6, Report on the Fish and Fisheries of the Coastal Waters of Florida. pp 263-342. *In*: Report of the

Commissioner for 1896. U.S. Commission on Fish and Fisheries, Bureau of Commercial Fisheries. U.S. Government Printing Office, Washington, D.C.

Coleman, F. C., C. C. Koenig, and W. F. Hernkind. 1992. Survey of Florida inshore shrimp trawling by-catch and preliminary tests of by-catch reduction devices. Annual Report to the Florida Department of Environmental Protection.

Craig, M. T., R. T. Graham, R. A. Torres, J. R. Hyde, M. O. Freitas, B. P. Ferreira, M. Hostim-Silva, L. C. Gerhardinger, A. A. Bertoncini, D. R. Robertson. 2009. How many species of goliath grouper are there? Cryptic genetic divergence in a threatened marine fish and the resurrection of a geopolitical species. Endang. Species Res. 7: 167-174.

DeMaria, D. 1989. Letter to the Gulf of Mexico Fishery Management Council, September 10, 1989. [see Appendix A].

Eschmeyer, W. N. and Fricke, R. (eds.) 2010. Catalog of Fishes electronic version (15 January 2010). http://research.calacademy.org/ichthyology/catalog/fishcatmain.asp

Evermann, B. W. and B. A. Bean. 1897. Indian River and its fishes. Part 5, Report on the Fisheries of the Indian River, Florida. pp 227-248 In: Report of the Commissioner for 1896. U.S. Commission on Fish and Fisheries, Bureau of Commercial Fisheries. U.S. Government Printing Office, Washington, D.C.

Florida State Board of Conservation. 1941. Fourth Biennial Report (for 1939-1940). Tallahassee, Florida.

Florida State Board of Conservation. 1945. Sixth Biennial Report (for 1943-1944). Tallahassee, Florida.

Florida State Board of Conservation. 1947. Seventh Biennial Report (for 1945-1946). Tallahassee, Florida.

Florida State Board of Conservation. 1949. Eighth Biennial Report (for 1947-1948). Tallahassee, Florida.

Florida State Board of Conservation. 1950. Ninth Biennial Report (for 1949). Tallahassee, Florida.

Gilmore, R. G., L. H. Bullock, and F. H. Berry. 1978. Hypothermal mortality in marine fishes of south-central Florida January 1977. Northeast Gulf Science 2 :77-97.

Gulf of Mexico Fishery Management Council. 1990. Amendment 2 to the Fishery Management Plan for Reef Fish, February 1990. Tampa, FL.

Hale, L. F. 2010. Bottom longline fishery bycatch of goliath grouper (Epinephelus itajara) from observer data. NOAA Fisheries/SEFSC. SEDAR23-DW-01.

Hale, L.F. and J.K. Carlson. 2007. Characterization of the shark bottom longline fishery, 2005-2006. NOAA Technical Memorandum NMFS-SEFSC-554, 28 p.

Hale, L. F., S. J.B. Gulak, and J. K. Carlson. 2009. Characterization of the shark bottom longline fishery: 2008. NOAA Technical Memorandum NMFS-SEFSC-586, 26 p.

Hale, L.F., S.J.B. Gulak, and J.K. Carlson. 2010. Characterization of the shark bottom longline fishery, 2009. NOAA Technical Memorandum NMFS-SEFSC-596, 25 p.

Hale, L.F., L.D. Hollensead, and J.K. Carlson. 2007. Characterization of the shark bottom longline fishery, 2007. NOAA Technical Memorandum NMFS-SEFSC-564, 25 p.

Jordan, D. S. 1884. The fishes of the Florida Keys. *In*: Bulletin of the U. S. Fish Commission, Vol. IV, for 1884. U.S. Government Printing Office, Washington, D.C.

Jordan, D. S. 1887. A catalogue of the fishes known to inhabit the waters of North America, north of the Tropic of Cancer, with notes on the species discovered in 1883 and 1884. Appendix XXIV to Part XIII. Report of the Commissioner for 1885. U.S. Commission on Fish and Fisheries, Bureau of Commercial Fisheries. U.S. Government Printing Office, Washington, D.C.

Jordan, D. S. and C. H. Eigenmann. 1890. A review of the genera and species of Serranidae found in the waters of America and Europe. In: Bulletin of the U.S. Fish Commission, Vol. VIII, for 1888. U.S. Government Printing Office, Washington, D.C.

Jordan, D. S. and C. H. Gilbert. 1882. Synopsis of the fishes of North America. Bulletin of the United States National Museum. No. 16. pp 1-1018 + lvi. Government Printing Office. Washington, D.C.

Lichtenstein, M. H. C. 1822. Die Werke von Marcgrave und Piso Über die Naturgeschichte Brasiliens, erläutert aus den wieder aufgefundenen Original-Abbildungen. Abhandlungen der Königlichen Akademie der Wissenschaften zu Berlin 1820-21: 267-288. [Also issued as pp. 31-52 (1822).] as cited in www.fishbase.org.

McCarthy, K. 2010. Calculated goliath grouper discards from commercial vertical line and longline fishing vessels in the Gulf of Mexico and US South Atlantic. SEDAR23-DW-04. National Marine Fisheries Service, Southeast Fisheries Science Center Sustainable Fisheries Division, Contribution SFD-2010-013. Available from: http://www.sefsc.noaa.gov/sedar/

Morgan, A., P. W. Cooper, T. Curtis, and G. H. Burgess. 2009. Overview of the U. S. East Coast bottom longline shark fishery, 1994-2003. Marine Fisheries Review 7: 23-38.

Meyer, D.L., M. S. Fonseca, P. L. Murphey, M. W. LaCroix, P. E. Whitfield, D. R. Colby, and G. W. Thayer. 1991. Impact of bait shrimp trawling on seagrass beds and fish by-catch in Tampa Bay, Florida. National Marine Fisheries Service, Beaufort, NC. Final Report, Department of Natural Resources Contract # C4488.

National Marine Fisheries Service (NMFS). 1995. Characterization of the reef fish fishery of the eastern Gulf of Mexico. Report to the Gulf of Mexico Fishery Management Council Reef Fish Management Committee. Key West, FL July 17-18, 1995. NMFS Southeast Fishery Science Center, Galveston and Miami Laboratories.

National Marine Fisheries Service (NMFS). 2003. Final 1 to the Fishery Management Plan for Atlantic Tunas, Swordfish, and Sharks. Office of Sustainable Fisheries, Highly Migratory Species Management Division, Silver Spring, MD.

Nelson, J. S., E. J. Crossman, H. Espinosa-Pérez, L. T. Findley, C. R. Gilbert, R. N. Lea, J. D. Williams. 2001. Recommended change in the common name for a marine fish: Goliath grouper to replace jewfish (*Epinephelus itajara*). Fisheries 26: 31.

Nelson, J. S., E. J. Crossman, H. Espinosa-Pérez, L. T. Findley, C. R. Gilbert, R. N. Lea, J. D. Williams. 2004. Common and Scientific Names of Fishes from the United States, Canada, and Mexico. Sixth edition. Special Publication 29. American Fisheries Society. Bethesda, MD.

Porch, C.E., A-M. Ecklund, G.P. Scott 2006. A catch-free stock assessment model with application to goliath grouper (*Epinephelus itajara*) off southern Florida. Fisheries Bulletin 104: 89-101.

Quinn, T.J. II and R.B Deriso. 1999. Quantitative Fish Dynamics. Oxford University Press, New York. 542p+xv.

Schroeder, W. C. 1924. Fisheries of Key West and the clam industry of southern Florida. Appendix XII to the Report of the U.S. Commissoner of Fisheries for 1923. Bureau of Fisheries Document No. 962. U.S. Government Printing Office, Washington, D.C.

Scott-Denton, E. 1995. National Marine Fisheries Service, Southeast Fisheries Science Center, Galveston Laboratory. Supplement to the report "Characterization of the reef fish fishery of the eastern U.S. Gulf of Mexico." MARFIN Grant No. 94MARFIN17.

SEDAR 3. 2003. Goliath Grouper Data Workshop Report. SEDAR3-DW-1. South Atlantic Fishery Management Council. Charleston, SC. http://www.sefsc.noaa.gov/sedar/

SEDAR 6. 2004. The goliath grouper in southern Florida: Assessment review and advisory report. Edited by: M.C.S. Kingsley. South Atlantic Fishery Management Council. Charleston, SC. http://www.sefsc.noaa.gov/sedar/

Smith, G. B. 1976. Ecology and distribution of eastern Gulf of Mexico reef fishes. Florida Marine Research Publications no. 19, iii+78pp. Florida Department of Natural Resources Marine Research Laboratory, St. Petersburg, Florida.

Smith, H. M. 1895. Report of the division of statistics and methods of the fisheries. *In*: Part XIX. Report of the Commissioner for the year ending June 30, 1893. U.S. Commission on Fish and Fisheries, Bureau of Commercial Fisheries. U.S. Government Printing Office, Washington, D.C.

South Atlantic Fishery Management Council. 1990. Amendment 2 to the Fishery Management Plan for the Snapper Grouper Fishery of the South Atlantic Region, July 1990. Charleston, SC.

Steele, P. and S. Levitt. 1999a. Effectiveness of bycatch reduction devices in rollerframe trawls used in the Florida shrimp fishery. Report to the Florida Marine Fisheries Commission, May 7, 1999.

Steele, P. and S. Levitt. 1999b. Effectiveness of bycatch reduction devices in otter trawls used in the Florida shrimp fishery. Report to the Florida Marine Fisheries Commission, May 7, 1999.

Stevenson, C. H. 1893. Report on the Coast Fisheries of Texas. *In*: Part XVII. Report of the Commissioner for 1889 to 1891. U.S. Commission on Fish and Fisheries, Bureau of Commercial Fisheries. U.S. Government Printing Office, Washington, D.C.

Sutherland, D. L. and D. E. Harper. 1983. The wire fish-trap fishery of Dade and Broward Counties, Florida December 1979 – September 1980. Florida Marine Research Publications no. 40, iv+21pp. Florida Department of Natural Resources Marine Research Laboratory, St. Petersburg, Florida.

Taylor, R. G. and R. H. McMichael, Jr. 1983. The wire fish-trap fisheries in Monroe and Collier Counties, Florida. Florida Marine Research Publications no. 39, iii+19pp. Florida Department of Natural Resources Marine Research Laboratory, St. Petersburg, Florida.

Thompson, B. G., 1984. Fishery Statistics of the United States 1977. Statistical Digest No. 71. U.S. Dept. of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service. Washington, D.C.

U.S. Bureau of Fisheries. 1887. Report of the Commissioner for 1885. U.S. Commission of Fish and Fisheries. U.S. Government Printing Office, Washington, D.C.

U.S. Bureau of Fisheries. 1892. Report of the Commissioner for 1888. U.S. Commission of Fish and Fisheries. U.S. Government Printing Office, Washington, D.C.

U.S. Bureau of Fisheries. 1893. Report of the Commissioner for 1889-1891. U.S. Commission of Fish and Fisheries. U.S. Government Printing Office, Washington, D.C.

U.S. Bureau of Fisheries. 1898. Report of the Commissioner for the year ending June 30, 1897. U.S. Commission of Fish and Fisheries. U.S. Government Printing Office, Washington, D.C.

U.S. Bureau of Fisheries. 1900. Report of the Commissioner for the year ending June 30, 1899. U.S. Commission of Fish and Fisheries. U.S. Government Printing Office, Washington, D.C.

U.S. Bureau of Fisheries. 1905. Report of the Commissioner for the year ending June 30, 1903. U.S. Commission of Fish and Fisheries. U.S. Government Printing Office, Washington, D.C.

U.S. Bureau of Fisheries. 1921. Report of the Commissioner for the fiscal year 1919. U.S. Commission of Fish and Fisheries. U.S. Government Printing Office, Washington, D.C.

Wilcox, W. A. 1897. The commercial fisheries of Indian River, Florida. Part 5, Report on the Fisheries of the Indian River, Florida. pp 249-262+plates 23-59. In: Report of the Commissioner for 1896. U.S. Commission on Fish and Fisheries, Bureau of Commercial Fisheries. U.S. Government Printing Office, Washington, D.C.

3.8. *TABLES*

Table 3.1. Commercial landings (pounds whole wt.) reported by state and year. Landings for 1890-1936 are from the U.S. Bureau of Commercial Fisheries. Landings from 1939-1949 are from the USFWS' Statistical Digest Series. Landings from 1950-2008 are from the NOAA Fisheries commercial fishery landings web page. In addition, commercial landings reported to the Florida State Board of Conservation (FL SBC) are shown for the 1939-1959 period (landings for 1949-1959 were sent by the FL SBC to the USFWS). Gaps in years and blanks mean that those data were not collected or were unavailable.

Year	Texas	Louisiana	Mississippi	Alabama	Florida West Coast	Florida East Coast	Georgia	South Carolina	North Carolina	TX-NC	Florida statewide (federal)	FL statewide (FL SBC)
1890	9,500											
....												
1902	65,722	0	0	2,000			0	79,500	0	147,222		
....												
1923	13,450	0	5,200	0	109,188	250	2,767	0	0	130,855	109,438	
....												
1928	75,746	2,000	5,700	3,400	49,477	13,500	3,200	0	0	153,023	62,977	
1929	43,859	10,000	1,353	150	74,003	13,500	1,473	0	0	144,338	87,503	
1930	1,430	6,000	1,274	5,021	18,050	8,000	4,629	0	0	44,404	26,050	
1931	275	7,050	690	0	7,314	2,250	0	0	0	17,579	9,564	
1932	5,750	2,400	0	0			0	0	0	38,440		
....												
1936	2,900	21,000	0	0	10,000	28,800	0	0	0	62,700	38,800	
....												183,111
1940	10,000	14,200	0	0	96,100	18,000	0	0	0	138,300	114,100	189,506
1941												
1942												
1943												424,141
1944												218,219
1945	12,500	2,500	0	2,700	206,500	216,300	0	0	0	440,500	422,800	475,859
1946												251,243
1947												202,961

Table 3.1 (continued).

Year	Texas	Louisiana	Mississippi	Alabama	Florida West Coast	Florida East Coast	Georgia	South Carolina	North Carolina	TX-NC	Florida statewide (federal)	FL statewide (FL SBC)
1948	7,600	0	0	5100								221,547
1949	5,300	0	0	3,600	177,900						177,900	196,048
1950	20,800	0	0	7,400	74,200	23,300	0	0	0	125,700	97,500	
1951	73,900	500	500	0	65,200	54,400	0	0	0	194,500	119,600	120,563
1952	31,500	400	200	53,600	44,200	40,000	0	0	0	169,900	84,200	84,419
1953	24,600	3,400	0	123,000	97,500	35,700	0	0	0	284,200	133,200	132,744
1954	22,600	5,700	0	0	55,600	31,500	0	0	0	115,400	87,100	86,356
1955	3,500	0	0	2,000	53,200	24,100	0	0	0	82,800	77,300	77,187
1956	2,200	1,100	0	1,000	36,500	17,300	0	0	0	58,100	53,800	
1957	1,000	0	0	5,600	27,200	24,300	0	0	3,400	61,500	51,500	
1958	30,400	600	0	7,000	51,800	34,400	0	0	8,400	132,600	86,200	76,130
1959	20,200	18,300	0	18,500	65,100	9,000	0	0	600	131,700	74,100	62,076
1960	0	20,000	0	4,400	66,800	11,000	0	0	0	115,500	77,800	
1961	0	9,500	0	24,900	50,600	16,200	0	0	700	101,900	66,800	
1962	300	4,100	0	15,500	48,500	21,400	0	0	0	89,800	69,900	
1963	7,800	8,300	0	41,400	65,500	16,700	0	0	0	139,700	82,200	
1964	2,700	2,200	0	118,400	86,200	31,700	0	0	0	241,200	117,900	
1965	0	1,300	0	134,200	61,400	40,100	0	0	0	237,000	101,500	
1966	0	1,700	0	100,300	41,900	38,700	0	0	0	182,600	80,600	
1967	200	200	0	76,500	67,400	55,800	0	0	0	200,100	123,200	
1968	0	200	0	115,600	99,200	50,800	0	0	0	265,800	150,000	
1969	0	2,900	0	49,900	101,900	46,100	0	0	0	200,800	148,000	
1970	0	6,500	0	73,300	130,400	21,200	0	0	0	231,400	151,600	
1971	0	2,400	0	41,500	148,900	3,300	0	0	0	196,100	152,200	
1972	0	0	0	80,000	150,700	7,600	0	0	0	238,300	158,300	
1973	0	5,500	0	59,400	161,500	15,800	0	0	0	242,200	177,300	

Table 3.1 (continued).

Year	Texas	Louisiana	Mississippi	Alabama	Florida West Coast	Florida East Coast	Georgia	South Carolina	North Carolina	TX-NC	Florida statewide (federal)	FL statewide (FL SBC)
1974	0	300	0	29,200	160,700	46,400	0	0	0	236,600	207,100	
1975	0	0	0	22,900	185,500	40,500	0	0	0	248,900	226,000	
1976	0	0	0	15,900	184,900	53,200	0	0	0	254,000	238,100	
1977	0	0	0	22,500	199,800	50,800	0	0	0	273,100	250,600	
1978	0	32	0	4,551	192,249	17,185	0	0	0	214,017	209,434	
1979	0	0	0	2,690	160,071	18,064	0	0	0	180,825	178,135	
1980	0	0	0	2,887	201,875	19,423	0	0	0	224,185	221,298	
1981	0	0	0	6,062	183,414	12,397	1,154	0	0	203,027	195,811	
1982	0	0	0	12,827	156,836	6,131	0	0	0	175,794	162,967	
1983	0	0	0	13,536	174,541	12,293	0	0	0	200,370	186,834	
1984	0	0	0	7,240	89,377	11,440	0	0	0	108,057	100,817	
1985	0	0	0	0	101,539	9,367	0	0	0	110,906	110,906	
1986	0	0	0	0	108,952	10,492	0	0	0	119,444	119,444	
1987	24	1,146	0	0	99,540	17,911	0	0	0	118,621	117,451	
1988	491	0	0	0	135,715	12,931	0	0	0	149,137	148,646	
1989	0	0	0	0	93,066	8,669	0	0	0	101,735	101,735	
1990	0	2,272	0	0	7,488	1,814	0	0	0	11,574	9,302	
1991	0	798	0	0	0	0	0	0	0	798	0	
1992-2009	0	0	0	0	0	0	0	0	0	0	0	
Total	255,515	99,348	700	1,293,693	4,286,963	1,019,417	1,154	0	13,100	6,969,890	5,306,380	

Table 3.2. Reported and adjusted commercial landings of goliath grouper in Florida, 1918-2009.

	Reported commercial landings (pounds whole wt.)					Adjusted commercial landings (pounds whole wt)			
Year	Monroe County	Lee County	FL West Coast	FL statewide (federal)	FL statewide (FL SBC)	Monroe County	Lee Co landings	FL West Coast	FL statewide
1918	9,000	11,280	69,844	82,331		9,000	11,280	69,844	82,331
……..									
1923			109,188	109,438				109,188	109,438
……..									
1928	14,100	2,400	49,477	63,377		14,100	2,400	49,477	63,377
1929	34,950	0	74,003	87,503		34,950	0	74,003	87,503
1930	8,800	0	18,050	26,050		8,800	0	18,050	26,050
1931	1,200	0	7,314	9,564		1,200	0	7,314	9,564
1932				30,290					30,290
……..									
1936	3,900	4,100	10,000	38,800		3,900	4,100	10,000	38,800
……..									
1940			96,100	114,100	189,506				189,506
……..									
1944					218,219				218,219
1945	5,200	10,300	206,500	422,800	475,859	5,200	10,300		475,859
1946					251,243				251,243
1947					202,961				202,961
1948					221,547				221,547
1949			177,900		196,048			177,900	196,048
1950	0	8,576	74,200	97,500		0	10,120	74,200	97,500
1951	5,690	13,617	65,200	119,600	120,563	5,690	13,617	65,200	119,600
1952	1,106	8,644	44,200	84,200	84,419	1,106	8,644	44,200	84,200
1953	9,033	17,657	97,500	133,200	132,744	9,033	17,657	97,500	133,200
1954	4,415	9,443	55,600	87,100	86,356	4,415	9,443	55,600	87,100
1955	12,395	17,371	53,200	77,300	77,187	12,395	17,371	53,200	77,300
1956	2,593	14,533	36,500	53,800		2,593	14,533	36,500	53,800
1957	4,235	8,264	27,200	51,500		4,235	8,264	27,200	51,500
1958	3,216	12,515	51,800	86,200	76,130	3,795	14,768	51,800	86,200
1959	31,317	4,987	65,100	74,100	62,076	36,954	5,885	65,100	74,100
1960	36,141	3,202	66,800	77,800		42,646	3,778	66,800	77,800
1961	36,042	3,016	50,600	66,800		36,042	3,016	50,600	66,800
1962	27,701	6,712	48,500	69,900		27,701	6,712	48,500	69,900
1963	40,800	5,500	65,500	82,200		40,800	5,500	65,500	82,200
1964	59,202	7,261	86,200	117,900		59,202	7,261	86,200	117,900
1965	27,250	15,028	61,400	101,500		27,250	3,807	50,179	90,279
1966	15,203	15,882	41,900	80,600		15,203	4,023	30,041	68,741
1967	21,295	27,951	67,400	123,200		21,295	7,081	46,530	102,330

1968	24,376	60,592	99,200	150,000		24,376	6,478	45,086	95,886
1969	11,343	81,221	101,900	148,000		11,343	8,684	29,363	75,463
1970	13,994	103,694	130,400	151,600		13,994	8,983	35,689	56,889
1971	19,055	119,015	148,900	152,200		19,055	10,310	40,195	43,495
1972	18,974	124,346	150,700	158,300		18,974	10,772	37,126	44,726
1973	22,307	127,139	161,500	177,300		22,307	11,014	45,375	61,175
1974	23,785	119,335	160,700	207,100		23,785	10,338	51,703	98,103
1975	18,280	139,932	185,500	226,000		18,280	12,122	57,690	98,190
1976	8,982	160,936	184,900	238,100		8,982	13,942	37,906	91,106
1977	32,065	136,108	199,800	250,600		32,065	11,791	75,483	126,283
1978	32,646	143,099	192,249	209,434		32,646	13,001	62,151	79,336
1979	16,919	133,260	160,071	178,135		16,919	11,583	38,394	56,458
1980	13,359	168,401	201,875	221,298		13,359	13,829	47,303	66,726
1981	22,712	138,984	183,414	195,811		22,712	12,039	56,469	68,866
1982	18,651	123,246	156,836	162,967		18,651	16,981	50,571	56,702
1983	19,440	136,380	174,541	186,834		19,440	28,408	66,569	78,862
1984	12,306	48,630	89,377	100,817		12,306	26,680	67,427	78,867
1985	19,180	52,946	101,539	110,906		19,180	52,946	101,539	110,906
1986	22,894	61,165	108,952	119,444		22,894	61,165	108,952	119,444
1987	26,246	46,841	99,540	117,451		26,246	46,841	99,540	117,451
1988	24,329	86,337	135,715	148,646		24,329	86,337	135,715	148,646
1989	24,748	41,786	93,066	101,735		24,748	41,786	93,066	101,735
1990	1,312	972	7,488	9,302		1,312	972	7,488	9,302
1991-2009	0	0	0	0		0	0	0	0

Sources: unless noted, commercial landings from 1950-2008 are from the NOAA web page, 1939-1949 from the USFWS Statistical Digests, and 1897-1938 from the U.S. Bureau of Fisheries. Reported county landings for Lee and Monroe for 1978-1985 were from the Accumulated Landings System (Josh Bennett, NOAA Fisheries Southeast Fisheries Science Center, personal communication)

Adjustment to Lee County and Monroe County totals for gutted weight to whole weight conversion factor.

Landings suspected to be inflated by over-reporting by a dealer (GMFMC 1990, SAFMC 1990).

Annual totals (after adjustment) for over-reporting by a dealer.

Partial year (January-May only) adjustment needed.

Source: Florida trip ticket data, 1986-2009.

Source: State of Florida Board of Conservation (FL SBC).

Table 3.3. Adjusted commercial landings (pounds whole wt.) of goliath grouper reported by state and year. Gaps in years and blanks mean that those data were not collected or were unavailable.

Year	Texas	Louisiana	Mississippi	Alabama	Florida West Coast	Florida East Coast	Georgia	South Carolina	North Carolina	TX-NC	FL statewide
1890	9,500										
....											
1897	33,281										
....											
1918	39,965	0	8,800	2,000	69,844	12,487	0	0	0	133,096	82,331
....											
1927	11,175	0	7,500	200	295,159	15,100	2,388	0	0	331,522	310,259
1928	75,746	2,000	5,700	3,400	49,477	13,500	3,200	0	0	153,423	63,377
1929	43,859	10,000	1,353	150	74,003	13,500	1,473	0	0	144,338	87,503
1930	1,430	6,000	1,274	5,021	18,050	8,000	4,629	0	0	44,404	26,050
1931	275	7,050	690	0	7,314	2,250	0	0	0	17,579	9,564
1932	5,750	2,400	0	0			0	0	0	38,440	30,290
....											
1936	2,900	21,000	0	0	10,000	28,800	0	0	0	62,700	38,800
....											
1940	10,000	14,200	0	0		18,000	0	0	0	213,706	189,506
1941											
1942											
1943											424,141
1944											218,219
1945	12,500	2,500	0	2,700		216,300	0	0	0	493,559	475,859
1946											251,243
1947											202,961
1948	7,600	0	0	5100							221,547

Table 3.3. (continued) Adjusted commercial landings (pounds whole wt.) of goliath grouper reported by state and year. Gaps in years and blanks mean that those data were not collected or were unavailable.

Year	Texas	Louisiana	Mississippi	Alabama	Florida West Coast	Florida East Coast	Georgia	South Carolina	North Carolina	TX-NC	FL statewide
1949	5,300	0	0	3,600	177,900						196,048
1950	20,800	0	0	7,400	74,200	23,300	0	0	0	125,700	97,500
1951	73,900	500	500	0	65,200	54,400	0	0	0	194,500	119,600
1952	31,500	400	200	53,600	44,200	40,000	0	0	0	169,900	84,200
1953	24,600	3,400	0	123,000	97,500	35,700	0	0	0	284,200	133,200
1954	22,600	5,700	0	0	55,600	31,500	0	0	0	115,400	87,100
1955	3,500	0	0	2,000	53,200	24,100	0	0	0	82,800	77,300
1956	2,200	1,100	0	1,000	36,500	17,300	0	0	0	58,100	53,800
1957	1,000	0	0	5,600	27,200	24,300	0	0	3,400	61,500	51,500
1958	30,400	600	0	7,000	51,800	34,400	0	0	8,400	132,600	86,200
1959	20,200	18,300	0	18,500	65,100	9,000	0	0	600	131,700	74,100
1960	0	20,000	0	4,400	66,800	11,000	0	0	0	102,200	77,800
1961	0	9,500	0	24,900	50,600	16,200	0	0	700	101,900	66,800
1962	300	4,100	0	15,500	48,500	21,400	0	0	0	89,800	69,900
1963	7,800	8,300	0	41,400	65,500	16,700	0	0	0	139,700	82,200
1964	2,700	2,200	0	118,400	86,200	31,700	0	0	0	241,200	117,900
1965	0	1,300	0	134,200	50,179	40,100	0	0	0	225,779	90,279
1966	0	1,700	0	100,300	30,041	38,700	0	0	0	170,741	68,741
1967	200	200	0	76,500	46,530	55,800	0	0	0	179,230	102,330
1968	0	200	0	115,600	45,086	50,800	0	0	0	211,686	95,886
1969	0	2,900	0	49,900	29,363	46,100	0	0	0	128,263	75,463
1970	0	6,500	0	73,300	35,689	21,200	0	0	0	136,689	56,889
1971	0	2,400	0	41,500	40,195	3,300	0	0	0	87,395	43,495
1972	0	0	0	80,000	37,126	7,600	0	0	0	124,726	44,726

Table 3.3. (continued) Adjusted commercial landings (pounds whole wt.) of goliath grouper reported by state and year. Gaps in years and blanks mean that those data were not collected or were unavailable.

Year	Texas	Louisiana	Mississippi	Alabama	Florida West Coast	Florida East Coast	Georgia	South Carolina	North Carolina	TX-NC	FL statewide
1973	0	5,500	0	59,400	45,375	15,800	0	0	0	126,075	61,175
1974	0	300	0	29,200	51,703	46,400	0	0	0	127,603	98,103
1975	0	0	0	22,900	57,690	40,500	0	0	0	121,090	98,190
1976	0	0	0	15,900	37,906	53,200	0	0	0	107,006	91,106
1977	0	0	0	22,500	75,483	50,800	0	0	0	148,783	126,283
1978	0	32	0	4,551	62,151	17,185	0	0	0	83,919	79,336
1979	0	0	0	2,690	38,394	18,064	0	0	0	59,148	56,458
1980	0	0	0	2,887	47,303	19,423	0	0	0	69,613	66,726
1981	0	0	0	6,062	56,469	12,397	1,154	0	0	76,082	68,866
1982	0	0	0	12,827	50,571	6,131	0	0	0	69,529	56,702
1983	0	0	0	13,536	66,569	12,293	0	0	0	92,398	78,862
1984	0	0	0	7,240	67,427	11,440	0	0	0	86,107	78,867
1985	0	0	0	0	101,539	9,367	0	0	0	110,906	110,906
1986	0	0	0	0	108,952	10,492	0	0	0	119,444	119,444
1987	24	1,146	0	0	99,540	17,911	0	0	0	118,621	117,451
1988	491	0	0	0	135,715	12,931	0	0	0	149,137	148,646
1989	0	0	0	0	93,066	8,669	0	0	0	101,735	101,735
1990	0	2,272	0	0	7,488	1,814	0	0	0	11,574	9,302
1991	0	798	0	0	0	0	0	0	0	798	0
1992-2009	0	0	0	0	0	0	0	0	0	0	0

Source: State of Florida Board of Conservation.

Annual totals (after adjustment) for over-reporting by a dealer

Partial year (January-May only) adjustment needed.

3.9. *FIGURES*

Figure 3.1 Map of the Southeastern United States, Bahamas, Cuba, the Yucatan Peninsula, Mexico.

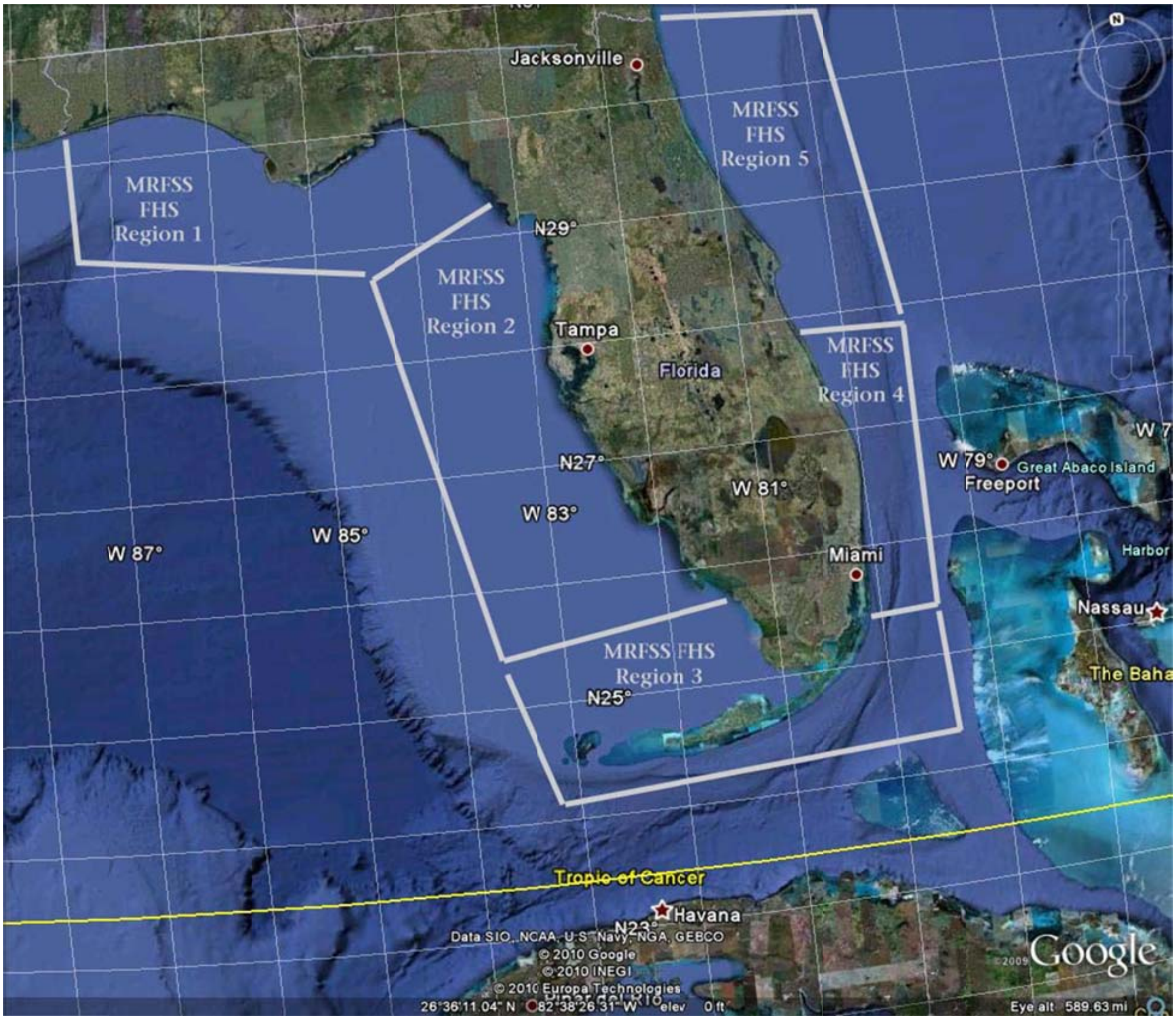


Figure 3.2. A map of Florida indicating the MRFSS For-Hire Survey (FHS) regions. Region 1 includes for-hire vessels based from Escambia County to Dixie County, Region 2 ranges from Levy County to Collier County, Region 3 includes vessels from all of Monroe County including the Florida Keys, Region 4 stretches from Miami-Dade County to Indian River County, and Region 5 extends from Brevard County to Nassau County. Shore (SH) and private/rental boats angler interviews were included in these regions based upon the county where the intercept occurred. Commercial (and recreational) landings for Florida have typically included FHS Regions 1-3 (Escambia County to Monroe County) in the Florida Gulf of Mexico region, and FHS Regions 4-5 (Nassau County to Miami-Dade County) comprise the Florida Atlantic Coast region.

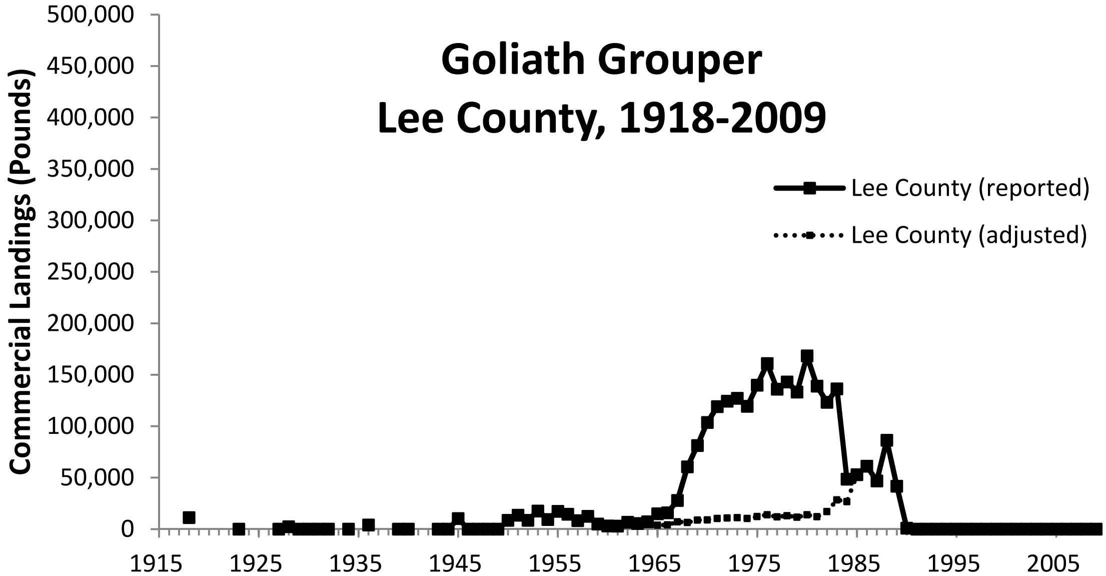


Figure 3.3. Reported and adjusted commercial landings of goliath grouper for Lee County, 1918-2009.

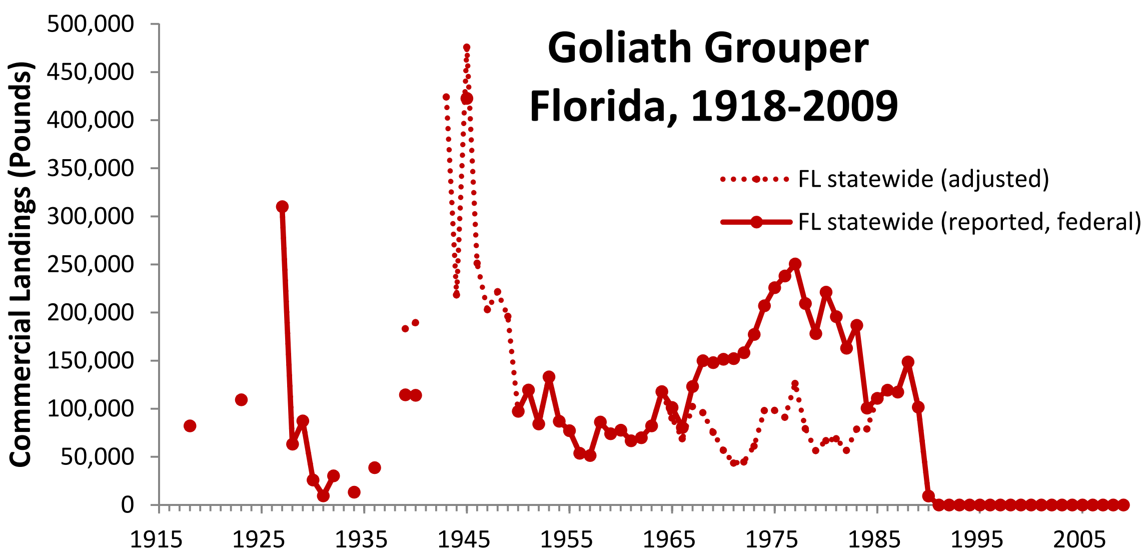


Figure 3.4. Reported and adjusted commercial landings of goliath grouper for Florida, 1918-2009. The adjustments were made to the reported landings from 1939-1949 and 1965-1984.

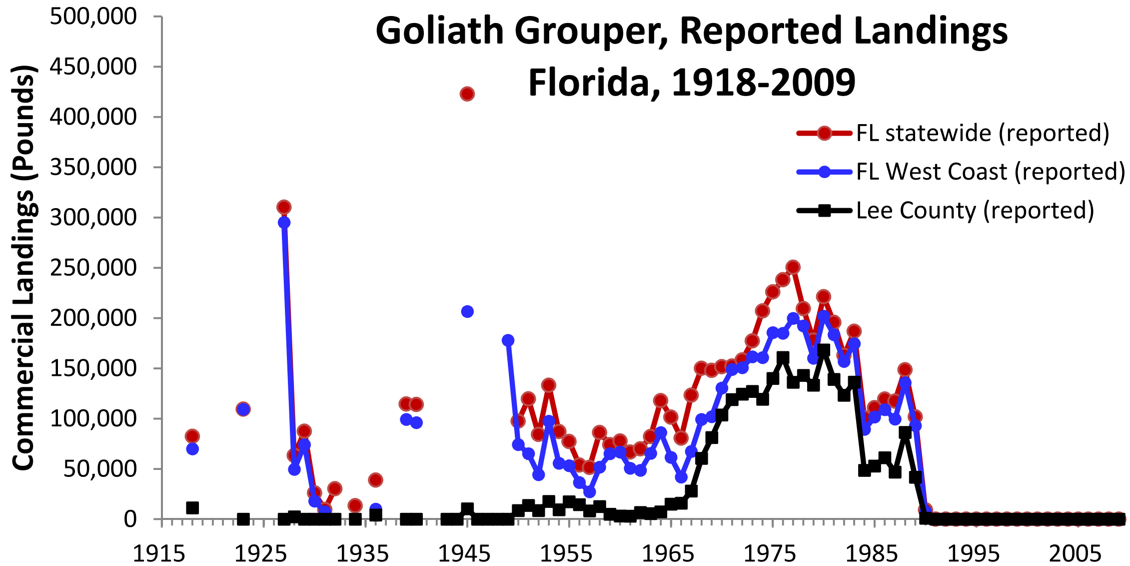


Figure 3.5. Reported commercial landings of goliath grouper for Florida, Florida west coast, and Lee County from 1918 to 2009.

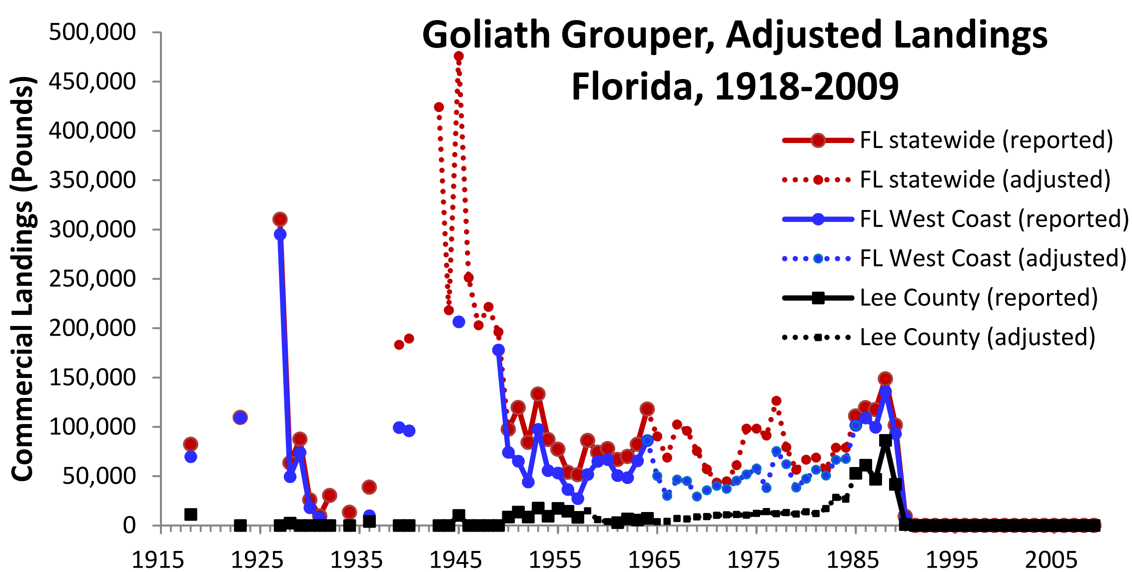


Figure 3.6 Reported and adjusted commercial landings of goliath grouper for Florida, Florida west coast, and Lee County from 1918 to 2009. The adjustments were mainly to the reported landings from 1939-1949 and 1965-1984.

APPENDIX A. Letter from Mr. Don DeMaria to the Gulf of Mexico Fishery Management Council, September 10, 1989, regarding goliath grouper.

Don DeMaria
P.O. Box 884
Key West, Fla. 33041
Sept. 10, 1989
305-745-3045

Chairman of the Gulf of Mexico Fishery Management Council
5401 West Kennedy Boulevard
Suite 881
Tampa, Fla. 33609

Dear Sir:

I talked With Doug Gregory recently about the situation we have with jewfish in the Gulf of Mexico. He informed me of the procedure the Gulf Council must go thru to enact certain rules and regulations. I honestly feel these procedures will take to long and the situation warrants emergency action with immediate protection for the jewfish.

I have written several letters in the past to the Council, but have refrainedfrom describing the gory details of the abuse of this fishery. Maybe it is time.

Before I get into this I should tell you something about myself and my involvement in this fishery. As you are probably aware of I am on your reef fish advisory panel. I am a commercial fisherman and a member of O.F.F. My main source of income for the past 11 years has been spearfishing (mostly jewfish). I have seen this fishery go from having spawning aggregations of jewfish in excess of 100 on a single wreck to having zero.

When I got my first boat built in the Keys I bought a Loran-C. The old conch fishermen laughed at me. They claimed they did not need a 2,000 dollar piece of equipment to catch fish (Loran-C was fairly expensive when it first came out). No one else at the fish house had a Loran. Now it is rare to find a boat without one.

I spent alot of time talking with shrimpers about hangs in the Gulf. Many shrimpers gave me Loran numbers where they lost gear. We found alot of these hangs and retrieved some of their gear (doors,nets, etc.). I also got numbers from bandit boats for wrecks as far north as Tampa. They were more than happy to give me numbers. They claimed there were so many jewfish on these wrecks they could not fish for the high priced grouper and snapper. At that time jewfish was a very low priced fish in the Tampa/Ft. Myers area where most of these boats docked and unloaded at. The fish were not even worth wasting ice on.

The jewfish has always been something of a local delicacy in Key West. I figured I could catch these jewfish in the Gulf that no one seemed to want and bring them back to Key West where there was a demand for them.

The first trip I made to the North was incredible. The least amount of jewfish any one wreck had was about 50. I could have stopped at the first wreck and loaded the boat and came home. I did not do that. I only took 5 or 6 from each wreck and moved on. I did it this way for a number of years and the fish seemed to return every year with no noticable decrease in their numbers, but I was the only one doing this back then.

3

In all Fairness I should mention the netters. I did not witness this one personally, but a good friend of mine Peter Gladding did. A sink net was set in one of the cuts on the north side of Marquesas. When this net was hauled in it had 400 pounds of small jewfish (20 inches) in it. They were all sold on Stock Island to a fish house.

Last, but not least, are the hook and liners. I have lost count of how many gut-hooked jewfish I have seen in an emaciated state on these wrecks. I speared one that was hiding under a barge. When I pulled him out I noticed a piece of stainless cable hanging out of its mouth. The cable was about 400 to 500 pound test and attached to a mustad shark hook. The other end, with the swivel, had a piece of monofilament tied to it that looked to be about 30 lb. test. The shark hook was lodged deep in this fishes stomach. This fish was so emaciated that we could not sell it. What could this angler possibly be thinking when he tied a rig like this to 30 lb. test line. What do these anglers think happens to these fish when they swallow these large hooks and break the line off. Obviously they either do not think or simply do not care. Certainly the man that stood on the back deck of one of these large Marco Island dive boats did neither when he tried fishing between dives with a heavy handline with two large hooks attached trying to pull two jewfish up at one time from the spawning aggregation they were anchored over. The jewfish kept breaking his line. What do you presume happened to the jewfish that broke off trailing a baited hook from its mouth? Maybe another jewfish grabbed it and both died or the one swan into the wreck, snagged the trailing hook and died there.

For years I thought the jewfish went into deeper water and there was a population of them out there that we would not be able to touch with conventional scuba gear. This is not so I have been doing some extended deep dives (200 feet and over) on mixed gas (tri-mix, helium-oxygen-nitrogen) this past summer, and guess what? There are no jewfish in the deep water. Their limit seems to be about 150 feet.

If an immediate clousure is enacted will it affect any commercial fishermen who target jewfish? To my knowledge there are only two of us that target jewfish and have the capabilities (large boat, ice, holding capacity, etc.) to properly care for these fish. One is Todd Reynolds, who I talked with for the first time on the phone the other day and seems to be a really nice guy, the other is myself. I have seen this fish beat down so low that I no longer feel comfortable with myself pursuing this fish. Enough is enough!

The shrimpers catch a few in their nets as a bycatch off Key West in the winter. Now that the rule making T.E.D.s mandatory has gone into effect they will no longer catch any.

Longliners caught a few inshore, but they have been pushed so far offshore that I seriously doubt they will catch any in the deep water.

The other sector that hunts these fish is the outboard fleet and the large "sport" dive boats. These boats do not have the means to properly take care of their catch, as I have explained earlier in this letter. If they sell their fish, and they do, it is in violation of a Florida law to sell improperly iced seafood.

-4

I have talked with several of these persons that target jewfish from small fast boats. They boast that "if Florida prohibits the harvest in state waters and the sale in the state we will still take them. We know plenty of individuals that will buy them. We will not take any under 50 inches and tell the Marine Patrol they all came out of Federal waters beyond the stressed area and these fish are for our consumption." How are you going to deal with these people?

The large "sport" dive boats that operate between the South West Florida coast and Tortugas make trips on a regular basis and dive some of the wrecks in between. Todd claims he dived a wreck recently that one of these boats just hit and found only one jewfish and this fish was lying on the bottom dying. It was shot in the side and its air bladder was broke. They do not float when speared like this. I observed a jewfish in a condition similiar to this on this same wreck several years ago.

So, who are we keeping this fishery open to and why?

I am not alone in my feelings on this matter. Lew Bullock (a biologist from D.N.R.) feels they are being overfished. He has been sampling my catches for the last 3 years. It was thought that jewfish, like groupers, changed sex after they reached a certain size. Starting life as a female and changing to male. His data shows no such trend. Many of the larger fish I have taken are female.

As you are well aware of the Florida Marine Fishery Commission has proposed a total ban on the harvest of jewfish in state waters and a prohibition on their sale in the state of Florida.

We have some very knowledgeable people claiming there is a problem with this fishery that demands immediate action.

Can this be a cycle we are seeing this year in their spawning activity? I do not think so. We are not dealing with a migratory fish such as the mackerals and crawfish. These fish we only hit as they move thru. Jew fish are large, relatively long lived (the average age of the fish I catch is 12 years) sedimentary reef dwellers that congregate in large numbers to spawn over these artificial reefs and wrecks in the Gulf. Most of the harvest occurs during these spawning aggregations and almost all of these fish are over 50 inches.

This letter turned out to be a bit long winded. I am distributing it to several different agencies. I have absolutely nothing to gain and much to lose from the stand I am taking on this issue. It will certainly mean a decrease in my income if a ban is imposed and I am sure I will make some enemies. Someone has to speak out. I have had alot of experience with this fishery. I do know what I am talking about on this topic.

Sincerely

Don DeMaria

Don DeMaria

c.c. Organized Fishermen of Florida
Florida Marine Fishery Commission
William Turner
Florida Marine Patrol Marathon Office

4. RECREATIONAL STATISITCS

4.1. *OVERVIEW*

4.1.1. Group Membership

Chair: Benjamin C. Hartig (SAFMC representative), Richard Taylor (St. Petersburg Dive Club), Bob Zales (GMFMC AP), Gregg DeBrango(SAFMC AP), Joseph Munyandorero (FWC; leader and editor), Joe O'Hop (FWC, draft preparation). Additional consultations on certain matters (released fish condition, depth of catches, general released fish condition, and recaptures of tagged fish) occurred with Kevin McCarthy (NOAA SEFSC), Jennifer Schull (NOAA SEFSC), Don DeMaria (SAFMC AP), and Angela Collins (FWC).

4.1.2. Issues

The commercial and recreational landings workgroup discussed issues such as accuracy (survey coverage), inclusion of "recreational catch" that was sold commercially, potential for misidentification in the landings records, recreational releases (discards), release (or discard) mortality, and research needs.

4.2. *REVIEW OF WORKING PAPERS*

There were no working papers submitted to review.

4.3. *RECREATIONAL LANDINGS*

4.3.1. Historical perspective on U.S. recreational landings information.

Historical recreational landings data for goliath grouper begin relatively recently with the NOAA Fisheries Southeast Fishery Science Center's Southeast Head Boat Survey (HBS) in 1976 when that survey expanded to Florida's Atlantic Coast and to the Florida Keys in 1979, and it expanded again to sample head boats operating in the Gulf of Mexico from the Florida west coast to Texas in 1986 (Fig. 4.1). The HBS began making landings estimates for Florida's Atlantic Coast in 1981 and for the Gulf of Mexico in 1986 (Tables 4.1, 4.2). The HBS can make estimates of released fish by head boat anglers beginning with 2004. The NOAA Fisheries Marine Recreational Fishery Statistics Survey (MRFSS) began collecting data on recreational fishing (including harvested and released fish) in 1979, and catch and landings statistics are available for the shore, private/rental vessels, and for-hire vessels (charters, guides, and head boats for some early years) from 1981 (Tables 4.3, 4.4); http://www.st.nmfs.noaa.gov/st1/recreational/index.html). Some improvements to the MRFSS methodology have been made over time. The methods for estimating catches and effort in the charter boat mode use region definitions in Florida (Fig. 4.2) useful for sampling and estimation purposes. Goliath groupers are not commonly observed in either the HBS or the MRFSS. The Everglades National Park (ENP)Angler Creel Survey has conducted surveys of anglers fishing in the Ten Thousand Islands and Florida Bay habitats since 1974 (e.g., Cass-Calay 2010). The Texas Parks and Wildlife Department has had a creel survey collecting data on landed fish by private boat anglers since 1974 and by party boat anglers since 1983. Goliath grouper are uncommon in the reports for Texas anglers during 1983-1990 when they would still be legal to harvest (see Green et al. 2002), and since no information is collected on released fish there are no creel survey data from Texas after the prohibition on retention and harvest of goliath grouper after 1990 except from the HBS. Additional comments on aspects of the recreational fishery up to 1989 can be found in the federal amendments to the Fishery Management Plan for Reef Fish (GMFMC 1990) and the Fishery Management Plan for the Snapper Grouper Fishery of the South Atlantic Region (SAFMC 1990).

The recent trend for stock assessment models is to take landings back to the time when there is little exploitation. The MRFSS provides recreational landings starting in 1981, well after the exploitation of the snapper-grouper complex by recreational anglers began. Historical recreational fishing data in the Southeast U.S. is very limited prior to MRFSS. Recreational landings were recognized as a major source of removals from stocks and the National Survey of Fishing and Hunting was expanded to estimate landings of saltwater species starting in 1960. The Salt-water Angling Surveys of 1960 (Clark 1962), 1965 (Deuel and Clark 1968), and 1970 (Deuel 1973) provide estimates of recreational grouper landings but not specifically for goliath grouper because few anglers listed this species on the survey forms that they returned. For goliath grouper (and other species uncommon in catches), it would be very difficult to estimate recreational landings from the Salt-water Angling Surveys and for this reason was not attempted.

McClenachan (2009) examined historical photographs of Key West head boat catches from 1956-1960 and 1965-1985 for changes in the size of trophy fish and frequency of goliath groupers in the catches. She also examined newspaper accounts of goliath grouper catches from 1923 to 1977 from the Florida Keys. There was a seven-fold decrease in the number of goliath groupers per trip photographed from head boat catches of the 1956-1960 compared to the 1965-1979 time series, and fewer goliath groupers were noted from shore in newspaper accounts perhaps beginning before 1950. McClenachan (2009) did not find a significant change in the size frequency distribution of goliath grouper in head boat catches of the 1956-1960 compared to the 1965-1979 time series, which may be at least partly due to fewer available photographs showing goliath groupers in the catches. However, there was a decline in the size of fish caught from shore in the newspaper accounts between 1923 and 1977 which may indicate a depletion of larger goliath grouper living in nearshore habitats.

4.3.2. Preliminary landings and discussion of methods

The commercial and recreational landings workgroup discussed issues of unreported purchases of goliath grouper from sport fishermen by seafood dealers and unreported direct sales to restaurants by sport fishermen. Landings made by recreational anglers which are subsequently sold are, by definition, commercial landings. The issues of “backdoor sales” and non-reporting have existed since the beginning of the commercial landings surveys by the U.S. Bureau of Fisheries and continues to the present day. In the Tenth Biennial Reports of the Florida State Board of Conservation for 1951-1952, special mention was made regarding the lack of knowledge of the level of harvest by sport fishermen, of the ability of some sport fishermen to turn a profit from their “recreational” harvests by selling to dealers and restaurants, and of the potential for these activities to compete with commercial fishing resulting in increasing tensions between sport and commercial fishermen. DeMaria (1989; Appendix A of the commercial section) and comments made during SEDAR 3 mentioned the same concern over unreported sales of goliath grouper in the Florida Keys. There was no consensus by the DW commercial and recreational landings workgroup over potential adjustments that could be made to the commercial or recreational landings for these unreported sales in a county or for Florida. The recommendation of this workgroup was to leave the reported landings unadjusted for any assumed level of unreported sales.

The amount of total recreational catch of goliath grouper reported in the MRFSS is relatively low and imprecise (Table 4.6) especially during the 1981-1998 time period, and the amount of goliath grouper that might have been sold from an MRFSS-intercepted trip is also likely to be low. It is possible that the MRFSS goliath grouper recreational landings estimates for 1981-1989 contain some fish that were sold, but it is likely that such sales represent only a small and probably negligible portion of the MRFSS estimates. Beginning in February of 1990, retention of goliath grouper was prohibited in Florida state waters and later in all federal waters of the southeast U.S. The amount of harvest of goliath groupers in 1990 and later reported in both the HBS and the MRFSS is low and most if not all of the catch of goliath grouper was reported in the MRFSS as released and usually reported as released alive. There are reports of goliath grouper caught by head boat anglers during the 2004-2009 time period when the HBS included discard reporting on the trip reports, and all were reported by the captains to have been "released alive."

4.3.3. Recommendations on recreational landings

At the time of the DW, recreational landings had not been compiled, nor had they been compiled for SEDAR 3 or SEDAR 6, and in fact were unnecessary for the catch-free assessment model used for SEDAR 6. A documentation of the existing landings information and recommendations on aspects of the landings series are appropriate, however, even if these data are unnecessary for the catch-free (Porch et al. 2006) assessment model. The recreational landings data (compiled after the DW) in Tables 4.1, 4.3, and 4.5 are proposed as the recommended preliminary recreational landings series for goliath grouper. The HBS estimates (from trip reports by captains of head boats) were reviewed for coding problems during 1990 to 2009 and were revised (Ken Brennan, NOAA Fisheries, Beaufort Laboratory, personal communication). There are estimation issues with the harvest weights from both the HBS (Table 4.2) and the MRFSS (Table 4.4) because relatively few goliath grouper were measured and weighed. Additional discussion on estimating an "average individual weight" for this species is warranted before generating a harvest estimate in terms of weight. There are some length measurements of angler-caught goliath grouper available from the ENP Angler Creel Survey in some years prior to regulation (Table 4.7) which may be useful for generating a size-frequency distribution for goliath groupers in the catch from inshore areas (e.g., Fig. 4.3).

4.4. *RECREATIONAL DISCARDS AND RELEASE MORTALITY*

4.4.1. Discards

The commercial and recreational catch workgroup discussed releases of goliath grouper by recreational anglers. All of the available information from the MRFSS and HBS suggest that most anglers were abiding by the prohibition and were releasing goliath groupers. The levels of total catch from the MRFSS (Table 4.5) show an increasing trend in the numbers of goliath groupers caught by recreational anglers especially from 2000 to 2007. While the numbers of goliath groupers caught (and released) has declined somewhat in 2008 and 2009, the numbers of goliaths caught by recreational anglers is above the number of goliaths caught during 1981 to 1999.

4.4.2. Recommendations on recreational discards and release mortality

The commercial and recreational catch statistics workgroup were presented with information from the MRFSS total catch estimates, and the Brusher and Schull (2009) goliath grouper study in the Ten Thousand Islands (Everglades National Park) involving capture-recapture of immature fish (140 to ~1000 mm), releases of goliath grouper observed from commercial bottom longline trips, and releases of goliath grouper from commercial vertical line and bottom longline vessel logbooks.

The number of goliath grouper caught by recreational anglers has grown tremendously in Florida during the 2000-2009 compared to previous years (Table 4.5). Nearly all of these released fish were reported to have been released alive from 1990 to 2009. The MRFSS data on the disposition of released fish indicate that the immediate release mortality of goliath grouper appears to be low. In addition, most of the goliath grouper caught in Florida came from inshore (rivers, enclosed bays) and nearshore (state waters) habitats (Table 4.8, 4.9) which are generally shallower compared to offshore (federal waters) habitats.

Brusher and Schull (2009) used trot lines, blue crab traps, and fish traps to sample and tag 1,683 juvenile goliath grouper in the Ten Thousand Islands area of the Florida Everglades. Of the individual fish sampled 1,144 were sampled for hard parts (fin rays, spines, scales) and of these they recaptured 667 fish with 275 recaptured two or more times. So it appears that for juvenile goliath grouper, release mortality may be relatively low at least at shallow depths.

On the basis of the MRFSS total recreational catch data, the distribution of catches (i.e., inshore, nearshore, and offshore), and the findings of Brusher and Schull (2009), the workgroup concluded that the immediate release mortality of goliath grouper was probably low and probably less, because of the depth at which fish were caught, than the mortality observed or reported by commercial bottom longline and vertical line vessels. The workgroup recommended that a 5% release mortality rate be used for the recreational vertical hook and line fishery.

This point estimate for the immediate release mortality of recreationally caught goliath grouper could be bracketed for sensitivity runs. There were no specific recommendations on the ranges for sensitivity runs for release mortality estimates from the commercial and recreational landings workgroup. The behavior of the computer model to changes in assumptions on release mortality could be important, and a suggested range on release mortalities should be used to examine the sensitivity of the model to different levels of release mortalities. For example, a range for the recreational hook and line release mortality could be from 5% to 15%.

4.5. *RECREATIONAL EFFORT*

There was no separate analysis of recreational fishing effort for goliath grouper presented during the DW.

4.6. *BIOLOGICAL SAMPLING*

There is little information available on sizes and weights of goliath grouper from recreational catches prior to the prohibitions on harvest in 1990. The most information available is from Bullock et al (1992), and some of those specimens, collected for age and growth information, may not be appropriate for use in average weight and size calculations. Very few specimens were measured by the MRFSS and HBS, and not enough to generate size frequencies especially on an annual basis. Few otoliths or other structures appropriate for ageing purposes have been collected from recreational catches other than those in the Bullock et al (1992) study. With the prohibition on harvest of this species, nearly all size and age information from any source (commercial, recreational, fishery independent) became unavailable after 1989. Typically, data after 1989 on size and age of goliath grouper comes from specimens killed by red tide or cold winter temperatures and from special studies such as those in the Ten Thousand Islands of the Everglades National Park (e.g., Brusher and Schull 2009).

4.7. *ADEQUACY FOR CHARACTERIZING CATCH FOR ASSESSMENT ANALYSES*

Characterizing size and age in recreational catches of goliath grouper will be challenging and problematic both before and after 1990. The information on landings by sector is non-existent prior to 1981 or 1986 period. There is no discard data for goliath grouper available for the recreational fishery before 1981 (MRFSS) or 2004 (HBS). Some limited size information is available from recreational catches in the MRFSS and HBS, and additional size information in angler catches is available from the ENP Angler Creel Survey. At present, the modeling approach (Clay et al 2004) does not require these types of data inputs. The harvest (landings plus any release mortality) data could possibly be suitable for Stock Reduction or Surplus Production Analysis (see Quinn and DeRiso 1999) if some assumptions are made about release mortality to estimate harvests (due to release mortality) after the prohibition on take of goliath grouper and to convert commercial or recreational catches to either numbers or weight.

4.8. *ACKNOWLEDGEMENTS*

Data on the occurrence of goliath grouper in recreational fisheries came from a variety of sources including the Everglades National Park Angler Creel Survey (Jason Osborne), the NMFS Southeast Head Boat Survey (Ken Brennan), and the NMFS Marine Recreational Fishery Statistics Survey. The many field biologists involved in those surveys deserve to be recognized for this valuable service to our fisheries, as do the anglers who voluntarily participate in these surveys and patiently answer the questionnaires and allow their fish to be measured and weighed after the end of their fishing trips. John Brusher and Jennifer Schull allowed generous access to their data on the goliath grouper that they collected in the Ten Thousand Islands (Everglades National Park) which has allowed the construction of a new growth curve, extended the amount of length-weight data available for conversion equations, and to apply to length frequency data from the ENP Angler Creel Survey. Their data on recaptures of young goliath grouper influenced recommendations on levels of release mortality in recreational fisheries used in this assessment. Members of the Fish Biology, Fishery Dependent Monitoring, Fishery Independent Monitoring, and Fish Health groups at FWRI collected and processed many of the red tide and cold kill specimens. Dr. Chris Koenig supplied a spreadsheet listing dates and measurements of goliath groupers compiled by Dr. McClenachan from Key West newspapers. Kellee Thomas with the FWC's Fish and Wildlife Research Institute's library helped locate many hard to find references and provided other document services for the DW report.

4.9. *LITERATURE CITED*

Brusher, J. H. and J. Schull. 2009. Non-lethal age determination for juvenile goliath grouper *Epinephelus itajara* from southwest Florida. Endang. Species. Res. 7: 205-212.

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. 2010. Monitoring changes in the catch rates and abundance of juvenile goliath grouper using the ENP Creel Survey, 1973-2009. SEDAR-DW-02.

Clark, J. R. 1962. The 1960 Salt-Water Angling Survey. United States Fish and Wildlife Survey, Bureau of Sport Fisheries and Wildlife Circular 153. Department of the Interior. U.S. Government Printing Office, Washington, DC. iv+36p.

DeMaria, D. 1989. Letter to the Gulf of Mexico Fishery Management Council, September 10, 1989. [see Appendix A of the commercial fishery section].

Deuel, D. G. and J. R. Clark. 1968. The 1965 Salt-Water Angling Survey. United States Fish and Wildlife Survey, Bureau of Sport Fisheries and Wildlife Resource Publication 67. Department of the Interior. U.S. Government Printing Office, Washington, DC. iii+51p.

Deuel, D. G. 1973. The 1970 Salt-Water Angling Survey. Statistics and Market News Division, Current Fishery Statistics No. 6200. National Oceanic and Atmospheric Administration, U. S. Department of Commerce. U.S. Government Printing Office, Washington, DC. iv+54p.

Florida State Board of Conservation. 1953. Tenth Biennial Report (for 1951-1952) Tallahassee, Florida.

Green, L. M., G. Lewis, and R. P. Campbell. 2002. Trends in finfish landings of sport-boat anglers in Texas marine waters, May 1974 – May 1998. Coastal Fisheries Division Management Data Series No. 204. Texas Parks and Wildlife Department. Austin, TX. ix+382p.

Gulf of Mexico Fishery Management Council. 1990. Amendment 2 to the Fishery Management Plan for Reef Fish, February 1990. Tampa, FL.

McClenachan, L. 2009. Historical declines of goliath grouper populations in South Florida, USA. Endangered Species Research 7: 175-181.

Porch, C, A-M. Eklund, and G. P. Scott. 2006. A catch-free stock assessment model with application to goliath grouper (Epinephelus itajara) off southern Florida. Fish. Bull. 104: 89-101.

Quinn, T.J. II and R.B Deriso. 1999. Quantitative Fish Dynamics. Oxford University Press, New York. 542p+xv.

South Atlantic Fishery Management Council. 1990. Amendment 2 to the Fishery Management Plan for the Snapper Grouper Fishery of the South Atlantic Region, July 1990. Charleston, SC.

4.10. *TABLES*

Table 4.1. Number of goliath grouper landed by head boat anglers by area (Figure 4.1.), 1981-2009. (The survey began sampling areas 18-27 in 1986.)

	Head Boat Area													
	1-6	7	8	11	12	17	18	21	22	23-24	25	26	27	
Year	NC - GA	NE FL (Fernandina Beach-St. Augustine)	NE FL (Daytona Beach - Sebastian)	SE FL (Ft. Pierce - Miami)	Florida Keys (Key Largo-Key West)	Dry Tortugas (vessels from Key West)	Dry Tortugas (vessels from SW FL)	SW FL (Naples - Cedar Key)	FL Middle Grounds	NW FL - LA (Carrabelle, FL – Empire /Grand Isle, LA)	NE TX (Sabine Pass - Freeport)	Port Aransas, TX	SE TX (Port Isabelle - South Padre Island)	Total
1981	0	0	2	0	25	28								55
1982	0	4	1	25	11	47								88
1983	0	0	3	3	10	38								54
1984	0	0	2	0	2	13								17
1985	0	0	3	1	0	13								17
1986	0	0	0	1	1	3	4	56	0	0	17	8	4	94
1987	0	0	0	29	0	2	0	23	0	0	2	1	0	57
1988	0	0	4	0	0	0	0	23	0	0	5	0	0	32
1989	0	0	1	19	0	1	0	117	0	0	0	2	0	140
1990	0	0	0	0	0	0	0	3	0	0	0	0	0	3
1991	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1992	0	0	1	0	0	0	0	0	0	0	0	0	0	1
1993	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1994	0	0	0	0	0	0	0	1	0	0	0	0	0	1
1995	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1996	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1997	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1998	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1999	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2000	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2001	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2002	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2003	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2004	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2005	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2006	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2007	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2008	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2009	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	0	4	17	78	49	145	4	223	0	0	24	11	4	559

*The two fish (one in 1992 and one in 1994) reported in the landings during the moratorium may have been miscoded, and the biomass was set to 0 in this table for those entries.

Table 4.2. Weight (pounds) of goliath grouper landed by head boat anglers by area (Figure 4.1.), 1981-2009. (The survey began sampling areas 18-27 in 1986.)

	Head Boat Survey Area													
	1-6	**7**	**8**	**11**	**12**	**17**	**18**	**21**	**22**	**23-24**	**25**	**26**	**27**	
Year	**NC - GA**	**NE FL (Fernandina Beach-St. Augustine)**	**NE FL (Daytona Beach - Sebastian)**	**SE FL (Ft. Pierce - Miami)**	**Florida Keys (Key Largo-Key West)**	**Dry Tortugas (vessels from Key West)**	**Dry Tortugas (vessels from SW FL)**	**SW FL (Naples-Cedar Key)**	**FL Middle Grounds**	**NW FL - LA (Carrabelle, FL - Empire-Grand Isle, LA)**	**NE TX (Sabine Pass - Freeport)**	**Port Aransas, TX**	**SE TX (Port Isabelle - South Padre Island)**	**Total**
1981	0.0	0.0	126.1	0.0	1,576.3	3,129.4								4,831.9
1982	0.0	60.1	15.0	625.6	473.4	6,387.8								7,561.9
1983	0.0	0.0	300.9	42.0	140.0	3,579.5								4,062.4
1984	0.0	0.0	188.0	0.0	188.0	1,222.0								1,598.0
1985	0.0	0.0	116.4	30.5	0.0	397.0								543.9
1986	0.0	0.0	0.0	4.9	4.9	14.6	481.7	7,752.5	0.0	0.0	1,749.3	595.5	297.7	10,901.0
1987	0.0	0.0	0.0	89.3	0.0	308.0	0.0	4,082.9	0.0	0.0	355.0	177.5	0.0	5,012.8
1988	0.0	0.0	5.4	0.0	0.0	0.0	0.0	3,562.3	0.0	0.0	810.0	0.0	0.0	4,377.7
1989	0.0	0.0	68.1	1,293.2	0.0	64.5	0.0	7,544.3	0.0	0.0	0.0	129.0	0.0	9,098.9
1990	0.0	0.0	0.0	0.0	0.0	0.0	0.0	228.8	0.0	0.0	0.0	0.0	0.0	228.8
1991	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1992	0.0	0.0	0*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0*
1993	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1994	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0*	0.0	0.0	0.0	0.0	0.0	0*
1995	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1996	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1997	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1998	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1999	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2001	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2002	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2003	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2004	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2005	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2006	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2007	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2008	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2009	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	0.0	60.1	819.9	2,085.4	2,382.6	15,102.8	481.7	23,170.8	0.0	0.0	2,914.4	902.0	297.7	48217.3

*The two fish (one in 1992 and one in 1994) reported in the landings during the moratorium may have been miscoded, and the biomass was set to 0 in this table for those entries

Table 4.3. Recreational harvest of goliath grouper (in numbers of fish, types a+b1) in the southeast region of the United States, 1981-2009*.

Year	Texas	Louisiana	Mississippi	Alabama	West Florida	East Florida	Georgia	South Carolina	North Carolina	Grand Total		Florida Total	Florida % of total
1981	0	0	0	0	22,871	1,173	0	0	0	24,044		24,044	100.0
1982	0	1,774	0	0	7,869	0	0	0	0	9,643		7,869	81.6
1983	0	0	0	0	0	0	0	0	0	0		0	-----
1984	0	629	0	0	0	5,350	0	0	0	5,979		5,350	89.5
1985	0	0	0	0	7,238	0	0	0	0	7,238		7,238	100.0
1986	**	4,988	0	0	944	0	0	0	0	5,932		944	15.9
1987	**	120	0	0	3,090	1,260	0	0	0	4,469		4,349	97.3
1988	**	0	0	0	2,316	896	0	0	0	3,212		3,212	100.0
1989	**	0	0	0	1,717	403	0	0	0	2,120		2,120	100.0
1990	**	0	0	0	0	0	0	0	0	0		0	-----
1991	**	0	0	0	0	0	0	0	0	0		0	-----
1992	**	0	0	0	0	0	0	0	0	0		0	-----
1993	**	0	0	0	0	0	0	0	0	0		0	-----
1994	**	0	0	0	0	0	0	0	0	0		0	-----
1995	**	0	0	0	0	0	0	0	0	0		0	-----
1996	**	0	0	0	0	0	0	0	0	0		0	-----
1997	**	0	0	0	0	0	0	0	0	0		0	-----
1998	**	0	0	0	0	0	0	0	0	0		0	-----
1999	**	0	0	0	0	0	0	0	0	0		0	-----
2000	**	0	0	0	0	0	0	0	0	0		0	-----
2001	**	0	0	0	0	0	0	0	0	0		0	-----
2002	**	0	0	0	729	0	0	0	0	729		729	100.0
2003	**	0	0	0	0	0	0	0	0	0		0	-----
2004	**	0	0	0	0	0	0	0	0	0		0	-----
2005	**	0	0	0	0	0	0	0	0	0		0	-----
2006	**	0	0	0	0	0	0	0	0	0		0	-----
2007	**	0	0	0	0	0	0	0	0	0		0	-----
2008	**	0	0	0	1,542	631	0	0	0	2,174		2,174	100.0
2009	**	0	0	0	0	0	0	0	0	0		0	-----
Total	**	7,511	0	0	48,316	9,713	0	0	0	65,540		58,029	88.5

* source: Personal communication from the National Marine Fisheries Service, Fisheries Statistics Division, April 26, 2010.
Marine Recreational Fishery Statistics Survey, catch types "a" (inspected, harvested catch), and "b1" (unavailable harvest or released dead)
http://www.st.nmfs.noaa.gov/st1/recreational/queries/index.html
** Texas recreational catch no longer included in the MRFSS. Texas Parks and Wildlife

Table 4.4. Recreational harvest of goliath grouper (in pounds of fish, types a+b1) in the southeast region of the United States, 1981-2009*.

Year	Texas	Louisiana	Mississippi	Alabama	West Florida	East Florida	Georgia	South Carolina	North Carolina	Grand Total		Florida Total	Florida % of total
1981	0	0	0	0	***	1,294	0	0	0	1,294		1,294	100.0
1982	0	50,611	0	0	1,087,190	0	0	0	0	1,137,801		1,087,190	95.6
1983	0	0	0	0	0	0	0	0	0	0		0	-----
1984	0	57,952	0	0	0	21,230	0	0	0	79,182		21,230	26.8
1985	0	0	0	0	188,293	0	0	0	0	188,293		188,293	100.0
1986	**	13,340	0	0	20,807	0	0	0	0	34,147		20,807	60.9
1987	**	2,291	0	0	44,996	31,931	0	0	0	79,218		76,927	97.1
1988	**	0	0	0	3,574	4,345	0	0	0	7,919		7,919	100.0
1989	**	0	0	0	***	***	0	0	0	***		***	100.0
1990	**	0	0	0	0	0	0	0	0	0		0	-----
1991	**	0	0	0	0	0	0	0	0	0		0	-----
1992	**	0	0	0	0	0	0	0	0	0		0	-----
1993	**	0	0	0	0	0	0	0	0	0		0	-----
1994	**	0	0	0	0	0	0	0	0	0		0	-----
1995	**	0	0	0	0	0	0	0	0	0		0	-----
1996	**	0	0	0	0	0	0	0	0	0		0	-----
1997	**	0	0	0	0	0	0	0	0	0		0	-----
1998	**	0	0	0	0	0	0	0	0	0		0	-----
1999	**	0	0	0	0	0	0	0	0	0		0	-----
2000	**	0	0	0	0	0	0	0	0	0		0	-----
2001	**	0	0	0	0	0	0	0	0	0		0	-----
2002	**	0	0	0	***	0	0	0	0	***		***	100.0
2003	**	0	0	0	0	0	0	0	0	0		0	-----
2004	**	0	0	0	0	0	0	0	0	0		0	-----
2005	**	0	0	0	0	0	0	0	0	0		0	-----
2006	**	0	0	0	0	0	0	0	0	0		0	-----
2007	**	0	0	0	0	0	0	0	0	0		0	-----
2008	**	0	0	0	***	2,729	0	0	0	***		***	100.0
2009	**	0	0	0	0	0	0	0	0	0		0	-----
Total	**	124,194	0	0	1,344,860	61,529	0	0	0	1,530,583		1,406,389	91.9

* source: Personal communication from the National Marine Fisheries Service, Fisheries Statistics Division, April 26, 2010.
Marine Recreational Fishery Statistics Survey, catch types "a" (inspected, harvested catch), and "b1" (unavailable harvest or released dead).
http://www.st.nmfs.noaa.gov/st1/recreational/queries/index.html
** Texas recreational catch no longer included in the MRFSS. Texas Parks and Wildlife Division's recreational catch estimates do not include released fish.
*** average weights not available to estimate harvest.

Table 4.5. Total recreational catch (in numbers of fish, including releases) of goliath grouper in the US southeast, 1981-2009*

Year	Texas	Louisiana	Mississippi	Alabama	West Florida	East Florida	Georgia	South Carolina	North Carolina	Grand Total	Florida Total	Florida % of total
1981	0	0	0	0	22,871	1,173	0	0	0	24,044	24,044	100.0
1982	0	1,774	0	0	7,869	0	0	0	0	9,643	7,869	81.6
1983	0	0	0	0	0	120	0	0	0	120	120	100.0
1984	1,516	629	0	1,289	0	5,350	0	0	0	8,784	5,350	60.9
1985	0	0	0	0	8,992	0	0	0	0	8,992	8,992	100.0
1986	**	4,988	0	0	1,339	0	0	0	0	6,327	1,339	21.2
1987	**	120	0	0	3,090	1,260	0	0	0	4,469	4,349	97.3
1988	**	0	0	0	2,316	896	0	0	0	3,212	3,212	100.0
1989	**	0	0	0	7,977	403	0	0	0	8,380	8,380	100.0
1990	**	0	0	0	1,928	0	0	0	0	1,928	1,928	100.0
1991	**	0	0	0	4,426	1,296	0	0	0	5,722	5,722	100.0
1992	**	0	0	0	3,062	0	0	0	0	3,062	3,062	100.0
1993	**	0	0	0	5,316	0	0	0	0	5,316	5,316	100.0
1994	**	0	0	0	4,404	0	0	0	0	4,404	4,404	100.0
1995	**	0	0	0	12,979	904	0	0	0	13,883	13,883	100.0
1996	**	159	0	0	1,752	690	0	0	0	2,601	2,442	93.9
1997	**	0	0	0	4,879	3,363	0	0	0	8,242	8,242	100.0
1998	**	0	0	0	6,245	1,622	0	438	0	8,305	7,867	94.7
1999	**	0	0	171	5,417	2,638	0	0	0	8,226	8,055	97.9
2000	**	0	0	0	22,663	10,630	0	0	0	33,294	33,294	100.0
2001	**	0	0	0	31,443	9,951	0	0	0	41,393	41,393	100.0
2002	**	0	0	0	14,861	16,034	0	0	87	30,982	30,895	99.7
2003	**	0	0	0	38,705	10,649	0	0	0	49,354	49,354	100.0
2004	**	0	0	0	42,185	12,532	964	0	0	55,680	54,716	98.3
2005	**	0	0	734	83,185	17,734	0	0	0	101,653	100,919	99.3
2006	**	0	0	0	95,809	26,584	0	0	0	122,394	122,394	100.0
2007	**	0	0	0	114,534	40,329	0	0	0	154,863	154,863	100.0
2008	**	0	0	0	35,805	14,991	0	0	0	50,796	50,796	100.0
2009	**	0	0	0	31,013	15,098	0	0	0	46,111	46,111	100.0
Total	**	7,670	0	2,194	615,065	194,247	964	438	87	822,180	809,311	98.4

* source: Personal communication from the National Marine Fisheries Service, Fisheries Statistics Division, April 26, 2010. Marine Recreational Fishery Statistics Survey (MRFSS) http://www.st.nmfs.noaa.gov/st1/recreational/queries/index.html

MRFSS catch types: "a" (inspected, harvested catch), "b1" (unavailable for measurement or fish released dead),"b2" (caught, released alive).

** Texas recreational catch no longer included in the MRFSS. Texas Parks and Wildlife Division's recreational catch estimates do not include released fish.

Table 4.6. Estimated total recreational catch (numbers of fish including releases) of goliath grouper by coast in Florida, and proportional standard errors (PSE) from the Marine Recreational Fisheries Statistics Survey (MRFSS), 1981-2009.

	West Florida		East Florida		Florida	
Year	Total Catch	PSE	Total Catch	PSE	Total Catch	PSE
1981	22,871	96.3	1,173	50	24,044	91.7
1982	7,869	65.9	0	0	7,869	65.9
1983	0	0	120	100.1	120	100.1
1984	0	0	5,350	72.4	5,350	72.4
1985	8,992	82.8	0	0	8,992	82.8
1986	1,339	76.4	0	0	1,339	76.4
1987	3,090	52.5	1,260	100	4,349	47.2
1988	2,316	57.6	896	100	3,212	50
1989	7,977	67.7	403	57.7	8,380	64.5
1990	1,928	100	0	0	1,928	100
1991	4,426	88.9	1,296	100	5,722	72.4
1992	3,062	78.4	0	0	3,062	78.4
1993	5,316	52.2	0	0	5,316	52.2
1994	4,404	41.8	0	0	4,404	41.8
1995	12,979	41.3	904	100.1	13,883	39.2
1996	1,752	70.8	690	100	2,442	58.1
1997	4,879	42.9	3,363	79.9	8,242	41.3
1998	6,245	26.6	1,622	63.6	7,867	24.8
1999	5,417	28.8	2,638	41.7	8,055	23.7
2000	22,663	24.8	10,630	29.8	33,294	19.4
2001	31,443	29.7	9,951	38.2	41,393	24.4
2002	14,861	26.6	16,034	31.1	30,895	20.6
2003	38,705	22.3	10,649	34.5	49,354	19
2004	42,185	17.3	12,532	28.3	54,716	14.8
2005	83,185	13.8	17,734	31.2	100,919	12.6
2006	95,809	12.4	26,584	28.5	122,394	11.5
2007	114,534	13.4	40,329	29.3	154,863	12.5
2008	35,805	22.6	14,991	26.2	50,796	17.7
2009	31,013	20	15,098	24.7	46,111	15.7
Total	615,065		194,247		809,312	

* source: Personal communication from the National Marine Fisheries Service, Fisheries Statistics Division, April 26, 2010.
Marine Recreational Fishery Statistics Survey, catch types "a" (inspected, harvested catch), "b1" (unavailable for measurement or fish released dead), "b2" (caught, released alive).

Table 4.7. Number of goliath grouper measured by year and length class from the Everglades National Park Angler Creel Survey, 1974-1990.

Total Length (mm)	1974	1975	1976	1977	1978	1982	1983	1984	1986	1987	1988	1989	1990	Total
200-249	0	2	0	0	0	0	0	0	0	0	0	0	0	2
250-299	0	3	2	1	0	0	0	0	0	0	0	0	0	6
300-349	3	10	2	2	0	0	0	0	0	0	0	0	0	17
350-399	2	14	9	11	0	0	0	1	0	0	0	0	0	37
400-449	0	21	8	11	1	0	0	0	0	0	0	0	1	42
450-499	1	11	12	6	0	0	1	0	0	0	0	1	1	33
500-549	2	14	11	11	0	0	1	1	0	0	2	0	0	42
550-599	1	14	8	9	0	0	0	0	1	0	1	0	0	34
600-649	1	19	16	5	0	1	0	0	0	1	0	1	0	44
650-699	2	9	6	5	2	0	0	0	0	0	0	0	0	24
700-749	1	28	4	7	0	0	0	0	0	0	0	0	0	40
750-799	1	10	3	6	2	0	0	0	0	0	0	0	0	22
800-849	2	5	1	2	0	0	1	1	0	0	0	0	0	12
850-899	1	5	1	4	1	1	0	0	0	0	0	0	0	13
900-949	0	5	1	3	0	0	1	0	0	0	0	0	0	10
950+	2	10	5	8	1	0	6	0	2	0	0	0	0	34
Total	19	180	89	91	7	2	10	3	3	1	3	2	2	412

Table 4.8. Estimated total recreational catch (numbers of fish including releases) of goliath grouper on the West coast of Florida (Monroe - Escambia counties) by water body and by mode of fishing from the MRFSS, 1981-2009.

a. by Water Body

Year	Estuarine/River (Inland)	Nearshore (Ocean <= 10 miles)	Federal Waters (Ocean > 10 mi)	Total
1981	0	22,871	0	22,871
1982	0	7,869	0	7,869
1983	0	0	0	0
1984	0	0	0	0
1985	0	1,754	7,238	8,992
1986	0	0	1,339	1,339
1987	0	1,193	1,897	3,090
1988	0	0	2,316	2,316
1989	6,260	0	1,717	7,977
1990	0	0	1,928	1,928
1991	0	3,897	528	4,425
1992	799	2,263	0	3,062
1993	2,135	3,181	0	5,316
1994	539	2,406	1,459	4,404
1995	10,297	811	1,871	12,979
1996	1,752	0	0	1,752
1997	1,716	1,316	1,847	4,879
1998	2,427	2,243	1,576	6,246
1999	4,404	611	402	5,417
2000	18,826	2,918	920	22,664
2001	26,953	4,425	66	31,444
2002	11,927	2,144	790	14,861
2003	24,892	13,479	334	38,705
2004	32,593	5,264	4,328	42,185
2005	45,523	33,064	4,599	83,186
2006	71,984	20,241	3,583	95,808
2007	94,040	16,791	3,703	114,534
2008	21,873	5,626	8,305	35,804
2009	23,523	3,771	3,719	31,013
Total	402,463	158,138	54,465	615,066

b. by Mode of Fishing

Year	Charter (CH)	Private/Rental (PR)	Shore (SH)	Total
1981	0	22,871	0	22,871
1982	0	7,869	0	7,869
1983	0	0	0	0
1984	0	0	0	0
1985	0	8,992	0	8,992
1986	395	944	0	1,339
1987	1,193	1,897	0	3,090
1988	2,316	0	0	2,316
1989	0	3,025	4,952	7,977
1990	0	1,928	0	1,928
1991	528	0	3,897	4,425
1992	0	799	2,263	3,062
1993	341	4,975	0	5,316
1994	1,840	2,564	0	4,404
1995	0	12,979	0	12,979
1996	0	1,752	0	1,752
1997	2,389	2,490	0	4,879
1998	2,041	4,205	0	6,246
1999	790	3,777	850	5,417
2000	1,325	7,434	13,905	22,664
2001	1,820	27,210	2,414	31,444
2002	876	12,998	987	14,861
2003	2,423	31,345	4,937	38,705
2004	5,750	33,524	2,911	42,185
2005	5,270	61,819	16,097	83,186
2006	9,123	70,266	16,419	95,808
2007	10,307	90,072	14,155	114,534
2008	6,277	26,606	2,921	35,804
2009	3,368	16,135	11,510	31,013
Total	58,372	458,476	98,218	615,066

Table 4.9. Estimated total recreational catch (numbers of fish including releases) of goliath grouper on the East coast of Florida (Nassau – Miami-Dade counties) by water body and by mode of fishing from the MRFSS, 1981-2009.

b. by Water Body

Year	Estuarine/River (Inland)	Nearshore [Ocean <= 10 miles)	Federal Waters (Ocean > 10 mi)	Total
1981	1,173	0	0	1,173
1982	0	0	0	0
1983	0	0	120	120
1984	0	5,350	0	5,350
1985	0	0	0	0
1986	0	0	0	0
1987	0	1,260	0	1,260
1988	0	896	0	896
1989	0	403	0	403
1990	0	0	0	0
1991	0	0	1,296	1,296
1992	0	0	0	0
1993	0	0	0	0
1994	0	0	0	0
1995	904	0	0	904
1996	0	690	0	690
1997	3,363	0	0	3,363
1998	1,622	0	0	1,622
1999	1,617	1,022	0	2,639
2000	5,992	4,639	0	10,631
2001	7,065	2,177	709	9,951
2002	13,202	1,935	896	16,033
2003	9,100	1,549	0	10,649
2004	12,264	268	0	12,532
2005	15,241	1,577	915	17,733
2006	24,560	2,025	0	26,585
2007	37,833	967	1,529	40,329
2008	11,246	2,551	1,193	14,990
2009	13,319	0	1,778	15,097
Total	158,501	27,309	8,436	194,246

b. by Mode of Fishing

Year	Charter (CH)	Private/Rental (PR)	Shore (SH)	Total
1981	0	1,173	0	1,173
1982	0	0	0	0
1983	120	0	0	120
1984	0	5,350	0	5,350
1985	0	0	0	0
1986	0	0	0	0
1987	0	1,260	0	1,260
1988	0	896	0	896
1989	403	0	0	403
1990	0	0	0	0
1991	0	1,296	0	1,296
1992	0	0	0	0
1993	0	0	0	0
1994	0	0	0	0
1995	0	904	0	904
1996	0	690	0	690
1997	0	3,363	0	3,363
1998	0	1,622	0	1,622
1999	0	2,639	0	2,639
2000	0	4,197	6,434	10,631
2001	0	1,486	8,465	9,951
2002	0	14,098	1,935	16,033
2003	54	7,994	2,601	10,649
2004	346	12,186	0	12,532
2005	323	8,632	8,778	17,733
2006	394	17,055	9,136	26,585
2007	0	19,198	21,131	40,329
2008	348	8,745	5,897	14,990
2009	455	9,689	4,953	15,097
Total	2,443	122,473	69,330	194,246

4.11. *FIGURES*

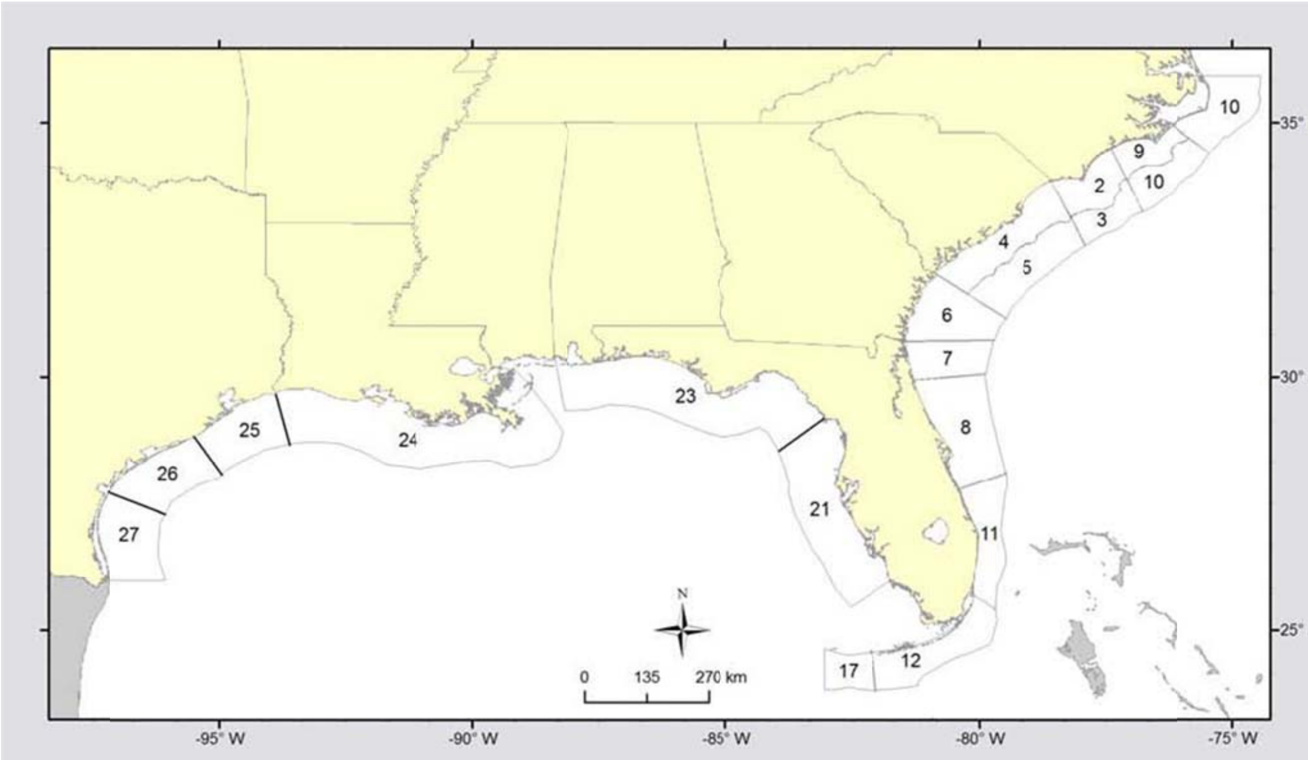


Figure 4.1. Map of the Southeastern U.S. showing area definitions used by the NMFS Southeast Head Boat Survey.

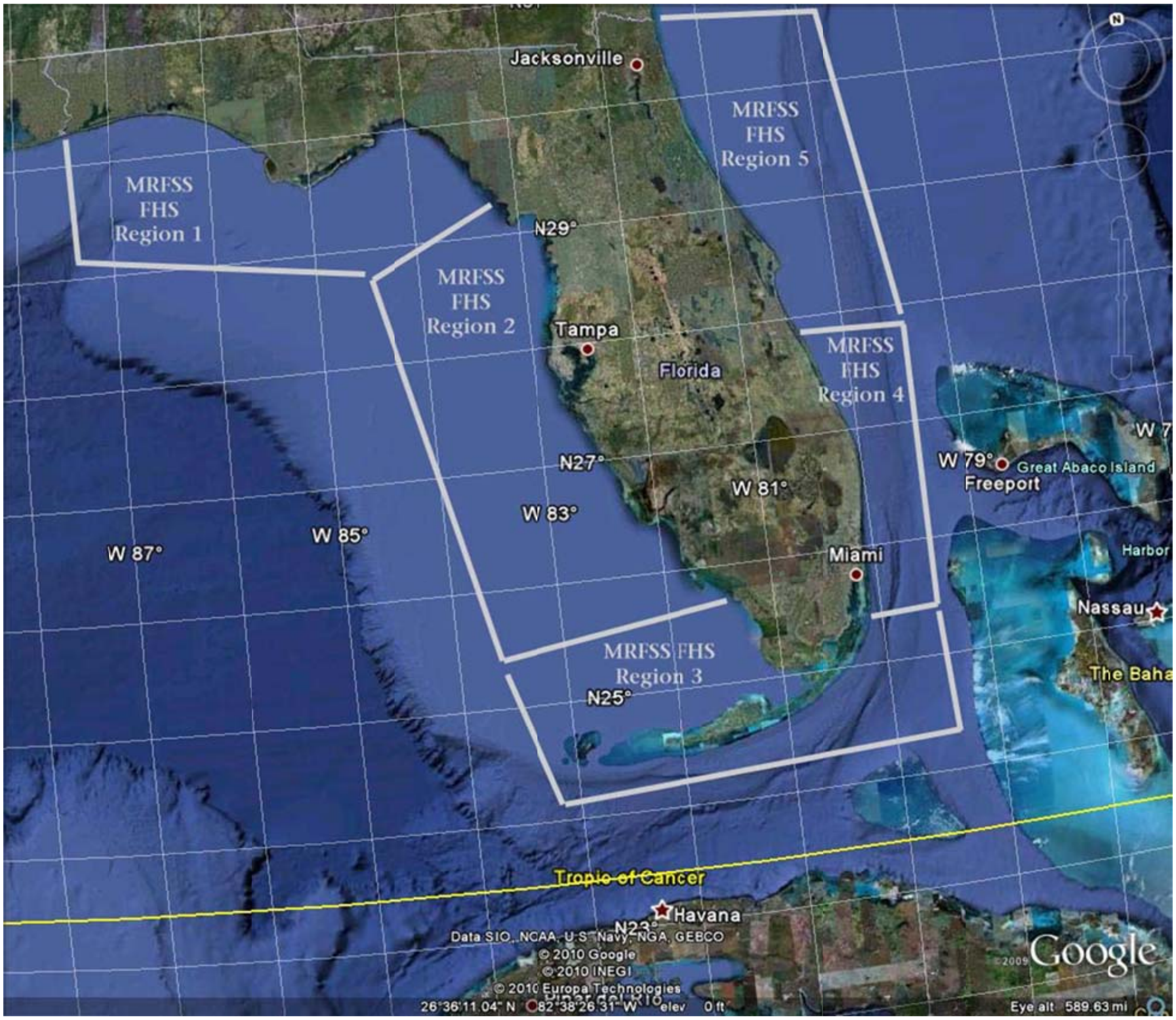


Figure 4.2. A map of Florida indicating the MRFSS For-Hire Survey (FHS) regions. Region 1 includes for-hire vessels based from Escambia County to Dixie County, Region 2 ranges from Levy County to Collier County, Region 3 includes vessels from all of Monroe County, Region 4 stretches from Miami-Dade County to Indian River County, and Region 5 extends from Brevard County to Nassau County. Shore (SH) and private/rental boats angler interviews were included in these regions based upon the county where the intercept occurred.

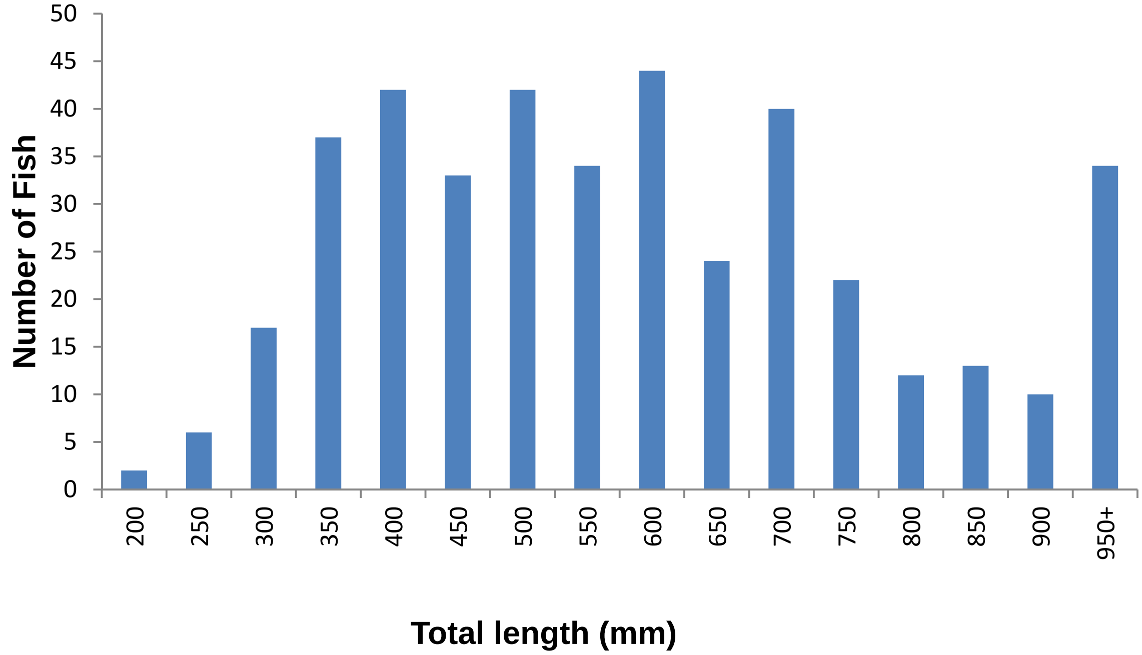


Figure 4.3. Measurements (by length class) of goliath grouper from the Everglades National Park Angler Creel Survey, 1973-1990.

5. MEASURES OF POPULATION ABUNDANCE

5.1. *OVERVIEW*

Several indices of abundance were considered for use in the assessment model. The possible indices came primarily from fishery dependent data sources. The DW recommends that all indices be reviewed further at the assessment workshop.

5.1.1. Group Membership

Membership of this DW working group included Walter Ingram (leader), Kevin McCarthy, Adam Pollack and Clay Porch.

5.2. *REVIEW OF INDICES*

The working group reviewed one working paper describing index construction:

SEDAR23-DW-02 (Everglades National Park Creel Survey)

The working group also conducted analyses on several other data sources during and after the data workshop. Therefore, the results of these analyses are described in the sections below.

5.3. *FISHERY DEPENDENT INDICES*

5.3.1. Everglades National Park Creel Survey (SEDAR23-DW-02)

The historical center of abundance of goliath grouper is the Ten Thousand Islands area of southwest Florida. Detailed catch and effort data are available from this region from 1973-2009. The data were collected by Everglades National Park (ENP) during voluntary dockside interviews of sport fishermen. Using this data, a standardized index of abundance was created for juvenile goliath grouper through a delta-lognormal modeling approach. The variables tested for inclusion included: year, angler skill, area, and season. The details concerning these variables are contained in the document. The index (Table 5.1; Figure 5.1) shows a substantial decline in abundance of juveniles during the late 1970s and early 1980s. Since that time, a strong increase through 2007 and decline from 2008-2009 is evident, suggesting that strong year classes recently occurred in ENP, but that as these animals matured and left the juvenile habitat, they may not have been replaced with ongoing strong recruitment.

5.3.2. Headboat Survey

Headboat catch data was analyzed in order to develop abundance indices for Goliath grouper. The time series was split into two time series: 1976-1985; and 1986-2009, with a data holiday from 1990 to 2004. The reason for the split was the change in the sampling procedures where prior to 1986 data was only collected in the Atlantic. In 1986, sampling started included the Gulf of Mexico as well, which changed aerial coverage of sampling in and around the Florida Keys and South Florida. A delta-lognormal approach was used in modeling these two time series, with year and area included as variables in both the binomial and lognormal submodels. The headboat data was limited to the following headboat survey areas, which served as categories in the area variable: Northeast Florida (Section 1), Fernandina Beach through St. Augustine, FL; Northeast Florida (Section 2), Daytona Beach through Sebastian, FL; Southeast Florida, Fort Pierce through Miami, FL; Florida Keys, Key Largo through Key West, FL; Dry Tortugas, Florida, Fishing Area Around (Vessels docked in FL Keys) The Dry Tortugas, FL; Dry Tortugas, Florida, Fishing Area Around (Vessels docked on west coast of FL), The Dry Tortugas, FL; Southwest Florida, Naples through Cedar Key, FL. Due to the low frequency of Goliath in the data, variance estimates of index values were calculated using a bootstrap approach. With this approach 80% of the data were randomly selected from each time series and models were ran 1000. This provided a distribution of index values for each year. The standard deviation of the index values was derived for each to provide an annual standard error estimate, by which the coefficient of variation (CV) on the index value was derived. Figures 5.2 and 5.3. summarize the results.

5.3.3. Two Visual Surveys

Introduction: Two visual surveys are examined for evidence that the number of goliath grouper has increased in the waters off South Florida since a harvest moratorium was imposed in 1990. Both surveys are standardized to account for the unbalanced design of the sampling procedure: the personal observations of a professional spearfisher (DeMaria[3]) and a volunteer fish-monitoring program administered by the Reef Education and Environmental Foundation (REEF 2010).

<u>Field data collection: DeMaria Survey:</u>

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

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

numbers recorded during the early years may be underestimates since there were many more fish to count at that time.

The specific locations included in Mr. DeMaria's survey are indicated in Figure 5.4. 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 covered 34,143 surveys conducted at about 1,700 dive sites from June 1993 through 2009. 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 11,668 surveys at 77 sites (see Table 5.2). Most of the sites that made the cut are located in the Florida Keys (47), the rest being located along the Florida east coast south of Cape Canaveral (13) or along the Florida west coast off Pinellas and Lee counties (17). The majority of the 60 sites from southeast Florida were first surveyed in 1994 or 1995, whereas few of the sites from southwest Florida were surveyed prior to 1999. Accordingly, two separate analyses were conducted, one for the Florida Keys and east coast (11,668 surveys at 60 sites since 1994) and another for southwest Florida (277 surveys at 17 sites since 1999). The former may be regarded as an update of the index developed in Porch and Eklund (2004).

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. A few sites were also reported as rubble, sloping dropoffs, ledges, or shear dropoffs. For this study, 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 1999) 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 of Akaike's information criteria (AIC_c, 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. There are two options for constructing annual indices of abundance when the data indicate significant year/season or year/location interactions. The first is simply to standardize the data for each season and location separately and then compute some form of weighted average, in which case the difficulty lies in determining appropriate weighting factors. The second option is to model the year-interactions as random effects, i.e., assume they are effectively random over the temporal and spatial scales being examined. This allows indices of abundance to be constructed in the usual way, but with variance estimates that appropriately reflect the added uncertainty expected when significant year interactions are present.

Standardized measures of visual counts for year Y may be computed from the log-linear predictor $\alpha + \beta_Y$ using the formula

$$N_Y = \exp\{\alpha + \beta_Y + s_R^2 /2\} - c$$

where s_R^2 is the residual variance. However, this formula is biased when the GLM estimates of α and β_Y are used in place of the unknown true values. The equivalent unbiased measure is

(2) $$N_Y = \exp\{\alpha + \beta_Y + (d+1)(s_R^2 - s_Y^2)/2d\} - c$$

where d denotes the degrees of freedom for the residual variance and s_Y^2 is the estimated variance of $\alpha + \beta_Y$ (Bradu and Mundlak 1970, Gavaris 1980).

Statistical modeling: REEF Survey:

Porch and Eklund (2004) used a censored Poisson distribution to model the counts of goliath grouper in the REEF samples. Their model is extended here to accommodate category "3" (counts of 11-100 fish), which has occasionally been reported at some survey sites:

(3) $$p(N) = \begin{cases} \dfrac{e^{-\mu}\mu^N}{N!} & N = 0,1 \\ \displaystyle\sum_{k=2}^{10} \frac{e^{-\mu}\mu^k}{k!} & N = 2 \\ 1 - \displaystyle\sum_{k=0}^{10} \frac{e^{-\mu}\mu^k}{k!} & N = 3 \end{cases}$$

where N is the reported abundance category and μ is the expected count of goliath grouper (to be estimated). Accordingly, maximum likelihood estimates for the parameters (α and β, described below) may be obtained by minimizing the negative loglikelihood expression

$$L = \sum_{N_i=0} \mu_i + \sum_{N_i=1} (\mu_i - \ln \mu_i) - \sum_{N_i=2} \ln\left(\sum_{k=2}^{10} \frac{e^{-\mu_i} \mu_i^k}{k!} \right) - \sum_{N_i=3} \ln\left(1 - \sum_{k=0}^{10} \frac{e^{-\mu_i} \mu_i^k}{k!} \right) \quad (4)$$

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

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

where the γ_i is the offset covariate (dive duration), α is the scaling coefficient (intercept) 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 AIC_c criteria (Hurvich and Tsai 1995). Interaction effects were not estimated owing to the limited data for many of the sites.

All model fits (negative loglikelihood minimizations) were accomplished using the utilities provided in the software package AD Model Builder[4]. Standardized measures of visual counts for each year were constructed as

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

Confidence limits for C_Y were obtained by the inverse-Hessian method.

Results and Discussion: The fit of the models was poor for both the east and the western coasts, accounting for only a few percent of the variation in the data. Not surprisingly, the standardized indices are similar to the time series of annual means (Table 5.2, Figure 5.1). The error bars are wide owing to high variability and low replication at many sites. This is particularly true for the west where there were only 277 surveys.

The most important factors in standardizing the REEF surveys from southeast Florida were the year and location (geozone). The only important factor for southwest Florida was

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

location, the year effect being insignificant. The effect of habitat type was statistically significant for both regions, but explained little of the variation. There was no discernible relationship between the number of goliath grouper counted and dive duration, visibility or experience level in either the east or the west. The large size and generally unwary nature of goliath grouper makes them easy to spot early in the dive, even under relatively poor visibility.

The REEF surveys from southeastern Florida indicate very low abundance from 1994 to 1996 with a substantial increasing trend thereafter (Figure 5.1). On the other hand, the REEF surveys from southwestern Florida exhibit little trend other than a dip in 2005 (possibly due to the 2005 red tide event) followed by a spike up in 2006. Porch and Eklund (2004) noted that the increase in the REEF southeastern Florida survey does not begin until several years after the 1990 moratorium on harvest, whereas the DeMaria survey of five wrecks in Southwest Florida exhibited a more immediate recovery and then fluctuated with no long term trend after the mid 1990s. They suggested that the 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. The REEF data for the southwestern sites does not extend early enough in time to corroborate this trend, but is consistent with DeMaria survey for the overlapping time period in the sense that there is little trend (Figure 2).

The average number of goliath grouper seen on the western sites (about 2 per dive) was much greater than for the eastern sites (about 0.05 per dive). The disparity may reflect a greater abundance of goliath grouper in southwest Florida, but may also be attributed to the fact that most of the sites surveyed in southwestern Florida are high relief artificial structures that attract and hold more fish than the lower-relief natural sites surveyed in southeastern Florida. Regardless of the cause, it is generally believed that the center of abundance of the goliath population is along the southwest coast and it is important to develop an index that reflects this part of the population. More surveys from more sites in the southwest are therefore encouraged to improve the precision of this index.

5.4. *CONSENSUS RECOMMENDATIONS AND SURVEY EVALUATIONS*

The workshop group recommends that all indices be reviewed further at the assessment workshop.

5.5. LITERATURE CITED

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

Gavaris, S. 1980. Use of a multiplicative model to estimate catch rate and effort from commercial data. Can. J. Fish. Aquat. Sci. 37:2272-2275.

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.

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.

Porch, C. E., and A._M. Eklund. 2004. Standardized visual counts of goliath grouper off South Florida and their possible use as indices of abundance. Gulf Mex. Sci. 22:155-163.

REEF (Reef Environmental Education Foundation). 2010. World Wide Web electronic publication. www.reef.org, date of download 9 March 2010.

SAS. 1999. SAS/STAT User's Guide, Version 8. SAS Institute Inc. SAS Campus Drive, Cary, NC 27513. 3884 pp.

5.6. TABLES

Table 5.1. Abundance index statistics including nominal CPUE (goliath / 1000 angler hours), number of trips interviewed, proportion positive trips (PPT), standardized CPUE, upper and lower 95% confidence intervals and coefficients of variation (CV).

YEAR	Nominal CPUE	TRIPS	PPT	Rel Index	Lower 95% CI	Upper 95% CI	CV
1973	2.461	3861	0.02797	0.78819	0.49661	1.25098	0.23409
1974	0						
1975	2.485	4467	0.02373	0.40779	0.25116	0.66211	0.24593
1976	5.828	3552	0.05293	1.27542	0.85619	1.89994	0.20127
1977	4.801	4240	0.04363	0.86734	0.57974	1.2976	0.20348
1978	5.333	3649	0.04056	0.91079	0.59486	1.3945	0.21543
1979	3.27	2296	0.02831	0.61987	0.35953	1.06871	0.27748
1980	3.771	4161	0.02788	0.66362	0.42088	1.04637	0.23067
1981	1.907	5787	0.01572	0.38802	0.23817	0.63212	0.2477
1982	1.467	5440	0.00956	0.28677	0.15993	0.51418	0.29829
1983	1.148	6233	0.01027	0.26475	0.15251	0.45957	0.28109
1984	0.861	7808	0.00768	0.2301	0.13165	0.40218	0.28472
1985	0.615	6748	0.00519	0.14015	0.07111	0.2762	0.34921
1986	0.543	7765	0.00489	0.13479	0.0697	0.26066	0.33894
1987	0.459	6615	0.00454	0.10484	0.0512	0.21469	0.37019
1988	0.724	4123	0.00752	0.1398	0.06881	0.28401	0.36583
1989	1.567	3944	0.01851	0.30095	0.17773	0.50961	0.26798
1990	0.996	6422	0.00934	0.1558	0.08852	0.27424	0.28844
1991	1.006	5377	0.0093	0.17418	0.09567	0.31712	0.30645
1992	1.133	5816	0.01118	0.23787	0.13642	0.41477	0.28347
1993	1.75	6100	0.01623	0.25947	0.15983	0.42124	0.24588
1994	4.375	7076	0.03392	0.68509	0.46564	1.00796	0.19488
1995	7.29	5266	0.03988	1.07861	0.72533	1.60395	0.20037
1996	8.824	7084	0.04644	1.16931	0.81348	1.68078	0.18292
1997	4.895	7854	0.03119	0.71318	0.48385	1.05122	0.19582
1998	3.537	6238	0.0234	0.53169	0.34502	0.81936	0.21878
1999	3.811	5766	0.02359	0.55115	0.35574	0.8539	0.22156
2000	4.238	5540	0.0287	0.79369	0.52089	1.20937	0.21294
2001	4.755	5525	0.03566	0.71494	0.47851	1.06819	0.2028
2002	5.465	4588	0.04228	0.73732	0.49235	1.1042	0.204
2003	14.357	4177	0.08906	1.86283	1.31286	2.64319	0.17629
2004	14.158	4319	0.08984	1.97697	1.39912	2.79347	0.17416
2005	16.676	3352	0.10292	2.31596	1.63334	3.28388	0.17594
2006	28.377	3547	0.1497	3.54136	2.56247	4.8942	0.16283
2007	36.405	3807	0.19359	5.18082	3.84717	6.97679	0.14964
2008	27.521	3197	0.14232	3.5495	2.55093	4.93898	0.16631
2009	18.234	2943	0.0965	2.24707	1.56085	3.23499	0.18372

Table 5.2. Sites in the Reef Education and Environmental Foundation database used for the "east coast" analysis, with the number of years between 1994 and 2009 during which at least one survey was conducted and the number of surveys where 0, 1, 2-10 or more than 10 goliath grouper were observed.

Location	REEF geozone	Number of years	Number of surveys 0 seen	1 seen	2-10 seen	>10 seen
Southeast Florida						
Esso Bonaire Wreck	32010006	7	14	3	8	3
Commercial Pier Reefs	33010001	13	954	1	0	0
Juno Ledge	33010005	13	28	3	7	0
Mizpah	33010007	9	6	3	4	1
Breakers Reef	33010009	16	250	1	0	0
Finks' Grouper Hole	33010022	14	44	0	1	0
Shark Reef	33010023	10	32	2	0	0
Amaryllis Wreck, West Palm	33010026	7	7	3	0	0
Scarface (Jupiter)	33010033	10	42	10	5	0
Opal Tower/HillsboroughDomes	33010038	12	64	0	2	0
Delray Ledge	33010042	13	64	1	1	0
Ancient Mariner	33010122	10	74	3	2	0
Rodeo 25	33010150	6	11	1	0	0
Anchor Chain E6	34030001	15	165	4	0	0
South Ledges/Undersea Hwy E3	34030003	14	125	1	0	0
Grecian Rocks	34030004	16	398	2	0	0
Key Largo Dry Rocks (Christ)	34030005	16	384	1	0	0
Carysfort Reef	34030006	15	217	1	0	0
South Carysfort Reef	34030007	15	109	2	0	0
French Reef	34030008	16	839	36	1	0
Molasses Reef	34030009	16	1630	56	18	0
Benwood Wreck	34030011	16	460	12	0	0
Mike's Wreck/Seneca E6/7	34030013	16	163	7	0	0
City of Washington Wreck	34030014	16	221	34	4	0
Train Wheel Wreck E4	34030017	11	60	2	1	0
Horseshoe Reef	34030018	16	104	9	1	0
Carysfort Deep Ledge	34030021	6	28	1	0	0
N. North Dry Rocks (Dble N.)	34030023	16	269	1	0	0
Wellwood Grounding Site M12	34030024	11	218	0	0	1
Duane Wreck	34030026	11	77	12	2	0

Bibb Wreck	34030027	7	7	5	2	0
Minnow Caves/N. Dry Rocks	34030028	16	203	1	0	0
Sand Island	34030030	14	93	1	0	0
The Elbow Reef	34030031	16	113	4	2	0
Banana Reef	34030032	11	21	2	0	0
The Slab	34030033	7	4	5	0	0
Dixie Ledge	34030036	7	77	6	0	0
Alligator Reef	34040002	13	157	1	0	0
Conch Reef	34040004	16	252	6	9	0
Wreck of the Eagle	34040007	10	28	7	14	0
Tennessee Reef Research	34040008	12	123	2	0	0
Pleasure Reef	34040011	10	31	2	0	0
Sombrero Reef	34050001	16	284	10	3	0
Samantha's Ledge	34050002	14	148	0	1	0
Coffins Patch	34050004	14	175	3	0	0
Looe Key - East	34050005	13	232	13	2	0
Looe Key - Research	34050006	9	90	5	0	0
Western Sambo	34080001	16	407	19	1	0
Eastern Sambo	34080002	12	135	6	0	0
Rock Key	34080003	16	221	12	4	0
Sand Key	34080004	16	280	4	0	0
Middle Sambo	34080005	13	122	3	0	0
Eastern Dry Rocks	34080008	15	204	18	1	0
Nine Foot Stake	34080009	12	113	1	0	0
Trinity Cove	34080016	9	37	4	2	0
Western Dry Rocks	34080018	14	210	1	0	0
Texas Rock	34100004	12	127	8	1	0
Pulaski	34100005	8	87	2	0	0
Riley's Hump	34100008	10	87	17	9	0
Windjammer Site (French Wrk)	34100015	9	34	14	2	0
Southwest Florida						
Clearwater Wreck	23010007	8	12	6	19	2
Rube Allen (Pinellas #1)	23010018	8	11	8	12	0
Veteran's Reef	23010043	7	6	3	5	0
Edison Artificial Reef	23050001	8	5	4	14	0
Charlie's Artificial Reef Pegasus	23050009	8	2	2	11	0
Boca Grande, Phosphate Pier	23050012	8	3	0	8	12

Bay Ronto	23050013	6	1	3	3	4
Mary's Artificial Reef	23050014	6	6	3	5	0
Charlie's Reef Hopper Cars	23050024	8	0	1	13	0
Pace's Place Reef	23050028	6	0	2	9	0
ARC Reef Pilings	23050035	6	3	4	0	0
Pace's Place Barge & Crane	23050036	6	2	1	6	0
Doc Kline Pilings	23050037	6	1	2	5	0
ARC Rubble	23050038	6	0	2	6	0
ARC Tetrahedrons	23050039	6	8	4	1	0
ARC Towers	23050048	7	0	0	11	8
South Reef Rock	23050056	6	8	5	5	0

Table 5.3. Relative standardized counts of goliath grouper from REEF surveys in southeast and southwest Florida waters with 95% confidence limits (LC and UC) and coefficient of variation.

Year	Relative index	LC	UC	CV
Southeast survey				
1994	0.15	0.04	0.26	0.39
1995	0.00	0.00	0.00	0.39
1996	0.06	-0.06	0.18	1.01
1997	0.47	0.18	0.76	0.32
1998	0.65	0.29	1.01	0.29
1999	0.58	0.28	0.89	0.27
2000	0.62	0.37	0.86	0.21
2001	0.57	0.40	0.74	0.15
2002	0.78	0.59	0.97	0.13
2003	1.65	1.32	1.98	0.10
2004	1.19	0.86	1.53	0.14
2005	1.36	0.92	1.80	0.16
2006	1.64	1.22	2.05	0.13
2007	2.42	1.95	2.88	0.10
2008	1.85	1.29	2.41	0.15
2009	2.02	1.58	2.45	0.11
Southwest survey				
1999	0.74	0.07	1.41	0.46
2000	0.82	0.50	1.14	0.20
2001	0.84	0.54	1.14	0.18
2002	1.09	0.76	1.41	0.15
2003	1.12	0.77	1.46	0.16
2004	1.23	0.81	1.64	0.17
2005	0.88	0.49	1.28	0.23
2006	0.98	0.61	1.34	0.19
2007	0.53	0.31	0.75	0.21
2008	1.61	0.66	2.55	0.30
2009	1.17	0.44	1.91	0.32

5.7. *FIGURES*

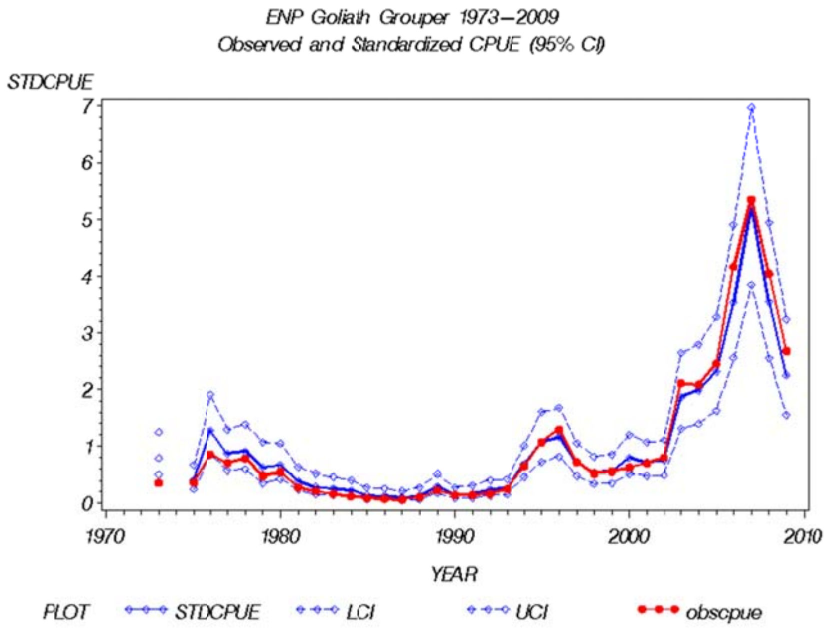
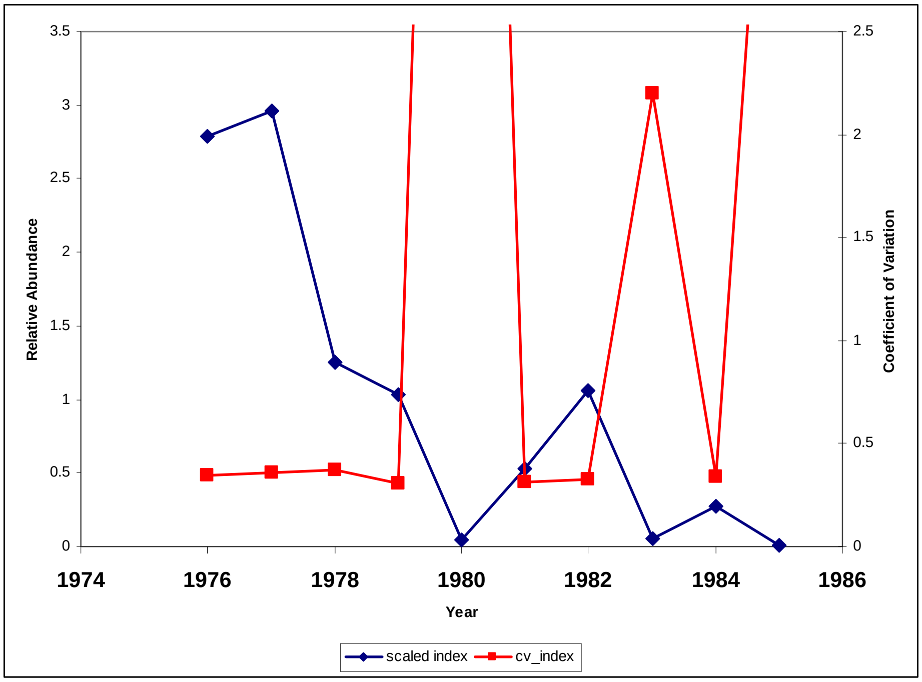
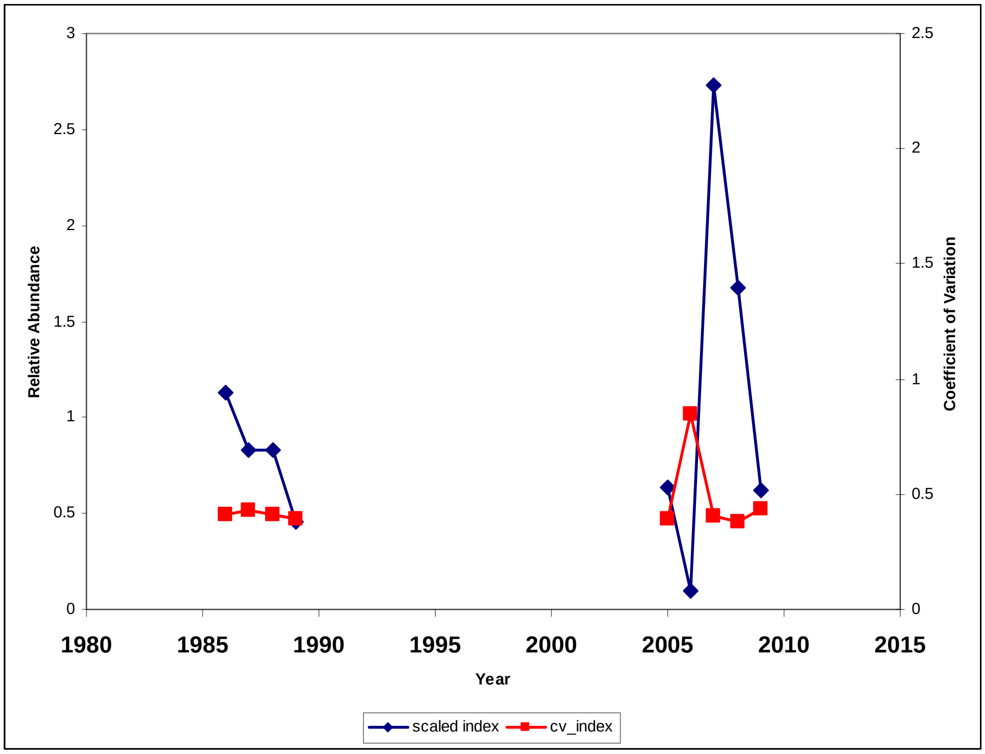


Figure 5.1. The nominal (red) and standardized catch per unit effort during 1973-2009 (solid red). Nominal CPUE is the average annual catch per unit effort before standardization. Both series have been scaled to their respective means. The dashed blue lines are the upper and lower 95% confidence limits for the standardized CPUE estimates.



Year	Modeled Frequency	Modeled Non-zero CPUE	Index	Scaled Index	CV
1976	0.021126	1.836007	0.038787	2.78372341	0.348168
1977	0.020223	2.037252	0.041200	2.9569142	0.357341
1978	0.008159	2.135467	0.017422	1.25040206	0.370409
1979	0.007847	1.838026	0.014423	1.03515847	0.307089
1980	0.004488	0.134916	0.000606	0.04346123	9.798135
1981	0.004043	1.812455	0.007327	0.52585993	0.310760
1982	0.006990	2.118325	0.014806	1.06263963	0.324357
1983	0.005068	0.158117	0.000801	0.05750754	2.198148
1984	0.001886	2.015016	0.003801	0.27278837	0.342376
1985	0.001538	0.104614	0.000161	0.01154516	4.69872

Figure 5.2. Annual abundance indices and corresponding CVs of Goliath grouper encountered by headboats from 1976 to 1985.



Year	Modeled Frequency	Modeled Non-zero CPUE	Index	Scaled Index	CV
1986	0.052703	1.125377	0.059311	1.128921	0.411015
1987	0.033821	1.285895	0.04349	0.827795	0.431727
1988	0.044337	0.984593	0.043654	0.830904	0.410809
1989	0.039106	0.609011	0.023816	0.453318	0.390926
2005	0.02329	1.44092	0.033559	0.638765	0.394512
2006	0.008477	0.589809	0.005	0.095165	0.850289
2007	0.038214	3.753649	0.143443	2.730288	0.404272
2008	0.042032	2.096232	0.08811	1.677079	0.382234
2009	0.034445	0.942242	0.032456	0.617765	0.433994

Figure 5.3. Annual abundance indices and corresponding CVs of Goliath grouper encountered by headboats from 1986 to 1989 and 2005 to 2009.

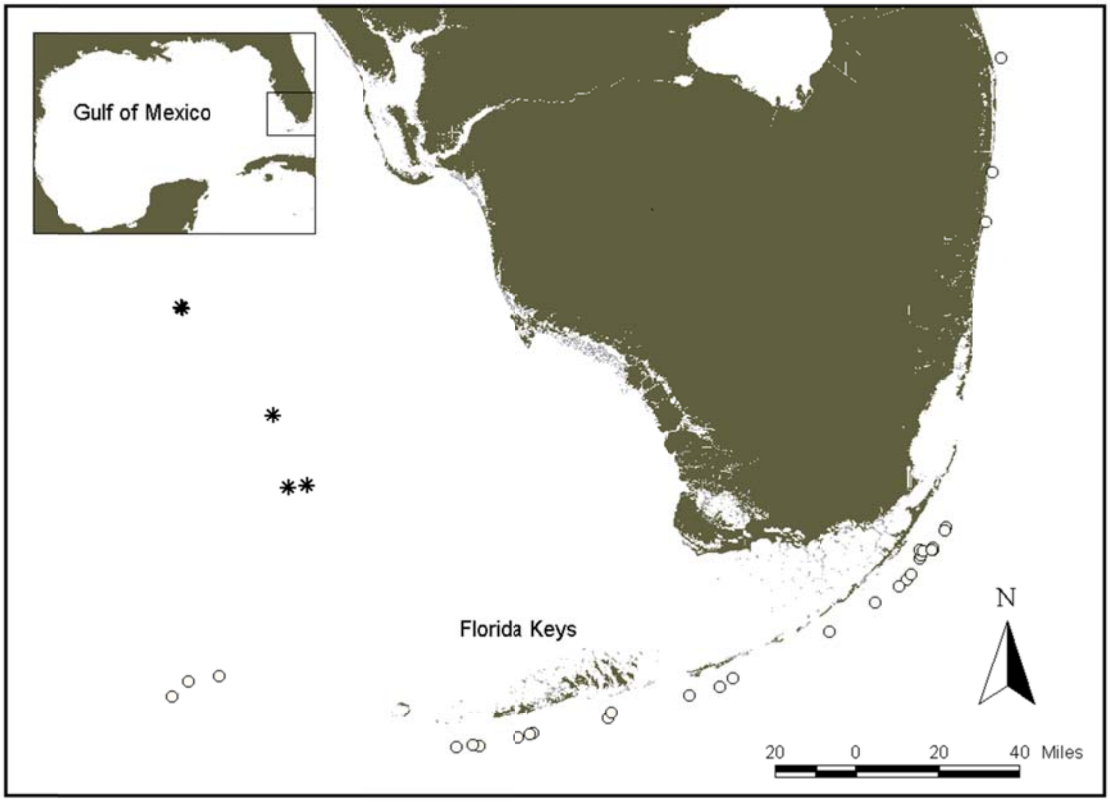


Figure 5.4. Survey locations for two diver censuses: asterisks represent artificial structures in the eastern Gulf of Mexico where goliath grouper were observed from 1982-2002; circles represent locations where the Reef Education and Environmental Foundation's volunteer divers observed goliath grouper from 1994-2002.

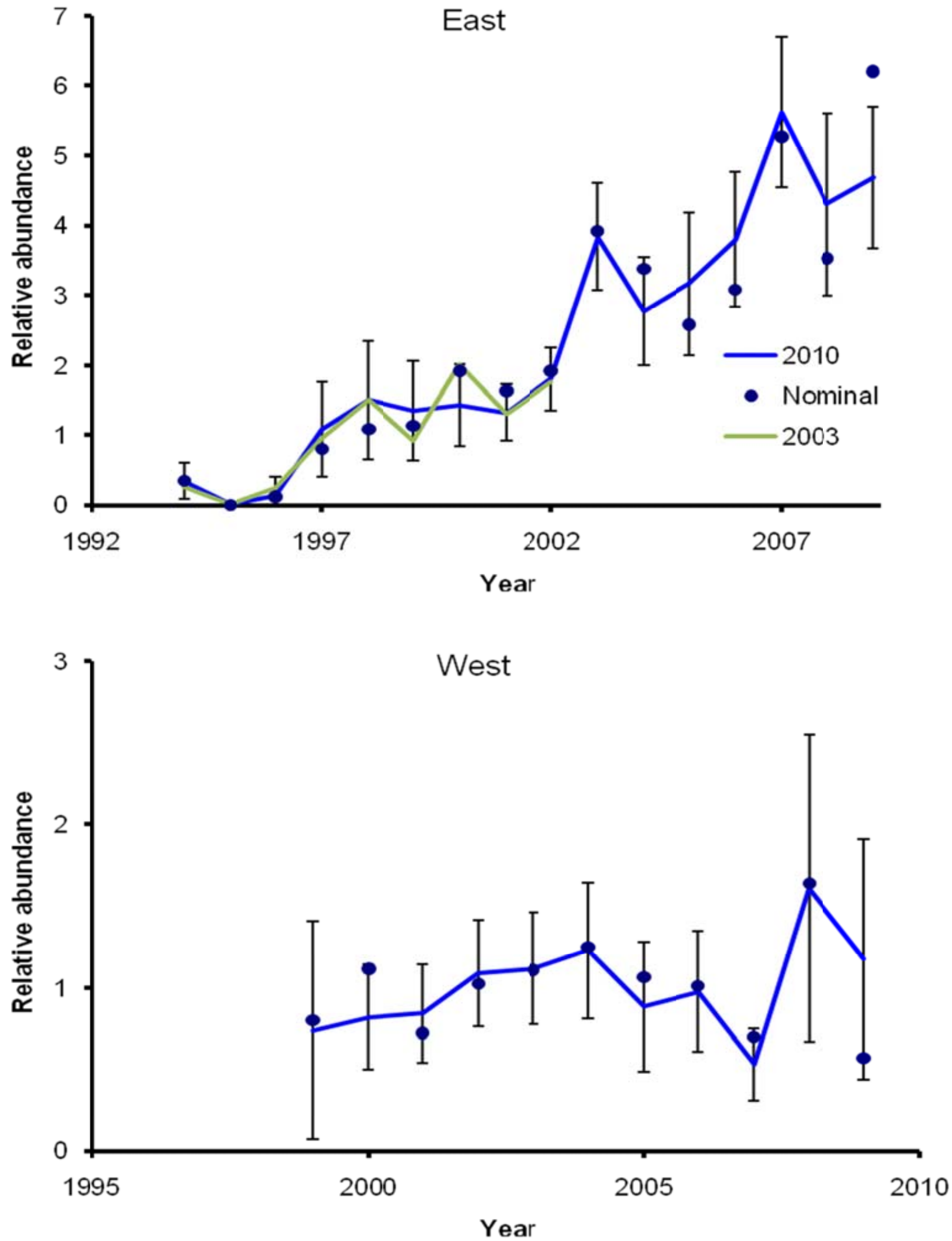


Figure 5.5. Relative standardized counts of goliath grouper (line) with approximate 95% confidence intervals compared with the corresponding nominal indices (circles) from the REEF database of diver observations of goliath grouper in Florida, U.S.A., from 1994-2009. The “East” index is presented relative to the 1994-2002 mean to facilitate comparison with the result from Porch and Eklund (2004). Nominal counts (dots) were computed as an average across all observations in a year assuming abundance category 2 represented 2 fish and abundance category 3 represented 11 fish.

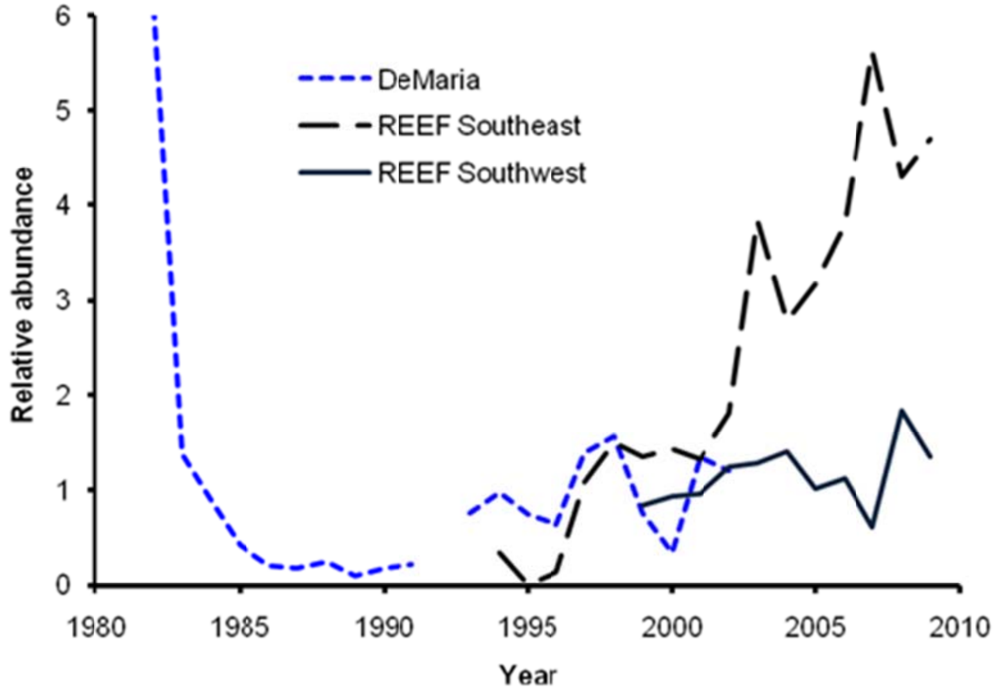


Figure 5.6. Comparison of REEF and DeMaria relative indices of goliath grouper abundance (normalized to the 1994-2002 means).

SEDAR

Southeast Data, Assessment, and Review

SEDAR 23

South Atlantic and Gulf of Mexico Goliath Grouper

SECTION III: Assessment Workshop Report

November 2010

SEDAR
4055 Faber Place Drive, Suite 201
North Charleston, SC 29405

Table of Contents

1. WORKSHOP PROCEEDINGS

1.1. INTRODUCTION

1.1.1 Workshop time and Place

The SEDAR 23 Assessment Workshop was held August 2 - 5, 2010 in Saint Petersburg, Florida. Additionally, a webinar was held on 15 September 2010.

1.1.2 Terms of Reference

1. Review any changes in data following the data workshop and any analyses suggested by the data workshop. Summarize data as used in each assessment model. Provide justification for any deviations from Data Workshop recommendations.
2. Develop population assessment models that are compatible with available data and recommend which model and configuration is deemed most reliable or useful for providing advice. Document all input data, assumptions, and equations.
3. Provide estimates of stock population parameters (fishing mortality, abundance, biomass, selectivity, stock-recruitment relationship, etc); include appropriate and representative measures of precision for parameter estimates.
4. Characterize uncertainty in the assessment and estimated values, considering components such as input data, modeling approach, and model configuration. Provide appropriate measures of model performance, reliability, and 'goodness of fit'.
5. Provide yield-per-recruit, spawner-per-recruit, and stock-recruitment evaluations, including figures and tables of complete parameters.
6. Provide estimates for SFA criteria consistent with applicable FMPs, proposed FMPs and Amendments, other ongoing or proposed management programs, and National Standards. This may include: evaluating existing SFA benchmarks, estimating alternative SFA benchmarks; and recommending proxy values.
7. Provide declarations of stock status relative to SFA benchmarks.
8. Perform a probabilistic analysis of proposed reference points and provide the probability of overfishing at various harvest or exploitation levels.
9. Project future stock conditions (biomass, abundance, and exploitation) and develop rebuilding schedules if warranted; include estimated generation time. Stock projections shall be developed in accordance with the following:
    A) If stock is overfished:
        F=0, F=current, F=Fmsy, Ftarget (OY),
        F=Frebuild (max that rebuild in allowed time)
    B) If stock is overfishing
        F=Fcurrent, F=Fmsy, F= Ftarget (OY)
    C) If stock is neither overfished nor overfishing
        F=Fcurrent, F=Fmsy, F=Ftarget (OY)
10. Provide recommendations for future research and data collection (field and assessment); be as specific as practicable in describing sampling design and sampling intensity and emphasize items which will improve future assessment capabilities and reliability.

11. Prepare an accessible, documented, labeled, and formatted spreadsheet containing all model parameter estimates and all relevant population information resulting from model estimates and any projection and simulation exercises. Include all data included in assessment report tables and all data that support assessment workshop figures.
12. Complete the Assessment Process Report (Section III of the SEDAR Stock Assessment Report), prepare a first draft of the Summary Report, and develop a list of tasks to be completed following the workshop.

1.1.3. List of Participants

Workshop Panel

Anne Lange .... SAFMC SSC
Bob Zales, II........ GMFMC AP
Gregg DeBrango .... SAFMC AP
Joe O'Hop .... FWC FWRI
Joseph Munyandorero .... FWC FWRI
Sean Powers .... GMFMC SSC

Council Representation

Ben Hartig .... SAFMC
Bill Teehan .... GMFMC

Observers

Chad Hanson .... Pew
Dave Chagaros .... FWC
Dustin Addis .... FWC
Dennis O'Hern .... GMFMC AP
Luiz Barbieri .... SAFMC and GMFMC SSC/FWC FWRI
Wade Cooper .... FWC

Staff

Karen Burns .... GMFMC Staff
Julie Neer .... SEDAR
Tina O'Hern .... GMFMC Staff
Tyree Davis .... NMFS Miami
Emily Muehlstein .... GMFMC Staff

1.1.4. List of Data Workshop Working and Reference Papers

Documents Prepared for the Assessment Workshop		
SEDAR23-AW-01	Standardized visual counts of goliath	Clay Porch

	grouper off south Florida	
SEDAR23-AW-02	Analysis of Headboat Data for Goliath Grouper	Walter Ingram
SEDAR23-AW-03	Standardized proportion of private vessel trips with catches of goliath grouper from the Marine Recreational Fisheries Statistics Survey in south Florida, 1991-2009	Joe O'Hop
Reference Documents		
SEDAR23-RD28	Behavior, Habitat, and Abundance of the Goliath Grouper, *Epinephelus itajara*, in the Central Eastern Gulf of Mexico	Angela B. Collins and Luiz R. Barbieri

1.2. *STATEMENTS ADDRESSING EACH TERMS OF REFERENCE*

1. Changes to data after the Data Workshop (DW) and analyses suggested at the DW are reviewed in Section 2 (Data Review and Update). The rationale for changes and additional analyses conducted after the DW and AW are also presented in that section.
2. There was one population model that was considered suitable for this assessment, and it was the "catch-free" stock assessment model as used in SEDAR 6 by Porch et al. (2003; 2006). There were some adjustments to the SEDAR 6 configuration based upon the DW and AW recommendations and follow-up analyses described in Section 2. A change in the calculation of natural mortality from constant to age-specific was incorporated into the model based on the DW recommendation. Additionally, exploratory analyses using stock-reduction analysis was conducted and is described in a SEDAR 23 working paper. Input data, assumptions, and equations are either documented in this document or are presented in Porch et al. (2003; 2006).
3. Estimates from the "catch-free" model are relative measures rather than equilibrium solutions for F and SSB that are needed to meet fishery management needs. The relative status for F and SSB in the current year and for projections provided by the model allow an assessment

of population status, but not for levels of allowable catch to meet management targets or goals.

4. Uncertainty for the relative F and SSB are addressed in part through the use of Markov Chain Monte Carlo methods and through sensitivity runs examining the effects of assuming different maximum ages for goliath grouper and different levels of the effectiveness of the moratorium on reducing fishing mortality since 1990. However, implementation uncertainty (because of compliance issues or natural events such as cold kills, red tides, and etc.) is not addressed.
5. Only relative measures for yield-per-recruit, spawner-per-recruit, and stock-recruitment evaluations are provided from the "catch-free" model and are of limited utility unless there are additional data that can be used to scale the relative values. While these values are calculated by the model, they are not tabulated.
6. Because only relative measures are computed by the "catch-free" model, they are not suitable "as is" for SFA requirements. However, the relative SSB- and F- ratios are presented in reference to the current SAFMC management benchmark for OY ($F_{50\%SPR}$).
7. Relative stock status is examined relative to the $F_{50\%SPR}$ and $SSB_{Fat\ 50\%SPR}$ management benchmarks.
8. A probabilistic analysis (using the MCMC) outcomes is presented regarding the relative benchmarks; however, because this assessment model does not use or estimate catches, there is no analysis of proposed harvesting or exploitation levels.
9. Projections of relative $SSB_{year}/SSB_{F\ at\ 50\%SPR}$ in future years using the currently estimated fishing mortality rate in 2009 are made. There is no actual estimate of fishing mortality rate in this closed fishery. F is estimated using a Bayesian prior developed by the DW participants.
10. Recommendations on future research and data collection were provided at the DW. An additional recommendation for a "research fishery" was briefly discussed at the Assessment Workshop (AW), but was never formalized.
11. Spreadsheets containing calculations for model parameters and containing results of model runs are available for the Review Workshop (RW) participants.

2. DATA REVIEW AND UPDATE

The SEDAR 23 Goliath Grouper Data Workshop (DW) was held on April 27-29, 2010 in St. Petersburg, Florida. Participants reviewed the available information on goliath grouper in the southeastern United States and made recommendations on the definition of the stock, age-specific natural mortality, maturity, length-weight relationships, growth curve, and a modified prior distribution for the potential effectiveness of the moratorium on harvest. New information on aging from spines and additional research survey data were explored for possible use in the assessment, commercial and recreational landings data were reviewed. The DW panel recommended that the aging information for specimens collected by Brusher and Schull (2009) be combined with the Bullock et al. (1992) data to form the basis for a new growth curve to be developed for the Assessment Workshop (AW).

The SEDAR 23 AW was held on August 2-5, 2010 in St. Petersburg, Florida. Participants reviewed the recommendations from the DW and the reports by the working groups. New indices of abundance based on the REEF, MRFSS, and Head Boat Surveys were developed for potential inclusion into the catch-free (Porch et al. 2006) model. Additional information on historical commercial landings (and adjustments to landings) was presented, and new data from research surveys of habitats in the West Florida shelf (Collins and Barbieri 2010) became available. The AW panel was presented with some initial model runs using the lengthened (through 2009) index series for the Everglades National Park (ENP) Angler Creel Survey and REEF (Atlantic Coast and Florida Keys) consistent in configuration with previous runs made during SEDAR 6 as well as preliminary runs made with the new growth curve parameters and priors on moratorium effectiveness.

The AW made several recommendations for preceding with the assessment including revisions to the length-weight equation (omitting three observations from newspaper accounts), revising the MRFSS catch index (proportion positives) to include all regions rather than just southeast and southwest Florida, and revising the age distribution and vulnerability curve for goliath grouper measured in the ENP Angler Creel Survey based upon the new growth curve. The AW panel recommended dropping the interview index used in SEDAR 6, and not to use the newly developed Head Boat Survey catch index because it covered only a relatively short portion of the time series. Additionally, the AW recommended that the 1942-1950 portion of the commercial landings series (not used in the catch-free model) should be smoothed to reduce the impact of an apparently large increase in landings during the 1942-1945 years on analyses (e.g, stock-reduction analyses) which would make use of those data. There was some concern that the early portion of the commercial landings may not have been reliably reported. The commercial landings series (and recreational landings if possible) could be useful for a stock reduction analysis (SRA; e.g., Martell et al. 2008), and was proposed as a further exploration of these data to examine potential management benchmarks that may arise from such an analysis (SEDAR 23-RW-01).

Following the AW, a webinar was held on September 15, 2010 to discuss the revisions recommended by the AW panel and progress on model parameters. The 1942-1950 commercial landings were re-analyzed and loess estimates for this portion of the commercial landings (Figure 2.2.1) were presented. In addition, because it is beneficial for stock reduction analyses to use longer time series, commercial landings data from 1918 to the present with loess smoothing applied to the 1918-1950 portion of the time series was proposed for use in the SRA. A revised length-weight equation (Table 2.1.1) and the coefficient of variation for length measurements by age were calculated for use in the catch-free and SRA models. A revised growth curve (Table 2.1.2, Figure 2.2.2) was also calculated. A revised MRFSS catch (proportion positives) index (Figure 2.2.3) was presented. A revised age distribution and vulnerability curve for the ENP Angler Creel Survey based on the revised growth curve and age-adjusted natural mortality were presented (Figure 2.2.4) and compared to the results (Figure 2.2.5) from SEDAR 6 using a total mortality (fishing and natural mortality) adjusted age-length key method (Porch et al., 2003). In addition, the vulnerability relationship linking the diver surveys (DeMaria, REEF southeast and REEF southwest) and the MRFSS index to age ranges in the model was developed using the lengths of goliath grouper measured in offshore habitats (Collins and Barbieri, 2010) and the revised growth curve –natural mortality age-adjusted probabilistic aging method and compared to the logistic equation used in SEDAR 6 (Figure 2.2.6).

The remainder of the webinar was used to discuss a preliminary run of a SRA and a preliminary run of the catch-free model showing the fits to the five indices recommended by the AW panel and the resultant biomass trajectory. The webinar participants suggested that sensitivity runs encompass a range of natural mortality values corresponding to maximum ages for goliath grouper that were 25%, 50%, 75% and 100% older than the known maximum age (37 years).

Following the webinar, additional work was needed for computing model parameters that were sensitive to the natural mortality estimates suggested for sensitivity runs. Both (juvenile for the ENP index and adult for the offshore indices) of the vulnerability curves for the indices should depend upon natural mortality estimates for deriving the functional relationships between vulnerability and age. A range of hypothetical maximum ages (40, 50, 60, 70, and 80 years) for goliath grouper was chosen to represent the uncertainty in the knowledge of the maximum longevity of this species. Natural mortality rates based on maximum age were estimated following Hewitt and Hoenig (2005), and age-adjusted natural mortality rates were calculated (Table 2.1.3) following Lorenzen (2005) and a spreadsheet solution supplied at a previous SEDAR by Dr. Paul Medley.

Coding and model configuration for incorporating age-adjusted natural mortalities internally within the catch-free model was provided by Dr. Clay Porch (NOAA Fisheries, Southeast Fisheries Science Center, personal communication). The coding for the age-specific natural mortality rates used a biomass relationship (Table 2.1.4) rather than numbers as provided at the DW. Age-specific natural mortality as a function of biomass is calculated following Lorenzen (1996) in the model as follows:

$$\mathbf{M}_{\boldsymbol{L,a}} = \mathrm{M}_u \cdot \mathbf{w}_{\boldsymbol{a}}^{\mathbf{b}},$$

where a is age, M_u is the natural mortality rate per year at unit weight, **b** is the allometric scaling factor, $\mathbf{w}_{\boldsymbol{a}}$ is the weight at age (mid-year) in grams, and $\mathbf{M}_{\boldsymbol{L,a}}$ is the age-specific mortality rate per year at mean length at age. Values for M_u and **b** were for "natural systems" from Lorenzen (1996), and are equal to 3 and -0.288, respectively. If age-specific mortality rates are calculated over a specific range of ages or weights are not in grams, this equation is modified as follows:

$$\mathbf{M}_{\boldsymbol{L,a}} = \mathrm{M}_u \cdot (\mathbf{\Sigma M}_{\boldsymbol{C,r}} / \mathbf{\Sigma M}_{\boldsymbol{L,r}}) \cdot \mathbf{c} \cdot \mathbf{w}_{\boldsymbol{a}}^{\mathbf{b}},$$

where **r** is the number of ages over which the adjustment factor is calculated, $\mathbf{\Sigma M}_{\boldsymbol{C,r}}$ is the cumulative sum of constant natural mortality rates over the desired range of ages (i.e., $\mathbf{r} \cdot \mathbf{M}$), $\mathbf{\Sigma M}_{\boldsymbol{L,r}}$ is the cumulative sum of the age-specific natural mortality rates over that same range of ages, and **c** is a scaling factor to convert the weight units to grams. [For example, if biomass units are kilograms, $\mathbf{c} = (1000\text{g/kg})^{-0.288}$.] The values for "alpha" in Table 2.1.4 correspond to the maximum ages used in calculating age-specific natural mortality are model input parameters and equal $[\mathrm{M}_u \cdot (\mathbf{\Sigma M}_{\boldsymbol{C,r}} / \mathbf{\Sigma M}_{\boldsymbol{L,r}}) \cdot \mathbf{c}]$.

After the webinar, Dr. Porch discussed the development of the age-length key used in SEDAR 6 (Porch et al. 2003) which incorporated a constant natural mortality rate and a lower-bounded estimate for fishing mortality. The proportions of lengths at age (binned in 20 mm or other desired increments) from the aged samples (Brusher and Schull 2009) were calculated. The sum of lengths in each length category (binned in the same increments as the aged sample) from the ENP Angler Creel Survey measurements were multiplied by the proportions of lengths at age from the aged samples. The sum of the products of lengths at each age is an estimate of the expected number (unadjusted for total mortality) at each age ($\mathbf{e_a}$) in the unaged sample. Four parameters (N, F, and mode and cv for a gamma distribution) are given starting values and used for an iterative solution to minimize a residual sum of squares at a given natural mortality estimate. A hypothetical population is constructed by calculating:

$$\mathbf{N}_a = \mathbf{N}_{a-1} \cdot \mathbf{e}^{(-(\mathbf{M}+\mathbf{F})\cdot \mathbf{s}_{a}-1)},$$

where $\mathbf{N}_a$ is the number of animals expected at age, **M** is the estimate of natural mortality (fixed for an age), **F** is fishing mortality (iteratively solved for and bounded at some minimum value), and $\mathbf{s}_{a-1}$ is the vulnerability at age from the fitted distribution (in this case, a gamma distribution). Vulnerability at age is calculated by:

$$\mathbf{s}_a = [(\mathbf{a} / \mathbf{x}) \cdot \mathbf{e}^{(1-\mathbf{a}/\mathbf{x})\wedge(1/(\mathbf{cv}^2)-1)}]$$

where **x** and **cv** are the trial mean and cv of a gamma function. The predicted number at age ($\mathbf{p}_a$) adjusting for total mortality is calculated by:

$$\mathbf{p}_a = \mathbf{F} \cdot \mathbf{s}_a \cdot \mathbf{N}_a \cdot (1-\mathbf{e}^{(-(\mathbf{M}+\mathbf{F})\cdot \mathbf{s}_a)} / (\mathbf{M} + \mathbf{F} \cdot \mathbf{s}_a),$$

and the residual sum of squares ($\mathbf{r}_a$) is calculated as:

$$\mathbf{r}_a = (\mathbf{p}_a - \mathbf{e}_a)^2,$$

where the $\mathbf{e}_a$ are the calculated number of animals expected from the numbers at age calculated from the age-length key without adjusting for mortality, and these equations are solved iteratively to minimize the residual sum of squares.

As a result of this discussion, the vulnerability curve for the ENP Angler Creel Survey Index was re-examined with the age-length key technique used in SEDAR 6, adjusting for age-specific natural mortality rates (Lorenzen, based on numbers) and using a bounded fishing mortality rate (Figure 2.2.7). The fits appeared more satisfactory than the revised growth curve-age-adjusted natural mortality probabilistic method (Figure 2.2.4) proposed during the webinar, and the parameters in Table 2.1.5 were derived using this age-length key method.

Logistic fits to the estimated offshore age distribution (adjusting for age-specific natural mortality and the new growth curve) also were calculated using the total mortality adjusted age-length key method (Table 2.1.6) and compared to the relationship assumed for SEDAR 6 (Figure 2.2.8). The SEDAR 6 parameters were chosen based upon the vulnerability curve derived for inshore habitats (i.e., Everglades National Park) and the indications from research studies that larger animals appeared to leave these habitats presumably for offshore areas. The data from the Bullock et al. (1992) study were thought to be potentially biased towards larger animals and the animals sampled and aged may not represent the true vulnerability of goliath grouper to fishing mortality in offshore habitats. With the availability of the underwater measurements of goliath grouper in offshore habitats, it seemed like an opportune time to examine the possible age structure of animals in those habitats using an age-length key. Unfortunately, there is no sure way to test whether the estimated age structure is close to the real age structure without some representative sampling for the ages of those animals. The revised fits have very similar points of inflection (a_{50}) ranging from 5.5 to 5.2 but are not as knife-edged in selectivity (slopes range from 1.02 to 1.06 depending upon the natural mortality rate used) compared to fixed slope of 0.2 in SEDAR 6. The fits seem reasonable in that there are smaller (and presumably younger) goliath groupers in offshore areas along with larger (and presumably older) ones, so the vulnerability curve should allow for some interaction of the offshore-derived indexes (DeMaria, REEF southeast, REEF southwest, and MRFSS) with younger ages rather than being so “knife-edged” in vulnerability. Compared to the logistic fit from the new growth curve and age-specific natural mortality rate probabilistic method (Figure 2.2.5), the age-length key method produces a steeper curve (Figure 2.2.8), allows for some vulnerability of the younger aged fish occurring in offshore areas, and as such is a little more conservative in its implications for vulnerability at age. For these reasons, the vulnerability curve for the offshore portions of the goliath grouper population was modeled using the total mortality adjusted age-length key method.

2.1. TABLES

Table	Description
2.1.1	Revised goliath grouper length (TL, mm)-weight (whole, kg) conversion equations (power function, $\log_e$ transformed linear fit and non-linear fit).
2.1.2	Revised growth (von Bertalannfy) equation combining age data from Bullock et al. (1992) and Brusher and Schull (2009).
2.1.3	Constant and age-adjusted natural mortality vectors (based on population numbers) for several hypothetical maximum ages. Values are calculated for mid-year, and adjusted for target ages starting at age 4 and ending at the maximum age. The target M value was derived following Hewitt and Hoenig (2005). $\mathbf{M}_c$ = constant natural mortality rate. $\mathbf{M}_L$ =age-adjusted natural mortality rate at mean length (L) at age.
2.1.4	Age-adjusted natural mortality vectors (based on population biomass) for several hypothetical maximum ages. Values are calculated for mid-year, and adjusted for target ages starting at age 4 and ending at the maximum age. The target M value was derived following Hewitt and Hoenig (2005). "Alpha" is a multiplier to adjust for ranges of target ages, and may be further modified if biomass is not in grams. $\mathbf{M}_L$ =age-adjusted natural mortality rate.
2.1.5	Parameters (mean, cv) of gamma fits for the vulnerability curve linked to the ENP Angler Creel Survey Index. F is the fishing mortality rate, and N is numbers of fish. Both are bounded at minimum values and are adjusted during the fitting process (minimizing a residual sum of squares) to estimate the mean and cv of the gamma fit.
2.1.6	Parameters (a_{50},slope) of logistic fits for the vulnerability curve linked to the offshore (adult) indices. F is the fishing mortality rate arbitrarily bounded at 0.1, and N is numbers of fish. Both are bounded at minimum values and are adjusted during the fitting process (minimizing a residual sum of squares) to estimate the a_{50} value (inflection point for the curve, interpreted as the age at 50% vulnerability) and slope of the logistic fit.

Table 2.1.1. Revised goliath grouper length (TL, mm)-weight (whole, kg) conversion equations (power function, $\log_e$ transformed linear fit and non-linear fit).

Dependent vs. independent	model	n	ln(a)	a	b	MSE
Whole wt (kg) vs. TL (mm)	Wt=ln(a)+b·ln(TL)	1,211	-18.8530	6.490e-09	3.151	0.01526
Whole wt (kg) vs. TL (mm)	$Wt = a \cdot TL^b$	1,211	-------	1.0113-08	3.090	6.0237

Table 2.1.2. Revised growth (von Bertalannfy) equation combining age data from Bullock et al. (1992) and Brusher and Schull (2009).

Study	L_∞ (mm)	k ($year^{-1}$)	t_0 (years)	n
SEDAR 23	2,221	0.0937	-0.6842	1,401

Table 2.1.3. Constant and age-adjusted natural mortality vectors (based on population numbers) for several hypothetical maximum ages. Values are calculated for mid-year, and adjusted for target ages starting at age 4 and ending at the maximum age. The target M value was derived following Hewitt and Hoenig (2005). $\mathbf{M}_c$ = constant natural mortality rate. $\mathbf{M}_L$ =age-adjusted natural mortality rate at mean length (L) at age.

max. age	**37**		**40**		**50**		**60**		**70**		**80**	
start age	4		4		4		4		4		4	
end age	37		40		50		60		70		80	
Target M	0.1217		0.1128		0.0906		0.0757		0.0651		0.0571	
Age	$\mathbf{M}_c$	$\mathbf{M}_L$	$\mathbf{M}_c$	$\mathbf{M}_L$	$\mathbf{M}_c$	$\mathbf{M}_L$	$\mathbf{M}_c$	$\mathbf{M}_L$	$\mathbf{M}_c$	$\mathbf{M}_L$	$\mathbf{M}_c$	$\mathbf{M}_L$
0		0.660		0.623		0.523		0.452		0.397		0.355
1	0.941	0.425	0.945	0.401	0.956	0.337	0.963	0.291	0.968	0.256	0.972	0.229
2	0.833	0.322	0.844	0.304	0.873	0.256	0.893	0.221	0.907	0.194	0.918	0.173
3	0.738	0.264	0.754	0.249	0.797	0.209	0.828	0.181	0.850	0.159	0.867	0.142
4	0.653	0.227	0.674	0.214	0.728	0.180	0.767	0.155	0.796	0.137	0.819	0.122
5	0.578	0.201	0.602	0.190	0.665	0.160	0.711	0.138	0.746	0.121	0.773	0.108
6	0.512	0.183	0.538	0.172	0.608	0.145	0.659	0.125	0.699	0.110	0.731	0.098
7	0.453	0.168	0.480	0.159	0.555	0.133	0.611	0.115	0.655	0.101	0.690	0.090
8	0.401	0.157	0.429	0.148	0.507	0.124	0.567	0.107	0.614	0.095	0.652	0.084
9	0.355	0.148	0.383	0.140	0.463	0.117	0.525	0.101	0.575	0.089	0.616	0.080
10	0.315	0.141	0.343	0.133	0.423	0.112	0.487	0.096	0.539	0.085	0.581	0.076
11	0.279	0.135	0.306	0.127	0.386	0.107	0.452	0.092	0.505	0.081	0.549	0.072
12	0.247	0.130	0.273	0.122	0.353	0.103	0.419	0.089	0.473	0.078	0.519	0.070
13	0.218	0.125	0.244	0.118	0.322	0.099	0.388	0.086	0.443	0.075	0.490	0.067
14	0.193	0.122	0.218	0.115	0.294	0.096	0.360	0.083	0.415	0.073	0.463	0.065
15	0.171	0.118	0.195	0.112	0.269	0.094	0.334	0.081	0.389	0.071	0.437	0.064
16	0.152	0.116	0.174	0.109	0.246	0.092	0.309	0.079	0.365	0.070	0.413	0.062
17	0.134	0.113	0.156	0.107	0.224	0.090	0.287	0.078	0.342	0.068	0.390	0.061
18	0.119	0.111	0.139	0.105	0.205	0.088	0.266	0.076	0.320	0.067	0.368	0.060
19	0.105	0.109	0.124	0.103	0.187	0.087	0.246	0.075	0.300	0.066	0.348	0.059
20	0.093	0.108	0.111	0.102	0.171	0.085	0.228	0.074	0.281	0.065	0.328	0.058
21	0.082	0.106	0.099	0.100	0.156	0.084	0.212	0.073	0.263	0.064	0.310	0.057
22	0.073	0.105	0.089	0.099	0.143	0.083	0.196	0.072	0.247	0.063	0.293	0.056
23	0.065	0.104	0.079	0.098	0.130	0.082	0.182	0.071	0.231	0.063	0.277	0.056
24	0.057	0.103	0.071	0.097	0.119	0.082	0.169	0.070	0.217	0.062	0.261	0.055
25	0.051	0.102	0.063	0.096	0.109	0.081	0.156	0.070	0.203	0.061	0.247	0.055
26	0.045	0.101	0.056	0.095	0.099	0.080	0.145	0.069	0.190	0.061	0.233	0.054
27	0.040	0.101	0.050	0.095	0.091	0.080	0.134	0.069	0.178	0.061	0.220	0.054
28	0.035	0.100	0.045	0.094	0.083	0.079	0.125	0.068	0.167	0.060	0.208	0.054
29	0.031	0.099	0.040	0.094	0.076	0.079	0.116	0.068	0.156	0.060	0.197	0.053
30	0.028	0.099	0.036	0.093	0.069	0.078	0.107	0.068	0.147	0.059	0.186	0.053
31	0.024	0.098	0.032	0.093	0.063	0.078	0.099	0.067	0.137	0.059	0.175	0.053
32	0.022	0.098	0.029	0.092	0.058	0.078	0.092	0.067	0.129	0.059	0.166	0.053
33	0.019	0.098	0.026	0.092	0.053	0.077	0.085	0.067	0.121	0.059	0.156	0.052
34	0.017	0.097	0.023	0.092	0.048	0.077	0.079	0.066	0.113	0.058	0.148	0.052
35	0.015	0.097	0.020	0.091	0.044	0.077	0.073	0.066	0.106	0.058	0.140	0.052
36	0.013	0.097	0.018	0.091	0.040	0.077	0.068	0.066	0.099	0.058	0.132	0.052
37	0.012	0.096	0.016	0.091	0.037	0.076	0.063	0.066	0.093	0.058	0.124	0.052
38	0.010	0.096	0.015	0.091	0.033	0.076	0.058	0.066	0.087	0.058	0.118	0.052
39	0.009	0.096	0.013	0.090	0.031	0.076	0.054	0.066	0.082	0.058	0.111	0.051
40	0.008	0.096	0.012	0.090	0.028	0.076	0.050	0.065	0.076	0.058	0.105	0.051

Table 2.1.4. Age-adjusted natural mortality vectors (based on population biomass) for several hypothetical maximum ages. Values are calculated for mid-year, and adjusted for target ages starting at age 4 and ending at the maximum age. The target M value was derived following Hewitt and Hoenig (2005). "Alpha" is a multiplier to adjust for ranges of target ages, and may also be adjusted if biomass is not in grams. $\mathbf{M}_L$ =age-adjusted natural mortality rate.

max. age	**37**	**40**	**50**	**60**	**70**	**80**
start age	4	4	4	4	4	4
end age	37	40	50	60	70	80
Target M	0.1217	0.1128	0.0906	0.0757	0.0651	0.0571
alpha*	0.453311	0.426729	0.357335	0.307574	0.270053	0.240728
Age	$\mathbf{M}_L$	$\mathbf{M}_L$	$\mathbf{M}_L$	$\mathbf{M}_L$	$\mathbf{M}_L$	$\mathbf{M}_L$
0	0.711	0.669	0.560	0.482	0.424	0.378
1	0.429	0.404	0.338	0.291	0.256	0.228
2	0.320	0.301	0.252	0.217	0.190	0.170
3	0.261	0.245	0.205	0.177	0.155	0.138
4	0.224	0.211	0.176	0.152	0.133	0.119
5	0.199	0.187	0.157	0.135	0.118	0.106
6	0.181	0.170	0.142	0.123	0.108	0.096
7	0.167	0.157	0.131	0.113	0.099	0.089
8	0.156	0.147	0.123	0.106	0.093	0.083
9	0.148	0.139	0.116	0.100	0.088	0.078
10	0.141	0.132	0.111	0.095	0.084	0.075
11	0.135	0.127	0.106	0.091	0.080	0.072
12	0.130	0.122	0.102	0.088	0.077	0.069
13	0.126	0.118	0.099	0.085	0.075	0.067
14	0.122	0.115	0.096	0.083	0.073	0.065
15	0.119	0.112	0.094	0.081	0.071	0.063
16	0.117	0.110	0.092	0.079	0.070	0.062
17	0.114	0.108	0.090	0.078	0.068	0.061
18	0.112	0.106	0.089	0.076	0.067	0.060
19	0.111	0.104	0.087	0.075	0.066	0.059
20	0.109	0.103	0.086	0.074	0.065	0.058
21	0.108	0.101	0.085	0.073	0.064	0.057
22	0.107	0.100	0.084	0.072	0.063	0.057
23	0.105	0.099	0.083	0.072	0.063	0.056
24	0.105	0.098	0.082	0.071	0.062	0.056
25	0.104	0.098	0.082	0.070	0.062	0.055
26	0.103	0.097	0.081	0.070	0.061	0.055
27	0.102	0.096	0.081	0.069	0.061	0.054
28	0.102	0.096	0.080	0.069	0.061	0.054
29	0.101	0.095	0.080	0.069	0.060	0.054
30	0.101	0.095	0.079	0.068	0.060	0.053
31	0.100	0.094	0.079	0.068	0.060	0.053
32	0.100	0.094	0.079	0.068	0.059	0.053
33	0.099	0.093	0.078	0.067	0.059	0.053
34	0.099	0.093	0.078	0.067	0.059	0.053
35	0.099	0.093	0.078	0.067	0.059	0.052
36	0.098	0.093	0.078	0.067	0.059	0.052
37	0.098	0.092	0.077	0.067	0.058	0.052
38	0.098	0.092	0.077	0.066	0.058	0.052
39	0.098	0.092	0.077	0.066	0.058	0.052
40	0.098	0.092	0.077	0.066	0.058	0.052

Table 2.1.5. Parameters (mean, cv) of gamma fits for the vulnerability curve linked to the ENP Angler Creel Survey Index. F is the fishing mortality rate, and N is numbers of fish. Both are bounded at minimum values and are adjusted during the fitting process (minimizing a residual sum of squares) to estimate the mean and cv of the gamma fit.

max. age	37		40		50		60		70		80	
	M_c	M_L	M_c	M_L	M_c	M_L	M_c	M_L	M_c	M_L	M_c	M_L
F	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100
N	2620.9	5589.6	2531.9	5204.4	2324.1	4318.4	2195.2	3776.8	2108.2	3413.5	2045.1	3154.1
mode	3.4903	3.6320	3.4756	3.6117	3.4394	3.5591	3.4156	3.5218	3.3989	3.4939	3.3864	3.4723
cv	0.3437	0.3395	0.3436	0.3396	0.3433	0.3400	0.3431	0.3403	0.3430	0.3405	0.3429	0.3407

Table 2.1.6. Parameters (a_{50},slope) of logistic fits for the vulnerability curve linked to the offshore (adult) indices. F is the fishing mortality rate arbitrarily bounded at 0.1, and N is numbers of fish. Both are bounded at minimum values and are adjusted during the fitting process (minimizing a residual sum of squares) to estimate the a_{50} value (inflection point for the curve, interpreted as the age at 50% vulnerability) and slope of the logistic fit.

max. age	37		40		50		60		70		80	
	M_c	M_L	M_c	M_L	M_c	M_L	M_c	M_L	M_c	M_L	M_c	M_L
F	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100
N	19.52	51.26	18.45	45.98	15.51	34.56	13.81	28.11	12.72	24.04	11.95	21.27
a_{50}	5.3862	5.5272	5.3509	5.4912	5.2384	5.3914	5.1601	5.3144	5.1029	5.2532	5.0589	5.2034
slope	1.0895	1.0244	1.0907	1.0298	1.0930	1.0430	1.0934	1.0517	1.0930	1.0576	1.0924	1.0619

2.2. FIGURES

Figure	**Description**
2.2.1	Reconstructed historical commercial landings of goliath grouper reported in Florida, 1918 to 2009. Loess smoothing was applied to the reported commercial landings for 1918 to 1950, and linear interpolation between loess estimates was used to fill gaps in the landings series.
2.2.2	Revised growth (von Bertalannfy model) curve combining the lengths and ages from otoliths collected by Bullock et al. (1992), spine and otolith ages and lengths from Brusher and Schull (2009), and ages and lengths from specimens collected from cold kills and other sources.
2.2.3	Revised MRFSS catch index (proportion positives) using all regions of Florida. Proportion postives for trips (n=153,355) with catch of goliath grouper. Interviews from the same trip were pooled from MRFSS private/rental boat trips from 1991-2009 even if there was no catch of any fish). Final model variables : year, survey region, and water body.
2.2.4	Estimated age frequency of angler-caught goliath grouper in the Everglades National Park (1974-1990) using the new growth curve and age-adjusted natural mortality from specimens measured during 1997-2002 by Brusher and Schull (2009). The vulnerability curve developed for SEDAR 6 (Porch et al. 2003) is also shown
2.2.5	Length measurements of goliath grouper from inshore and offshore studies show movement of larger animals to offshore habitats. Estimated age frequency of goliath grouper in offshore habitats of the West Florida shelf using length measurements by divers (Collins and Barbieri 2010). The resulting vulnerability curve (logistic fit) is linked to the indices which apply to offshore (adult) animals.
2.2.6	Estimated age frequency of angler-caught goliath grouper in the Everglades National Park (1974-2001) using an age-length key developed for SEDAR 6 (Porch et al. 2003) from specimens measured during 1997-2002 by Brusher and Schull (2009).
2.2.7	Estimated age frequency of angler-caught goliath grouper in the Everglades National Park (1974-2001) using an age-length key developed for SEDAR 23 from specimens measuredd during 1997-2002 by Brusher and Schull (2009).
2.2.8	Vulnerability curve using estimates of ages from underwater measurements of total length of goliath grouper in offshore habitats on the West Florida shelf (Collins and Barbieri 2010) using an age-length key developed for SEDAR 23

	using age determinations from Bullock et al. (1992), Brusher and Schull (2009), and additional specimens from cold kills and other sources that were aged.

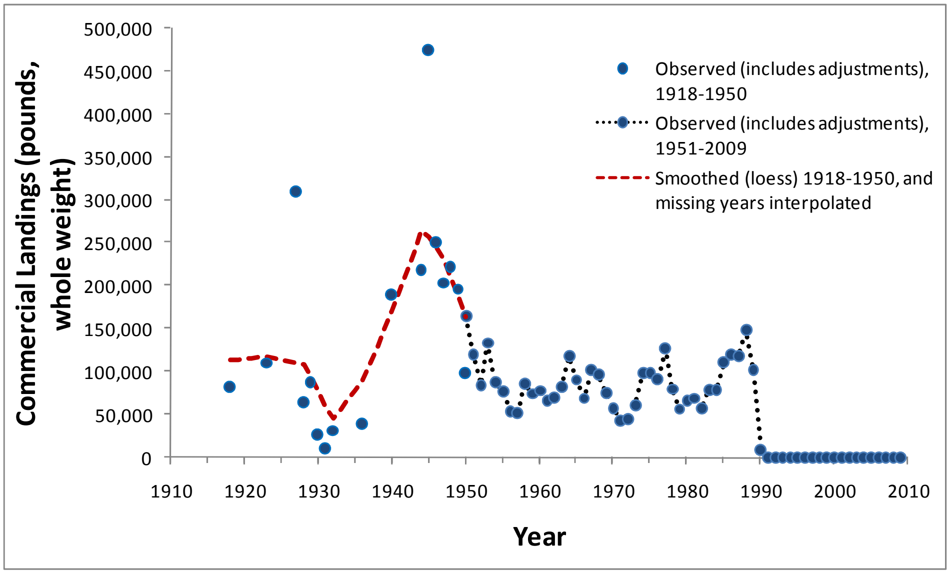


Figure 2.2.1. Reconstructed historical commercial landings of goliath grouper reported in Florida, 1918 to 2009. Loess smoothing was applied to the reported commercial landings for 1918 to 1950, and linear interpolation between loess estimates was used to fill gaps in the landings series.

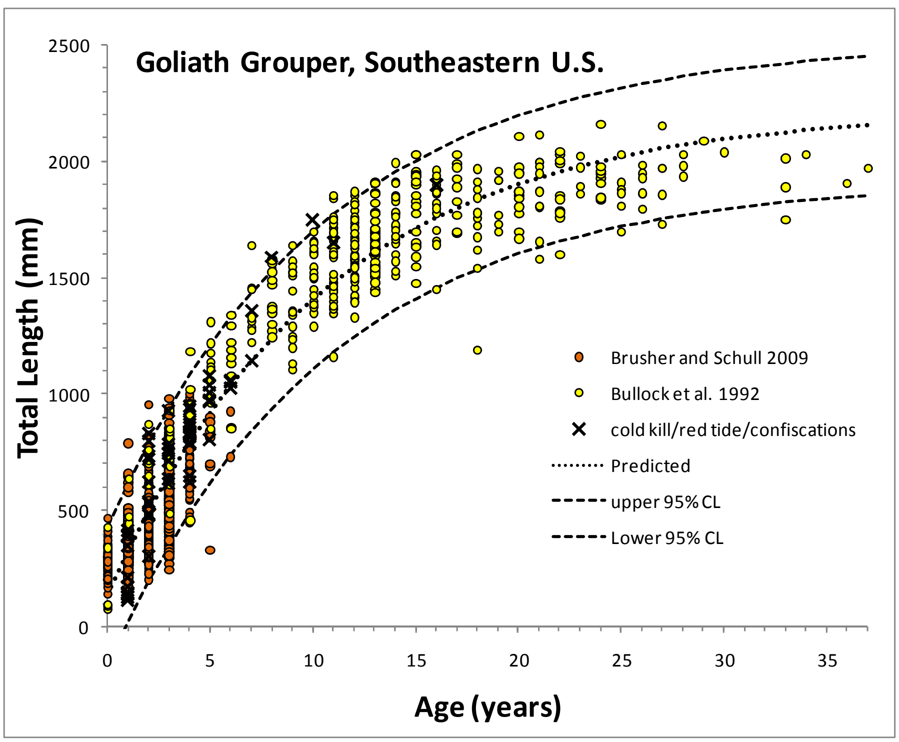


Figure 2.2.2. Revised growth (von Bertalannfy model) curve combining the lengths and ages from otoliths collected by Bullock et al. (1992), spine and otolith ages and lengths from Brusher and Schull (2009), and ages and lengths from specimens collected from cold kills and other sources.

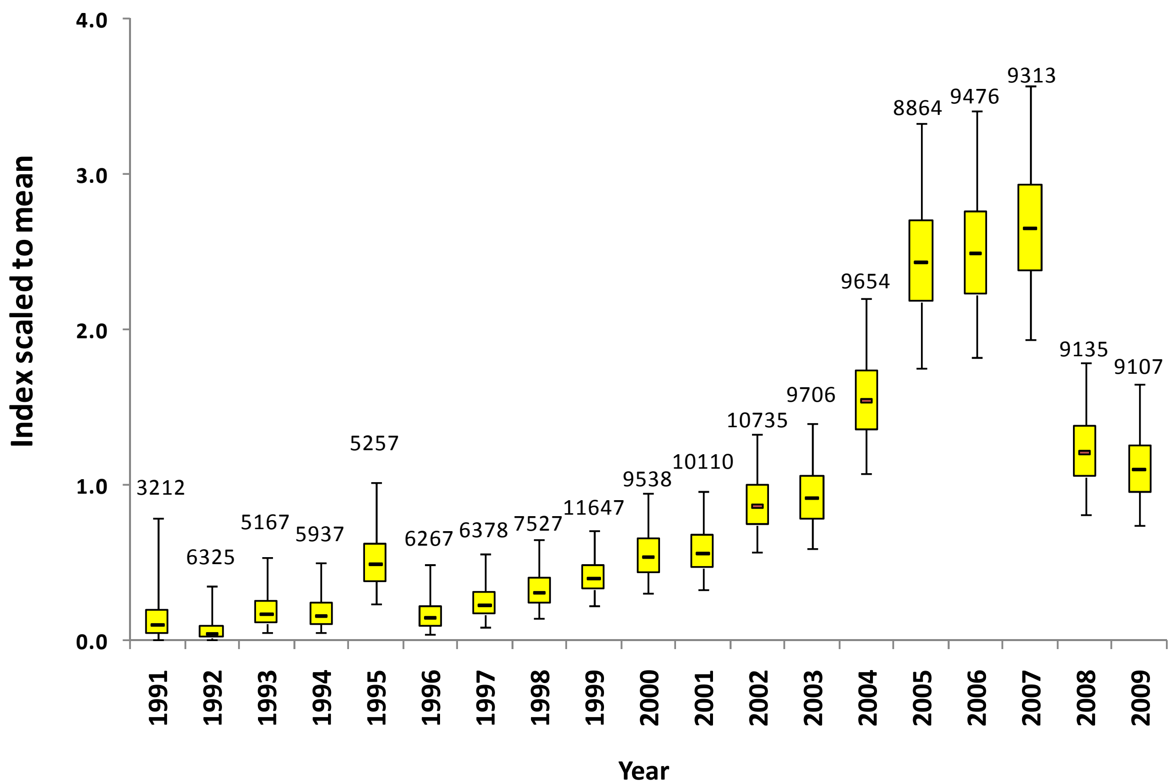
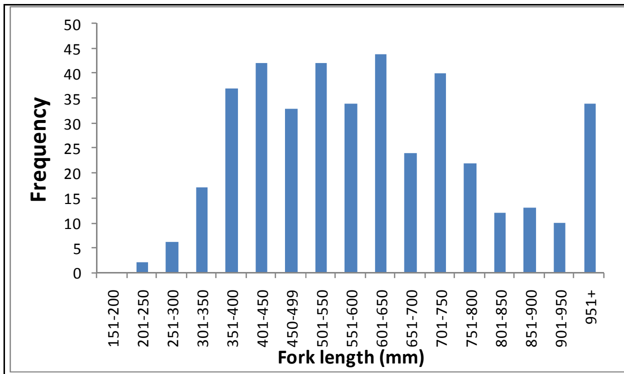
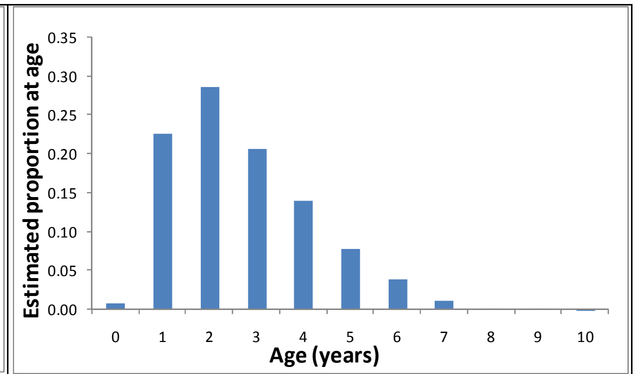


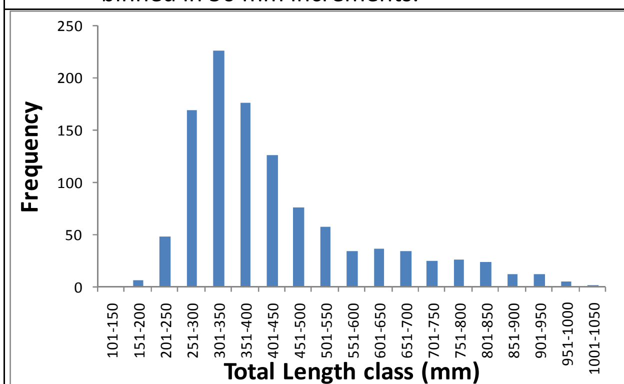
Figure 2.2.3. Revised MRFSS catch index (proportion positives) using all regions of Florida. Proportion postives for trips (n=153,355) with catch of goliath grouper. Interviews from the same trip were pooled from MRFSS private/rental boat trips from 1991-2009 even if there was no catch of any fish). Final model variables : year, survey region, and water body.



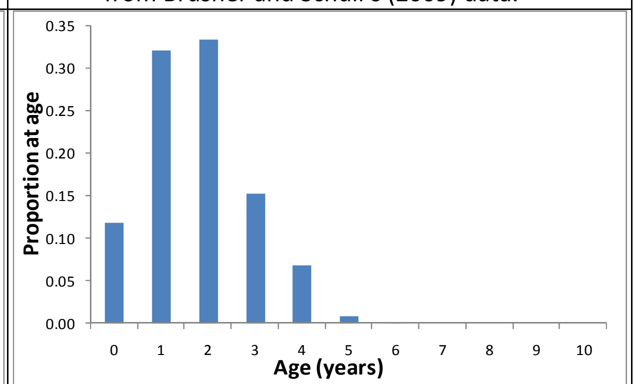
a. Goliath grouper lengths measured in the ENP Angler Creel Survey, 1974-1990. Goliath grouper: Fork Lengths (= Total Length) were binned in 50 mm increments.



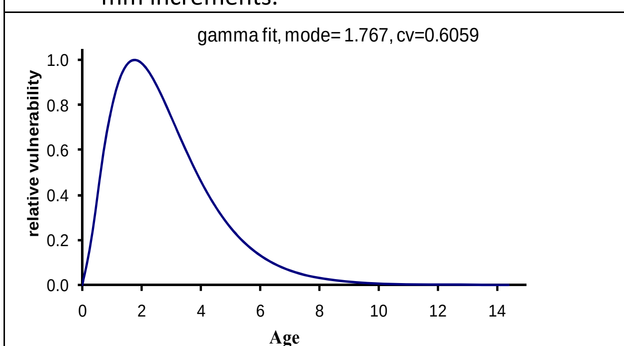
b. Goliath grouper predicted ages in the ENP Angler Creel Survey using the new growth curve and age-adjusted natural mortality developed from Brusher and Schull's (2009) data.



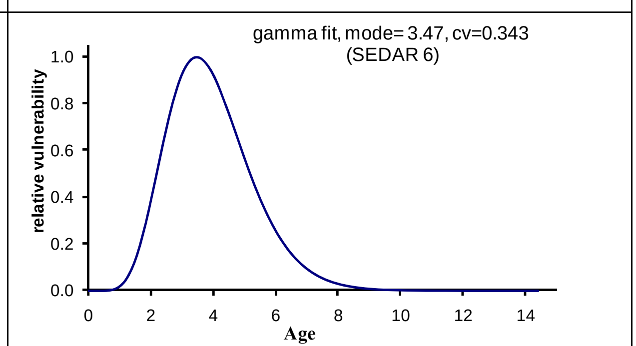
c. Goliath grouper lengths measured in the Everglades National Park, 1997-2002 (Brusher and Schull 2009) from all gears and binned in 50 mm increments.



d. Ages of goliath grouper caught in mangroves and other habitats in the ENP, 1997-2002 (Brusher and Schull 2009) from all gears.

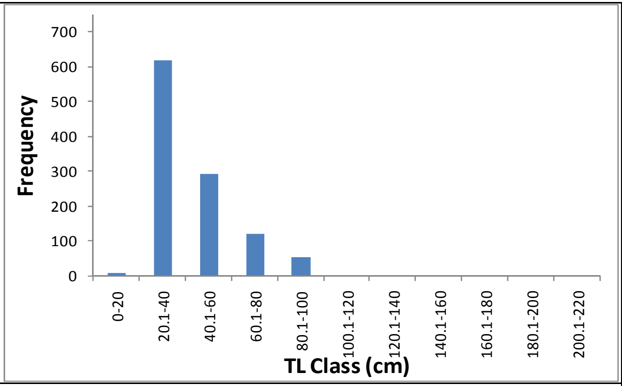


e. Alternative gamma fit to estimated ages of goliath grouper from angler creels in the ENP using the new growth curve and age-adjusted natural mortality.

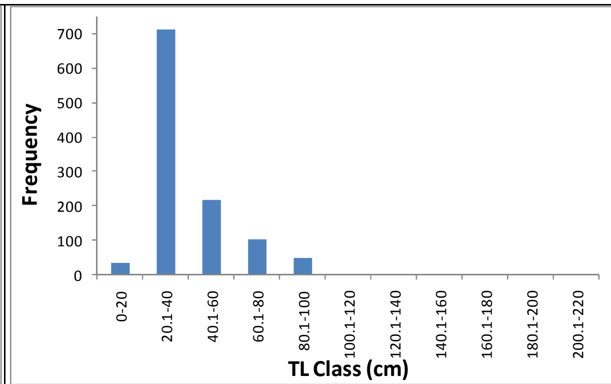


f. Gamma fit for ages estimated by a total mortality-adjusted age-length key for ENP angler creels used for the vulnerability curve linked to the ENP catch index used in SEDAR 6.

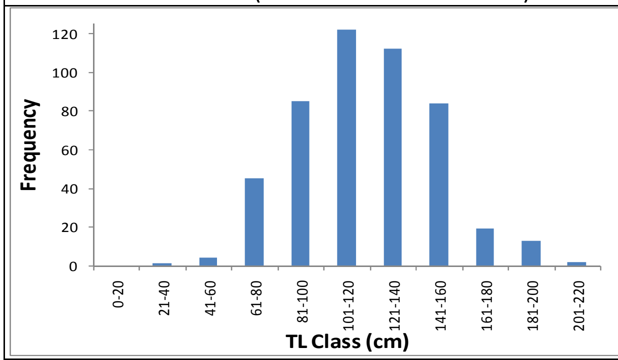
Figure 2.2.4. Estimated age frequency of angler-caught goliath grouper in the Everglades National Park (1974-1990) using the new growth curve and age-adjusted natural mortality from specimens measured during 1997-2002 by Brusher and Schull (2009). The vulnerability curve fit to the estimated ages for the ENP creel data using this method is shown in e), and the curve developed for SEDAR 6 (Porch et al. 2003) using a total mortality adjusted age-length key is shown in f).



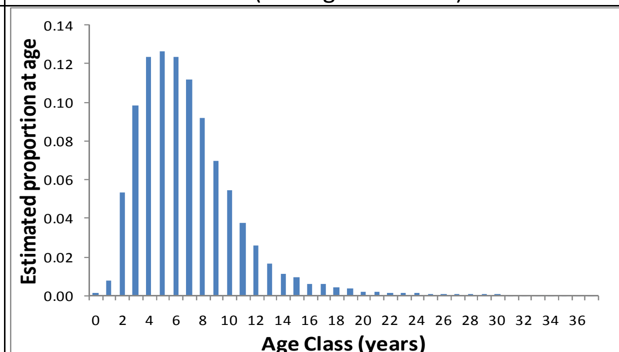
a. Goliath grouper lengths (binned in 20 cm increments) measured in the Everglades National Park (Brusher and Schull 2009).



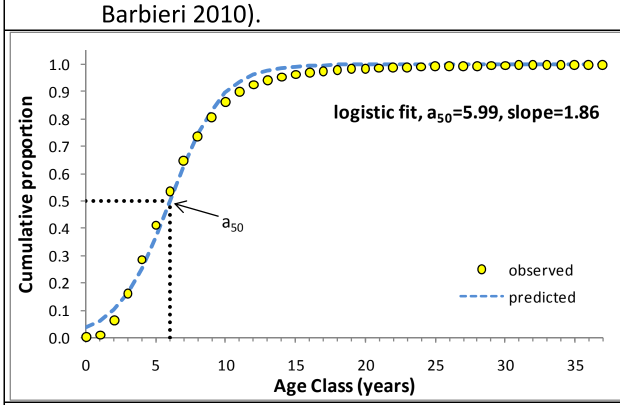
b. Goliath grouper lengths (binned in 20 cm increments) measured in the Everglades National Park (Koenig et al. 2007)..



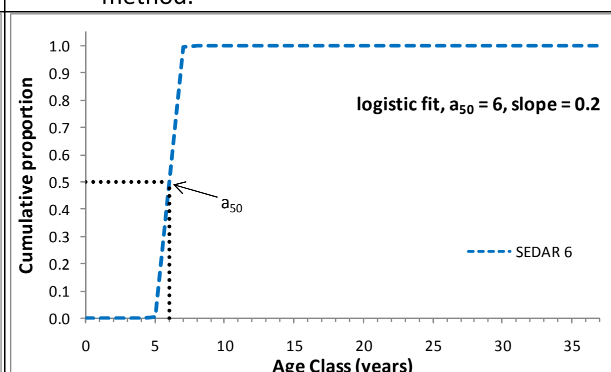
c. Goliath grouper lengths (binned in 20 cm increments) measured by divers in offshore habitats of the West Florida Shelf (Collins and Barbieri 2010).



d. Estimated ages of goliath grouper in West Florida shelf offshore habitats using a revised growth curve and age-adjusted natural mortality method.

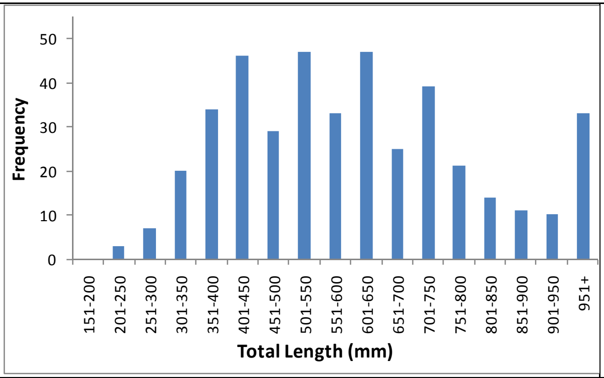


e. Vulnerability curve for goliath grouper in offshore habitats from a logistic fit to the ages estimated using the revised growth curve and age-adjusted natural mortality method from the lengths in Collins and Barbieri (2010).

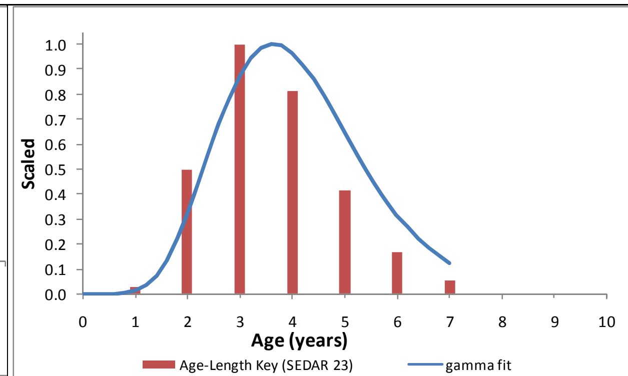


f. Vulnerability curve for goliath grouper in offshore habitats used in SEDAR 6.

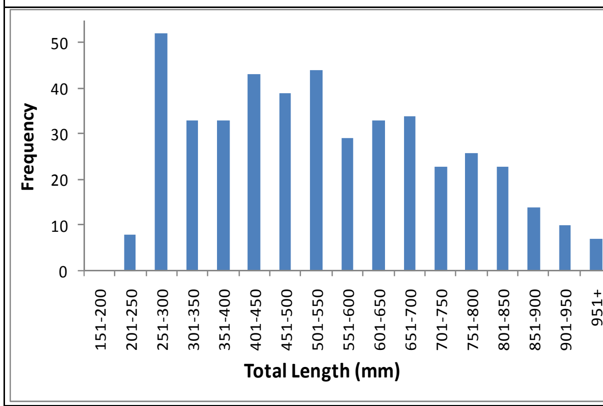
Figure 2.2.5. Length measurements of goliath grouper from inshore and offshore studies show movement of larger animals to offshore habitats. Estimated age frequency of goliath grouper in offshore habitats of the West Florida shelf using length measurements by divers (Collins and Barbieri 2010). The resulting vulnerability curve (logistic fit) is linked to the indices which apply to offshore (adult) animals.



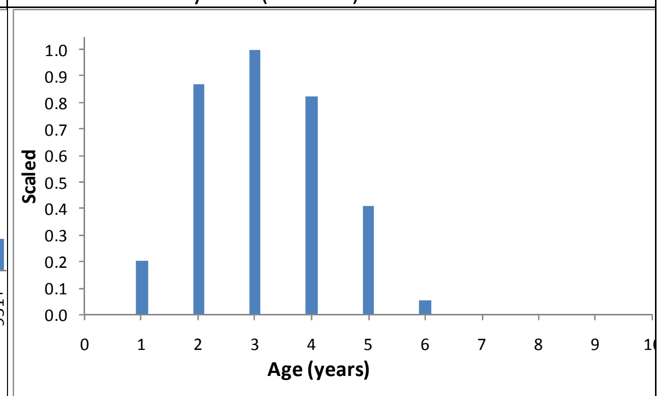
a. **Angler-caught g**oliath grouper lengths (fork length=total length) measured in the Everglades National Park Angler Creel Survey, 1974-2001.



b. Goliath grouper predicted ages in the ENP Angler Creel Survey using a total mortality adjusted age-length key developed from Brusher and Schull's (2009) data for SEDAR 6. A constant natural mortality rate (M=0.11) was used.

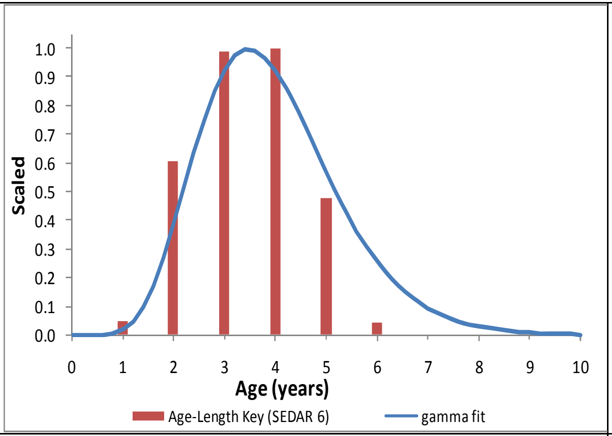


c. Goliath grouper lengths measured (binned in 50 mm increments) in the ENP, 1997-2002 (Brusher and Schull 2009) from all gears except blue crab traps.

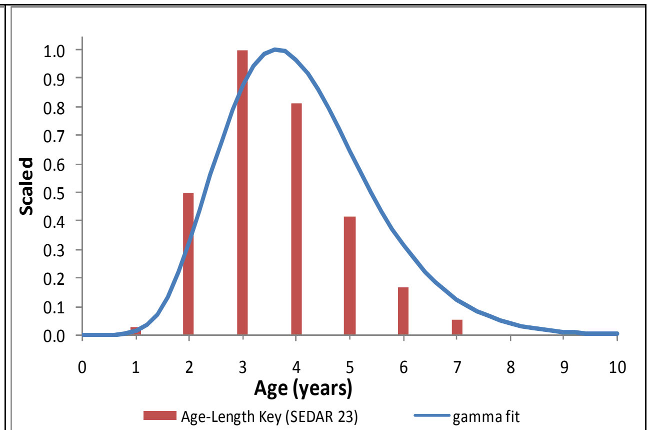


d. Goliath grouper ages measured in the ENP, 1997-2002 (Brusher and Schull 2009) from all gears except blue crab traps.

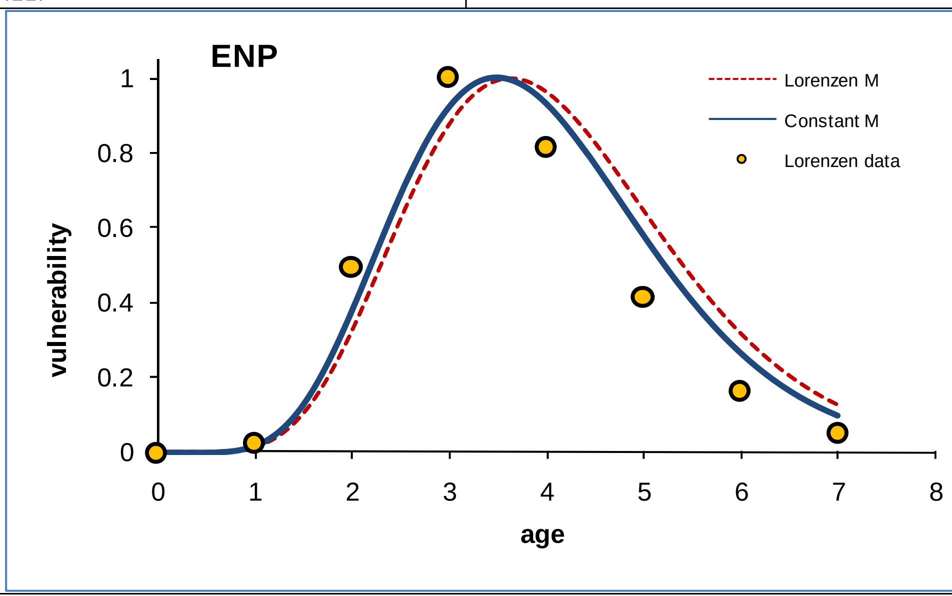
Figure 2.2.6. Estimated age frequency of angler-caught goliath grouper in the Everglades National Park (1974-2001) using an age-length key developed for SEDAR 6 (Porch et al. 2003) from specimens caught by all gears except blue crab traps measured during 1997-2002 by Brusher and Schull (2009).



a. Goliath grouper predicted ages in the ENP Angler Creel Survey using an age-length key developed from Brusher and Schull's (2009) data for SEDAR 6, constant natural mortality M=0.11.

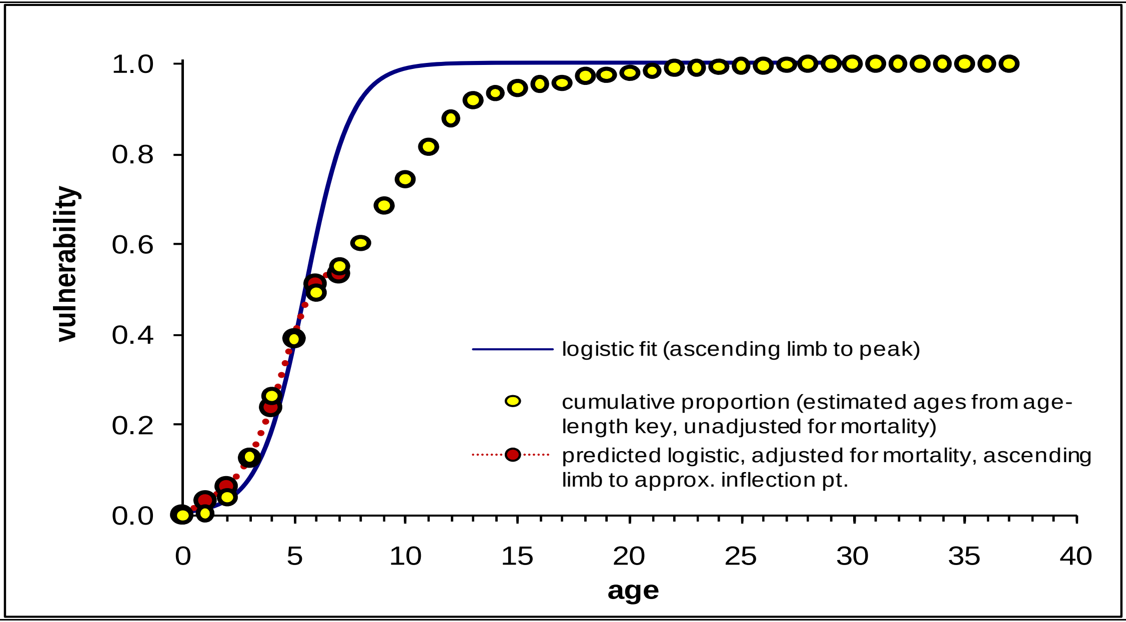


b. Goliath grouper predicted ages in the ENP Angler Creel Survey using an age-length key developed from Brusher and Schull's (2009) data for SEDAR 23, age-adjusted natural mortality for M=0.12..

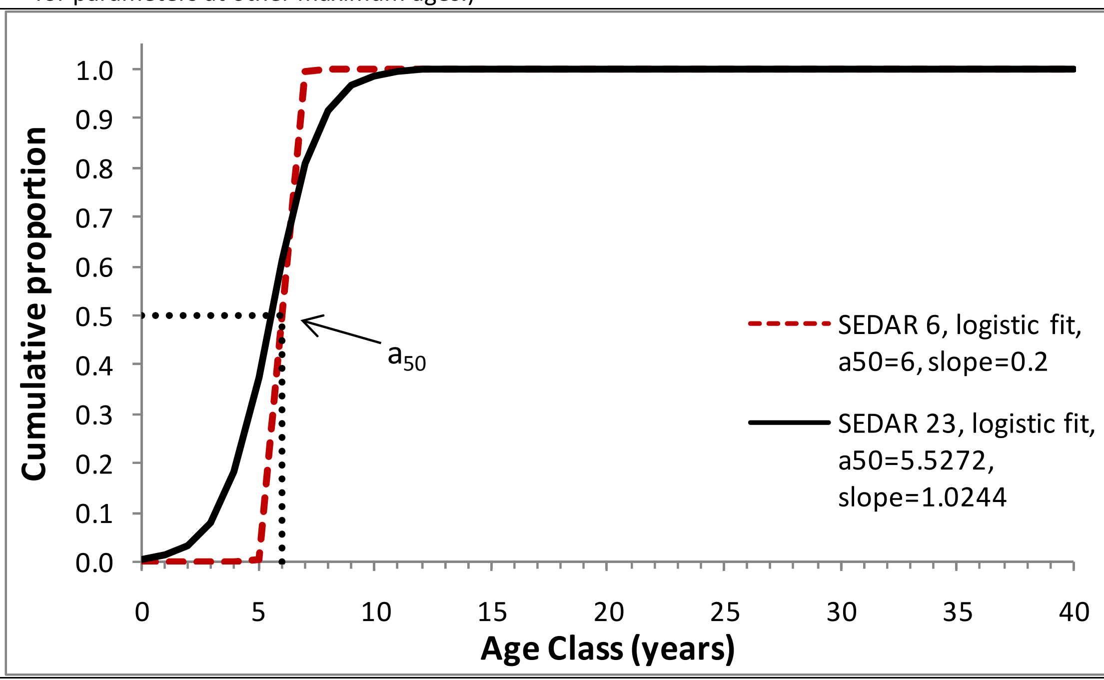


c. Comparison of vulnerability curves derived using a gamma fit to predicted ages from a total mortality adjusted age-length key either with a constant natural mortality rate (M=0.12) or age-adjusted natural mortality rates for SEDAR 23.

Figure 2.2.7. Estimated age frequency of angler-caught goliath grouper in the Everglades National Park (1974-2001) using an age-length key developed for SEDAR 6 and SEDAR 23 from specimens measured during 1997-2002 by Brusher and Schull (2009).



a. Vulnerability curve (logistic fit) for estimated ages of goliath grouper measured by divers in offshore areas of the West Florida shelf (Collins and Barbieri 2010). This example shows the curve obtained for M=0.12 (age-specific natural mortality rate, max. age=37 years). **a_{50}**=5.527, **slope**=1.024 (see Table 2.1.6 for parameters at other maximum ages.)



b. SEDAR 6 vulnerability curve for goliath grouper assumed for offshore areas compared to a curve derived from underwater measurements of goliath grouper in offshore areas of the west Florida shelf.

Figure 2.2.8. Vulnerability curve using estimates of ages from underwater measurements of total length of goliath grouper in offshore habitats on the West Florida shelf (Collins and Barbieri 2010) using an age-length key developed for SEDAR 23 using age determinations from Bullock et al. (1992), Brusher and Schull (2009), and additional specimens from cold kills and other sources that were aged.

2.3. REFERENCES

Brusher, J. H. and Schull, J. 2009. Non-lethal age determination for juvenile goliath grouper *Epinephelus itajara* from southwest Florida. Endangered Species Research 7: 205-212.

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

Collins, A. B., and Barbieri, L. R. 2010. Behavior, habitat, and abundance of the goliath grouper, *Epinephelus itajara*, in the central eastern Gulf of Mexico. Cooperative Research Project Report, NOAA award number NA07NMF4540085.

Hewitt, D. A. and Hoenig, J. M. 2005. Comparison of two approaches for estimating natural mortality based on longevity. . Fishery Bulletin 103:433-437.

Koenig, C.C., Coleman, F.C., Eklund, A.M., Schull, J., and Ueland, J. 2007. Mangroves as essential nursery habitat for goliath grouper (*Epinephelus itajara*). Bulletin of Marine Science, 80: 567-586.

Lorenzen, K. 1996. The relationship between body weight and natural mortality in juvenile and adult fish: a comparison of natural ecosystems and aquaculture. Journal of Fish Biology 49: 627-647.

Lorenzen, K. 2005. Population dynamics and potential of fisheries stock enhancement: practical theory for assessment and policy analysis. Philosophical Transactions of the Royal Society of London. Fisheries Theme Issue 2004.

Martell, S. D., Pine, W. E. III, and Walters ,C. J. 2008. Parameterizing age-structured models from a fisheries management perspective. Canadian Journal of Fisheries and Aquatic Sciences 65: 1586-1600.

Porch, C.E., Eklund, A.M., and Scott, G.P. 2003. An assessment of rebuilding times for goliath grouper. NOAA Fisheries, Sustainable Fisheries Division Contribuition No. SFD-2003-0018. SEDAR 6-RW-3.

Porch, C.E., Eklund, A.M., and Scott, G.P. 2006. A catch-free stock assessment model with application to goliath grouper (*Epinephelus itajara*) off southern Florida. Fishery Bulletin 104: 89-101.

3. STOCK ASSESSMENT MODELS AND RESULTS

One model (the catch-free model by Porch et al. 2006) was developed for the assessment of goliath grouper. Another model [stock reduction analysis (SRA)] was explored for the potential to produce other management benchmarks from the highly reconstructed but incomplete (i.e., no recreational harvest in terms of biomass was available) catch series. The results from the SRA are preliminary and need further refinement, and are provided as a working paper to this SEDAR (SEDAR23-RW-01).

3.1. CATCH-FREE STOCK ASSESSMENT MODEL

The only assessment of goliath grouper in U.S. waters prior to this SEDAR endeavor utilized the catch-free assessment model (Porch et al. 2003, 2006). This model is an age-structured production model and utilizes known biological information regarding a species, incorporates indices of abundance and effort (if known, or a proxy) and other auxiliary information from meta-analyses of stocks with similar life history characteristics allowing for informative priors on parameters such as fishing mortality (F) and natural mortality (M) rates, growth curve parameters and vulnerabilities. The catch-free model has a flexible model structure, and provides management benchmarks relative to pre-exploitation levels and projections for future years. There is no dependence upon harvest estimates as inputs for the model. The results and benchmarks are derived from a reconstruction of a population based upon biological parameters and abundance indices and the results are relative to a population assumed to be at "near virgin" levels. Benchmarks in this assessment model are relative based on spawning potential ratio (SPR) assuming a Beverton-Holt spawner-recruit function. Porch et al. (2003, 2006) provide the theoretical and practical development for this model and inputs as well as assessment results through 2002, and the analyses were based upon interviews with long-time fishermen in southern Florida and upon indices of abundance for the Everglades National Park Angler Creel Survey (through 1999), and for the DeMaria and REEF diver surveys (through 2002) of some offshore sites in southern Florida waters.

The previous assessment estimated that the potential for spawning stock biomass (SSB) in a future year exceeding $SSB_{F\ at\ 50\%SPR}$ (the current benchmark for management of this species in the southeastern US) might occur as early as 2006 (50% chance) and that there was a 95% chance that the population might recover by 2012 (Porch et al. 2003). Under more conservative assumptions on the effectiveness of the moratorium on preventing harvest, recovery would not have occurred by 2017 (Porch et al. 2006). Or, under more optimistic assumptions on selectivities reducing fishing pressure on younger ages, there was a 70-80% chance that recovery might occur by 2017 (Porch et al. 2006).

3.1.1. Catch-free Assessment Model Methods

3.1.1.1. Overview of Data and Sources

The catch-free model utilizes known or estimated biological parameters (growth, length-weight, fecundity, maximum lifetime reproductive rate, maximum age, etc.), indices of abundance and fishing effort (or a proxy for effort), functions for fishing mortality that are defined to operate over several defined time periods, an estimate of natural mortality (M), and functions for catchability and vulnerability at age that are linked to each of the indices of abundance. The model uses no catch, harvest, or landings information other than those data used to develop the vulnerability curves and indices of abundance. The model currently addresses the population dynamics of a single stock only, but this is not an issue with this assessment. The Data Workshop (DW) panel recommended that goliath grouper in the southeastern U.S. and U.S. Gulf of Mexico be treated as a single stock based upon genetics work on this species (Craig et al. 2009).

A refinement to the catch-free model for this assessment incorporated coding for age-specific M (Dr. Clay Porch, NOAA Fisheries, Southeastern Fisheries Science Center, personal communication) based upon Lorenzen (1996) rather than treating M as constant as in the previous assessment (Porch et al. 2003, 2006). This refinement (see Section 2) used the relationship developed by Lorenzen (1996) and is based upon biomass rather than the age-specific M based upon population numbers (Lorenzen 2005) recommended for use during the DW. The catch-free model estimates biomass at the mid-year point in its calculations, and the age-specific M based upon biomass generated by the model also is calculated at mid-year. The age-specific M based upon population numbers recommended by the DW was used for generating the vulnerability curves that were linked to the indices of abundance.

Additional refinements to the input data (see Section 2) were to the growth curve, length-weight relationship, and the vulnerability curves linked to the ENP Angler Creel Survey Index and for the offshore abundance indices (DeMaria REEF southeast, REEF southwest, MRFSS). There was also a difference in the calculation of the target M between SEDAR 6 and this assessment (Figure 3.3.1). In SEDAR 6, M was calculated using the regression equation established for fish (Hoenig 1983), whereas in this assessment M was calculated using the regression equation drawn from all taxa following the recommendation by Hewitt and Hoenig (2005). Natural mortality based upon maximum ages of other reef fish species have been calculated using either equation in previous SEDAR assessments (Figure 3.3.1). No additional information on the maximum age of goliath grouper has been published since Bullock et al. (1992), so this assessment relied upon the oldest specimen (37 years old) found in that study. Because the age-length keys utilize an estimate for M (either constant as in SEDAR 6 or age-specific as in this assessment) and the AW panel recommended a range of maximum ages to consider for sensitivity runs, additional hypothetical maximum ages of 40, 50, 60, 70, and 80 years were used to calculate values for M and for age-specific M (Tables 2.1.3 and 2.1.4). The age-specific M in numbers at age (Table 2.1.3) were used for the age-length keys to develop the vulnerability curves for the juvenile (Table 2.1.5) and adult (Table 2.1.6) portions of the goliath grouper population that were linked to specific indices of abundance. The age-specific M based upon biomass (Table 2.1.4) is calculated internally in the catch-free model. Model input parameters for M are the slope (-0.288) and intercept (3) from Lorenzen (1996), however the intercept (Table 2.1.4 "alpha") was modified (see Section 2) to take into account the adjustments for the ranges of ages (4-37) over which the DW recommended that M be adjusted, and also for the units of biomass from the length-weight relationship that was also an input to the model.

3.1.1.2. Model Configuration and Equations

The catch-free model and parameter (".prm") and data (".dat") configuration files used in SEDAR 6 were obtained from Dr. Clay Porch (NOAA Fisheries, Southeast Fishery Science Center, personal communication). AD-Model Builder (http://admb-project.org/) version 9.0.0 was used to implement the model, and code was compiled and linked using Borland C++ (version 5.5). The population modeling equations were thoroughly presented in Porch et al. (2003) and Porch et al. (2006). A refinement to the model used in SEDAR 6 which permitted age-specific natural mortality to be used in the calculations was added by Dr. Porch in September, 2010, and the formulas for these computations are discussed in Section 2.

The parameters for the continuity run were configured using the .prm file received from Dr. Porch, and modified slightly after conferring with him regarding some of the parameters (Table 3.2.1) in relation to SEDAR 6. The parameters for model runs for SEDAR 23 used some of the same settings as in SEDAR 6, and modifications for SEDAR 23 are in Table 3.2.2.

Abundance and effort indices used during SEDAR 6, SEDAR 23 continuity run, and SEDAR 23 model runs are in Table 3.2.3. The model used in SEDAR 23 was configured similarly to that used in SEDAR 6, and used indices of abundance derived from the DeMaria observations (Porch et al. 2003) at specific wrecks in southwest Florida, observations by recreational divers at sites in southeast Florida and the Florida Keys (REEF southeast; Porch 2010), and a catch index developed from the Everglades National Park (ENP) Angler Creel Survey from 1974-2009 (Cass-Calay 2010). Two indices of abundance [REEF southwest (Porch 2010) and MRFSS (O'Hop 2010) were added to the model, and the interview index from SEDAR 6 was dropped from the model at the request of the AW panel. Data (.dat) files showing the values for the indices of abundance and effort for the continuity and proposed base run are included in Appendix A.

3.1.1.3. Parameters Estimated

The catch-free model is very flexible, and parameter estimation may be turned on (i.e., allowing the model to solve for a parameter) or off (i.e., treating the value in the parameter file as fixed). The configurations used in the SEDAR 23 continuity and model runs are in Tables 3.2.1 and 3.2.2. There were a total of 304 estimated values in the continuity model, and 305 values estimated in the proposed base model and each of the sensitivity runs. Parameters were estimated for fishing mortalities in the historical period (ϕ_1), modern period (ϕ_2), and post-moratorium period (ϕ_3), lifetime reproductive rate (α), lifetime reproductive rate-1 (α-1), asymptotic length (L_∞), catchabilities linked to each of the indices (except for the interview index in the continuity run), selectivity for the modern era, overall variance, fishing mortality deviations (1980-1989), recruitment deviations (1980-2009), $F_{20\%SPR}$, $F_{30\%SPR}$, $F_{40\%SPR}$, $F_{50\%SPR}$, $F_{60\%SPR}$, , natural mortality (M – only for constant M in the continuity run, not for the age-specific M in the other SEDAR 23 model runs), moratorium effectiveness (1- ϕ_3), F_{MSY}, F_{mature},F_{max},$F_{0.1}$, $B_{current}$, $F_{current}$, $B_{current}/B_{F\ at\ 20\%SPR}$, $B_{current}/B_{F\ at\ 30\%SPR}$, $B_{current}/B_{F\ at\ 40\%SPR}$, $B_{current}/B_{F\ at\ 50\%SPR}$, $B_{current}/B_{Fat60\%SPR}$, $B_{current}/B_{MSY}$, $B_{current}/B_{mature}$, $B_{current}/B_{max}$, $B_{current}/B_{F\ at\ 0.1}$,

$F_{current}/F_{20\%SPR}$, $F_{current}/F_{30\%SPR}$, $F_{current}/F_{40\%SPR}$, $F_{current}/F_{50\%SPR}$, $F_{current}/F_{60\%SPR}$, B_{year} for 1950-2029, B_{year}/B_{ref} (where year = 1950-2029, and ref= $B_{F\ at\ 50\%SPR}$ in SEDAR 23 configurations), $\log(F_{apical,\ year})$ for 1950-1989 (F_{apical} was fixed to $F_{current}$ for 1990-2029), and for the projections B_{year}/B_{ref} for 2004-2009 and projections for 2010-2024. The current year used for these runs was 2009. A comparison of the components incorporated into the negative log likelihood function for the continuity and other runs is in Table 3.2.4.

3.1.1.4. Uncertainty and Measures of Precision

There is a great deal of uncertainty with many of the life history and population parameters for goliath grouper. Porch et al. (2003, 2006) incorporated the use of Bayesian priors for many of these parameters that were based upon meta-analyses of fish with similarities in their life history traits. Other parameters for which prior distributions were constructed were based upon length-at-age and length in catches for juvenile goliath grouper in the ENP Angler Creel Survey and underwater measurements of goliath grouper (Collins and Barbieri 2010). Still other priors were constructed, for example, based upon consensus opinion given by DW participants on a prior distribution covering the plausible range of values for the effectiveness of the moratorium on harvest (i.e., a percentage reduction in fishing mortality rates; Figure 3.3.2) since this quantity is unmeasured nor likely to be known with any certainty. The potential for introducing bias into the analyses exists with priors constructed from expert opinion, and it also can be introduced when running sensitivity analyses where the unknown values are fixed to values selected by analysts (Porch et al. 2006). However, when unbiased data are not available or are inadequate for the task, analyses depending upon uninformative priors will probably not yield useful advice because the range in plausible outcomes may be too large. By using a subjective prior such as for the effectiveness of the moratorium, perhaps more realistic limits may be placed on the uncertainty for this parameter.

By allowing the catch-free model to estimate parameters using priors (i.e., turning on phase-estimation for the parameter), the model uses the parameter “best estimate” and distributional shape (function type, variance or coefficient of variation, and probability density function) to adjust the parameter estimate within the bounds provided by the prior distribution during the model convergence process. When a valid convergence is achieved, the model generates a variance-covariance matrix for the parameters that are estimated. To explore the precision on these parameter estimates, either likelihood profiles can be generated using the routines provided by ADMB, or ADMB's Markov Chain Monte Carlo simulations (MCMC) that use the variance-covariance matrix to start the Metropolis-Hastings method algorithm can be used. Likelihood profiling was not successful to date with model configurations used in SEDAR 23, so uncertainty was examined using MCMC. The initial runs used approximately 10 million MCMC trials designed to yield approximately 2.5 million accepted samples. "Burn-in" and autocorrelation among samples were assessed using the R (version 2.11.0; http://www.r-project.org/) package 'boa' diagnostics. Most parameters of interest appeared to have a burn-in period of less than 500,000 accepted samples, so a burn-in period of 500,000 was chosen. Autocorrelation among samples became non-significant for most parameters of interest between lags of 400 and 500, so a thinning rate of 500 was chosen for sample selection.

In addition to the MCMC runs, the DW recommended sensitivity runs for alternative values of natural mortality corresponding to ages of 25%, 50%, 75%, and 100% older than the known maximum age of goliath grouper. To make reasonable increments for ages, natural mortality rates corresponding to 40, 50, 60, 70, and 80 years were calculated (Table 2.1.3). Age-specific natural mortality rates based on biomass were generated from these target rates for M using Lorenzen (1996) for the model, and age-specific M based on numbers were used to generate the parameters for vulnerability curves using age-specific total mortality adjusted age-length keys (see Sections 2 and 3.1.1.1). Additional sensitivity runs included using the SEDAR 6 prior on the percentage reduction in F due to the moratorium on harvest, and an additional prior for that parameter that had a slightly lower mean than that recommended by the DW participants.

3.1.1.5. Benchmark / Reference Points Methods

The South Atlantic Fishery Management Council (SAFMC) adopted benchmark proxies for the snappers and most of the groupers in 1998 (Amendment 11) of $F_{30\%SPR}$ as their Maximum Fishing Mortality Threshold (MFMT, now called the overfishing limit, OFL) and the Minimum Stock Size Threshold (MSST) is (1 – M) $SSB_{F\ at\ 30\%SPR}$ or 0.88 $SSB_{F\ at\ 30\%SPR}$. However, for goliath grouper, the MSY proxy for MFMT is the F at 40% static SPR. In the same amendment, the SAFMC chose the yield corresponding to $F_{45\%SPR}$ as their optimum yield (OY) goal for most groupers except for goliath grouper, for which the OY proxy is set to 50% static SPR. The Gulf of Mexico Fishery Management Council (GMFMC) also has adopted $F_{30\%SPR}$ as their OFL for reef fish and they chose 0.8 $SSB_{F\ at\ 30\%SPR}$ as their MSST. The GMFMC's amendment that contained their optimum yield definition (Amendment 18B) was not accepted and the council is considering OY alternatives at this time.

The catch-free model produces relative benchmarks rather than direct estimates of the equilibrium catch levels associated with particular catch levels (e.g., MSY; Porch et al. 2006). Therefore, the model results may be used to examine the relative level of recovery in the stock, but not provide the typical advice to fisheries managers on levels of catch that may be sustainable. The OY definition for goliath grouper from the SAFMC was the most conservative benchmark and because the model benchmarks are relative, the MCMC results were analyzed to examine the outcomes for the relative $SSB_{F\ at\ 50\%SPR}$ and relative $F_{50\%SPR}$ more thoroughly as these relative benchmarks will likely determine whether the stock is considered to be overfished and whether overfishing may still be occurring.

3.1.1.6. Projection methods

The catch-free assessment model, as in SEDAR 6, was configured to produce projections based upon the state of the population in the final year of the assessment (in this case, 2009) and projects relative levels of spawning stock biomass based upon the relative fishing mortality rate in the current year ($F_{current}$). At present, any implementation uncertainty is not included in the projections. The uncertainty in the projections results from the optimized solution from the model's variance-covariance matrix, and uncertainty in the attainment of the relative benchmarks in the projections was examined using MCMC analyses.

3.1.2. Catch-free Assessment Model Results

3.1.2.1. Measures of Overall Model Fit

Fits of the catch-free model to the indices of abundance were reasonable overall. The ENP index is an index geared toward the immature portion of the population (primarily ages under 6 years old), whereas the DeMaria, REEF Southeast, REEF Southwest, and MRFSS indices are linked to the adult portion of the population. In the continuity run, the longer time series for the ENP and REEF Southeast indices and similarity in trends provided more model guidance than the DeMaria index which ends in 2002 (Figure 3.3.3). There were some conflicting trends between the DeMaria index and the ENP and REEF Southeast indices during the years in which they overlap. The coverage (4 sites) of the DeMaria index is less than that of the ENP and REEF Southeast indices, so it may well be that conditions at the DeMaria sites during some years may have been different than those at REEF sites or anglers' catch rates of juveniles in the ENP. No new observations at the DeMaria sites have been made after 2002, so it is not known how trends at those sites compared to sites comprising the other indices. The index fits from the proposed base run are similar to those of the continuity run (Figure 3.3.4) for the DeMaria, REEF Southeast, and ENP indices. In both the continuity run and the proposed base run, the predicted fit increases only slightly in 2007 and shows a downward trend in 2008 and 2009 compared to the ENP index. Because this is mainly an index for juvenile recruitment, both the upward trend after 2002 and the downward trend after 2007 have large implications for guiding model behavior through the calculations involving recruitment.

3.1.2.2. Parameter estimates and associated measures of uncertainty

Proper convergence of the model runs was confirmed by checking that the eigenvalues from the ADMB matrix inversion were positive which yielded a valid variance-covariance matrix. Parameter estimates for relative fishing mortality rate ratios are in Table 3.2.5, relative spawning stock biomass ratios are in Table 3.2.6, and population parameter estimates from the model runs are presented in Table 3.2.7.

A comparison of the continuity run which used the same model configuration (constant M, same growth curve, same priors on F and vulnerabilities, same indices) as used during SEDAR 6 except that the REEF Southeast and ENP Angler Creel Survey indices were extended through 2009 showed some similarities in relative fishing mortality rates spawning stock biomass (SSB) trajectories and projections (Figure 3.3.6). Relative fishing mortality rates (F_{apical} for age 6) were somewhat higher in the continuity run prior to the moratorium on harvest in 1990, and SSB decreased more quickly from 1950 than in the SEDAR 6. Conversely, relative F was estimated to be lower in the post-moratorium period and SSB recovered a bit more slowly than projected in SEDAR 6 to 2007. Even so, the continuity run surpassed the level of recovery projected in SEDAR 6 after 2007 (Figure 3.3.6) probably as a result of the strong increasing trends in both the REEF Southeast and ENP indices (Figure 3.3.3a) after 2002. SSB is projected to level off after 2012 probably as a result of the decreasing trends in these indices in 2008-2009. The percentage reduction in F is estimated to exceed 98% using the same prior on moratorium effectiveness as used in SEDAR 6. For the continuity run, the goliath grouper population modeled with these parameters and indices of abundance would have recovered from being overfished at least by 2009 (Figure 3.3.6 c) using the criteria that more than 50% of MCMC outcomes for $F_{2009}/F_{50\%SPR}$ are less than one, and more than 50% of MCMC outcomes for $SSB_{2009}/SSB_{F\ at\ 50\%SPR}$ are greater than MSST.

3.1.2.3. Relative Spawning Stock Biomass and Fishing Mortality Rates

Trajectories for relative SSB and F for the proposed base run and other sensitivity runs are presented in Figure 3.3.7, and model results for the runs are presented in Tables 3.2.5, 3.2.6, and 3.2.7. The model was configured to use $F_{current}$ for the projected years, and to use the current OY definition ($F_{50\%SPR}$) as the reference benchmark. There were notable differences between the continuity run and the base model and sensitivity runs. The SEDAR 23 model runs used an updated growth curve developed after the DW, age-specific natural mortality was incorporated into the model after the AW and webinar, a new prior was developed for the moratorium effectiveness on reducing F after 1990 at the DW, a new length-weight relationship was developed after the AW, and new vulnerability curves were developed incorporating the new growth curve and age-specific M after the AW and webinar.

Three levels for the percentage reduction in F due to the moratorium (or, moratorium effectiveness) corresponding to the prior used in SEDAR 6, the prior developed by the DW participants during SEDAR 23, and a prior with a slightly lower mean were used for sensitivity runs. In addition, natural mortality rates corresponding to the known maximum age of 37 years and for hypothetical maximum ages of 40, 50, 60, 70, and 80 years were used also for these sensitivity runs. [An additional set of runs was configured to use a starting year of 1918 for later comparisons with a stock-reduction analysis described in a SEDAR 23 working paper.]

In all runs, relative F was estimated to have increased sharply in 1980 and reached a peak during 1985, falling rapidly until 1990 when the moratorium was implemented. This result is a from the general lack of information provided to the model prior to 1974 except for the index of effort derived from the population estimates for south Florida from the U.S. Census Bureau. There is a downward trend in the ENP Angler Creel Survey data from 1974-1980, and the only other index of abundance for the time period (DeMaria) beginning in 1983 also shows declines during the early portion of its time series through 1985 (Figure 3.3.3). Since the former is a juvenile (ages under 6 years, primarily) index, and the latter is an adult index, the declines in the latter index affect a greater portion of the population and probably account for more of the steeper rise in relative F and greater declines in relative SSB during this time period. The four indices (REEF Southeast, REEF Southwest, ENP, and MRFSS) that cover the time period from

2003-2009 show similarities in their trend information – an upward trend to 2007, and a subsequent decline in 2008. These trends at the end of the time series appear to have had an impact in guiding the relative SSB trajectory a little more sharply upwards than seen for relative SSB from SEDAR 6. In addition, the downward trend in the indices appears to lead to a plateau or slight downward trend in relative SSB within a few years after 2009 (for maximum ages of 50 years or less) or at least a slower rise in relative SSB (for maximum ages of 60 years or more) depending upon the value of M used.

Using the prior on the moratorium effectiveness developed by the DW for SEDAR 23, less than 50% of the MCMC outcomes only for the model run using the M corresponding to the known maximum age (37 years) fell below the relative $F_{2009}/F_{50\%SPR}$ benchmark, meaning that the overfishing was not occurring. Using the hypothetical maximum ages in the sensitivity runs, overfishing was not being prevented based upon the estimate of the posterior distribution for the percentage reduction in F due to the moratorium (i.e., F would need to be reduced if meet this benchmark based upon the SEDAR 23 prior for this parameter). If the moratorium effectiveness was higher (e.g., using the SEDAR 6 prior), overfishing would probably not be occurring.

Generally for the relative SSB trajectories, the runs using the prior developed for SEDAR 6 for moratorium effectiveness show a faster rise in SSB after 1990 and plateau at a higher level (Figure 3.3.7) for runs with this configuration (Table 3.2.6) compared to the SEDAR 23 prior and the prior set to a slightly lower mean value. The model estimates the value for the prior used the SEDAR 6 moratorium effectiveness around 98% regardless of the target value of M used. For the prior on the moratorium effectiveness developed for SEDAR 23, the model estimates the value at 90-91%, and for the slightly lower prior 89-90%. For the effect these priors have on relative SSB: the more the moratorium was effective in reducing fishing mortality, the greater were the gains in relative SSB after 2009 (Figure 3.3.8).

3.1.2.4. Stock-Recruitment Parameters

Little is known directly about the fecundity of goliath grouper. The model estimates recruitment with a Beverton-Holt stock-recruitment relationship based on a meta-analysis of data from Myers et al. (1999) by Porch et al. (2003, 2006). The distribution for the maximum lifetime fecundity parameter (α) for "large, highly fecund fish with long life spans" (which also corresponds to periodic strategists of Rose et al. 2001) was used to describe a lognormal prior for use in the model. The same prior for this parameter as used in SEDAR 6 (Porch et al. 2003,

2006) was adopted for use in SEDAR 23. Fecundity at age is unknown and was modeled as a function of weight-at-age. Steepness (h) is another (and perhaps more familiar to SEDAR assessments) parameter to characterize stock-recruit relationships, but it is not estimated by the catch-free model. However, it can be calculated with the following formula:

$$h = \alpha / (4 + \alpha) .$$

Steepness calculated from the α estimates from the model runs are in Table 3.2.7.

3.1.2.5. Evaluation of Uncertainty

Uncertainty was approached through the use of priors on selected parameters (fishing mortality rates during some time periods, recruitment/reproductive rate, growth (L_∞), selectivity, catchabilities (though these were uninformative priors), and overall variance, and through the use of MCMC simulations. Additionally, sensitivity runs using different target M for age-specific natural mortality rates were used to examine the question "What if goliath grouper can live longer than the known maximum age of 37 years?" Finally, one of the parameters (moratorium effectiveness) that had a relatively large impact on whether goliath grouper are estimated to have recovered from being overfished is difficult to know with any certainty. This parameter was modeled using a prior distribution based on consensus opinions at SEDAR 6 and revisited during SEDAR 23. Model runs using these different prior distributions should prove informative regarding model behavior, and a slightly lower prior for this parameter was created to further explore model response.

Uncertainty in the model estimates for attaining the relative SSB and F benchmarks was examined using MCMC simulations. Phase plots of MCMC outcomes for F_{2009}/ $F_{50\%SPR}$ and SSB_{2009}/ $SSB_{F\ at\ 50\%SPR}$ were used for presenting the scattering of points around the benchmarks for F- and SSB-ratios. MCMC outcomes were binned, and the percentage of F_{2009}/ $F_{50\%SPR}$ outcomes which exceeded one and the percentage of SSB_{2009}/ $SSB_{F\ at\ 50\%SPR}$ which fell at or below MSST (= 1-M) were assessed. If 50% or more of the F-ratios exceeded one, the population was defined to be experiencing overfishing. If 50% or less of the SSB-ratios were below MSST, the population was defined to be overfished.

There is additional uncertainty about the relationship of fecundity at age and whether the goliath grouper population is fully occupying its historical range (Porch et al. 2006). While the indices of abundance used in this model are showing generally increasing trends compared to pre-2002 values, the numbers of animals noted by divers and researchers have increased in some areas, and recreational anglers are reporting more catch (and release) of goliath grouper, this species is not commonly seen in the Florida Keys Reef Fish Visual Census though they are noted in records of cold kills in the Florida Keys in January of 2010 and in some canals and channels there (Don DeMaria, personal communication). So, whether the population has expanded throughout its historical range in the southeastern U.S. is still unknown.

The phase plot for $SSB_{2009}/SSB_{F\ at\ 50\%SPR}$ vs. $F_{2009}/F_{50\%SPR}$ (Figure 3.3.8 a; proposed base run B-1) shows that the point estimate for these ratios have exceeded the benchmark values, and that 55% of the MCMC outcomes have exceeded the SSB-ratio benchmark (Figure 3.3.9 a) and 53% of the MCMC outcomes have not exceeded the F-ratio benchmark. Point estimates from other model configurations for 2009 at higher maximum ages (lower M values) are below MSST and most exceed one for the F-ratio. At least for the prior on ϕ_3 chosen by the DW participants for model configurations for SEDAR 23 (and at the growth rate, maturity and vulnerability schedules used in the model), only the proposed base run (B-1) is at the relative benchmarks (i.e., neither overfished nor is overfishing occurring) for 2009. If goliath grouper live longer than 37 years, recovery at least to the current F and SSB relative benchmarks will take more time.

3.1.2.6. Benchmarks / Reference Points / ABC values

The catch-free model does not require knowledge of the total removals (harvest) from the population (Porch et al. 2006), and in fact, knowledge of the harvest of goliath grouper is incompletely known and there are questions about the validity of the reported commercial landings over at least a portion of time period. And, recreational landings are not well-described by either the Marine Recreational Fishery Statistics Survey or the Southeast Head Boat Survey in that goliath groupers are not frequently caught nor is their average size or weight from these surveys adequately known. Therefore, it will be difficult to describe the amount of harvest (recreational or commercial) of these animals from the southeastern U.S. The fishery management benchmarks, reference points, and ABC values cannot be determined using this model without additional information such as an estimate of the absolute abundance from surveys covering the range of the species (Porch et al. 2006).

However, this assessment model does estimate a population's relative abundance, and can provide a measure of population status relative to an assumed unfished population. The SAFMC's optimum yield (OY) definition ($F_{OY} = F_{50\%\ SPR}$) was chosen to provide a benchmark or reference point for this assessment for assessing recovery at least in the context of the waters of south Florida.

3.1.2.7. Projections

Projections were made with the catch-free model using the F calculated in the current year. Since there is no harvest allowed at this time, $F_{current}$ is derived from the model's estimate of the posterior distribution for ϕ_3 [note: 100*(1- ϕ_3) is the percentage reduction of F due to effectiveness of the moratorium]. Relative SSB by year for the projections are made using $F_{current}$, and uncertainty in the projections was assessed using MCMC simulations for 2010-2014. The proportions of MCMC trials with ($SSB_{year}/SSB_{F\ at\ 50\%SPR}$) < MSST were calculated to estimate in which year would the population be expected to have recovered (if at all). Implementation uncertainty (i.e., compliance with regulations), sources of episodic mortality (e.g., cold kills, red tides, diseases, unusual weather events, etc.), good or bad recruitment years, and other potential factors which affect natural populations are not taken into account in these projections.

One of the model configurations (B-1 to B-6) for the current year (2009) had MCMC outcomes that met the benchmark criteria of $SSB_{2009}/SSB_{F\ at\ 50\%SPR}$ less than MSST (Figure 3.3.9 a-c, s-u), and that was proposed base run B-1. Only one other run (B-2 in 2010) surpassed the relative SSB benchmark in the projected years using the SEDAR 23 priors. The relative SSB-ratio for runs B-3, B-4, B-5, and B-6 did not exceed the MSST benchmark during the five years simulated, and only B-3 would be projected to do so in the 20 years for which projections were made (see biomass trajectories for these runs in Figure 3.1.5.6 "SEDAR 23" column). The implications of these projections are that, if M is too high (i.e., goliath grouper live longer than is currently known and their longevity is older than 50 years), recovery from being overfished will be significantly longer (if at all) than thought. Also, the percentage reduction in F (i.e., at a 90-91% reduction in fishing mortality rate after the moratorium) would not be enough stop overfishing for hypothetical maximum ages of 40 years or older. Using the old prior on F from SEDAR 6 (i.e. the moratorium was over 98% effective in reducing the fishing mortality rate), the relative SSB-ratio for even the hypothetical ages for goliath grouper of 70 and 80 years would be projected to exceed one in under 20 years (Figure 3.3.6 "SEDAR 6" column). With a percent reduction in F that is slightly less than the configuration chosen for SEDAR 23 (89-90%

reduction in F after the moratorium), the rate of recovery in biomass is noticeably slower (Figure 3.3.6 "lower" column).

MCMC samples for the percent reduction in F after the moratorium (Figure 3.3.11), steepness (calculated from α; Figure 3.3.12), and the age-specific natural mortality for age 1 animals (Figure 3.3.13) show no surprising results. The posterior distribution for the percent reduction in F as represented by the MCMC samples is, not surprisingly, of similar shape to the prior even though it is shifted to a higher mean. Lower values for M led to lower values in the estimate of this parameter, while slightly greater reductions in F were seen in model runs with higher M. The lifetime reproductive rate (α) is another one of the parameters that was assigned a prior distribution and solved for in the model. The MCMC samples (in terms of steepness) should represent a meaningful population parameter in terms of the model configuration. Steepness values were perhaps a little high for periodic strategists (e.g., Rose et al. 2001) but not beyond the realm of possibility and certainly values of this magnitude are presented in other reef fish stock assessments in the southeast U.S. The samples of M at Age 1 were centered close to the point estimates entered into the model, and this parameter was not used in the negative log likelihood calculations during the minimization process.

3.1.3. Discussion

Without a better understanding of longevity in goliath grouper, it may be prudent to treat the current known maximum age (37 years) as an estimate that may be modified if older animals are ever found. This has happened recently with some other reef fish in the southeastern region as we have gained more insight through increased sampling of hard parts for aging. It would not be difficult to imagine that goliath grouper may live 40-50 years in unfished or lightly fished populations. Likewise, without a better understanding of historical harvests including recreational harvest (average sizes or weights, especially), it will be difficult to develop management benchmarks for yields and F in any terms other than relative ones. A fisheries-independent survey as suggested by Porch et al. (2006) that is sufficiently designed to estimate absolute abundances throughout the range of this species may allow the calculation of management benchmarks by scaling the results from the catch-free model. An alternative would be the long-term monitoring of an experimental fishery to detect changes in relative abundance (Porch et al. 2006). [There was discussion at the SEDAR 23 AW regarding the perceived need for additional population data for goliath groupers using a rigorously controlled research fishery, but it was never finalized as a research recommendation.] Lastly, it is important to consider whether goliath groupers have increased sufficiently in population in all portions of their historical range. This assessment has focused on data from south Florida out of necessity since there is very little information from other states in the southeastern U.S. There is a lack of knowledge of historical abundances of goliath grouper throughout its historical range, so it will be difficult to devise meaningful criteria for this aspect of population recovery.

3.2. TABLES

Table	Description
3.2.1	List of catch-free model parameters, estimates, bounds, phase of estimation, pdf, and coefficient of variation or standard error used in SEDAR 23 for continuity run.
3.2.2	List of catch-free model parameters, estimates, bounds, phase of estimation, pdf, and coefficient of variation or standard error used in SEDAR 23 for proposed base run.
3.2.3	Comparison of catch-free model indices and other data used in SEDAR 6, SEDAR 23 continuity run, and SEDAR 23 model runs.
3.2.4	Comparison of the components included in the negative log-likelihood calculations used in the continuity run and other model runs.
3.2.5	Relative fishing mortality rate ratios estimated by model runs in SEDAR 23.
3.2.6	Relative spawning stock biomass ratios estimated by model runs in SEDAR 23.
3.2.7	Selected population parameters estimated or calculated from model runs in SEDAR 23.

Table 3.2.1. List of catch-free model parameters, estimates, bounds, phase of estimation, pdf, and coefficient of variation (cv) or standard error (se) used in SEDAR 23 for continuity run.

Parameters	Description	Function Type	Best estimate	lower bound	upper bound	phase of estimation	pdf*	cv (-) or SE of prior	SEDAR
F_h (historical expected F_{apical}, fixed starting value)	constant	2	0	-0.01	0.5	-2	2	-1	6
$F_{\phi1}$ (historical Fapical, estimated)	constant	2	0.3	-0.01	0.5	1	2	-1	6
$F_{\phi2}$ (modern era Fapical, before moratorium)	average with previous year before change	-1	1	0.02	10	1	2	-1	6
$F_{\phi3}$ (Fapical after moratorium on harvest)	average over previous 10 years	-10	0.16	0.01	0.9	3	5	-0.88	6
M (constant, slope)	constant	1	0.09677	0.01	0.7	3	1	-0.4	6
α-1 (maximum lifetime fecundity-1)	Beverton-Holt stock-recruitment	10	2.64809	0.01	150	2	1	1.310438	6
L_∞ (growth curve, asymptotic length in cm)	von Bertalannfy growth curve	8	200.600	150.000	300	5	2	-0.1	6
k (growth curve, exponent)	von Bertalannfy growth curve	8	0.126	0.000	10	-6	0	0.0204	6
t_0 (growth curve, intercept)	von Bertalannfy growth curve	8	-4.900	-5.000	10	-1	0	0.1	6
growth curve parameter (1= von Bertalannfy, other=Chapman-Richards)	von Bertalannfy growth curve	8	1.000	0.000	10	-1	0	0.1	6
a (length-weight, intercept in g/cm)	von Bertalannfy growth curve	8	1.31E-05	0.00E+00	10	-1	0	0.1	6
b (length-weight, slope)	von Bertalannfy growth curve	8	3.056	0.000	10	-1	0	0.1	6

Table 3.2.1. (continued) List of catch-free model parameters, estimates, bounds, phase of estimation, pdf, and coefficient of variation (cv) or standard error (se) used in SEDAR 23 for continuity run.

Parameters	Description	Function Type	Best estimate	lower bound	upper bound	phase of estimation	pdf*	cv (-) or SE of prior	SEDAR
q1 (catchability, index 1)	constant	1	0.5000	0.01	10	1	2	-2	6
q2 (catchability, index 2)	constant	1	0.5000	0.01	10	1	2	-2	6
q3 (catchability, index 3)	constant	1	0.5000	0.01	10	1	2	-2	6
q4 (catchability, index 4)	constant	1	0.5000	0.01	10	-1	0	-0.1	6
s_1 (selectivity for historical period, a50, for fh and fϕ1)	logistic selectivity function	6	2.5100	0	10	-4	2	-0.1	6
s_1 (selectivity for historical period, slope, for fh and fϕ1)	logistic selectivity function	6	0.5250	0	10	-1	0	0.1	6
s_2 (selectivity for modern period, a50, for fϕ2 and fϕ3)	logistic selectivity function	6	2.5100	2	10	4	2	-0.1	6
s_2 (selectivity for modern period, slope, for fϕ2 and fϕ3)	logistic selectivity function	6	0.525	0	10	-1	0	0.1	6

Table 3.2.1. (continued) List of catch-free model parameters, estimates, bounds, phase of estimation, pdf, and coefficient of variation (cv) or standard error (se) used in SEDAR 23 for continuity run.

Parameters	Description	Function Type	Best estimate	lower bound	upper bound	phase of estimation	pdf*	cv (-) or SE of prior	SEDAR
v_1 (vulnerability, a50, for index 1)	logistic selectivity function	6	6.0000	4	10	-4	2	-0.1	6
v_1 (vulnerability, slope, for index 1)	logistic selectivity function	6	0.2000	0	10	-1	0	0.1	6
v_2 (vulnerability, a50,for index 2)	logistic selectivity function	6	6.0000	4	10	-4	2	-0.1	6
v_2 (vulnerability, slope, for index 2)	logistic selectivity function	6	0.2000	0	10	-1	0	0.1	6
v_3 (vulnerability, mode, for index 3)	gamma selectivity function	7	3.4700	0	10	-4	2	-0.1	6
v_3 (vulnerability, cv, for index 3)	gamma selectivity function	7	0.3430	0	10	-1	0	0.1	6
v_4 (vulnerability, a50, for index 4)	logistic selectivity function	6	6.0000	4	10	-4	2	-0.1	6
v_4 (vulnerability, slope, for index 4)	logistic selectivity function	6	0.2000	0	10	-1	0	0.1	6
idv (not used)	constant	14	1.00	0	10	-1	0	0.1	6
overall cv	constant	1	-0.2	-1	-0.01	5	2	-0.5	6

*probability density function: 0=none, 1=autocorrelated lognormal, 2=autocorrelated normal, 3=uniform, 4=uniform (log-scale), 5=gamma, 6=beta

30 parameters (not all are estimated), 4 catchabilities, 6 selectivities, 1 overall cv.

Phase of estimation: the phase when model will begin estimating this parameter. If negative, model estimation is turned off.

Table 3.2.2. List of catch-free model parameters, estimates, bounds, phase of estimation, pdf, and coefficient of variation (cv) or standard error (se) used in SEDAR 23 for proposed base run.

Parameters	Description	Function Type	Best estimate	lower bound	upper bound	phase of estimation	pdf*	cv (-) or SE of prior	SEDAR
f_h (historical expected Fapical, fixed starting value)	constant	2	0	-0.01	0.5	-2	2	-1	6
$f_{\phi 1}$ (historical Fapical, estimated)	constant	2	0.3	-0.01	0.5	1	2	-1	6
$f_{\phi 2}$ (modern era Fapical, before moratorium)	average with previous year before change	-1	1	0.02	10	1	2	-1	6
$f_{\phi 3}$ (Fapical after moratorium on harvest)	average over previous 10 years	-10	0.14	0.01	0.9	3	5	-0.4	23
M (age-specific, intercept)	power	12	0.45331	0.01	0.7	-3	0	-0.4	23
M(age-specific, slope)	power	12	-0.288	-1	-0.1	-3	0	-0.4	23
α-1 (maximum lifetime fecundity-1)	Beverton-Holt stock-recruitment	10	2.64809	0.01	150	2	1	1.310438	6
L_∞ (growth curve, asymptotic length in mm)	von Bertalannfy growth curve	8	2221	150	3000	5	2	-0.11	23
k (growth curve, exponent)	von Bertalannfy growth curve	8	0.0937	0	10	-6	0	0.00295	23
t_0 (growth curve, intercept)	von Bertalannfy growth curve	8	-0.6842	-5	10	-1	0	0.1	23
growth curve parameter (1= von Bertalannfy, other=Chapman-Richards)	von Bertalannfy growth curve	8	1.0000	0	10	-1	0	0.1	6
a (length-weight, intercept in kg/mm)	von Bertalannfy growth curve	8	1.01E-08	0	10	-1	0	0.1	23
b (length-weight, slope)	von Bertalannfy growth curve	8	3.09	0	10	-1	0	0.1	23

Parameters	Description	Function Type	Best estimate	lower bound	upper bound	phase of estimation	pdf*	cv (-) or SE of prior	SEDAR
q1 (catchability, index 1)	constant	1	0.5000	0.01	10	1	2	-2	6
q2 (catchability, index 2)	constant	1	0.5000	0.01	10	1	2	-2	6
q3 (catchability, index 3)	constant	1	0.5000	0.01	10	1	2	-2	6
q4 (catchability, index 4)	constant	1	0.5000	0.01	10	1	2	-2	6
q5 (catchability, index 5)	constant	1	0.5000	0.01	10	1	2	-2	6
s_1 (selectivity for historical period, a_{50}, for f_h and $f_{\phi1}$)	logistic selectivity function	6	2.5100	0	10	-4	2	-0.1	6
s_1 (selectivity for historical period, slope, for f_h and $f_{\phi1}$)	logistic selectivity function	6	0.5250	0	10	-1	0	0.1	6
s_2 (selectivity for modern period, a_{50}, for $f_{\phi2}$ and $f_{\phi3}$)	logistic selectivity function	6	2.5100	2	10	4	2	-0.1	6
s_2 (selectivity for modern period, slope, for $f_{\phi2}$ and $f_{\phi3}$)	logistic selectivity function	6	0.5250	0	10	-1	0	0.1	6
v_1 (vulnerability, a_{50}, for index 1)	logistic selectivity function	6	5.5272	4	10	-4	2	-0.1	23
v_1 (vulnerability, slope, for index 1)	logistic selectivity function	6	1.0244	0	10	-1	0	0.1	23
v_2 (vulnerability, a_{50},for index 2)	logistic selectivity function	6	5.5272	4	10	-4	2	-0.1	23
v_2 (vulnerability, slope, for index 2)	logistic selectivity function	6	1.0244	0	10	-1	0	0.1	23
v_3 (vulnerability, mean, for index 3)	gamma selectivity function	7	3.6320	0	10	-4	2	-0.1	23

Table 3.2.4.2. (continued) List of catch-free model parameters, estimates, bounds, phase of estimation, pdf, and coefficient of variation (cv) or standard error (se) used in SEDAR 23 for proposed base run

Table 3.2.2. (continued) List of catch-free model parameters, estimates, bounds, phase of estimation, pdf, and coefficient of variation (cv) or standard error (se) used in SEDAR 23 for proposed base run.

Parameters	Description	Function Type	Best estimate	lower bound	upper bound	phase of estimation	pdf*	cv (-) or SE of prior	SEDAR
v_3 (vulnerability, cv, for index 3)	gamma selectivity function	7	0.3395	0	10	-1	0	0.1	23
v_4 (vulnerability, a_{50}, for index 4)	logistic selectivity function	6	5.5272	0	10	-4	2	-0.1	23
v_4 (vulnerability, slope, for index 4)	logistic selectivity function	6	1.0244	0	10	-1	0	0.1	23
v_5 (vulnerability, a_{50},for index 5)	logistic selectivity function	6	5.5272	0	10	-4	2	-0.1	23
v_5 (vulnerability, slope, for index 5)	logistic selectivity function	6	1.0244	0	10	-1	0	0.1	23
Index variances (not used for these runs)	constant	14	1.00	0	10	-1	0	0.1	6
overall cv	constant	1	-0.2	-1	-0.01	5	2	-0.5	6

*probability density function: 0=none, 1=autocorrelated lognormal, 2=autocorrelated normal, 3=uniform, 4=uniform (log-scale), 5=gamma, 6=beta
34 parameters (not all are estimated), 5 catchabilities, 7 selectivities, 1 overall cv.
Phase of estimation: the phase when model will begin estimating this parameter. If negative, model estimation is turned off.

.

Table 3.2.3. Comparison of catch-free model indices and other data used in SEDAR 6, SEDAR 23 continuity run, and SEDAR 23 model runs.

Item	SEDAR 6 configuration (indices)	SEDAR 23 continuity (indices)	SEDAR 23 configuration (indices)
Abundance Index 1	DeMaria (1982-1991, 1993-2002)	DeMaria (1982-1991, 1993-2002)	DeMaria (1982-1991, 1993-2002)
Abundance Index 2	REEF SE (1994, 1996-2002)	REEF SE (1994, 1996-2009)	REEF SE (1994, 1996-2009)
Abundance Index 3	ENP Angler Creel Survey, 1973, 1975-1999	ENP Angler Creel Survey, 1973, 1975-2009	ENP Angler Creel Survey, 1973, 1975-2009
Abundance Index 4	Interviews (1950, 1990)	Interviews (1950, 1990)	MRFSS, 1991-2009
Abundance Index 5	n.a.	n.a.	REEF SW, 1999-2009
Effort Index	proxy, U.S. census (1950-2002)	proxy, U.S. census (1950-2002)	proxy, U.S. census (1950-2009)
time periods applied to fishing mortality rates			
f_h	1950	1950	1950
$f\phi 1$	1951-1979	1951-1979	1951-1979
$f\phi 2$	1980-1989	1980-1989	1980-1989
$f\phi 3$	1990-2002	1990-2009	1990-2009
projections	2003-2020 (using $F_{current}$)	2010-2029 (using $F_{current}$)	2010-2029 (using $F_{current}$)
ages	1-20+	1-20+	1-20+
spawning season	June	June	June
maturity	ages 1-5 (immature), 6-20 (mature)	ages 1-5 (immature), 6-20 (mature)	ages 1-5 (immature), 6-20 (mature)
benchmark	$F_{50\%SPR}$	$F_{50\%SPR}$	$F_{50\%SPR}$

components of negative log likelihood function	continuity run	proposed base and sensitivity runs
Abundance indices	3 of 4 (1 not estimated)	5
process errors		
fishing mortality (F)	√	√
recruitment	√	√
priors		
F historical	√	√
F modern	√	√
M (natural mortality)	1 (constant)	not estimated
r (recruitment)	√	√
k (growth, L_∞)	√	√
q (catchabilities)	3 of 4 (1 not estimated)	5
s (selectivities)	1 (modern period)	1 (modern period)
overall variance	√	√
penalties		
equilibrium stats	√	√
projections	√	√

Table 3.2.4. Comparison of the components included in the negative log-likelihood calculations used in the continuity run and other model run.

Type	Model configuration			Model Results											
	Max Age	M	ϕ_3	% reduction in F	F_{2009} (relative)	$F_{2009}/F_{MSY\ adult}$	$F_{2009}/F_{MSY\ fleet}$	$F_{2009}/F_{max\ Y/R}$	$F_{2009}/F_{0.1}$	$F_{2009}/F_{20\%\ SPR}$	$F_{2009}/F_{30\%\ SPR}$	$F_{2009}/F_{40\%\ SPR}$	$F_{2009}/F_{50\%\ SPR}$	$F_{2009}/F_{60\%\ SPR}$
Base B-1	37	0.12	S23	91.0%	0.034	0.256	0.389	0.267	0.451	0.275	0.404	0.572	0.811	1.190
B-2 (40)	40	0.11	S23	91.0%	0.035	0.274	0.411	0.289	0.482	0.292	0.429	0.610	0.868	1.280
B-3 (50)	50	0.09	S23	90.5%	0.036	0.326	0.471	0.349	0.568	0.339	0.503	0.721	1.040	1.561
B-4 (60)	60	0.076	S23	90.4%	0.036	0.368	0.517	0.396	0.635	0.379	0.567	0.820	1.198	1.833
B-5 (70)	70	0.065	S23	90.2%	0.036	0.403	0.556	0.437	0.695	0.417	0.628	0.917	1.355	2.112
B-6 (80)	80	0.057	S23	90.1%	0.036	0.434	0.589	0.473	0.748	0.453	0.687	1.012	1.512	2.402
S-1 (37)	37	0.12	S6	98.0%	0.006	0.046	0.068	0.044	0.074	0.045	0.066	0.093	0.132	0.193
S-2 (40)	40	0.11	S6	98.0%	0.006	0.050	0.074	0.048	0.081	0.049	0.071	0.101	0.144	0.212
S-3 (50)	50	0.09	S6	98.2%	0.006	0.062	0.088	0.061	0.099	0.059	0.088	0.125	0.180	0.270
S-4 (60)	60	0.076	S6	98.1%	0.006	0.072	0.100	0.072	0.116	0.069	0.102	0.148	0.215	0.328
S-5 (70)	70	0.065	S6	98.0%	0.007	0.081	0.110	0.082	0.130	0.078	0.117	0.170	0.250	0.387
S-6 (80)	80	0.057	S6	98.0%	0.007	0.089	0.119	0.090	0.143	0.086	0.130	0.191	0.284	0.448
L-1 (37)	37	0.12	lower	90.0%	0.038	0.286	0.435	0.302	0.510	0.311	0.456	0.646	0.917	1.345
L-2 (40)	40	0.11	lower	90.0%	0.039	0.306	0.460	0.326	0.545	0.330	0.485	0.690	0.983	1.449
L-3 (50)	50	0.09	lower	89.3%	0.040	0.366	0.530	0.396	0.645	0.386	0.572	0.820	1.183	1.777
L-4 (60)	60	0.076	lower	89.1%	0.041	0.414	0.584	0.451	0.723	0.432	0.646	0.936	1.366	2.092
L-5 (70)	70	0.065	lower	88.9%	0.041	0.455	0.629	0.498	0.793	0.476	0.717	1.048	1.549	2.418
L-6 (80)	80	0.057	lower	88.8%	0.041	0.491	0.668	0.540	0.856	0.518	0.787	1.159	1.733	2.756
Continuity	37	0.11	S6	98.1%	0.006	0.042	0.067	0.017	0.048	0.038	0.055	0.076	0.106	0.151
B1918 (37)	37	0.12	S23	90.8%	0.034	0.256	0.389	0.267	0.451	0.275	0.403	0.571	0.811	1.189
S1918 (37)	37	0.12	S6	98.4%	0.006	0.046	0.068	0.044	0.074	0.045	0.066	0.093	0.132	0.193
L1918 (37)	37	0.12	lower	89.7%	0.038	0.286	0.435	0.302	0.509	0.311	0.456	0.645	0.916	1.344

Table 3.2.5. Relative fishing mortality rate ratios estimated by model runs in SEDAR 23.

Table 3.2.6. Relative spawning stock biomass ratios estimated by model runs in SEDAR 23.

Type	Model configuration			Model Results										
	Max Age	M	ϕ3 prior	% reduction in F	SSB_{2009} (relative)	SSB_{2009} $/SSB_{MSY}$ *adult*	SSB_{2009} $/SSB_{MSY}$ *fleet*	SSB_{2009} $/SSB_{max}$ *Y/R*	SSB_{2009} $/SSB_{F\ at}$ *0.1*	SSB_{2009} $/SSB_{F}$ *at 20% SPR*	SSB_{2009} $/SSB_{F\ at}$ *30% SPR*	SSB_{2009} $/SSB_{F\ at}$ *40% SPR*	SSB_{2009} $/SSB_{F}$ *at 50% SPR*	SSB_{2009} $/SSB_{F}$ *at 60% SPR*
Base B-1	37	0.12	S23	91%	0.448	1.889	1.783	2.953	1.522	2.818	1.711	1.229	0.958	0.786
B-2 (40)	40	0.11	S23	91%	0.412	1.712	1.613	2.564	1.364	2.521	1.538	1.106	0.864	0.709
B-3 (50)	50	0.09	S23	91%	0.298	1.256	1.178	1.714	0.975	1.783	1.099	0.795	0.622	0.511
B-4 (60)	60	0.076	S23	90%	0.224	0.960	0.898	1.238	0.732	1.313	0.816	0.592	0.465	0.382
B-5 (70)	70	0.065	S23	90%	0.176	0.773	0.721	0.957	0.580	1.017	0.637	0.464	0.365	0.300
B-6 (80)	80	0.057	S23	90%	0.144	0.648	0.603	0.777	0.479	0.820	0.517	0.378	0.298	0.245
S-1 (37)	37	0.12	S6	98%	0.542	2.131	2.028	3.787	1.862	3.604	2.113	1.495	1.157	0.943
S-2 (40)	40	0.11	S6	98%	0.492	1.941	1.844	3.287	1.674	3.236	1.908	1.352	1.047	0.855
S-3 (50)	50	0.09	S6	98%	0.361	1.446	1.368	2.192	1.208	2.303	1.377	0.982	0.763	0.624
S-4 (60)	60	0.076	S6	98%	0.274	1.121	1.057	1.584	0.913	1.702	1.030	0.739	0.576	0.472
S-5 (70)	70	0.065	S6	98%	0.217	0.911	0.857	1.224	0.726	1.319	0.807	0.582	0.455	0.373
S-6 (80)	80	0.057	S6	98%	0.179	0.769	0.721	0.995	0.601	1.065	0.657	0.476	0.373	0.306
L-1 (37)	37	0.12	lower	90%	0.445	1.855	1.749	2.855	1.479	2.723	1.661	1.194	0.933	0.765
L-2 (40)	40	0.11	lower	90%	0.401	1.679	1.581	2.479	1.323	2.434	1.491	1.074	0.840	0.689
L-3 (50)	50	0.09	lower	89%	0.290	1.228	1.151	1.652	0.944	1.717	1.062	0.769	0.603	0.496
L-4 (60)	60	0.076	lower	89%	0.217	0.936	0.874	1.191	0.707	1.262	0.787	0.572	0.449	0.370
L-5 (70)	70	0.065	lower	89%	0.170	0.752	0.701	0.920	0.559	0.976	0.613	0.447	0.352	0.290
L-6 (80)	80	0.057	lower	89%	0.139	0.629	0.585	0.747	0.461	0.787	0.497	0.364	0.287	0.236
Continuity*	37	0.11	S6	98%	0.659	2.371	2.371	--------	3.859	6.776	3.138	2.042	1.513	1.202
B1918 (37)	37	0.12	S23	91%	0.455	1.882	1.777	2.945	1.518	2.810	1.706	1.225	0.956	0.783
S1918 (37)	37	0.12	S6	98%	0.540	2.122	2.019	3.770	1.855	3.591	2.105	1.489	1.152	0.939
L1918 (37)	37	0.12	lower	90%	0.444	1.849	1.744	2.845	1.475	2.717	1.656	1.191	0.930	0.763

Table 3.2.7. Selected population parameters estimated or calculated from model runs in SEDAR 23.

	Model configuration			Model Results				
				Lifetime Reproductive Rate	Steepness	$M_{age\ 1}$	% reduction in F	Growth Curve
Type	Max Age	M	ϕ3 prior	α	α/(4 + α)	(year^{-1})	(1-ϕ3)*100%	L∞ (mm)
Base B-1	37	0.12	S23	22.0	0.846	0.403	90.9	2383
B-2 (40)	40	0.11	S23	22.9	0.851	0.384	90.8	2353
B-3 (50)	50	0.09	S23	25.5	0.864	0.329	90.6	2290
B-4 (60)	60	0.076	S23	28.0	0.875	0.287	90.4	2255
B-5 (70)	70	0.065	S23	31.0	0.886	0.255	90.3	2232
B-6 (80)	80	0.057	S23	34.1	0.895	0.229	90.2	2215
S-1 (37)	37	0.12	S6	17.2	0.811	0.405	98.4	2370
S-2 (40)	40	0.11	S6	17.7	0.816	0.386	98.4	2341
S-3 (50)	50	0.09	S6	19.5	0.830	0.331	98.2	2280
S-4 (60)	60	0.076	S6	21.4	0.843	0.288	98.1	2247
S-5 (70)	70	0.065	S6	23.6	0.855	0.255	98.1	2225
S-6 (80)	80	0.057	S6	26.0	0.867	0.229	98.0	2209
L-1 (37)	37	0.12	lower	22.9	0.851	0.403	89.8	2385
L-2 (40)	40	0.11	lower	23.8	0.856	0.384	89.7	2355
L-3 (50)	50	0.09	lower	26.5	0.869	0.329	89.4	2291
L-4 (60)	60	0.076	lower	29.3	0.880	0.287	89.2	2257
L-5 (70)	70	0.065	lower	32.3	0.890	0.255	89.0	2233
L-6 (80)	80	0.057	lower	35.7	0.899	0.228	88.9	2216
Continuity*	37	0.11	S6	8.8	0.687	0.113	98.1	2006
B1918 (37)	37	0.12	S23	22.0	0.846	0.403	90.9	2384
S1918 (37)	37	0.12	S6	17.1	0.811	0.405	98.4	2371
L1918 (37)	37	0.12	lower	22.8	0.851	0.403	89.8	2386

ϕ3 priors (see Figure 3.3.2):
SEDAR 6 (S6) μ=0.16, cv=0.88
SEDAR 23 (S23) μ=0.14, cv=0.4
"lower" μ=0.16, cv=0.4
* Continuity model used a constant rate of natural mortality across all ages.

3.3. FIGURES

Figure	**Description**
3.3.1	Natural mortality rates (M · year $^{-1}$) based on longevity in reef fish species from SEDAR assessments and M calculated using relationships developed by Hoenig (1983). RedG=red grouper, SnowyG=snowy grouper, Goliath G=Goliath grouper, BlackG=black grouper, MuttonS=Mutton snapper, RedS=red snapper, G=Gulf of Mexico, SA=South Atlantic.
3.3.2	Prior distribution for the percentage reduction in fishing mortality in the years after the moratorium on harvest went into effect in 1990 (moratorium effectiveness) based upon the DW participants opinions. The solid line represents the opinions expressed during the SEDAR 23 DW, the dashed line represents the prior distribution used in SEDAR 6, and the dotted line represents a slightly lower prior distribution used some sensitivity runs.
3.3.3	Indices of abundance in continuity (a) and proposed base model and sensitivity runs (b).
3.3.5.4	Index fits and standardized residuals for SEDAR 23 continuity run.
3.3.5.5	Index fits and standardized residuals for SEDAR 23 proposed base model run.
3.3.6	Relative fishing mortality rates and spawning stock biomass trajectories for the continuity run compared with results from SEDAR 6.
3.3.7	Comparison of ratios of biomass and fishing mortality rates by year for catch-free model simulations based on different maximum ages and priors for F (Φ_3) from 1990-2009.
3.3.8	Phase plots of the relative F-ratio against the relative SSB-ratio at the $F_{50\%SPR}$ reference point for catch-free model simulations based on different maximum ages using the SEDAR 23 prior for F (Φ_3).
3.3.9	MCMC outcomes for relative $SSB_{2009}/SSB_{F\ at\ 50\%SPR}$ during the current year and 5 projected years based on different maximum ages using the SEDAR 23 prior for F (Φ_3).
3.3.10	MCMC outcomes for relative $F_{2009}/F_{50\%SPR}$ based on different maximum ages using the SEDAR 23 prior for F (Φ_3).
3.3.11	MCMC outcomes for the percentage reduction in F [100*(1-ϕ3)] since 1990 based on different maximum ages using the SEDAR 23 prior for F (Φ_3).
3.3.12	MCMC outcomes for steepness calculated from the α parameter.
3.3.13	MCMC outcomes for M at age 1 (age-specific natural mortality rates).

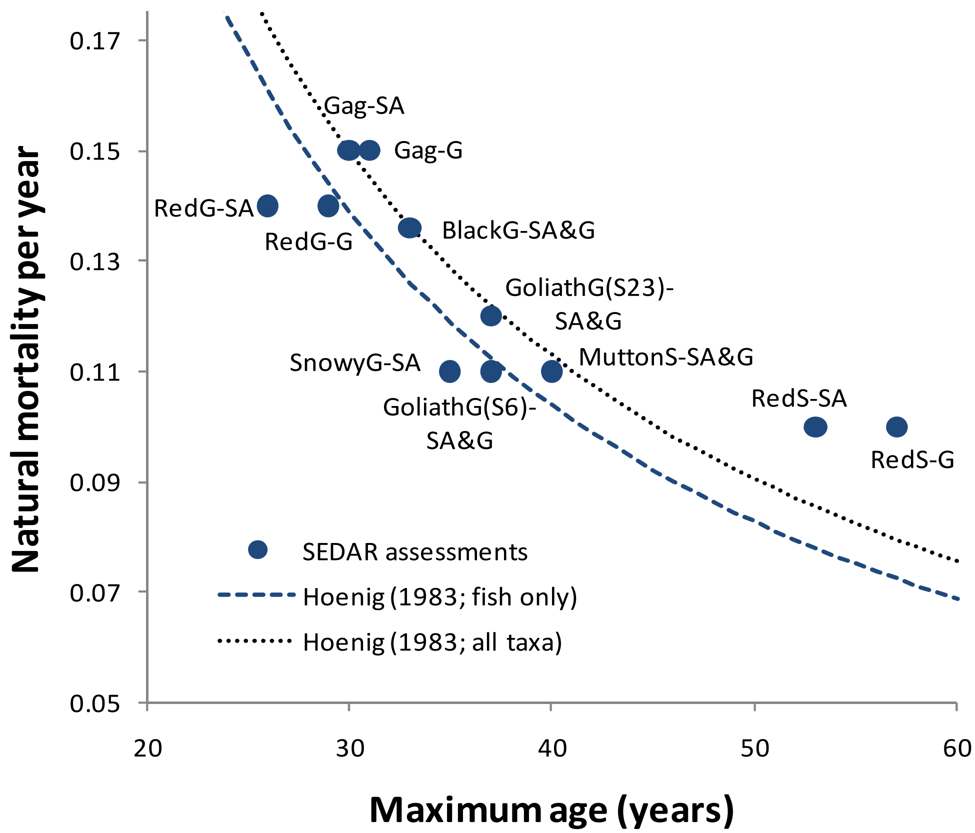


Figure 3.3.1. Natural mortality rates (M · year^{-1}) based on longevity in reef fish species from SEDAR assessments and M calculated using relationships developed by Hoenig (1983). RedG=red grouper, SnowyG=snowy grouper, GoliathG=Goliath grouper, BlackG=black grouper, MuttonS=Mutton snapper, RedS=red snapper, G=Gulf of Mexico, SA=South Atlantic.

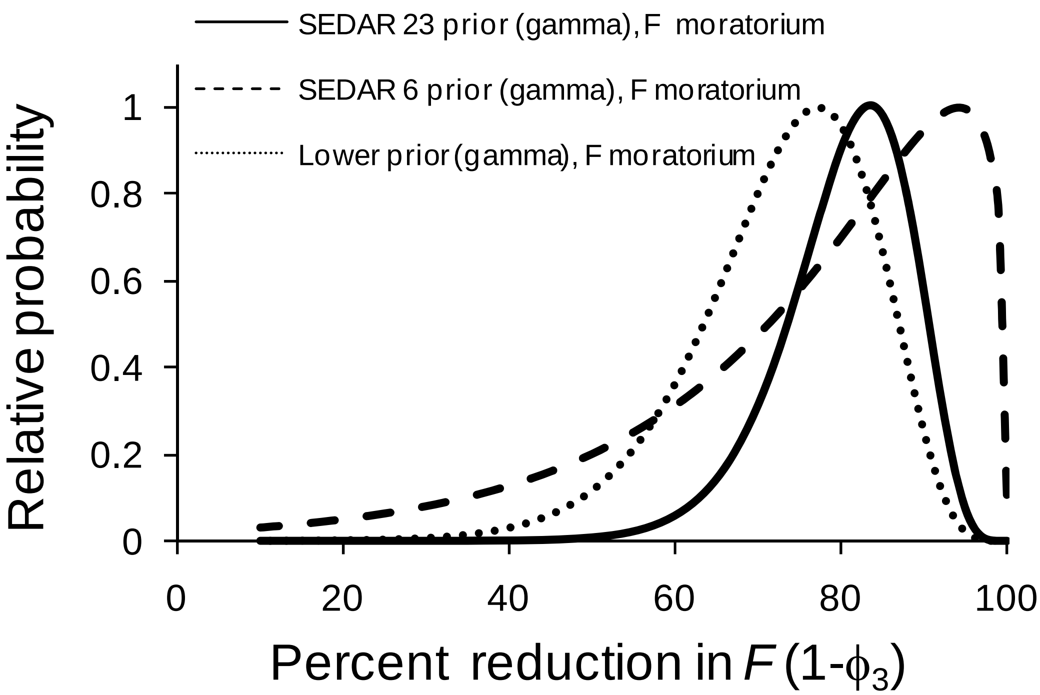
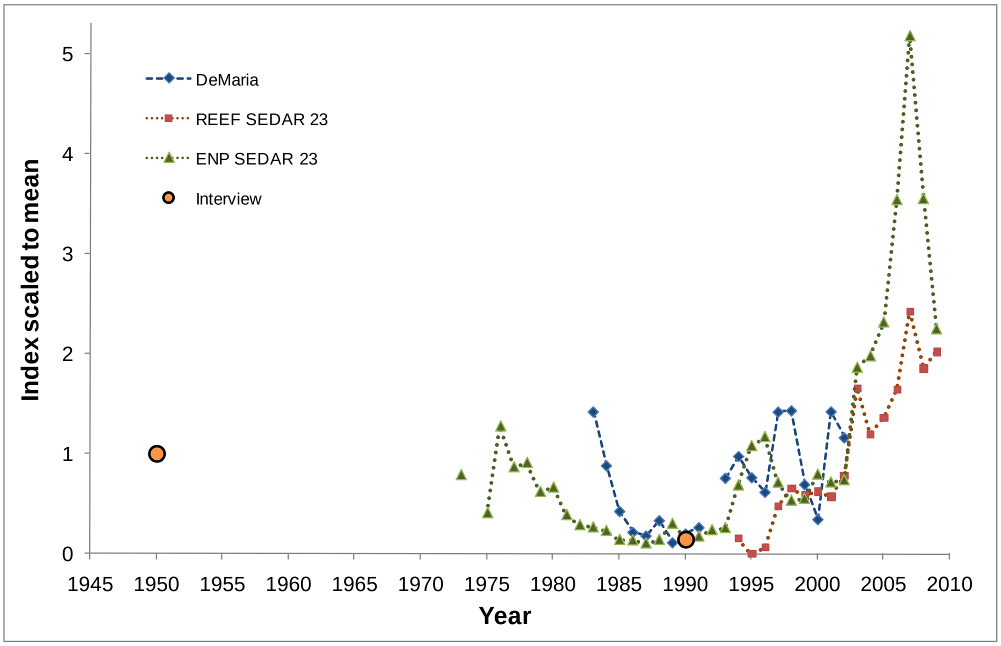
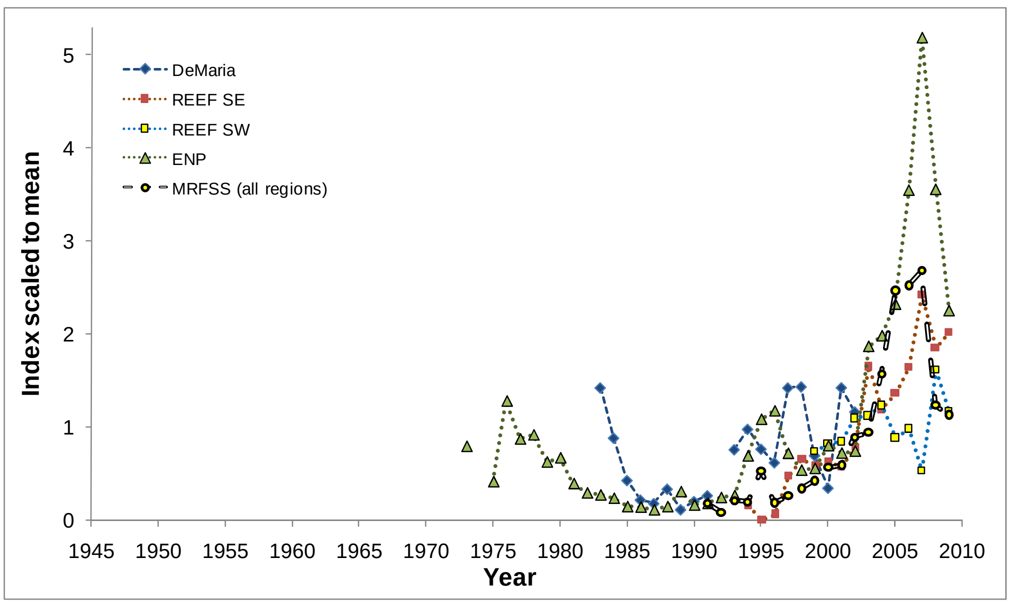


Figure 3.3.2. Prior distribution for the percentage reduction in fishing mortality in the years after the moratorium on harvest went into effect in 1990 (moratorium effectiveness) based upon the DW participants opinions. The solid line represents the opinions expressed during the SEDAR 23 DW, the dashed line represents the prior distribution used in SEDAR 6, and the dotted line represents a slightly lower prior distribution used in some sensitivity runs.

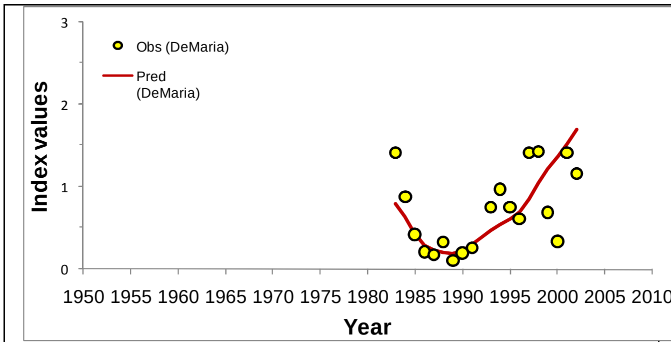


a. Indices of abundance included in SEDAR 23 continuity model run.

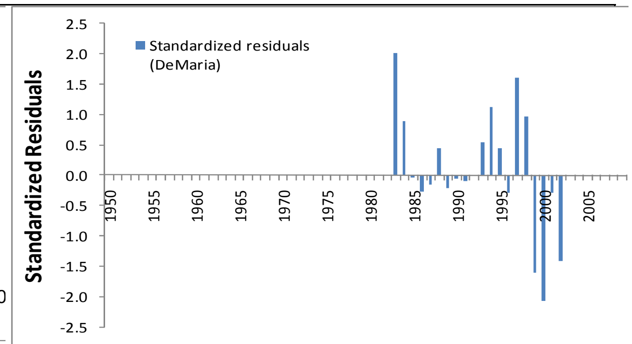


b. Indices of abundance included in SEDAR 23 proposed base model run and sensitivity runs.

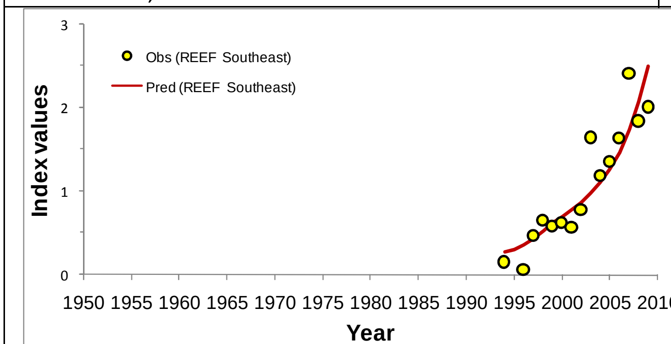
Figure 3.3.3. Indices of abundance in continuity (a) and proposed base model and sensitivity runs (b).



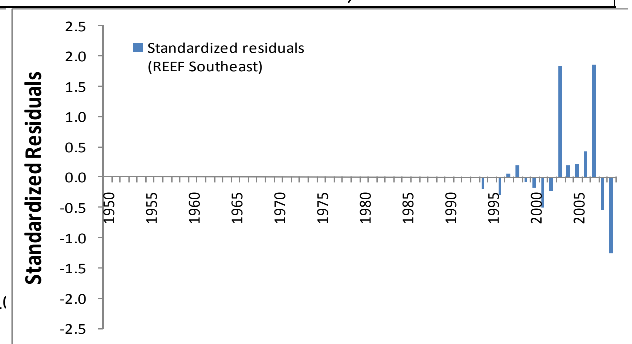
a. Fit, DeMaria index.



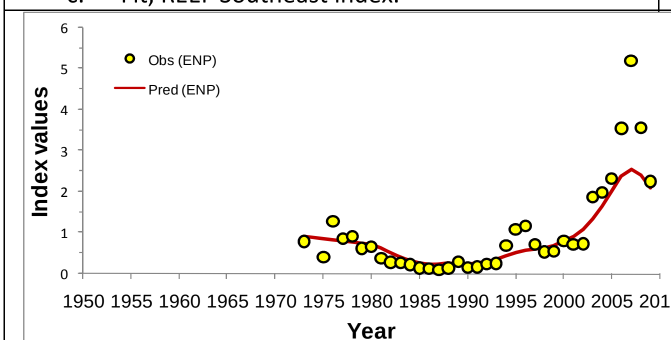
b. Standardized residuals, DeMaria index.



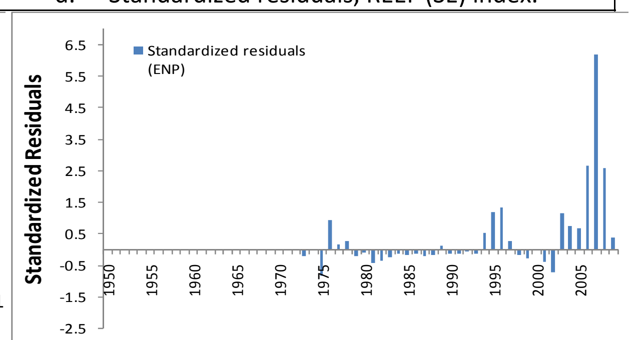
c. Fit, REEF Southeast index.



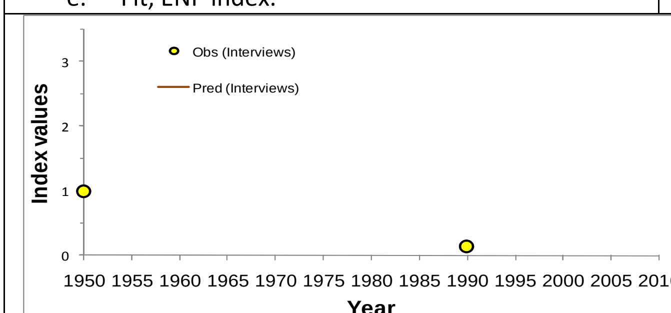
d. Standardized residuals, REEF (SE) index.



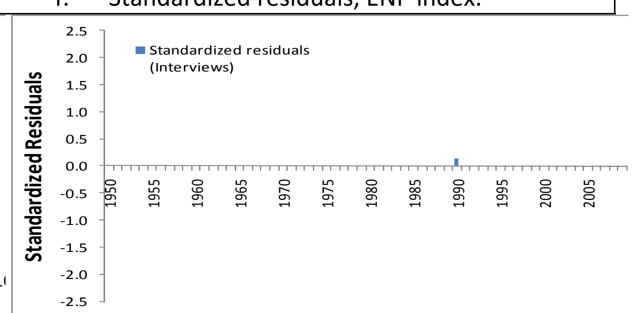
e. Fit, ENP index.



f. Standardized residuals, ENP index.

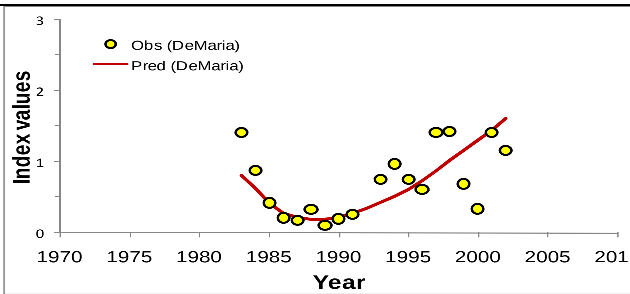


g. Fit, Interview index.

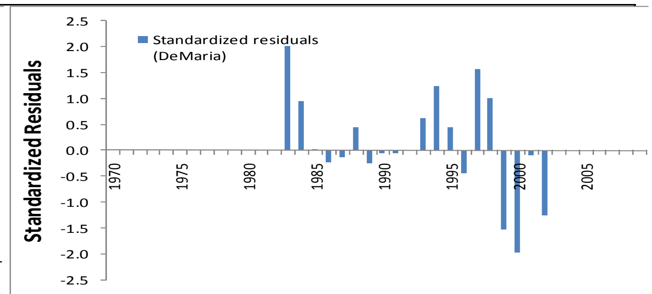


h. Standardized residuals, Interview index.

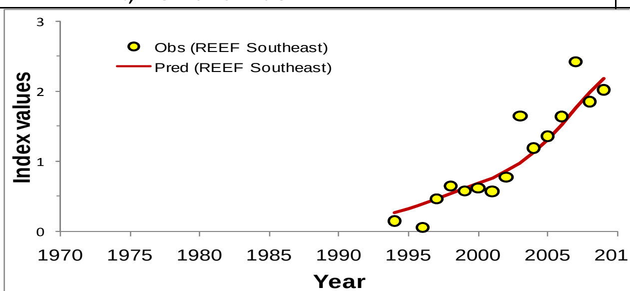
Figure 3.3.4. Index fits and standardized residuals for SEDAR 23 continuity run.



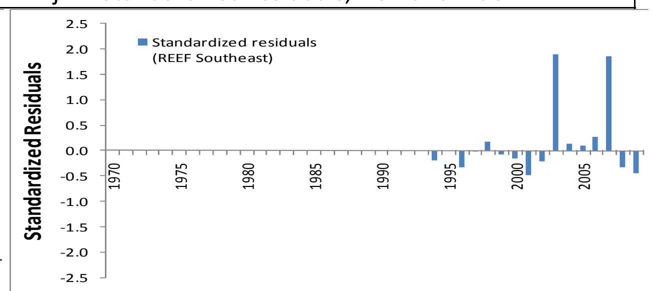
i. Fit, DeMaria index.



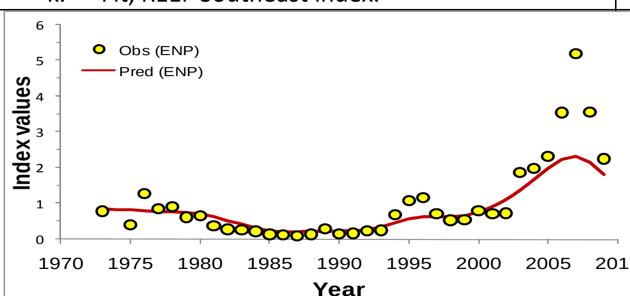
j. Standardized residuals, DeMaria index.



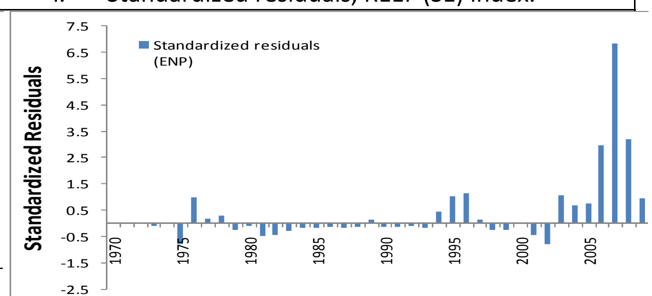
k. Fit, REEF Southeast index.



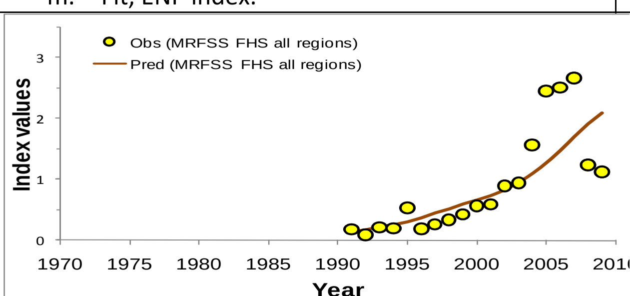
l. Standardized residuals, REEF (SE) index.



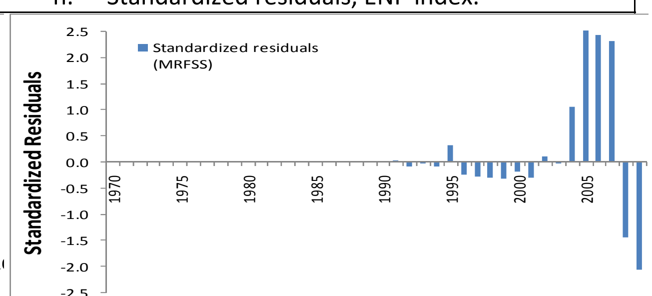
m. Fit, ENP index.



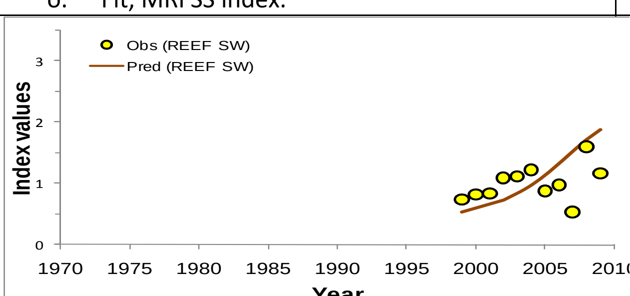
n. Standardized residuals, ENP index.



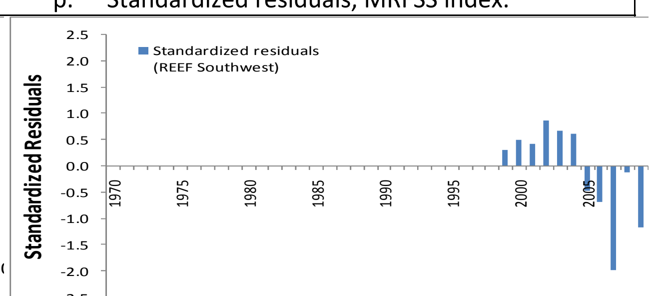
o. Fit, MRFSS index.



p. Standardized residuals, MRFSS index.

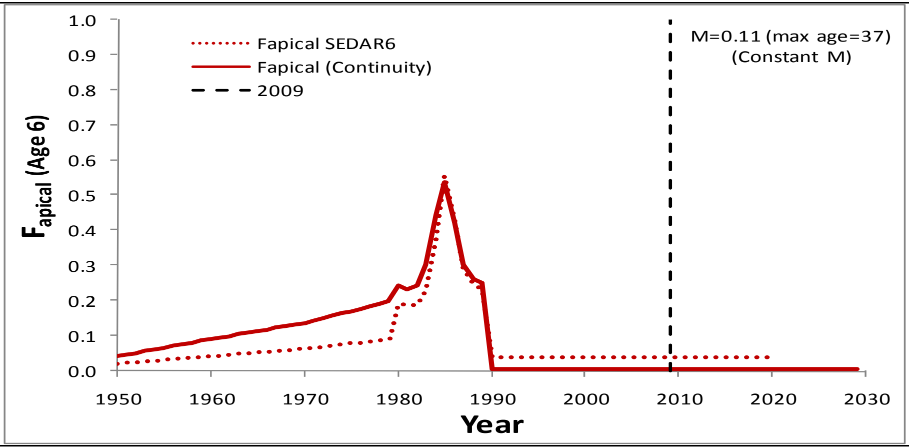


q. Fit, REEF Southwest index.

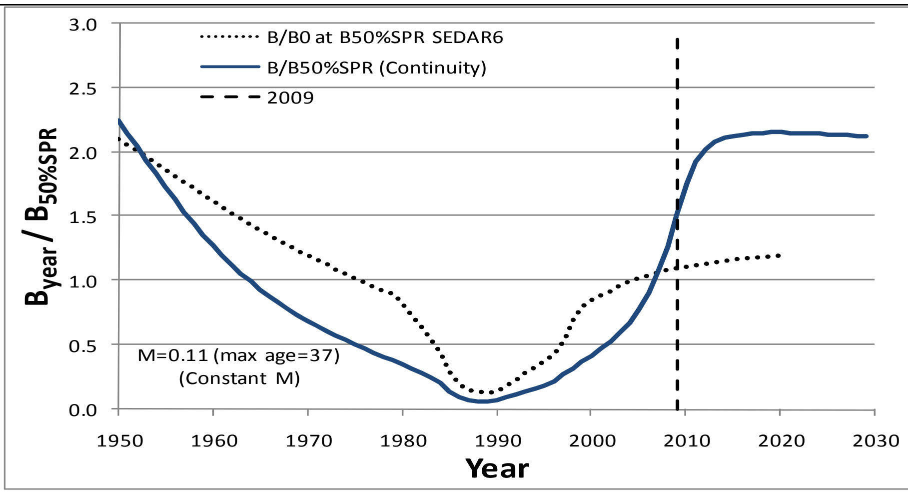


r. Standardized residuals, REEF (SW) index.

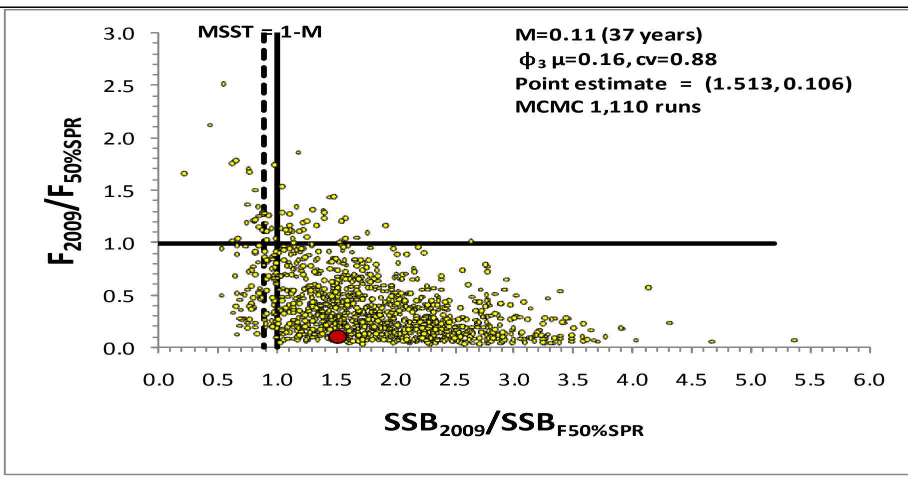
Figure 3.3.5. Index fits and standardized residuals for SEDAR 23 proposed base model run.



a. Relative fishing mortality rates for continuity run, constant M=0.11 (max age 37 years)



b. Relative biomass and fishing mortality rates for continuity run, constant M=0.11 (max age 37 years)



c. Phase plot of $SSB_{2009}/SSB_{F50\%SPR}$ versus $F_{2009}/F_{50\%SPR}$ in relation to Minimum Stock Size Threshold (MSST).

Figure 3.3.6. Relative fishing mortality rates, spawning stock biomass trajectories, and phase plot for the continuity run compared with results from SEDAR 6.

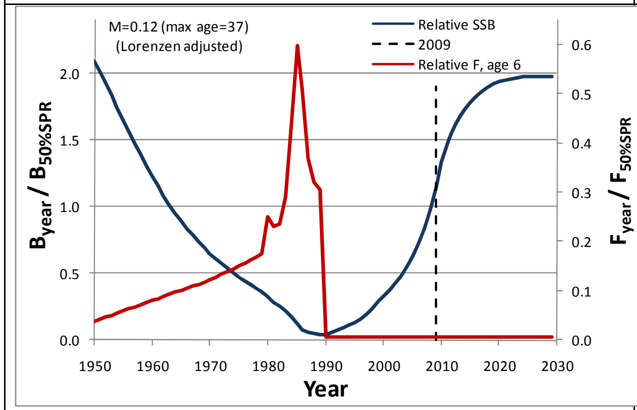
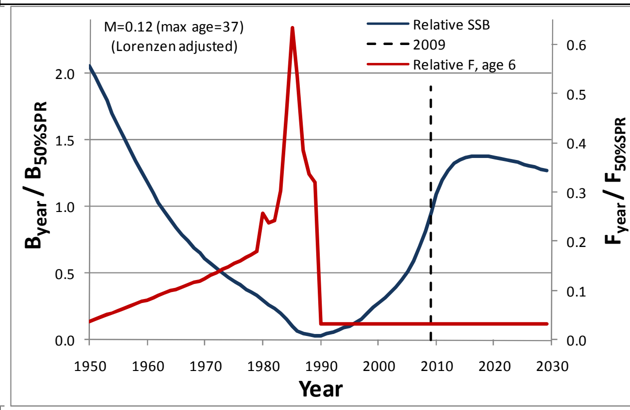
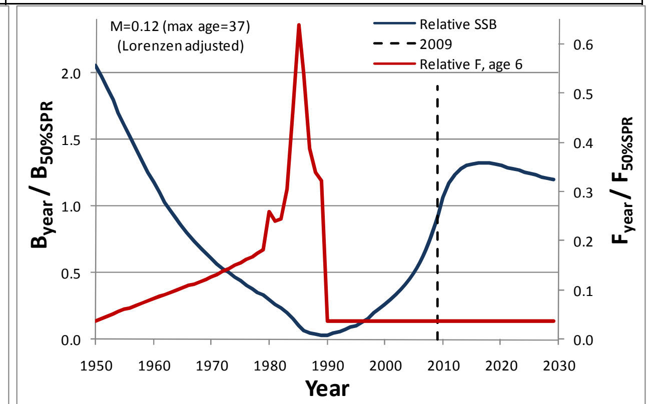
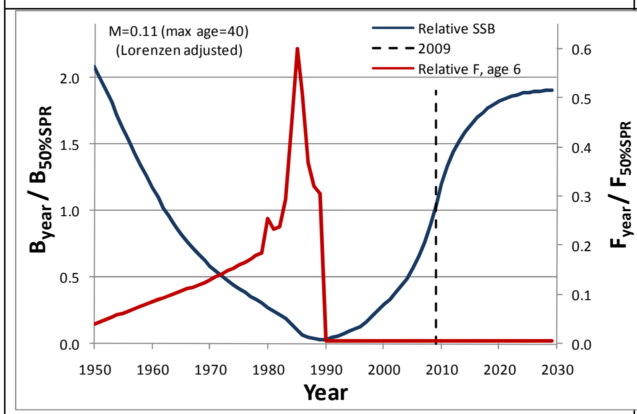
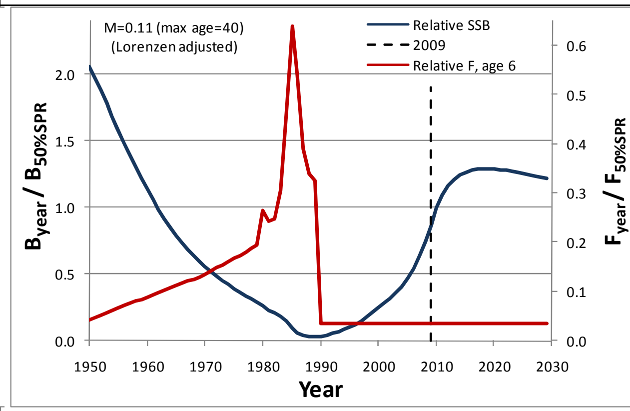
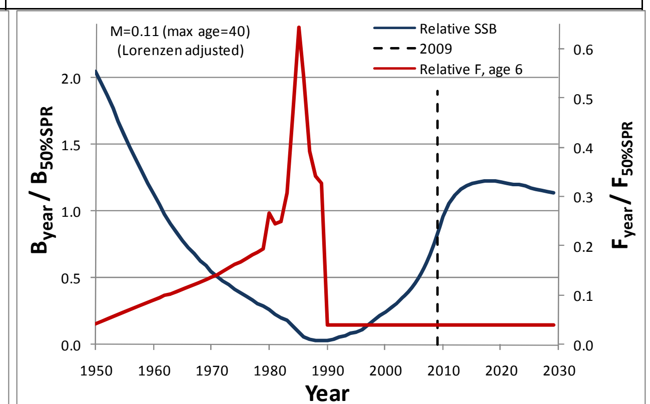
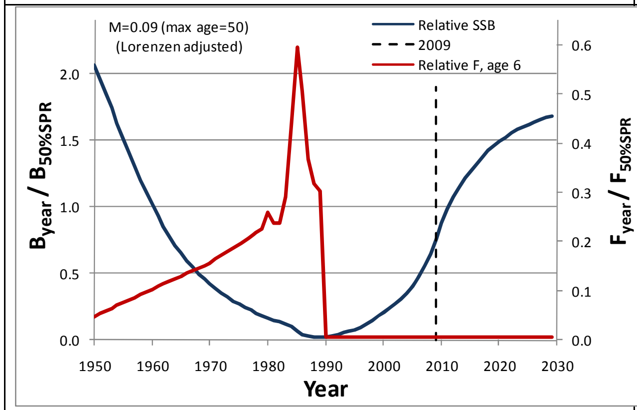
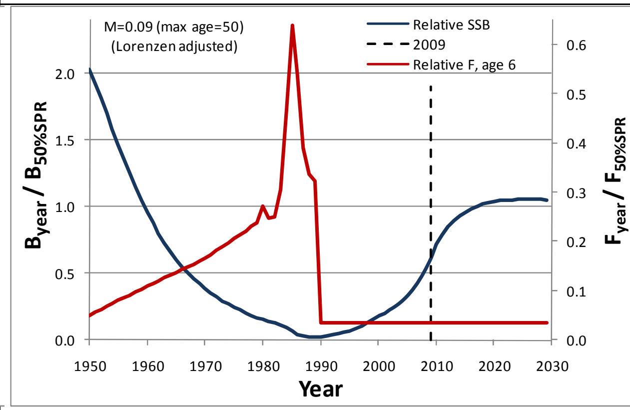
Φ_3 set to SEDAR 6 prior (μ=0.16, cv=0.88)	**Φ_3 set to SEDAR 23 prior (μ=0.14, cv=0.40)**	**Φ_3 set to lower prior (μ=0.165, cv=0.40)**
		
a. Relative biomass and fishing mortality rates for M=0.12 (max age 37 years) – sensitivity run S-1.	b. Relative biomass and fishing mortality rates for M=0.12 (max age 37 years) – proposed base run B-1.	c. Relative biomass and fishing mortality rates for M=0.12 (max age 37 years) – sensitivity run L-1
		
d. Relative biomass and fishing mortality rates for M=0.11 (max age 40 years)– sensitivity run S-2	e. Relative biomass and fishing mortality rates for M=0.11 (max age 40 years)– sensitivity run B-2	f. Relative biomass and fishing mortality rates for M=0.11 (max age 40 years)– sensitivity run L-2

Figure 3.3.7. Comparison of ratios of biomass and fishing mortality rates by year for catch-free model simulations based on different maximum ages and priors for F (Φ_3) from 1990-2009.

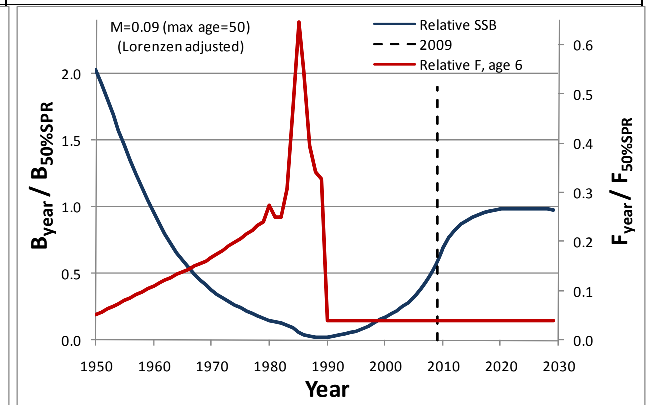
Φ_3 set to SEDAR 6 prior (μ=0.16, cv=0.88)	**Φ_3 set to SEDAR 23 prior (μ=0.14, cv=0.40)**	**Φ_3 set to lower prior (μ=0.165, cv=0.40)**



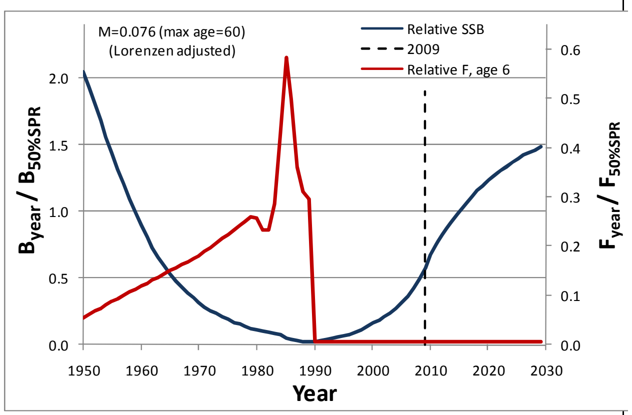
g. Relative biomass and fishing mortality rates for M=0.09 (max age 50 years)– sensitivity run S-3



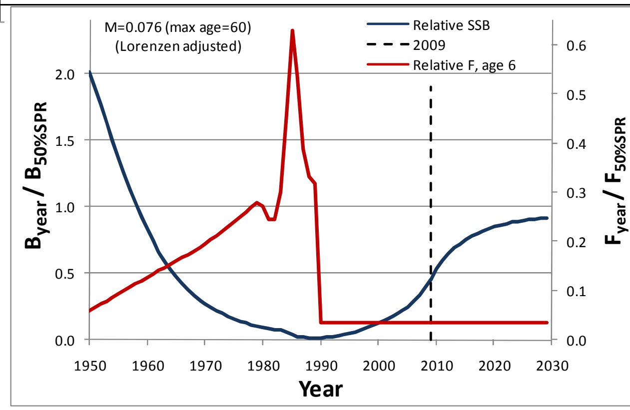
h. Relative biomass and fishing mortality rates for M=0.09 (max age 50 years)– sensitivity run B-3



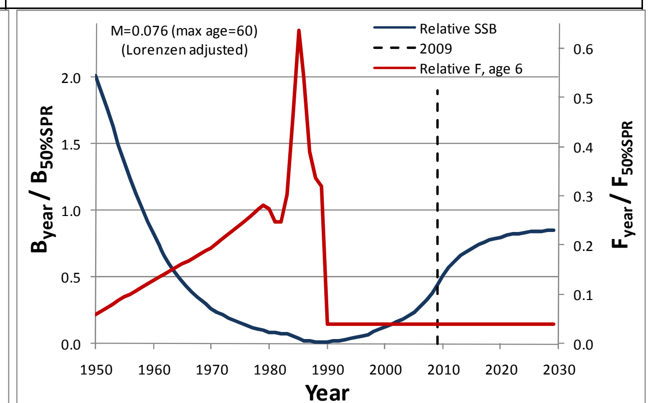
i. Relative biomass and fishing mortality rates for M=0.09 (max age 50 years)– sensitivity run L-3



j. Relative biomass and fishing mortality rates for M=0.076 (max age 60 years)– sensitivity run S-4



k. Relative biomass and fishing mortality rates for M=0.076 (max age 60 years)– sensitivity run B-4



l. Relative biomass and fishing mortality rates for M=0.076 (max age 60 years)– sensitivity run L-4

Figure 3.3.7. (continued) Comparison of ratios of biomass and fishing mortality rates by year for catch-free model simulations based on different maximum ages and priors for F (Φ_3) from 1990-2009.

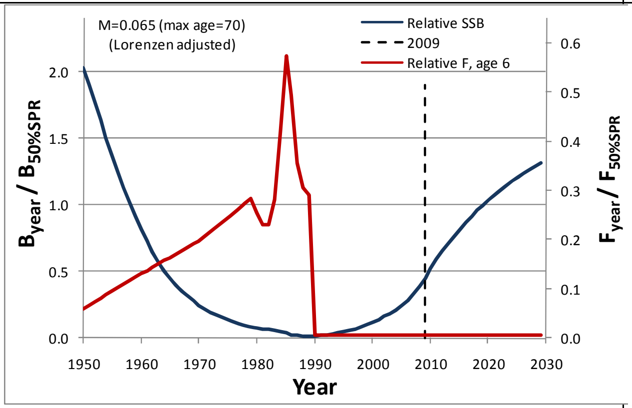
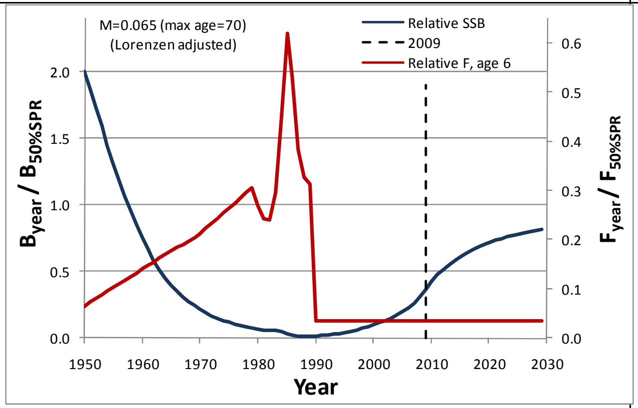
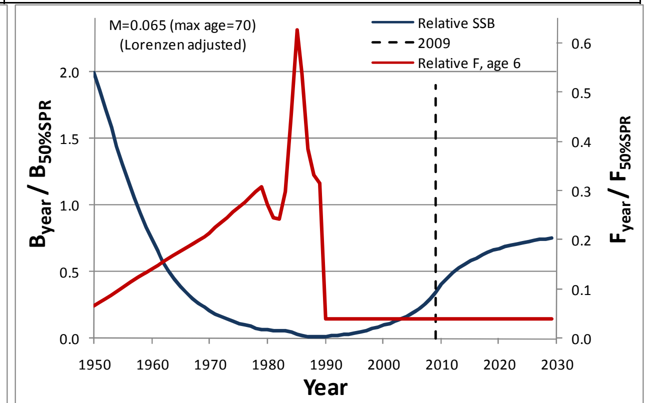
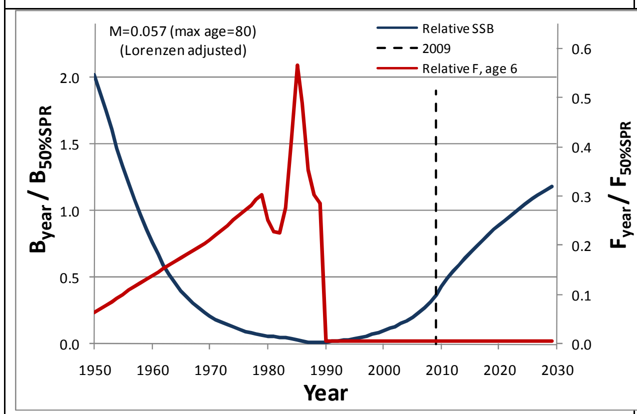
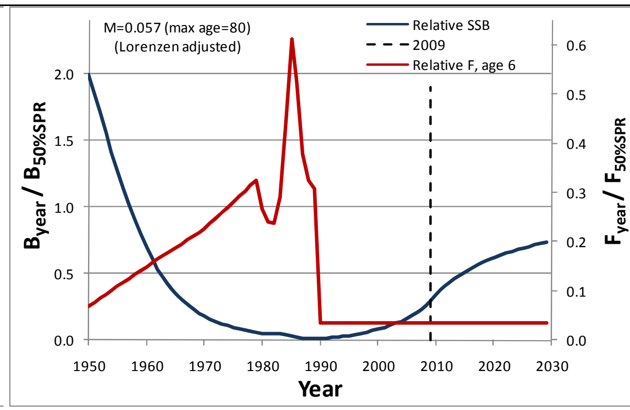
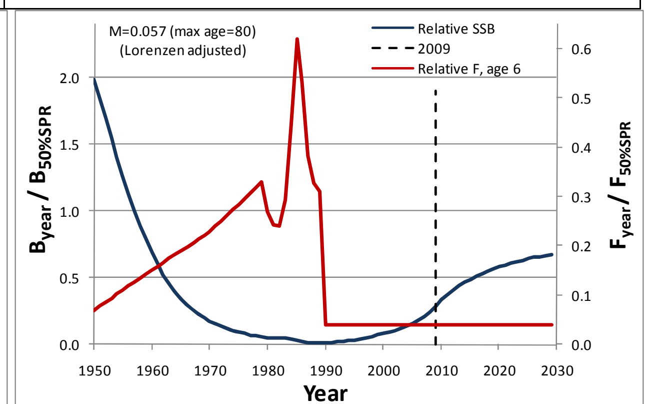
<table>
<tr><th>Φ₃ set to SEDAR 6 prior (μ=0.16, cv=0.88)</th><th>Φ₃ set to SEDAR 23 prior (μ=0.14, cv=0.40)</th><th>Φ₃ set to lower prior (μ=0.165, cv=0.40)</th></tr>
<tr><td>
</td><td>
</td><td>
</td></tr>
<tr><td>m. Relative biomass and fishing mortality rates for M=0.065 (max age 70 years)– sensitivity run S-5</td><td>n. Relative biomass and fishing mortality rates for M=0.065 (max age 70 years)– sensitivity run B-5</td><td>o. Relative biomass and fishing mortality rates for M=0.065 (max age 70 years)– sensitivity run L-5</td></tr>
<tr><td>
</td><td>
</td><td>
</td></tr>
<tr><td>p. Relative biomass and fishing mortality rates for M=0.057 (max age 80 years)– sensitivity run S-6</td><td>q. Relative biomass and fishing mortality rates for M=0.057 (max age 80 years)– sensitivity run B-6</td><td>r. Relative biomass and fishing mortality rates for M=0.057 (max age 80 years)– sensitivity run L-6</td></tr>
</table>

Figure 3.3.7. (continued) Comparison of ratios of biomass and fishing mortality rates by year for catch-free model simulations based on different maximum ages and priors for F (Φ_3) from 1990-2009.

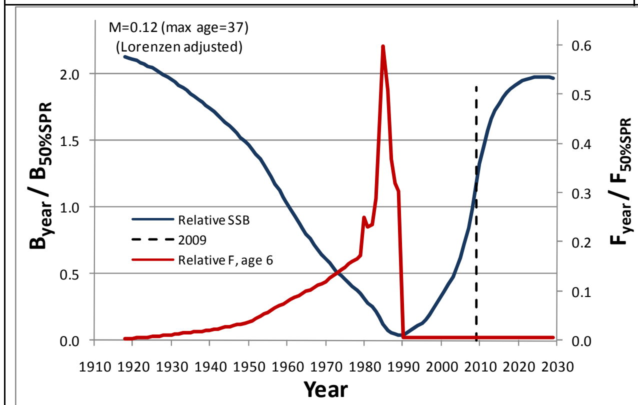
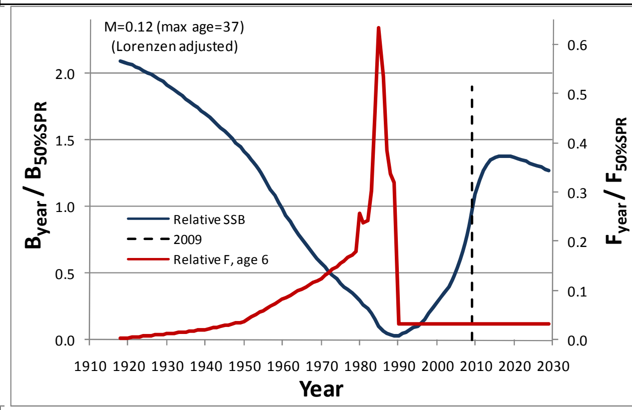
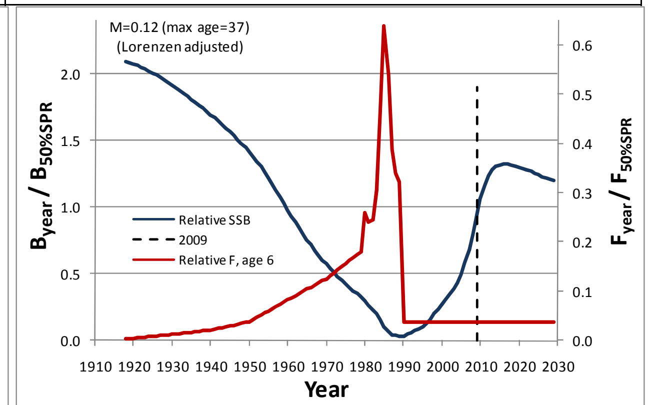
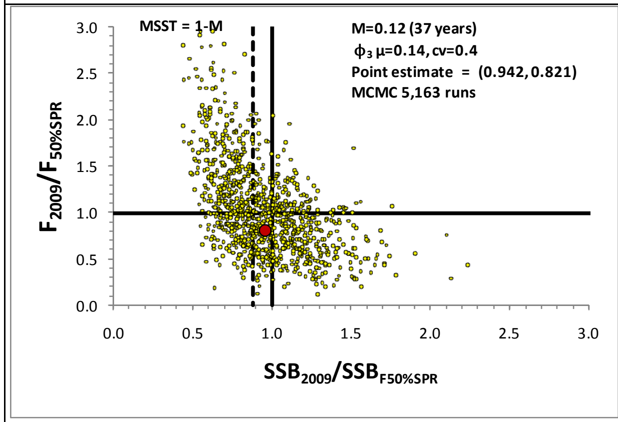
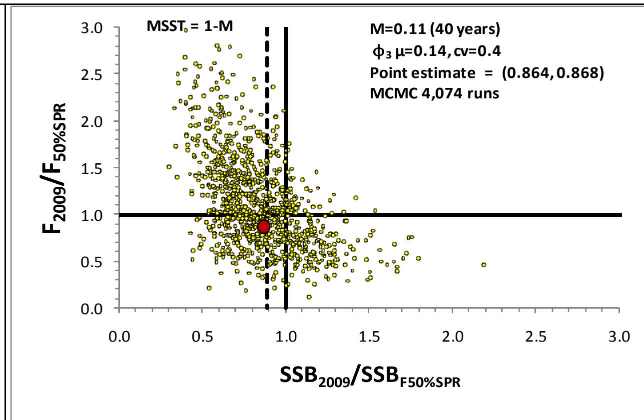
<table>
<tr><th>Φ₃ set to SEDAR 6 prior (μ=0.16, cv=0.88)</th><th>Φ₃ set to SEDAR 23 prior (μ=0.14, cv=0.40)</th><th>Φ₃ set to lower prior (μ=0.165, cv=0.40)</th></tr>
<tr><td>
</td><td>
</td><td>
</td></tr>
<tr><td>s. Relative biomass and fishing mortality rates for M=0.12 (max age 37 years) –S1918</td><td>t. Relative biomass and fishing mortality rates for M=0.12 (max age 37 years) –B1918</td><td>u. Relative biomass and fishing mortality rates for M=0.12 (max age 37 years) –L1918</td></tr>
</table>

Figure 3.3.7. (continued) Comparison of ratios of biomass and fishing mortality rates by year for catch-free model simulations based on different maximum ages and priors for F (Φ_3) from 1990-2009.

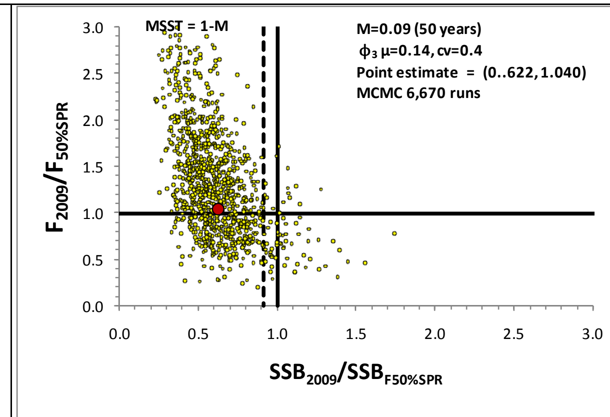
Φ_3 set to SEDAR 23 prior (μ=0.14, cv=0.40)



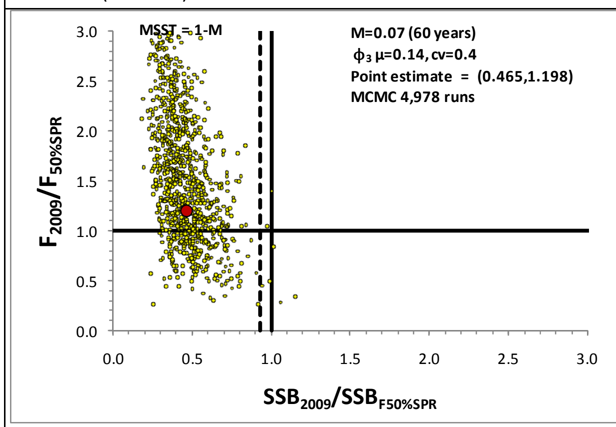
a. Phase plot of the F ratio against the SSB ratio for M=0.12 (observed max. age 37 years) using the current benchmark (50% SPR).



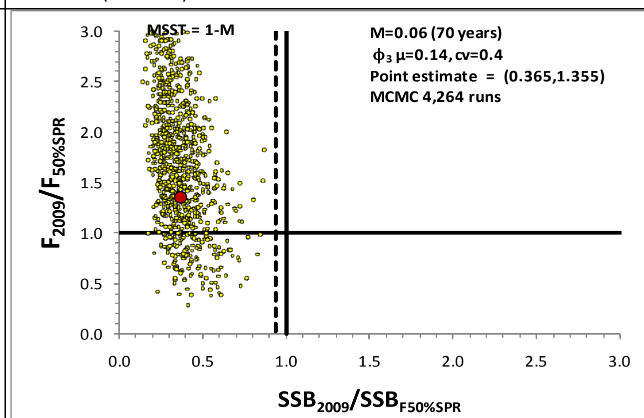
b. Phase plot of the F ratio against the SSB ratio for M=0.11 (hypothetical max. age 40 years) using the current benchmark (50% SPR).



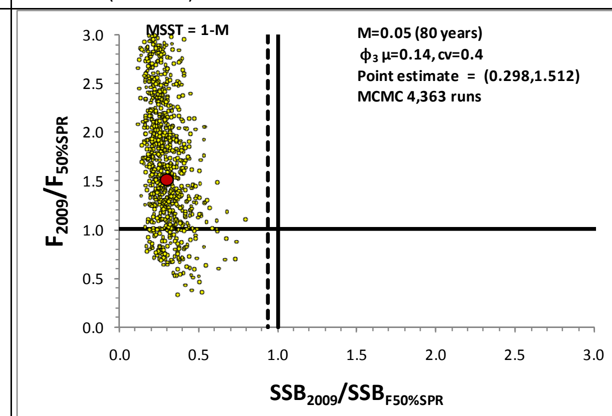
c. Phase plot of the F ratio against the SSB ratio for M=0.09 (hypothetical max. age 50 years) using the current benchmark (50% SPR).



d. Phase plot of the F ratio against the SSB ratio for M=0.076 (hypothetical max. age 60 years) using the current benchmark (50% SPR).

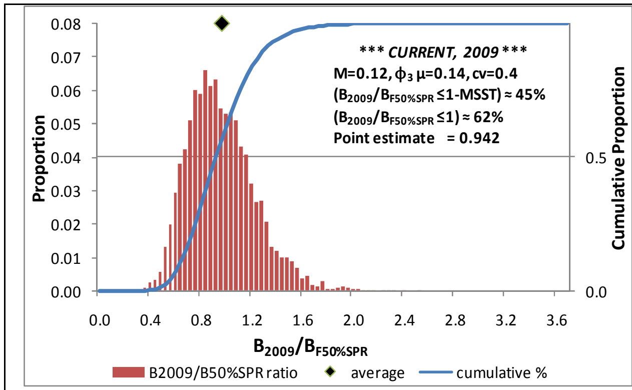


e. Phase plot of the F ratio against the SSB ratio for M=0.065 (hypothetical max. age 70 years) using the current benchmark (50% SPR).

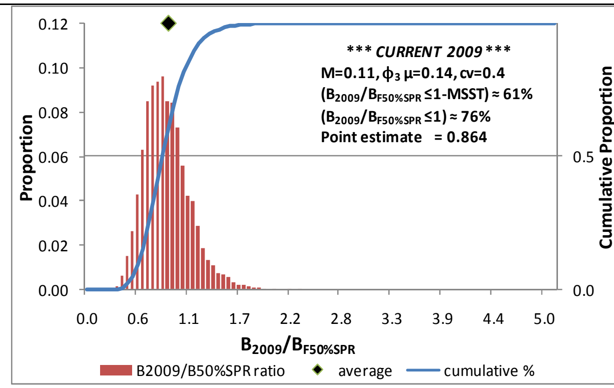


f. Phase plot of the F ratio against the SSB ratio for M=0.056 (hypothetical max. age 80 years) using the current benchmark (50% SPR).

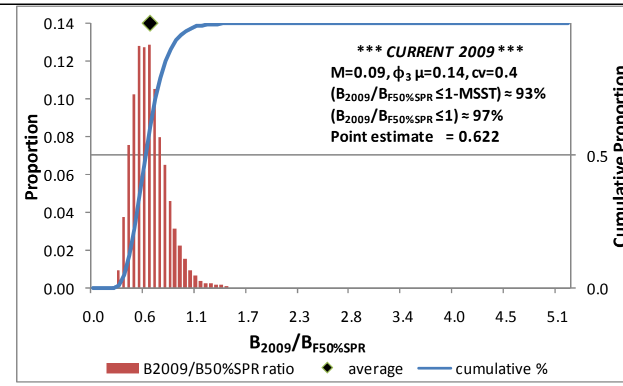
Figure 3.3.8. Phase plots of the relative F-ratio against the relative SSB-ratio at the $F_{50\%SPR}$ reference point for catch-free model simulations based on different maximum ages using the SEDAR 23 prior for F (Φ_3).



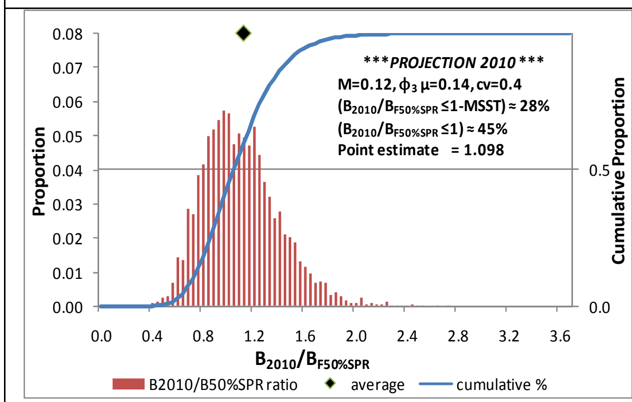
a. MCMC outcomes for the relative SSB ratio for 2009, proposed base run B-1. (max. age = 37 years)



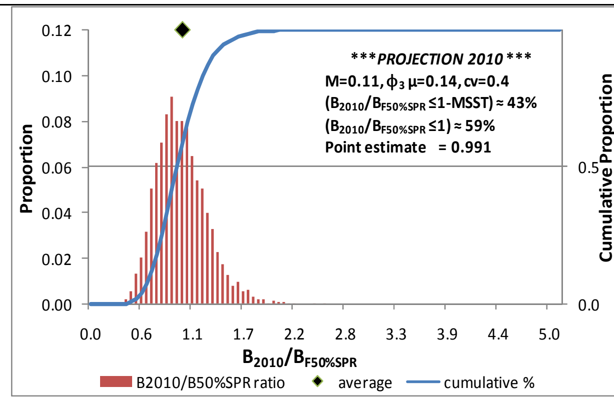
b. MCMC outcomes for the relative SSB ratio for 2009, run B-2. (max. age = 40 years)



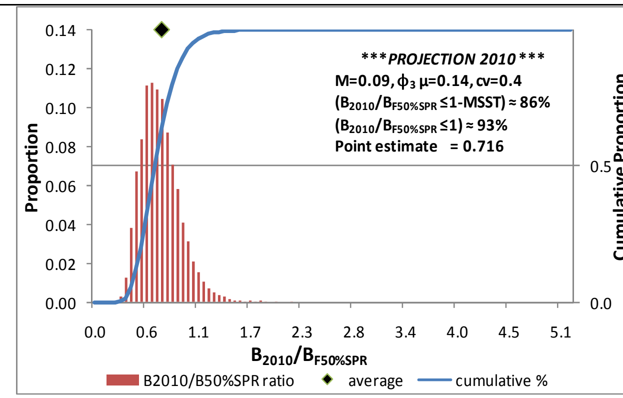
c. MCMC outcomes for the relative SSB ratio for 2009, run B-3. (max. age = 50 years)



d. MCMC outcomes for the relative SSB ratio for 2010 (first projected year), proposed base run B-1. (max. age = 37 years)

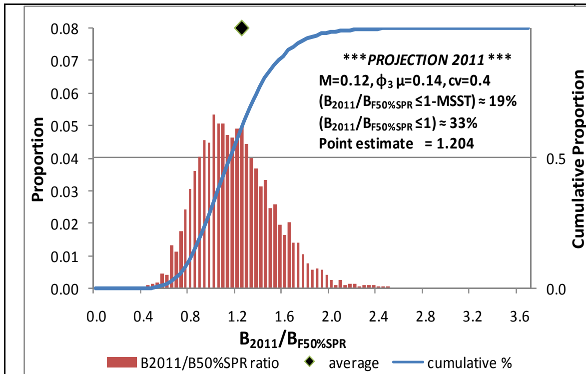


e. MCMC outcomes for the relative SSB ratio for 2010 (first projected year), run B-2. (max. age = 40 years)

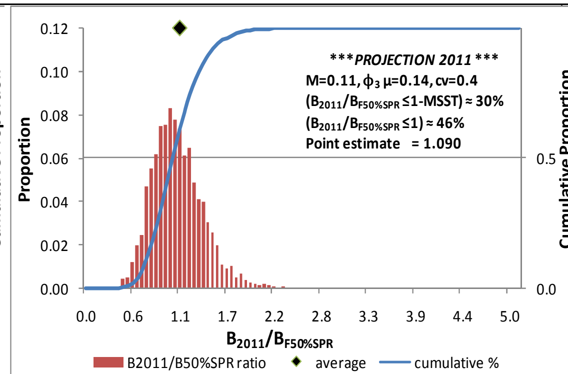


f. MCMC outcomes for the relative SSB ratio for 2010 (first projected year), run B-3. (max. age = 50 years)

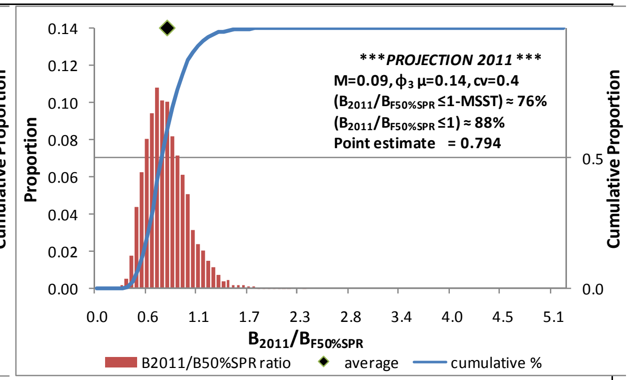
Figure 3.3.9. MCMC outcomes for relative $SSB_{2009}/SSB_{F\ at\ 50\%SPR}$ during the current year and 5 projected years based on different maximum ages using the SEDAR 23 prior for F (Φ_3).



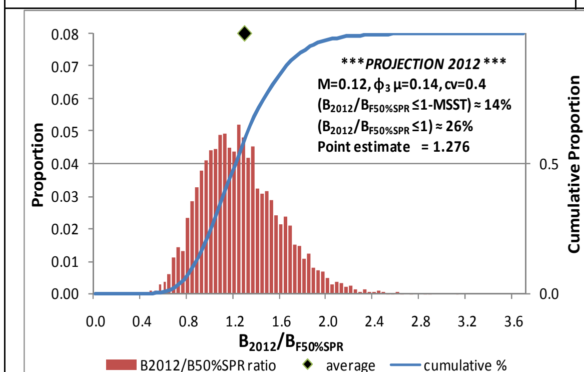
g. MCMC outcomes for the relative SSB ratio for 2011 (second projected year), proposed base run B-1.



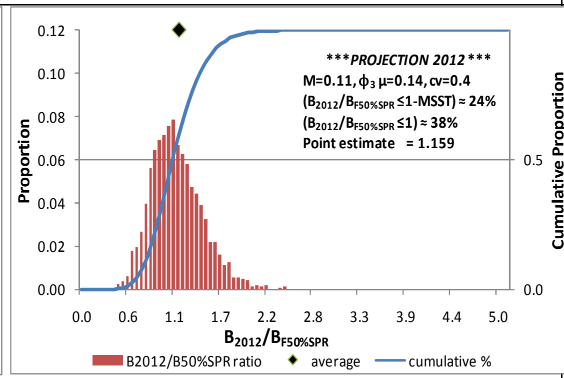
h. MCMC outcomes for the relative SSB ratio for 2011 (second projected year), run B-2.



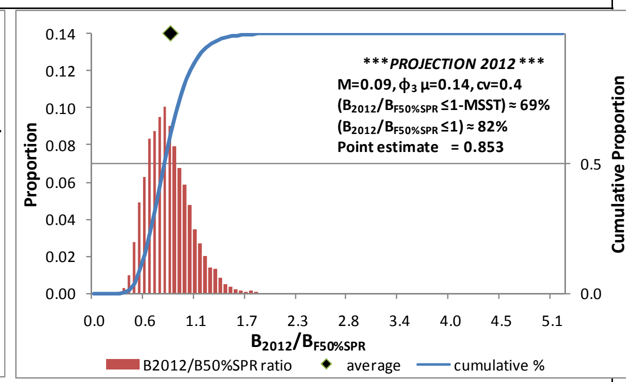
i. MCMC outcomes for the relative SSB ratio for 2011 (second projected year), run B-3.



j. MCMC outcomes for the relative SSB ratio for 2012 (third projected year), proposed base run B-1.

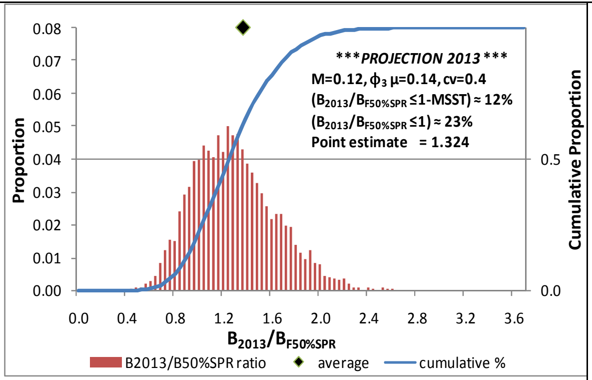


k. MCMC outcomes for the relative SSB ratio for 2012 (third projected year), run B-2.

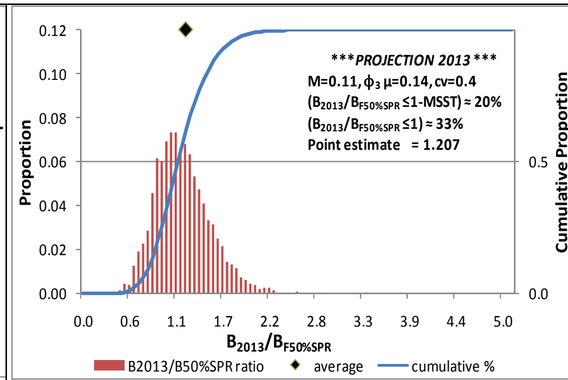


l. MCMC outcomes for the relative SSB ratio for 2012 (third projected year), run B-3.

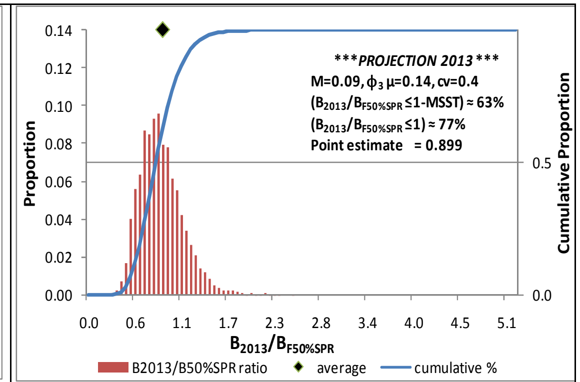
Figure 3.3.9. (continued) MCMC outcomes for relative $SSB_{2009}/SSB_{F\ at\ 50\%SPR}$ during the current year and 5 projected years based on different maximum ages using the SEDAR 23 prior for F (Φ_3).



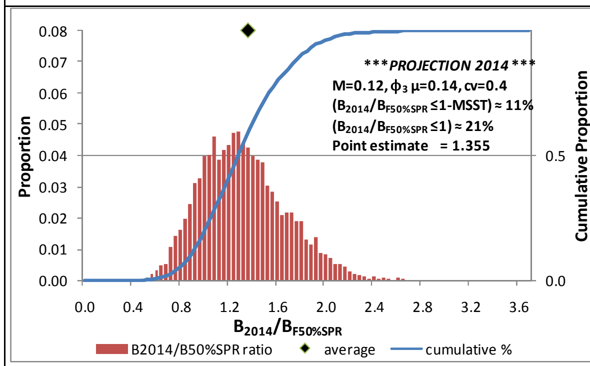
m. MCMC outcomes for the relative SSB ratio for 2013 (fourth projected year), proposed base run B-1.



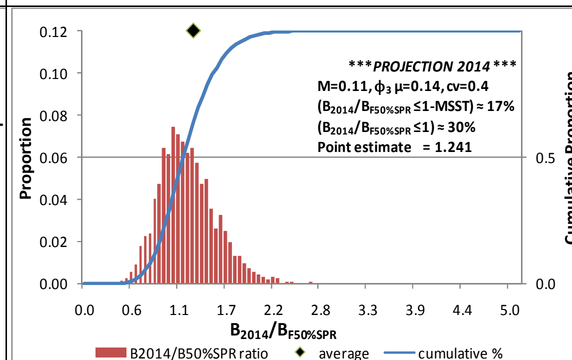
n. MCMC outcomes for the relative SSB ratio for 2013 (fourth projected year), run B-2.



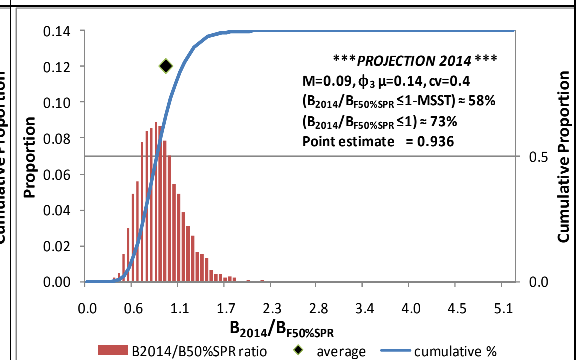
o. MCMC outcomes for the relative SSB ratio for 2013 (fourth projected year), run B-3.



p. MCMC outcomes for the relative SSB ratio for 2014 (fifth projected year), proposed base run B-1.

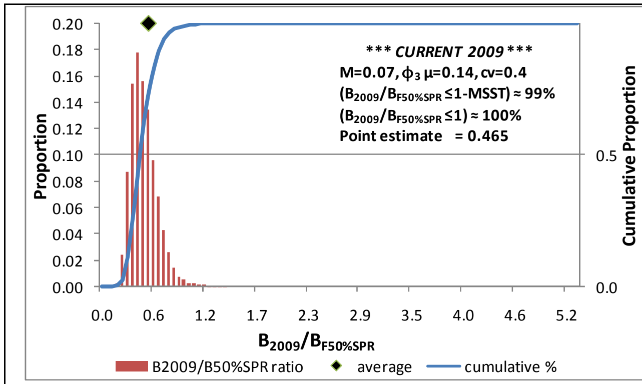


q. MCMC outcomes for the relative SSB ratio for 2014 (fifth projected year), run B-2.

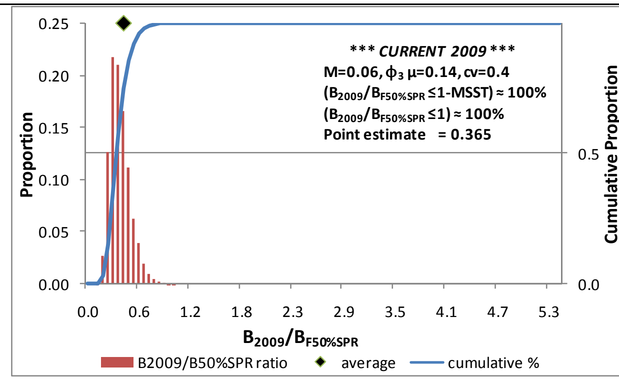


r. MCMC outcomes for the relative SSB ratio for 2014 (fifth projected year), run B-3.

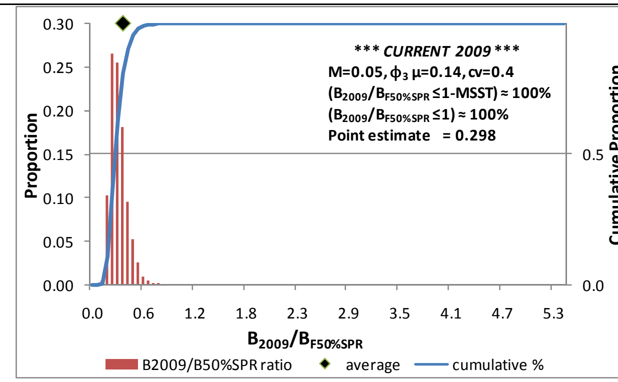
Figure 3.3.9. (continued) MCMC outcomes for relative $SSB_{2009}/SSB_{F\ at\ 50\%SPR}$ during the current year and 5 projected years based on different maximum ages using the SEDAR 23 prior for F (Φ_3).



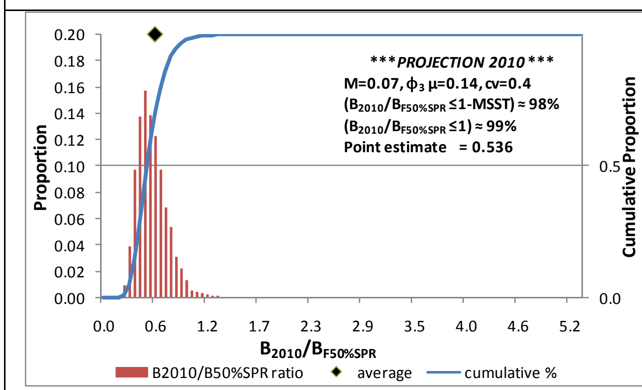
s. MCMC outcomes for the relative SSB ratio for 2009, run B-4. (max. age = 60 years)



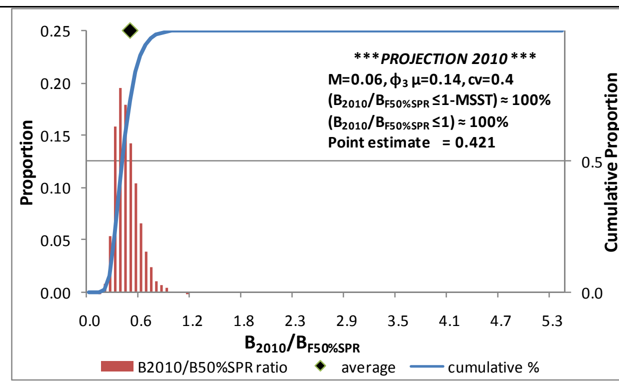
t. MCMC outcomes for the relative SSB ratio for 2009, run B-5. (max. age = 70 years)



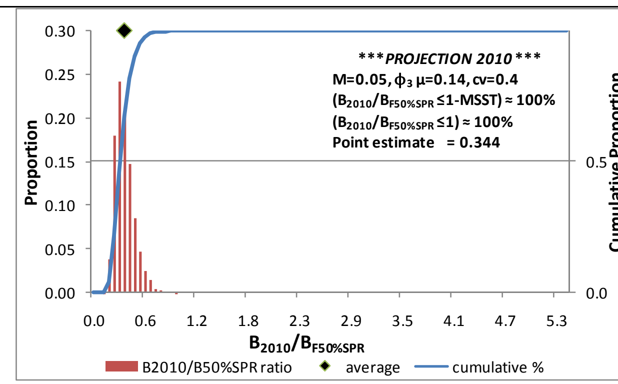
u. MCMC outcomes for the relative SSB ratio for 2009, run B-6. (max. age = 80 years)



v. MCMC outcomes for the relative SSB ratio for 2010 (first projected year), run B-4.

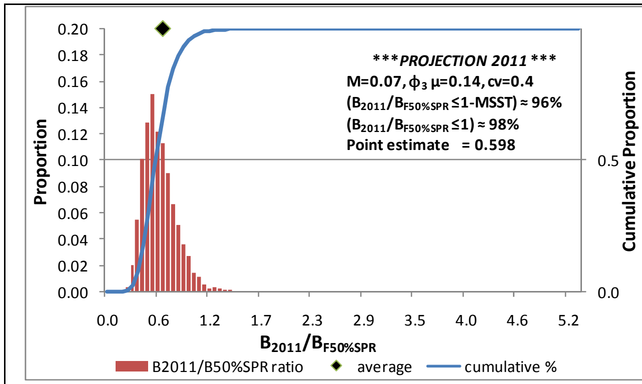


w. MCMC outcomes for the relative SSB ratio for 2010 (first projected year), run B-5.

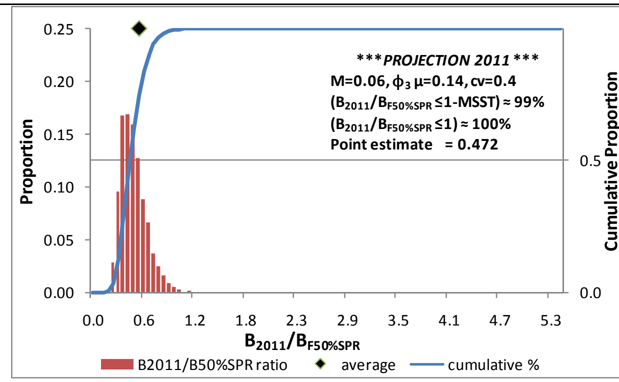


x. MCMC outcomes for the relative SSB ratio for 2010 (first projected year), run B-6.

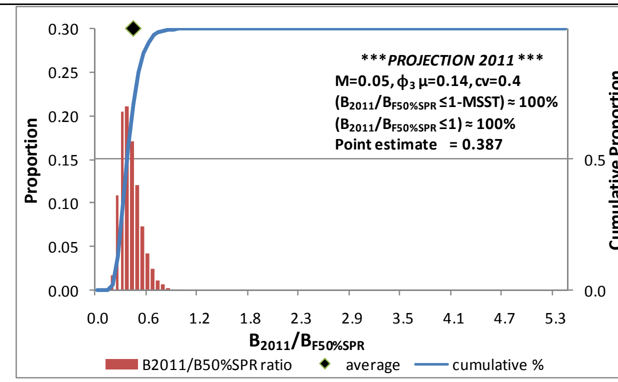
Figure 3.3.9. (continued) MCMC outcomes for relative $SSB_{2009}/SSB_{F\ at\ 50\%SPR}$ during the current year and 5 projected years based on different maximum ages using the SEDAR 23 prior for F (Φ_3).



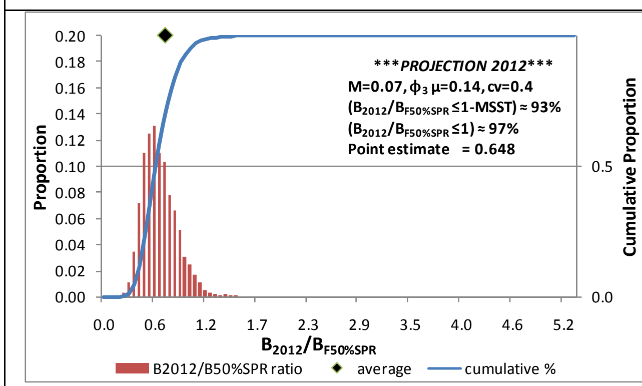
y. MCMC outcomes for the relative SSB ratio for 2011 (second projected year), run B-4.



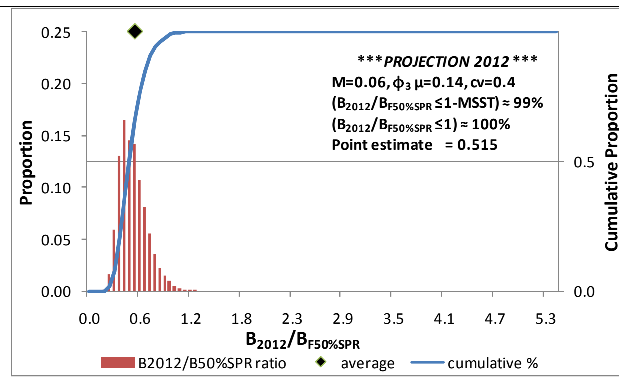
z. MCMC outcomes for the relative SSB ratio for 2011 (second projected year), run B-5.



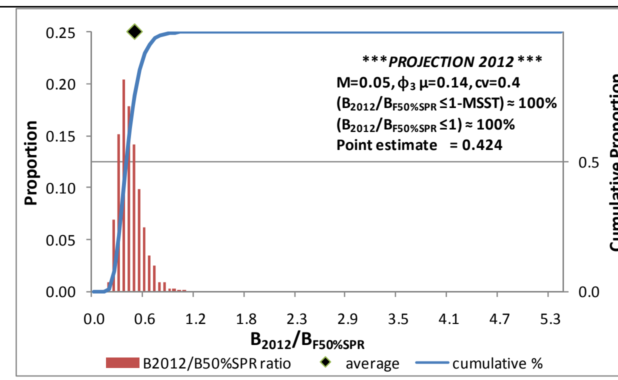
aa. MCMC outcomes for the relative SSB ratio for 2011 (second projected year), run B-6.



bb. MCMC outcomes for the relative SSB ratio for 2012 (third projected year), run B-4.

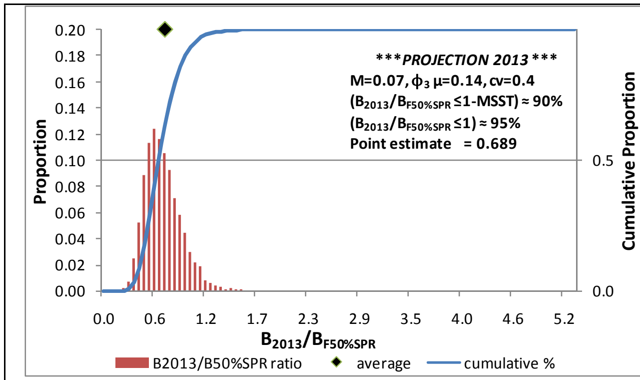


cc. MCMC outcomes for the relative SSB ratio for 2012 (third projected year), run B-5.

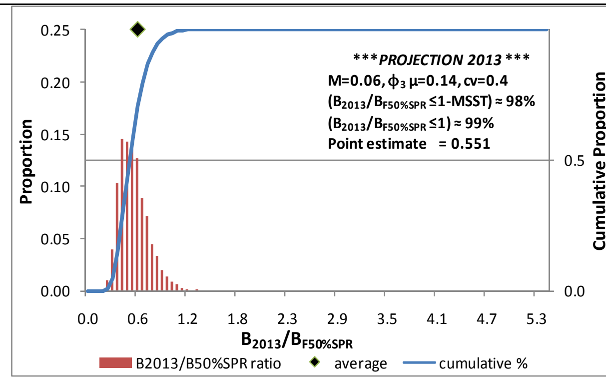


dd. MCMC outcomes for the relative SSB ratio for 2012 (third projected year), run B-6.

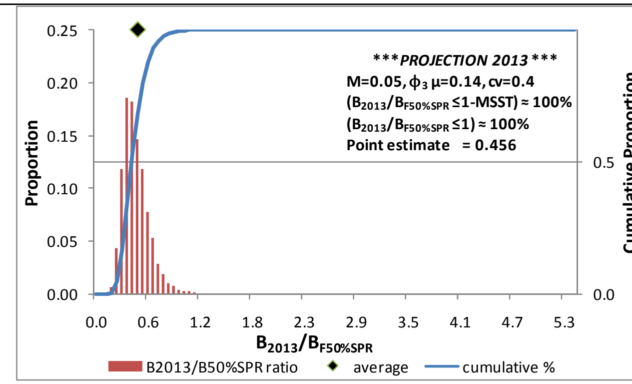
Figure 3.3.9. (continued) MCMC outcomes for relative $SSB_{2009}/SSB_{F\ at\ 50\%SPR}$ during the current year and 5 projected years based on different maximum ages using the SEDAR 23 prior for F (Φ_3).



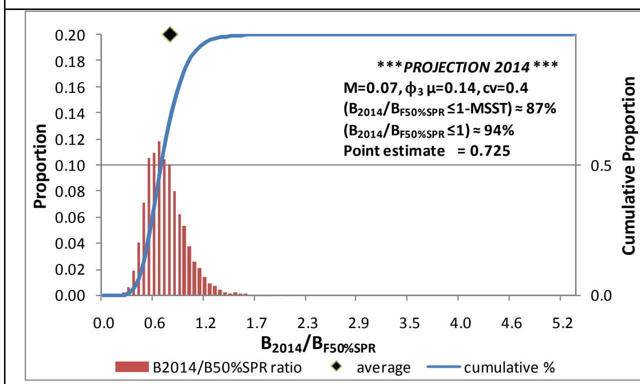
ee. MCMC outcomes for the relative SSB ratio for 2013 (fourth projected year), run B-4.



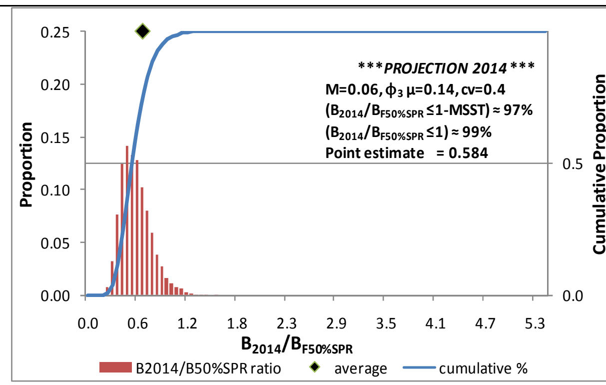
ff. MCMC outcomes for the relative SSB ratio for 2013 (fourth projected year), run B-5.



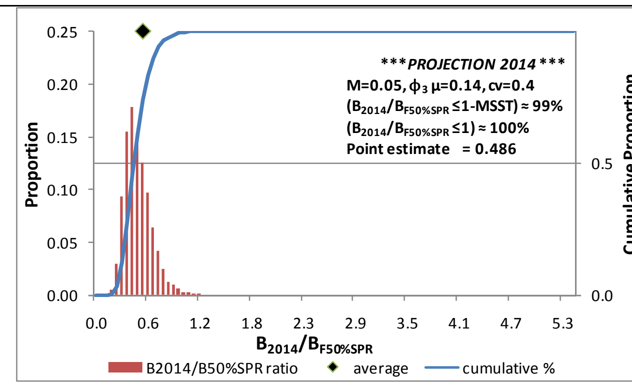
gg. MCMC outcomes for the relative SSB ratio for 2013 (fourth projected year), run B-6.



hh. MCMC outcomes for the relative SSB ratio for 2014 (fifth projected year), run B-4.

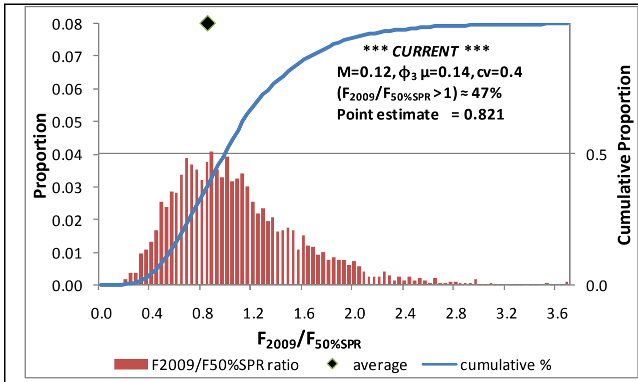


ii. MCMC outcomes for the relative SSB ratio for 2014 (fifth projected year), run B-5.

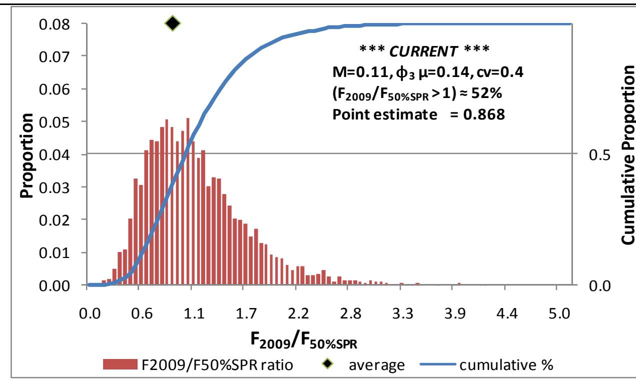


jj. MCMC outcomes for the relative SSB ratio for 2014 (fifth projected year), run B-6.

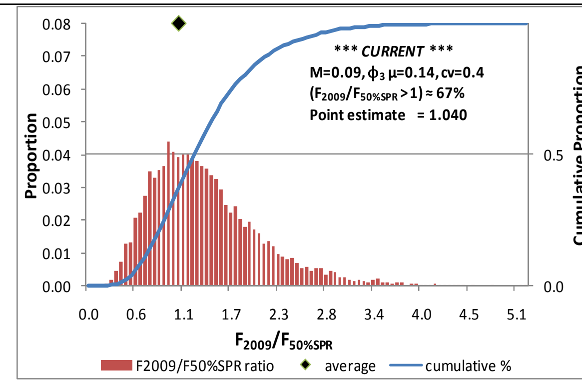
Figure 3.3.9. (continued) MCMC outcomes for relative $SSB_{2009}/SSB_{F\ at\ 50\%SPR}$ during the current year and 5 projected years based on different maximum ages using the SEDAR 23 prior for F (Φ_3).



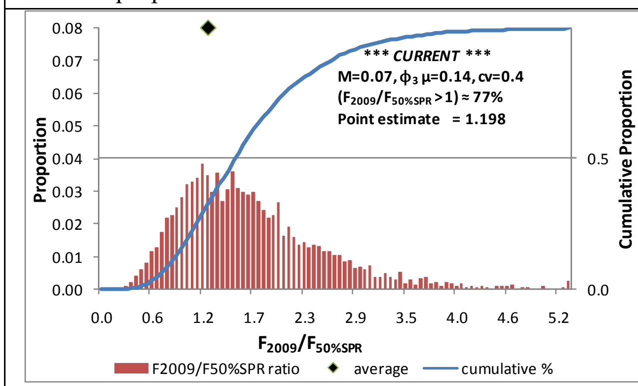
a. MCMC outcomes for $F_{2009}/F_{50\%SPR}$ for the proposed base run B-1.



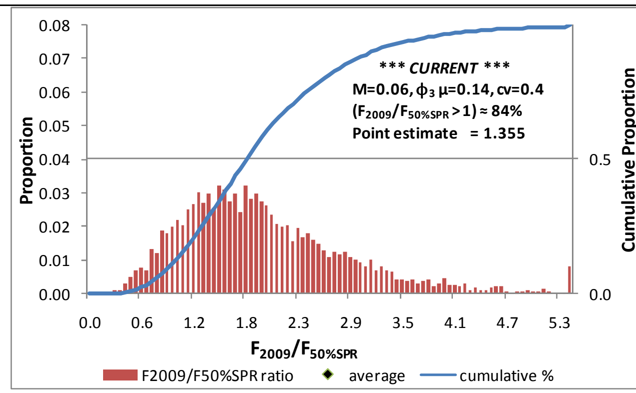
b. MCMC outcomes for $F_{2009}/F_{50\%SPR}$ for run B-2.



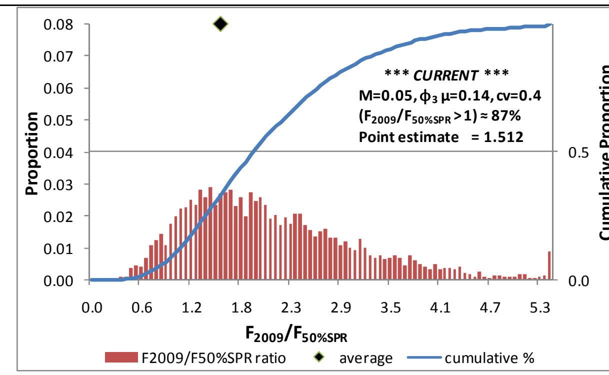
c. MCMC outcomes for $F_{2009}/F_{50\%SPR}$ for run B-3.



d. MCMC outcomes for $F_{2009}/F_{50\%SPR}$ for run B-4.

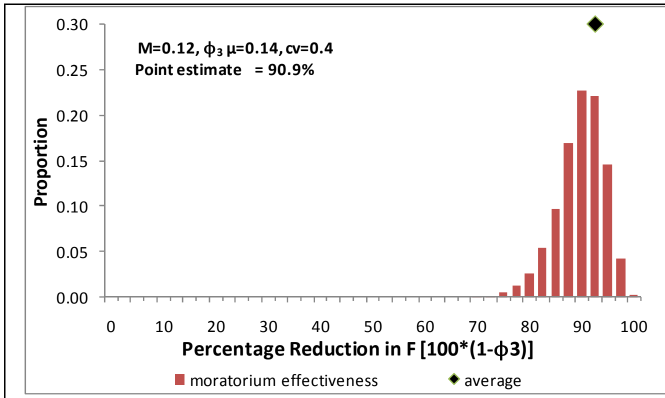


e. MCMC outcomes for $F_{2009}/F_{50\%SPR}$ for run B-5.

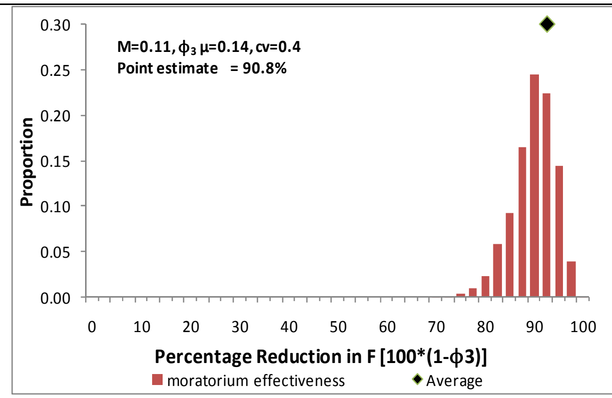


f. MCMC outcomes for $F_{2009}/F_{50\%SPR}$ for run B-6.

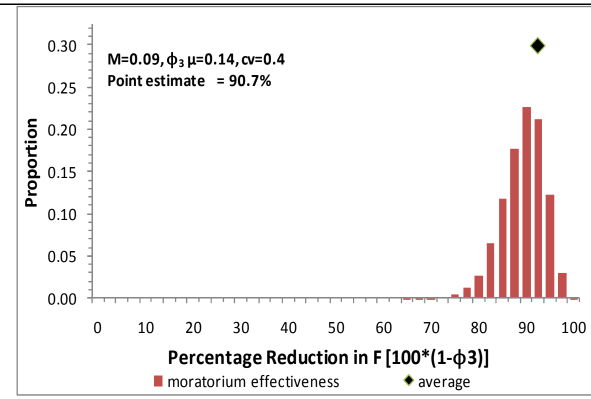
Figure 3.3.10. MCMC outcomes for relative $F_{2009}/F_{50\%SPR}$ based on different maximum ages using the SEDAR 23 prior for F (Φ_3).



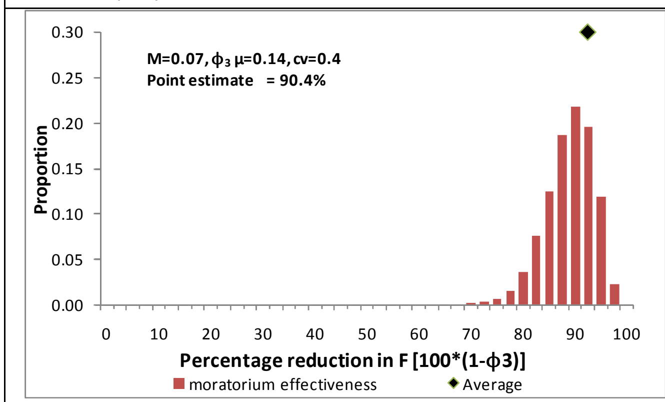
a. MCMC outcomes for the percentage reduction in F after the moratorium on harvest in 1990 for the proposed base run B-1.



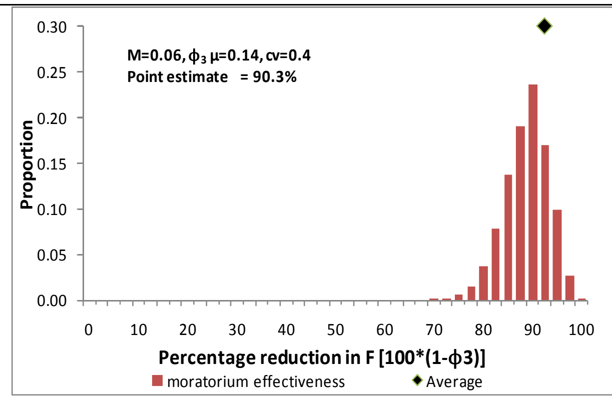
b. MCMC outcomes for the percentage reduction in F after the moratorium on harvest in 1990 for run B-2.



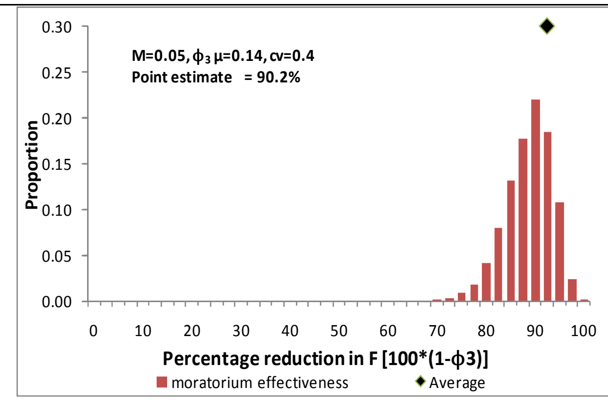
c. MCMC outcomes for the percentage reduction in F after the moratorium on harvest in 1990 for run B-3.



d. MCMC outcomes for the percentage reduction in F after the moratorium on harvest in 1990 for run B-4.

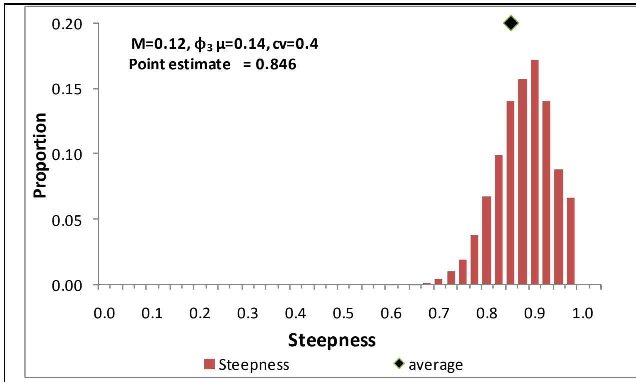


e. MCMC outcomes for the percentage reduction in F after the moratorium on harvest in 1990 for run B-5.

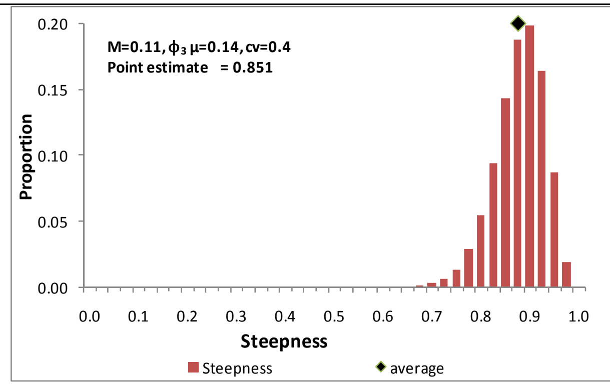


f. MCMC outcomes for the percentage reduction in F after the moratorium on harvest in 1990 for run B-6.

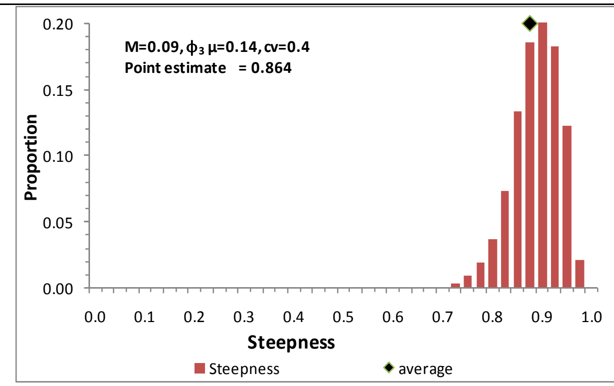
Figure 3.3.11. MCMC outcomes for the percentage reduction in F [100*(1-ϕ3)] since 1990 based on different maximum ages using the SEDAR 23 prior for F (Φ_3).



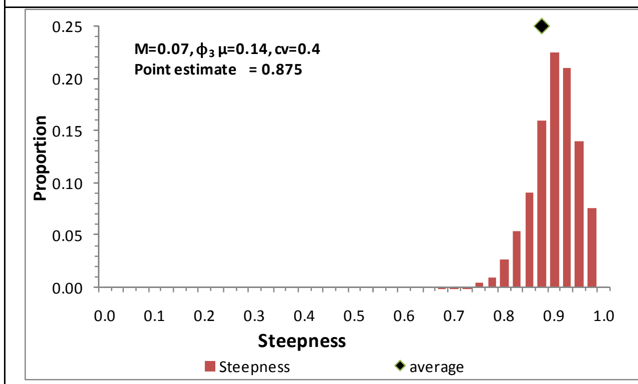
a. MCMC outcomes for steepness (h) calculated from the α-parameter for the proposed base run B-1.



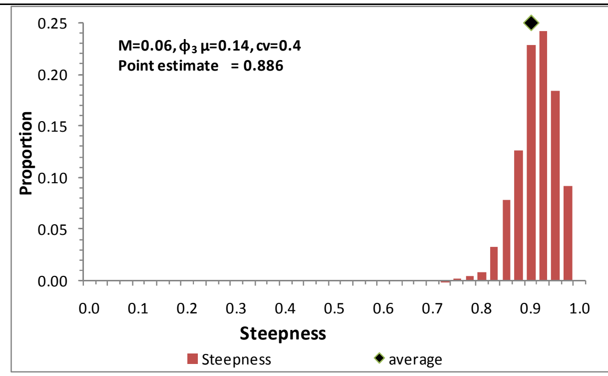
b. MCMC outcomes for steepness (h) calculated from the α-parameter for run B-2.



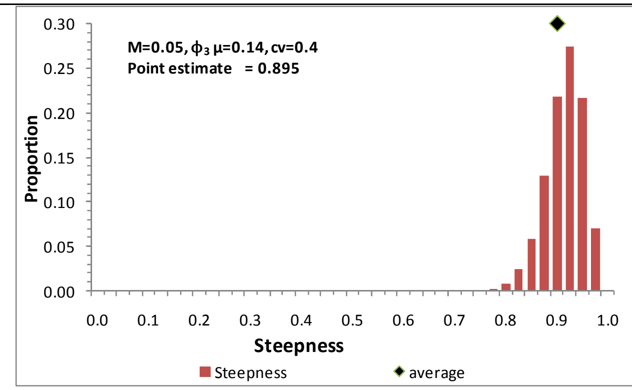
c. MCMC outcomes for steepness (h) calculated from the α-parameter for run B-3.



d. MCMC outcomes for steepness (h) calculated from the α-parameter for run B-4.

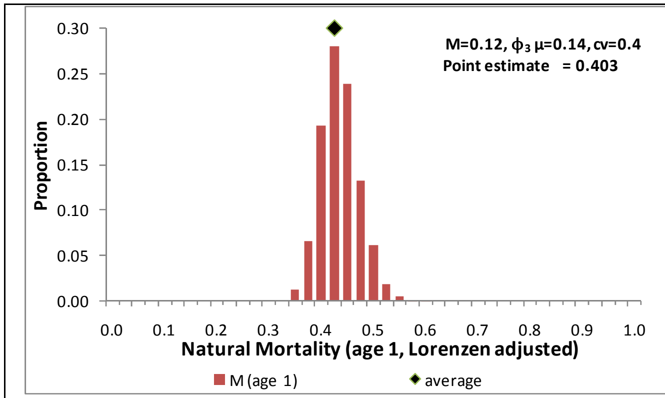


e. MCMC outcomes for steepness (h) calculated from the α-parameter for run B-5.

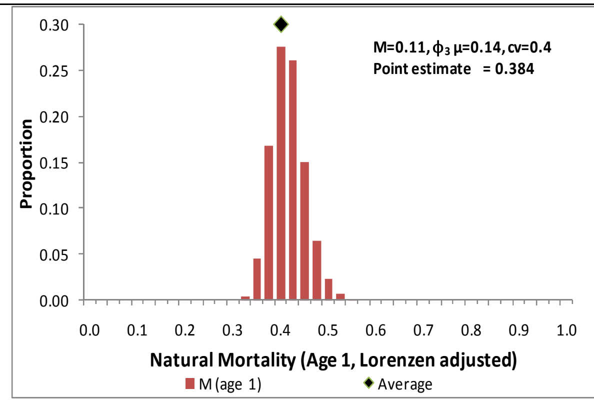


f. MCMC outcomes for steepness (h) calculated from the α-parameter for run B-6.

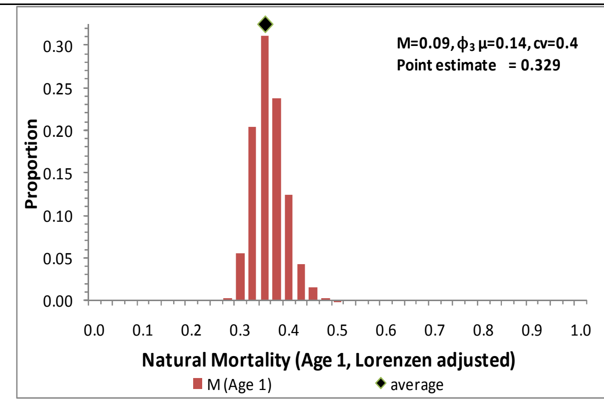
Figure 3.3.12. MCMC outcomes for steepness calculated from the α-parameter.



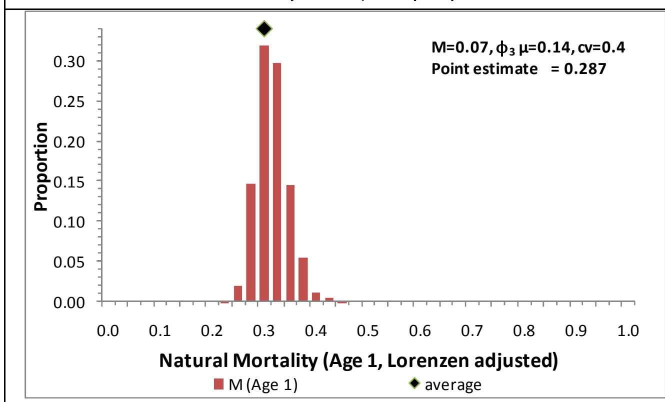
a. MCMC outcomes for M at age 1 (age-specific natural mortality rates) for proposed base run B-1.



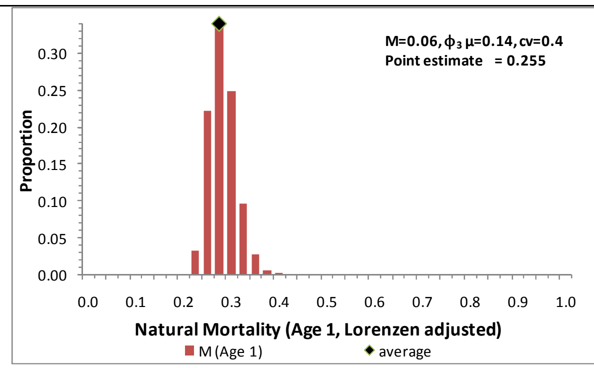
b. MCMC outcomes for M at age 1 (age-specific natural mortality rates) for run B-2.



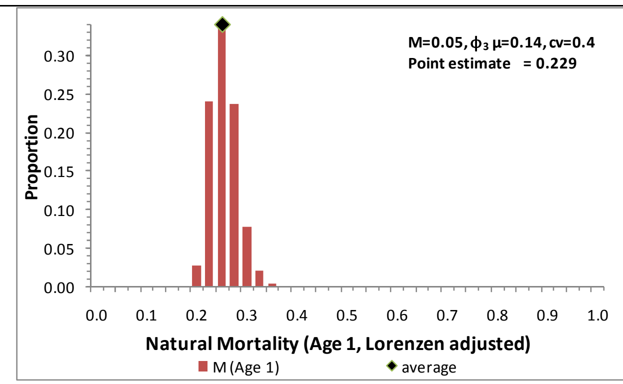
c. MCMC outcomes for M at age 1 (age-specific natural mortality rates) for run B-3.



d. MCMC outcomes for M at age 1 (age-specific natural mortality rates) for run B-4.



e. MCMC outcomes for M at age 1 (age-specific natural mortality rates) for run B-5.



f. MCMC outcomes for M at age 1 (age-specific natural mortality rates) for run B-6.

Figure 3.3.13. MCMC outcomes for M at age 1 (age-specific natural mortality rates).

3.4. REFERENCES

ADMB Project. 2009 AD Model Builder: automatic differentiation model builder. Developed by David Fournier and freely available from admb-project.org.

Brusher, J. H. and Schull, J. 2009. Non-lethal age determination for juvenile goliath grouper *Epinephelus itajara* from southwest Florida. Endangered Species Research 7: 205-212.

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

Collins, A. B., and Barbieri, L. R. 2010. Behavior, habitat, and abundance of the goliath grouper, *Epinephelus itajara*, in the central eastern Gulf of Mexico. Cooperative Research Project Report, NOAA award number NA07NMF4540085.

Craig, M.T., Graham, R., Torres, R. A., Hyde, J. R., Freitas, M. O., Ferreira, B. P., Hostim-Silva, M., Gerhardinger, L. C., Bertoncini, A. A., and Robertson, D. R. 2009. How many species of goliath grouper are there? Cryptic genetic divergence in a threatened marine fish and the resurrection of a geopolitical species. Endangered Species Research 7: 167-174.

Hoenig, J. M. 1983. Empirical use of longevity data to estimate mortality rates. Fishery Bulletin 81:898-903.

Hewitt, D. A. and Hoenig, J. M. 2005. Comparison of two approaches for estimating natural mortality based on longevity. . Fishery Bulletin 103:433-437.

Koenig, C.C., Coleman, F.C., Eklund, A.M., Schull, J., and Ueland, J. 2007. Mangroves as essential nursery habitat for goliath grouper (*Epinephelus itajara*). Bulletin of Marine Science, 80: 567-586.

Lorenzen, K. 1996. The relationship between body weight and natural mortality in juvenile and adult fish: a comparison of natural ecosystems and aquaculture. Journal of Fish Biology 49: 627-647.

Lorenzen, K. 2005. Population dynamics and potential of fisheries stock enhancement: practical theory for assessment and policy analysis. Philosophical Transactions of the Royal Society of London. Fisheries Theme Issue 2004.

Martell, S. D., Pine, W. E. III, and Walters ,C. J. 2008. Parameterizing age-structured models from a fisheries management perspective. Canadian Journal of Fisheries and Aquatic Sciences 65: 1586-1600.

Myers, R.A., Bowen, K.G., and Barrowman, N. J. 1999. Maximum reproductive rate of fish at low population sizes. Canadian Journal of Fisheries and Aquatic Sciences 56: 2404-2419.

O'Hop, J. 2010. Standardized proportion of private vessel trips with catches of goliath grouper from the Marine Recreational Fisheries Statistics Survey in south Florida, 1991-2009. SEDAR 23-AW-03.

Porch, C. E. 2010. Standardized visual counts of goliath grouper off south Florida. SEDAR 23-AW-01.

Porch, C.E., Eklund, A.M., and Scott, G.P. 2003. An assessment of rebuilding times for goliath grouper. NOAA Fisheries, Sustainable Fisheries Division Contribuition No. SFD-2003-0018. SEDAR 6-RW-3.

Porch, C.E., Eklund, A.M., and Scott, G.P. 2006. A catch-free stock assessment model with application to goliath grouper (*Epinephelus itajara*) off southern Florida. Fishery Bulletin 104: 89-101.

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.

3.5. APPENDIX A

This appendix contains the input parameter and data files for the continuity run for SEDAR 23 Goliath grouper. That configuration was with constant natural mortality curve with an average of 0.11 per year for ages 4-33, four indices of abundance: DeMaria, REEF Southeast, ENP Angler Creel Survey, and Interviews.

```
#//////////////////////////////////////////////////////////////////////////////////////////////
#//////////////////////////////////////////////////////////////////////////////////////////////
#// INPUT DATA FILE FOR PROGRAM AP-MODEL
#//
#//   Important notes:
#//    (1) Comments may be placed BEFORE or AFTER any line of data, however they MUST begin
#//        with a # symbol in the first column.
#//    (2) No comments of any kind may appear on the same line as the data (the #
#//        symbol will not save you here)
#//    (3) Blank lines without a # symbol are not allowed.
#//
#// Manufactured data
#//////////////////////////////////////////////////////////////////////////////////////////////
#//////////////////////////////////////////////////////////////////////////////////////////////
#
####################################################
# GENERAL INFORMATION
####################################################
# first year in simulation (beginning of historical period)
# |     last year of historical period
# |     |     last year when data are available
# |     |     |     end of simulation (year to project to)
# |     |     |     |
  1950  1979  2009  2029
# year when fishing mortality rate in modern period becomes relatively constant so that no f_devs are
estimated from that point on
# (enter negative value if no such period exists)
  1990
# first and last age in the simulation
  1 20
# scale of variance parameters (1 = log scale variance, 2 = observation scale variance, 0=force equal
weighting)
  1
# method of modifying variance parameters (0= do not modify, 1 = add annual values to variance, -1 =
multiply annual values by variance)
  1
# spawning season (integer representing number of months elapsed when spawning occurs)
  6
# maturity schedue (fraction m of each age class that is sexually mature
  0 0 0 0 0 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
# fecundity schedule (index of per capita fecundity of each age class)
  -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1
####################################################
# INDICES OF ABUNDANCE (e.g., CPUE) If there are no series, there should be no entries between the comment
lines.
####################################################
# number of index data series
  4
# pdf of observation error for each series (1) lognormal, (2) normal
  1 1 1 1
# units (1=numbers, 2=weight, 10=number relative to virgin levels, 20=weight relative to virgin levels (in
case of 10 or 20, you should fix the corresponding q to 1)
```

```
  1 1 1 10
# months elapsed at time index observed
  6 6 6 0
# option to (1) scale or (0) not to scale index observations
  0 0 0 0
# set of index variance parameters each series is linked to
  1 1 1 1
# set of q parameters each series is linked to
  1 2 3 4
# set of s parameters each series is linked to
  3 4 5 6
# observed indices by series )
# DeMaria
#|    REEF
#|     |    ENP (juv)
#|     |     |        Interviews
#|     |     |        |         year
-1      -1      -1      1.000   1950
-1      -1      -1      -1      1951
-1      -1      -1      -1      1952
-1      -1      -1      -1      1953
-1      -1      -1      -1      1954
-1      -1      -1      -1      1955
-1      -1      -1      -1      1956
-1      -1      -1      -1      1957
-1      -1      -1      -1      1958
-1      -1      -1      -1      1959
-1      -1      -1      -1      1960
-1      -1      -1      -1      1961
-1      -1      -1      -1      1962
-1      -1      -1      -1      1963
-1      -1      -1      -1      1964
-1      -1      -1      -1      1965
-1      -1      -1      -1      1966
-1      -1      -1      -1      1967
-1      -1      -1      -1      1968
-1      -1      -1      -1      1969
-1      -1      -1      -1      1970
-1      -1      -1      -1      1971
-1      -1      -1      -1      1972
-1      -1      0.788   -1      1973
-1      -1      -1      -1      1974
-1      -1      0.408   -1      1975
-1      -1      1.275   -1      1976
-1      -1      0.867   -1      1977
-1      -1      0.911   -1      1978
-1      -1      0.620   -1      1979
-1      -1      0.664   -1      1980
-1      -1      0.388   -1      1981
-6.42   -1      0.287   -1      1982
1.42    -1      0.265   -1      1983
0.88    -1      0.230   -1      1984
0.424   -1      0.140   -1      1985
0.214   -1      0.135   -1      1986
0.177   -1      0.105   -1      1987
0.331   -1      0.140   -1      1988
0.110   -1      0.301   -1      1989
0.198   -1      0.156   .1444   1990
0.261   -1      0.174   -1      1991
-1      -1      0.238   -1      1992
```

```
0.755   -1      0.259   -1      1993
0.974   0.15    0.685   -1      1994
0.761   -1      1.079   -1      1995
0.615   0.06    1.169   -1      1996
1.419   0.47    0.713   -1      1997
1.431   0.65    0.532   -1      1998
0.691   0.58    0.551   -1      1999
0.342   0.62    0.794   -1      2000
1.421   0.57    0.715   -1      2001
1.161   0.78    0.737   -1      2002
-1      1.65    1.863   -1      2003
-1      1.19    1.977   -1      2004
-1      1.36    2.316   -1      2005
-1      1.64    3.541   -1      2006
-1      2.42    5.181   -1      2007
-1      1.85    3.550   -1      2008
-1      2.02    2.247   -1      2009
# annual scaling factors for variance (use this option to account for annual differences in the variance,
e.g., to down-weight observations based on very little data)
# DeMaria
#|    REEF
#|    |        ENP (juv)
#|    |        |      Interviews
#|    |        |       |        year
-1      -1      -1      1.000   1950
0.000   0.000   0.000   0.000   1951
0.000   0.000   0.000   0.000   1952
0.000   0.000   0.000   0.000   1953
0.000   0.000   0.000   0.000   1954
0.000   0.000   0.000   0.000   1955
0.000   0.000   0.000   0.000   1956
0.000   0.000   0.000   0.000   1957
0.000   0.000   0.000   0.000   1958
0.000   0.000   0.000   0.000   1959
0.000   0.000   0.000   0.000   1960
0.000   0.000   0.000   0.000   1961
0.000   0.000   0.000   0.000   1962
0.000   0.000   0.000   0.000   1963
0.000   0.000   0.000   0.000   1964
0.000   0.000   0.000   0.000   1965
0.000   0.000   0.000   0.000   1966
0.000   0.000   0.000   0.000   1967
0.000   0.000   0.000   0.000   1968
0.000   0.000   0.000   0.000   1969
0.000   0.000   0.000   0.000   1970
0.000   0.000   0.000   0.000   1971
0.000   0.000   0.000   0.000   1972
0.000   0.000   0.234   0.000   1973
0.000   0.000   0.000   0.000   1974
0.000   0.000   0.246   0.000   1975
0.000   0.000   0.201   0.000   1976
0.000   0.000   0.203   0.000   1977
0.000   0.000   0.215   0.000   1978
0.000   0.000   0.277   0.000   1979
0.000   0.000   0.231   0.000   1980
0.000   0.000   0.248   0.000   1981
0.089   0.000   0.298   0.000   1982
0.066   0.000   0.281   0.000   1983
0.046   0.000   0.285   0.000   1984
0.031   0.000   0.349   0.000   1985
```

```
0.047   0.000   0.339   0.000   1986
0.067   0.000   0.370   0.000   1987
0.059   0.000   0.366   0.000   1988
0.090   0.000   0.268   0.000   1989
0.114   0.000   0.288   0.693   1990
0.078   0.000   0.306   0.000   1991
0.000   0.000   0.283   0.000   1992
0.249   0.000   0.246   0.000   1993
0.113   0.39    0.195   0.000   1994
0.077   0.00    0.200   0.000   1995
0.055   1.01    0.183   0.000   1996
0.092   0.32    0.196   0.000   1997
0.133   0.29    0.219   0.000   1998
0.075   0.27    0.222   0.000   1999
0.215   0.21    0.213   0.000   2000
0.082   0.15    0.203   0.000   2001
0.110   0.13    0.204   0.000   2002
0.000   0.10    0.176   0.000   2003
0.000   0.14    0.174   0.000   2004
0.000   0.16    0.176   0.000   2005
0.000   0.13    0.163   0.000   2006
0.000   0.10    0.150   0.000   2007
0.000   0.15    0.166   0.000   2008
0.000   0.11    0.184   0.000   2009
####################################################
# INDEX OF RELATIVE EFFORT (you must enter values for each year, even if they are only dummy values)
####################################################
# how to treat effort data (0) do not use values below, instead replace with a default of 1.0 for all
years
# |                        (1) use values below
# |                        (-1)use values below, then rescale relative to maximum value
  1
# value year
0.207   1950
0.231   1951
0.255   1952
0.278   1953
0.302   1954
0.326   1955
0.350   1956
0.373   1957
0.397   1958
0.421   1959
0.445   1960
0.468   1961
0.490   1962
0.513   1963
0.536   1964
0.559   1965
0.582   1966
0.604   1967
0.627   1968
0.650   1969
0.673   1970
0.706   1971
0.738   1972
0.771   1973
0.804   1974
0.836   1975
0.869   1976
```

```
0.902   1977
0.935   1978
0.967   1979
1.000   1980
1.000   1981
1.000   1982
1.000   1983
1.000   1984
1.000   1985
1.000   1986
1.000   1987
1.000   1988
1.000   1989
1.000   1990
1.000   1991
1.000   1992
1.000   1993
1.000   1994
1.000   1995
1.000   1996
1.000   1997
1.000   1998
1.000   1999
1.000   2000
1.000   2001
1.000   2002
1.000   2003
1.000   2004
1.000   2005
1.000   2006
1.000   2007
1.000   2008
1.000   2009
#####################################################
# Projection specifications
#####################################################
# selectivity for reference points (1=fishery, 2=use maturity vector)
  1
# non-negative=input reference (should have value between 0 and 1)
# otherwise, -0.1=B at F0.1, -1=B at msy, -2=B at Fmax, -20=Bspr20, -30=Bspr30, -40=Bspr40, -50=Bspr50, -
60=Bspr60, -999=Bcurrent)
 -50
# control for recruitment deviations (0=none, + = variance, - = -cv)
 -0.40
# projected F values (non-negative=input F, -0.1=F0.1, -1=Fmsy, -2=Fmax, -20=Fspr20, -30=Fspr30, -
40=Fspr40, -50=Fspr50, -60=Fspr60, -999=Fcurrent)
# |       Std. error (or negative CV) of implementation uncertainty (not being used at present)
# |       |       year
# |       |       |
  -999    -0.01    2010
  -999    -0.01    2011
  -999    -0.01    2012
  -999    -0.01    2013
  -999    -0.01    2014
  -999    -0.01    2015
  -999    -0.01    2016
  -999    -0.01    2017
  -999    -0.01    2018
  -999    -0.01    2019
  -999    -0.01    2020
```

```
  -999    -0.01    2021
  -999    -0.01    2022
  -999    -0.01    2023
  -999    -0.01    2024
  -999    -0.01    2025
  -999    -0.01    2026
  -999    -0.01    2027
  -999    -0.01    2028
  -999    -0.01    2029

#/////////////////////////////////////////////////////////////////////////////////////////
#/////////////////////////////////////////////////////////////////////////////////////////
#// PARAMETER FILE FOR PROGRAM DATAPOOR
#//
#//   Important notes:
#//    (1) Comments may be placed BEFORE or AFTER any line of data, however they MUST begin
#//        with a # symbol in the first column.
#//    (2) No comments of any kind may appear on the same line as the data (the #
#//        symbol will not save you here)
#//    (3) Blank lines without a # symbol are not allowed.
#//
#/////////////////////////////////////////////////////////////////////////////////////////
#/////////////////////////////////////////////////////////////////////////////////////////
#
####################################################
# DIMENSION ARRAYS
####################################################
# total number of process parameters
  30
# number of sets of each parameter type
#       catchabilities q   selectivity vectors   index variances
        4                      6                   1
####################################################
# SPECIFICATIONS FOR PROCESS PARAMETERS
####################################################
#       nature of function (1=constant, 2-3=polynomials, 13=process correlation, 14=process variance
scaling parameter
#       |       best guess of parameter value (median of prior)
#       |       |        lower bound for parameter
#       |       |        |       upper bound for parameter
#       |       |        |       |       phase of estimation (enter -1 to fix at best guess and not
estimate)
#       |       |        |       |       |      probability density function of prior (0=none,
1=lognormal, 2=normal)
#       |       |        |       |       |      |       negative value is read as CV, positive value is
read as standard error (must be on logscale if overall_pdf=1, aritmetic scale otherwise) of prior
#       |       |        |       |       |      |     |
#f_ph parameters for expected F during prehistoric era (SEDAR 6)
        2       0.0   -0.010 0.5  -2     2       -1.0
        2       0.3   -0.010 0.5  1      2       -1.0
#f    parameters for expected F during modern era before change in regulations- note if nature=-1 then
F=parameter*F(last year of historical period))   (SEDAR 6)
        -1      1.0      0.02  10.0   1  2       -1.0
#f2   parameters for expected F during modern era after change in regulations- note if nature=-1 then
F=parameter*F(last year before change)) (SEDAR 6)
        -10     0.16    0.01  0.9   3    5       -0.88
#m    natural mortality rate (per Clay Porch - from max age 37 years, Hoenig's M=0.11 (fish only), 0.09677
is the mode of the distribution) (SEDAR 6)
        1       0.09677  0.01   0.7  3    1      -0.4
#r   parameter alpha minus 1 (SEDAR 6)
```

```
       10      2.648087     0.01        150.0 21       1.310438
#w   parameters (by record) for vonBertalannfy equation (Linf, k, t0, cv) and length-weight equation
(intercept in grams, slope) (SEDAR 6)
        8   0.2006E+03  150     300   5       2      -0.1
        8   1.2600E-01  0       10     -6       0       0.0204
        8  -4.9000E+00 -5.00    10     -1       0       0.1
        8   0.1000E+01  0       10     -1       0       0.1
        8   1.3100E-05  0       10     -1       0       0.1
        8   0.3056E+01  0       10     -1       0       0.1
#q      (SEDAR 6)
         1  0.5000E+00  .01        10       1       2       -2
         1  0.5000E+00  .01        10       1       2       -2
         1  0.5000E+00  .01        10       1       2       -2
         1  1.0000E+00  .01        10       -1       0       0.1
#s_prehistic (SEDAR 6)
         6  2.5100E+00  0       10      -4       2       -0.1
         6  0.5250E+00  0       10      -1      0       0.1
#s_modern (SEDAR 6)
         6  2.5100E+00  2       10      4       2       -0.1
         6  0.5250E+00  0       10      -1      0       0.1
#_s_survey 1 (SEDAR 6)
         6  6.0000E+00  4       10     -4       2       -0.1
         6  0.200E+00  0       10      -1      0       0.1
#_s_survey 2    (SEDAR 6)
         6  6.0000E+00  4       10     -4      2       -0.1
         6  0.200E+00  0       10      -1      0       0.1
#_s_survey 3    (SEDAR 6)
         7  3.4700E+00  0       10      -4       2       -0.1
         7  0.3430E+00  0       10      -1      0       0.1
#_s_survey 4    (SEDAR 6)
         6  6.0000E+00  0       10      -4       2       -0.1
         6  0.200E+00  0       10      -1      0       0.1
#idv    (SEDAR 6)
        14  1.0000E+00  0       10       -1      0       0.1
#overall var    (SEDAR 6)
        1   -0.2        -1     -0.01      5     2       -0.5
####################################################
# SPECIFICATIONS FOR PROCESS DEVIATION PARAMETERS
####################################################
#       best guess of parameter value (central tendency of prior)
#       |       lower bound for parameter
#       |         |     upper bound for parameter
#       |         |       |     phase of estimation (enter -1 to fix at best guess and not estimate)
#       |         |       |        |    probability density function of prior
#       |         |       |        |      |     standard error or negative CV of prior (superfluous in
case of deviations)
#_f___|       |   |        |       |      |       (SEDAR 6)
      0.50  -0.001 1.0   -1    0         0.1
      0.15     0    1000. -1    0         0.1
      0.000  -5     5     5    1   0.1
#_r___|       |   |        |       |      |       (SEDAR 6)
      0.5    -0.001 1.0   -1    0         0.1
      0.15    0     100.0  -1    0        0.1
      0.0000 -5     5      4    1   0.1
#_q___|       |   |        |       |      |       (SEDAR 6)
      0.0    -0.001 1.0   -1    0         0.1
      0.10    0     100.0 -1    0         0.1
      0.0000 -5     5      -1    1   0.1
# End of file #
```

3.6. APPENDIX B

This appendix contains the input parameter and data files for the proposed base model run for SEDAR 23 Goliath grouper. That configuration was with age-specific natural mortality curve with an average of 0.1217 per year for ages 4-37, and five indices of abundance: DeMaria, REEF Southeast, ENP Angler Creel Survey, MRFSS, and REEF Southwest.

```
#///////////////////////////////////////////////////////////////////////////////////////////
#///////////////////////////////////////////////////////////////////////////////////////////
#// INPUT DATA FILE FOR PROGRAM AP-MODEL
#// * rev - months elapsed for the MRFSS index set to mid-year (6)
#//   Important notes:
#//    (1) Comments may be placed BEFORE or AFTER any line of data, however they MUST begin
#//        with a # symbol in the first column.
#//    (2) No comments of any kind may appear on the same line as the data (the #
#//        symbol will not save you here)
#//    (3) Blank lines without a # symbol are not allowed.
#//
#// Manufactured data - updated indices
#///////////////////////////////////////////////////////////////////////////////////////////
#///////////////////////////////////////////////////////////////////////////////////////////
#
####################################################
# GENERAL INFORMATION
####################################################
# first year in simulation (beginning of historical period)
# |     last year of historical period
# |     |     last year when data are available
# |     |     |     end of simulation (year to project to)
# |     |     |     |
  1950  1979  2009  2029
# year when fishing mortality rate in modern period becomes relatively constant so that no f_devs are
estimated from that point on
# (enter negative value if no such period exists)
  1990
# first and last age in the simulation
  1 20
# scale of variance parameters (1 = log scale variance, 2 = observation scale variance, 0=force equal
weighting)
  1
# method of modifying variance parameters (0= do not modify, 1 = add annual values to variance, -1 =
multiply annual values by variance)
  1
# spawning season (integer representing number of months elapsed when spawning occurs)
  6
# maturity schedue (fraction m of each age class that is sexually mature
  0 0 0 0 0 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
# fecundity schedule (index of per capita fecundity of each age class)
  -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1
####################################################
# INDICES OF ABUNDANCE (e.g., CPUE) If there are no series, there should be no entries between the comment
lines.
####################################################
# number of index data series
  5
# pdf of observation error for each series (1) lognormal, (2) normal
  1 1 1 1 1
# units (1=numbers, 2=weight, 10=number relative to virgin levels, 20=weight relative to virgin levels (in
case of 10 or 20, you should fix the corresponding q to 1)
```

```
  1 1 1 1 1
# months elapsed at time index observed
  6 6 6 6 6
# option to (1) scale or (0) not to scale index observations
  0 0 0 0 0
# set of index variance parameters each series is linked to
  1 1 1 1 1
# set of q parameters each series is linked to
  1 2 3 4 5
# set of s parameters each series is linked to
  3 4 5 6 7
# observed indices by series )
# DeMaria
#|    REEF SE
#|     |    ENP (juv)
#|     |     |        MRFSS (PR,FHS regions 1-5)
#|     |     |        |       REEF SW    year
-1      -1      -1      -1      -1      1950
-1      -1      -1      -1      -1      1951
-1      -1      -1      -1      -1      1952
-1      -1      -1      -1      -1      1953
-1      -1      -1      -1      -1      1954
-1      -1      -1      -1      -1      1955
-1      -1      -1      -1      -1      1956
-1      -1      -1      -1      -1      1957
-1      -1      -1      -1      -1      1958
-1      -1      -1      -1      -1      1959
-1      -1      -1      -1      -1      1960
-1      -1      -1      -1      -1      1961
-1      -1      -1      -1      -1      1962
-1      -1      -1      -1      -1      1963
-1      -1      -1      -1      -1      1964
-1      -1      -1      -1      -1      1965
-1      -1      -1      -1      -1      1966
-1      -1      -1      -1      -1      1967
-1      -1      -1      -1      -1      1968
-1      -1      -1      -1      -1      1969
-1      -1      -1      -1      -1      1970
-1      -1      -1      -1      -1      1971
-1      -1      -1      -1      -1      1972
-1      -1      0.788   -1      -1      1973
-1      -1      -1      -1      -1      1974
-1      -1      0.408   -1      -1      1975
-1      -1      1.275   -1      -1      1976
-1      -1      0.867   -1      -1      1977
-1      -1      0.911   -1      -1      1978
-1      -1      0.620   -1      -1      1979
-1      -1      0.664   -1      -1      1980
-1      -1      0.388   -1      -1      1981
-6.42   -1      0.287   -1      -1      1982
1.42    -1      0.265   -1      -1      1983
0.88    -1      0.230   -1      -1      1984
0.424   -1      0.140   -1      -1      1985
0.214   -1      0.135   -1      -1      1986
0.177   -1      0.105   -1      -1      1987
0.331   -1      0.140   -1      -1      1988
0.110   -1      0.301   -1      -1      1989
0.198   -1      0.156   -1      -1      1990
0.261   -1      0.174   0.1740  -1      1991
-1      -1      0.238   0.0801  -1      1992
```

```
0.755   -1      0.259   0.2048  -1      1993
0.974   0.15    0.685   0.1921  -1      1994
0.761   -1      1.079   0.5260  -1      1995
0.615   0.06    1.169   0.1811  -1      1996
1.419   0.47    0.713   0.2562  -1      1997
1.431   0.65    0.532   0.3353  -1      1998
0.691   0.58    0.551   0.4196  0.74    1999
0.342   0.62    0.794   0.5639  0.82    2000
1.421   0.57    0.715   0.5842  0.84    2001
1.161   0.78    0.737   0.8878  1.09    2002
-1      1.65    1.863   0.9373  1.12    2003
-1      1.19    1.977   1.5691  1.23    2004
-1      1.36    2.316   2.4613  0.88    2005
-1      1.64    3.541   2.5165  0.98    2006
-1      2.42    5.181   2.6744  0.53    2007
-1      1.85    3.550   1.2335  1.61    2008
-1      2.02    2.247   1.1251  1.17    2009
# annual scaling factors for variance (use this option to account for annual differences in the variance,
e.g., to down-weight observations based on very little data)
# DeMaria
#|    REEF(SE)
#|    |        ENP (juv)
#|    |        |      MRFSS (PR,FHS regions 2,4)
#|    |        |       |       REEF(SW)  year
-1      -1      -1      0.000   -1      1950
0.000   0.000   0.000   0.000   -1      1951
0.000   0.000   0.000   0.000   -1      1952
0.000   0.000   0.000   0.000   -1      1953
0.000   0.000   0.000   0.000   -1      1954
0.000   0.000   0.000   0.000   -1      1955
0.000   0.000   0.000   0.000   -1      1956
0.000   0.000   0.000   0.000   -1      1957
0.000   0.000   0.000   0.000   -1      1958
0.000   0.000   0.000   0.000   -1      1959
0.000   0.000   0.000   0.000   -1      1960
0.000   0.000   0.000   0.000   -1      1961
0.000   0.000   0.000   0.000   -1      1962
0.000   0.000   0.000   0.000   -1      1963
0.000   0.000   0.000   0.000   -1      1964
0.000   0.000   0.000   0.000   -1      1965
0.000   0.000   0.000   0.000   -1      1966
0.000   0.000   0.000   0.000   -1      1967
0.000   0.000   0.000   0.000   -1      1968
0.000   0.000   0.000   0.000   -1      1969
0.000   0.000   0.000   0.000   -1      1970
0.000   0.000   0.000   0.000   -1      1971
0.000   0.000   0.000   0.000   -1      1972
0.000   0.000   0.234   0.000   -1      1973
0.000   0.000   0.000   0.000   -1      1974
0.000   0.000   0.246   0.000   -1      1975
0.000   0.000   0.201   0.000   -1      1976
0.000   0.000   0.203   0.000   -1      1977
0.000   0.000   0.215   0.000   -1      1978
0.000   0.000   0.277   0.000   -1      1979
0.000   0.000   0.231   0.000   -1      1980
0.000   0.000   0.248   0.000   -1      1981
0.089   0.000   0.298   0.000   -1      1982
0.066   0.000   0.281   0.000   -1      1983
0.046   0.000   0.285   0.000   -1      1984
0.031   0.000   0.349   0.000   -1      1985
```

```
0.047   0.000   0.339   0.000   -1      1986
0.067   0.000   0.370   0.000   -1      1987
0.059   0.000   0.366   0.000   -1      1988
0.090   0.000   0.268   0.000   -1      1989
0.114   0.000   0.288   0.000   -1      1990
0.078   0.000   0.306   1.388   -1      1991
0.000   0.000   0.283   1.385   -1      1992
0.249   0.000   0.246   0.652   -1      1993
0.113   0.39    0.195   0.630   -1      1994
0.077   0.00    0.200   0.383   -1      1995
0.055   1.01    0.183   0.641   -1      1996
0.092   0.32    0.196   0.475   -1      1997
0.133   0.29    0.219   0.381   -1      1998
0.075   0.27    0.222   0.294   0.46    1999
0.215   0.21    0.213   0.295   0.20    2000
0.082   0.15    0.203   0.277   0.18    2001
0.110   0.13    0.204   0.220   0.15    2002
0.000   0.10    0.176   0.221   0.16    2003
0.000   0.14    0.174   0.184   0.17    2004
0.000   0.16    0.176   0.165   0.23    2005
0.000   0.13    0.163   0.160   0.19    2006
0.000   0.10    0.150   0.155   0.21    2007
0.000   0.15    0.166   0.202   0.30    2008
0.000   0.11    0.184   0.203   0.32    2009
####################################################
# INDEX OF RELATIVE EFFORT (you must enter values for each year, even if they are only dummy values)
####################################################
# how to treat effort data (0) do not use values below, instead replace with a default of 1.0 for all
years
# |                        (1) use values below
# |                        (-1)use values below, then rescale relative to maximum value
  1
# value year
0.207   1950
0.231   1951
0.255   1952
0.278   1953
0.302   1954
0.326   1955
0.350   1956
0.373   1957
0.397   1958
0.421   1959
0.445   1960
0.468   1961
0.490   1962
0.513   1963
0.536   1964
0.559   1965
0.582   1966
0.604   1967
0.627   1968
0.650   1969
0.673   1970
0.706   1971
0.738   1972
0.771   1973
0.804   1974
0.836   1975
0.869   1976
```

```
0.902   1977
0.935   1978
0.967   1979
1.000   1980
1.000   1981
1.000   1982
1.000   1983
1.000   1984
1.000   1985
1.000   1986
1.000   1987
1.000   1988
1.000   1989
1.000   1990
1.000   1991
1.000   1992
1.000   1993
1.000   1994
1.000   1995
1.000   1996
1.000   1997
1.000   1998
1.000   1999
1.000   2000
1.000   2001
1.000   2002
1.000   2003
1.000   2004
1.000   2005
1.000   2006
1.000   2007
1.000   2008
1.000   2009
####################################################
# Projection specifications
####################################################
# selectivity for reference points (1=fishery, 2=use maturity vector)
  1
# non-negative=input reference (should have value between 0 and 1)
# otherwise, -0.1=B at F0.1, -1=B at msy, -2=B at Fmax, -20=Bspr20, -30=Bspr30, -40=Bspr40, -50=Bspr50, -
60=Bspr60, -999=Bcurrent)
 -50
# control for recruitment deviations (0=none, + = variance, - = -cv)
 -0.40
# projected F values (non-negative=input F, -0.1=F0.1, -1=Fmsy, -2=Fmax, -20=Fspr20, -30=Fspr30, -
40=Fspr40, -50=Fspr50, -60=Fspr60, -999=Fcurrent)
# |       Std. error (or negative CV) of implementation uncertainty (not being used at present)
# |       |       year
# |       |       |
  -999    -0.01    2010
  -999    -0.01    2011
  -999    -0.01    2012
  -999    -0.01    2013
  -999    -0.01    2014
  -999    -0.01    2015
  -999    -0.01    2016
  -999    -0.01    2017
  -999    -0.01    2018
  -999    -0.01    2019
  -999    -0.01    2020
```

```
  -999    -0.01    2021
  -999    -0.01    2022
  -999    -0.01    2023
  -999    -0.01    2024
  -999    -0.01    2025
  -999    -0.01    2026
  -999    -0.01    2027
  -999    -0.01    2028
  -999    -0.01    2029


#/////////////////////////////////////////////////////////////////////////////////////////////
#/////////////////////////////////////////////////////////////////////////////////////////////
#// PARAMETER FILE FOR PROGRAM DATAPOOR - Lorenzen M, max age=37, M=0.1217, new ENP and offshore
vulnerability vectors
#//  * rev q5 - turned it on.
#//   Important notes:
#//    (1) Comments may be placed BEFORE or AFTER any line of data, however they MUST begin
#//        with a # symbol in the first column.
#//    (2) No comments of any kind may appear on the same line as the data (the #
#//        symbol will not save you here)
#//    (3) Blank lines without a # symbol are not allowed.
#//       Updated growth curve, f2 (moratorium effectiveness), survey index distribution parms adjusted
for Lorenzen M and F, Clay's method,
#//       new length-weight, Clay's new Lorenzen parms,
#/////////////////////////////////////////////////////////////////////////////////////////////
#/////////////////////////////////////////////////////////////////////////////////////////////
#
####################################################
# DIMENSION ARRAYS
####################################################
# total number of process parameters - count the number of entries in the process parameter section
  34
# number of sets of each parameter type
#       catchabilities q    selectivity vectors    index variances
        5                      7                    1
####################################################
# SPECIFICATIONS FOR PROCESS PARAMETERS
####################################################
#       nature of function (1=constant, 2-3=polynomials, 12=power, 13=process correlation, 14=process
variance scaling parameter
#       |       best guess of parameter value (median of prior)
#       |       |        lower bound for parameter
#       |       |        |       upper bound for parameter
#       |       |        |       |       phase of estimation (enter -1 to fix at best guess and not
estimate)
#       |       |        |       |       |      probability density function of prior (0=none,
1=lognormal, 2=normal)
#       |       |        |       |       |      |       negative value is read as CV, positive value is
read as standard error (must be on logscale if overall_pdf=1, aritmetic scale otherwise) of prior
#       |       |        |       |       |      |     |
#f_ph parameters for expected F during prehistoric era
        2       0.0   -0.010   0.5      -2       2       -1.0
        2       0.3   -0.010   0.5       1       2       -1.0
#f    parameters for expected F during modern era before change in regulations- note if nature=-1 then
F=parameter*F(last year of historical period))
        -1      1.0     0.02  10.0       1       2       -1.0
#f2   parameters for expected F during modern era after change in regulations- note if nature=-1 then
F=parameter*F(last year before change))
        -10     0.14    0.01   0.9       3      5        -0.40
```

```
#m    natural mortality rate - Lorenzen M parameters modified for ages 4-37 in terms of weight (Lorenzen
1996, eqn for "Natural", M=alpha*wt(grams)^-0.288, alpha=3)
#     length-wt equation is in kg, so M(Lorenzen) = (1000 grams/kilogram)^-0.288 * adjustment factor for
target ages * 3 * wt[kg]^(-0.288)
        12      0.453311  0.01  0.7      -3      0       -0.4
        12      -0.288   -1    -.1      -3      0       -0.4
#r   parameter alpha minus 1
        10      2.648087  0.01 150.0     2       1       1.310438
#w (by record) for vonBertalannfy equation (Linf, k, t0, cv) and length-weight equation (intercept in
kilograms, slope)
        8       0.2221E+04   150    3000  5     2      -0.11
        8       0.0937E-00   0      10   -6     0       0.00295
        8      -0.6842E+00  -5.00   10   -1     0       0.1
        8       0.1000E+01   0      10   -1     0       0.1
        8       1.0110E-08   0      10   -1     0       0.1
        8       3.0900E+00   0      10   -1     0       0.1
#q      (linked to survey indices 1-DeMaria, 2-REEF (SE), 3-ENP, 4-MRFSS (PR, FHS regions 2 and 4), 5-REEF
(SW)
         1  0.5000E+00  .01        10     1     2       -2
         1  0.5000E+00  .01        10     1     2       -2
         1  0.5000E+00  .01        10     1     2       -2
         1  0.5000E+00  .01        10     1     2       -2
         1  0.5000E+00  .01        10     1     2       -2
#s_prehistic
         6  2.5100E+00   0       10      -4      2      -0.1
         6  0.5250E+00   0       10      -1      0       0.1
#s_modern
         6  2.5100E+00   2       10       4      2      -0.1
         6  0.5250E+00   0       10      -1      0       0.1
#_s_survey 1 DeMaria Lorenzen M adjusted, WFL offshore diver measurements, age-length key
         6  5.5272E+00  4       10      -4      2      -0.1
         6  1.0244E+00  0       10      -1      0       0.1
#_s_survey 2 REEF Southeast Lorenzen M adjusted, WFL offshore diver measurements, age-length key
         6  5.5272E+00  4       10      -4      2      -0.1
         6  1.0244E+00  0       10      -1      0       0.1
#_s_survey 3 ENP Angler Creel Survey, Lorenzen M adjusted, ENP angler creel survey, Brusher and Schull
ages, age-length key
         7  3.6320E+00  0       10      -4      2      -0.1
         7  0.3395E+00  0       10      -1      0       0.1
#_s_survey 4 MRFSS Lorenzen M adjusted, WFL offshore diver measurements, age-length key
         6  5.5272E+00  0       10      -4      2      -0.1
         6  1.0244E+00  0       10      -1      0       0.1
#_s_survey 5 REEF Southwest Lorenzen M adjusted, WFL offshore diver measurements, age-length key
         6  5.5272E+00  0       10      -4      2      -0.1
         6  1.0244E+00  0       10      -1      0       0.1
#idv
        14  1.0000E+00   0       10      -1      0       0.1
#overall var
        1   -0.2        -1     -0.01      5     2       -0.5
#####################################################
# SPECIFICATIONS FOR PROCESS DEVIATION PARAMETERS
#####################################################
#       best guess of parameter value (central tendency of prior)
#       |       lower bound for parameter
#       |         |     upper bound for parameter
#       |         |       |     phase of estimation (enter -1 to fix at best guess and not estimate)
#       |         |       |        |    probability density function of prior
#       |         |       |        |       |     standard error or negative CV of prior (superfluous in
case of deviations)
#_f_____|         |       |        |       |      |
```

```
      0.50   -0.001     1.0       -1      0      0.1
      0.15        0    1000.      -1      0      0.1
      0.000      -5       5        5      1     0.1
#_r_____|         |        |         |       |      |
      0.5    -0.001     1.0       -1      0      0.1
      0.15        0   100.0       -1      0      0.1
      0.0000     -5       5        4      1     0.1
#_q_____|         |        |         |       |      |
      0.0    -0.001     1.0       -1      0      0.1
      0.10        0   100.0       -1      0      0.1
      0.0000     -5       5       -1      1     0.1
# End of file #
```

SEDAR

Southeast Data, Assessment, and Review

SEDAR 23

Gulf of Mexico and South Atlantic Goliath Grouper

SECTION IV: Research Recommendations

SEDAR
4055 Faber Place Drive, Suite 201
North Charleston, SC 29405

1. DATA WORKSHOP RESEARCH RECOMMENDATIONS

1.1 LIFE HISTORY WORKING GROUP

Stock Definition:

- D. Jones has new MARFIN funding to use otolith microchemistry (laser ablation) to determine if there are distinct subpopulations based on geographic differences in chemical signatures. Juvenile habitat would be represented at the origin of otolith, adult habitat at the margins (SA and/or Gulf) ***goliath grouper were not originally considered in this MARFIN proposal, but could easily be added with availability of otoliths and moderate time resources.*
- Koenig referenced the availability of goliath grouper eggs from the SA and GOM which could be used for genetic population structure analysis. Eggs will be sampled for Dr Matthew Craig (U Puerto Rico) who has done the most extensive work on goliath grouper population genetics (Craig et al. 2009)
- Description of larval stages of goliath grouper is part of an ongoing MARFIN project by Koenig and Coleman.
- Limited recent drifter studies along the US South Atlantic coast have shown the potential for wide distribution patterns along the coast from Cape Hatteras to the Florida Keys (Lesher and Sedberry, SEDAR 10-DW-06). With location and timing of spawning now known, it would be a good opportunity to initiate additional drifter studies in the SA and GOM.
- Ongoing research (Koenig and Coleman) will verify known SPAGS and suspected SPAGS. It will also determine the size structure of spawning fish, their residency time on the SPAGS, and size-related fecundity. With more known SPAGS, there is the potential to assess the abundance of reproductive adults based on numbers present at SPAGS and knowing the geographical range of the participating spawners.

Age and Growth:

- A directed effort to collect hard parts from large, old fish to validate these methods for old individuals.
- More detailed information on maximum age and size is needed. There are no new data available for maximum age or maximum size since Bullock et al. 1992. There is reason to suspect that maximum age is a low estimate due to the small number of large, old fish sampled. Additionally, there is concern over whether or not the asymptote is fully represented due to the low number of samples represented at the oldest ages (Fig.1). However, this maximum age does fall within the values observed for other epinephelines [i.e., *E. fuscoguttatus* (42 y for females and 40y for males; Pears, 2006), *E. morio* (29 y; Lombardi-Carlson et al., 2006), *E.*), *H. nigitus* (41 y; Manooch, 1987), *E. striatus* (29 y; Sadovy and Ecklund 1999)]. However, the best species for comparison (due to similar size, tropical/subtropical distribution and ecological role) are the Indo-Pacific *E.*

lanceolatus and *E. tukula*; data on maximum size, age and growth rate are still being sought at the time of writing the present report.

- As suggested during the last SEDAR (SEDAR6, 2004): “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.”

Reproduction

- Ongoing research (Koenig and Coleman, MARFIN) will evaluate fecundity, sexual pattern, SPAG distribution, size structure and sex ratio within SPAGS, and mating system using non-lethal methods.

Habitat and Movement:

- We need spatially-explicit models. Due to microhabitat preferences and site attachment in both juvenile and adult goliath groupers, density values (as number of individuals per unit area or length of coastline) should be used with caution in population estimates and modeling; it is essential to contrast densities in high quality habitats versus low quality habitats, and not use a single density value which could results in over-estimates of total population levels. Future modeling efforts should also account for the known (or unknown) statewide spatial distribution of both juveniles and adults.
- We need a state-wide evaluation of habitat quality integrating habitat structure and water quality. Including this knowledge in our goliath grouper assessments will allow us to expand population models into ecosystem-based management.
- What is the extent of high quality mangrove habitat, and where is it located in Florida? There is a need for a state-wide assessment of mangroves as fish habitat, to evaluate potential high quality sites that are the nurseries, not only for juvenile goliath grouper but also for juveniles of a diverse group of other fish and invertebrate species.
- When evaluating high quality habitat (both in mangroves and reefs), in addition to evaluating the structural characteristics, what is the water quality of each habitat? There is a need to quantify, state-wide in real time and 24/7 the water quality (salinity, temperature, dissolved oxygen) of mangroves, and coastal reefs. This research question applies not only to goliath grouper but also to all estuarine and coastal species that use mangroves and reefs (coral reefs, reef ledges) during their life history.
- What are the biological corridors used during the ontogenetic migrations (from juvenile mangrove habitat to reef adult habitat) and the spawning migrations (from resident habitat to spawning aggregation sites)? We don’t know if goliath grouper use a specific path or network (=biological corridor) during their two major migratory events (ontogenetic and reproductive).
- What are the maximum distances that can be covered by juveniles in ontogenetic migrations towards the adult habitat, and by adults in their spawning migrations? These data are needed to understand the ontogenetic and spawning connectivity within the goliath grouper population.

1.2 COMMERCIAL AND RECREATIONAL STATISTICS WORKING GROUP

The prohibition on any harvest of goliath grouper precludes any fishery dependent research other than that conducted by on-board observers or recorded in fishermen's logbooks. Continued collection of size, frequency in the catches by gear, and observed release condition is important for obtaining release mortality estimates and possibly an estimate of numbers caught by gear, fishing area, and depth. It is expected that as the abundance of this species increases, so too will the frequency of encounter with fishing gears. Brusher and Schull's (2009) study that goliath grouper have a reasonably good chance of surviving the encounter with fishing gear at least in shallower waters. Capture-recapture studies could be designed to examine the effects of releases from the recreational fishery. With the apparent increase in numbers of goliath grouper reported by anglers, it is inevitable that more encounters with fishing gear will occur and this seems to be borne out by reports from angler surveys such as the ENP Angler Creel Survey and the MRFSS. Surveys of spawning aggregations are needed to extend the usefulness of Don DeMaria's earlier surveys and to monitor population trends of adults.

1.3 INDICES OF ABUNDANCE WORKING GROUP

No research recommendations were provided by the Working Group.

2. ASSESSMENT WORKSHOP RESEARCH RECOMMENDATIONS

Recommendations on future research and data collection were provided at the DW. An additional recommendation for a "research fishery" was briefly discussed at the Assessment Workshop (AW), but was never formalized.

3. REVIEW PANEL RESEARCH RECOMMENDATIONS

Although results were unsatisfactory for this stock assessment, they did serve to clarify additional research necessary for future assessment efforts. The next benchmark assessment cannot be successfully completed without data from the research recommended by the Data, Assessment, and Review Panels.

<u>Stock Definition:</u>

- Goliath grouper should be genetically sampled from as many areas in the South Atlantic and Gulf of Mexico as possible to allow for a more thorough examination of the current single stock definition.
- Examination of spawning aggregations over the entire distribution range should include seasonality, sex ratios, and individual fidelity.

<u>Long-term monitoring</u>:

- Basic reproductive data are lacking throughout the species distribution, including: size and age at maturity for each sex, sexual sequence with size and age for each sex, and fecundity.
- As described in the above research recommendations by the Life History Working Group, research on age structure, and locations of suitable juvenile and adult habitat, discard and discard mortality rates should be accomplished throughout the species distribution

<u>Economic impact:</u>

- Because of the relatively small size of a potentially reopened consumptive fishery for goliath grouper, a socio-economic evaluation of the relative benefits of consumptive versus non-consumptive uses would be beneficial. There may be greater long-term economic benefit to development of sustainable non-consumptive eco-tourism venues than would be possible from a consumptive fishery.

SEDAR
Southeast Data, Assessment, and Review

SEDAR 23

South Atlantic and Gulf of Mexico

Goliath Grouper

SECTION V: Review Workshop Report

January 2011

SEDAR
4055 Faber Place Drive, Suite 201
North Charleston, SC 29405

Table of Contents

1. INTRODUCTION

1.1 WORKSHOP TIME AND PLACE

The SEDAR 23 Review Workshop was held November 15-17, 2010 in Key West, Florida.

1.2 TERMS OF REFERENCE

1. Evaluate the adequacy, appropriateness, and application of data used in the assessment.
2. Evaluate the adequacy, appropriateness, and application of methods used to assess the stock.
3. Recommend appropriate estimates of stock abundance, biomass, and exploitation.
4. Evaluate the methods used to estimate population benchmarks and management parameters (*e.g., MSY, Fmsy, Bmsy, MSST, MFMT, or their proxies*); recommend appropriate management benchmarks and provide estimated values for management benchmarks, and declarations of stock status.
5. Evaluate the adequacy, appropriateness, and application of the methods used to project future population status; recommend appropriate estimates of future stock condition (e.g., exploitation, abundance, biomass).
6. Evaluate the adequacy, appropriateness, and application of methods used to characterize uncertainty in estimated parameters. Provide measures of uncertainty for estimated parameters. Ensure that the implications of uncertainty in technical conclusions are clearly stated.
7. Ensure that stock assessment results are clearly and accurately presented in the Stock Assessment Report and that reported results are consistent with Review Panel recommendations.
8. Evaluate the SEDAR Process as applied to the reviewed assessments and identify any Terms of Reference which were inadequately addressed by the Data or Assessment Workshops.

9. Consider the research recommendations provided by the Data and Assessment workshops and make any additional recommendations or prioritizations warranted. Clearly denote research and monitoring needs that could improve the reliability of future assessments. Recommend an appropriate interval for the next assessment, and whether a benchmark or update assessment is warranted.
10. Prepare a Peer Review Summary summarizing the Panel's evaluation of the stock assessment and addressing each Term of Reference. Develop a list of tasks to be completed following the workshop. Complete and submit the Summary Report within 3 weeks of workshop conclusion.

The review panel may request additional sensitivity analyses, evaluation of alternative assumptions, and correction of errors identified in the assessments provided by the assessment workshop panel; the review panel may not request a new assessment. Additional details regarding the latitude given the review panel to deviate from assessments provided by the assessment workshop panel are provided in the *SEDAR Guidelines* and the *SEDAR Review Panel Overview and Instructions*.

** The panel shall ensure that corrected estimates are provided by addenda to the assessment report in the event corrections are made in the assessment, alternative model configurations are recommended, or additional analyses are prepared as a result of review panel findings regarding the TORs above.**

1.3 LIST OF PARTICIPANTS

Workshop Panel

Luiz Barbieri, Chair .... SAFMC and GMFMC SSC/FWC FWRI
Shannon Cass-Calay .... GMFMC SSC
Barbara Dorf .... GMFMC SSC
Jamie Gibson .... CIE Reviewer
John Hoenig .... SAFMC SSC
Sven Kupschus .... CIE Reviewer
Kevin Stokes .... CIE Reviewer

Analytic Representation

Joe O'Hop .... FWC FWRI
Joseph Munyandorero .... FWC FWRI

Council Representation

Ben Hartig .... SAFMC
Kay Williams .... GMFMC

Official Observers

Ben Fairey .... GMFMC AP

Other Observers

Angela Collins .... FWRI
Bill Causey .... NOS

Don DeMaria ....

Sarah Frias-Torres... Ocean Research & Conservation Association

Doug Gregory ....FL SeaGrant

Manoj Shivlani... CIE/RAMAS

Bill Teehan.. FWC

Staff

Karen Burns ....GMFMC Staff

Patrick Gilles...NMFS Miami

Rachael Lindsay.. SEDAR

Julie Neer .... SEDAR

1.4 LIST OF REVIEW WORKSHOP WORKING PAPERS AND DOCUMENTS

Documents Prepared for the Review Workshop		
SEDAR23-RW-01	Application of Stock Reduction Analysis to goliath grouper (*Epinephelus itajara*) off southeastern U.S.A, 1918 – 2009	Joseph Munyandorero
SEDAR23-RW-02	Working paper for the review panel	Sarah Frias-Torres

2. REVIEW PANEL REPORT

1. SEDAR 23 Review Panel Summary Report

The stock assessment of goliath grouper presented by the SEDAR 23 Assessment Workshop (AW) provided the Review Panel with thorough descriptions of the data available for assessing goliath grouper, information about the life history of this species, as well as outputs and results from the catch-free model developed for this stock by Porch et al. (2006). The panel felt the proposed base model parameterization as presented was inappropriate to provide information on goliath grouper stock status or benchmarks as it does not reflect appropriate stock dynamics. Further, the panel felt that the output of the model is unlikely to represent real changes in the F trajectories because some model assumptions were thought to be heavily influencing the model output, and the recruitment pattern did not appear realistic with respect to expected patterns of recruitment for a long-lived species. A stochastic stock reduction analysis (SSRA) was also presented for exploratory purposes. In principle, with appropriate attention to better quantifying removals and to sensitivity testing the SSRA could be used in the future to provide more relevant information for management purposes. The Review Panel briefly considered the SSRA but could not review it to draw conclusions as it had not already been considered by the AW. In any case, results from the SSRA would critically depend on credible inputs on removals, which are difficult to derive given some uncertainties in the historical commercial landings and recreational catch. These uncertainties were well described by the data workshop (DW). The catch-free model did not require such an input.

2. Terms of Reference:

1. Evaluate the adequacy, appropriateness, and application of data used in the assessment.

The Review Panel comments, concerns, and recommendations on the adequacy, appropriateness, and application of the data used in the SEDAR 23 assessment is listed below in itemized format.

<u>Stock structure</u>: Genetic data were used by the data working group to examine stock structure. The panel feels it is safe to say that stocks don't extend to other countries. However, within the United States the resolution of the data is not fine enough to determine spatial structure of stocks. Tagging data demonstrate site fidelity but also long distance movements (~175 km). A single stock within US waters was assumed for the assessment for convenience. This may be reasonable but there are some potential problems with this approach. Management actions may need to be made on a finer spatial scale to prevent localized depletion but the data and models used do not allow for this. Interpretation of indices with varying spatial coverage may be complicated by fish movement patterns which are poorly understood.

The Review Panel thought it might be helpful to evaluate the indices of abundance at a finer temporal and spatial scales. This may shed some light on stock structure and is important for assessing how the indices can be incorporated in an assessment model (see discussion under Indices).

<u>Indices</u>: Multiple indices were developed covering both juvenile and adult life stages. Standard, credible statistical modelling was thoroughly used. Nevertheless, there are some

issues of note. The panel felt it needed more information on the indices, specifically more background on their nature and construction, the conclusions of the DW on the quality of the data, as well as technical details including maps and diagnostics (residuals). The SEDAR criteria for standardizing indices should be followed (the panel did not find this information in the DW report). The panel accepted the indices at face value as other issues already suggested likely rejection of the catch-free assessment model. However, if the assessment had been viewed more positively the panel would have needed to consider the indices in greater detail to advise on their utility. Specific comments and recommendations are presented below.

- <u>ENP creel survey</u>**:** This is the index with the longest time series and the only index spanning the implementation of the moratorium. It covers fish ranging in size from 200mm to 1000mm (predominantly ages 2-8). It only covers part of the juvenile geographic range (though when it was started it was believed to cover the core of the distribution; since the moratorium the distribution has expanded). It is a fishery index based on intercept interviews and there is uncertainty about fishery changes through time. In recent years the index has shown a strong increase but the index declined significantly in 2008 and 2009.

- <u>REEF</u>**:** Positive aspects of the reef survey are that it is not fishery based and it has broad spatial coverage. The panel had concerns over the logarithmic nature of the index (observations are binned in intervals of unequal size) and noted that DW panels for several other SEDAR assessments have rejected REEF for this reason. The panel did not discuss this at length but rather accepted the index at face value. The panel believed the index (both SE and SW subsets) showed increases in stock size over time though the rates of increase is not likely plausible in terms of the assessment. It might be possible to handle the binning using a Poisson model to get an index of abundance but in the extreme, if all observations are in the largest bin then one could not detect even large changes. Simulation might be used to investigate how to use these data—but this would need to be in the context of an assessment model (and may therefore not be useful at this time).

  The panel noted that the SW and SE REEF indices show different behavior. There is a problem with including indices in a model without an explanation or description of the mechanisms giving rise to the discrepancies. A possible explanation is a range expansion or redistribution of fish, or it may be indicative of differing demographics in the two areas. In either case, it needs to be determined how to weight the two indices. (See comments on 'Stock Structure' above.)

- <u>MRFFS</u>**:** This index is important but there are three issues. First, the index is highly variable. Second, there may have been changes in recreational targeting and reporting. Third, this is a proportion positive index for private boats only. It may have been more appropriate to consider trips only in areas where goliath grouper are likely targeted. As a proportion positive index the steep increase may be appropriately structured. However, the panel had concern about how the assessment model treats the index (with errors treated as log-normal instead of binomial).

- <u>DeMaria</u>**:** This index is critical to the assessment because it drives the little bits of variability being estimated by the model (all else is fixed by assumption and the

DeMaria index is the only information presented in that time period). The very rapid declining of this index drives the estimated decline prior to the moratorium. The index represents observations on 4 artificial reefs, in the same general area which is difficult to access. Thus, it could be indicative of a local depletion, potentially after depletion in other areas had occurred. Such a sharp decline during a period of relatively constant catches (adjusted) or slow fall off (non-adjusted) suggests need for care in interpretation. The assessment model output suggests a trebling of F in the period of the DeMaria decline despite constant catch and (presumably) effort. Although this index is potentially important—because it includes information on older fish and is the only information for that time period, the review panel questioned whether it was indicative of the abundance decline of the entire stock and whether the resulting F estimates were realistic.

Reproduction**:** Although the panel believed the reproductive parameters used in the model were based on the best available information, they questioned their sufficiency because they came from early studies or from proxy species. Specifically, age-at-maturity, and spawning frequency are needed for deriving SPR. The panel notes that information suggests an earlier age-at-maturity for males than females which seems to contradict the assumption of protogyny (as observed in other members of the family). Spawning frequency is not known. Thus, there is a need to determine the basic reproductive characteristics of the species.

Natural Mortality**:** The panel notes that there was a lot of effort devoted to modelling age-specific M, a parameter that does influence the current stock status and estimated recovery times. Note that if a different assessment model is adopted the value of natural mortality rate may be very important so there is value in trying to improve the estimation of M.

The panel notes that the value of T_{MAX} (longevity) is what determines the natural mortality rate in the Hoenig model and an underestimate of T_{MAX} results in an overestimate of natural mortality. The maximum recorded age (37 years) may be low because the older fish were fished down and there has only been 20 years since the fishery was closed. Therefore, it was appropriate for the assessment to consider higher values of longevity. It would be appropriate to consider the suite of alternative estimators of natural mortality based on life history correlates. This was apparently done, but the results do not appear in the DW report.

The panel had some concerns about the adjustment of the natural mortality rate, based on Lorenzen’s model, to obtain age-specific natural mortality. The panel felt that Hoenig’s method describes natural mortality of most of the exploited phase of the life history and there is no reason to contradict this model; Lorenzen’s model can be used to adjust Hoenig’s M upward for younger ages. In the goliath grouper assessment, mortality rates for all ages were apparently modified so that the overall mortality rate matched Hoenig’s M. This methodology should be justified. It was also noted that adjusting Hoenig’s M by the Lorenzen method has not been tested and there are some species for which this is likely inappropriate because natural mortality may be lower for at least some younger ages.

Growth: The panel felt the data used were the best available and most appropriate to use. However, it was also noted that this is a primary aspect of the catch-free assessment model and errors in the growth estimates and in the estimates of variability in growth has impacts on the estimated recruitment. If this model were to be used in the future it would be important to look at improving the estimates of growth.

Selectivity: Two methods were used to estimate selectivity. The Panel considered one of the methods inappropriate because it does not take account of cohort sizes. The other method uses a value of F to adjust for unequal cohort sizes but, as this is a parameter that needs to be estimated the Panel felt this procedure leads to some circular reasoning. (See section on selectivity under TOR # 2).

Removals: Information on removals is not needed for the catch-free model but it could still be useful diagnostically. For the alternative model presented, Stock Reduction Analysis (SRA), information on removals is of key importance. The Panel agreed with the AW that there are major concerns about the removal data, including uncertainties in the treatment of questionable records from one dealer and the smoothing of the data. If a model is used that requires removal data then there is a critical need to find the best method for reconstruction of the time series of landings as well as exploration of a variety of scenarios encompassing plausible landings values. In particular, the data should be considered both with and without the adjustments. For recreational removals, the MRFSS figures by number suggest there could be very high catches—possibly equal or greater than historical commercial landings. There is a need to explore methods of constructing historical series.

Discards: The Panel discussed whether discards should be modelled as constant catch versus constant exploitation rate. This issue should be further explored in the next assessment and a clear justification of the decision included in the stock assessment report.

2. Evaluate the adequacy, appropriateness, and application of methods used to assess the stock.

The Review Panel were presented with an assessment of the stock dynamics of goliath grouper using the catch-free method developed by Porch et al. (2006), which had previously been used to assess the stock. The AW presented a model run employed the settings previously adopted by SEDAR 6 to assess the stock updated with current data (a continuity run); as well as a proposed base run, which differed in the indices used, dropping the fisher interview index, adding the MRFSS and the REEF SW index, and with a different prior as to the effectiveness of the moratorium. In addition, the constant natural mortality at age used in the continuity run was replaced by age dependent natural mortality (see TOR #1 above), and selectivities were reassessed. Full MCMC runs were presented to assess model uncertainty for both runs and the uncertainty in some key parameters such as the maximum age and the effectiveness of the moratorium were explored for the proposed base run.

Both runs indicated that there had been a sharp decline in SSB since 1950 reaching a low around 1990, the time at which the moratorium was established for this stock. Both runs also indicated that a reduction in F and an increase in SSB associated with the moratorium. SSB since that time is estimated to have reached higher relative levels in 2009 in the continuity run than in the proposed base run (1.4 x B50%SPR instead of 1 x B50%SPR). Fishing mortality is estimated to have risen slowly from 1950 to 1980 after which it increased, and subsequently decreased five-fold to 1989 when it dropped away to residual levels associated with the effectiveness of the moratorium, although this pattern may have been largely influenced by some model assumptions (see below).

The choice of the catch-free model is logical given the types of available data as the catch is unknown since the implementation of the moratorium and highly uncertain prior to that. In addition, the available age data is too sparse to develop an explicit age-based assessment to estimate cohort strength. However, its appropriateness to management as currently implemented by the Council is questionable given that it is essentially a method that only provides estimates of relative fishing mortality and abundance. To obtain relative levels of abundance the model is scaled, in this case by assuming the biomass at the beginning of the time series equaled the unexploited equilibrium biomass, an assumption unlikely to be appropriate given the historical landings record of goliath grouper. The model does not provide estimates of the value of the unexploited equilibrium biomass. Because the model does not provide estimates of the actual abundance or biomass, the assessment is unable to provide information on catch limits and hence stock status projections other than under a zero catch scenario.

The review panel examined the proposed base model run and voiced the following concerns:

<u>Moratorium Effectiveness</u>: fishing mortality although nominally estimated within the assessment is essentially fixed or at least highly constrained. At the end of the time series (post moratorium) F is largely governed by the choice of the prior on moratorium effectiveness as the parameters would otherwise be highly correlated to recent recruitment levels. Additional runs performed at the request of the panel using alternative priors suggest that the most parsimonious solution points to an unrealistic 100% effectiveness of the moratorium, mainly because the recent rate of SSB increase suggested by the indices is greater than that deemed realistic by the implemented stock-recruitment relationship.

<u>Historic levels of F</u>: relative changes in F during 1950-1978 are guided by the proxy index of historical fishing pressure based on the US census indicating a mildly exponential increase in F over the period where no index information exists. Available landings data for that period, although not used in the assessment, appears to be inconsistent with this assumption.

<u>Selectivities</u>: in the following period, F is less constrained and spikes dramatically with a five-fold increase in 5 years. Fluctuations of this magnitude are considered to be unlikely over such a short time frame and are not anecdotally supported. Industry representatives at the meeting indicated that this was a serial depletion over a longer time period under a spatially expanding fishery, rather than a short-term high intensity depletion. Even in this period, the model F is still effectively constrained externally by the methodology of determining selectivities, which require a priory estimate of total mortality to develop age length-keys—which the Panel considered a circular argument.

In other words, the model is being supplied with a predetermined F trajectory, such that the output from the model closely reflects these input parameters. The Panel felt that at least in some instances these constraints seemed to be unnecessary in the sense that the model converged—suggesting that there is sufficient information to determine the required parameters in the absence of such constraints.

The model diagnostics in the form of the residual patterns on the indices generally suggest temporally autocorrelated residual patterns, particularly for those indices providing information in recent years. All indices indicate strong increases in biomass from 1990 to 2008 (where available), so that the serial autocorrelation in opposing directions suggests that the implied rate of increase is different for different indices.

Prior to 1990 only two indices are effective in guiding the assessment. The residual pattern suggest that most of the information of the decline of the stock in the early period is driven by the ENP index modified by the DeMaria index altering the rate of the decline to a more recent and much sharper decline. Nevertheless, the low point of the series is entirely independent of the inclusion of the index and hence is most likely driven by the overly sharp increase in the indices in conjunction with the fixed mortality rates. The sharp rate of decline seems unrealistic and may be associated with the small spatial scale over which the DeMaria index is derived.

Residual patterns suggest relatively little influence of individual tuning series (robust to the inputs) implying consistency of the information. However, the residuals suggest a failure of the model to represent realistic stock dynamics possibly due to the strong constraints in the model regarding F.

Given these caveats the panel felt the proposed base model parameterization as presented here is inappropriate in providing information on stock status or benchmarks as it does not reflect appropriate stock dynamics. The output of the model is unlikely to represent real changes in the F trajectory as described above. Furthermore, the panel questioned whether the recruitment estimates are realistic with respect to expected recruitment relationship for a long-lived species. In order to fit the rapid, recent increases in some abundance indices, the model produced estimates of the maximum reproductive rate that were high relative to the prior (considered to be reasonable) used for this parameter in the model, as well as a series of positive recruitment deviates in recent years, potentially implying that the stock-recruitment dynamics were not well characterized by the model. These dynamics would largely determine the reference levels against which relative status is evaluated.

3. Recommend appropriate estimates of stock abundance, biomass, and exploitation.

The assessment runs presented by the AW utilize a catch-free model with limited data input and a wide range of assumptions and constraints. By definition, the model used can only provide estimates of relative abundance, biomass and exploitation (and related benchmarks)—there is no information provided to the model to allow scaling to absolute values.

At SEDAR 6 the catch-free model was adopted to provide relative estimates and to provide guidance on the possible recovery time of goliath grouper. At SEDAR 23 the same model was employed but the context has changed with a management need for information to guide possible OFL/ABC setting. The catch-free model cannot provide this information as it does not use data on removals to scale necessary estimates and because it cannot take account of possible future exploitation patterns.

At the SEDAR 23 RW a stochastic stock reduction analysis (SSRA) was also presented for exploratory purposes. In principle, with appropriate attention to better quantifying removals and to sensitivity testing the SSRA could be used to provide more relevant information for management purposes. The Review Panel briefly considered the SSRA but could not review it to draw conclusions as it had not already been considered by the AW. In any case, results from the SSRA would critically depend on credible inputs on removals, which are presently considered uncertain by the DW as the catch-free model did not require such an input (see TOR #1).

4. Evaluate the methods used to estimate population benchmarks and management parameters (*e.g., MSY, Fmsy, Bmsy, MSST, MFMT, or their proxies*); recommend appropriate management benchmarks and provide estimated values for management benchmarks, and declarations of stock status.

In principle, use of the catch-free model to estimate F and SSB relative to SPR-based benchmarks is appropriate given the uncertainty in the landings data, but is limited in its capacity to provide catch advice. The AW did assess status relative to population benchmarks for continuity and proposed runs of the catch-free model (Fig 3.3.8 of the AW Report). Interpretation of the estimated ratios is, however, problematic for reasons outlined in ToR #2.

The review workshop (RW) did not discuss the use of the $F_{50\%SPR}$ proxy as a B_{MSY}-related reference point (as opposed to alternative %SPR values or for the species generally given uncertain life-history). However, even if the F and SSB ratios were accepted at face value, estimation of current (and projected) status is highly dependent on the assumed level of natural mortality (see Fig 3.3.8 of the AW Report) and the assumed level of moratorium efficacy. This latter point was not investigated by the AW but limited runs during the RW demonstrated the dependency.

The issue of sensitivity to natural mortality is significant. At an assumed T_{max} of 37 years, the point estimate of $F_{2009}/F_{50\%SPR}$ is 0.821. As T_{max} increases, the point estimate exceeds 1 at T_{max} = 50 years and rises linearly to greater than 1.5 at T_{max} = 80 years. The ratio of $SSB_{2009}/SSB_{F50\%SPR}$ declines exponentially from over 0.9 to less than 0.3 over the same range of T_{max}. As noted in ToR 1, the exploration of sensitivity to T_{max} in the range 37 (maximum observed age) to 80 years was deemed appropriate (based on comparison of other grouper species).

It is not possible, therefore, for the RW to recommend appropriate benchmarks or to provide estimates. Nevertheless, some qualitative statements can be made about abundance, biomass and exploitation, and stock status, based solely on data. Whilst interpretation of indices is not straightforward (see ToR 1), all indices suggest that abundance and biomass have increased since 1990 when the moratorium was implemented. The extent of that increase is difficult to gauge given the nature of the indices which all suggest faster rates of increase, and in some cases variability, than seem plausible given the biology of the species. There are also clear indications from indices representative of younger fish that recent recruitment may be less than in the preceding years. It is difficult to interpret the degree of previous stock decline as the perceived status in 1990 is strongly driven by the way the assessment must interpret the limited DeMaria index information (see ToR 1 and ToR 2).

5. Evaluate the adequacy, appropriateness, and application of the methods used to project future population status; recommend appropriate estimates of future stock condition (e.g., exploitation, abundance, biomass).

Notwithstanding the issues with the underlying assessment model, the panel agreed that the methods used by the AW to project future population status were adequate. Projections of the relative levels of spawning stock biomass were made based upon the state of the population and the relative fishing mortality rate in the final year of the assessment (2009). Uncertainty in the projections was assessed using MCMC simulations for the projection time period. This method ensures that the uncertainty in the current stock biomass and current fishing mortality, including covariance in the estimated model parameters, is carried forward throughout the projections. However, as stated in the assessment report, the projection methods did not include other sources of potential variability, such as implementation uncertainty, episodic sources of mortality (e.g. cold kills, red tide mortalities, etc.) or good and bad recruitment years. Uncertainty in the projections is not fully quantified as a result. While these other factors could theoretically be incorporated into the projection model via Monte Carlo simulation within the MCMC runs , given that the underlying sampling distributions for these other sources of variability are not known, the panel considered the methods as implemented were appropriate for this assessment.

Although the methods used to project future population status were implemented correctly, due to the underlying issues in the assessment model, estimates of future stock condition cannot be made at this time.

6. Evaluate the adequacy, appropriateness, and application of methods used to characterize uncertainty in estimated parameters. Provide measures of uncertainty for estimated parameters. Ensure that the implications of uncertainty in technical conclusions are clearly stated.

The Review Panel believed that the methods used to characterize uncertainty in the estimated parameters were appropriate for this assessment and that the methods were correctly applied.

The AW used two methods within ADMB to characterize uncertainty: the calculation of asymptotic standard errors and covariances for parameter estimates, as well as the use of Bayesian Markov Chain Monte Carlo (MCMC) methods implemented with this software. The use of two methods allowed the uncertainty of the resulting estimates to be evaluated. Of these methods, MCMC has two advantages: it produces estimates of the marginal posterior probability distributions that constrain the resulting confidence intervals to be within the parameter bounds and that parameter covariance is preserved during the simulations. The AW used cumulative probability distributions, based on the MCMC runs, to evaluate the probability that management benchmarks had been met or exceeded, an approach the panel considered to be appropriate for carrying forward the uncertainty in an individual model run. The methods used by the AW to select an appropriate burn-in period and an appropriate level of thinning of the MCMC chain to reduce autocorrelation were considered appropriate.

In addition to assessing the uncertainty in the model output, the AW used informative priors on some input parameters (e.g. the maximum lifetime reproductive rate and the effectiveness of the fishery closure) to input uncertainty in these values into the model. Although this approach can strongly influence model output, its influence can be less than fixing the parameter at a constant value, an approach at times used when data are not sufficient to provide a parameter estimate.

The AW also evaluated the effects of assumed parameter values on the model output. As an example, they thoroughly evaluated the influence of the maximum age of goliath grouper by repeating the analysis using several assumed values, clearly illustrating how uncertainty in this life history characteristic influenced the model output. The panel agreed with the AW that maximum age was a key source of uncertainty in the assessment. At the review meeting, the assessment team also evaluated the effect of the prior on the effectiveness of the fishery closure by using a less informative prior for this parameter, thereby demonstrating that the model would converge with less information being provided to the model about the value for this parameter. Additionally, the assessment team carried out a retrospective analysis and ran the assessment model using subsets of the survey indices to characterize the sensitivity of the model output to both recent data and the influence of the individual surveys.

Overall, the methods used by the AW to characterize uncertainty aided the Panel in its evaluation of the assessment. Although the methods used to characterize the uncertainty in the estimated parameters were considered appropriate, due to the underlying issues in the assessment model (parameter estimates from the model were not accepted), measures of the uncertainty for the estimated parameters cannot be provided at this time.

7. Ensure that stock assessment results are clearly and accurately presented in the Stock Assessment Report and that reported results are consistent with Review Panel recommendations.

The Review Panel ensured that the stock assessment results were clearly and accurately presented in the SEDAR 23 Summary Report and that the results were consistent with the Review Panel recommendations.

8. Evaluate the SEDAR Process as applied to the reviewed assessments and identify any Terms of Reference which were inadequately addressed by the Data or Assessment Workshops.

The Review Panel had no specific comments about the SEDAR process in regard to the review of the goliath grouper stock assessment. However, issues of relevance to the overall SEDAR process were discussed. The international members of the panel noted that a short summary of US management regulations and benchmarks would have provided a useful reminder of the legislative and management framework in which the panel is expected to operate.

9. Consider the research recommendations provided by the Data and Assessment workshops and make any additional recommendations or prioritizations warranted. Clearly denote research and monitoring needs that could improve the reliability of future assessments. Recommend an appropriate interval for the next assessment, and whether a benchmark or update assessment is warranted.

Although results were unsatisfactory for this stock assessment, they did serve to clarify additional research necessary for future assessment efforts. The next benchmark assessment cannot be successfully completed without data from the research recommended by the Data, Assessment, and Review Panels.

<u>Stock Definition</u>:

- Goliath grouper should be genetically sampled from as many areas in the South Atlantic and Gulf of Mexico as possible to allow for a more thorough examination of the current single stock definition.
- Examination of spawning aggregations over the entire distribution range should include seasonality, sex ratios, and individual fidelity.

<u>Long-term monitoring</u>:

- Basic reproductive data are lacking throughout the species distribution, including: size and age at maturity for each sex, sexual sequence with size and age for each sex, and fecundity.
- As described in the above research recommendations by the Life History Working Group, research on age structure, and locations of suitable juvenile and adult habitat, discard and discard mortality rates should be accomplished throughout the species distribution

<u>Economic impact</u>:

- Because of the relatively small size of a potentially reopened consumptive fishery for goliath grouper, a socio-economic evaluation of the relative benefits of consumptive versus non-consumptive uses would be beneficial. There may be greater long-term economic benefit to development of sustainable non-consumptive eco-tourism venues than would be possible from a consumptive fishery.

10. Prepare a Peer Review Summary summarizing the Panel's evaluation of the stock assessment and addressing each Term of Reference. Develop a list of tasks to be completed following the workshop. Complete and submit the Summary Report within 3 weeks of workshop conclusion.

This report constitutes the Review Panel's summary evaluation of the stock assessment and discussion of the Terms of Reference. The Review Panel will complete edits to its report and submit to SEDAR for inclusion in the full set of documents associated with SEDAR 23.

3.2. References

Porch, C.E., Eklund, A.M., and Scott, G.P. 2006. A catch-free stock assessment model with application to goliath grouper (*Epinephelus itajara*) off southern Florida. Fishery Bulletin 104: 89-101.