SEDAR

Southeast Data, Assessment, and Review

SEDAR 12
Stock Assessment Report

Gulf of Mexico Red Grouper

SEDAR 12
Stock Assessment Report 1

2006

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Table of Contents

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SECTION I. Introduction

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1. SEDAR Overview

SEDAR (Southeast Data, Assessment and Review) was initially developed by the Southeast Fisheries Science Center and the South Atlantic Fishery Management Council to improve the quality and reliability of stock assessments and to ensure a robust and independent peer review of stock assessment products. SEDAR was expanded in 2003 to address the assessment needs of all three Fishery Management Council in the Southeast Region (South Atlantic, Gulf of Mexico, and Caribbean) and to provide a platform for reviewing assessments developed through the Atlantic and Gulf States Marine Fisheries Commissions and state agencies within the southeast.

SEDAR strives to improve the quality of assessment advice provided for managing fisheries resources in the Southeast US by increasing and expanding participation in the assessment process, ensuring the assessment process is transparent and open, and providing a robust and independent review of assessment products. SEDAR is overseen by a Steering Committee composed of NOAA Fisheries representatives: Southeast Fisheries Science Center Director and the Southeast Regional Administrator; Regional Council representatives: the Executive Directors and Chairs of the South Atlantic, Gulf of Mexico, and Caribbean Fishery Management Councils; and Interstate Commissions: the 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.

SEDAR workshops are organized by SEDAR staff and the lead Council. Data and Assessment Workshops are chaired by the SEDAR coordinator. 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 and 3 reviewers appointed by the Center for Independent Experts (CIE), an independent organization that provides independent, expert reviews of stock assessments and related work. The Review Workshop Chair is appointed by the SEFSC director and is usually selected from a NOAA Fisheries regional science center. Participating councils may appoint representatives of their SSC, Advisory, and other panels as observers to the review workshop.

SEDAR 12 was charged with assessing red grouper (*Epinephelus morio*) in the U.S. waters of the Gulf of Mexico. This task was accomplished through workshops held between July 2006 and February 2007.

2. Red Grouper Management Overview

2.1. Fishery Management Plan and Amendments

The following summary describes only those management actions that likely affect grouper fisheries and harvest. For a complete history of management of the entire reef fish fishery, please contact the Gulf of Mexico Fishery Management Council.

Original GMFMC FMP

The Reef Fish FMP, including an EIS, was implemented in November 1984. Regulations were designed to rebuild declining reef fish stocks and included prohibitions on the use of fish traps, roller trawls, and powerhead-equipped spear guns within an inshore stressed area and direction to NMFS to develop data reporting requirements in the reef fish fishery.

GMFMC Amendments affecting red grouper

Amendment 1 (EA/RIR/IRFA), to the Reef Fish FMP, implemented in 1990, set objectives to stabilize long-term population levels of all reef fish species by establishing a survival rate of biomass into the stock of spawning age fish to achieve at least 20 percent spawning stock biomass-per-recruit (SSBR) by January 1, 2000. Among the grouper management measures implemented were:
Set a 20-inch total length minimum size limit on red, Nassau, yellowfin, black, and gag grouper;
Set a 50-inch total length minimum size limit on jewfish (goliath grouper);
Set a five-grouper recreational daily bag limit;
Set an 11.0 MP commercial quota for grouper, with the commercial quota divided into a 9.2 MP shallow-water grouper (SWG) quota and a 1.8 MP deep-water grouper (DWG) quota. Shallow-water grouper were defined as black grouper, gag, red grouper, Nassau grouper, yellowfin grouper, yellowmouth grouper, rock hind, red hind, speckled hind, and scamp (until the SWG quota was filled). Deep-water grouper were defined as misty grouper, snowy grouper, yellowedge grouper, warsaw grouper, and scamp once the SWG quota was filled. Jewfish (goliath grouper) was not included in the quotas;
Allowed a two-day possession limit for charter vessels and headboats on trips that extend beyond 24 hours, provided the vessel has two licensed operators aboard as required by the U.S. Coast Guard, and each passenger can provide a receipt to verify the length of the trip. All other fishermen fishing under a bag limit were limited to a single day possession limit;
Established a framework procedure for specification of TAC to allow for annual management changes;
Established a longline and buoy gear boundary at approximately the 50-fathom depth contour west of Cape San Blas, Florida, and the 20-fathom depth contour east of Cape San Blas, inshore of which the directed harvest of reef fish with longlines and buoy gear was prohibited, and the retention of reef fish captured incidentally in other longline operations (e.g., sharks) was limited to the recreational daily bag limit. Subsequent

changes to the longline/buoy boundary could be made through the framework procedure for specification of TAC;

Limited trawl vessels (other than vessels operating in the unsorted groundfish fishery) to the recreational size and daily bag limits of reef fish;

Established fish trap permits, allowing up to a maximum of 100 fish traps per permit holder;

Prohibited the use of entangling nets for directed harvest of reef fish. Retention of reef fish caught in entangling nets for other fisheries was limited to the recreational daily bag limit;

Established the fishing year to be January 1 through December 31;

Extended the stressed area to the entire Gulf coast; and

Established a commercial reef fish vessel permit.

Amendment 3 (EA/RIR/IRFA), implemented in July 1991, provided additional flexibility in the annual framework procedure for specifying TAC by allowing the target date for rebuilding an overfished stock to be changed. It revised the FMP's primary objective from a 20 percent SSBR target to a 20 percent spawning potential ratio (SPR). The amendment also transferred speckled hind from the SWG quota category to the DWG quota category.

Amendment 4 (EA/RIR/IRFA), implemented in May 1992, established a moratorium on the issuance of new commercial reef fish permits for a maximum period of three years. Amendment 4 also changed the time of year TAC is specified from April to August and included additional species in the reef fish management unit.

Amendment 5 (SEIS/RIR/IEFA), implemented in February 1994, established restrictions on the use of fish traps, created a special management zone (SMZ) with gear restrictions off the Alabama coast, created a framework procedure for establishing future SMZs, required that all finfish except for oceanic migratory species be landed with head and fins attached, and closed the region of Riley's Hump (near Dry Tortugas, Florida) to all fishing during May and June to protect mutton snapper spawning aggregations.

Amendment 9 (EA/RIR/IRFA), implemented in July 1994, provided for collection of red snapper landings and eligibility data from commercial fishermen for the years 1990 through 1992. This amendment also extended the reef fish permit moratorium and red snapper endorsement system through December 31, 1995, in order to continue the existing interim management regime until longer-term measures could be implemented.

Amendment 16B (EA/RIR/IRFA), implemented by NMFS in November 1999 set a recreational daily bag limit of one speckled hind and one warsaw grouper per vessel, with the prohibition on the sale of these species when caught under the bag limit.

Amendment 18A (SEIS/RIR/IRFA) was approved by the Council at the October 2005 Council meeting for submission to the Secretary. This amendment addresses: 1) maximum crew size on charter vessels while commercially fishing, 2) use of reef fish for bait, 3) vessel monitoring systems for commercial reef fish vessels, 4) simultaneous commercial and recreational harvest on a vessel, 5) changes to the TAC framework procedure, and 6) sea turtle/smalltooth sawfish bycatch mortality measures.

Amendment 19 (EA/RIR/IRFA), also known as the Generic Amendment Addressing the Establishment of the Tortugas Marine Reserves, was implemented on August 19, 2002. This amendment establishes two marine reserves off the Dry Tortugas where fishing for any species and anchoring by fishing vessels is prohibited.

Amendment 20 (EA/RIR/IRFA), implemented July 2003, established a three-year moratorium on the issuance of charter and headboat vessel permits in the recreational for-hire reef fish and coastal migratory pelagic fisheries in the Gulf of Mexico EEZ.

Amendment 21 (EA, RIR, IRFA), implemented in June 2004, continued the Steamboat Lumps and Madison-Swanson reserves for an additional six years, until June 2010. In combination with the initial four-year period (June 2000 - June 2004), this allowed a total of ten years in which to evaluate the effects of these reserves and to provide protection to a portion of the gag spawning aggregations.

Amendment 22 (SEIS/RIR/IRFA), implemented July 5, 2005, specified bycatch reporting methodologies for the reef fish fishery.

Amendment 24 (EA/RIR/IRFA), implemented on August 17, 2005, replaced the commercial reef fish permit moratorium that was set to expire on December 31, 2005 with a permanent limited access system.

Amendment 25 (SEIS/RIR/IRFA), implemented June 15, 2006, replaced the reef fish for-hire permit moratorium that expires in June 2006 with a permanent limited access system.

Council Regulatory Amendments

A July 1991 regulatory amendment, implemented November 12, 1991, provided a one-time increase in the 1991 quota for SWG from 9.2 MP to 9.9 MP to provide the commercial fishery an opportunity to harvest 0.7 MP that went unharvested in 1990.

A November 1991 regulatory amendment, implemented June 22, 1992, raised the 1992 commercial quota for SWG to 9.8 MP after a red grouper stock assessment indicated that the red grouper SPR was substantially above the Council's minimum target of 20 percent.

An August 1999 regulatory amendment, implemented June 19, 2000, increased the commercial size limit for gag from 20 to 24 inches TL, increased the recreational size limit for gag from 20 to 22 inches TL, prohibited commercial sale of gag, black, and red grouper each year from February 15 to March 15 (during the peak of gag spawning season), and established two marine reserves (Steamboat Lumps and Madison-Swanson) that are closed year-round to fishing for all species under the Council's jurisdiction.

An October 2005 regulatory amendment, implemented January 1, 2006, established a 6,000-pound GW aggregate deep-water and shallow-water grouper trip limit for the commercial grouper fishery starting in 2006.

A July 15, 2006 regulatory amendment established recreational red grouper management measures to replace those implemented by interim rule on august 9, 2005. The recreational red grouper bag limit was set to one fish and captain and crew were not allowed to retain a bag limit of fish while on charter. The Council approved a February 15 to March 15 closure for red grouper, black grouper and gag but this measure was not implemented pending the results of the SEDAR 10 gag grouper assessment.

2.2. Emergency and Interim Rules

Emergency Rule to set Commercial Trip Limits An Emergency rule was implemented on March 3, 2005 to set stepped commercial trip limits. 1) Beginning at 12:01 a.m., local time, March 3, 2005, a 10,000-pound trip limit for deep-water grouper and shallow-water grouper combined is in effect; 2) if on or before August 1 more than 50 percent of either the shallow-water grouper quota (8.8 million pounds) or red grouper quota (5.31 million pounds) is reached, the trip limit will be 7,500 pounds; and 3) if on or before October 1 more than 75 percent of either the shallow-water grouper quota or red grouper quota is reached, the trip limit will be 5, 500 pounds until either the red grouper or shallow water grouper quota is met.

Interim Rule to set Recreational This temporary rule, implemented on August 9, 2005, reduced the red grouper bag limit from 2 fish per person per day to 1 fish per person per day, established a closure of the recreational fishery, from November 1 through December 31, 2005, for all grouper species, and reduced the aggregate bag limit to 3 grouper, combined, per person per day, excluding Goliath grouper and Nassau grouper, but not to exceed 1 speckled hind or 1 warsaw grouper per vessel per day or 1 red grouper per person per day.

An October 31 Court decision increased the aggregate grouper bag limit from three to five fish per person per day and prohibited only red grouper from being harvested during November-December 2005. The red grouper bag limit remained one per person per day after the closure expired.

2.3. Secretarial Amendments

Secretarial Amendment 1, implemented July 15, 2004, established a rebuilding plan, a 5.31 MP GW commercial quota, and a 1.25 MP GW recreational target catch level for red grouper. The amendment also reduced the commercial quota for SWG from 9.35 to 8.8 MP GW and reduced the commercial quota for DWG from 1.35 to 1.02 MP

GW. The recreational bag limit for red grouper was also reduced to two fish per person per day.

2.4. Control Date Notices

Control date notices are used to inform fishermen that a license limitation system or other method of limiting access to a particular fishery or fishing method is under consideration. If a program to limit access is established, anyone not participating in the fishery or using the fishing method by the published control date may be ineligible for initial access to participate in the fishery or to use that fishing method. However, a person who does not receive an initial eligibility may be able to enter the fishery or fishing method after the limited access system is established by transfer of the eligibility from a current participant, provided the limited access system allows such transfer. Publication of a control date does not obligate the Council to use that date as an initial eligibility criteria. A different date could be used, and additional qualification criteria could be established. The announcement of a control date is primarily intended to discourage entry into the fishery or use of a particular gear based on economic speculation during the Council's deliberation on the issues. The following summarizes control dates that have been established for the Reef Fish FMP. A reference to the full Federal Register notice is included with each summary.

November 1, 1989 - Anyone entering the commercial reef fish fishery in the Gulf of Mexico and South Atlantic after November 1, 1989, may not be assured of future access to the reef fish resource if a management regime is developed and implemented that limits the number of participants in the fishery. [54 FR 46755]

November 18, 1998 - The Council is considering whether there is a need to impose additional management measures limiting entry into the recreational-for-hire (i.e., charter vessel and headboat) fisheries for reef fish and coastal migratory pelagic fish in the EEZ of the Gulf of Mexico and, if there is a need, what management measures should be imposed. Possible measures include the establishment of a limited entry program to control participation or effort in the recreational-for-hire fisheries for reef fish and coastal migratory pelagics. [63 FR 64031] (In Amendment 20 to the Reef Fish FMP, a qualifying date of March 29, 2001, was adopted.)

July 12, 2000 - The Council is considering whether there is a need to limit participation by gear type in the commercial reef fish fisheries in the exclusive economic zone (EEZ) of the Gulf of Mexico and, if there is a need, what management measures should be imposed to accomplish this. Possible measures include modifications to the existing limited entry program to control fishery participation, or effort, based on gear type, such as a requirement for a gear endorsement on the commercial reef fish vessel permit for the appropriate gear. Gear types which may be included are longlines, buoy gear, handlines, rod-and-reel, bandit gear, spear fishing gear, and powerheads used with spears. [65 FR 42978]

November 16, 2004 Should the GMFMC take action to further restrict participation and effort in the grouper fishery, they may use October 15, 2004, as a possible control date regarding the eligibility of catch histories. Consideration of a control date does not commit the GMFMC or NOAA Fisheries to any particular management regime or criteria for eligibility in the commercial grouper fishery. The GMFMC may or may not use this control date as part of the qualifying criteria for an IFQ or other management program for the Gulf of Mexico grouper fishery. Fishermen are not guaranteed future participation in a fishery or after the control date under consideration.

2.5. Management Program Specifications

Table 2.5.1. General Management Information

Species	Red Grouper, *Epinephelus morio*
Management Unit	Gulf of Mexico
Management Unit Definition	All U. S. federal waters in the Gulf of Mexico between the States territorial waters and the 200 mile seaward boundary of the EEZ.
Management Entity	Gulf of Mexico Fishery Management Council
Management Contact	Frank S. Kennedy
Current stock exploitation status	Overfishing (2002 stock assessment)
Current stock biomass status	Not overfished (2002 stock assessment)

Table 2.5.2. Current management criteria

Criteria	Current Definition	Current Value
MSST	$(1-M)SS_{MSY}$ (M=0.2)	672 mt female gonad weight
MFMT	F_{MSY}	0.306
MSY	Yield at F_{MSY}	7.56 mp gw
OY	Yield at $0.75*F_{MSY}$	7.385 mp gw
F_{OY}	$0.75*F_{MSY}$	0.2295
M	0.2	0.2
Probability value for evaluating status		Default 50%

NOTE: mp gw = million pounds gutted weight

Table 2.5.3. Stock Rebuilding Information

Rebuilding Parameter	Value
Rebuilding Plan Year 1	2003
Generation Time (Years)	Not Defined
Rebuilding Time (Years)	10 years
Rebuilt Target Date	2012
Time to rebuild @ F=0 (Years)	2 – 4 years

Specific Rebuilding Schedule: (provide levels of exploitation or landings specified in the rebuilding plan)

Secretarial Amendment 1 established an Annual ABC [TAC] during the first three year interval of the rebuilding plan (2003 – 2005) of 6.56 million pounds gutted weight split 81 percent commercial and 19 percent recreational. The ABC for subsequent intervals [three years] will be set following a future stock assessment. Table 5.1 of Secretarial Amendment details the rebuilding schedule and lists the scheduled increases to ABC levels. ABCs are based on annual yields at a constant F trajectory, with estimated annual yields averaged over each three year step.

Summarized rebuilding schedule:

PERIOD	ABC (million gutted pounds)
2003-2005	6.56
2006-2008	7.23
2009-2011	7.33

In 2005 the GMFMC chose to not increase the TAC as scheduled for 2006-2008 until the SEDAR 12 assessment is completed. Therefore, the TAC will remain at 6.56 mp gw until further GMFMC action.

In 2005 the Council approved Regulatory Amendments to reduce recreational landing by 33% (one fish bag limit, no bag limit allowed for Captain and crew, 2/15 – 3/15 season closure) and a 6,000 pound trip limit to extend the commercial fishing season. Through an Interim Rule, recreational harvest reductions (1 fish bag limit and a November – December closure) took effect in August, 2005 and the recreational Regulatory Amendment is scheduled to become effective by July, 2006; the Regulatory Amendment for the commercial trip limit took effect in January, 2006.

Table 2.5.4. Stock projection information.

Projection Parameter	Value
First Year of Management	2008
Projection Criteria during interim years should be based on (e.g., exploitation or harvest)	Exploitation (constant F)
Projection criteria values for interim years should be determined from (e.g., terminal year, avg. of X years)	3 year average

Secretarial Amendment 1 established landings levels based on a constant F projection averaged for three-year intervals. Interim year projections for the recreational fishery from 2006 – 2008 should be based on a constant F projection using the previous three years average F value. However, the commercial fishery should be restricted to no more than 5.31 mp gw per year if the constant F projections suggest that the commercial fishery would exceed that amount. Preliminary 2006 landings should be used to adjust the interim year projections if possible. Commercial quota monitoring for 2006 suggests that the 5.31 mp gw may not be met.

Table 2.5.5. Quota Calculation Details

Current Red Grouper Quota Value	5.31 mp gw
Current Other Shallow-water Grouper Allocation Value	3.49 mp gw
Current Total Shallow-water Grouper Quota (sum of above)	8.80 mp gw
Next Scheduled Quota Change	2008
Annual or averaged quota ?	Averaged
If averaged, number of years to average	3

The commercial shallow water grouper (SWG) fishery has a 5.31 million pound, gutted weight, red grouper quota within an 8.8 million pound, gutted weight, quota applied to the entire shallow water grouper complex. Red grouper is the only species in the SWG complex with an individual quota allocation.

The commercial red grouper quota represents the proportion of total red grouper harvest landed by the commercial sector during 1999-2001 (calculated as 81% in Secretarial Amendment 1) multiplied by the red grouper ABC. The red grouper ABC is based on projected annual yields at a constant F trajectory, averaged over three-year steps.

The remainder of the shallow-water grouper quota represents the previous shallow-water grouper quota in gutted weight minus average annual commercial harvest of red grouper in gutted weight during 1999-2001. In Secretarial Amendment 1 this was calculated as 9.35 – 5.86 = 3.49 mp gutted weight. Based on the revised landings data in Turner (2006), this would now be 9.35 – 5.94 = 3.41 mp gutted weight.

The 2002 assessment included mortality of red grouper associated with bycatch at 33% for the commercial fishery and 10% for the recreational fishery; however, estimates of MSY and OY did not separate those values into expected landings and losses due to bycatch mortality. The RFSAP recommended ABC ranges based on a constant F_{MSY} but did not separate allowable landings and bycatch mortality. Likewise, Secretarial Amendment 1 established landings quota for each three-year period based on the yield projections from the RFSAP report (Table 4) which includes bycatch; thus, the quota apparently includes bycatch mortality. The 1999 stock assessment indicated that commercial release mortality estimates for longline could be as high as 90 percent but the RFSAP recommended using 33% for all commercial gears. The recreational release mortality rate of 10% is estimated from Burns and Wilson 1996.

2.6. Management and Regulatory Timeline

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

Table 2.6.1 Regulatory History of the Recreational Fishery

Date or Year.	Source	ABC or TAC	Size Limits	Bag Limits	Season Closures	Area Closures	Gear Prohibitions
11/84–8/85	FMP		None	None	None	None	None
8/85-90	Florida		18 in.				
1990–2/94	Amend 1		20 in.	5			
2/94-6/00	Amend 5		20 in.	5		Riley's Hump Closed May-June,	
6/00-8/02	Reg. Amend		20 in.	5		Added Steamboat & Madison-Swanson closed all year	
8/02-7/04	Amend 19		20 in.	5		Added Dry Tortugas closed all year	
7/04-8/05	Sec. Amend 1	1.25 mp gw	20 in.	2 fish within 5 fish aggregate		Continued	
8/05-7/06	Interim Rule	1.25 mp gw	20 in.	1 fish within 5 fish aggregate		Continued	
7/06-?	Reg. Amend	1.25 mp gw	20 in.	1 fish within 5 fish aggregate and no Capt or Crew bag while under charter	2/15-3/15 Pending	Continued	

Table 2.6.2 Regulatory History of the Commercial Fishery

Date or Year.	Source	ABC	Size Limits	Trip Limits	Quota	Season Closure	Area Closure	Gear Prohibition
11/84–8/85	FMP		None	None	None			
1990–11/91	Amend 1		20 in.	None	9.2 mp ww SWG			LL & traps >20f
11/90-12/90	Reg. Amend		20 in.	None	9.2 mp ww SWG		Quota closed 11/8/90	Cont.
11/91-12/91	Reg. Amend		20 in.	None	9.9 mp ww SWG			Cont.
6/92-2/94	Reg. Amend		20 in.	None	9.8 mp ww SWG			Cont.
2/94-6/00	Amend 5		20 in.	None	9.8 mp ww SWG		Riley's Hump Closed May-June,	Cont.
6/00-8/02	Reg. Amend		20 in.	None	9.8 mp ww SWG	Closed 2/15-3/15 to sale of red, gag and black grouper	Added Steamboat & Madison-Swanson closed all year	Cont.
8/02-7/04	Amend 19		20 in.	None	9.8 mp ww SWG	Cont.	Added Dry Tortugas closed all year	Cont.
7/04-3/05	Sec. Amend 1	6.56 mp gw	20 in.	None	5.31 mp gw red grouper	Cont.	Cont.	Cont.
3/05-1/06	Emergency Rule	6.56 mp gw	20 in.	10k@50%/7.5 k@75%/5.5k	5.31 mp gw red grouper	Cont.	Cont.	Cont.
1/06-?	Reg. Amend	6.56 mp gw	20 in.	6,000 pounds	5.31 mp gw red grouper	Cont.	Cont.	Cont.

Table 2.6.3 Regulatory History of commercial Quota Management

Amendment 1, implemented on February 21, 1990, set an 11.0 MP commercial quota for grouper, with the commercial quota divided into a 9.2 MP shallow-water grouper (SWG) quota and a 1.8 MP deep-water grouper (DWG) quota. Shallow-water grouper were defined as black grouper, gag, red grouper, Nassau grouper, yellowfin grouper, yellowmouth grouper, rock hind, red hind, speckled hind, and scamp (until the SWG quota was filled). Deep-water grouper were defined as misty grouper, snowy grouper, yellowedge grouper, warsaw grouper, and scamp once the SWG quota was filled. Jewfish (goliath grouper) was not included in the quotas

Secretarial Amendment 1 to the Reef Fish FMP, implemented on July 15, 2005, established a 5.31 million pound gutted weight red grouper commercial quota, reduced the commercial shallow water grouper (SWG) quota to 8.8 million pounds gutted weight (red grouper is part of the SWG) and stipulated that the SWG fishery would close if either the red grouper or the SWG quota was met. The Amendment also reduced the deep water grouper (DWG) quota to 1.02 million pounds gutted weight and set a 0.44 mp gw tilefish quota. Subsequent to the implementation of this amendment, regulatory closures were as follows:

Date or Year.	Source		Quota			Quota Closures		
		Red Grouper	SWG	DWG	Tilefish	SWG	DWG	Tilefish
1990	Amend 1	None	9.2 mp ww	1.8 mp ww	None	11/08/90	None	None
11/91-12/91	Reg. Amend	None	9.9 mp ww	Cont	None	None	None	None
6/92-2/94	Reg. Amend	None	9.8 mp ww	Cont	None	None	None	None
7/04	Sec Amend 1	5.31 mp gw	8.8 mp gw	1.02 mp gw	0.44 mp gw	11/15/04	7/15/04	
2005		5.31 mp gw	8.8 mp gw	1.02 mp gw	0.44 mp gw	10/10/05	6/23/05	11/21/05
2006		5.31 mp gw	8.8 mp gw	1.02 mp gw	0.44 mp gw		6/27/06	

3. Assessment History

Pre-SEDAR assessments of Gulf of Mexico resources were typically prepared by scientists of the Southeast Fisheries Science Center and reviewed by the Gulf of Mexico Fishery Management Council (GMFMC) Reef Fish Stock Assessment Panel (RFSAP) and Science and Statistics Committee (SSC). Excerpts from RFSAP reports addressing previous assessments are compiled into a single document for convenience (SEDAR12-RW01). Previous stock assessments referenced below are provided for reference and organized under the SEDAR 12 research document listing as follows: Goodyear and Schirripa, 1991 (SEDAR12-RD04), Goodyear and Schirripa, 1993 (SEDAR12-RD07), Schirripa et al, 1999 (SEDAR12-RD05), and SEFSC, 2001 (SEDAR12-RD02).

The first documented assessment of the Gulf of Mexico stock of red grouper is Goodyear and Schirripa, 1991 (SEFSC cont. MIA-90/91-86). This assessment compiled available life history and fishery data from the 1960's through 1990, evaluated and interpreted trends in data sources, evaluated recent regulatory changes, and estimated mortality through catch curve analysis. Some of the challenges identified included difficulty evaluating SPR for a hermaphroditic species with limited life history research, interpretation of growth models based on competing data sources, estimation of release and natural mortality, inadequate biological sampling of grouper fisheries, a lack of direct age observations from the fisheries, and uncertainties in landings statistics due to incomplete and imprecise reporting.

Published natural mortality estimates evaluated in the 1991 assessment ranged from 0.17 to 0.32; the assessment adopted a natural mortality value of M=0.2 with little justification while acknowledging that it could be excessive given the abundance of older ages in the population.

Discard losses are identified as an increasing challenge to stock productivity. Although the discard mortality rate is uncertain, the high number of discards resulting from recent size limit changes raised concern. The authors suggested that eliminating the minimum size limit could increase yield per recruit for even moderate discard mortality assumptions.

Implementation of an 18" minimum size limit by Florida in 1986 had little perceived impact of commercial fisheries but led to an initial decline in recreational harvest followed by recovery as the fishery moved from near shore state waters to offshore federal (EEZ) waters. Additional regulations implemented in 1990 included an increase in minimum size to 20", a 5 fish recreational creel restriction, and a commercial quota intended to reduce commercial exploitation 20%. Fishery changes attributed to these actions include a 70% decline in recreational harvest numbers, a 20% decline in commercial harvest (exacerbated by premature fishery closure), and notable shifts in harvest length compositions.

Because fishery age samples are lacking, growth models were used to assign catches by length to age classes for use in the catch curve analyses. Two alternative catch-age matrices were developed to address differences in estimated growth rate observed between a study conducted in the mid1960's and another in the late 1980's. It was not known whether the growth disparity was legitimate or simply reflected methodological differences between separate studies, although several hypothesis enabling a change in population growth were proposed.

Upon review of this assessment in October, 1991, the GMFMC RFSAP endorsed status estimates based on recent growth data and biological references based on yield per recruit analyses. Fishing mortality rates were stated as being between F0.1 and Fmax depending on the assumed discard mortality rate. Estimated SPR exceeded the 20% SPR limit then in effect for all discard mortality assumptions.

The next assessment, also prepared by Goodyear and Schirripa, was completed in 1993 with through 1992. Enhancements in this version included inclusion of landings and effort data from the Cuban fleets operating off the west coast of Florida, 1950-1976; development of CPUE indices for several fisheries based on the logbook program introduced in 1990; and development of a VPA analysis. There was no resolution of the growth disparity and only minor improvement in fishery dependent sampling. Growth modeling was again used to develop catches at age. Results of the catch curves and VPA analyses remained quite variable when uncertainties in growth and age assignment were considered, although no notable changes in stock status were suggested by this assessment. The RFSAP reviewed this assessment in August 1993 and accepted the findings.

In 1994 the GMFMC RFSAP reviewed two detailed analyses of the red grouper growth disparity and determined that differences were related to sampling (Goodyear 1994 and undated). This work led to acknowledgement that significant bias is introduced into stock assessments when catch ages are determined from growth models based on data from length-stratified sampling, size-selective gears, or fisheries restricted by minimum sizes. Although it was believed that sampling bias could be addressed, bias introduced by the minimum size could not be removed and therefore the results of previous red grouper assessments were deemed invalid at this time.

Major revisions were included in the next assessment, prepared by Schirripa, Legault, and Ortiz in 1999 including data through 1997. The catch time series was extended, with landings statistics evaluated back to the 1940's and acknowledgement of a fishery back to at least 1880. Recreational landings for 1940-1981 were inferred through regression with population to enable estimation of total harvest removals prior to inception of MRFSS. Additional indices were developed, including headboat CPUE, tag-recapture study CPUE, and two fishery-independent indices provided through SEAMAP beginning in 1992. Growth models were evaluated further and a probabilistic approach for converting catch at length to catch at age was incorporated. Two assessment approaches were considered: a production model and a catch-age model.

Considerable effort was devoted to evaluating growth models and trends in growth rates by comparing newly available capture-recapture growth estimates with those obtained through traditional back-calculation from hard parts. The authors concluded that both approaches were useful in estimating growth parameters and noted that consistency in estimates between the two methods suggested that estimated values were reliable.

Both production models (ASPIC) and forward projection catch-age models (ASAP) were developed to evaluate stock status. Neither of the previous assessment approaches (catch curves and VPA) were updated in this assessment. Ages were determined for the forward projecting model through the Goodyear (1995) probabilistic approach that also enables estimation of discards.

The production model performed reasonably well, but lacked ability to address perceived changes in fishery characteristics (e.g., catchability and selectivity) over time and did not allow inclusion of available information on size or age of capture. The catch-age model provided greater flexibility and incorporated more available data, but was highly parameterized and sensitive to steepness and data series duration. Both models suggested that the stock was overfished and overfishing was occurring in 1997. Both models indicated that fishing mortality was increasing while both SSB and recruitment were decreasing, and that peak abundance occurred sometime during the 1940's or 1950's.

The RFSAP reviewed the assessment in September 1999 and accepted the methods and results. Management recommendations were based on the ASAP model incorporating the long time series (1940-1997). The stock was considered overfished and overfishing was occurring in the terminal year (1997).

The sequence of events becomes less clear after this point. The December 2000 RFSAP report indicates that the RFSAP questioned aspects of the assessment following the September 1999 meeting noted above, setting off a chain of analyses and reviews extending over several years. In response to concerns about the assessment, NMFS/SEFSC prepared additional analyses that were presented to the RFSAP in August 2000. This led to further requests to conduct an extensive suite of additional analyses evaluating a range of alternative assumptions, culminating in a RFSAP meeting in December 2000 to review the results of the August recommendations. The RFSAP based its December 2000 recommendations on runs configured with a short landings time series, updated 1998-99 harvest data, a 33% release mortality rate for the longline fishery, longline discards estimated through the probabilistic approach, and steepness values of 0.7 and 0.8. There was no change in the estimated stock status despite these efforts. According to estimates from the chose configuration, the stock was both overfished and overfishing in the terminal year 1997 .

The basic configuration agreed to by the RFSAP in December 2000 was updated by NMFS/SEFSC in 2002, including data through 2001. New data sources included additional age and growth information provided by a 1992-2001 life history study and subsequent improved catch-age allocations, and updated fecundity information based on 1992-2001 sampling.

The RFSAP reviewed the updated assessment in September, 2002. The panel based management advice on assessment configurations including the newly available life history information. Steepness values of 0.7 and 0.8 were used to develop a range for management parameter estimates, with a caveat that the 0.8 value was well above both the estimated value (0.68) and expected values for species of similar life history. It was believed at this time that the stock was showing some signs of recovery, as the stock was no longer overfished and runs based on steepness 0.8 suggesting that overfishing was no longer occurring. The panel noted that increases in catch in the terminal years may be the result of recent strong year classes while acknowledging a lack of information available at the time to evaluate such a hypothesis. The panel also commented that recent increases in abundance and thus biomass appeared the result of recent increased recruitment.

References

SEFSC. 2002. Draft status of red grouper in United States waters of the Gulf of Mexico during 1986 - 2001. Southeast Fisheries Science Center, Miami, FL. Sustainable Fisheries Division contribution SFD 01/02-175rev.

Goodyear, C. P. and M. J. Schirripa. 1991. The red grouper fishery of the Gulf of Mexico. Southeast Fisheries Science Center, Miami, FL. Miami Laboratory contribution MIA 90/91-86. 80 pp.

Goodyear, C. P. and M. J. Schirripa. 1993. The red grouper fishery of the Gulf of Mexico. Southeast Fisheries Science Center, Miami, FL. Miami Laboratory contribution MIA 92/93-75. 122 pp.

Goodyear, C. P. 1994. Biological reference points for red grouper: uncertainty about growth. Southeast Fisheries Science Center, Miami, FL. Miami Laboratory contribution MIA 93/94-60. 26 pp.

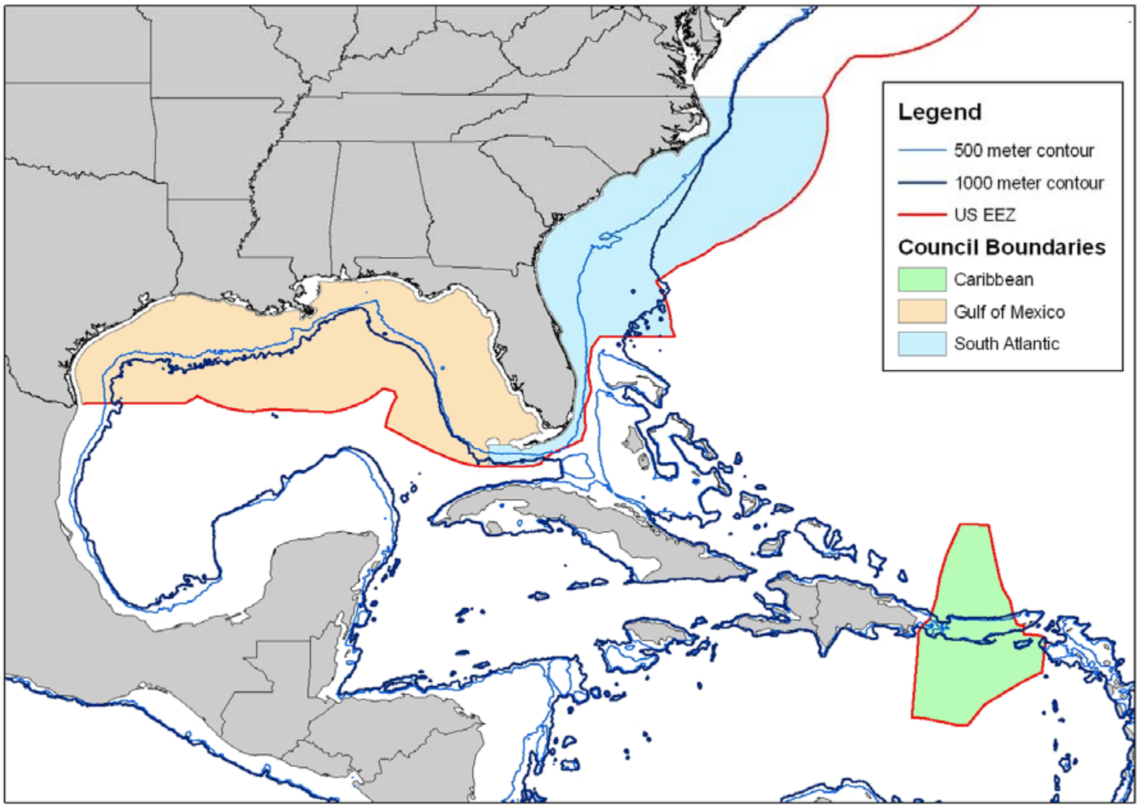
Goodyear C. P. (no date). Red grouper mean size at age: an evaluation of sampling strategies using simulated data. Unpublished manuscript, Southeast Fisheries Science Center, Miami, FL. 8 pp.

SEDAR. 2007. Excerpts from Gulf of Mexico Fishery Management Council Reef Fish Stock Assessment Panel reports addressing red grouper, 1999-2002. SEDAR, Charleston, SC. SEDAR12-RW01.

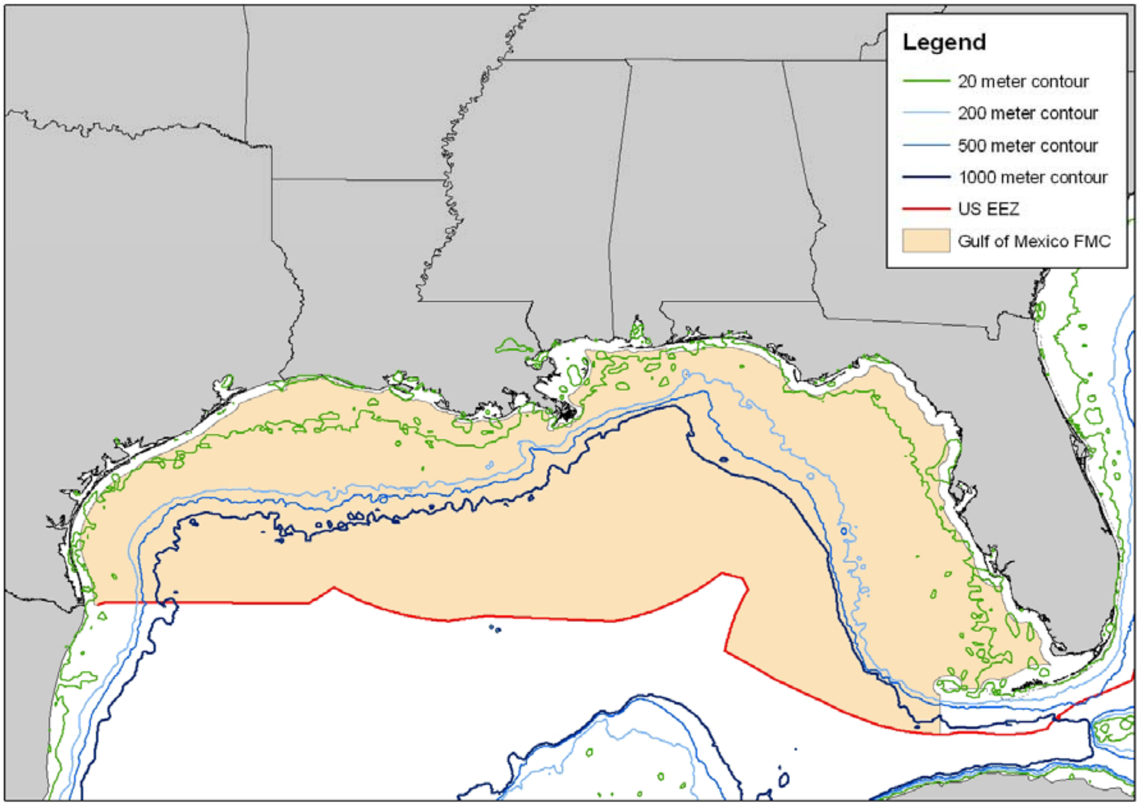
Schirripa, M. J., C. M. Legault, and M. Ortiz. 1999. The red grouper fishery of the Gulf of Mexico: assessment 3.0. Southeast Fisheries Science Center, Miami, FL. Sustainable Fisheries Division Contribution SFD 98/99-56. 57 pp.

4. Overview Maps

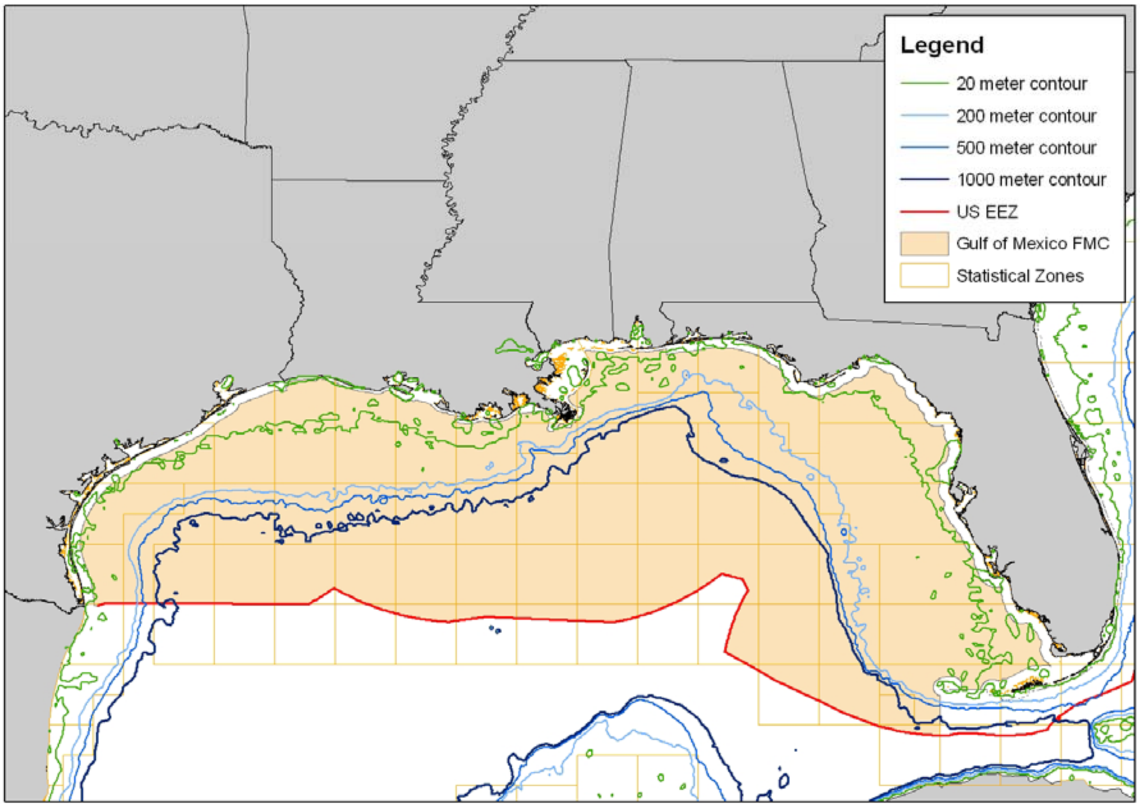
1. Southeastern United States, showing Fishery Management Council boundaries of the EEZ.



2. Gulf of Mexico showing EEZ, Gulf Council boundary, and depth contours.



3. Statistical zones of the Gulf of Mexico.



5. Advisory Report

SEDAR 12 Advisory Report

Gulf of Mexico Red Grouper

Stock Distribution and Identification

This assessment applies to red grouper within US waters of the Gulf of Mexico. The Gulf of Mexico and South Atlantic stocks are divided along the Florida Keys.

Assessment Methods

Three modeling approaches are considered in this assessment: a surplus production model (ASPIC), a forward projection age-structured model (ASAP), and a stochastic stock reduction analysis (SRA). A Virtual Population Analysis (VPA) was consulted to evaluate assumptions and configuration options regarding changes and catchability and selectivity for the age structured model.

The forward projection catch-age model using the ASAP software was chosen for evaluating stock status and providing management advice. The Review Panel recommended ASAP configuration is detailed in the Consensus Summary. The Panel's recommended configuration includes time-varying catchability, adjusted natural mortality scaling, incorporation of the NMFS longline survey, and reduced influence by the derived discard age composition.

Assessment Data Summary

The base assessment includes data from 1986 - 2005. The fishery is divided into four fleets and the population is modeled over ages 1 - 20 with the final age (20) treated as a plus group. Specific data sources included in the ASAP model and the years over which information is available are summarized as follows:

Landings (fleets):
- Commercial longline, 1986- 2005
- Commercial handline, 1986-2005
- Commercial trap, 1986-2005
- Recreational, 1986 - 2005 (MRFSS and headboat combined)

Discards:
- Commercial, by fleet 1990-2005
- Recreational, 1986-2005
- Discards estimated in numbers for both recreational and commercial fleets are converted to weight (gutted pounds) using the estimated age composition and the growth model.

Length & Age Composition:
- The assessment model accepts direct age composition information available from otolith sampling of the fisheries. Otolith sampling is sporadic across years and fisheries between 1986 and 1991. Sampling intensity increases considerably for 1991 and later. All available otolith samples are used for evaluating age composition.
- Discard age composition is provided through an iterative probabilistic modeling approach.

Indices :
- Commercial longline CPUE, 1990-2005

Commercial handline CPUE, 1990-2005
MRFSS recreational CPUE, 1986-2005
Headboat CPUE, 18" size limit, 1986-1990
Headboat CPUE, 20" size limit, 1991-2005
SEAMAP Video, 1993-2005 (years incomplete)
NMFS Longline, 2000-2005 (years incomplete)

Life History:

Natural mortality is set at a base M=0.14. Specific values vary across ages based on a scaled Lorenzen curve.
Reproductive information (maturity, fecundity, and sex ratio) is updated from previous assessments to incorporate results from several recent studies.
Discard mortality rates are updated from previous assessments to incorporate results of recent research. Estimated mortality on discards is 0.4 for the longline fleet and 0.1 for all other components

Catch Trends

Total landings are variable with an overall declining trend during the start of the assessment period, falling from nearly 9 million pounds (mp) in the initial year 1986 to the period low of 4.6 mp in 1998. Total landings then increase sharply, nearing 8 million pounds in 1999 and stabilizing thereafter. Total landings observed between 1999 and the terminal year 2005 averaged 7.5 million pounds which compares favorably to the estimated Optimal Yield (OY) of 7.6 million pounds.

Commercial longline landings gradually increase during the 1986-2005 assessment period. Landings during the late 1980's through early 1990's are more variable than in later years, therefore both the high (4.3 mp in 1993) and the low (2.0 mp in 1990) observed values occur within a few years.

Commercial handline landings decline considerably over the assessment period, falling from 3.74 million pounds in 1990 to less than 1 million pounds in 1998. Handline landings increase by 2000 to the current level around 1.5 million pounds.

Commercial trap landings are considerably lower than either handline or longline, seldom exceeding 1 mp over the assessment period.

Recreational landings including all components are slightly less than total commercial landings. With the exception of the 1995-1997 period when landings were considerably less than average at 0.5 mp, recreational landings vary between 1 and 3 mp.

Fishing Mortality Trends

Annual estimates of instantaneous fishing mortality (F) reported for each fishery, including those for both discard and directed components, are apical or peak values observed across all ages for the given fishery and year. This is analogous to 'fully recruited' fishing mortality.

Total apical fishing mortality for all directed fleets combined is estimated at F=0.18 in 1986 at the start of the analytical period. Fishing mortality increases steadily in the early portion of the series, reaching a peak of F=0.30 in 1993 before falling steadily to F=0.15 in 1998. Fishing mortality increases slightly in 1999 to around F=0.2, although a downward trend since 2000 ends with a terminal estimate of F=0.15 for 2005.

Mortality attributed to the commercial longline fishery increases over the early portion of the assessment period, from a low of F=0.07 in 1986 to a high of F=0.17 in 1993. Longline mortality thereafter declines, falling to F=0.1 in the terminal year (2005). Fishing mortality contributed by the commercial handline fishery exhibits a pattern similar to that of the commercial longline, reaching a peak F=0.1 in 1990 before declining steadily to the terminal estimate of F=0.04. Commercial trap mortality is variable, but generally below F=0.07.

Recreational mortality estimates also peak during the middle of the assessment period, initially rising from F=0.01 in 1986 to the observed peak in 1992 of F=0.15 before falling to the minimum observed F=0.04 in 1997. Mortality increases slightly thereafter, reaching F=0.11 in 2004 and averaging 0.08 during 1998-2005.

Fishing mortality attributed to discards is typically only around 10% of that attributed to landings, with peak values of $F_{DISCARD}$=0.03 (all fleets combined) occurring during 1990-1994.

Stock Abundance and Biomass Trends

Total stock abundance averages 27.6 million fish and varies with little trend between 1986 and 1999. However, abundance jumps sharply in 2000 to 40.5 million fish as the strong 1999 year class enters the estimated population at age 1. Total abundance tapers off gradually thereafter to the terminal estimate of 31.7 million fish for 2005.

Spawning stock is measured as total female gonad weight. Estimated spawning stock gradually improves over the assessment period, from just below 500 metric tons (mt) of eggs in late 1980's to over 700 mt in the last few years which include the observed high of 752 mt of eggs in 2005.

Estimated recruitment at age 1 exhibits two notably strong year classes (1996 and 1999) but little overall trend otherwise. Recruitment over the assessment period averages 9.6 million fish, with peak values of 13 million in 1997 and 22 million in 2000.

Status Determination Criteria

Management benchmark recommendations are based on the Review Panel's chosen model configuration as described here and in the consensus summary.

Status Determination Table

Criteria	Recommended Values[1]	
	Definition	Value
MSST (egg weight)	$(1\text{-}M)SS_{MSY}$	509 mt
MFMT (apical F)	F_{MSY}	0.21
MSY (gutted weight)	Yield at F_{MSY}	7.72 mp
F_{MSY}	F_{MSY}	0.21
OY (gutted weight)	Yield at $0.75*F_{MSY}$	7.6 mp
F_{OY}	$0.75*F_{MSY}$	0.16
M (base)	--	0.14

1. Note that reference points and yield reflect only directed fisheries landings. There is an additional allowance for estimated discards.

Stock Status

The Gulf of Mexico stock of red grouper was not overfished and was not experiencing overfishing in 2005.

The stock is considered recovered based on estimated spawning stock in excess of the MSY level as of January 1, 2005. Current model estimates indicate the stock ceased being overfished in 1992 when the spawning stock exceeded the MSST, and reached recovered status 7 years later in 1999 when the spawning stock exceeded the level associated with MSY. Increases in the spawning stock observed over the last 5 years are largely due to recent strong year classes and therefore represent a trend which may not continue into the future.

Current model estimates indicate the stock has not experienced overfishing since 1994. Exploitation dropped to target levels (F_{OY}) in 1997 and 1998, then climbed above F_{OY} during most years thereafter. Exploitation in 2005 is 97% of F_{OY}.

Stock status determinations relative to current estimates for benchmark values are summarized in the *Status Summary Table* below.

Status Summary Table

Criteria	Value
SS_{MSY} (MT eggs)	591
SS_{2005} (MT eggs)	752
SS_{2005}/SS_{MSY}	1.27
SS_{2005}/MSST	1.48
F_{MSY} (MFMT)	0.21
F_{OY}	0.16
F_{2005}	0.16
F_{2005}/MFMT	0.73
F_{2005}/F_{OY}	0.97

Projections

Short term projections (2006 - 2015) were prepared to evaluate a range of future fishing mortality (F_{MSY}, F_{OY}, $F_{current}$) and harvest strategies (OY, current harvest limit). Projections were prepared assuming management changes could take place in 2008, selectivity remains constant for all fisheries, and discard rates remain constant for all fisheries. Future recruitment is estimated from the average estimated over the assessment period.

Projection results indicate spawning stock will remain above SS_{MSY} and fluctuate around its current level through at least 2015 if fishing mortality and total removals are held at current conditions which are consistent with management at the stated optimal yield. Spawning stock will decline to SS_{MSY} levels by 2015 if mortality increases to F_{MSY}. Fishing mortality will stabilize near the current level, which is just below F_{OY}, if landings are maintained at either current or OY levels.

Allowable Biological Catch

Because overfishing is not occurring and estimated spawning stock exceeds the MSY spawning stock level, Allowable Biological Catch (ABC) levels are recommended based on exploitation at F_{OY}. Point estimates of ABC exceed OY for the near future due to high current stock abundance caused in part by the strong 1999 cohort. The long-term sustainability of catch limits in excess of predicted OY will depend on how future recruitment compares to the long term average used in the projection analyses.

Annual deterministic ABC for landings only, including 80% confidence intervals. Values are millions of gutted pounds.

YEAR	ABC (landings)	Lower	Upper
2008	7.97	7.97	7.97
2009	7.94	7.88	8.03
2010	7.89	7.68	8.26
2011	7.84	7.43	8.52
2012	7.79	7.22	8.84
2013	7.75	7.09	9.07
2014	7.72	7.03	9.21
2015	7.69	7.02	9.35

Uncertainty

Uncertainty is evaluated though confidence intervals calculated on key model output, sensitivity analyses used to examine configuration alternatives, and retrospective analyses used to examine terminal year effects. The 95% confidence interval on current stock status is approximately +- 14% of the mean estimate, although this estimate of the confidence interval does not include all potential factors that could contribute to the uncertainty. The RP finds that the level of natural mortality and the degree of drift in fishery catchability are influential aspects of the model configuration and appropriate sensitivity analyses to alternative levels of these configuration factors have been provided. Retrospective bias is most noticeable in estimates of exploitation and recruitment. A likely source of the retrospective bias is recruitment uncertainty during each cohort's youngest ages that is attributed to a lack of independent survey information prior to age 3. The cause of apparent retrospective bias in fishing mortality is more difficult to ascertain, but one likely factor is the relatively short time series of adequate age sampling.

The RP finds that the degree of uncertainty in the red grouper stock assessment is not so high as to interfere with the use of these results as the technical basis for management of this stock. The current management plan sets the target level of the fishery at 75% of the best estimate of the fishing mortality limit. Such a buffer is consistent with the degree of uncertainty in this assessment.

Special Comments

The Review Panel finds that the red grouper assessment in 2006 is a significant improvement over the assessment conducted in 2002 and addresses certain deficiencies directed at previous assessments. In particular, the addition of longer time series of indices improved estimates of long term trends, while direct age composition data has greatly improved estimates of year-to-year changes in recruitment and allowed modification of natural mortality levels. Improved age composition data and additional years of analysis enable the assessment to track recent recruitments, notably the large recruitment from the 1999 year class. However, lack of a pre-recruit survey prevents detection of recruitment fluctuations past 2002.

Some revision of historical stock status estimates has occurred, and the RP finds that the magnitude of these changes is not unexpected given the degree of uncertainty in the estimates. Management measures and other factors that influence the level of fishing activity, and therefore fishing mortality (F), have resulted in recent levels of F that are quite close to the F level that would produce optimum yield (OY). This conclusion is derived from model results that are clearly supported by the stable or upward trends in the fishery CPUE and survey indicator data, and in the fishery age composition data which indicate a broad age distribution with an increasing number of older fish appearing in the fishery and continued occurrence of new recruits. Management measures have successfully maintained observed landings over the last 7 years near the optimal yield level. Recent strong recruitment events, such as the 1999 year class, contribute significantly to the recent increase in spawning stock measures.

Table 1. Landings and discards[1] by sector in gutted pounds, 1986 – 2005.

	Landings			Dead Discards[1]			Removals (Landings + Dead Discards)		
YEAR	Commercial	Recreational	Total Landings	Commercial	Recreational	Total Dead Discard	Total Commercial	Total Recreational	Total Removals
1986	6,312,986	2,400,380	8,713,366	0	20,657	20,657	6,312,986	2,421,037	8,734,023
1987	6,717,890	1,464,710	8,182,600	0	19,021	19,021	6,717,890	1,483,731	8,201,621
1988	4,742,496	2,476,070	7,218,566	0	34,758	34,758	4,742,496	2,510,828	7,253,324
1989	7,367,911	2,761,150	10,129,061	0	81,650	81,650	7,367,911	2,842,800	10,210,711
1990	4,809,282	1,131,710	5,940,992	733,671	228,556	962,227	5,542,953	1,360,266	6,903,219
1991	5,094,501	1,775,110	6,869,611	1,155,185	407,354	1,562,539	6,249,686	2,182,464	8,432,150
1992	4,463,277	2,658,180	7,121,457	721,264	356,598	1,077,862	5,184,541	3,014,778	8,199,319
1993	6,379,626	2,091,160	8,470,786	732,983	234,183	967,166	7,112,609	2,325,343	9,437,952
1994	4,902,862	1,808,240	6,711,102	446,280	224,934	671,214	5,349,142	2,033,174	7,382,316
1995	4,746,140	1,862,570	6,608,710	601,308	225,097	826,405	5,347,448	2,087,667	7,435,115
1996	4,454,146	893,755	5,347,901	566,243	159,758	726,001	5,020,389	1,053,513	6,073,902
1997	4,848,486	562,328	5,410,814	623,516	149,181	772,697	5,472,002	711,509	6,183,511
1998	3,948,566	643,058	4,591,624	543,057	208,428	751,485	4,491,623	851,486	5,343,109
1999	5,974,706	1,152,810	7,127,516	734,532	283,487	1,018,019	6,709,238	1,436,297	8,145,535
2000	5,838,300	2,107,730	7,946,030	621,851	300,042	921,893	6,460,151	2,407,772	8,867,923
2001	5,964,506	1,327,770	7,292,276	756,182	223,726	979,908	6,720,688	1,551,496	8,272,184
2002	5,907,248	1,611,110	7,518,358	726,561	260,670	987,231	6,633,809	1,871,780	8,505,589
2003	4,937,970	1,275,830	6,213,800	623,068	283,721	906,789	5,561,038	1,559,551	7,120,589
2004	5,749,039	3,000,140	8,749,179	812,431	421,755	1,234,186	6,561,470	3,421,895	9,983,365
2005	5,410,594	1,630,140	7,040,734	894,328	243,491	1,137,819	6,304,922	1,873,631	8,178,553

1. Information on the size of discards from the various fisheries is not available; the amounts presented here are based on assumptions about the age composition (as used in the assessment) and their weight at age.

Table 2. Estimated total annual fishing mortality attributed to both landings and discard components with stock status evaluations relative to MFMT and F_{OY}.

	APICAL F[1]		Relative Fishing Mortality[2] (Landings)	
YEAR	LANDINGS	DISCARD	F/Fmsy	F/Foy
1986	0.18	0.01	0.84	1.13
1987	0.19	0.01	0.87	1.16
1988	0.16	0.01	0.76	1.02
1989	0.23	0.01	1.06	1.41
1990	0.20	0.03	0.95	1.27
1991	0.23	0.03	1.09	1.46
1992	0.23	0.03	1.08	1.44
1993	0.27	0.03	1.25	1.67
1994	0.22	0.03	1.02	1.36
1995	0.20	0.02	0.96	1.28
1996	0.16	0.02	0.77	1.03
1997	0.16	0.02	0.74	0.98
1998	0.13	0.02	0.62	0.83
1999	0.18	0.02	0.85	1.13
2000	0.19	0.02	0.90	1.19
2001	0.18	0.02	0.86	1.14
2002	0.18	0.02	0.85	1.14
2003	0.16	0.02	0.73	0.97
2004	0.18	0.02	0.84	1.13
2005	0.16	0.02	0.73	0.97

1. Landings and discard Fs are additive. Apical F reflects the maximum annual value across ages for all fleets combined.
2. Relative fishing mortality used to evaluated stock status is determined based on the landings component.

Table 3. Stock abundance, age-1 recruitment, spawning stock, and spawning stock status.

	Spawning Stock			Abundance (Millions of fish)	
YEAR	SS (Metric Tons[1])	Status SS/MSST	Status SS/SS_{MSY}	Total Stock	Recruitment (Age 1)
1986	506	0.99	0.85	23.11	6.07
1987	485	0.95	0.82	27.73	12.45
1988	473	0.93	0.80	29.91	11.77
1989	476	0.94	0.81	27.98	8.35
1990	475	0.93	0.80	29.60	11.52
1991	500	0.98	0.84	30.22	10.17
1992	531	1.04	0.90	29.13	8.71
1993	549	1.08	0.93	26.32	6.53
1994	550	1.08	0.93	24.99	7.02
1995	567	1.11	0.96	26.14	8.87
1996	561	1.10	0.95	24.91	6.97
1997	568	1.12	0.96	31.23	13.81
1998	582	1.15	0.98	28.71	7.40
1999	618	1.21	1.04	25.83	5.60
2000	639	1.26	1.08	40.57	22.34
2001	626	1.23	1.06	34.78	7.98
2002	660	1.30	1.12	31.85	7.72
2003	700	1.38	1.18	32.02	9.65
2004	734	1.44	1.24	32.49	10.03
2005	752	1.48	1.27	31.70	9.33

1. Spawning stock is measured in mature female gonad weight.

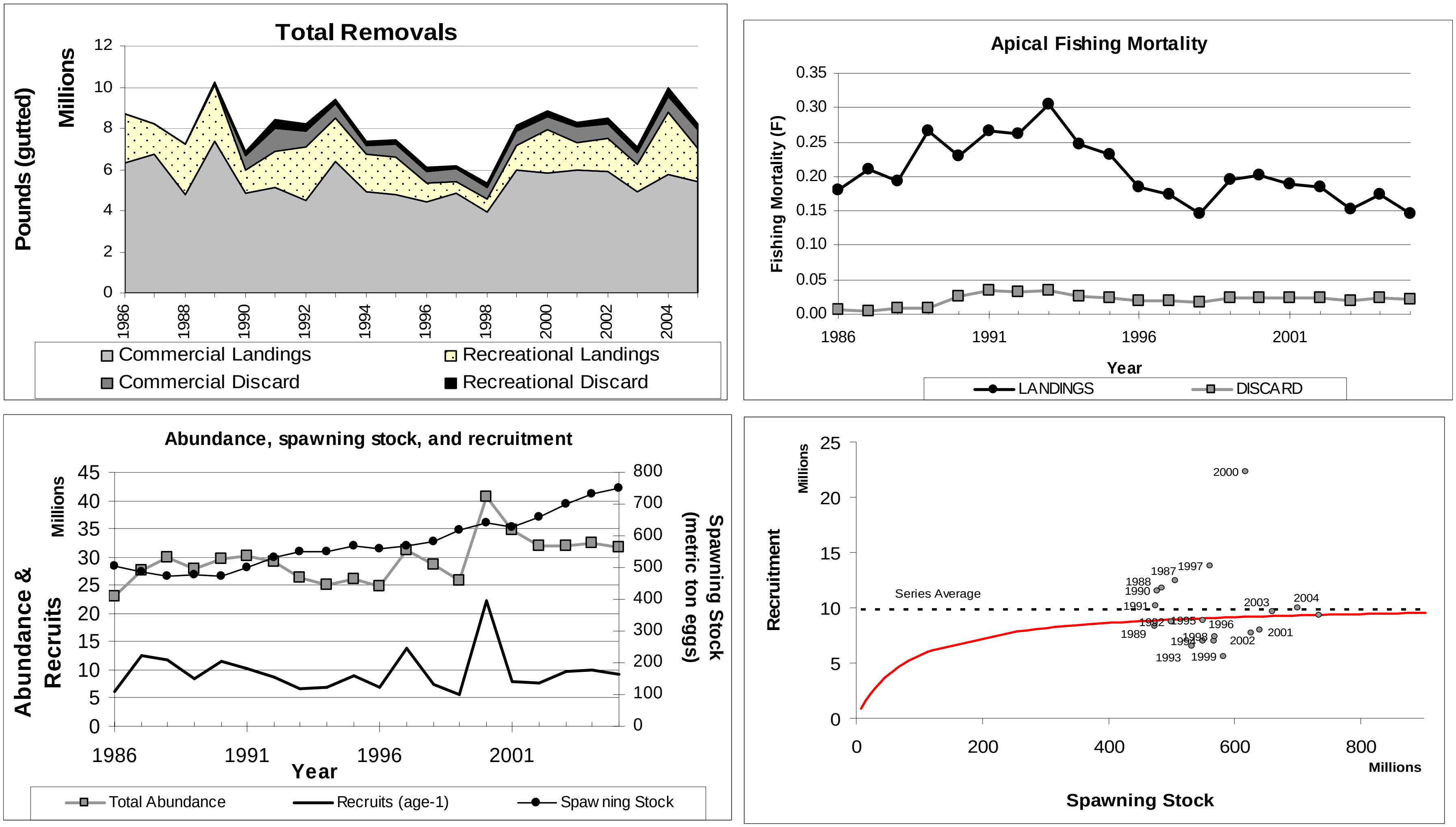


Figure 1. Stock estimates. Total removals in gutted pounds by fishery (upper left); total apical fishing mortality attributed to discard and directed removals (upper right); time series of important population parameter estimates including recruits at age 1, total abundance in numbers, and spawning stock egg weight (lower left); stock recruitment plot showing annual estimates (points) predicted relationship (solid line) and series average (dashed line) (lower right).

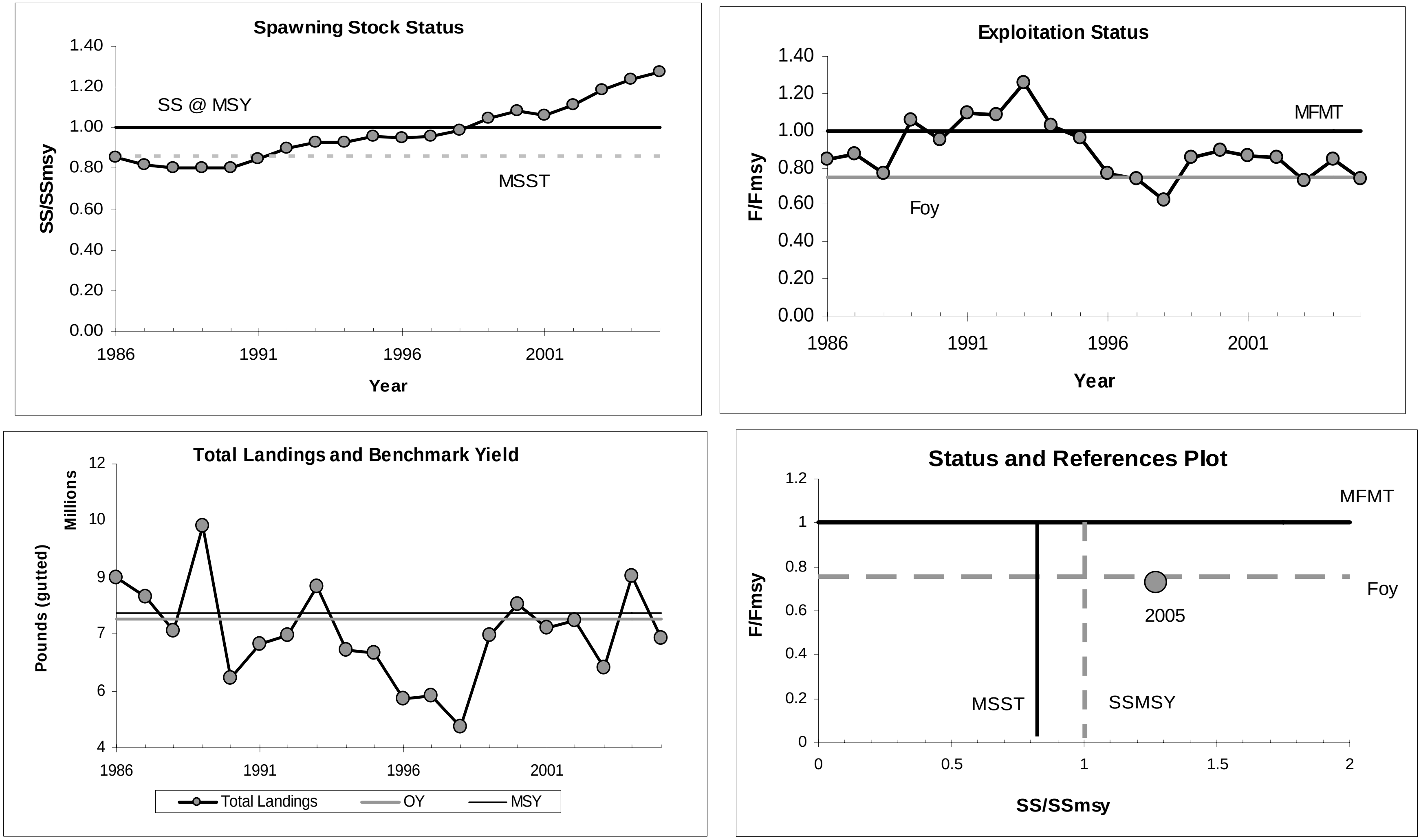


Figure 2. Population management benchmarks and status. Spawning stock relative to MSY level with reference lines for MSST and MSY (stock recovery)(upper left); exploitation compared to target and limit exploitation levels (upper right); phase plot comparing current status and management reference levels (lower right); Total landings compared to estimated benchmark landings (lower left).

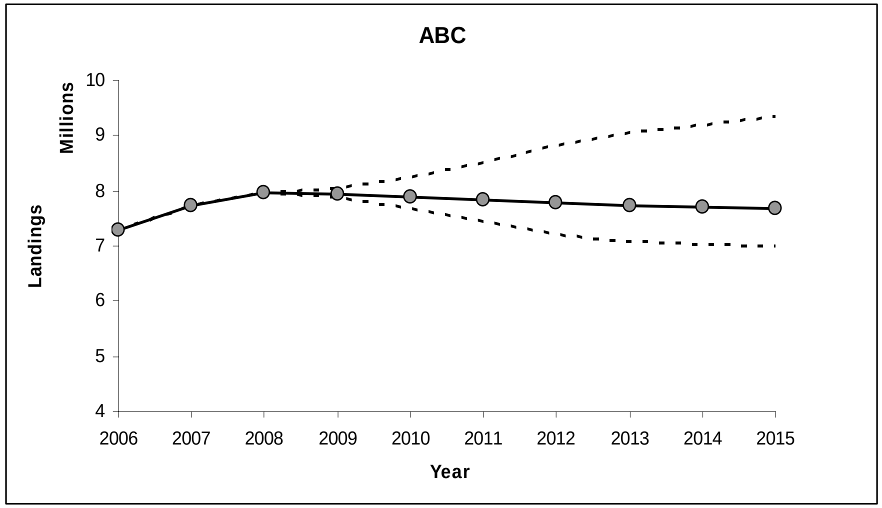


Figure 3. Estimated future landings (ABC) based on exploitation at F_{OY} including 80% confidence intervals based on recruitment deviations.

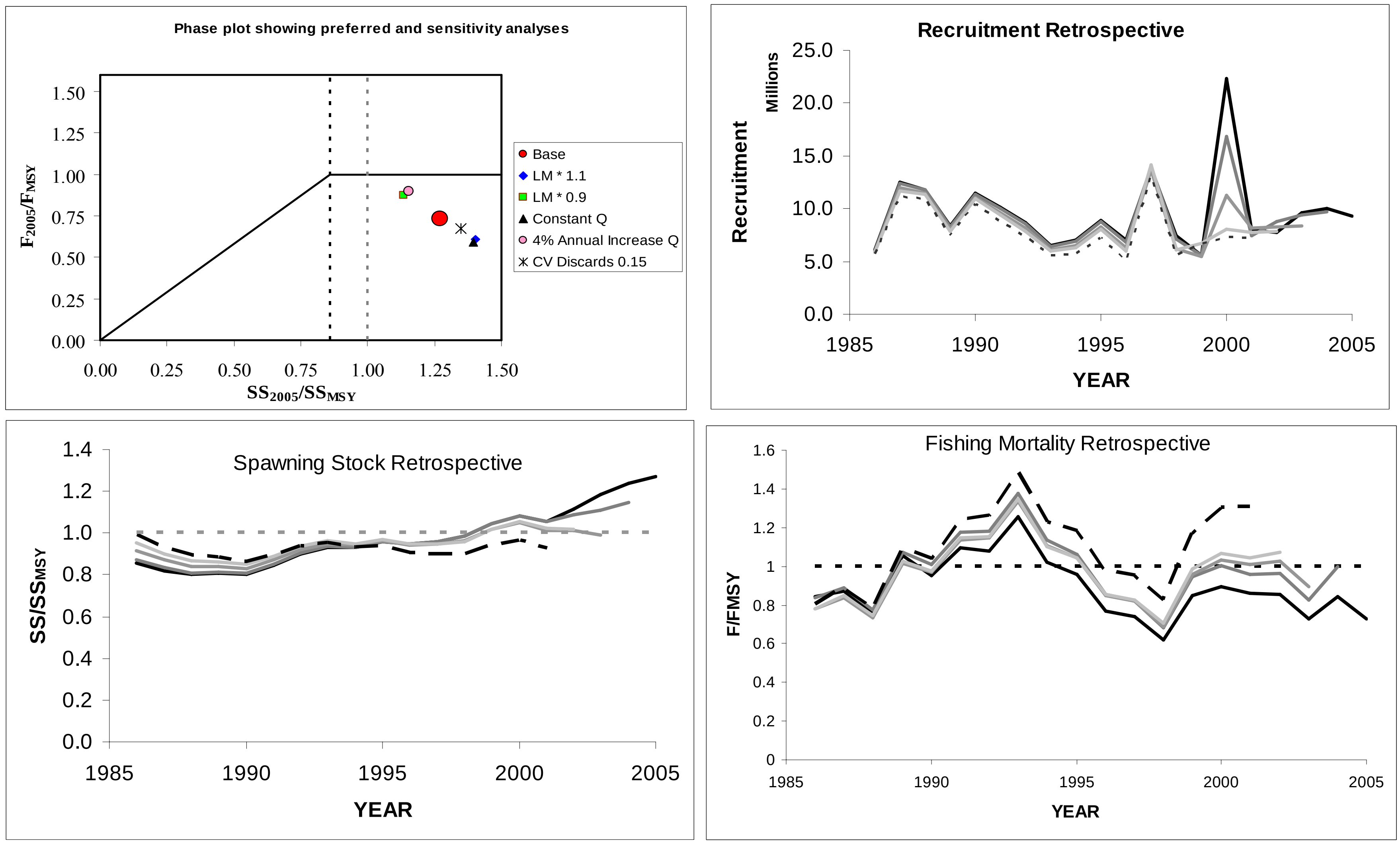


Figure 4. Illustrated model uncertainties. Point estimates of terminal stock status relative to management limits for base and review sensitivity runs (upper left panel); results of retrospective analyses for recruitment (upper right) spawning stock (lower left) and exploitation (lower right)

SEDAR 12

Stock Assessment Report 1

Gulf of Mexico Red Grouper

SECTION II. Data Workshop

SEDAR
1 Southpark Circle # 306
Charleston, SC 29414

1. Introduction

1.1. Workshop Time and Place

The SEDAR 12 data workshop was held June 24 - 28, 2006, in St. Petersburg, FL.

1.2. Terms of Reference

1. Characterize stock structure and develop a unit stock definition.
2. 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. Document all programs used to develop indices, addressing program objectives, methods, coverage, sampling intensity, and other relevant characteristics. Consider relevant fishery dependent and independent data sources; develop values by appropriate strata (e.g., age, size, area, and fishery); provide measures of precision. Evaluate the degree to which available indices adequately represent fishery and population conditions. Recommend which data sources should be considered in assessment modeling.
4. Characterize commercial and recreational catch, including both landings and discard removals, in weight and number. Evaluate the adequacy of available data for accurately characterizing harvest and discard by species and fishery sector. Provide length and age distributions if feasible.
5. Provide recommendations for future research in areas such as sampling, fishery monitoring, and stock assessment. Include specific guidance on sampling intensity and coverage where possible.
6. Prepare complete documentation of workshop actions and decisions (Section II. of the SEDAR assessment report).

1.3. List of Participants

1.4.

NAME Appointed by/Affiliation

<u>Appointed Panelists</u>

Ralph Allen ....GMFMC/Reef Fish AP
Josh Bennett .... SEFSC/Miami
Steve Brown..GMFMC/FL FWCC
Craig Brown.. SEFSC/Miami
Mike Burton ....SEFSC-Beaufort
Shannon Cass-Calay .... SEFSC/Miami
Ching Chih .... SEFSC/Miami
Richard Cody ....GMFMC/FL FWCC
Doug DeVries .... SEFSC/Miami
Sandra Diamond.. GMFMC SSC/Texas Tech Univ.

Guillermo Diaz.. SEFSC/Miami
Dave Donaldson.. GSMFMC/Gulf FIN
Barbara Dorf .... GMFMC/TX PWD
Elizabeth Fetherston.. GMFMC NGO/Ocean Conservancy
Gary Fitzhugh .... SEFSC/Panama City
Chris Gledhill .... SEFSC/Pascagoula
David Gloeckner .... SEFSC/Beaufort
Walter Ingram .... SEFSC/Pascagoula
Linda Lombardi-Carlson.. SEFSC/Panama City
Gus Loyal.. GMFMC/Reef Fish AP
Vivian Matter .... SEFSC/Miami
Kevin McCarthy.. SEFSC/Miami
Mike Murphy .... GMFMC FAP/FL FWCC
Joe O'Hop .... GMFMC/FL FWCC
Patricia Phares.. SEFSC/Miami
Clay Porch.. SEFSC/Miami
Steven Saul.. SEFSC/RSMAS-UMIA
Beverly Sauls .... GMFMC/FL FWCC
Tom Sminkey.. SEFSC/MRFSS
Robert Spaeth.. GMFMC Reef Fish AP
Steve Turner.. SEFSC/Miami
John Walter .... SEFSC/Miami
Bob Zales .... GMFMC/Reef Fish AP
Victor Zarate-Noble .... SEFSC/INP - Mexico

Council Representation
Roy Williams .... GMFMC

Observers
Karen Burns .... Mote Marine Lab
Scott Nichols.. SEFSC/Pascagoula
Dennis O'Hern.. GMFMC / Reef Fish AP

Staff
John Carmichael.. SEDAR Coordinator/Chair
Patrick Gilles.. SEFSC/Miami
Stu Kennedy.. GMFMC
Tina Trezza .... GMFMC

1.5. Supporting Documents

Data Workshop Working Papers

Document #	Title	Authors
SEDAR12-DW1	The use of an otolith reference collection to monitor age reader precision for red grouper (Epinephelus morio)	Palmer, C. L., Farsky, R. A., Gardner, C., and Lombardi-Carlson, L. A.
SEDAR12-DW2	Bottom longline fishery bycatch of red grouper from observer data	Hale, L.
SEDAR12-DW3	Temporal and spatial trends in red grouper (Epinephelus morio) age and growth from the northeastern Gulf of Mexico: 1979-2005	Lombardi-Carlson, L., C. Palmer, C. Gardner and B. Farsky
SEDAR12-DW4	An update of Gulf of Mexico red grouper reproductive data and parameters for SEDAR 12	Fitzhugh , G.R., H.M. Lyon, W.T. Walling, C.F. Levins, and L.A. Lombardi-Carlson
SEDAR12-DW5	Catch rates, distribution and size/age composition of red grouper, *Epinephelus morio*, collected during NOAA Fisheries Bottom Longline Surveys from the U.S. Gulf of Mexico	Ingram, W., M. Grace, L. Lombardi-Carlson and T. Henwood
SEDAR12-DW6	SEAMAP Reef Fish Survey of Offshore Banks: Yearly Indices of Abundance for red grouper (*Epinephelus morio*)	Gledhill, C. T., G. W. Ingram, Jr., K. R. Rademacher, P. Felts, B. Trigg, and L. Lombardi-Carlson
SEDAR12-DW7	Research Trawl and Shrimp Bycatch Results Relevant to Red Grouper	Nicholls, S.
SEDAR12-DW8	Spatial and temporal patterns in demographics and catch rates of red grouper from a fishery-independent trap survey in the northeast Gulf of Mexico, 2004-2005	De Vries, D.
SEDAR12-DW9	Length frequency distributions for red groupers caught by commercial fisheries in the Gulf of Mexico from 1984 to 2005	Chih, C-P.
SEDAR12-DW10	Selected sampling issues regarding the length/age frequency distributions of red groupers caught by commercial fisheries in the Gulf of Mexico from 1984 to 2005	Chih, C-P.
SEDAR12-DW11	Quantitative Historical Analysis of the United States and Cuban Gulf of Mexico Red Grouper Commercial Fishery	Saul, S.
SEDAR12-DW12	Length Frequency Analysis of the Gulf of Mexico Recreational Red Grouper Fishery	Saul, S.
SEDAR12-DW-13	Trends in Red Grouper Mortality Rates Estimated from Tag Recaptures (1990-2006)	Porch, C. E.
SEDAR12-DW-14	Recreational Survey Data for Red Grouper in the Gulf of Mexico	Matter, V. M.
SEDAR12-DW-15	Backcalculation of recreational catch of red grouper from 1945 to 1985	Walter, J. F.
SEDAR12-DW-16	Standardized catch rates for red grouper from the United States Gulf of Mexico handline, longline, and trap fisheries, 1990-2005	McCarthy, K. and S. Cass-Calay
SEDAR12-DW-17	Calculated red grouper discards by vessels with Federal permits in the Gulf of Mexico.	McCarthy, K.

Reference Documents Discussed at the Data Workshop

SEDAR12-RD01 2006 FishBull 104:343-349	Depredation of catch by bottlenose dolphins (*Tursiops truncatus* in the Florida king mackerel (*Scomberomorus cavalla*) troll fishery.	Zollet, E. A., A. J. Read
SEDAR12-RD02 2002 SFD-01/02-175rev	Draft status of red grouper in United States waters of the Gulf of Mexico during 1986-2001	SEFSC Staff
SEDAR12-RD03 2002 PCL Cont. 2002-06	Red Grouper age-length structure and description of growth from the eastern Gulf of Mexico: 1992-2001	Lombardi-Carlson, L. A., G. R. Fitzhugh, and J. J. Mikulas

2. Life History

2.1 Stock Definition

The red grouper fishery has been managed in the US as separate Gulf and Atlantic stock units with the boundary being U.S. Highway 1 in the Florida Keys. The DW reviewed the available stock structure information (see summaries below with embedded research questions) and concluded there is no evidence that suggests different stock management units need to be considered at this time. The DW recommends that the status quo be maintained until further studies suggest otherwise.

Population genetics
Genetic studies have not revealed any separate stock structure or reproductive isolation among southeastern U.S. Atlantic, northeastern Gulf of Mexico, and southwestern Mexico Gulf of Mexico (Yucatan peninsula) collections of red grouper based upon mitochondrial DNA (Richardson and Gold 1997) or microsatellite genetic markers (Zatcoff et al. 2004). Red grouper may have a more complex stock structure based on possible separated distributions and evidence of little movement but a longer timescale of generations may be needed to detect genetic differences (Zatcoff et al. 2004).

Tagging
Extensive tagging (n=15,000+) in the northeastern Gulf, centered off Manatee and Sarasota counties, by Mote Marine Laboratory strongly suggested that red grouper (age 2-4 yr) move very little. Of 1152 recaptures, 61% were within 1 mile of the tagging site, 26% ranged from 1.1 to 10 miles, 12% had moved 10.1-100 miles, and only 1% were recovered >100 miles from where the red grouper were tagged. No verifiable recaptures were made in the Atlantic Ocean. The maximum distance moved was 233 miles (unpublished results, Karen Burns). This strong tendency to move only short distances could contribute to future stock separation given enough time. It is possible that further research will reveal a more complex subpopulation structure that may not be genetically distinct but are functionally independent units (e.g. red snapper, Fischer et al. 2004).

Demographic comparisons
Lombardi-Carlson et al. (2006) found significant differences in size and age structure and in growth rates of red grouper north and south of 28°N latitude, supporting a hypothesis that red grouper may have some degree of subpopulation structure. In recent years both fishery dependent and independent surveys have clearly shown that red grouper in the Gulf are characterized by periodic strong year classes – the latest being 1996 and 1999 (and possibly 2002, DeVries et al. 2006, SEDAR12-DW-08). A comparison of dominant cohorts in Mexican, U.S. northeastern Gulf, and southeastern Atlantic waters could provide considerable insight on stock structure. If red grouper populations in all three areas are characterized by the same dominant year classes, this would strongly suggest common recruitment patterns and a single spawning stock. This is one area of research that should receive more attention, given the potential impacts stock structure has on assessments and management.

Larval transport and connectivity
There is no evidence that red grouper spawned off Yucatan, Mexico are transported to U.S. Gulf and Atlantic waters, although this is certainly a possibility given the direction of flow (north and east) in the Yucatan Straits and the Straits of the Florida. The DW was not aware of any larval duration estimates specifically for red grouper, but other grouper species have been estimated to have durations of 31-66 d (Lindeman et al. 2000). Examination of ichthyoplankton samples from the NMFS Pascagoula larval bluefin tuna surveys, conducted in April and May, could prove fruitful in addressing this question.

Spatial patterns in landings and possible recruitment hot spots
The spatial distribution of commercial landings shows no evidence of multiple stocks as there are no obvious spatial discontinuities in landings off the Florida Keys or southwest Florida (Steve Brown, FWC, personal communication.). However, the distribution of major fishing grounds and the limited movement seen in tagging (see below) suggest that recruitment may not be spatially uniform, and centers of recruitment may become evident as surveys are expanded. A starting hypothesis is that the Big Bend region (see DeVries et al. 2006, SEDAR12-DW-08) and the shallow (< 20 m) areas off southwest Florida (Pinellas and Charlotte counties) may be two primary sources of recruitment. The DW is not aware of any research involving otolith chemical markers in red grouper that could answer questions regarding recruitment sources and subpopulation structure.

2.2. Mortality Estimates

2.2.1 Natural Mortality

Previous red grouper assessments assumed a constant natural mortality rate of 0.2 yr^{-1} (Schirripa et al. 1999). Maximum age of red grouper in the Gulf of Mexico has been estimated at 29 years (SEDAR 12-DW-03). Using this information, natural mortality (M) of red grouper was estimated to be M = 0.14 using the regression model reported by Hoenig (1983) for teleosts: $\ln(M) = 1.46-1.01*\ln(t_{max})$. It should be noted that the Data Workshop (DW) did not use the alternative “rule of thumb” approach for estimating M from longevity ($M=2.98/t_{max}$, Quinn and Deriso 1999, Cadima 2003). Recent work by Hewitt and Hoenig (2005) recommend the regression model over the rule-of-thumb approach. Natural mortality was also estimated using a variety of models based on von Bertalanffy growth or reproductive parameters (e.g., Jensen 1996). Using these alternative models, M ranged from 0.14-0.24.

An age-varying M approach was developed during the gag SEDAR assessment workshop (SEDAR10-SAR1 2006, following Lorenzen 1996). This approach inversely relates the natural mortality-at-age to the mean weight-at-age by a power function, $M = 3W^{-0.288}$, incorporating a scaling parameter. Lorenzen (1996) provided point estimates and 90% confidence intervals of the power and scaling parameters for oceanic fishes, which are used for initial parameterization. In both the SEDAR 04-AW and the SEDAR 10-AW, it was concluded that the Lorenzen approach is more biologically plausible than a fixed M for all ages. The Lorenzen estimate was re-scaled to the oldest observed age (29) so that the cumulative natural mortality through this age was equivalent to that of constant M (0.14) for all ages from the Hoenig (1983) method. The resulting vector is shown in Figure 2.1.

Recommendation for AW: The DW recommended this vector as the most appropriate for the red grouper assessment.

2.2.2 Total Mortality

Catch curve estimates of instantaneous total mortality (Z), using data summarized in SEDAR12-DW-03, equaled 0.33 based on ages 5-28 yr in the Gulf of Mexico. Combining all cohorts for the 5-12 year age interval (encompassing the more common ages in the landings), an overall Z of 0.30 was observed. A catch curve was also developed for red grouper 13-28 years and Z (0.31) was similar to the value for individuals in the 5-12 year age interval.

The Mote Marine Laboratory (MML) tagging database provided information on the time between release and recaptures of tagged red grouper. A form of survival analysis was applied to these data to estimate annual mortality rates (SEDAR12-DW-13, Figure 2.2). The estimates were very high, on the order of 2 yr^{-1}. However, an examination of the distribution of releases and recaptures revealed that the great majority of the data came from a relatively restricted region off Sarasota and within 10 miles of shore. The DW discussed whether the tagging-based mortality estimates could be a result of locally high fishing mortality rates and a low level of mixing between the tagged population and the overall population of red grouper. An anecdotal account indicated that the fishing mortality rate on red grouper in shallow waters off Sarasota was very high (Gus Loyal, personal communication during SEDAR12 DW). Therefore the group felt that the trends in this area are unlikely to reflect the overall trends for the whole U.S. Gulf of Mexico.

The previous two red grouper assessments used an index of abundance constructed by dividing the observed catch by the relative mortality rate index estimated from the Mote Marine Lab tagging data. While the trends of this relative index were relatively insensitive to assumptions related to non-fishing loss rates, the spatial coverage of the index was considered to be too limited to reflect the overall trends in the entire Gulf.

Recommendation for AW:
The DW recommended the use of the catch-curve derived total mortality estimates (Z) as a check on model results. The DW did not recommend the use of the abundance index derived from the Mote tagging data.

2.2.3 Release Mortality

During the last red grouper assessment, point estimates of release mortality by fishing sector were adopted for use. Point estimates were 33% and 90% for commercial hook-and-line and long-line sectors respectively (long-line was also evaluated at 33%), and 10% for the recreational hook-and-line sector (NMFS 2002). During the gag SEDAR10 DW, it was determined that enough information was available to apply a depth-related function for release mortality which would be preferred over using point estimates. This was further conditioned on whether the catches, and thus releases within each sector, could be related to depth based upon available catch records and trip information (TIP data base). However, it became apparent during DW discussions that red grouper release mortality estimates which could be applied to a depth-function were not as complete as those for gag reviewed during SEDAR10. The DW reviewed the available sources of data for red grouper and made recommendations for continued work (see below). Some recommendations were to continue to investigate the development of depth-related functions before the red grouper AW scheduled in October, some recommendations were for future research, and there were also some recommendations pertaining to management of future SEDARs.

Review of the available data sources: The DW noted that much research had been undertaken in the last decade pertaining to release mortality of red grouper and associated species in the reef fish complex and that many of the results were still being incorporated into scientific papers and reports. Surface observations of fish condition at the time of release are a common type of data used which the DW denoted as <u>pre-release mortality</u>; a minimum estimate of release mortality. Observations of fish from cages and from tag-recaptures are used to estimate <u>post-release mortality</u> which typically reflects a higher rate of realized mortality than what can be observed from surface releases. Based on these two general release mortality approaches, results with <u>accompanying depth data</u> were primarily available from seven sources for red grouper.

<u>Pre-release mortality from commercial catches</u>. Hale (2006, SEDAR12-DW-02) reports on condition of releases recorded by observers in the Gulf of Mexico shark bottom long-line fishery during the second and third trimester seasons of 2005. These results were compared with a 1995 observer report (cited within SEDAR12-DW-02) of the bottom long-line sector, however, the 1995 study did not report specific depths for observations. Pre-release mortality estimates were also available from commercial self-reported results obtained via the Cooperative Research Program (CRP). Robert Spaeth contributed observations of release condition from commercial long-line catches obtained during the years 2000-2001. Eric Schmidt contributed observations from 6 commercial hook-and-line trips of release condition of 348 fish from a 2003 CRP project. Conditions of released fish were based on NMFS Galveston observer program (1. live, normal appearance, 2. live, air bladder/stomach protruding, 3. live, eyes protruding, 4. live, combination of 2 & 3, and 5. dead on arrival).

<u>Pre-release mortality from recreational catches</u>. Sauls (2005) interviewed anglers aboard headboats fishing off the Florida coast. From direct observations, Sauls recorded the release condition of discards. Similarly, MRFSS data obtained from interviews in the private and charterboat sectors are coded for condition of fish at the time of release. Both of these data sources will be further explored for development of a depth-mortality function (recommendations below).

<u>Post-release mortality from tag and cage studies.</u> Koenig (preliminary report to Gulf Council) determined depth-related capture-release mortality for red grouper caught on electric reels with circle hooks and placed in cages at various depths off Apalachicola and Carrabelle, Florida. Control fish were captured at 20 m. Experimental fish were caught and kept in cages at depths of 18.3, 31.1, 35.1, 36.6, 39.0, 39.6, 39.9 and 41.2 m. All fish were returned to the bottom within 33 min of capture and periodically checked using SCUBA at 1, 7, and 13 days. Wilson and

Burns (1996) used shipboard hyperbaric chambers, in-situ cage observations and tag-recapture data to determine potential post-release survival rates for red grouper caught on the central west Florida shelf. In follow-up work, Burns et al. (2004) compared red grouper acute mortality estimates of headboat-caught fish taken in depths of 10 – 43 m off Panama City, Daytona and St. Augustine, Florida, with mortality estimates from simulated depths (21.3, 27.4, 42.7 and 61m) for red grouper kept in hyperbaric chambers.

The DW release mortality discussions focused on developing depth-related functions using pre-release data specific to the respective commercial and recreational sectors and post-release data applied across all sectors. The recommendations below advise treating the data consistently among the various research studies.

Recommendations for AW:
The DW recommended that NMFS further investigate using logistic regression on pre-release mortality by depth for the commercial long-line and commercial and recreational hook-and-line sectors based on the above datasets. As a separate phase of release mortality, it is recommended that logistic regression be applied to the post-release tag and cage data.

Although some of these commercial pre-release datasets are self-reported by fishermen (Spaeth and Schmidt results), the depth related release mortality estimates are similar to observer data and thus are recommended to be applied.

The DW did not recommend use of the 1995 commercial long-line and hand-line pre-release estimates from SEFSC (13.3% and 6.9% pre-release mortality respectively) because there are no associated depth data.

The DW did recommend the use of the (pre-release) point estimate of 3.3% for the commercial trap sector because the anecdotal information indicates there is little apparent depth-related trap mortality, unlike hook-and-line and long-line gears. Further, results from Mote's CRP project (Award #NA03NMF4540417) support higher depth-related survival estimates for trap caught fish relative to other gears (Based upon pre-release method, Figure 2.3, Burns and Robbins, in prep.).

The DW suggested that NMFS use only dead on boat (category 4) for the headboat observations (Sauls 2005) to fit the pre-release mortality with depth equation.

The DW did not suggest using "floaters" or "strugglers" in the various visual categories because although these do give more information than pre-release mortality (e.g., live vs. dead), these categories do not reflect total post-release mortality that should be estimated separately using cage and tag data.

Similarly, the DW recommended using MRFSS B1 data to count dead in hand (pre-release mortality) so no additional pre-release mortality is needed for MRFSS. (Code B2 as post-release mortality only. Use B1(released)/(B1(released)+B2) for estimating future pre-release mortality in projections.)

The DW suggests that predation estimates from the FL headboat observer study be applied to predation from all fisheries as these estimates appear to be the only predation data readily available.

Recommendations for future research:
The DW recommends that studies be performed with larger sample sizes for pre- and post-release mortality. The DW further noted that information on predation upon release was sparse and suggests that all observer studies collect predation data and record release condition of fish (see categories above) when possible. More specifically, the DW recommends future experimental studies to relate “sink or swim” observations to post-release mortality and suggests that controls are needed for all cage studies, such that control fish are captured and caged at depth (without bringing to the surface at all). Furthermore, it was suggested that Burns’ tag data be recoded to incorporate the comments regarding “sink or swim” into a standardized data field and used to estimate pre-release and predation mortality by sector.

The DW strongly recommends more research dedicated to determine methodologies to decrease release mortality (see Bartholomew and Bohnsack 2005).

Recommendations for the SEDAR process:
The DW suggests that the South Atlantic and Gulf Councils coordinate with CRP and MARFIN officers to provide all grant reports dealing with discards to be available at SEDARs and that all PI’s on grants dealing with said species are invited to SEDAR. The DW further suggests that all documents (including old assessments and references within) that were used in previous stock assessments for said species are more readily available to SEDAR participants.

2.3 Age Data

2.3.1 Age Structure Samples

Age data were provided to the DW by NMFS Panama City with data from the Gulf of Mexico commercial and recreational fisheries, and fishery independent surveys (1979-2005, n=16,376; SEDAR 12-DW-03).

Red grouper were collected by a fishery independent bottom long-line survey (2000-2005, SEDAR 12-DW-05), that was randomly stratified by depth and covers the entire west Florida shelf (the primary fishing area for red grouper). All of the red grouper were caught in the first depth strata (9-55 m). This survey provides fishery independent age structure data (n=348, age range 2-21 yr, mean age 6.3 yr).

Issues:
1.) Pre-2000 samples sizes of long-line and hand-line collected otoliths were low compared to recent years.
2.) Throughout the time series the recreational industry, and in particular the private sector, was not well represented (n<150, 1991-2005).

3.) Fishery independent samples were also not well represented throughout the time series (n<1142, 1991-2005).

Recommendations for future research:
1.) Conduct further review of current sampling methodologies by sector, including detailed comparison of length data from otolith samples and from more expansive port-based length sampling (via TIP; see SEDAR 12-DW-10).
2.) Bring increased attention to the need for strategies improving port sampling (representation of fishery sectors and random sampling)
3.) Increase the sampling of the recreational sector for biological samples throughout the docks and ports of Florida's west coast.
4.) Continue support of fishery-independent surveys including all gears (hand-line, long-line, and trap) throughout the west Florida shelf.

2.3.2 Age Reader Precision

Four readers participated in estimating age for the age structure data used in this data workshop. Overall reader pair comparison results show high precision between all four readers. An APE of 3.45%, CV of 4.28%, and a resulting 2.27% index of precision (D) reflect low reader error. Percent agreement comparisons among the primary reader and all secondary readers show the overall agreement was 96% ± two bands. The precision results suggest that the age determination from the four readers were reliable (SEDAR12-DW-01).

Issues: Differences in otolith interpretations and methodologies in the past have led, in some instances, to incompatible datasets.

Recommendations for future research: 1) Continue exchanges of calibration otolith sets and age workshops among state and federal agencies and universities to continue improvements of data comparability and quality control. 2) Continue use and development of a reference collection as a means to monitor precision between readers.

2.3.3 Age Patterns

Red grouper year-class trends are apparent for the Gulf of Mexico due to the ease of aging red grouper otoliths and the availability of a continuous series of age structure sampling from 1991 to 2005 from the Gulf. Strong year classes were evident in the Gulf of Mexico 1989, 1990, 1991, 1996, and 1999. Red grouper were found to be on average 7.53 ± 0.02 yr (range = 1-29 yrs) (SEDAR12-DW-03).

Recommendations for future research: Continue age structure sampling on an annual basis.

2.3.4. *Assigning age to catch*

During the DW workshop, there were discussions on the adequacy of age samples, by year and fishing sector, for assigning age proportions directly to catch as opposed to developing an age-key. Lengths obtained along with otolith sampling for age, were compared to lengths obtained though routine TIP intercepts (Chih 2006, SEDAR 12 DW-10). It was observed that there were more inconsistencies in TIP (length-based) and otolith-associated (age-based) length frequency distributions between 1991 and 2000 than from 2001 to 2005 (SEDAR 12 DW-10). In the earlier years, otolith samples were lower in number and restricted more to commercial hook and line landings than in later years and this led to concerns about whether collections could be assumed to be random. In DW discussions, it was certainly noted that otolith collections were sparse in the very early time series (e.g., 1991). However, it was also discussed that the length frequency comparisons in SEDAR 12 DW-10 did not take into account regional differences (see Lombardi et al. 2006, SEDAR). The discussion generally recognized that the need for age-key approach may be restricted more to the periods, regions, and sectors where sampling was sparse.

Recommendation prior to AW: Complete a comparison of age-based and length-based samples for year, region and fishery sector to more clearly identify where gaps exist. Based upon this analysis, further recommend where age proportions could be applied directly and where an age-key approach should be applied.

2.4 Growth

There have been several growth studies on red grouper in the Gulf of Mexico (see citations within SEDAR 12-DW-03). The updated data set provides an increased sample size for improved temporal coverage. Growth models can be influenced by the use of size-biased samples, such as those collected from fisheries with minimum size-limits. Thus, a size-modified von Bertalanffy growth model accounting for size limited data was used for the Gulf of Mexico (1991-2005, n=15,593). The red grouper size limit has remained at 20 in or 508 mm since 1990 for commercial and recreational fisheries.

The model was fit to observed lengths and fractional ages. Red grouper data from the entire time series were fit to the size-modified von Bertalanffy growth model to obtain population growth parameters. The modified growth model resulted in an asymptotic length within the range of observed lengths (L_∞=854 mm, TL range 171-1007 mm), a growth coefficient (K) of 0.16 yr^{-1} and predicted t_o close to zero (t_o =-0.19 yr).

While the workgroup acknowledged that increased annual aging and correction for size-biased sampling has reduced uncertainties about growth compared to Goodyear (1994), there were still uncertainties and interest about the cause of the smaller size-at-age estimated from samples collected in the 1960s versus that determined from samples collected since the 1990s (L_∞=792 mm TL, k= 0.18, to = -0.45, Moe 1969; originally reported in SL and converted to TL, Lombardi-Carlson et al. 2002; Figure 2.4). While there have been efforts to find original samples from the 1960s and check aging precision, it is likely that early samples have been misplaced due to fire and/or renovation at the Florida Fish and Wildlife Conservation Commission, Florida Wildlife Research Institute, St. Petersburg, FL (Martin Moe, Personal communication).

Recommendation for AW: The DW recommended application of the size-modified von Bertalanffy model.

Recommendation for future research: Continue search for original samples and raw data on age and growth collected during the 1960s.

2.5 Reproduction

There have been several studies of the reproductive biology of red grouper (see references within SEDAR12-DW-04). The DW reviewed the age-based data needed for the model parameters regarding maturity, sexual transition and fecundity.

Maturity:
As red grouper have been found to be protogynous hermaphrodites (female first, then male), all transitional and male fish were considered to be mature (see sexual transition below). Age based data were reviewed from Moe (1969), Burgos (2001) and Panama City (Fitzhugh et al. 2006, SEDAR12-DW-04). In all cases, histological staging techniques were used. Comparisons were based upon three definitions of maturity. 1) classic maturity based upon the proportion of females at age that exhibited evidence of prior or current reproductive development (combines resting mature and active mature females into the numerator of a proportion of total inactive (resting), active, and immature females). 2) definite maturity based upon active females. This eliminates resting females that are subject to more uncertainty in classification. Thus active females are the numerator of a proportion of total active and immature females. This approach is used in the MARMAP program and was used in the gag assessment (Wyanski, personal communication, SEDAR12-DW-04). 3) Panama City applied a third method defined as a measure of "effective maturity" as it recognizes that despite evidence of prior spawning, not all mature females may be sexually active in a given year (following Pears et al. 2006). In this third method, active females during the peak spawning months (Mar-May) are the numerator of a proportion of total inactive (resting), active, and immature females (Fitzhugh et al. 2006, SEDAR12-DW-04).

Issues: There were general similarities in the age-based results of the various studies but it was noted that age-at-maturity increases as one applies different definitions: first classic maturity, then definite maturity and finally effective maturity (Figure 2.5). This may occur because females are undergoing reproductive development over several years. For instance, there may be initial development in young females even though these females may not develop to final spawning state, then followed by the year of first spawning, and then perhaps followed by several years with some likelihood of skipped spawning (Moe 1969, Collins et al. 2002, Fitzhugh 2006 SEDAR12-DW-04, Jorgensen et al. 2006). However this reproductive ontogeny is not well known.

Recommendation for AW: The DW recommended using the intermediate maturity definition (definite maturity) as it should be most robust to uncertainties in female reproductive ontogeny (but see research recommendations below) and then two data sets for the northeastern Gulf of Mexico (NMFS Panama City data, Fitzhugh et al. 2006 and Moe 1969) could be similarly compared using the definite mature definition (Figure 2.6).

Issue: Based on definite maturity, the Panama City data (SEDAR-DW-04) reflected a younger age-at-maturity for the eastern Gulf compared to Moe (1969), suggesting a temporal shift in maturity with time. The DW discussed data sources and treatment that may have affected this difference. The Panama City data may not have adequately sampled the young inshore component of the population as well as the offshore adults. The raw data for Moe (1969) was not available and thus exact sample sources are not known. It was also not clear whether age was treated the same way between the studies (see age determination SEDAR12-DW-03, Lombardi-Carlson et al. 2006). The workgroup noted that no single study systematically sampled the population.

Recommendations for AW: Fit (definite) maturity using both NMFS Panama City (SEDAR-DW-04) and Moe (1969) data (Figure 2.6).

Consider a temporal change in reproductive traits for the eastern Gulf (see recommendation under transition below).

Recommendation for future research: Undertake more systematic collection of maturity data (e.g. to characterize the inshore and younger aged fish as well as the adults in mid and outer-shelf depths).

Sexual Transition

The various studies (Panama City SEDAR10-DW-4, Moe 1969, Burgos 2001 and Koenig reported in Schirripa et al. 1999) showed some differences in age at transition that also may have been related to either temporal differences or differences in the sources of the samples, similar to the sampling issue for maturity (Figure 2.7). Moe's earlier study using data from the eastern Gulf in the 1960s showed the most notable differences with an older age at transition (50% about age 16). By contrast, the Panama City data reflected a younger age (50% by age 11) and Burgos (2001), with relatively few males sampled, showed an even younger age (between 8 and 9 yr). The Panama City dataset, however, had a large sample size and covered the adult stock; thus it was discussed whether the shift was due to a temporal change since the 1960s. Since the Panama City dataset covered a relatively long continuous time period (1991-2005), the dataset was further parsed and examined to see if any temporal shift from early (1991-1995) to later (2001-2005) periods could be detected over the decade. No shift was apparent.

Recommendation for AW: Fit the various transition data sets as a continuity case. However, since it is possible that Moe's 1960s data reflected a different age-at-transition for the population, the DW recommended that the earlier (1960s) age-at-transition be fit separately from the later (1990s+) data series (NMFS Panama City, Fitzhugh et al. 2006 and Koenig data, reported in Schirripa et al. 1999). Thus, the DW recommends the AW consider a temporal change in age-at-transition and age-at-maturity for red grouper from the west Florida shelf.

Fecundity and spawning frequency

Since red grouper are considered to be indeterminate spawners, batch fecundity (BF) and spawning frequency were estimated (see 2002 assessment, Fitzhugh et al. 2006, SEDAR12-DW-04). In the last assessment (NMFS 2002) it was noted that samples were sparse (< 40 BF estimates by age) and a fit to the data were affected by a single influential (outlying) value. The DW noted the number of batch fecundity estimates has increased since the last assessment but the sample size was still relatively low compared to gonad weight observations, and the same outlying observation still influenced the model fit. The DW also discussed the spawning frequency results, which are used as a multiplier of batch fecundity to obtain annual fecundity estimates. Typically, spawning frequency is calculated as a point estimate by year and aggregated over ages. The DW noted that age-based data are being collected to enable an estimation of spawning frequency by age, which would be useful to the age-based modeling approach of the assessment. However, it was noted that there was a high degree of uncertainty in the fits of spawning frequency that statistically would not be significant by age (SEDAR12-DW-04).

The workgroup reviewed the data for gonad weight at age for active females (histologically noted to have yolked oocytes) during peak spawning, Mar-May, as a proxy for relative fecundity by age class. This was adopted and first used in the 2002 assessment (actually chosen as the preferred method by the reef fish stock assessment panel, RFSAP, 2002). The benefits of using gonad weight were larger sample sizes and the avoidance of the multiplication of several uncertain estimates (batch fecundity, spawning frequency and annual spawning duration). The DW further noted that gonad weight is generally well estimated. In workgroup discussions, it was also noted that where there was even enough data to separate the data spatially (by region north or south of 28° N latitude) there was an indication of a possible regional effect (Figure 2.8).

Recommendations for AW: Use gonad weight -age relationship of active females for fecundity (Figure 2.8, as updated from the 2002 assessment, NMFS 2002).

Recommendations for future research:
Continue work on fecundity and spawning frequency and incorporate a spatial-temporal design to improve estimates of reproductive potential by age. Statistically test for regional effect. Continue work on spawning pattern to better understand and discriminate between annual asynchrony in spawning (skipped spawning) and seasonal asynchrony in spawning. Explore model sensitivities to reproductive parameters.

Issue: The previous assessment defined the per capita fecundity as the product of the proportion female and gonad weight; the 2002 Reef Fish Stock Assessment Panel elected not to incorporate the percent activity estimates as a measure of maturity because they believed that the use of gonad weight observations implicitly included to some degree a measure of activity (Addendum to 2002 assessment, Table A1). The members of the Data Workshop felt that the information available no longer support that assertion.

Recommendation for AW: Define the per capita fecundity as the product of proportion female, gonad weight (of active females as a proxy for fecundity) and maturity.

2.6 Movements and Migrations

As discussed in the stock identification section, red grouper tend to show limited movements although some exceptions have been noted (Karen Burns, Mote Marine Laboratory, personal communication). Some movements tend to be offshore towards deeper water and related to ontogeny. Red grouper spend their larval phase in the plankton, settling and residing on inshore hardbottom areas for up to 5 years as juveniles and finally, at onset of sexual maturity, inhabit the continental shelf and shelf edge (Moe 1966). Undersized red grouper caught, tagged and released inshore by recreational fishers have been recaptured offshore, in some cases by commercial long-liners 117- 868 days after release (Burns and Robbins, in prep.). Of 1,157 red grouper recaptures, 512 fish showed zero movement and 81% were recaptured within 5 nm of the release site (Figure 2.8). However, some fish did exhibit long distance movements. One individual was recaptured 233 nm from the release site (unpublished results, Karen Burns, Mote Marine Laboratory). These data agree with those of Bullock and Smith (1991) who reported that smaller red grouper usually occur in shallow water (3-18 m) off southwest Florida, and then, following several years, are found in commercial catches at depths greater than 36 m. Koenig and Coleman (2006) reported that red grouper can exhibit high site fidelity at older ages upon reaching mid- to outer shelf depths which they attributed to the species habitat-structuring and haremic mating behavior. None of their tagged fish moved more than 1.2 nm. Thus, in general, tagging data reveal that most red grouper exhibit limited movements throughout their life span which could give rise to complex sub-stock structure.

There have been some reports of movements in red grouper which do not appear related to ontogeny. Some onshore/offshore movements have been explained by fishers as inshore summer feeding migrations (William Ward, personal communication). Bannerot's comments noted in Bullock and Smith (1991) reported seasonal movements of offshore (27-91 m) adult red grouper in the Florida Keys. Moe (1972) reported 22 tagged red grouper traveled 16 mi within 50 days. The Mote tagging data also reveal that groups of similar sized fish which were caught together on the same date at the same location were then recaptured together on the same date at some other same site. This type of pattern has been characterized as "cohort movement" (Karen Burns, Mote Marine Laboratory, personal communication). These cohort movements (recapture groups of 2-5 fish) have occurred during all months of various years but it is not known how common or widespread these might be due to the nature of fishery-dependent recaptures. Perhaps similar to "cohort movement", red grouper may move in large numbers in response to events such as hurricanes. Following Hurricane Lili in 2002, juvenile and adult red grouper were commonly caught on artificial reefs and petroleum platforms off Mississippi where they had not previously been reported (Franks 2003). However, since 2002, reports of red grouper off Mississippi have become scarce (Jim Franks, Gulf Coast Marine Laboratory, personal communication, August 2006).

2.7 Meristic Conversions

Meristic relationships were calculated for red grouper in the eastern Gulf of Mexico for length types (total and fork) and body weights (whole and gutted), (Table 1). Coefficients of determination were high for linear (length) and nonlinear (weight) regressions ($r^2 \geq 0.95$).

2.8 Literature Cited

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

Bullock, L.H. and G.B. Smith 1991. Sea basses (Pisces: Serranidae). In: Memoirs of the Hourglass Cruises. Vol. 8. Florida Marine Research Institute, Department of Natural Resources, St. Petersburg, FL. 243p.

Burns, K.M. and V. Restrepo. 2002. Survival of reef fish after rapid depressurization: field and laboratory studies. Pages 148-151 *in* J.A. Lucy and A.L. Studholme, editors. Catch and release in marine recreational fisheries. American Fisheries Society, Symposium 30, Bethesda, Maryland.

Burns, K. M., N.F. Parnell, and R.R. Wilson. 2004. Partitioning release mortality in the undersized red snapper bycatch: comparison of depth vs. hooking effects. Mote Marine Laboratory Technical Report No. 932. 36 p.

Burns, K. M. and B. D. Robbins. In Prep. Cooperation long-line sampling off the west Florida shelf shallow grouper complex: Characterization of life history, undersized bycatch and targeted habitat. Mote Marine Laboratory Technical Report No. 1119.

Burgos, J. M. 2001. Life history of the red grouper (*Epinephelus morio*) off the North Carolina and South Carolina coast. Master's Thesis. University of Charleston, South Carolina. 90 p.

Cadima, E.L. 2003. Fish Stock Assessment Manual. FAO Fish. Tech. Pap. 393, 161 p. FAO, Rome.

Chih, Ching-Ping. 2006. Selected sampling issues regarding the length/age frequency distributions of red groupers caught by commercial fisheries in the Gulf of Mexico from 1984 to 2005. Sustainable Fisheries Division Contribution No. SFD-2006-028. 42 p. SEDAR 12 DW-10.

DeVries, D.A., J.H. Brusher and G.R. Fitzhugh. 2006. Spatial and temporal patterns in demographics and catch rates of red grouper from a fishery-independent trap survey in the northeast Gulf of Mexico, 2004-2005. Draft working document. SEDAR12-DW-08. Panama City Laboratory Contribution 06-13. 7 p.

Fischer, A.J., M.S. Baker, Jr., and C.A. Wilson. 2004. Red snapper (Lutjanus campechanus) demographic structure in the northern Gulf of Mexico based on spatial patterns in growth rates and morphometrics. Fisheries Bulletin 102:593-603.

Fitzhugh, G.R., H.M. Lyon, L.A. Collins, W.T. Walling and L. Lombardi-Carlson. 2005. Update of gag (*Mycteroperca microlepis*) reproductive parameters: Eastern Gulf of Mexico. Draft working document for SEDAR 10 Data Workshop 25 p. SEDAR10-DW-03.

Franks, J.S. 2003. First record of goliath grouper, *Epinephelus itajara*, in Mississippi coastal waters with comments on the first documented occurrence of red grouper, *Epinephelus morio*, off Mississippi. Gulf and Caribbean Fisheries Institute. 56: 295-306.

Goodyear, C. P. 1994. Biological reference points for red grouper: effects of uncertainty about growth. NMFS, Southeast Fisheries Science Center, Miami, FL, Contribution: MIA-93/94-60, 26p.

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

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

Hoenig, J. M., P. Pepin, and W.D. Lawing. 1990. Estimating relative survival rate for two groups of larval fishes from field data: do older larvae survive better than young? Fishery Bulletin 88: 485-491.

Ingram, W., M. Grace, L. Lombardi-Carlson, and T. Henwood. 2006. Catch rates, distribution and size/age composition of red grouper, *Epinephelus morio,* collected during NOAA Fisheries Bottom Longline Surveys from the U.S. Gulf of Mexico. SEDAR-12-DW-05. 2006.

Jensen, A.L. 1996. Beverton and Holt life history invariants result from trade-off of reproduction and survival. Canadian Journal Fisheries and Aquatic Sciences 53:820-822.

Jorgensen, C., B. Ernande, O. Fiksen, and U. Dieckmann. 2006. The logic of skipped spawning in Fish. Canadian Journal Fisheries and Aquatic Sciences 63:200-211.

Koenig, C. Preliminary results of depth-related capture-release mortality of dominant reef fish in the eastern Gulf of Mexico. Report to the Gulf of Mexico Fishery Management Council. 5 p.

Koenig, C.C. and F. C. Coleman. 2006. Demographics, density, and seasonal movement patterns of reef fish in the northeastern Gulf of Mexico associated with marine reserves. MARFIN Grant NA17FF2876 final report. 62 p.

Lindeman, K.C., R. Pugliese, G.T. Waugh, and J.S. Ault. 2000. Development patterns within a multispecies reef fishery: management applications for essential fish habitats and protected areas. Bulletin of Marine Science 66:929-956.

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.

Lombardi-Carlson, G.R. Fitzhugh and J. J. Mikulas. 2002. Red grouper (*Epinephelus morio)* age – length structure and description of growth from the eastern Gulf of Mexico: 1992-2001. NMFS, SEFSC, Panama City Laboratory Contribution 2002-6. 19 p + Tables and Figures.

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. Draft working document for SEDAR 12 Data Workshop. 43 p. SEDAR 12-DW-03.

Moe, M. A., Jr. 1966. Tagging fishes in Florida offshore waters. Florida Board of Conservation Marine Research Laboratory Technical Series. No. 49: 1-40.

Moe, M.A., Jr. 1969. Biology of the red grouper (*Epinephelus morio* Valenciennes) from the eastern Gulf of Mexico. Professional Paper Series Marine Laboratory of Florida. No. 10. 95 p.

Moe, M. A., Jr. 1972. Movement and migration of south Florida fishes. Florida Department of Natural Resources Marine Research Laboratory Technical Series. No. 69: 1- 25.

NMFS. 2002. Status of red grouper in United States Waters of the Gulf of Mexico during 1986-2001. NOAA, NMFS, Southeast Fisheries Science Center, Sustainable Fisheries Division Contribution No. SFD-01/02-175. (plus Addendum).

Pears, R.J., J.H. Choat, B.D. Mapstone, and G.A. Begg. 2006. Demography of a large grouper, *Epinephelus fuscoguttatus*, from Australia's Great Barrier Reef: implications for fishery management. Marine Ecology Progress Series 307:259-272.

Porch, C.E. 1998. Estimating Atlantic bluefin tuna mortality from the release and recapture dates of recovered tags. International Commission for the Conservation of Atlantic Tunas, Collected Volume of Scientific Papers, SCRS/98/65, Miami, Florida.

Quinn, T.J., and R.B. Deriso. 1999. Quantitative Fish Dynamics, 542 p. Oxford Univ. Press, New York, NY.

RFSAP. 2002. September 2002 report of the Reef Fish Stock Assessment Panel. Gulf of Mexico Fishery Management Council, Tampa, Florida.

Richardson, L.R., and J.R. Gold. 1997. Mitochondrial DNA diversity in and population structure of red grouper, *Epinephelus morio*, from the Gulf of Mexico. Fisheries Bulletin 95:174-179.

Rideout, R.M., G.A. Rose, and M.P.M. Burton. 2005. Skipped spawning in female iteroparous fishes. Fish and Fisheries 2005: 50-72.

Sauls, B. 2005. Headboat at-sea sampling protocols. Florida Fish and Wildlife Conservation Commission Internal Report. 8pp.

Schirripa, M.J., C.M. Legault, and M. Ortiz. 1999. The red grouper fishery of the Gulf of Mexico: assessment 3.0. SEFSC, SFD. Contribution No. SFD – 98/99- 56.

SEDAR 10-SAR1. 2006. Stock assessment report of Gulf of Mexico and South Atlantic gag grouper. SEDAR Charleston, SC. 449 p.

Southeast Fisheries Science Center. 1995. Characterization of the reef fish fishery of the eastern U.S. Gulf of Mexico. Report to the Gulf of Mexico Fishery Management Council

Wilson, R.R. and K.M. Burns. 1996. Potential survival of released groupers caught deeper than 40 m based on shipboard and *in-situ* observations, and tag-recapture data.
Bulletin of Marine Science 58: 234-247.

Zatcoff, M.S., Ball, A.O., and G.R. Sedberry. 2004. Population genetic analysis of red grouper, *Epinephelus morio*, and scamp, *Mycteroperca phenax*, from the southeastern U.S. Atlantic and Gulf of Mexico. Marine Biology. 144:769-777.

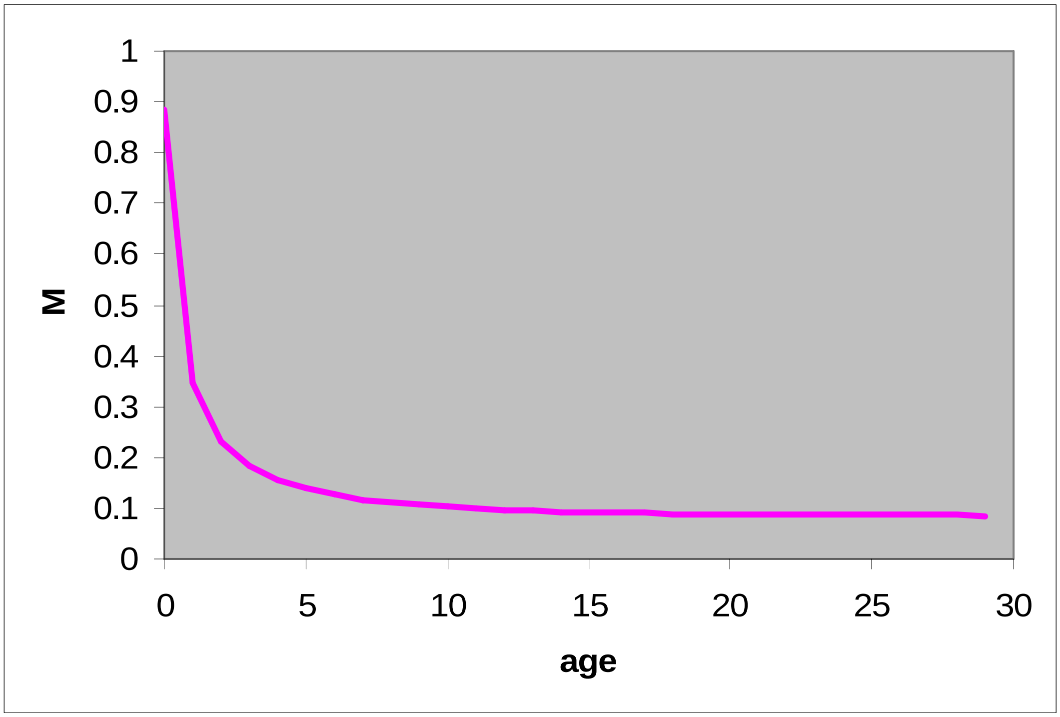


Figure 2.1. Age-varying M estimated using the Lorenzen approach.

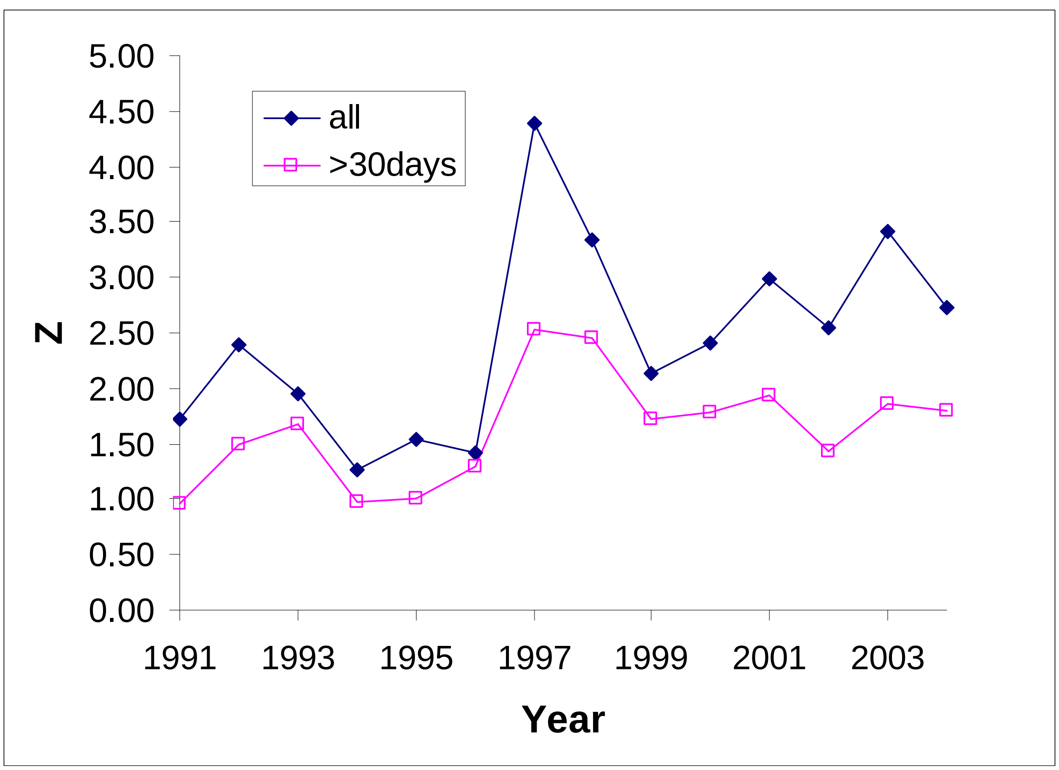


Figure 2.2. Annual mortality rates derived from tag and recapture data. One estimate used all

recaptures and a second estimate was based on recaptures that were made after at least 30 days.

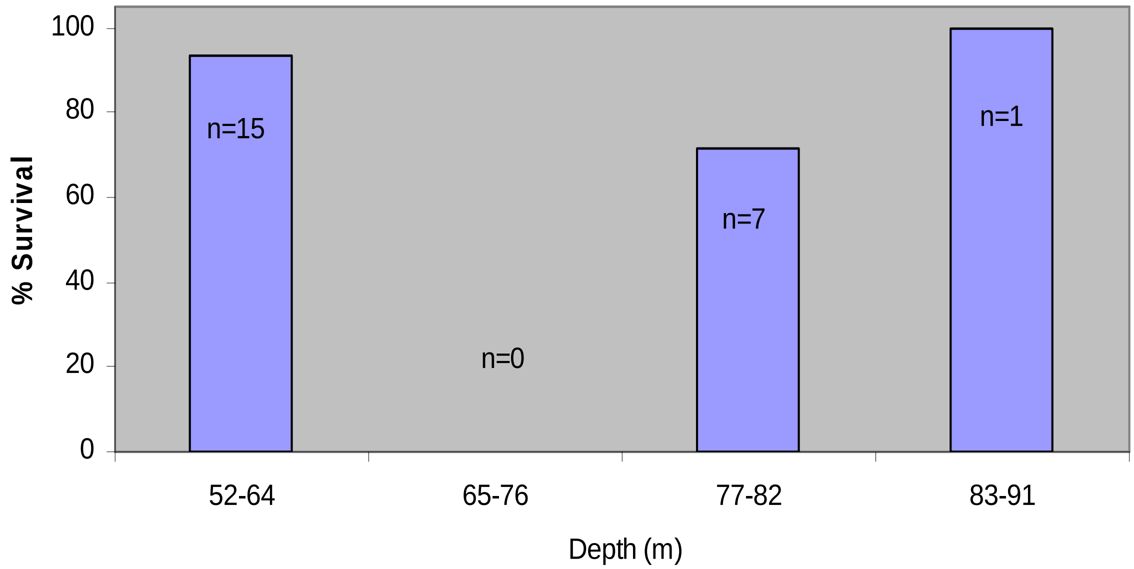


Figure 2.3. Red grouper survival (determined from pre-release method) at various depths for fish caught in commercial reef fish traps.

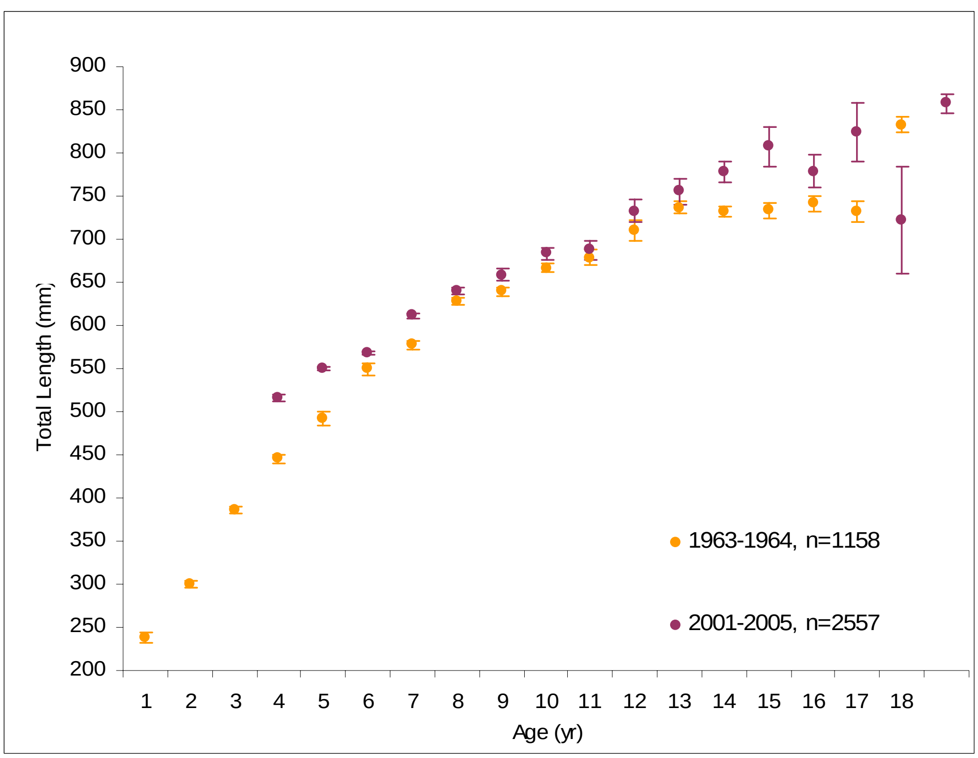


Figure 2.3. Size-at-age comparisons (mean with standard error bars) for those age classes n>5 from commercial hand-line caught red grouper from the west Florida shelf between two time periods (1960s, Moe 1969; 2000s, Lombardi-Carlson et al. 2006).

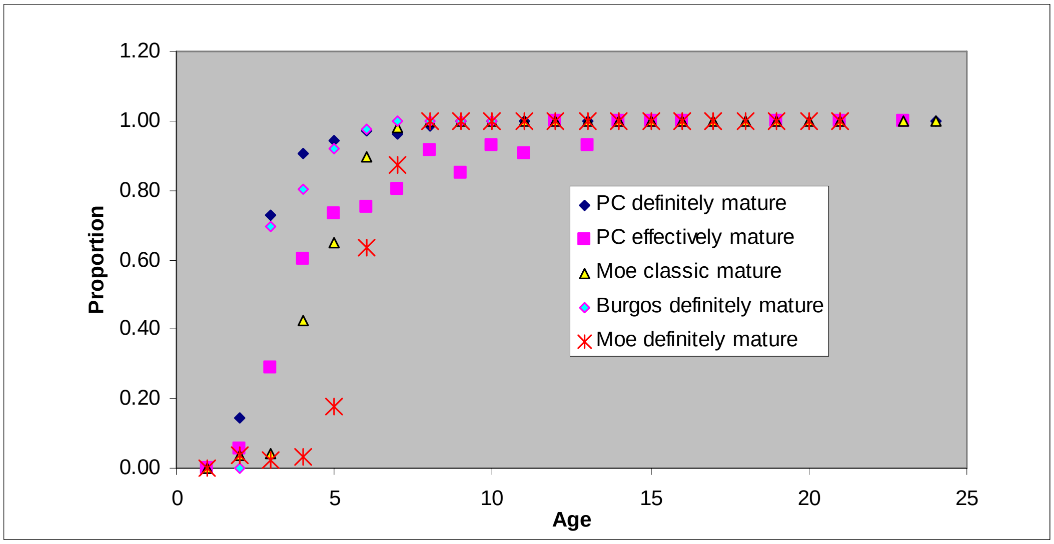


Figure 2.4. Maturity data sets for red grouper. Note that the Burgos dataset is for South Atlantic red grouper and is shown here for comparison.

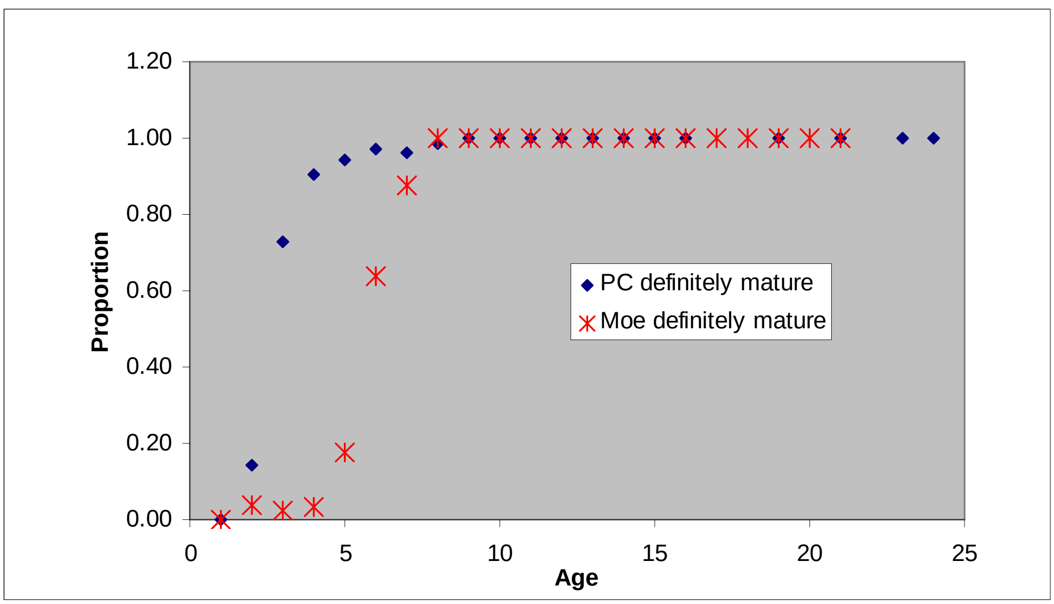


Figure 2.5. The PC maturity data set (1991-2005) contrasted with Moe's (1969) data set.

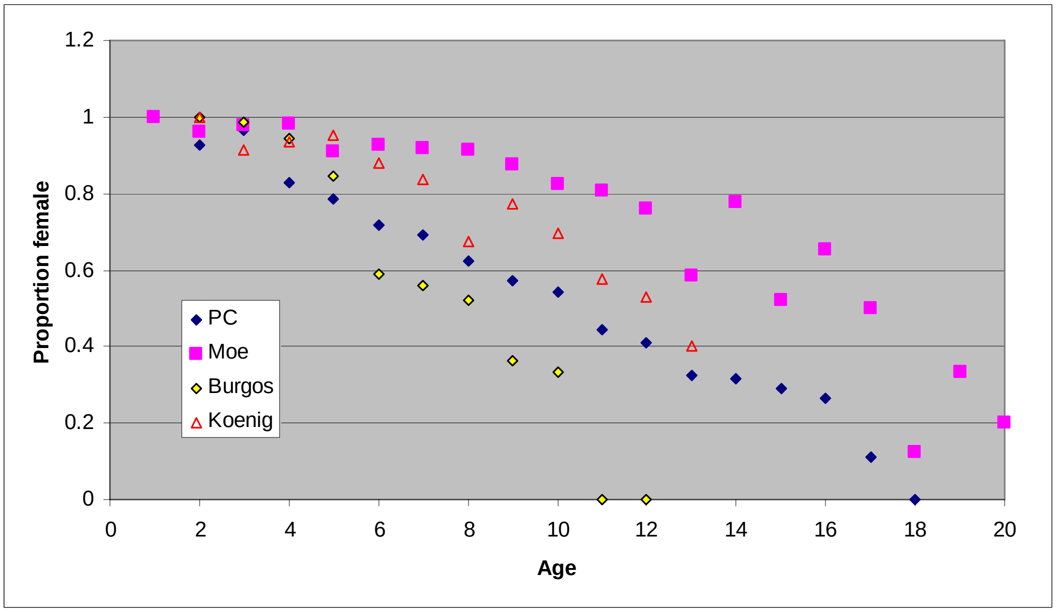


Figure 2.6. Female-to-male transition data sets for red grouper. Note that the Burgos dataset pertains to the South Atlantic and is shown here for comparison.

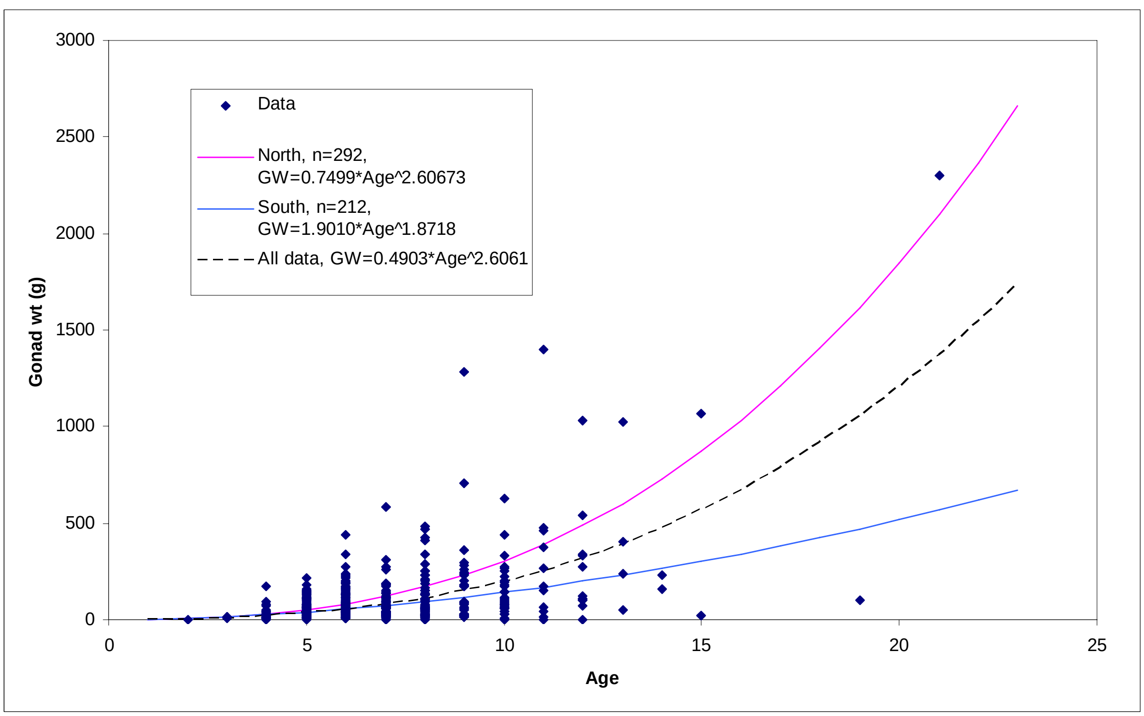


Figure 2.7. A proxy for fecundity based upon gonad weight at age for active (yolked) females sampled during March-May.

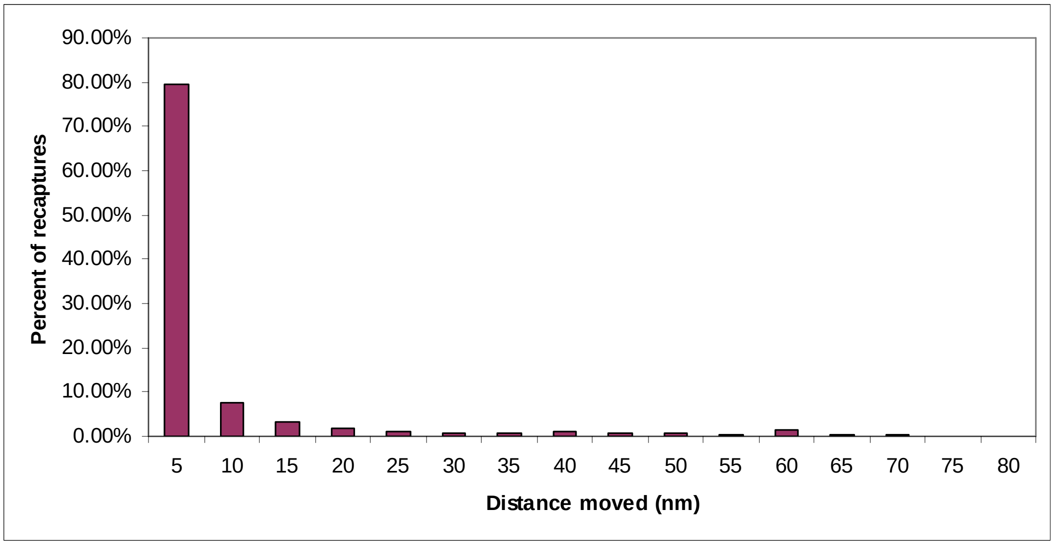


Figure 2.8. Distance moved for tagged red grouper (Mote Marine Laboratory tagging database).

Table 2.1. Meristic regressions for red grouper from the Gulf of Mexico (1991-2005). Refer to SEDAR-12-DW-03, for details.

Conversion and Units	Equation	n	r^2 values	Data Ranges
FL (mm) to TL (mm)	TL = 1.05 * FL – 5.95	4954	0.99	TL (mm): 171 – 954 FL (mm): 171 – 910
TL (mm) to W. Wt (kg)	W. Wt = 6 x 10^{-09} * ($TL^{\wedge 3.14}$)	3627	0.99	TL (mm): 213 – 954 W. Wt (kg): 0.14 – 16.96
FL (mm) to W. Wt (kg)	W. Wt = 7 x 10^{-09} * ($FL^{\wedge 3.14}$)	3101	0.95	FL (mm): 211 – 965 W. Wt (kg): 0.14 – 16.96
TL (mm) to G. Wt (kg)	G. Wt = 7 x 10^{-08} * ($TL^{\wedge 2.76}$)	629	0.99	TL (mm): 458 – 980 G. Wt (kg): 0.82 – 15.05
FL (mm) to G. Wt (kg)	G. Wt = 4 x 10^{-9} * ($FL^{\wedge 3.24}$)	2844	0.97	FL (mm): 420 – 890 G. Wt (kg): 0.91 – 16.69

3. Commercial Fishery

3.1 Overview

The Commercial Working Group discussed several issues concerning the landings history, calculation of the numbers of fish discarded at sea, and methods and stratification for developing catch at size. The landings history issues related to the boundary between the Gulf of Mexico and U.S. South Atlantic management units, the amount of red grouper included landings recorded as unclassified grouper and when the fishery shifted from landing fish whole to landing gutted fish.

3.2 Commercial Landings

specifications

In general the area designations used to separate red grouper landings in Gulf of Mexico and Atlantic waters were the same as those used for gag grouper (SEDAR 10) Waters North of the Florida Keys were assigned to the Gulf of Mexico and waters south of the Keys were assigned to the Atlantic with the exception that all of the Tortugas area (statistical area 2) was included in the Gulf.

As has been done in previous assessments and as recommended by the Life History working group, landings from United States Gulf of Mexico waters (statistical areas 2-21 and parts of area 1 as defined above) were considered to be from the assessed stock. Landings from outside those areas were excluded.

NOAA-SEFSC (National Oceanographic and Atmospheric Administration - Southeast Fisheries Science Center) landings were compared to FMRI (Florida Marine Research Institute) landings. Small differences (about 0.5% of the annual total) were identified in data from 1998 and 2001.

Where possible the gear and fishing area information reported by dealers was replaced by gear and fishing area reported in fishermen's logbook, because the first hand information was considered more accurate. In addition some monthly (the minimum temporal strata retained by NOAAA-SEFSC) landings reports from dealers have no fishing area and gear information, including Florida in 1977-1996 and Louisiana 1990-1999. Annual Florida Canvass data collected by NOAA port agents were used to assign gear and fishing area to Florida monthly landings from 1977-1992 . From 1993-2005 NOAA logbook data were used to assign gear and fishing area to Florida, Alabama, Mississippi and Texas landings. Logbook data were also used to assign gear and area to Louisiana monthly landings from 1990-2005. This approach has been used for grouper and snapper assessments for several years and the group agreed the treatment was appropriate.

The stratification to be used to develop the commercial catch at age for the assessment was considered. The objectives were to separate the primary fisheries and to separate strata which showed differences in size or age composition if substantial proportions of the landings were involved. The group decided to use the following fisheries:

1. Manual hook and line (gear codes 600-660 except for code 613), (referred to as handline).
2. Electric or hydraulic 'bandit' hook and line (gear code 613).
3. Long line (gear codes 675-677)
4. Traps (gear codes 300-355)
5. Other gears would be grouped into handlines to avoid confidentiality issues.

While the bandit rig fishery has existed for decades, the bandit rig landings were aggregated with handline in the data bases for many years. In the logbook data base bandit rig was not recorded until 2002. The size composition information showed differences between handline and bandit rig (see below), so for 2002-2005 handline and bandit rig were separated. Commercial catch rates from log books have bandit rig and handline combined. Therefore while bandit rig and handline landings are separated for 2002-2005, it is expected that the calculated catch at age for the two fisheries will be aggregated for the assessment.

The group then discussed what set of tables to include in the commercial landings section. The following are decided on.

1. Reported Landings of Red Grouper
2. Reported Landings of Unclassified Grouper
3. Calculated landings of Red Grouper (reported red grouper plus a Portion of Unclassified Grouper)

The group discussed how to apportion red grouper landings to the unclassified grouper landings. Red grouper was reported in the data starting in 1986 when the species codes for several groupers came into use. Before 1986 three species codes were primarily used; they were: unclassified grouper (NOAA Fisheries code 1410) goliath grouper and warsaw. Unclassified grouper coding continues in the data to the present, although its use has decreased dramatically over the years. After receiving much input from the Florida industry representatives, the group decided to apply the average ratio of red grouper to unclassified grouper stratified by gear and catch area from 1986-1989 back over time for hand line (including bandit gear) and traps. For long-line gear the same method would be applied to the years 1982-1985, with the landings prior to that apportioned to deep-water groupers. Long-lining for groupers occurred predominately if not entirely in the deeper waters from 1979-1981 with yellowedge grouper and speckled hind reportedly dominating the landings. Long-lining began to move into shallower waters and targeting red grouper in mid 1982; it was arbitrarily assumed that 20% of the 1982 Florida unclassified grouper landings would be considered as having come from inshore waters and thus were likely to have included red grouper.

For 1986-2006 (when most grouper landings were reported by species) two proportions were used to calculate the amount of red grouper included in unclassified groupers: (1) the proportion of the total unclassified grouper landings which came from trips which reported only unclassified groupers (no classified groupers) using data reported in Florida trip tickets and (2) the proportion of the total classified groupers which were red groupers. The rationale for using the first proportion was that if the trip was broken out by grouper species, the dealer was probably diligent in reporting major grouper species correctly (Figure 1 and Table 1). Trips with only unclassified grouper reported (no classified groupers) accounted for roughly 100,000 - 200,000 lb of landings in the late 1980's (Figure 1). The second proportion (the annual average ratio of red grouper to total classified groupers (codes 1411-1430) stratified by gear) was applied to calculated amount of unclassified grouper landings from trips which only reported unclassified groupers. These calculations were done by state, year and gear. For Alabama – Texas where red grouper landings are quite low relative to Florida, only the second proportion was used.

The Gulf of Mexico Fishery fishery management Council establishes quotas for groupers in gutted weight, therefore landings are presented in landings as gutted weight in pounds. Weight in the NOAA-SEFSC General Canvass data are generally in whole pounds. They were adjusted to whole pounds from the landed weight by a factor of 1.18. The exception to this are Florida data prior to 1986 which are on the system in 'as landed' condition. Much research was done, consulting port agents and industry personnel to determine what this landed condition was. Input from both sources indicates that gutting fish at sea began circa 1977, becoming the norm by 1980 and universal by 1982. The proper gutted to whole weight conversion factor is 1.048 (Goodyear and Schirripa 1993). This is different from the one used in the data. The group decided to use 1977 as the year to begin application of the factor. Thus all Florida landings before 1977 would be considered as landed whole and divided by 1.048 to convert them to gutted weight . In addition the landings for Florida from 1986 to 2005 and all other states in all years were divided by 1.18 to convert them to gutted weight.

Commercial Landings 1963-2005

Reported landings of red grouper and unclassified grouper are presented in Tables 1 and 2. The calculated landings of red grouper (reported red grouper plus a portion of the reported unclassified groupers) are presented in Table 3..

Historical landings

Calculated red grouper landings from the U.S. Gulf of Mexico waters are presented in SEDAR 12 DW-11 for 1880 to 1962. Landings of unclassified groupers are available for some years between 1880 and 1927 and for most years thereafter. The proportions of red grouper in the unclassified groupers and the proportions taken in U.S. waters were used to derive the calculated red grouper landings. The group considered the landings from 1927 to 1962 to be the most reliable because 1927 was the first year that landings were recorded in most years.

The group reviewed Cuban landings from US Gulf waters also from SEDAR 12 DW-11. Data were presented for 1937-1947 with gaps filled in by linear interpolation. After some discussion it decided to accept landings beginning in the year 1937, it being the first year of available data. There was uncrtainty about the reliability of the Cuban landings after the Cuban revolution; the reported Cuban landings may have been the result of Cuban government investment in the fishing industry or the reported landings could have been inflated for political purposes.

Total Commcial Landings 1880-2005

Total calculated commercial landings of red grouper from United States Gulf of Mexico waters are shown in Table 4 and Figure 2.

3.2 Commercial Discards

Handline and Longline Fisheries

Annual calculation of the number of red grouper discarded dead by the commercial fisheries were derived from (1) average discard rates from discard logbook reports provided starting in August 2001 and from (2) the total effort reported by commercial fishermen (SEDAR12-DW-17). In the previous assessment of red grouper (SEFSC 2002), discards were calculated during the age estimation process based on (1) the annual minimum size, (2) the landed catch at age and (3) the average proportion at each age that was below the minimum size; additionally some information from observer sampling that occurred in mid 1990's (Scott-Denton, 1996) was used for the longline fishery. For this assessment and the previous one it was assumed that there were no discards before the imposition of a minimum size in 1990. For this assessment discards were calculated by gear (handline, longline and trap) and whether or not the trip targeted red grouper. A trip was assumed to have targeted red grouper if other species associated with red grouper were landed on that trip; associated species were defined using the Stephens and McCall (2004) method.

Average discard rates per trip were estimated using a generalized linear modeling approach (GLM). Discard rates were estimated from commercial trips and stratified by gear (handline, longline and trap). For these analyses statistical areas were limited to areas 1-11 for handline, areas 1-10 for longline, and areas 1-8 for trap because of much reduced numbers of fishing trips outside of those areas. The GLM was used to identify factors such as year, quarter (Jan-Mar, Apr-Jun, etc.), days at sea, area, crew size, and targeting which significantly influenced the discard rate. For handline and longline, whether or not red grouper was targeted, and the area of fishing were determined to be significant factors, while for traps, only the factor whether or not red grouper was targeted was determined to be significant.

The calculation of total discards by gear were derived from the least square mean discard rates from the GLMs for significant strata (area and targeting for longline and handline) multiplied times the total annual effort in each of those strata. Since the GLMs indicated that there were not significant differences among years and the minimum size had been constant since 1990, the mean discard rates were applied to trips from 1990 through 2000 as well as 2001-2005 under the assumption that the 2001-2005 rates applied to the earlier period. The 1990-1992 calculations of discards were potentially an under-estimate because in those years only a random sample of 20% of Florida vessels were required to report to the coastal logbook program. Therefore the calculated discards for the years 1990-1992 were multiplied by five to provide final discard values. The discards calculated per trip were reviewed and some extremely high values (such as 1000s of discards on a handline trip of only a few days) were observed particularly in the handline fishery. Such values were considered illogical, and therefore the highest five percent of the discard estimates for each fishery was eliminated (McCarthy 2006a, SEDAR12-DW-17).

The commercial statistics working group reviewed the calculated discards for the handline fishery (Table 5) and concluded that they seemed reasonable. However the calculated numbers of discards from the longline fishery (Table 6) were substantial lower than for the handline fishery and concerns were raised, because the longline landings were larger than the handline landings (Table 4) while the fisheries occur in the same or similar areas. The completeness of longline red grouper discard reporting to the discard logbook program was questioned. Bob Spaethe, commercial fisherman, agreed to will query other commercial longline fishermen about their discard rates. The group also recommended that other possible sources of information on longline and handline discard rates be reviewed. Those sources were the NMFS fishery independent bottom longline survey from recent years and NMFS bottom longline observer data from the mid 1990's. An addendum to SEDAR-12-DW-17 (McCarthy, 2006b) examined proportions of red grouper catch that typically would have been discarded by commercial fishermen (for reasons such as regulatory measures) and compared those values to the calculated discard values from the logbook program. For the longline fishery the proportion of red grouper discards to pounds landed calculated from logbook reports was as low as one tenth of the same proportions calculated from the NMFS bottom longline survey (2004-2005) and from NMFS longline observer data (1995). In contrast for the handline fishery the discards to landings ratios calculated from logbook reports were similar to the discards to landings ratios calculated from the bottom longline survey and the observer data (handline and longline in the mid 1990s). The group recommended that an additional set of longline discards be calculated by multiplying the handline red grouper discards to landings ratios times the longline landings in each area and targeting stratum (Table 7). The calculated discards from the trap fishery are presented in Table 8; those values are quite low compared to the handline and longline fisheries, however similarly low discard rates were reported by NMFS observers for the trap fishery in the mid 1990s.

Shrimp Trawl Bycatch

SEDAR12-DW-7 provided estimates of red grouper caught in shrimp trawls using revised estimation methodology and data from a small number of historical, research trawl surveys which covered west Florida waters and shrimp fishery observers. Red grouper were observed sporadically in the trawl surveys and the observer data. The summer and fall groundfish surveys do not cover the majority of west Florida waters and only one red grouper has been caught, so data from those surveys were not used. The research surveys which included west Florida waters were not conducted annually so that it was considered inadvisable to estimate annual bycatch values. Overall the median bycatch was estimated to be 8,400 red grouper with a 95% confidence interval of 3,000-24,000 fish. Shrimp fishery observers recorded the length of 3 red grouper, and their average length was about 10".

3.3 Commercial Length Composition

The working group on age composition estimation recommended that one of the methods to be investigated would be the probabilistic approach developed by Goodyear (1994) used in previous assessments. In that approach age composition is derived from the probability of ages for an observed length given a growth curve. Length frequency distributions for red groupers caught by commercial fisheries in the Gulf of Mexico were constructed from data extracted from the Trip Interview Program (TIP) data base. Two factors that may influence length frequency distributions (gear and area) were examined. The length information from TIP used in this analysis included only data collected from unsorted landings to minimize the potential bias of the samples; samples from landings sorted into size categories were excluded.

Commercial length samples of red grouper were collected between 1984 and 2005. There were 3,61027l samples collected during this period with a mean of 16,410 lengths collected per year with a standard deviation of 13,022. However, during the period from 1984 through 1990 there was a large fraction of lengths that were collected from sorted catches. These samples were deleted from the analysis, resulting in few samples during this period (Figure 3). The resulting data set had a mean of 10,038 lengths collected per year, with a standard deviation of 15,327. The strata used for the data consisted of 2 areas and 4 gears by year. There were fewer samples before 1995, resulting in many cells without samples for the period before 1995 (Table 9). Over the whole period of length collection, the majority of lengths were collected from the longline fishery with more longline samples collected in the southern area (Figure 4).

The length composition by three gears (handline, longline and trap) and three regions was reviewed by Chih in SEDAR12 DW 9, and some differences were observed. The working group reviewed length compositions by four gears (manual handline, powered handline, longline and trap) and two areas (north and south of 28^{o} N) (Figure 4). Previous work had indicated that there might be differences in the sizes of groupers exploited by manual and powered handlines, and Lombardi-Carlson *et. Al* (SEDAR12 DW 3) concluded that there were geographic differences in red grouper size and age. All of the gears had modal proportions at 20 or 21 inches in both areas and generally had similar size distributions. In the northern area there appeared to be lower proportions of larger red grouper than in the southern area. Also it was noted that powered handlines appeared to exploited higher proportions of larger fish than manual handlines. Based on these differences the working group recommended that when age composition was calculated from size composition that the geographic differences and the differences between the types of handline be accounted for to the extent possible, recognizing that subsequently the calculated age compositions would be aggregated into region wide totals for handline, longline and trap.

The life history working group recommended that release mortality be calculated as a function of depth and was concerned that there might be a relationship between size and depth in the commercial fishery and that that relationship might have changed over time. An analysis demonstrated that there was no difference in median length over time by gear (Figure 5) or depth (deep > 40 fathoms, shallow < 40 fathoms) (Figure 6). There were also no differences in mean length by gear and area (Table 9). The length proportions by depth and period of years for longline and manual handline (Figure 7) showed some differences in their distribution, however most of these differences were most likely attributable to strata with small sample sizes. Even though there were some differences seen in the distributions, the general trends of the distributions were similar across strata. After 1996 the distributions were more similar; in those years a larger amount of random samples were collected (Figure 7).

Literature cited

Chih, C-P. 2006. Length frequency distributions for red groupers caught by commercial fisheries in the Gulf of Mexico from 1984 to 2005. SEDAR12 DW 9. 38p.

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. SEDAR12 DW 3. 43p.

McCarthy, K. 2006a. Calculated red grouper discards by vessels with federal permits in the Gulf of Mexico. SEDAR 12-DW-17. Sustainable Fisheries Division Contribution SFD-2006-030.

McCarthy, K. 2006b. Calculated red grouper discards by vessels with federal permits in the Gulf of Mexico: Addendum. SEDAR 12-DW-17. Sustainable Fisheries Division Contribution SFD-2006-044.

Scott-Denton, E. 1996. Characterization of the reef fish fishery of the eastern U.S. Gulf of Mexico. MARFIN Grant No. 95MFIH07. Supplementary Report.

SEFSC. 2002. Status of red grouper in United States waters of the Gulf of Mexico during 1986-2001. Nat. Mar. Fish. Serv. Miami Lab. Contrib. SFD-01/02-175. 65 p.

Stephens, A. and A. MacCall. 2004. A multispecies approach to subsetting logbook data for purposes of estimating CPUE. Fish. Res. 70:299-310.

Table 1. Proportion of total unclassified group landings from west Florida which were calculated to have come from trips with only unclassified groupers reported (no classified groupers reported). If less than 10,000 lb were redorded in the Florida trip ticket data base for a year and gear, then a multi-year average was used (handline 1997-2005, longline 1994-2005 and trap all years except 1987).

	handline	longline	trap
1986	0.475	0.077	0.624
1987	0.583	0.364	0.573
1988	0.679	0.446	0.624
1989	0.610	0.248	0.670
1990	0.505	0.238	0.717
1991	0.380	0.241	0.612
1992	0.439	0.167	0.576
1993	0.477	0.133	0.575
1994	0.407	0.142	0.575
1995	0.458	0.123	0.575
1996	0.429	0.099	0.579
1997	0.446	0.096	0.579
1998	0.482	0.108	0.578
1999	0.504	0.094	0.579
2000	0.549	0.091	0.593
2001	0.577	0.098	0.593
2002	0.545	0.068	0.593
2003	0.529	0.068	0.593
2004	0.529	0.068	0.593
2005	0.529	0.068	0.593

Table 2. Reported landings of classified groupers from United States Gulf of Mexico waters. Landings relatively small landings from 1983-1985 are not show because they could be confidential

	bandit	handline+	longline	trap	total
1963	-	-	-	-	-
1964	-	-	-	-	-
1965	-	-	-	-	-
1966	-	-	-	-	-
1967	-	-	-	-	-
1968	-	-	-	-	-
1969	-	-	-	-	-
1970	-	-	-	-	-
1971	-	-	-	-	-
1972	-	-	-	-	-
1973	-	-	-	-	-
1974	-	-	-	-	-
1975	-	-	-	-	-
1976	-	-	-	-	-
1977	-	-	-	-	-
1978	-	-	-	-	-
1979	-	-	-	-	-
1980	-	-	-	-	-
1981	-	-	-	-	-
1982	-	-	-	-	-
1983	-	-	-	-	-
1984	-	-	-	-	-
1985	-	-	-	-	-
1986	-	3,087,810	2,478,110	710,940	6,276,861
1987	-	2,477,761	3,718,034	440,824	6,636,618
1988	-	1,951,970	2,137,718	533,623	4,623,311
1989	-	3,709,499	3,044,123	576,882	7,330,504
1990	-	2,436,258	2,010,773	336,088	4,783,120
1991	-	2,126,028	2,584,269	373,911	5,084,208
1992	-	1,448,740	2,406,862	601,558	4,457,160
1993	-	1,356,806	4,300,409	715,294	6,372,509
1994	-	1,281,260	2,702,021	914,275	4,897,556
1995	-	1,221,113	2,464,036	1,056,394	4,741,542
1996	-	902,329	2,992,663	558,529	4,453,522
1997	-	1,005,281	3,135,603	707,030	4,847,914
1998	-	791,285	2,840,646	313,271	3,945,203
1999	-	1,256,428	3,944,001	772,130	5,972,559
2000	-	1,791,583	2,989,281	1,056,491	5,837,355
2001	-	1,661,578	3,534,933	767,662	5,964,173
2002	890,725	858,824	3,207,436	949,671	5,906,656
2003	713,308	433,720	3,067,598	722,936	4,937,561
2004	954,815	484,106	3,533,486	775,294	5,747,701
2005	1,055,772	438,848	3,304,285	610,315	5,409,219

Table 2. Reported landings of unclassified groupers from United States Gulf of Mexico waters. Fish trap landings are combined with handline+ because the reported amounts were often low and could have been from one or two vessels or dealers and thus would have been confidential.

	bandit	handline+	longline	total
1963		6,076,697	-	6,076,697
1964		6,955,683	-	6,955,683
1965		7,691,431	-	7,691,431
1966		6,893,927	-	6,893,927
1967		5,673,056	-	5,673,056
1968		6,129,853	-	6,129,853
1969		7,004,444	-	7,004,444
1970		6,845,063	-	6,845,063
1971		6,329,207	-	6,329,207
1972		6,617,656	-	6,617,656
1973		5,053,819	-	5,053,819
1974		5,647,069	-	5,647,069
1975		6,819,019	-	6,819,019
1976		5,708,300	-	5,708,300
1977		4,750,193	-	4,750,193
1978		4,405,684	-	4,405,684
1979		6,050,636	45,918	6,096,554
1980		6,060,006	701,039	6,761,045
1981		6,111,185	3,628,801	9,739,986
1982		5,548,103	6,546,482	12,094,585
1983		4,785,793	4,566,406	9,352,199
1984		5,338,581	3,824,822	9,163,404
1985		6,843,901	3,799,440	10,643,341
1986		241,738	325,333	567,072
1987		290,106	362,711	652,818
1988		414,269	298,431	712,700
1989		306,577	195,142	501,718
1990		140,900	111,921	252,821
1991		79,986	106,926	186,911
1992		97,561	88,426	185,988
1993		56,618	124,191	180,809
1994		23,062	45,211	68,274
1995		16,972	53,247	70,219
1996		9,997	38,479	48,476
1997		13,362	53,599	66,961
1998		26,378	75,932	102,311
1999		11,786	63,563	75,349
2000		12,005	35,979	47,984
2001		13,635	49,606	63,242
2002	4,373	4,366	38,102	46,841
2003	2,971	1,096	23,105	27,172
2004	5,595	1,915	28,292	35,802
2005	6,415	922	14,758	22,095

Table 3. Calculated landings of red grouper in United States Gulf of Mexico waters, based on reported landings of red grouper, unclassified grouper and classified groupers. Calculated landings by traps in several years (before 1982 in the south) are included in handline because the trap landings may be confidential.

	bandit		handline		longline		trap		total
	27N-	28N+	27N-	28N+	27N-	28N+	27N-	28N+	
1963	-	-	2,922,185	645,306	-	-			3,567,492
1964	-	-	2,997,192	1,161,550	-	-			4,158,742
1965	-	-	3,400,529	1,221,486	-	-			4,622,015
1966	-	-	3,513,384	927,669	-	-			4,441,053
1967	-	-	2,984,774	621,478	-	-			3,606,252
1968	-	-	3,194,890	764,497	-	-			3,959,387
1969	-	-	3,866,013	731,153	-	-			4,597,166
1970	-	-	3,990,735	490,522	-	-			4,481,257
1971	-	-	2,630,325	1,194,031	-	-			3,824,356
1972	-	-	2,505,256	1,460,628	-	-			3,965,884
1973	-	-	2,071,327	988,216	-	-			3,059,543
1974	-	-	2,431,559	1,138,033	-	-			3,569,592
1975	-	-	2,873,296	1,451,689	-	-			4,324,985
1976	-	-	2,646,299	1,094,774	-	-			3,741,074
1977	-	-	2,069,739	954,198	-	-			3,023,938
1978	-	-	1,989,353	836,297	-	-			2,825,649
1979	-	-	2,345,535	1,503,555	-	-			3,849,090
1980	-	-	2,455,635	1,447,412	-	-			3,903,047
1981	-	-	2,258,904	1,141,777	-	-			3,400,684
1982	-	-	2,128,708	1,008,346	491,156	324,507			3,952,717
1983	-	-	2,080,792	840,508	2,065,559	998,657			5,985,516
1984	-	-	2,160,940	789,985	2,186,665	300,429	311,570		5,749,589
1985	-	-	2,649,585	1,005,523	1,610,822	462,300	640,413	-	6,368,642
1986	-	-	2,323,615	792,655	2,121,754	360,338	714,626	-	6,312,988
1987	-	-	1,764,126	767,137	2,913,428	828,976	444,230	-	6,717,896
1988	-	-	1,079,115	955,975	1,775,908	396,335	465,243	69,922	4,742,498
1989	-	-	1,583,169	2,156,985	2,406,117	642,163	579,481	-	7,367,915
1990	-	-	921,246	1,533,004	1,478,953	536,848	293,693	45,540	4,809,283
1991	-	-	1,406,954	724,728	2,248,217	340,168	247,420	127,021	5,094,507
1992	-	-	1,137,068	315,865	2,291,491	116,948	293,706	308,200	4,463,278
1993	-	-	620,701	739,132	3,367,469	935,342	392,421	324,565	6,379,630
1994	-	-	572,448	710,731	2,175,091	528,365	334,386	581,835	4,902,857
1995	-	-	591,916	630,509	1,883,329	582,695	457,427	600,273	4,746,149
1996	-	-	483,492	419,084	2,293,802	699,030	309,715	249,025	4,454,147
1997	-	-	482,149	523,361	2,282,861	852,887	350,942	356,284	4,848,484
1998	-	-	415,342	376,300	2,311,823	531,691	167,244	146,170	3,948,571
1999	-	-	541,959	715,165	3,239,157	705,562	312,272	460,594	5,974,708
2000	-	-	888,025	904,052	2,375,844	613,573	424,323	632,477	5,838,293
2001	-	-	712,877	948,881	2,714,253	820,744	277,728	490,018	5,964,501
2002	325,432	565,447	309,096	549,884	2,489,261	718,275	362,099	587,750	5,907,243
2003	321,518	391,927	149,520	284,278	2,459,503	608,173	455,074	267,976	4,937,969
2004	325,482	629,753	151,906	332,414	2,791,789	742,093	386,994	388,614	5,749,046
2005	278,559	778,421	110,556	328,419	2,231,857	1,072,442	352,105	258,229	5,410,588

Table 4. Calculated commercial landings of red grouper from United States Gulf of Mexico waters.

	United States			Cuba	
	handline	longline	trap		total
1880	1,514,570	-	-	-	1,514,570
1881	1,367,907	-	-	-	1,367,907
1882	1,221,243	-	-	-	1,221,243
1883	1,074,579	-	-	-	1,074,579
1884	927,915	-	-	-	927,915
1885	781,251	-	-	-	781,251
1886	634,587	-	-	-	634,587
1887	487,923	-	-	-	487,923
1888	351,072	-	-	-	351,072
1889	382,936	-	-	-	382,936
1890	367,481	-	-	-	367,481
1891	419,686	-	-	-	419,686
1892	471,891	-	-	-	471,891
1893	524,096	-	-	-	524,096
1894	576,301	-	-	-	576,301
1895	604,047	-	-	-	604,047
1896	633,228	-	-	-	633,228
1897	650,743	-	-	-	650,743
1898	637,792	-	-	-	637,792
1899	627,917	-	-	-	627,917
1900	608,068	-	-	-	608,068
1901	583,730	-	-	-	583,730
1902	657,848	-	-	-	657,848
1903	679,978	-	-	-	679,978
1904	698,322	-	-	-	698,322
1905	712,916	-	-	-	712,916
1906	733,623	-	-	-	733,623
1907	741,211	-	-	-	741,211
1908	745,160	-	-	-	745,160
1909	906,095	-	-	-	906,095
1910	1,033,919	-	-	-	1,033,919
1911	1,226,845	-	-	-	1,226,845
1912	1,420,391	-	-	-	1,420,391
1913	1,614,555	-	-	-	1,614,555
1914	1,809,339	-	-	-	1,809,339
1915	2,004,741	-	-	-	2,004,741
1916	2,200,762	-	-	-	2,200,762
1917	2,397,402	-	-	-	2,397,402
1918	2,594,660	-	-	-	2,594,660
1919	2,479,176	-	-	-	2,479,176
1920	2,363,309	-	-	-	2,363,309
1921	2,247,059	-	-	-	2,247,059
1922	2,130,425	-	-	-	2,130,425
1923	2,013,409	-	-	-	2,013,409
1924	1,972,714	-	-	-	1,972,714
1925	1,930,450	-	-	-	1,930,450
1926	1,886,616	-	-	-	1,886,616
1927	1,845,048	-	-	-	1,845,048
1928	1,892,457	-	-	-	1,892,457
1929	2,087,548	-	-	-	2,087,548
1930	1,396,746	-	-	-	1,396,746
1931	1,235,880	-	-	-	1,235,880
1932	1,596,069	-	-	-	1,596,069
1933	2,088,019	-	-	-	2,088,019
1934	2,011,938	-	-	-	2,011,938
1935	2,527,271	-	-	-	2,527,271
1936	3,081,730	-	-	-	3,081,730
1937	3,339,280	-	-	6,486,300	9,825,580
1938	3,071,494	-	-	6,486,300	9,557,794
1939	4,594,140	-	-	6,486,300	11,080,440
1940	3,258,282	-	-	6,486,300	9,744,582
1941	3,486,070	-	-	6,486,300	9,972,370
1942	4,031,547	-	-	2,640,994	6,672,541
1943	4,201,159	-	-	2,029,448	6,230,607
1944	4,743,304	-	-	2,999,945	7,743,249
1945	4,966,420	-	-	1,668,658	6,635,078

	United States			Cuba	
	handline	longline	trap		total
1946	5,397,211	-	-	1,791,966	7,189,177
1947	5,424,857	-	-	1,891,760	7,316,617
1948	5,253,070	-	-	1,968,042	7,221,112
1949	5,362,641	-	-	2,020,812	7,383,453
1950	3,587,538	-	-	2,050,069	5,637,607
1951	4,040,872	-	-	2,055,813	6,096,685
1952	2,557,673	-	-	2,038,044	4,595,717
1953	1,981,046	-	-	1,996,763	3,977,809
1954	1,813,993	-	-	1,931,969	3,745,962
1955	1,669,557	-	-	1,843,662	3,513,219
1956	2,329,844	-	-	1,949,123	4,278,967
1957	2,850,830	-	-	2,773,565	5,624,395
1958	2,921,351	-	-	2,130,822	5,052,173
1959	3,947,231	-	-	-	3,947,231
1960	4,524,671	-	-	-	4,524,671
1961	4,444,277	-	-	-	4,444,277
1962	5,200,851	-	-	-	5,200,851
1963	3,567,492	-	-	1,015,863	4,583,355
1964	4,158,742	-	-	2,173,199	6,331,941
1965	4,622,015	-	-	4,225,336	8,847,351
1966	4,441,053	-	-	5,013,435	9,454,488
1967	3,606,252	-	-	5,271,405	8,877,657
1968	3,959,387	-	-	5,529,375	9,488,762
1969	4,597,166	-	-	5,787,345	10,384,511
1970	4,481,257	-	-	5,625,305	10,106,562
1971	3,824,356	-	-	3,144,358	6,968,714
1972	3,965,884	-	-	3,207,059	7,172,943
1973	3,059,543	-	-	6,050,765	9,110,308
1974	3,569,592	-	-	4,030,210	7,599,802
1975	4,324,985	-	-	4,030,210	8,355,195
1976	3,741,074	-	-	4,030,210	7,771,284
1977	3,023,938	-	-	-	3,023,938
1978	2,825,649	-	-	-	2,825,649
1979	3,849,090	-	-	-	3,849,090
1980	3,903,047	-	-	-	3,903,047
1981	3,400,681	-	-	-	3,400,681
1982	3,137,054	815,663	-	-	3,952,717
1983	2,921,300	3,064,216	-	-	5,985,516
1984	2,950,925	2,487,095	311,570	-	5,749,589
1985	3,655,108	2,073,122	640,413	-	6,368,642
1986	3,116,270	2,482,092	714,626	-	6,312,988
1987	2,531,263	3,742,403	444,230	-	6,717,896
1988	2,035,089	2,172,243	535,166	-	4,742,498
1989	3,740,154	3,048,280	579,481	-	7,367,915
1990	2,454,250	2,015,801	339,232	-	4,809,283
1991	2,131,682	2,588,385	374,441	-	5,094,507
1992	1,452,933	2,408,439	601,907	-	4,463,278
1993	1,359,833	4,302,811	716,986	-	6,379,630
1994	1,283,178	2,703,457	916,222	-	4,902,857
1995	1,222,425	2,466,024	1,057,700	-	4,746,149
1996	902,576	2,992,831	558,740	-	4,454,147
1997	1,005,510	3,135,748	707,226	-	4,848,484
1998	791,642	2,843,515	313,414	-	3,948,571
1999	1,257,123	3,944,719	772,866	-	5,974,708
2000	1,792,076	2,989,417	1,056,800	-	5,838,293
2001	1,661,758	3,534,997	767,746	-	5,964,501
2002	1,749,860	3,207,535	949,848	-	5,907,243
2003	1,147,243	3,067,675	723,050	-	4,937,969
2004	1,439,555	3,533,882	775,609	-	5,749,046
2005	1,495,955	3,304,299	610,334	-	5,410,588

Table 5. Calculated numbers of red grouper discards (live and dead) for the Gulf of Mexico handline fishery by year.

Year	Handline Hook-Hours	Calculated Discards
1990	1,291,153	253,082
1991	2,216,730	403,453
1992	2,534,915	495,706
1993	1,247,868	222,057
1994	1,496,248	263,099
1995	1,232,466	244,543
1996	1,788,615	316,766
1997	1,672,711	305,480
1998	1,661,657	301,903
1999	2,089,282	377,218
2000	1,809,033	343,245
2001	1,952,560	361,651
2002	2,009,180	351,833
2003	1,921,667	327,169
2004	1,653,992	290,903
2005	1,391,433	256,428
Total	27,969,508	5,114,537

Highlighted years include calculated discards based upon an expansion factor of 5

Table 6. Calculated numbers of red grouper discards (live and dead) for the Gulf of Mexico longline fishery by year. Discards were calculated by multiplying mean longline discards per hook-hour by hook-hours per trip.

Year	Longline Hooks Fished	Calculated Discards
1990	34,912,585	52,489
1991	60,327,355	87,446
1992	34,392,610	60,841
1993	27,193,873	49,764
1994	34,124,151	60,492
1995	30,466,739	46,246
1996	32,928,479	61,743
1997	37,498,471	69,474
1998	33,117,476	62,706
1999	33,625,178	65,944
2000	33,568,068	61,665
2001	32,260,977	61,994
2002	29,539,584	60,521
2003	32,750,065	64,865
2004	31,083,199	62,178
2005	22,864,859	46,110
Total	540,653,669	974,476

Highlighted years include calculated discards based upon an expansion factor of 5

Table 7. Longline yearly discards (live and dead) calculated using handline red grouper discards to landings ratios multiplied by longline landings. Landings are in pounds (whole weight) of red grouper, calculated discards are reported as number of red grouper.

Year	Landings	Calculated Discards
1990	2,973,347	392,423
1991	5,416,980	823,212
1992	2,694,136	368,905
1993	3,570,115	526,157
1994	2,806,842	410,837
1995	2,698,092	524,889
1996	3,489,131	581,653
1997	3,758,160	627,643
1998	3,533,230	539,625
1999	4,681,540	668,593
2000	3,603,542	551,148
2001	4,030,249	620,265
2002	3,865,969	584,435
2003	3,635,568	538,007
2004	4,023,130	594,490
2005	3,629,712	569,746
Total	58,409,746	8,922,029

Highlighted years include calculated discards based upon an expansion factor of 5

Table 8. Calculated numbers of red grouper discards (live and dead) for the Gulf of Mexico trap fishery by year.

Year	Traps Fished	Calculated Discards
1990	71,030	12,818
1991	137,305	26,097
1992	228,335	52,678
1993	63,565	14,230
1994	64,149	13,452
1995	62,093	12,564
1996	56,156	11,990
1997	41,746	9,846
1998	33,587	6,982
1999	38,843	8,446
2000	37,469	8,953
2001	42,018	9,134
2002	41,500	10,027
2003	32,555	8,017
2004	24,856	6,228
2005	18,733	4,815
Total	993,940	216,277

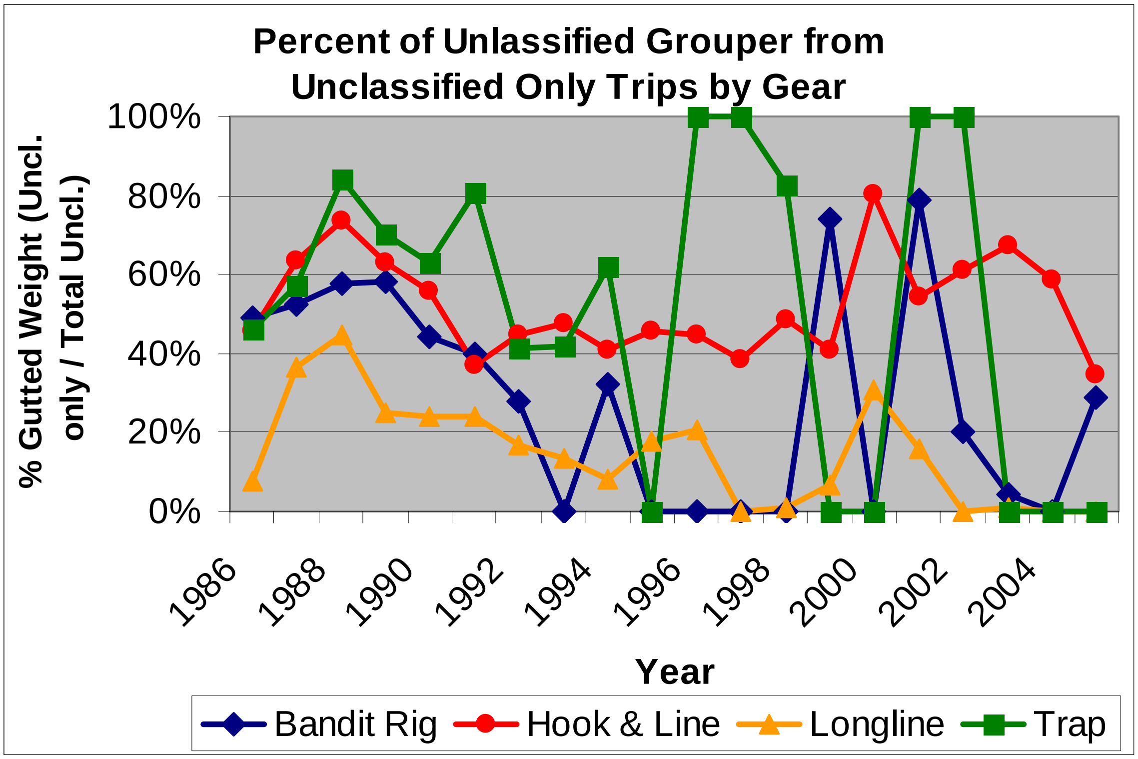
Highlighted years include calculated discards based upon an expansion factor of 5

Table 9. Number of unsorted lengths with area and gear identified, by year.

	North				South				
Year	Handline Manual	Handline Power	Longline	Trap	Handline Manual	Handline Power	Longline	Trap	Total
1984	72	68	0	0	13	540	476	18	1,187
1985	0	0	0	0	11	163	102	140	416
1986	0	0	0	0	2	0	0	0	2
1987	0	0	0	0	21	42	0	9	72
1988	0	0	31	0	0	0	0	0	31
1989	0	0	0	0	0	0	0	0	0
1990	13	0	0	0	12	0	264	19	308
1991	0	0	0	0	160	0	335	49	544
1992	1	0	0	0	48	0	56	42	147
1993	43	5	0	0	95	0	36	11	190
1994	8	39	0	0	184	0	75	33	339
1995	18	100	38	0	14	213	122	54	559
1996	25	239	0	0	3	33	44	36	380
1997	106	150	53	0	53	2	714	85	1,163
1998	196	560	2,762	169	249	827	14,156	51	18,970
1999	962	2,207	7,008	1,378	778	2,656	37,082	380	52,451
2000	978	1,578	5,069	2,097	718	3,998	25,144	517	40,099
2001	1,221	2,094	3,181	3,097	310	3,256	16,131	866	30,156
2002	1,551	1,080	2,359	1,689	140	2,552	15,436	489	25,296
2003	597	858	1,426	1,183	361	1,087	12,224	133	17,869
2004	371	1,024	1,066	20	328	909	8,581	353	12,652
2005	202	617	1,489	0	169	295	5,060	145	7,977

Table 10. Mean length and standard deviation of red grouper lengths by area and gear sampled from unsorted commercial catches.

	Handline Manual		Handline Power		Longline		Trap	
Area	Mean	SD	Mean	SD	Mean	SD	Mean	SD
North	23.24	3.19	23.59	3.32	24.26	3.32	24.07	3.36
South	23.63	3.16	24.98	3.67	25.02	3.63	24.11	3.23



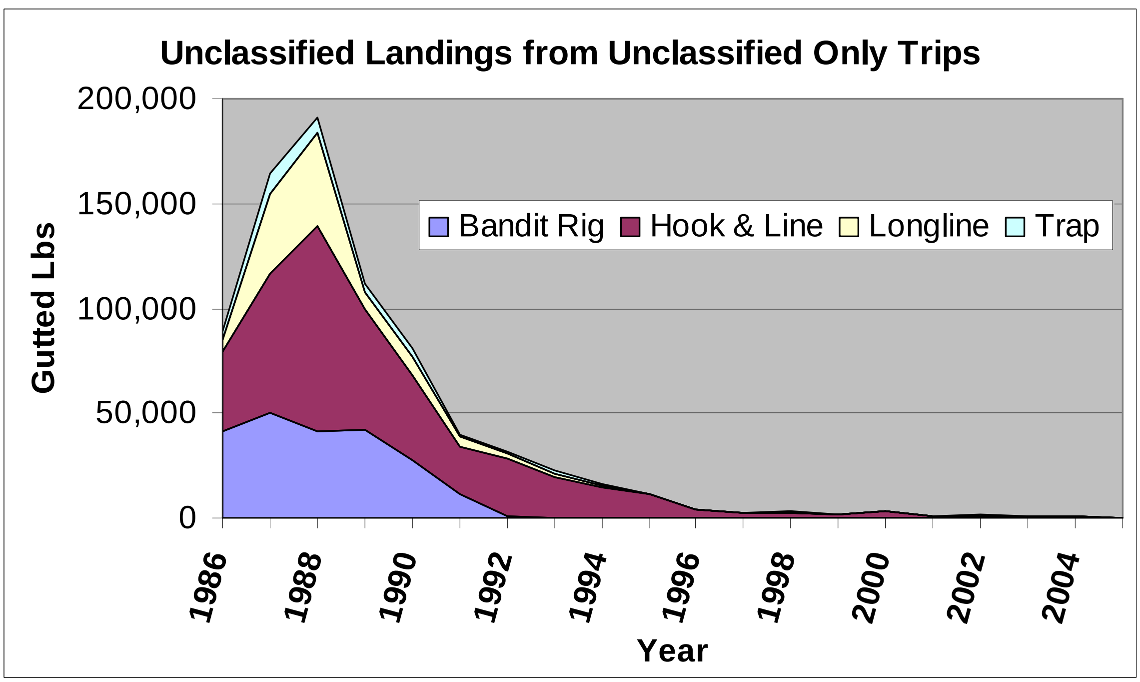


Figure 1. Gear specific proportion of commercial landings of unclassified groupers which were landed on trips reporting no classified groupers (upper panel) and gear specific landings of unclassified groupers from trips reporting no classified groupers (lower panel).

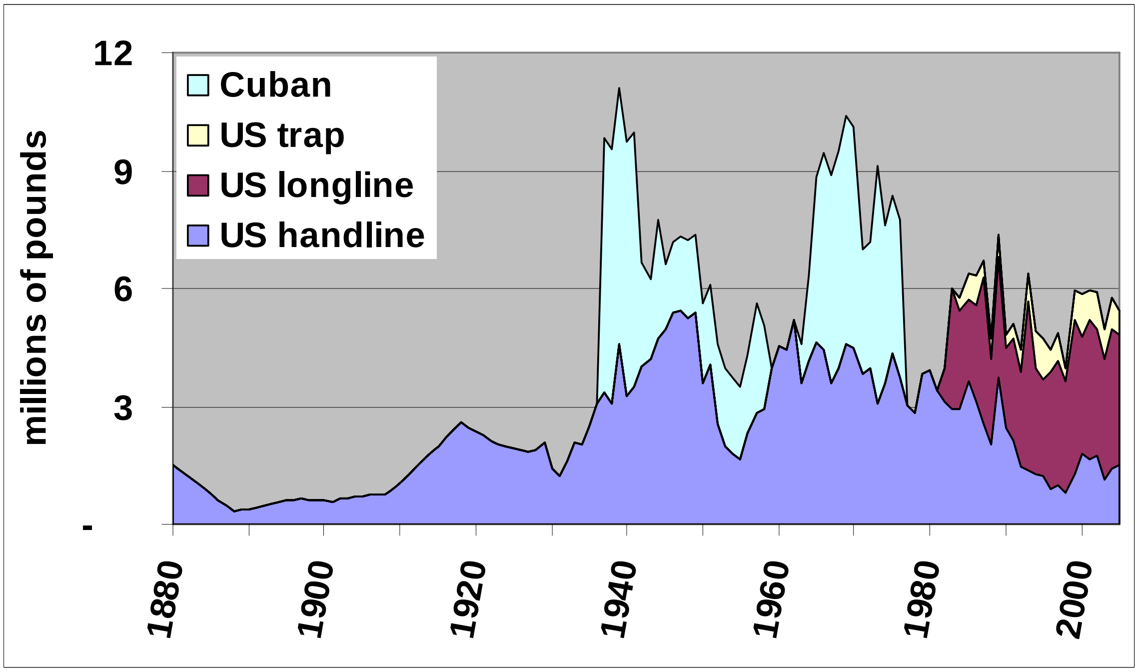


Figure 2. Calculated commercial landings of red grouper from United States Gulf of Mexico waters in pounds gutted weight.

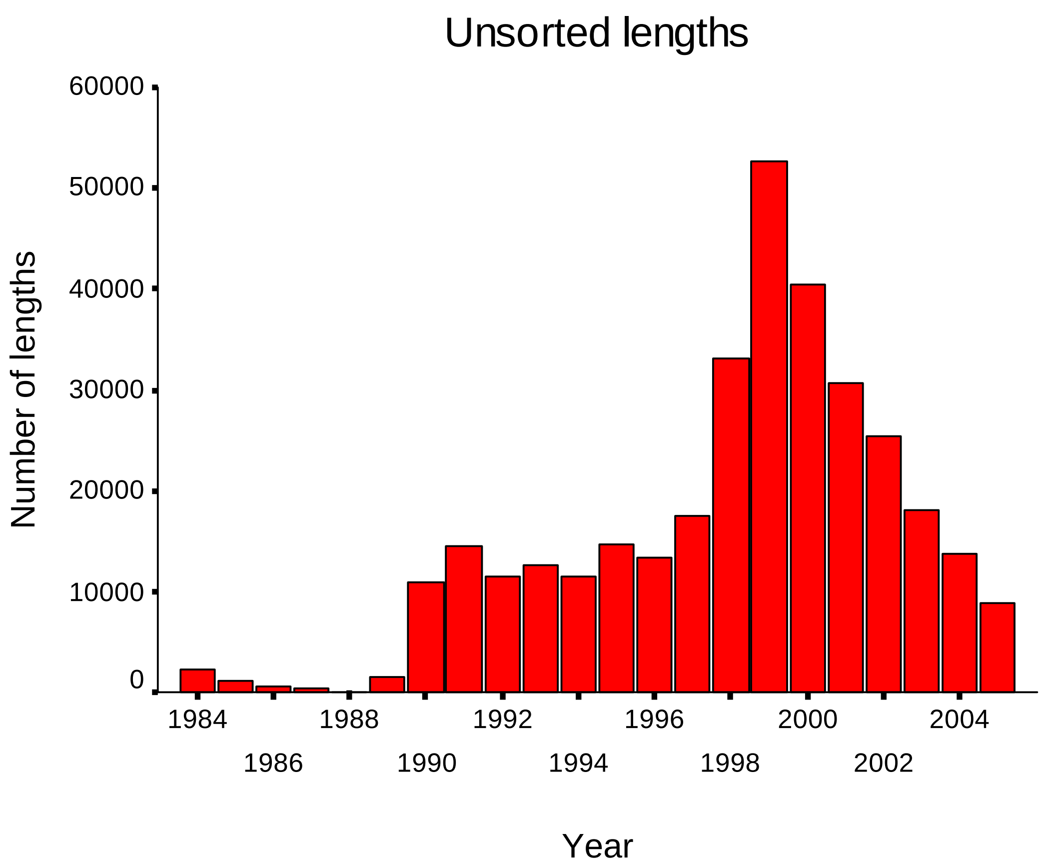
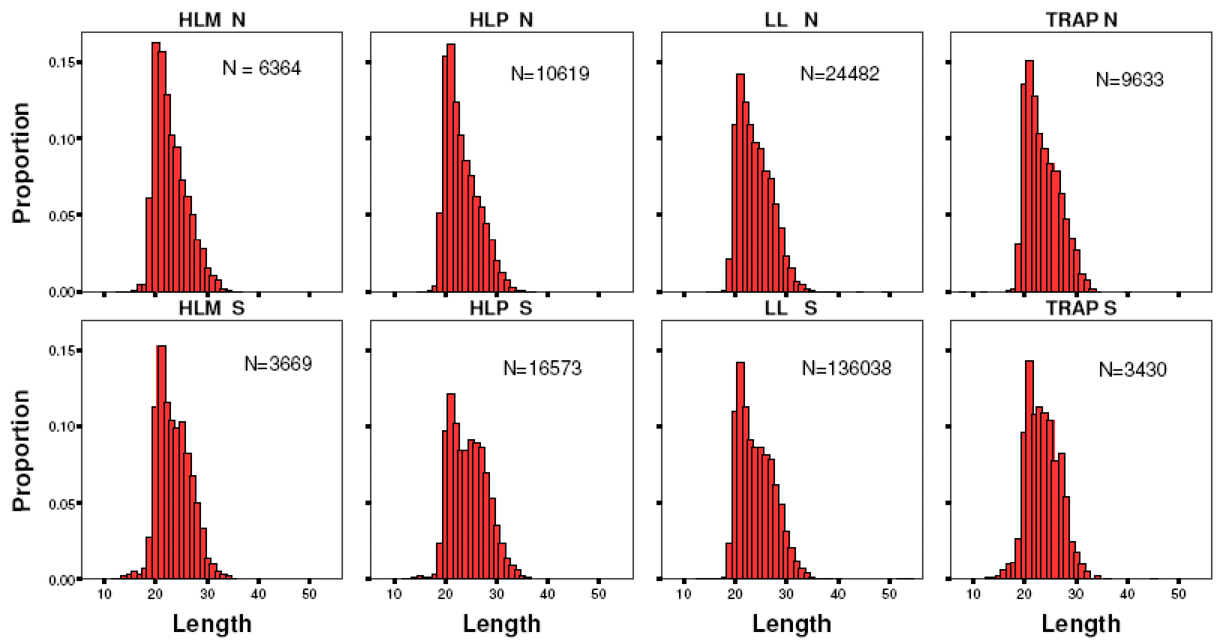


Figure 3. Number of unsorted lengths collected from commercial catches.



Gear: HLM = Handline Manual, HLP = Handline Power, LL = Longline, Trap = Fish Trap
Area: N = North (>= grid 6), S = South (grid 1-5)

Figure 4. Length distributions of red grouper collected from commercial catches, by area and gear type.

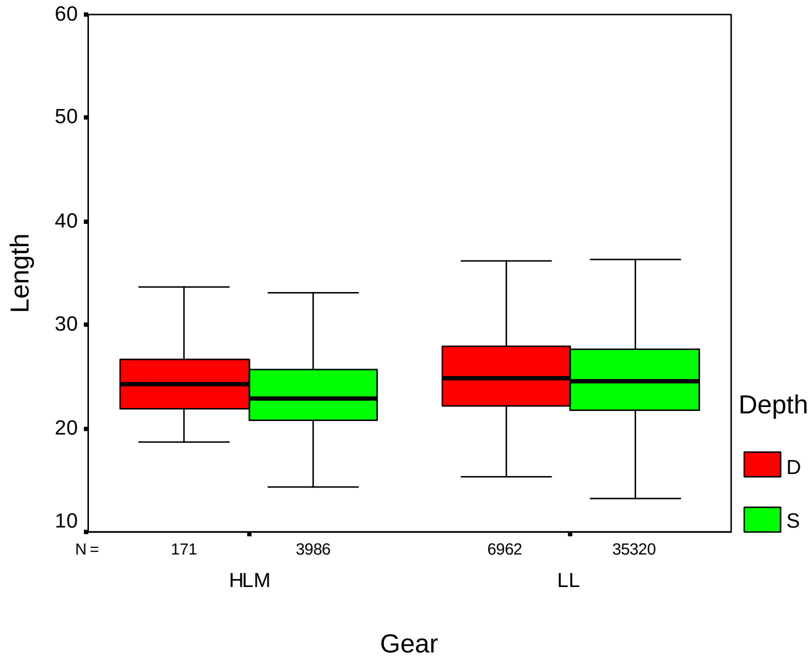


Figure 5. Median length of red grouper in commercial samples by gear and depth (S=shallow and D=deep).

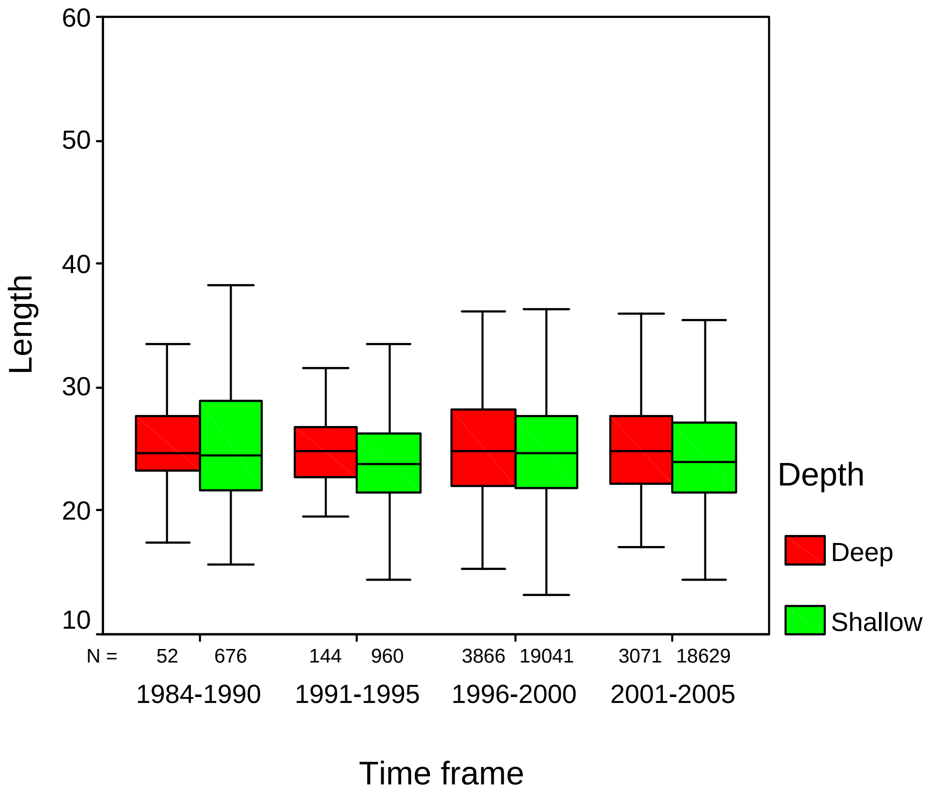


Figure 6. Median length of red grouper in commercial samples by time period and depth (S=shallow and D=deep).

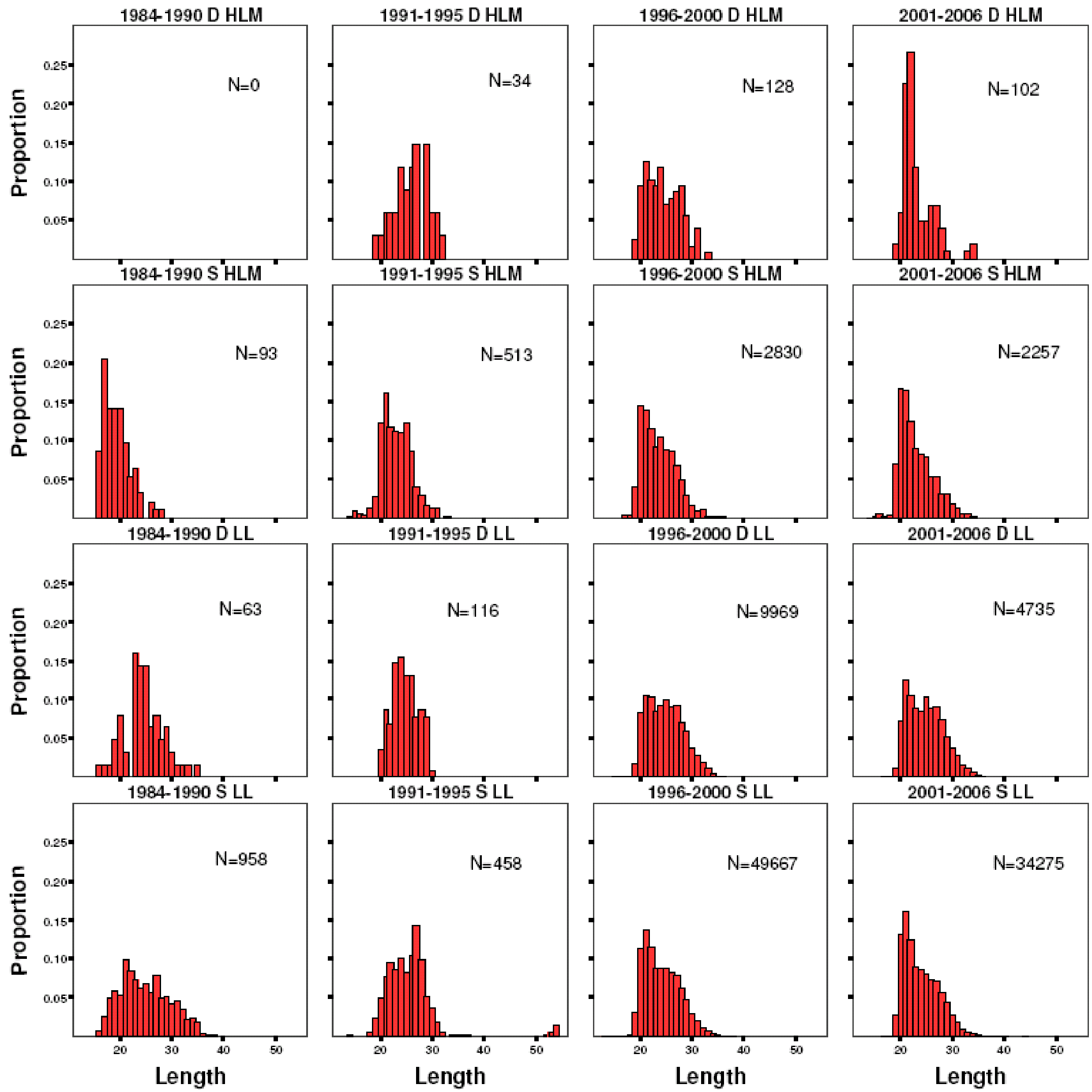


Figure 7. Length distributions of red grouper collected from commercial catches, by time frame, depth range and gear type.

4. Gulf of Mexico Red Grouper Recreational Statistics Group

OVERVIEW

Red grouper (*Epinephelus morio*) represent an important recreational fishery resource in the Gulf of Mexico. Recreational landings of red grouper during the most recent 5 years have averaged almost 300,000 fish annually, with an average of about 2.2 million more caught and discarded. This report represents the best scientific judgment of the SEDAR 12 Data Workshop, with ideas first vetted in the Recreational Statistics Group but final decisions left to the full working group. A summary of findings are presented here along with discussion of controversies that arose during the workshop.

LANDINGS

General Issues

Inclusion of Monroe County (Keys) catches in the Gulf of Mexico assessment

For management purposes and due to the possibility of distinct stock structure, the Gulf of Mexico and South Atlantic Fishery Management Council (GMFMC and SAFMC) red grouper stocks were split at the Florida Keys, with a line running down the center of the Keys and then west from Key West to the Dry Tortugas. Unfortunately, this split does not correspond exactly with reporting areas for recreational catches. The Marine Recreational Fisheries Statistics Survey (MRFSS) includes all of Monroe County landings in the official estimates for West Florida (Gulf of Mexico), yet there are indications that catches in Monroe County may come from both sides of the Keys. Similarly, Headboat Survey reporting areas 12 and 17, which are landings by Atlantic and Keys-based vessels fishing off the Keys and Dry Tortugas, may include trips to both sides of the delineation line. There was considerable discussion concerning the available information regarding the distribution of catches between Atlantic and Gulf, as well as the implications for constructing the catch series.

The available data regarding the distribution of catches by charter and private vessels include survey results from refinements to area coding in the 2005 MRFSS intercept survey for Florida West. Trips returning to the Florida Keys were intercepted and anglers asked whether they had fished in the Atlantic or the Gulf (for the upper/middle keys, “Gulf” likely refers to Florida Bay). Of the relatively few catches of red grouper, only 18% of charter landings and 30% of private landings occurred on Gulf trips. A single fisherman, a long-term headboat operator based in Key West, was contacted during the meeting, and expressed the opinion that all Keys red grouper catches occur in the Gulf.

Three options were considered for allocating MRFSS Monroe County between the Atlantic and Gulf. The first was to allocate all such catches to the Atlantic. The second option was to split these catches according to some proportion, perhaps derived from the available 2005 survey data. And the third option was to keep these catches in the Gulf, in keeping with the MRFSS design. However, the first option ignores information that some substantial fraction, at least, of the Keys catches occur in the Gulf. Option two requires the assumption that the ratio determined from limited catches in only one year would be applicable to all previous years. And both options one and two are problematic, since this deviates from the MRFSS design and may add uncertainty to the estimates. Considering this, and the fact that the habitat in Florida Bay and the Gulf near the Keys is suitable for red grouper, the recommendation was to maintain the convention of assigning the Monroe County catches to the Gulf of Mexico.

The available information regarding the distribution of catches by headboats was also examined. Plots of fishing locations reported in the Headboat Survey logbooks, which have a resolution to the nearest 10 minutes at best, suggest that some portion of overall effort (not specific to red grouper) occurs around the Dry Tortugas. The bulk of the fishing clearly occurs south of the Keys. Headboat Survey personnel as well as Florida observers also indicate that Keys-based headboats fish in the Atlantic. On this basis, it was recommended that the catches of the Florida Keys based headboats (areas 12 and 17), be assigned to the Atlantic. This treatment of the headboat catches is consistent with the conclusions of the SEDAR 10 Data Workshop on Gag Grouper.

MRFSS

Recreational fishery landings estimates for red grouper taken from the Gulf of Mexico are produced by the Marine Recreational Fishery Statistics Survey (MRFSS) conducted by NOAA Fisheries. Reliable estimated catch and effort statistics by fishing mode (shore, private or rental boats, charter boats and/or headboats) have been produced since 1981 for Louisiana through Florida. Texas was partially sampled by the MRFSS in 1981-1985, but has not participated in that survey since 1985. However, red grouper is not a component of that state's recreational fishery. Florida is divided into two 'states' for estimation purposes, East Florida which includes the Atlantic coast from the Georgia border through Miami-Dade County, and West Florida from the Alabama border through Monroe County. All fishing effort and catches from Monroe County are included in the West Florida estimates even if fishing actually occurred in the Atlantic Ocean.

In 1981-1985 charter boats and headboats were combined as an estimation category, but in 1986 a logbook program (the Headboat Survey), already operating in the Atlantic, was expanded to the Gulf of Mexico states to collect head boat catch and effort information via a census logbook. MRFSS discontinued sampling headboats and referred to the for-hire category simply as charter boats. In 2000, a new survey of charter boat effort was initiated due to lack of coverage of charter boat anglers by the MRFSS coastal household telephone survey (the component which provides effort estimates). This survey uses a directory of all known charter boats and uses a weekly telephone survey of the charter boat operators to directly obtain effort information from them, and the estimation expansion is based on the list of charter boats rather than the coastal population of households. The new survey also divides West Florida charter boats into three regions (panhandle, peninsula and Keys) in the estimation process. This survey methodology provides better coverage, better accuracy, better stratification of charter fishing effort along the Florida coast, and provides credible annual estimates for the charter fishery.

Shore mode

MRFSS estimated landings of red grouper from shore anglers from 1981 – 1998 but no landed fish have been observed or reported since then (Table 4.1). Most of these annual estimates have relatively high CVs, a reflection of these being rare events in the data. Shore landings from 1991-1995 are from ocean areas and were type A fish (examined, identified by MRFSS interviewer). In 1990, the majority were angler-reported dead fish (type B1) from inland waters, so the species identification may not be valid. However, the shore mode estimates were accepted as presented.

There was discussion considering whether or not red grouper is caught by shore mode It was concluded that this is reasonable, especially from bridges. No issues arose regarding the shore mode estimates.

Charter boat effort

Prior to 1998, charter boat effort was estimated using angler phone surveys. Interviews of charter boat captains in the Gulf of Mexico states began in 1998, and official estimates based on these interviews began in 2000. Data were collected using both methods beginning in 1998. Diaz and Phares (2004) examined these data for the period 1998 to 2003 using a generalized linear model that was standardized across a range of tempo-environmental factors. The GLM analysis provided a correction factor for each stratum, which were then applied to effort records prior to 1998. These corrections were used in relevant strata to adjust the expansion factors for the charter boat mode in MRFSS. The effect of these adjustments was detailed in Matter (SEDAR12-DW-14).

Wave 1, 1981

Data were not available for wave 1 in 1981. This gap was filled by determining the proportion of wave 1 to other waves in years 1982-1984 by fishing mode and area. These proportions were then used to estimate wave 1 in 1981 from the estimated catches in other waves of that year. This is the same methodology which was applied for the SEDAR 10 data workshop on gag grouper.

The potential impact of hurricanes on 2005 MRFSS catch and effort estimates

Red grouper are caught in the eastern portion of the Gulf of Mexico and are landed primarily in Florida, but are also caught by Alabama anglers and sporadically by Mississippi and Louisiana anglers (Table 4.2). During summer and early fall of 2005 there were several hurricanes that affected fishing in the Gulf of Mexico, culminating with the impact of Hurricanes Katrina and Rita on Mississippi and Louisiana, and to a lesser extent on Alabama and the panhandle region of Florida. Several of these storms also crossed Monroe County, Florida (Keys). Although these storms clearly disrupted fishing effort to some extent as they traveled through the Gulf and made landfall, the Gulf-wide red grouper charter boat harvest estimate (A+B1) for 2005 was higher than in previous years (Table 4.1). There was considerable discussion of these harvest estimates and the associated effort estimates, since these were at odds with the expectations of some of the Advisory Panel members participating in the workshop.

An examination of charter boat catches and effort by region of Florida (Table 8 in Matter [SEDAR 12-DW-14] and Tables 4.3 & 4.4) illustrates the regional and seasonal nature of the recreational fishery in 2005 relative to other recent years. Although the Gulf coast of Florida was impacted to some extent by the tropical storms of 2005, those impacts did not result in declines in annual charter fishing effort in the panhandle and peninsula regions of Florida (Table 4.3). However, total harvest of red grouper (all fishing modes) declined dramatically in 2005 in the panhandle and peninsula regions (Table 8 in Matter [SEDAR 12-DW-14]). Charter fishing effort in the Keys declined in 2005 which may have been a result of the storms passing through the Keys prior to entering the Gulf of Mexico. Charter boat harvest of red grouper in the Keys, typically a small proportion of annual statewide landings (Table 4.4), declined in 2005, and there was no charter boat harvest in the Keys during the storm season of July – October, 2005. Catch rates remained relatively high during the first 4 waves of 2005 in the panhandle and peninsula regions, as did effort, so landings during the spring and summer increased. In both the panhandle and peninsula regions, the declines in catch rates of red grouper in waves 5 and 6 resulted in lower seasonal landings relative to recent years even though effort was somewhat higher in wave 5. It should be noted that the retention of red grouper from federal waters was prohibited during November and December of 2005, although there was no such prohibition for catches in state waters.

The potential impact of red tide events on 2005 MRFSS catch and effort estimates

The presence of substantial red tide events along the Florida peninsula during 2005 might be expected to have affected the catch and effort of the recreational red grouper fishery there. We examined the distribution, duration and intensity of the 2005 events using data posted on the Florida Fish and Wildlife Research Institute internet web page. These data indicate that there were two distinct periods of red tide. The first occurred in February, extending into March, between Tampa Bay and Fort Myers and at times reaching concentrations that could (and did) lead to fish kills. There remained somewhat elevated red tide levels in the Sarasota area, until a second period of substantially elevated levels began in May. This event was centered around the Sarasota/Tampa bay area, with occasional extension south to the Ft. Myers area and north along the Florida Panhandle, and latest (with variable intensity) into December.

Fishermen attending this meeting indicated that these red tide events tended to discourage fishers from participating in this fishery, although they still made trips by traveling further offshore to reach untainted waters (following an unpleasant transit through the red tide zone).

Considering that the red tide events did not cover all areas, that areas covered were involved intermittently, and that it was possible to fish even during red tide events, it was concluded that the red tide events would not preclude the effort levels estimated through MRFSS.

Results

Annual catches as estimated from MRFSS (AB! And B2) are shown by mode (Table 4.1) and state (Table 4.2). Note that these tables do not agree with the preliminary numbers (Matter, SEDAR12-DW-14) but reflect analyses as described above.

Table 4.1. Estimated MRFSS A+B1 (number of fish killed) and B2 catch (number released alive) by mode for red grouper in the Gulf of Mexico. Charter and cbt/hbt estimates use the new method or are calibrated to the new.

	Cbt		Cbt/Hbt		Priv		Shore		All modes	
YEAR	AB1	B2	AB1	B2	AB1	B2	AB1	B2	AB1	B2
1981			182,113	27,053	104,360	50,058	15,020	3,855	301,493	80,967
1982			40,128	6,655	259,607	55,502	4,068	0	303,804	62,157
1983			77,192	24,959	540,104	190,529	24,684	0	641,980	215,488
1984			240,646	47,390	1,102,567	394,364	76,924	19,163	1,420,137	460,918
1985			331,973	76,877	432,956	39,262	0	5,121	764,929	121,260
1986	71,462	61,526			670,984	444,261	5,863	5,863	748,309	511,650
1987	55,612	63,738			337,531	403,467	10,105	0	403,249	467,205
1988	44,556	37,005			631,814	817,327	7,601	11,632	683,972	865,964
1989	38,901	91,183			712,589	1,877,785	0	1,794	751,490	1,970,761
1990	45,911	182,336			116,750	1,358,409	13,506	20,881	176,168	1,561,626
1991	14,124	47,116			264,147	2,922,955	9,378	33,429	287,649	3,003,500
1992	36,082	136,388			382,585	2,450,741	24,264	81,896	442,931	2,669,025
1993	30,156	109,133			315,253	1,621,466	16,797	7,567	362,205	1,738,166
1994	25,620	102,739			269,162	1,546,760	3,770	16,405	298,552	1,665,904
1995	54,786	135,386			226,334	1,481,149	1,315	5,099	282,435	1,621,635
1996	20,447	66,209			106,029	994,391	0	14,287	126,476	1,074,887
1997	21,474	102,748			64,735	968,470	1,369	8,894	87,578	1,080,112
1998	21,989	223,670			81,619	1,293,502	901	9,758	104,508	1,526,930
1999	33,278	324,000			144,732	1,756,987	0	6,049	178,011	2,087,036
2000	115,826	526,803			217,853	1,688,318	0	7,793	333,679	2,222,914
2001	58,136	230,251			156,663	1,432,283	0	3,234	214,799	1,665,768
2002	45,538	225,579			202,419	1,723,762			247,957	1,949,341
2003	45,062	293,344			172,294	1,786,673	0	914	217,356	2,080,930
2004	92,146	339,089			400,285	2,782,341	0	3,885	492,431	3,125,315
2005	110,636	330,132			133,512	1,380,510	0	2,419	244,148	1,713,061

Table 4.2. Estimated MRFSS A+B1 (number of fish killed) and B2 catch (number released alive) by state for red grouper in the Gulf of Mexico. Charter and cbt/hbt estimates use the new method or are calibrated to the new method.

	LA		MS		AL		FLW		All states	
YEAR	AB1	B2	AB1	B2	AB1	B2	AB1	B2	AB1	B2
1981							301,493	80,967	301,493	80,967
1982							303,804	62,157	303,804	62,157
1983							641,980	215,488	641,980	215,488
1984					352	0	1,419,785	460,918	1,420,137	460,918
1985							764,929	121,260	764,929	121,260
1986							748,309	511,650	748,309	511,650
1987							403,249	467,205	403,249	467,205
1988							683,972	865,964	683,972	865,964
1989							751,490	1,970,761	751,490	1,970,761
1990					0	226	176,168	1,561,400	176,168	1,561,626
1991	735	0					286,914	3,003,500	287,649	3,003,500
1992							442,931	2,669,025	442,931	2,669,025
1993							362,205	1,738,166	362,205	1,738,166
1994							298,552	1,665,904	298,552	1,665,904
1995					167	0	282,268	1,621,635	282,435	1,621,635
1996					1,033	0	125,443	1,074,887	126,476	1,074,887
1997							87,578	1,080,112	87,578	1,080,112
1998							104,508	1,526,930	104,508	1,526,930
1999					37	0	177,974	2,087,036	178,011	2,087,036
2000					33	0	333,646	2,222,914	333,679	2,222,914
2001					37	66	214,762	1,665,702	214,799	1,665,768
2002			595	0	1,673	10,818	245,688	1,938,523	247,957	1,949,341
2003			0	191	4,991	28,661	212,365	2,052,078	217,356	2,080,930
2004			942	0	12,072	8,863	479,417	3,116,452	492,431	3,125,315
2005					6,715	8,549	237,433	1,704,512	244,148	1,713,061

Table 4.3. Charter Boat fishing effort (number of angler-trips) in West Florida, by region of Florida. Total effort includes inland waters, state territorial seas, and the federal EEZ. Federal waters includes only those trips that fished predominantly in the federal EEZ.

	TOTAL EFFORT - ALL AREAS FISHED					FEDERAL WATERS OCEAN ONLY			
year	PANHANDLE	PENINSULA	KEYS	TOTALS		PANHANDLE	PENINSULA	KEYS	TOTALS
1998	145,953	299,533	155,662	601,149		88,371	95,517	98,487	282,375
1999	121,151	292,547	126,765	540,463		59,931	89,454	76,371	225,755
2000	165,378	317,981	116,944	600,302		90,244	112,976	72,057	275,278
2001	149,462	245,633	147,801	542,897		88,870	95,323	91,288	275,482
2002	157,200	252,087	171,873	581,160		98,422	84,243	109,864	292,529
2003	145,267	217,152	167,698	530,117		88,172	81,758	116,372	286,303
2004	176,496	210,403	177,278	564,177		100,219	81,055	124,874	306,148
2005	222,592	322,002	163,515	708,109		140,461	122,808	112,679	375,948

Table 4.4. Charter Boat harvest of red grouper, fishing effort, and CPUE from West Florida by region (MRFSS).

		HARVEST (A+B1) (numbers of fish)			EFFORT - ALL AREAS FISHED (number of angler-trips)			CPUE = HARVEST / EFFORT		
year	WAVE	PAN-HANDLE	PEN-INSULA	KEYS	PAN-HANDLE	PEN-INSULA	KEYS	PAN-HANDLE	PEN-INSULA	KEYS
2000	JAN/FEB	0	6,935	327	1,828	42,367	18,509	0.0000	0.1637	0.0177
	MAR/APR	1,200	7,418	0	28,096	53,623	24,816	0.0427	0.1383	0.0000
	MAY/JUN	1,817	45,712	13	49,547	94,270	32,056	0.0367	0.4849	0.0004
	JUL/AUG	1,302	39,302	0	50,958	72,950	19,119	0.0256	0.5388	0.0000
	WAVES 1-4	**4,319**	**99,367**	**340**	**130,429**	**263,210**	**94,500**	**0.0331**	**0.3775**	**0.0036**
	SEP/OCT	4,325	2,653	104	30,295	25,323	10,811	0.1428	0.1048	0.0096
	NOV/DEC	134	2,024	51	4,654	29,447	11,633	0.0288	0.0687	0.0044
	WAVES 5+6	**4,459**	**4,677**	**155**	**34,949**	**54,770**	**22,444**	**0.1276**	**0.0854**	**0.0069**
2001	JAN/FEB	28	295	315	1,216	39,103	26,674	0.0230	0.0075	0.0118
	MAR/APR	2,153	22,963	389	23,139	75,649	33,662	0.0930	0.3035	0.0116
	MAY/JUN	5,710	9,306	0	48,019	51,357	42,015	0.1189	0.1812	0.0000
	JUL/AUG	1,593	7,843	0	44,510	36,053	22,585	0.0358	0.2175	0.0000
	WAVES 1-4	**9,484**	**40,407**	**704**	**116,884**	**202,162**	**124,936**	**0.0811**	**0.1999**	**0.0056**
	SEP/OCT	1,690	2,154	104	27,821	16,006	7,259	0.0607	0.1346	0.0143
	NOV/DEC	31	3,139	385	4,756	27,466	15,606	0.0065	0.1143	0.0247
	WAVES 5+6	**1,721**	**5,293**	**489**	**32,577**	**43,472**	**22,865**	**0.0528**	**0.1218**	**0.0214**
2002	JAN/FEB	104	6,708	214	4,178	36,449	21,106	0.0249	0.1840	0.0101
	MAR/APR	1,071	4,460	863	18,747	66,021	40,504	0.0571	0.0676	0.0213
	MAY/JUN	6,054	10,537	0	49,253	70,017	48,636	0.1229	0.1505	0.0000
	JUL/AUG	3,211	1,134	102	52,679	29,691	26,368	0.0610	0.0382	0.0039
	WAVES 1-4	**10,440**	**22,839**	**1,179**	**124,857**	**202,178**	**136,614**	**0.0836**	**0.1130**	**0.0086**
	SEP/OCT	4,960	1,805	157	26,275	24,347	15,695	0.1888	0.0741	0.0100
	NOV/DEC	701	2,231	416	6,067	25,563	19,565	0.1155	0.0873	0.0213
	WAVES 5+6	**5,661**	**4,036**	**573**	**32,342**	**49,910**	**35,260**	**0.1750**	**0.0809**	**0.0163**
2003	JAN/FEB	213	1,001	1,170	2,044	37,013	30,038	0.1042	0.0270	0.0390
	MAR/APR	2,812	1,895	967	22,820	66,052	50,723	0.1232	0.0287	0.0191
	MAY/JUN	4,961	2,577	323	43,490	40,532	44,924	0.1141	0.0636	0.0072
	JUL/AUG	5,905	8,193	0	45,791	24,238	19,087	0.1290	0.3380	0.0000
	WAVES 1-4	**13,891**	**13,666**	**2,460**	**114,145**	**167,835**	**144,772**	**0.1217**	**0.0814**	**0.0170**
	SEP/OCT	4,836	5,279	0	26,908	21,197	7,977	0.1797	0.2490	0.0000
	NOV/DEC	196	5,443	388	4,214	28,120	14,950	0.0465	0.1936	0.0260
	WAVES 5+6	**5,032**	**10,722**	**388**	**31,122**	**49,317**	**22,927**	**0.1617**	**0.2174**	**0.0169**
2004	JAN/FEB	886	3,318	1,225	1,898	30,262	33,178	0.4668	0.1096	0.0369
	MAR/APR	3,300	4,449	334	27,356	57,117	44,926	0.1206	0.0779	0.0074
	MAY/JUN	8,762	14,283	4,545	63,292	49,375	47,899	0.1384	0.2893	0.0949
	JUL/AUG	7,397	13,429	92	57,097	31,639	25,343	0.1296	0.4244	0.0036
	WAVES 1-4	**20,345**	**35,479**	**6,196**	**149,643**	**168,393**	**151,346**	**0.1360**	**0.2107**	**0.0409**
	SEP/OCT	17,383	1,542	133	22,561	14,972	9,755	0.7705	0.1030	0.0136
	NOV/DEC	1,540	2,253	491	4,292	27,038	16,177	0.3588	0.0833	0.0304
	WAVES 5+6	**18,923**	**3,795**	**624**	**26,853**	**42,010**	**25,932**	**0.7047**	**0.0903**	**0.0241**
2005	JAN/FEB	3,973	6,772	606	5,312	38,181	29,910	0.7479	0.1774	0.0203
	MAR/APR	12,085	2,656	412	32,127	75,262	40,685	0.3762	0.0353	0.0101
	MAY/JUN	28,824	16,715	62	80,018	68,197	38,097	0.3602	0.2451	0.0016
	JUL/AUG	11,302	11,973	0	50,144	58,742	25,482	0.2254	0.2038	0.0000
	WAVES 1-4	**56,184**	**38,116**	**1,080**	**167,601**	**240,382**	**134,174**	**0.3352**	**0.1586**	**0.0080**
	SEP/OCT	8,403	506	0	44,726	28,628	9,215	0.1879	0.0177	0.0000
	NOV/DEC	348	0	321	10,266	52,993	20,126	0.0339	0.0000	0.0159
	WAVES 5+6	**8,751**	**506**	**321**	**54,992**	**81,621**	**29,341**	**0.1591**	**0.0062**	**0.0109**

Headboat Survey

The Headboat Survey has been conducted in the Gulf of Mexico since 1986. Total catch by trip is reported in logbooks provided to all headboats in Gulf coast States and corrections for non-reporting are made by the survey. This survey was described more fully in Matter (SEDAR12-DW-14). There were no controversial issues that came up in processing the headboat data for SEDAR 12, other than that of the allocation of Monroe County catches (described above) and the estimation of discards (described below). Results are shown in Table 4.5.

Table 4.5. Headboat Survey **estimated catch** (numbers of fish) by area groups for Gulf of Mexico red grouper. Estimated catch includes only kept fish and does not include the Florida Keys (areas 12+17).

YEAR	SW FL-Mid.gr. 18+21+22	NW FL-Texas 23-27	All Gulf areas
1986	31,692	1,221	32,913
1987	24,766	963	25,729
1988	27,298	656	27,954
1989	49,472	305	49,777
1990	14,306	276	14,582
1991	9,260	249	9,509
1992	8,875	174	9,049
1993	7,626	1,176	8,802
1994	8,893	724	9,617
1995	13,775	724	14,499
1996	13,880	1,714	15,594
1997	3,509	1,167	4,676
1998	3,527	855	4,382
1999	6,298	620	6,918
2000	7,965	896	8,861
2001	3,025	2,535	5,560
2002	2,363	2,039	4,402
2003	3,784	3,737	7,521
2004	8,742	5,068	13,810
2005	8,588	5,379	13,967

Texas Parks & Wildlife Survey

Red grouper is not a component of that state's recreational fishery. Therefore, no estimates were made and no issues arose.

Predicting historical recreational catches

Because available estimates for recreational catches start in 1981, it was necessary to generate estimates for earlier years through predictive relationships with known data and historical estimates of recreational fishing effort and catch rates. We separated the recreational fishing into three modes: private boat, headboat and charter boat, and obtained separate estimates of effort and catch per unit effort which, when multiplied together, provided separate mode-specific estimates of recreational catch. Catch is defined as total number of red grouper caught which includes released fish and corresponds to the sum of current MRFSS type A (observed landed), B1 (unobserved dead) and B2 (unobserved released alive) classifications. We excluded shore mode due to the negligible amount of shore catch of red grouper. As there were no catches from Texas, we excluded Texas estimated effort from the analyses and from tables and figures in this section.

Charter and headboat fishery

For the charter and headboat fishery we obtained historical catch per unit effort from interviews with charter boat and headboat captains or mates who were either active in the 1950's and 60's or who had knowledge of the respective fisheries during this period (Tables 4.6 and 4.7). We separated the headboat fishery into two areas of activity: a) Southwest and West Florida (SWFL) and b) Northwest and Panhandle Florida (NWFL). On the basis of historical information, catch rates in SWFL were higher in the 1950's than the present and have increased since the 1960's in NWFL. We did not determine historical headboat or charter boat catch rate or effort for areas west of the Panhandle of Florida due to negligible historical catches of red grouper.

Table 4.6. Anecdotal headboat catch rates

Headboat, Captain or Contact	Vessel	Port	First-hand	Red grouper per angler per trip	Years
Captain Johnny Georgiou	Two Georges Fleet	Tarpon Springs	Y		1950-1960's
Captain Mike Hubbard	Hubbards Fleet	Madeira Beach	Y	2-4, inshore; 5-6 offshore	1958-1963
Captain Bob Zales	Zodiac Fleet	Panama City	N	few until after Camille 1969	1965+
Captain James Cason	Flying Fisherman Fleet	Sarasota	Y	4-5	1960+
Captain Eddie Ranst	Admiral Fleet, Miss Cortez	Bradenton and Johns Pass	Y	4-5	1960+
Best historical estimates		SW, W FL		4	1945-1957
		NW FL		0	1945-1957

Table 4.7. Anecdotal charter boat catch rates

Charter boats, Captain/Contact	Vessel	Port	First-hand	Red grouper per angler per trip	Years
Captain Bob Zales	Zodiac Fleet	Panama City	Y	few until after Camille 1969	1965+
Captain James Cason	Flying Fisherman Fleet	Sarasota	Y	6+	1960+
Captain Gus Loyal	Shark Fleet	Sarasota	Y	5-6	1960+

Best historical estimates	SW, W FL		5	1945-57
	NW FL		0	1945-1957

From these interviews we obtained a headboat catch rate in SWFL of 4 red groupers per angler per trip for 1945-1957 with a linearly interpolated decrease forward to the average of MRFSS sampled headboat catch rates obtained for 1981 –1985 (Table 4.8, 0.25 per angler per trip). For NWFL we linearly interpolated the average of observed MRFSS intercept catch rates from the intercept survey for 1981 –1985 (0.0079 per angler per trip) back to a value of zero in 1957 on the basis that red grouper were rarely, if ever, caught before Hurricane Camille in 1969 (Bob Zales *pers. comm*., Table 4.8).

Table 4.8. Headboat and charter boat catch rates

Historical catch rates of red grouper per angler trip. Charter boat rates are historical estimates of red grouper per angler trip for bottom trips. CPUE for all charter trips is multiplied by the percentage of total charter trips that were bottom trips (Moe 1963, 32% in the SW, 59% in the NW).	West and Southwest Florida Major ports: Johns Pass, Clearwater, Sarasota, Tarpon Springs, Ft Myers		Northwest Florida and Panhandle Major ports: Carrabelle, Destin, Panama City, Pensacola	
	Headboat	Charter boat	Headboat	Charter boat
A. 1945-57 Historical estimates from captains	4	5*0.32 = 1.6	0	0*0.59= 0
B. 1958-1980 Linear interpolation from A to C	↓	↓	↑	↑
C. Average of MRFSS estimates from 1981-85	0.250	0.579	0.0079	0.0067

For charter boat catch rates we used a similar method of interpolating average MRFSS sampled charter boat catch rates for 1981-1985 (0.579 red grouper per angler per trip) back in time. We used a value of 5 red grouper per angler per trip in SWFL on the basis of anecdotal information from charter captains active in the 1950's and 1960's. These historical values were presumably for bottom fishing or targeted red grouper trips. To convert these into catch rates for all charter trips (the same units as the MRFSS charter catch rates) we obtained data from Moe (1963) on the percent of time spent bottom fishing versus trolling for charter boats in 1960 (32% of trips in the SWFL, 59% in the NWFL). These values were then multiplied by the historical catch rates to obtain catch rates for all charter trips. For NWFL we interpolated the average of MRFSS charter boat catch rates for 1981 –1985 (0.0067 per angler per trip) back to a value of zero in and prior to 1957 (Bob Zales *pers. comm*., Table 4.8).

To obtain historical effort in the headboat and charter modes we used estimates of the number of vessels, the number of trips, the average length of trips and the average number of passengers from surveys of the charter and headboat fisheries in 1955, 1960, and 1977 (Ellis et al. 1958, Moe 1963. Browder et al. 1981) to calculate the number of angler trips for the two regions (Tables 4.9 and 4.10). We linearly interpolated from a value of zero trips in 1945 to the 1955 value and then linearly interpolated between the estimates for 1955, 1960 and 1977. We also interpolated headboat and charter boat effort between the 1977 region-specific estimates and region-specific estimates for the beginning of MRFSS in 1981. As charter boat and headboats were not separated in MRFSS 1981-1985 effort estimates, this required separating charter and headboat effort into mode-specific components. This was done by obtaining a regression for the percentage of total for-hire (head + charter boats) trips that were charter trips versus year for the years 1945-1980 and 1986-2005 (Equation 1: charter/total for-hire ~ year, $r^2 = 0.933$, slope = 0.01 , intercept = 19.267).

As the Headboat Survey (HBS) survey effort was in angler-days we converted these to angler trips by obtaining ratios of headboat logbook angler-trips to angler-days and multiplying the HBS total angler-days by these ratios for each area (Table 4.11). For 1981-85 charter trips were roughly 55% of the total for-hire trips. To obtain separate effort estimates for each area in 1981 we divided the total headboat or charter boat trips for 1981 by the percentage of the 1977 headboat or charter boat effort that occurred in either NWFL or SWFL.

Table 4.9. Charter boat effort

Year	Area	Number of charter boats	Avg. trips per boat per year	Avg. anglers per boat	Angler trips	Time spent bottom fishing	Bottom effort (angler trips)	Avg. hours fished	Bottom effort (angler hours)
1955	W, SW Florida	165 [E]	113.4 [E]	3.7 [E]	74,844	32.1% [M]	24,019	3.8 [E]	91,274
	NWFL	76 [E]	108.8 [E]	3.7 [E]	30,595	59.7% [M]	18,264	4.0 [E]	72,143
1960	W, SW Florida	157 [M]	113.4 [E]	3.7 [E]	71,215	32.1% [M]	22,855	3.8 [E]	86,848
	NWFL	126 [M]	108.8 [E]	3.7 [E]	50,723	59.7% [M]	30,280	4.0 [E]	119,605
1977	W, SW Florida	138 [B]	113.4 [E]	3.7 [E]	62,597	32.1% [M]	20,089	3.8 [E]	76,338
	NWFL	108 [B]	108.8 [E]	3.7 [E]	43,476	59.7% [M]	25,954	4.0 [E]	102,519

[E] Ellis et al. (1958)
[M] Moe (1963)
[B] Browder et al. (1977)

Table 4.10. Headboat effort

Year	Area	Number of headboats	Avg. trips per boat per year	Avg. anglers per boat	Angler trips	Time spent bottom fishing	Bottom effort (angler trips)	Avg. hours fished	Bottom effort (angler hours)
1955	W, SW Florida	24 [E]	200.6 [E]	18.1 [E]	87,141	100%	87,141	3.4 [E]	291,921
	NWFL	57 [E]	115.8 [E]	17.9 [E]	111,550	100%	111,550	5.7 [E]	635,836
1960	W, SW Florida	28 [M]	200.6 [E]	18.1 [E]	101,664	100%	101,664	3.4 [E]	340,575
	NWFL	48 [M]	115.8 [E]	17.9 [E]	93,937	100%	93,937	5.7 [E]	535,441
1977	W, SW Florida	22 [B]	200.6 [E]	18.1 [E]	79,879	100%	79,879	3.4 [E]	267,594
	NWFL	23 [B]	115.8 [E]	17.9 [E]	45,011	100%	45,011	5.7 [E]	256,565

[E] Ellis et al. (1958)
[M] Moe (1963)
[B] Browder et al. (1977)

Table 4.11. Ratios of headboat logbook angler-trips to angler-days by area (1986-2005 combined) used to convert HBS angler-days to angler trips.

Area	ratio of headboat angler days to angler trips
Tortugas	0.247
SWFL	1.423
Middle Grounds	0.349
NWFL	1.380
LA	0.963

Private boat fishery

To obtain historical catch rates for the private boat fishery we used an average of MRFSS catch of type A, B1 and B2 red grouper per trip data from all private mode inshore and ocean trips for the years 1981-1985 from West Florida-Louisiana (Table 4.12, average of each year private angler catch divided by private angler effort for the years 1981-85 = 0.0918). Note that this catch rate of one red grouper per 11 angler trips is low because it applies to all MRFSS private boat trips, the majority of which are inshore. This also assumes that catch rates of red grouper from 1981-1985 are applicable for the years 1945-1980.

To predict private boat angler trips backwards for 1965-1980 we used a regression between the number of Florida vessel registrations (Boyd Walden, Chief Bureau of Titles and Registrations Division of Motor Vehicles) and natural log of MRFSS private boat angler trips from the West Coast of Florida to Louisiana for inshore and all ocean areas from 1981-2005 (Figure 4.1). Since Florida vessel registrations only existed back to 1965 we extended effort predictions back to 1955 using a regression of MRFSS private angler trips for 1981-2005 and total national boats owned (National Marine Manufacturers Association, http://www.nmma.org/facts/boatingstats/2002/files/retailexpenditures.asp.). The numbers of Florida registered vessels provided the best fit to the data with an r-squared of 0.84, however the number of national boats owned was also a strong predictor of private boat effort (r-squared of

0.73, Figure 4.1). We then linearly interpolated from the 1955 value to a value of 0 in 1945 to provide a gradual rather than abrupt increase in effort, consistent with our assumption that the private boat fishery begin in 1945 (Figure 4.2).

Figure 4.1. Regressions of private boat angler trips versus a) Florida vessels and b) national vessels.

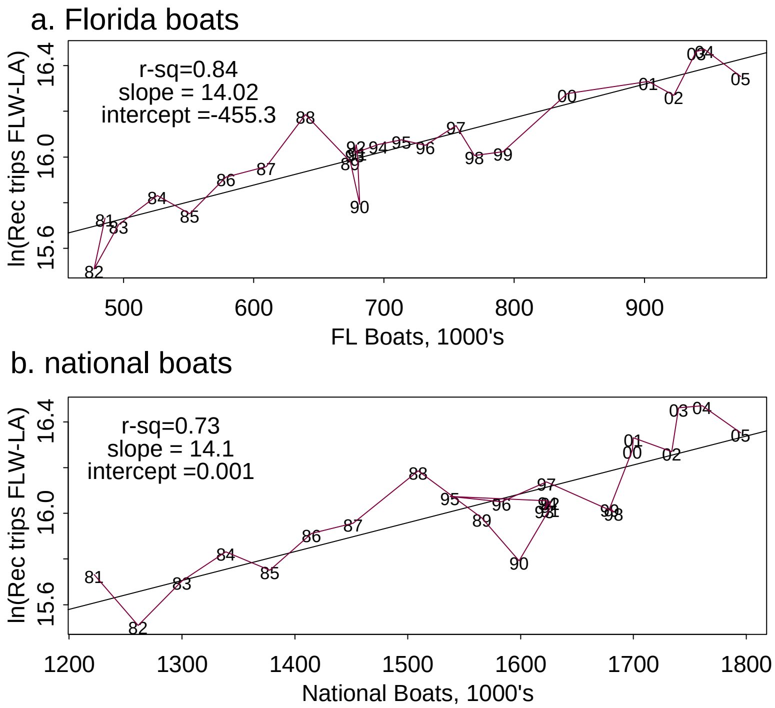


Figure 4.2. Predictions of private boat angler trips versus Florida boats and national boats. Diamonds are actual MRFSS private effort.

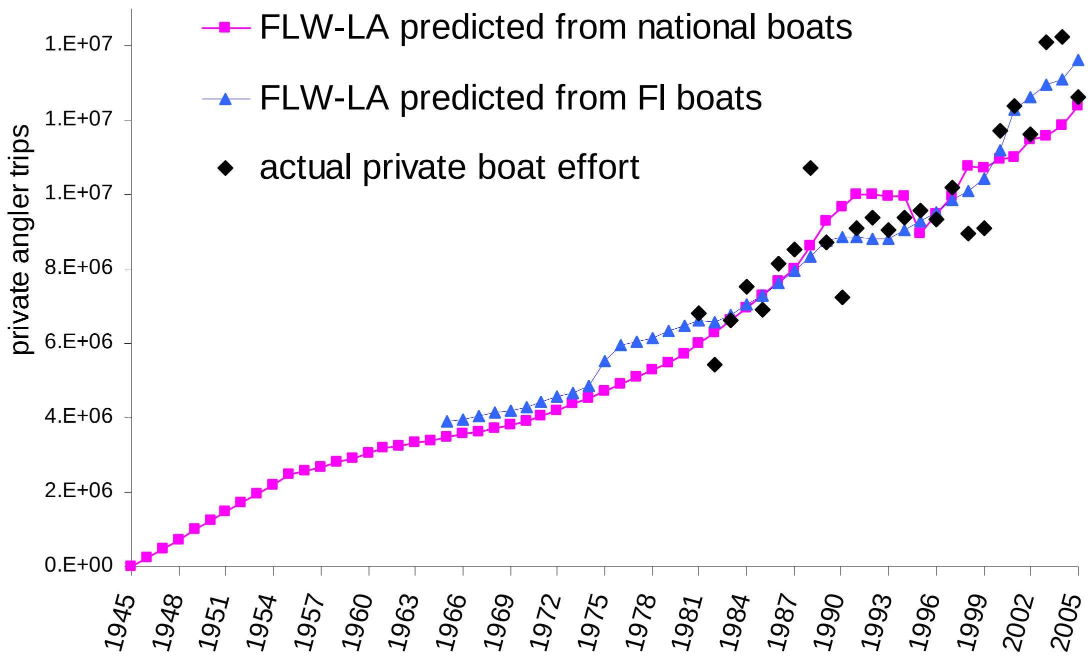
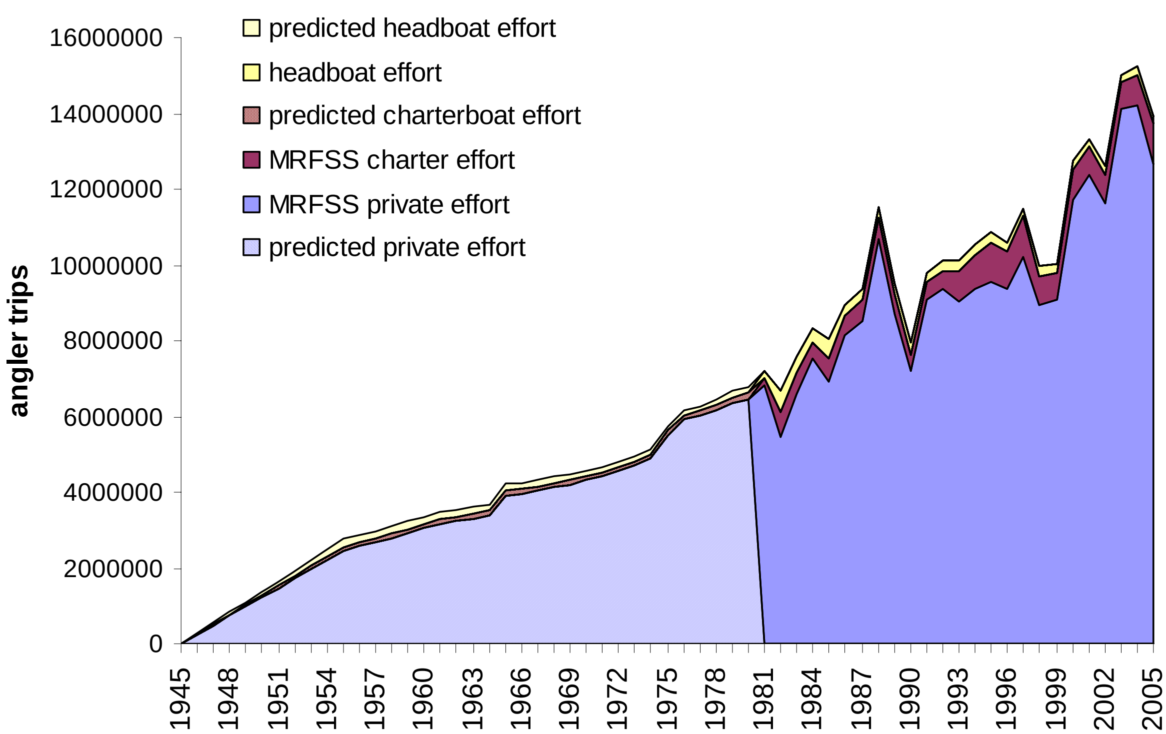


Figure 4.3. Back-calculated (1945-1980) and MRFSS/headboat survey (1981-2005) recreational effort in angler-trips by mode.



Constructing continuous series of effort and catch

We added in the total headboat and charter boat effort predictions to obtain total effort for 1945-1980 and appended these to MRFSS or HBS effort estimates for 1981-2005 to create a continuous time series of effort (Figure 4.3). A slight discontinuity between the predicted and MRFSS private angler effort exists between 1980 and 1981, however, no such discontinuity exists for the other modes as there are interpolated between the last charter/headboat study in 1977 and 1981 MRFSS charter/headboat estimates.

To construct continuous time series of recreational catch, we multiplied the charter and headboat effort by the corresponding CPUE and added these catches to the product of the private boat fishery CPUE and effort (Table 4.12, Figure 4.4). To separate MRFSS charter/headboat catches we used the same year-specific percentage of charter to total for-hire trips used to separate MRFSS charter headboat effort (Equation 1)

The drop in catches in 1981-82 without a concomitant drop in effort was due to very low MRFSS-estimated private boat catch rates of 0.02 and 0.06 red groupers per trip for 1981 and 1982, respectively. These were two of the lowest catch rates in the private boat fishery for the years 1981-2005. MRFSS charter boat and headboat catch rates in 1982 were also very low and suggest that these low catch rates were shared among all three modes. Despite this drop in catches the predicted historical catches are close to estimates at the start of the MRFSS survey. In addition, they appear to correctly reflect the shifting of the fishery away from its traditional headboat focus to one dominated by private vessel anglers.

Figure 4.4. Time series of predicted historical catches in the private, charter and headboat fisheries by mode. Post-1980 catches are MRFSS or Beaufort headboat survey estimates.

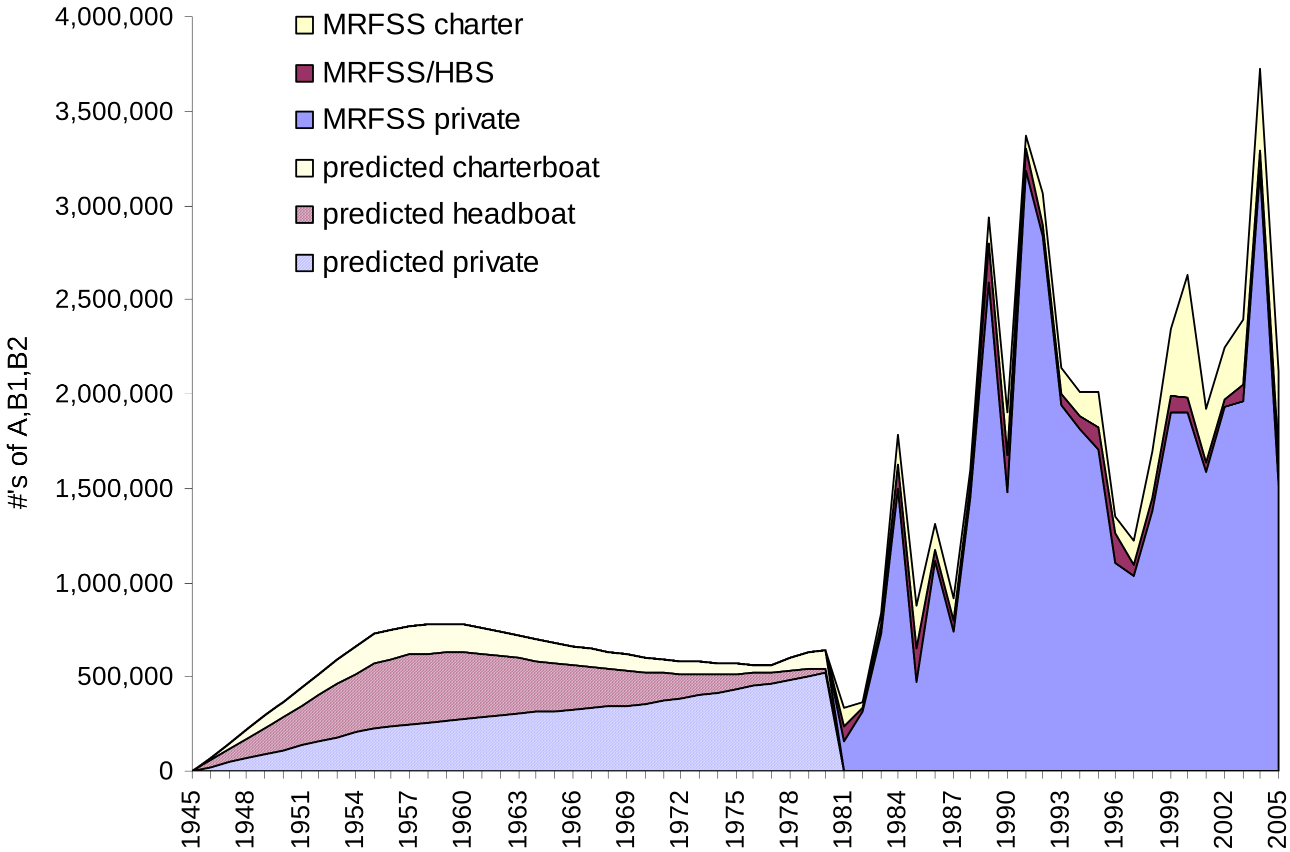


Table 4.12. Time series of effort in angler trips and catch by mode. Bold values are predicted, literature-based or linearly interpolated. Post-1980 catches are MRFSS or headboat survey estimates. Headboat effort from 1986 to 2005 is in angler-trips converted from angler-days. Shaded effort and catch values for 1981-1985 are split from a regression of the percentage of charter to total for-hire trips by year. Shore mode and Texas effort are not included. The solid underlined cells were used to obtain private angler catch rates as private catch/ private anger trips. Charter and cbt/hbt estimates use the new method or are calibrated to the new method.

year	charter boat effort	headboat effort	private effort	total effort	charter catch	headboat catch	private catch	total catch (does not include shore)
1945	0	0	0	0	0	0	0	0
1946	10,544	19,869	245,922	270,019	15,864	34,931	22,565	73,360
1947	21,088	39,738	491,843	540,038	31,728	69,862	45,130	146,719
1948	31,632	59,607	737,765	810,057	47,592	104,793	67,694	220,079
1949	42,176	79,476	983,686	1,080,076	63,456	139,724	90,259	293,439
1950	52,720	99,345	1,229,608	1,350,095	79,319	174,655	112,824	366,798
1951	63,263	119,214	1,475,529	1,620,114	95,183	209,586	135,389	440,158
1952	73,807	139,084	1,721,451	1,890,133	111,047	244,517	157,954	513,518
1953	84,351	158,953	1,967,372	2,160,152	126,911	279,448	180,518	586,877
1954	94,895	178,822	2,213,294	2,430,171	142,775	314,379	203,083	660,237
1955	105,439	198,691	2,459,215	2,700,190	158,639	349,310	225,648	733,597
1956	108,739	198,073	2,565,140	2,807,667	157,101	360,905	235,367	753,373
1957	112,039	197,455	2,675,628	2,919,706	155,562	372,500	245,505	773,567
1958	115,339	196,837	2,790,874	3,036,505	154,024	368,042	256,080	778,146
1959	118,639	196,219	2,911,084	3,158,267	147,027	362,801	267,110	776,938
1960	121,939	195,601	3,036,472	3,285,207	140,141	356,599	278,615	775,354
1961	121,006	191,442	3,167,261	3,411,420	133,778	335,474	290,615	759,868
1962	120,072	187,282	3,241,113	3,480,695	127,493	314,774	297,392	739,659
1963	119,139	183,123	3,316,688	3,551,693	121,284	294,498	304,326	720,109
1964	118,206	178,963	3,394,024	3,624,454	115,153	274,646	311,422	701,222
1965	117,273	174,804	3,921,068	4,146,920	109,098	255,219	359,782	724,099
1966	116,339	170,644	3,967,493	4,188,769	103,120	236,216	364,042	703,378
1967	115,406	166,485	4,044,019	4,260,718	97,219	217,637	371,063	685,920
1968	114,473	162,325	4,135,748	4,347,871	91,395	199,483	379,480	670,358
1969	113,539	158,166	4,211,667	4,419,213	85,648	181,753	386,446	653,847
1970	112,606	154,007	4,308,024	4,510,994	79,978	164,447	395,287	639,712
1971	111,673	149,847	4,407,886	4,606,279	74,384	147,565	404,450	626,400
1972	110,739	145,688	4,548,717	4,742,533	68,868	131,108	417,372	617,348
1973	109,806	141,528	4,683,421	4,872,661	63,428	115,075	429,732	608,236
1974	108,873	137,369	4,872,861	5,057,524	58,066	99,466	447,114	604,646
1975	107,940	133,209	5,517,608	5,697,695	52,780	84,282	506,274	643,336
1976	107,006	129,050	5,932,519	6,108,029	47,571	69,522	544,345	661,438
1977	106,073	124,890	6,045,849	6,216,783	42,439	55,186	554,743	652,369
1978	129,373	139,195	6,157,585	6,381,130	69,047	46,769	564,996	680,812
1979	152,673	153,500	6,353,259	6,629,417	87,752	35,322	582,950	706,024
1980	175,973	167,806	6,454,667	6,783,438	98,554	20,845	592,255	711,654
1981	199,273	182,111	6,801,904	7,183,287	109,289	99,877	154,418	363,584

Table 4.12, continued.

year	charter boat effort	headboat effort	private effort	total effort	charter catch	headboat catch	private catch	total catch (does not include shore)
1982	659,296	575,341	5,438,965	6,673,602	24,982	21,801	315,109	361,892
1983	536,566	447,057	6,608,030	7,591,653	55,724	46,428	730,633	832,785
1984	464,680	369,575	7,506,796	8,341,050	160,436	127,600	1,496,931	1,784,967
1985	624,403	473,931	6,927,563	8,025,897	238,360	170,491	472,218	881,068
1986	513,342	309,209	8,136,242	8,958,793	132,988	60,926	1,115,245	1,309,159
1987	546,764	296,941	8,517,788	9,361,493	119,350	55,425	740,998	915,773
1988	559,513	270,186	10,698,532	11,528,231	81,561	70,026	1,449,141	1,600,728
1989	524,157	279,532	8,712,307	9,515,995	130,084	212,070	2,590,374	2,932,528
1990	426,134	293,651	7,216,506	7,936,291	228,247	198,189	1,475,159	1,901,595
1991	449,908	238,013	9,086,738	9,774,660	61,240	116,562	3,187,102	3,364,904
1992	469,662	254,781	9,373,254	10,097,697	172,470	63,009	2,833,326	3,068,805
1993	788,055	276,340	9,041,306	10,105,702	139,289	58,870	1,936,719	2,134,878
1994	860,370	280,911	9,384,801	10,526,081	128,359	61,310	1,815,922	2,005,591
1995	1,020,387	255,800	9,570,896	10,847,082	190,172	111,715	1,707,483	2,009,370
1996	990,457	228,308	9,351,017	10,569,782	86,656	160,651	1,100,420	1,347,727
1997	1,091,871	214,024	10,195,083	11,500,978	124,222	63,695	1,033,205	1,221,122
1998	760,667	256,226	8,938,905	9,955,798	245,659	69,024	1,375,121	1,689,804
1999	683,768	245,624	9,097,803	10,027,194	357,278	84,613	1,901,719	2,343,610
2000	811,634	220,975	11,728,464	12,761,073	642,629	77,099	1,906,171	2,625,899
2001	742,386	216,187	12,371,138	13,329,711	288,387	48,167	1,588,946	1,925,500
2002	764,222	195,051	11,635,095	12,594,367	271,117	45,526	1,926,181	2,242,824
2003	691,362	200,454	14,110,007	15,001,823	338,406	93,098	1,958,967	2,390,471
2004	782,409	216,535	14,232,316	15,231,260	431,235	109,045	3,182,626	3,722,906
2005	943,305	175,620	12,636,632	13,755,557	440,768	160,221	1,514,022	2,115,011

DISCARDS

General Issues

The Beaufort Headboat Logbook Survey provides catch estimates of fish kept, but does not provide estimates of the number of fish released alive. In some previous SEDARs, the MRFSS charter boat data have been used to estimate discards for the headboat fishery by using MRFSS ratios of discards to landings and applying those to the catch estimates from the Headboat Survey (the Headboat Survey catch estimates are considered close to the definition of "A+B1" in MRFSS since the "B1" fish are not thought to be a significant amount on headboats). In recent years, new data have been gathered from the headboat fishery that allow us to see how well the MRFSS discard rates correspond to that fishery.

Discard Ratios from the headboat fishery

In the Headboat Survey logbook data, catch is self reported by vessel operators. Until 2004, logbooks, or trip reports, only included data on harvested catch. In 2004 the Headboat Survey began collecting discard data on trip reports. (No estimates of discards have been generated from this information thus far.) Although information on fish released has been requested on trip reports since then, it is apparent from the logbook data that many vessels have not recorded this information. For this reason we did not consider logbook data for trips that reported no discarded fish of any species (trips where presumably the crew ignored the new discarded catch fields). From these, the reported 2005 ratio of discarded red grouper to harvested red grouper for the Florida peninsula (areas 21 and 22) is 1.70. For the Florida panhandle and AL (area 23) the 2005 ratio is 0.03. [Note: There were no red grouper reported in the logbooks in 2005 in area 18 and a negligible amount from Texas (areas 25-27). There are no headboats in MS and no trip reports from LA (area 24) in 2005].

In addition to the logbook data, we obtained discard data from state-run observer surveys of headboat trips, which were implemented in Alabama in 2004, and in Florida in 2005. During randomly sampled trips, catches and releases of all species are observed. The 2005 ratio of discarded red grouper to harvested red grouper is 20.92 for the Florida peninsula (based on 655 trips in which red grouper were caught) and 2.13 for the Florida panhandle and Alabama (based on 196 trips in which red grouper were caught).

The discard ratios derived from the observer programs are distinctly higher than those from the Headboat Survey logbook data. Both, however, seem to indicate a higher level of discards in the Florida peninsula than in the Florida panhandle and Alabama. This regional difference in discard ratios was supported by the charter boat operators who were at the meeting. They considered the discards to landing ratio to be between 10 and 20 in the FL peninsula and around 3 in the FL panhandle and AL, anecdotal information that coincided more closely with the observer data than the logbook data. The group decided that the discard ratios derived from the observer programs were more convincing than the logbook data.

MRFSS Discard Ratios

Data on harvested and released fish from both the charter and private sectors have been collected since 1981 in the MRFSS. Because the charter sector is a for-hire fishery, it was thought that discard rates may be similar to the headboat fishery and the discard ratio from historic MRFSS charter catch data could be directly applied to headboat landings. However, the two for-hire fisheries do not operate in the same manner. Charter vessels generally carry fewer passengers and are more directed toward specific species. Given this, it was thought that the discard rates from the private sector may be more applicable to the headboat fishery.

Discard ratios from the MRFSS charter sector in 2005 were 6.58 for the FL peninsula and 1.03 for the FL panhandle and AL. Discard ratios from the MRFSS private sector in 2005 were 13.98 for the FL peninsula and 4.87 for the FL panhandle and AL. Since headboats do not operate in inshore areas, these ratios do not include inshore area estimates. Regional West Florida estimates (post stratified estimates) were provided by MRFSS. Charter estimates use the For-Hire Survey or new charter boat method. Figure 4.5 illustrates both MRFSS ratios and the Headboat observer data for the FL peninsula and Figure 4.6 illustrates the same information for the FL panhandle and Alabama. Table 4.13 shows data from all sources available in 2005.

Based on this analysis, it was decided that the annual discard ratios from MRFSS private boat catch estimates would be applied to logbook harvest data to estimate the number of red grouper released by headboat anglers back to 1986. Discard ratios will be applied by region. Florida peninsula ratios will be applied to Headboat Survey areas 18, 21, and 22 and Florida panhandle and Alabama ratios will be applied to Headboat Survey areas 23-27 (catches outside of area 23 only constitute about 100 fish over all years).

Table 4.13. Discard ratios from all sources available in 2005.

	FL peninsula	**FL panhandle + AL**
HBT logbk data	1.7	0.03
HBT obs data	20.92	2.13
MRFSS charter	6.58	1.03
MRFSS private	13.98	4.87

Figure 4.5. Ratios of fish **released alive** (B2) **to fish killed** (AB1) for the **FL peninsula** from post stratified MRFSS charter and private mode estimates. Inshore areas are not included. Charter estimates use the new method or are calibrated to the new method. Headboat At-Sea observer data from Florida in 2005 is included for comparison.

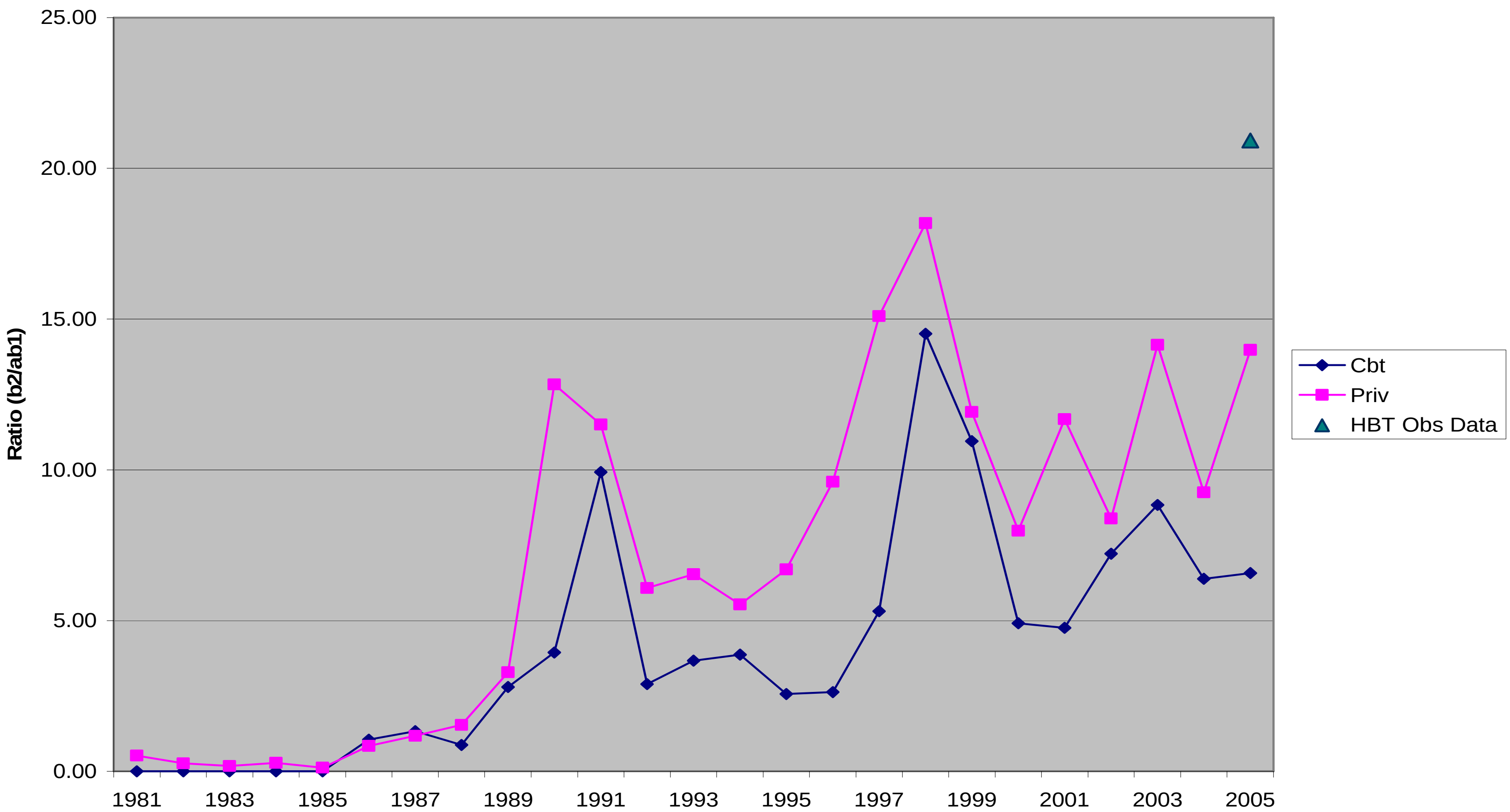
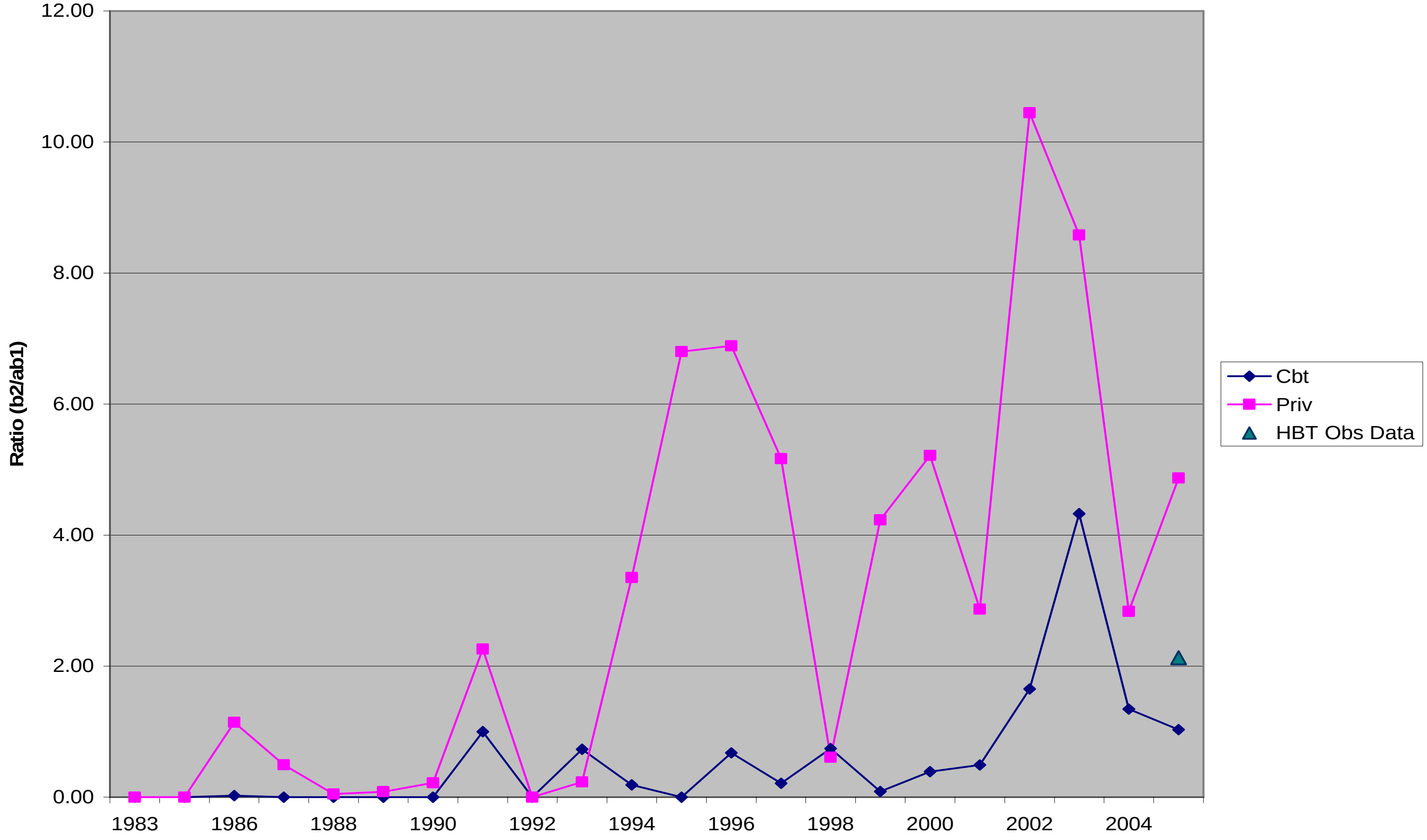


Figure 4.6. Ratios of fish **released alive** (B2) **to fish killed** (AB1) for FL panhandle and AL from MRFSS charter and private mode estimates. FL panhandle data taken from post stratified MRFSS estimates. Inshore areas are not included. Charter estimates use the new method or are calibrated to the new method. Headboat observer data from FL and AL for 2005 is included for comparison.



Average Depths of Red Grouper Catches

In order to apply predictive models of discard mortality for which depth is a factor, it is necessary to associate the depth at which the fish are caught with the landings. No depth information is directly available in the raw data from the recreational surveys. However, in the Headboat Survey there are records in the logbooks which contain the fishing location by 10 minute grid. This location can be associated with available Gulf of Mexico depth information recorded at 10 minute square resolution. For the subset of trips which caught red grouper and reported fishing locations, the weighted (by reported catch) mean fishing depth was calculated by year and Headboat Survey area (Table 4.14).

For the charter and private trips, average depths over time were assigned by drawing on the experience of the charter boat captains in attendance at this meeting (Table 4.15).

Table 4.14. Mean Depths at which Red Grouper are caught by Headboats in the Gulf of Mexico (Area 21 = SW FL, 23=NW FL and AL)

year	area	Number of Trips Catching Red Grouper*	Mean Depth (feet)
1986	21	735	74
1987	21	643	74
1988	21	737	64
1989	21	603	52
1990	21	371	59
1991	21	326	77
1992	21	206	106
1993	21	242	64
1994	21	132	49
1995	21	120	49
1996	21	38	42
1997	21	14	36
1998	21	3	36
1999	21		
2000	21		
2001	21	11	36
2002	21		
2003	21	5	36
2004	21		
2005	21		
* and reporting location to 10 min sq			

year	area	Number of Trips Catching Red Grouper*	Mean Depth (feet)
1986	23	34	109
1987	23	64	111
1988	23	97	170
1989	23	57	117
1990	23	13	103
1991	23	23	86
1992	23	30	166
1993	23	53	89
1994	23	19	92
1995	23	86	155
1996	23	77	290
1997	23	58	294
1998	23	5	75
1999	23	52	190
2000	23	77	110
2001	23	110	121
2002	23	86	120
2003	23	197	119
2004	23	242	65
2005	23	222	106
* and reporting location to 10 min sq			

Table 4.15: Estimated mean depth at which discarded fish are caught. These estimates were provided by meeting participants active in the charter and private red grouper fishery.

Estimated mean depth/distance from shore at which discarded fish are caught.

Florida Peninsula

< 10 miles from shore			> 10 miles from shore		
Mode	Average Depth (feet)	Distance from Shore (miles)	Mode	Average Depth (feet)	Distance from Shore (miles)
Priv/charter	40	nearly 10	Private	80 (60 in 1980s)	20
			Charter	100 (80 in 1980s)	25-30

Florida Panhandle

< 10 miles from shore			> 10 miles from shore		
Mode	Average Depth (feet)	Distance from Shore (miles)	Mode	Average Depth (feet)	Distance from Shore (miles)
Priv/charter	80	nearly 8	Private	150 (105 in 1990s)	30 (15-20 in 1990s)
			Charter	150 (120 in 1990s)	30 (20-25 in 1990s)

TOTAL RECREATIONAL CATCHES

The total recreational catches landed (AB1) and released (B2) for the Gulf of Mexico 1981-2005 were obtained by applying the annual MRFSS (private mode) discard ratios to the headboat logbook harvest data (as described previously). The results are shown in Table 4.16. It should be noted that estimates of post-release mortality among the B2 category fish has not been incorporated. In order to obtain estimates of total fishing mortality, it will be necessary to assume some fraction of the live releases do not survive, perhaps in some relationship to the average depths estimated in the previous section.

Table 4.16. Total recreational catches landed (AB1) and released (B2) for the Gulf of Mexico 1981-2005. Headboat Survey Florida Keys areas (12+17) are not included; MRFSS 1981 wave 1 has been filled in; MRFSS data includes Florida Keys (Monroe county). Charter and cbt/hbt estimates use the new MRFSS charter boat method or are calibrated to the new method. Headboat releases are estimated.

	Headboat Survey								MRFSS		TOTAL REC	
	Landed (AB1)			MRFSS private ratio (b2/ab1) [for calculating releases]		Released (B2)=landed * ratio			Landed (AB1)	Released (B2)	Landed (AB1)	Released (B2)
YEAR	23-27 (NWFL-TX)	18+21+22 (FL Peninsula)	All areas	FL Panhandle + AL	Peninsula	23-27 (NWFL-TX)	18+21+22 (FL Peninsula)	All areas				
1981				0	0.52				301,493	80,967	301,493	80,967
1982				0	0.27				303,804	62,157	303,804	62,157
1983				0	0.18				641,980	215,488	641,980	215,488
1984				0	0.28				1,420,137	460,918	1,420,137	460,918
1985				0	0.12				764,929	121,260	764,929	121,260
1986	1,221	31,692	32,913	1.14	0.84	1,392	26,621	28,013	748,309	511,650	781,222	539,663
1987	963	24,766	25,729	0.49	1.18	472	29,224	29,696	403,249	467,205	428,978	496,901
1988	656	27,298	27,954	0.05	1.54	33	42,039	42,072	683,972	865,964	711,926	908,036
1989	305	49,472	49,777	0.08	3.28	24	162,268	162,293	751,490	1,970,761	801,267	2,133,054
1990	276	14,306	14,582	0.22	12.83	61	183,546	183,607	176,168	1,561,626	190,750	1,745,233
1991	249	9,260	9,509	2.26	11.5	563	106,490	107,053	287,649	3,003,500	297,158	3,110,553
1992	174	8,875	9,049	0	6.08	0	53,960	53,960	442,931	2,669,025	451,980	2,722,985
1993	1,176	7,626	8,802	0.23	6.53	270	49,798	50,068	362,205	1,738,166	371,007	1,788,234
1994	724	8,893	9,617	3.35	5.54	2,425	49,267	51,693	298,552	1,665,904	308,169	1,717,597
1995	724	13,775	14,499	6.8	6.7	4,923	92,293	97,216	282,435	1,621,635	296,934	1,718,851
1996	1,714	13,880	15,594	6.89	9.6	11,809	133,248	145,057	126,476	1,074,887	142,070	1,219,944
1997	1,167	3,509	4,676	5.17	15.1	6,033	52,986	59,019	87,578	1,080,112	92,254	1,139,131
1998	855	3,527	4,382	0.61	18.18	522	64,121	64,642	104,508	1,526,930	108,890	1,591,572
1999	620	6,298	6,918	4.23	11.92	2,623	75,072	77,695	178,011	2,087,036	184,929	2,164,731
2000	896	7,965	8,861	5.22	7.98	4,677	63,561	68,238	333,679	2,222,914	342,540	2,291,152
2001	2,535	3,025	5,560	2.87	11.68	7,275	35,332	42,607	214,799	1,665,768	220,359	1,708,375
2002	2,039	2,363	4,402	10.45	8.39	21,298	19,826	41,124	247,957	1,949,341	252,359	1,990,465
2003	3,737	3,784	7,521	8.58	14.14	32,071	53,506	85,577	217,356	2,080,930	224,877	2,166,507
2004	5,068	8,742	13,810	2.84	9.25	14,371	80,864	95,234	492,431	3,125,315	506,241	3,220,549
2005	5,379	8,588	13,967	4.87	13.98	26,194	120,060	146,254	244,148	1,713,061	258,115	1,859,315

LENGTH FREQUENCY DISTRIBUTIONS

Recreational length samples from the MRFSS and the Headboat Survey were analyzed. For the MRFSS, mean length was found to be different (by about 4 inches) between those years prior to 1990 and for 1990 until the present due to the implementation of a new size limit in 1990. MRFSS length frequency means are consistent by wave and by private and charter boat mode. Average size of red grouper increases from inshore to offshore waters. For the Headboat Survey, mean length was also found to be different (by about 5 inches) between years before and after the implementation of the new size limit in 1990. No differences were noted by season; however there may be differences between areas sampled; this is difficult to determine accurately due to very different sample sizes for each area (Saul, SEDAR 12-DW-12).

Issues

There was concern about low sample sizes from MRFSS for the early years, particularly for charter trips (Table 4.17). It was recommended that data from all recreational sources be pooled since the frequency distributions appear similar. This may improve precision, especially as sample sizes from the Headboat Survey were highest from the early years and MRFSS sample sizes were highest from the latest years.

The effect of the imposition of size limits (18 in. TL, in July 1985, for Florida waters; 20 in. TL in 1990 for federal waters) on the length frequency distributions was discussed. Figures 4.7 and 4.8 compare distributions, by mode, for periods before July 1985, for 1981-1989 and 1990-2005. The effect of the 1990 regulation is clear, but the impact of the 1985 regulation is less obvious.

Table 4.17. Recreational length sample sizes by year. MRFSS sample sizes are shown by mode (charter, private, and shore) and headboat samples include those collect through MRFSS and the Beaufort Headboat Survey.

Year	Charter Boat	Private Boat	Shore Mode	Headboat: MRFSS and Headboat Survey	Total Samples
1981	11	16	12	16	55
1982	1	89	2	7	99
1983	10	59	2	37	108
1984	25	26	2	48	101
1985	0	12	0	29	41
1986	38	33	0	360	431
1987	27	111	1	543	682
1988	48	184	4	347	583
1989	59	155	0	669	883
1990	13	36	0	243	292
1991	13	91	2	9	115
1992	114	214	13	54	395
1993	21	117	2	31	171
1994	58	93	2	52	205
1995	73	117	0	57	247
1996	31	45	0	71	147
1997	49	29	1	47	126
1998	130	79	1	40	250
1999	255	136	0	106	497
2000	372	132	0	69	573
2001	351	110	0	52	513
2002	487	124	0	129	740
2003	658	91	0	217	966
2004	1,317	252	0	172	1,741
2005	1,106	102	0	72	1,280

Figure 4.7. MRFSS red grouper length frequency distributions for three periods: a) 1981-1989, b) 1990-2005 and 1981- June 1985.

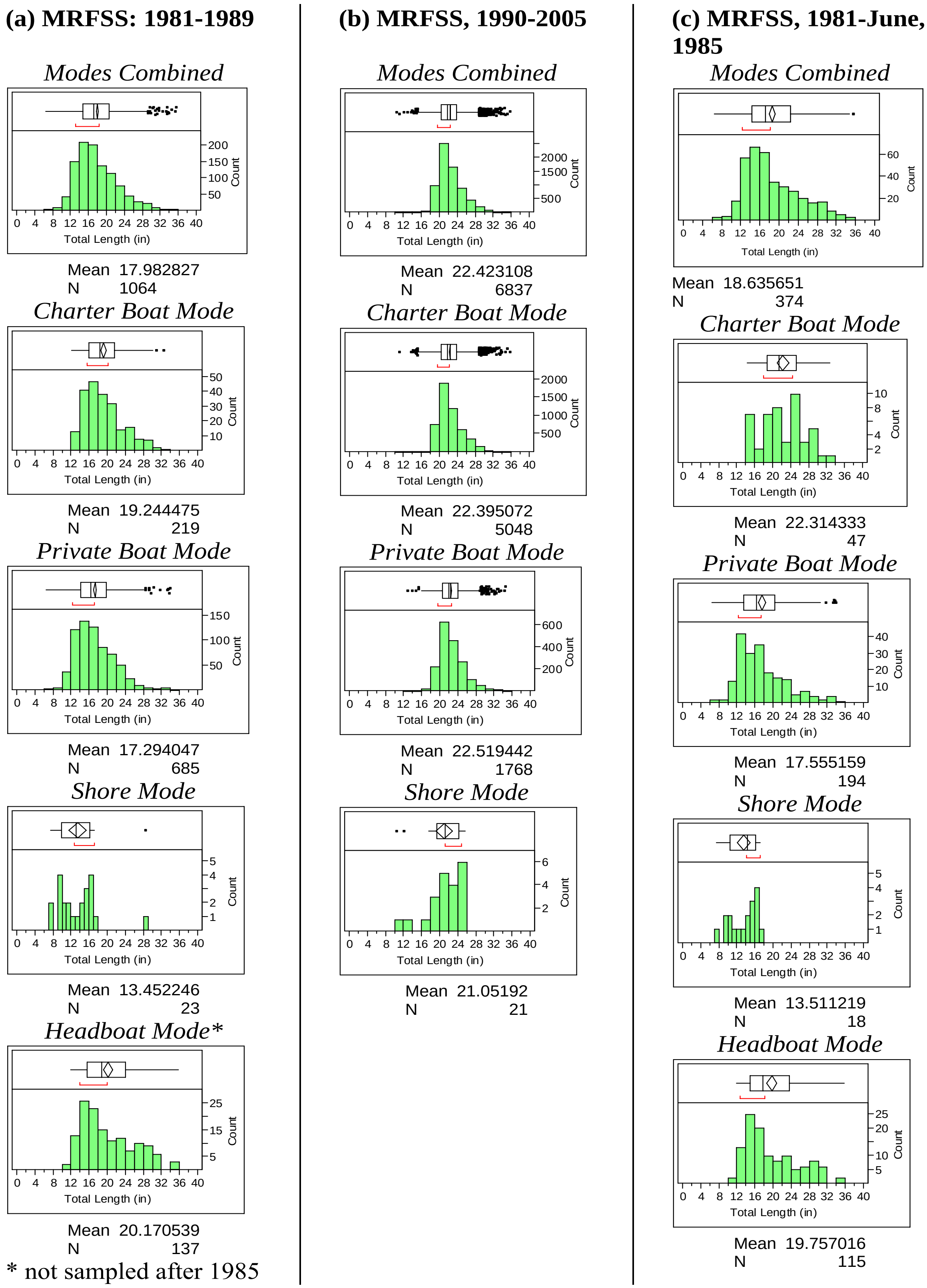
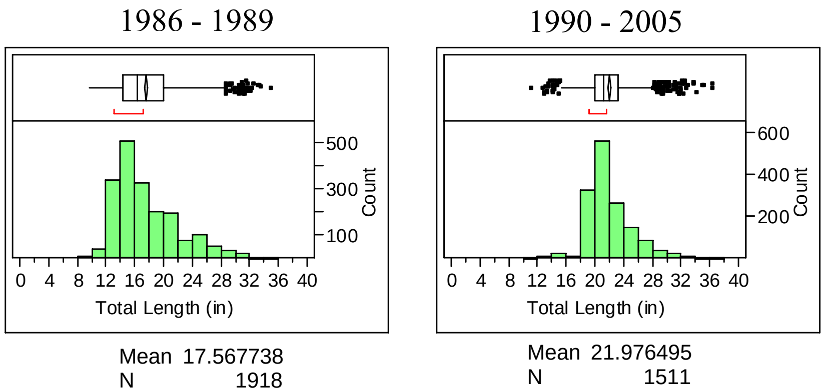


Figure 4.8. Headboat Survey for two periods, 1981-1989 and 1990-2005.



RESEARCH RECOMMENDATIONS

Interviews/data on catch rates are needed from recreational fisheries prior to 1981, in order to improve estimates of historical catches.

Discard mortality rates have a potentially high influence on the estimation of total mortality, since discard levels are so high. Therefore, it is recommended that there be further study of discard mortality rates, preferably linked to factors that can be obtained from available recreational data.

Discards undoubtedly have length/age frequency distributions which differ greatly from the landed catch, however there is little length or age information on these fish. Efforts should be made to collect such data. Collections methods could include length measurements of discarded fish obtained from anglers, at-sea observer programs, and/or the granting of special research permits allowing anglers to retain undersized fish as samples for researchers.

REFERENCES

Diaz, G. A. and P. Phares. 2004. Estimated conversion factors for calibrating MRFSS charter boat landings and effort estimates for the Gulf of Mexico in 1981-1997 with the for hire survey estimates with application to red snapper landings. National Marine Fisheries Service, Southeast Fisheries Science Center, Sustainable Fisheries Division, August, 2004. Sustainable Fisheries Division Contribution No. SFD-2004-036.

5. INDICES OF ABUNDANCE

Tables 5.1 to 5.3 summarize the available indices for red grouper in the U.S. Gulf of Mexico. The data sources, units, available years, and methodologies are summarized in Table 5.1. The recommendations and concerns of the SEDAR12 DW index of abundance working group are described in detail below, and in Table 5-2. The recommended indices and their associated variances are summarized in Table 5-3 and Figure 5.2.

5.1 FISHERIES DEPENDENT INDICES

In the following discussion, fishing locations are often referenced by shrimp statistical grid. These are illustrated in Figure 5-1.

5.1.1 COMMERCIAL HANDLINE

General Description:
The construction of the commercial handline index is described in the document SEDAR12-DW-16.

The NMFS Gulf of Mexico Reef Fish Logbook Program has collected catch and effort data by trip for permitted vessels since 1990. Between 1990 and 1992, a randomly selected subset (comprising 20% of vessels permitted in FL) were required to submit logbooks. After 1992, the data represent a complete census of commercial reef fish trips by vessels permitted in TX, LA, MS, AL and FL.

The logbook data include unique trip and vessel identifiers, and information regarding trip date, gear class, fishing area (shrimp statistical grids), days at sea, fishing effort, species caught and landed weight. Trips that occurred during red grouper or shallow water grouper closures were excluded from the analysis. Closures took place from February 15th to March 15th 2001 through 2005, Nov. 15th – Dec.31st 2004 and Oct. 10th - Dec. 31st 2005.

Methods:
Logbook data were restricted to statistical grids 1-11. There areas included >99% of the total gulf-wide handline landings of red grouper. Handline and electric reels were included in the analysis dataset, and were assumed to be equivalent. The Stephens and MacCall approach (2004) was applied to the dataset to restrict the trips to those that targeted the habitat of red grouper. Five factors were considered as possible influences on the proportion of trips that landed red grouper and are summarized below:

Factor	Levels	Value
YEAR	16	1990-2005
AREA	11	Gulf of Mexico shrimp grids 1-11
DAYS	4	1=1 day at sea, 2=2-3 days at sea, 4= 4-6 days at sea, 7=7-14 days at sea
MONTH	12	Month of the year
CREW	3	1, 2, 3 or more crew members

Handline catch rate was calculated in weight of fish per hook-hour. For each trip, catch per unit effort was calculated as:

CPUE = landings of red grouper/(number of lines fished*hooks per line*total hours fished)

The index was constructed using a delta-lognormal method. The final models were:

PPT = YEAR + DAYS + AREA

LN(CPUE) = YEAR + AREA + CREW + MONTH + YEAR*AREA + AREA*MONTH + YEAR*MONTH

Results:

Standardized catch rates developed from red grouper handline data were relatively constant during the first six years of the time series (Figure 5.2, Table 5.3). Catch rates decreased slightly over the three years ending in 1998. Over the last seven years of the time series examined, catch rates have been increasing, except for a decrease in 2003.

Utility:

The SEDAR12-DW working group recommends the use of the commercial handline index. Potential changes in catchability should be addressed by:

1) Assuming constant catchability.
2) Applying a 2% annual increase in catchability, as per gag grouper (SEDAR10)

5.1.2 COMMERCIAL LONGLINE

General Discussion:
The construction of the commercial longline index is described in the document SEDAR12-DW-16. The general discussion regarding the data source can be found in section 5.1.1.

Methods: For the longline index, logbook data were restricted to statistical grids 1-10. There areas included >99% of the total gulf-wide longline landings of red grouper. The Stephens and MacCall approach (2004) was applied to the dataset to restrict the trips to those that targeted the habitat of red grouper. Six factors were considered as possible influences on the proportion of trips that landed red grouper and are summarized below:

Factor	Levels	Value
YEAR	16	1990-2005
AREA	10	Gulf of Mexico shrimp grids 1-10
DAYS	13	1-2, 3-4, 5,6,7,8,9,10,11,12,13,14, 15-20 days at sea
MONTH	12	Month of the year
CREW	3	1, 2, 3 or more crew members

LENGTH OF LL	6	<3, 3-3.9, 4-4.9, 5-5.9, 6-6.9, and 7 or more miles

Longline catch rate was calculated in weight of fish per hook fished. For each trip, catch per unit effort was calculated as:

CPUE = total pounds of red grouper/(number of longline sets*number of hooks per set)

To construct the index, a lognormal model was applied to all trips, with an offset applied to trips that did not land red grouper (10% mean CPUE). A delta-lognormal was not attempted because of the proportion positive exceeded 90% annually, invalidating the assumptions of the binomial model. The final model for the lognormal on CPUE of successful trips was:

LN(CPUE) = YEAR + LENGTH + AREA + YEAR*AREA

Results:

Standardized catch rates developed from red grouper longline data have increased only slightly over the time series examined (Figure 5.2, Table 5.3). Somewhat higher catch rates were observed during the years 2001, 2004, and 2005. Lowest standardized CPUE was in 1992.

Utility:

The SEDAR12-DW working group recommends the use of the commercial longline index. Potential changes in catchability should be addressed by:

1) Assuming constant catchability.
2) Applying a 2% annual increase in catchability, as per gag grouper (SEDAR10)

5.1.3 COMMERCIAL TRAP

General Discussion:

The construction of the commercial trap index is described in the document SEDAR12-DW-16. The general discussion regarding the data source can be found in section 5.1.1.

Methods: For the trap index, logbook data were restricted to statistical grids 1-8. These areas included >99% of the total gulf-wide trap landings of red grouper. The Stephens and MacCall approach (2004) was applied to the dataset to restrict the trips to those that targeted the habitat of red grouper. Five factors were considered as possible influences on the proportion of trips that landed red grouper and are summarized below:

Factor	Levels	Value
YEAR	16	1990-2005
AREA	8	Gulf of Mexico shrimp grids 1-8
DAYS	9	1,2,3,4,5,6,7,8, 9-16 days at sea
MONTH	12	Month of the year
CREW	3	1, 2, 3 or more crew members

Fish trap catch rate was calculated in weight of fish per trap fished. For each trip, catch per unit effort was calculated as:

CPUE = total pounds of red grouper/number of traps fished

For trap data, the number of hours fished and the number of sets while using traps has clearly been misreported. This is probably due to confusion among fishers as to how those data should be reported. Calculating CPUE by soak time (total trap-hours fished) was not possible with the trap data.

To construct the index, a lognormal model was applied to all trips, with an offset applied to trips that did not land red grouper (10% mean CPUE). A delta-lognormal was not attempted because of the proportion positive exceeded 90% annually, invalidating the assumptions of the binomial model. The final model for the lognormal on CPUE of successful trips was:

LN(CPUE) = YEAR + AREA + DAYS + MONTH + YEAR*AREA + YEAR*DAYS + AREA*DAYS + AREA*MONTH + YEAR*MONTH

Results:

Red grouper standardized catch rates developed from trap data have no consistent trend over the time series (Table 5.3, Figure 5.2). A slight increase in catch rates during 1990-1994 was followed by four years of decreasing CPUE. The lowest catch rate in the series was observed in 1998 with the highest catch rate occurring in 1999. Catch rates steadily decreased during the period 2000-2003 then increased in 2005.

Utility:

The SEDAR12-DW working group ***did not recommend*** the commercial trap index due to the inadequacy of the available unit of effort. The group was concerned that traps per vessel was not appropriate and the variable trap sets (EFFORT) and soak time (FISHED) were often misreported

5.1.4 HEADBOAT SURVEY

A preliminary version of the headboat index was presented at the SEDAR12-DW. Important revisions were recommended by the index working group, and the SEDAR plenary. The concerns of the groups are listed below.

Issues discussed at the Data Workshop:

1) Upon examination of headboat size frequency distributions, it became apparent that the imposition of a 20 inch TL minimum size limit in February 1990 influenced the size of the landings, implying that fish smaller than 20" may have been discarded after the 20" size limit (Figure 5.3). Discards were not reported to the Headboat Survey program before 2004. Therefore, the group recommended that two indices be constructed, broken at the initiation of the 20" minimum size limit (Feb. 21, 1990

2) The group recommended that the vessel effect be modeled using a "repeated measures" approach (Little et al., 1998). This method will allow vessel interaction terms to be included if they are significant.

3) The group was concerned about possible year*area interaction terms that are not addressed in the preliminary index. The group was advised by fishermen that the high catch rates implied by the index may be regional in nature, and that some areas appear to be experiencing low catch rates. The group recommended that the area effect be carefully examined, and if necessary, regional indices be constructed.

4) The group recommended that trips occurring during red grouper/shallow water grouper closures be removed from the analysis.

The headboat index was revised taking into account the recommendations of the group. The revised headboat index is discussed below, and described in detail in document ***SEDAR12-AW-02.***

General Discussion:
Rod and reel catch and effort from party (head) boats in the Gulf of Mexico have been monitored by the NMFS Southeast Zone Headboat Survey (conducted by the NMFS Beaufort Laboratory) since 1986. The Headboat Survey collects data on the catch and effort for a vessel trip. Reported information includes landing date and location, vessel identification, the number of anglers, fishing location, trip duration and/or type (half/three-quarter/full/multi-day, day/night, morning/afternoon), and catch by species in number and weight.

Material and Methods:
Two revised indices were developed based on the recommendations of the SEDAR12-DW plenary using data from the NMFS Southeast Zone Headboat Survey. The first index was constructed for the period 1/1/1986-2/20/1990, and reflects the fishery during the FL 18" minimum size limit. The second index was constructed for the period 2/21/1990-12/31/2005 (excluding shallow water grouper closures). Based upon the typical geographic distribution of red grouper, three zones were defined off the Florida and Alabama coasts (NWFL-AL, FL Middle Grounds and SWFL). The analyses were restricted to data from these three zones. The Stephens and MacCall (2004) species association approach was used to identify trips that were likely to have fished in red grouper habitat based on the composition of other species landed. Only trips selected by the Stephens and MacCall (2004) approach were included in the analysis datasets.

The following factors were examined as possible influences on the proportion positive trips, and the catch rates on positive trips:

- YEAR
- SEASON (Dec-Feb, Mar-May, Jun-Aug, Sep-Nov)
- TRIPCAT (1/2 day, ¾ day, full day, multi-day)

- DAY/NIGHT (day trip, night trip, mixed)
- AREA (SW FL, FL Middle Grounds, NWFL-AL)
  VESSEL

The variation in catch rates by VESSEL was examined using a "repeated measures" approach (Little et al., 1998). The term "repeated measures" refers to multiple measurements taken over time on the same experimental unit (i.e. vessel). Specifying the repeated measure "VESSEL" and the subject "VESSEL(YEAR)" allows PROC MIXED to model the covariance structure of the data. This is particularly important because catch rates may vary by vessel ***and because*** catch rates on trips by a given vessel close in time can be more highly correlated that those far apart in time (Littell et al., 1998).

Catch rate (CPUE) on positive trips was calculated in number of fish per angler hour.

CPUE = number of fish / (anglers * hours fished)

The variable "Hours Fished" does not exist in the dataset. To estimate the number of hours fished, the following assumptions were necessary:

½ day trip = 5 hours fished
¾ day trip = 7 hours fished
1 day trip = 10 hours fished
1½ day trips = 15 hours fished
multi-day trips = number of days * 10 hours fished

A delta-lognormal approach (Lo et al. 1992) was used to develop the standardized catch rate indices. This method combines separate generalized linear modeling (GLM) analyses of the proportion positive trips (trips that caught Red Grouper) and the catch rates on successful trips to construct a single standardized index of abundance. Parameterization of each model was accomplished using a GLM procedure (GENMOD; Version 8.02 of the SAS System for Windows © 2000. SAS Institute Inc. Cary, NC, USA). The final delta-lognormal model was fit using the SAS macro GLIMMIX and the SAS procedure PROC MIXED (SAS Institute Inc. 1997) following the procedures described by Lo et al. (1992).

The final models were:

Minimum Size Limit 18" (1/1/1986-2/20/1990)

- PPT = YEAR + AREA + TRIPCAT

- LN(CPUE) = YEAR + AREA + SEASON + TRIPCAT + SEASON*AREA + VESSEL(YEAR)[1]

Minimum Size Limit 20" (2/21/1990 - 12/31/2005)

- PPT = YEAR + TRIPCAT + AREA + YEAR*AREA

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[1] The variation in catch rates by VESSEL were examined using a "repeated measures" approach (Little et al., 1998).

– LN(CPUE) = YEAR + AREA + VESSEL(YEAR)[1]

Results:

Standardized catch rates developed from red grouper headboat data during the Florida 18” minimum size limit (before 2/20/90), were relatively constant (Figure 5.2, Table 5.3). After the 20” minimum size limit commenced, catch rates remained relatively constant from 1990 to 2002, then rapidly increased. The estimated catch rates in 2005 are the highest on record (Figure 5.2, Table 5.3).

Utility:

The index of abundance working group expressed concern regarding the lack of discard information for the headboat survey. During the 2002 assessment, the headboat index was not included in the base models because the assessment group was concerned that targeting might have shifted during the time series, and the change in size limit might cause a shift in selectivity. These issues were addressed by the index author by 1) using the Stephens and MacCall approach to restrict trip to those that occurred in red grouper habitat, and 2) splitting the index at the change in size limit (2/21/90).

The group confirms that the construction or the HB index was consistent with the recommendations of the plenary session. *Therefore, the working group recommends that the index be presented to the assessment workshop for a final recommendation regarding its utility.*

5.1.5 MARINE RECREATIONAL FISHERY STATISTICS SURVEY (MRFSS)

General Description:
The construction of the MRFSS index is described in the document SEDAR12-AW-03.

Data collected and estimated by the Marine Recreational Fisheries Statistical Survey (MRFSS) were used to develop standardized catch per unit effort (CPUE) indices for red grouper stocks of the Gulf of Mexico. The recreational fisheries survey started in 1979, and its purpose is to establish a reliable database for estimating the impact of marine recreational fishing on marine resources. More detailed information on the methods and protocols of the survey can be found at http://www.st.nmfs.gov/st1/recreational/overview/ overview.html.

Methods:
Catch and effort data from the MRFSS survey was used to generate standardized relative indices of abundance for Gulf of Mexico red grouper.

The data source is the Marine Recreational Fisheries Statistical Survey (MRFSS) intercept data. The data was collected from 1979-2005, but the years 1979-1980 are no longer supported by the MRFSS program. 1981-1985 data were excluded due to very few observations of red grouper during this time. The low sample sizes made model convergence impossible.

Data included trip/interview records from the Florida west coast. The following exclusions were mode to the dataset:

1) inshore effort was excluded (very few red grouper)
2) HB were excluded (not available in dataset after 1985)
3) Trips outside of FL were excluded. (Over 95% of the catch occurs off FL)

The Stephens and MacCall (2004) approach was used to restrict the dataset to those trips that targeted the habitat of red grouper, based on the species composition of the trip.

The following factors were examined as possible influences on the proportion positive trips, and the catch rates on positive trips:

FACTOR	LEVELS	VALUES
YEAR	20	1986-2005
MODE	2	CB, PB
SEASON	4	Dec-Feb, Mar-May, Jun-Aug, Sep-Nov
AREA	2	<10 miles offshore >10 miles offshore
REGION	3	SWFL, CWFL, NWFL
RS_SEASON	2	Open, Closed

The factor RS_SEASON is the status of the red snapper fishery (open, closed), this factor was tested, but was not significant in any model

CPUE was calculated:

CPUE = (Number A + Number B1 +Number B2)/(Angler*Hours)

Where A is fish kept, B1 is typically dead fish not observed by the sampler (discarded dead, used as bait, etc) and B2 are fish released alive.

A delta-lognormal model was used to construct the index of abundance. The final models were:

- PPT = YEAR + AREA + REGION + YEAR + YEAR*REGION

- LN(CPUE) = YEAR + REGION + MODE + REGION*MODE + YEAR*REGION

Results:

The MRFSS index shows no consistent trend in catch rates of red grouper. During 1986-1990, the catch rates increase rapidly, followed by a steep decline until 1997. Thereafter, the catch rates show a generally increasing trend through 2004. The estimated catch rate during 2005 is lower than 2004, but still higher than the series average (Table 5.3.; Figure 5.2).

Issues discussed at the Data Workshop:

1) There was concern that some B2 animals (released alive) are subsequently recaptured on the same trip.

2) There was concern that the B2 reports may be inaccurate because the data are self-reported by fishermen who may not accurately recollect the number of animals released alive.

3) There was concern that the effect of the NRC report critical of the MRFSS recreational survey is not known. It is possible the changes in the sampling methodology may impact indices of abundance, and that the effects of possible changes are not predictable.

Utility: The group recommends the use of the MRFSS Recreational Index. Potential changes in catchability should be addressed by:

1) Assuming constant catchability.
2) Applying a 2% annual increase in catchability, as per gag grouper (SEDAR10)

5.2 FISHERIES INDEPENDENT INDICES

5.2.1 SEAMAP VIDEO SURVEY

The SEAMAP Video Survey is described in SEDAR12-DW-6. Annual indices of abundance were constructed for red grouper observed in the eastern Gulf of Mexico.

Methods:

- Two-stage sampling design
    - First-stage is made up of blocks 10 minutes of latitude by 10 minutes of longitude, selected by stratified random sampling
    - Second-stage units within a block are selected randomly.
- Random 20-minute sections of videos were reviewed.
- Mincount (i.e., maximum number of fish on the video image at any one time during 20 minute viewing) was recorded for all red grouper.
- Delta-lognormal model used to develop abundance index from mincount data.
    - Parameters tested for inclusion in each sub-model were year, stratum, and block nested within stratum, station depth.
    - All parameters were considered fixed, except for block nested within stratum, which was considered random. The estimates from each model were weighted

using the stratum area, and separate covariance structures were developed for each survey year.

Results:

- The model converged.
    - Red grouper East Gulf Index
        - Parameters retained binomial model: year, stratum, block number nested within stratum, depth
        - Parameters retained lognormal model: year
- Size of red grouper observed in videos
    - 217 red grouper were hit by lasers, indicating sizes ranging from 250 to 750 mm FL, with the majority of individuals falling between 400 and 550 mm FL.
- The results, including the standardized index and index variance are summarized in Table **5.3**. The relative index in compared to other fisheries-independent indices in Figure **5.2.**

Issues Discussed at Data Workshop:

Utility:

The group recommends the use of the eastern Gulf video survey index, and concludes the index applies to age 3+ red grouper based on length and age distributions.

5.2.2 SEAMAP BOTTOM LONGLINE SURVEY

The SEAMAP Bottom Longline Survey is described in SEDAR12-DW-5. Annual indices of abundance were constructed for red grouper observed in the eastern Gulf of Mexico.

Methods:

- Stratified (by depth) random sampling.
- One station consists of 100 hooks per one nautical mile of line soaked for one hour.
- Only survey years 2000 to 2005, during which circle-hooks were employed, were used
- Only data from stations within the depth range of capture for red grouper (i.e. 13 – 116 m) and east of 87° west longitude were used.
- Delta-lognormal model used to develop abundance index from mincount data.
    - Parameters tested for inclusion in each sub-model were year, area, salinity, dissolved oxygen, temperature and station depth.
    - All parameters were considered fixed.

Results:

- The model converged.
    - Red grouper East Gulf Index
        - Parameters retained binomial model: temperature, water depth, survey area and year
        - Parameters retained lognormal model: temperature, water depth, survey area and year
- Size/Age of red grouper observed in bottom longline surveys

  - 352 red grouper were hit by lasers, indicating sizes ranging from 250 to 900 mm TL, with the majority of individuals falling between 400 and 600 mm TL.
  - Fish aged 4 to 21 over all years of the survey.
- The results, including the standardized index and index variance are summarized in Table **5.3** The relative index in compared to other fisheries-independent indices in Figure **5.2.**

Issues Discussed at Data Workshop:

Utility:

The group recommends the use of the eastern Gulf bottom longline survey index (zero inflated), and concludes the index applies to age 4+ red grouper based on age distributions.

5.2.3 DRY TORTUGAS VISUAL CENSUS

This survey is described by Bohnsack and Bannerot and in a SEDAR12-DW working paper. The data are from visual surveys by divers within and outside the Dry Tortugas National Park. Additional analyses of these data will be prepared for the SEDAR 12 assessment workshop.

Methods:
- Bohnsack and Bannerot visual census method
  - Count all fish within a cylinder
  - Counts of red grouper at each station were generally 1 or 0
  - Size of fish estimated
- Data were available for the period 1994-2000, however additional data for the years after 2000 will be obtained from the survey PIs and incorporated in future analyses
- Model variables: Year, month, habitat (reef or not reef)
- Index constructed using a binomial model on proportion positive trips, main effects only, no interaction terms considered

Results:
- Size frequency data of 491 red grouper, size range of 5-85 cm with the majority of observed fish between 25 and 55 cm.
- The model converged
  - Parameters retained: year, month, habitat
- The results, including the standardized index and index variance are summarized in Table **###**. The relative index in compared to other fisheries-independent indices in Figure **###**

Utility:

THE GROUP RECOMMENDED REVISION, AND REQUESTED A REVIEW OF THE REVISED INDEX BEFORE APPROVAL. The concerns of the group are summarized below.

Issues Discussed at Data Workshop:

Survey area is at the southern extreme of the GMFMC management unit, and borders the South Atlantic management unit. The group was concerned that the abundance trend might not represent the GOM management unit.

The group was concerned that inside the park boundary, red grouper would experience different fishing pressure than outside the park. Only private vessels are allowed to fish within the park. Differences in fishing pressure might influence the index. The group recommended that this be investigated during the construction of the revised index.

Additional data exists from the Marquesas and the Florida Keys. The group discussed the addition of these samples to the index dataset, but ultimately decided not to include these samples.

The group recommended that data from 2000-2005 be added if feasible. The group recognized that changes in habitat classification took place, but felt that this might be handled by reclassifying the data into consistent grouped categories.

The group discussed an important change in methodology in 1999. At this time, the sampling method was changed from fixed stations to randomly selected stations. The group made two recommendations:

1) Model-based approaches (GENMOD/GLMMIX etc.) should construct separate indices for the two periods.

or 2) Non-model based approaches should be used that use habitat to estimate abundance.

Revisions requested by the DW panel:
1) "Model-based Index"
a) Break index in 1999 when sampling methodology changed
b) Examine habitat classification and choose most appropriate habitat classifications
c) Remove smallest fish from the dataset. (Contact Steve Turner for details).

5.2.4 EVERGLADES NATIONAL PARK CREEL SURVEY

Methods:

- Recreation sport fishers were interviewed by Everglades National Park personnel at boat ramps upon completion of their fishing trip.
- Data recorded included trip origin, area fished, number of fish kept and released by species, number of anglers, hours fished, species preference, angler residence, and type of fisher (i.e. skilled, family, novice, sustenance).
- Applied the association statistic as described by Cass-Calay and Schmidt (2003).
- Variables to be tested in model: year, area, season, fisher skill, and targeted species
- Lognormal zero-inflated model used to develop an index of abundance
- Catch per unit effort was number of fish per angler-hour

Results:
Proportion positive trips was very low, with several years of no positive trips

- The model converged when years with no or very few positive trips were excluded from the analysis

Utility:

This index was not recommended for use do to low sample sizes. Only 423 red grouper were observed from 1979-2005. The group felt that the index might not reflect the abundance of the GOM stock of red grouper.

5.2.5 NORTHEAST GULF INNER SHELF TRAP SURVEY (NMFS Panama City)

General Discussion:

The NMFS inner shelf trap survey is described in SEDAR12-DW-8. The survey began in 2004 based on a pilot study in 2002 and 2003 in the waters off Panama City, FL. The original objective of the survey was to use chevron fish traps to generate an age-based annual index of abundance for young (approx. age 0-3), pre-recruit gag, scamp, and red grouper in the northeast Gulf. In 2004 the objectives were expanded to include examining regional catch, recruitment, and demographic patterns of several other economically important reef fish species in the NE Gulf. The survey covers the waters off Panama City and a large portion of the Big Bend region. Beginning in 2005, at many of the sites, visual (stationary video) data on relative abundance and species composition was collected immediately preceding the trap set, and starting in 2006, this protocol is followed for all sets .

Methods:

- Systematic survey – limited but continually expanding sample universe. Goal is stratified random sampling when sample universe is large enough.

- 90 minute sets once or twice per year 2004-2005, once per year starting 2006.

Results:

- Red grouper caught in 18 of 59 (30.5%) trap sets (49 unique sites) in 2004 and in 33 of 101 (32.7%) trap sets (77 unique sites) in 2005.
- West of Cape San Blas
    - Frequency of occurrence: 27.3% in 2004 and 41.7% in 2005
    - Median catch per trap hour: 1.27 in 2004 and 0.93 in 2005
    - Dominated by 1999 year class
- East of Cape San Blas
    - Frequency of occurrence: 34.6% in 2004 and 29.9% in 2005
    - Median catch per trap hour: 1.31 in 2004 and 1.29 in 2005
    - Dominated by 2002 year class
- Visual data collected at 41 of the 101 trap sites in 2005, all east of Cape San Blas. Red grouper seen at 7of 41(17.1%) sites vs. 9 of 41 (22%) in corresponding trap sets - in only 2 instances were they both seen and caught in trap.

Issues Discussed at Data Workshop:

The group felt that this survey has enormous potential. Currently, the survey is primarily exploratory, and only two years of observations exist. Therefore, the group felt that the data could not be used for the 2006 assessment of red grouper. However the group would like to emphasize the importance of fisheries-independent surveys, and particularly those that index year-class strength. The group recognizes that large variations in year-class strength occur in red grouper. No recruitment indices were presented for the consideration of the SEDAR12 panel, and data sources used for other species (SEAMAP trawl) were not appropriate for use for red grouper, primarily due to extremely small sample sizes.

Therefore, the group strongly recommends that the NE Gulf Inner Trap Survey continue, and that the sampling methodology be standardized.

5.2.6. TAGGING INDEX (MOTE tagging data)

Methods:
Utility: Not recommended for the base cases.

5.3 RESEARCH RECOMMENDATIONS:

1) Fisheries-independent recruitment indices are lacking for red grouper. The group highly recommends the initiation and continued funding of such surveys, including, but not limited to the NE GULF INNER SHELF TRAP SURVEY. As trends can be regional in nature, the group highly recommends that recruitment trends be examined gulf-wide.

2) The group recommends that research be conducted to assess the possible impacts of hurricanes on the catch per unit effort of snapper/grouper complex members.

3) The group recommends that research be conducted to assess the possible impacts of red tide on the catch per unit effort of snapper/grouper complex members.

Table 5-1. A summary of catch series from the Gulf of Mexico available for the SEDAR10 data workshop.

Fishery Type	Data Source	Area	Years	Catch Units	Effort Units	Standardization Method	Age Range	USE for BASE
REC	Headboat	Areas 18-23; (NWFL-AL to SW FL)	1986-2/20/1990 and 2/21/1990-2005	Number	Angler*Hours	***2 indices (Size Limit)** Stephens and MacCall, delta-lognormal	To be determined (TBD)	***Provisionally accepted. Review at AW***
REC	MRFSS	Western FL	1986-2005	Number	Angler*Hours	Stephens and MacCall, delta-lognormal	TBD	YES
COM	Longline	Areas 1-10 (Eastern GOM)	1990-2005	Pounds	Hooks	Stephens and MacCall, Lognormal on all trips with offset to zeros	TBD	YES
COM	Handline	Areas 1-11 (Eastern GOM)	1990-2005	Pounds	Hook*Hour	Stephens and MacCall, delta-lognormal	TBD	YES
COM	Trap	Areas 1-8 (FL)	1990-2005	Pounds	Trap	Stephens and MacCall, Lognormal on all trips with offset to zeros		NO
Fish. Ind.	SEAMAP Video Survey	East Gulf	1993-2005 with missing years	Number (video minimum count) per site	20 minutes of video	Delta-lognormal model	Age 3+, few length obs from chevron and lasers	YES
Fish. Ind.	NMFS Longline	East Gulf	2000-2005	Number	100 hooks * hr	Delta-lognormal model	Ages 4+, otolith samples available	YES
Fish. Ind.	Dry Tortugas Visual Census	Dry Tortugas (SW FL)	1994-2000?	Count	square meter	Binomial model on PPT (Presence/Absence)	491 obs: 5-85 cm, most between 25-55 cm.	REVIEW after revisions
Fish. Ind.	ENP Creel Survey	SW FL	1979-2005	Number	angler*hour	Delta-lognormal?		NO

Table 5-2. *Pros and Cons for each index as identified by the SEDAR12-DW.*

Fishery Dependent Indices

Recreational: Headboat (*Working group recommended revisions and subsequent review*)

Pros: 1) Relatively long time series (1986-2004)
2) Large sample sizes
3) Considered a census of headboat landings and effort.

Cons: 1) Influenced by regulatory changes
2) Lacks discard rates until 2004
3) Variability in fishing practices at vessel level (targeting changes)
a) The Stephens and MacCall (2004) approach was applied to identify targeted trips using species composition.
b) a "repeated measures" approach (Little et al 1998) was used to adjust for vessel effect and vessel interaction terms
4) There was concern that there are important differences in the CPUE with area. The group recommended a careful examination of YEAR*AREA interactions. The analyst should determine whether area-specific indices are necessary.
5) Catchability may vary over time

Recreational: MRFSS (*Recommended for use*)

Pros: Data are from dockside interviews by scientific samplers.
Believed to be unbiased
Long time series
Complete area coverage
Only FD index that includes discard information (AB1B2)

Cons: Changes in catchability are possible

Commercial Indices – Handline and Longline (*Recommended for use*)

Pros: Complete census of fishing trips after 1992. (20% random sample of FL vessels 1990-1992)
Covers broad geographical area
Continuous, 16-year time series (1990-2005)

Cons: Self-reported data
Catchability may vary over time
Variability in fishing practices at vessel level (targeting?)
The group felt that this was adequately addressed by the application of the Stephens and MacCall (2004) approach to restrict the dataset to targeted trips.

Commercial Indices -TRAP (*Not recommended for SEDAR 12)*)

Pros: Same as other commercial series (see above)

Cons: In addition to the other concerns associated with the commercial indices, the group felt the unit of effort (TRAP: trap on boat) was inappropriate, as it does not indicate the number of trap sets on a trip or the soak time. The group expressed a lack of confidence that sets (NUMGEAR) and soak time (FISHED) are reliable variables in the trap dataset. Therefore, the group ***rejected*** the trap index.

Fishery Independent

SEAMAP (Video Survey)   (Recommended for use)

Pros: stratified random sample design
Adequate hard bottom coverage
Standardized sampling techniques

Cons: Data holidays (1993-1997, 2002, 2004 included years)

NMFS Longline Survey (Recommended for use)

Pros: Fisheries independent data
Stratified random sampling by depth
Standardized sampling technique.

Cons: Change from j-hooks to circle hooks in 2000.
Therefore, the group recommended only the use of the 2000-2005 data.

ENP Creel Survey (Not recommended for use)

Inadequate sample sizes, not possible to construct an index

Dry Tortugas Visual Survey (Revise and review)

Pros: Fisheries independent data

Cons: Extreme southern range of Management Unit
Borders South Atlantic Management Unit.
May not represent Gulf abundance trends.
Some sampling occurs within the park-where only private boats are allowed to fish. Other samples occur outside the park where there are commercial vessels.

SEAMAP TRAWL SURVEY

Inadequate sample sizes, not possible to construct an index

Table 5.3 The recommended indices of abundance and the associated CVs. These are the raw indices scaled to the mean each time series (e.g. the mean value of each index = 1.0).

	Fisheries-independent				Fisheries-dependent									
	Bottom Longline		Video		Comm LL		Comm HL		HB (18" MSL)		HB (20" MSL)		MRFSS	
Year	Index	CV	Index	CV	Index	CV	Index	CV	Index	CV	Index	CV	Index	CV
1986									0.7449	0.6107			0.6877	0.5493
1987									1.1838	0.4983			0.6576	0.5638
1988									1.0426	0.5136			0.9247	0.4661
1989									1.2184	0.5011			1.3183	0.4346
1990					0.7737	0.1327	0.6959	0.2279	0.8103	0.6458	0.8481	0.5446	1.8693	0.4526
1991					0.7786	0.1204	0.6475	0.2119			0.9423	0.5352	1.1475	0.4996
1992					0.6804	0.1333	0.7476	0.1961			0.7955	0.5576	1.2673	0.4226
1993			0.8879	0.1842	0.9729	0.1060	0.6832	0.1751			0.7635	0.5365	0.7809	0.4801
1994			0.8557	0.1531	0.8317	0.1037	0.8822	0.1664			0.8033	0.5433	0.9319	0.4468
1995			0.6481	0.2147	0.9769	0.1028	0.8712	0.1642			0.9190	0.5423	0.7691	0.5021
1996			0.9199	0.1602	0.8437	0.1029	0.6078	0.1704			0.7417	0.5698	0.6046	0.5141
1997			0.9445	0.1261	1.0119	0.0990	0.5657	0.1747			0.5691	0.5777	0.5448	0.5383
1998					0.9825	0.1013	0.5366	0.1745			0.6346	0.5745	0.7546	0.4446
1999					1.0022	0.1047	0.7175	0.1638			0.6312	0.5568	0.9295	0.4019
2000	0.5646	0.6673			0.9942	0.1013	0.9867	0.1583			0.8734	0.5499	1.0472	0.3967
2001	0.6539	0.2889			1.3186	0.0973	1.4534	0.1552			0.8444	0.5314	0.8691	0.3973
2002	1.6735	0.8118	1.1164	0.1012	1.0246	0.1011	1.5219	0.1518			0.9270	0.5296	0.9032	0.3919
2003	1.0420	0.2289			0.9776	0.1010	1.1400	0.1508			1.3753	0.4891	1.1128	0.3610
2004	1.3907	0.1925	1.2912	0.0865	1.2777	0.0982	1.7734	0.1477			2.0143	0.4701	1.6755	0.3046
2005	0.6753	0.5804	1.3365	0.0710	1.5529	0.0984	2.1694	0.1495			2.3172	0.4693	1.2045	0.3378

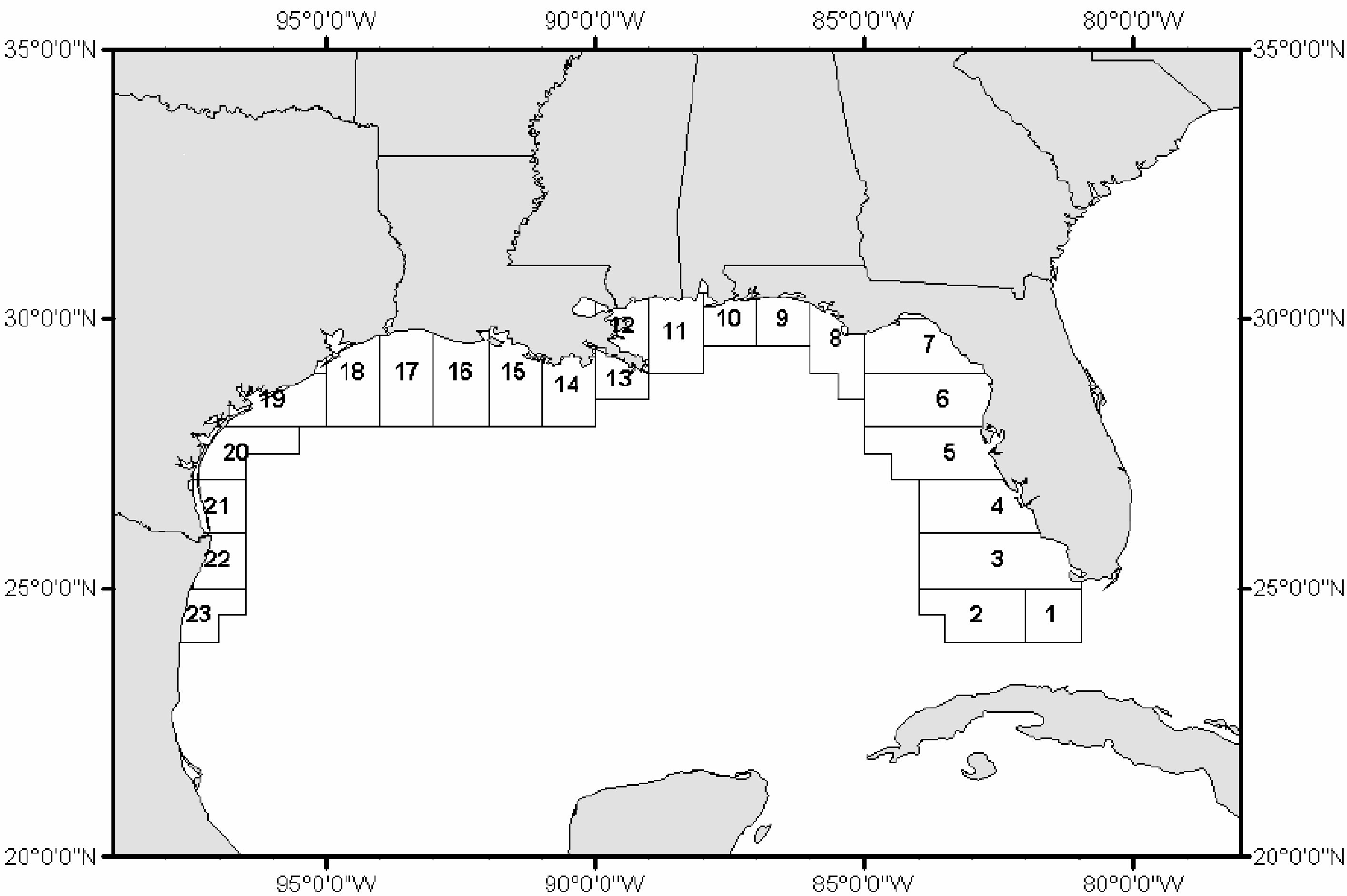


Figure 5-1. Shrimp statistical grids used to identify fishing areas in the U.S. Gulf of Mexico.

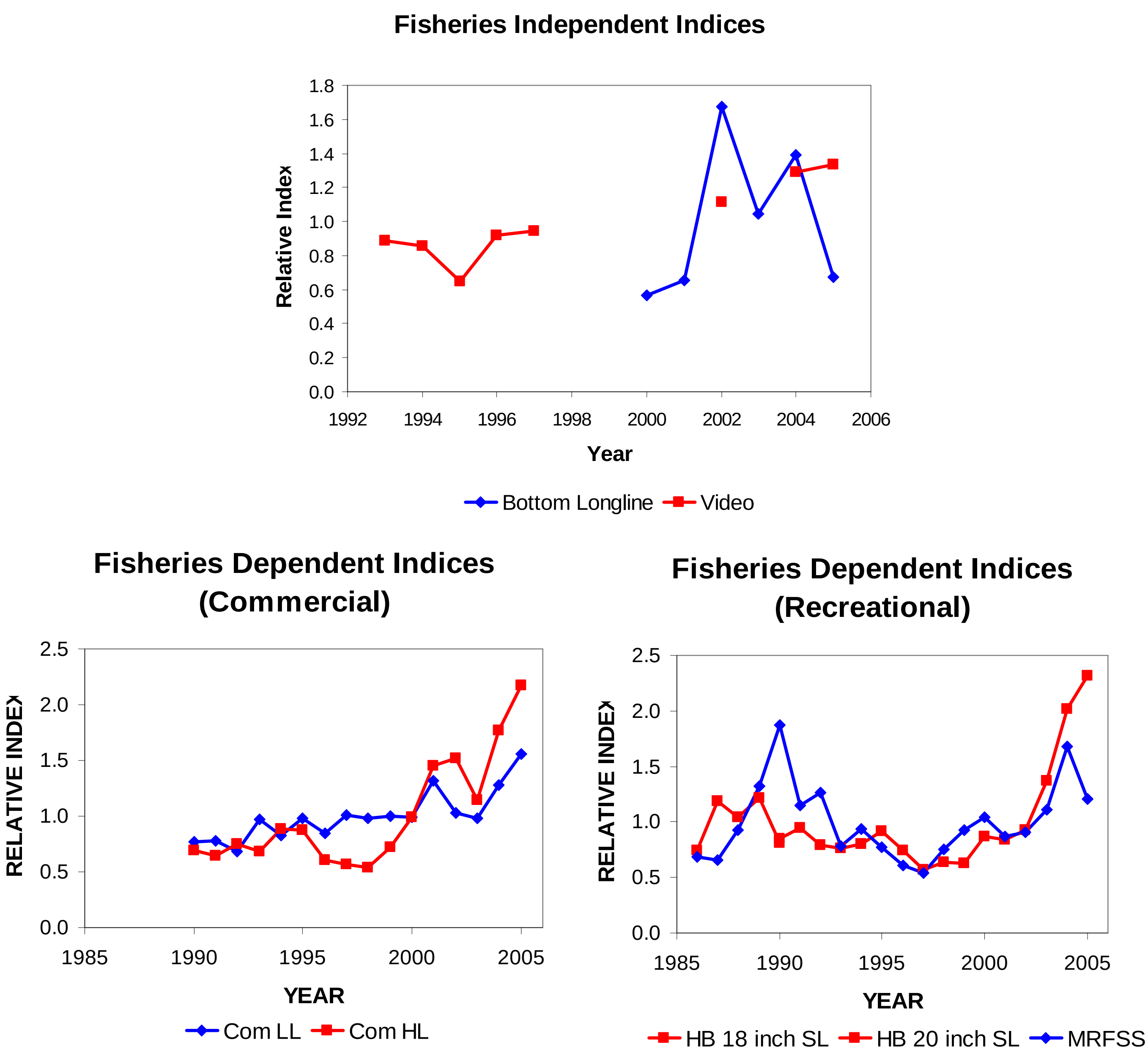


Figure 5.2 Recommended indices of abundance.

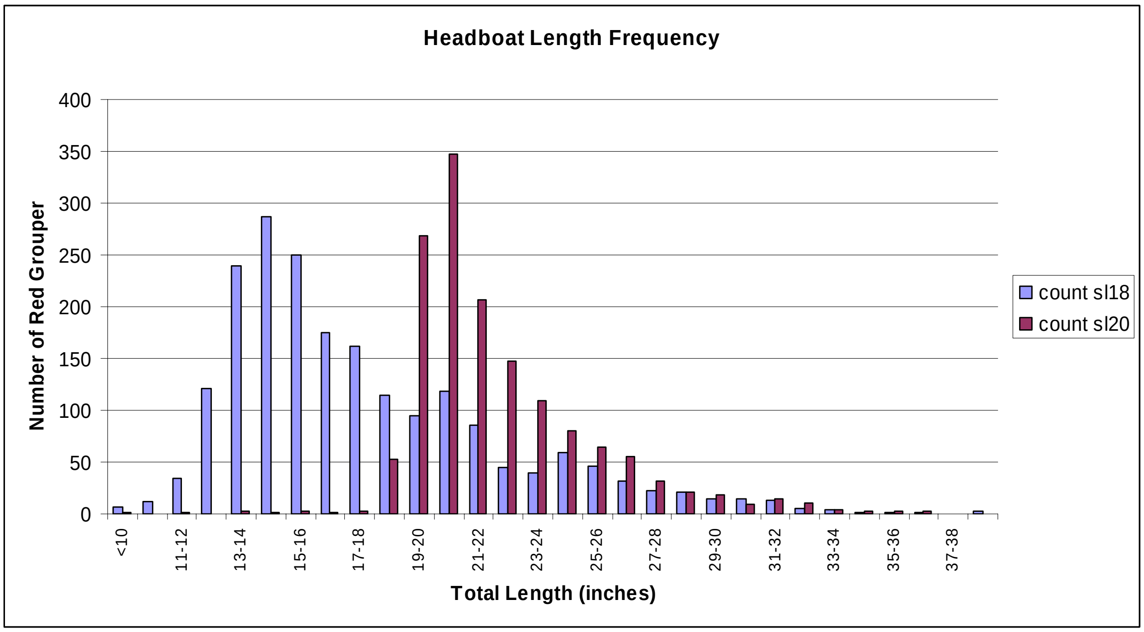


Figure 5.3. Size distribution red grouper landed by the Headboat fishery during the 18" minimum size limit (before 2/21/90) and during the 20" minimum size limit (after 2/21/90).

SEDAR 12

Stock Assessment Report 1

Gulf of Mexico Red Grouper

SECTION III. Assessment Workshop

SEDAR
1 Southpark Circle # 306
Charleston, SC 29414

Table of Contents

1. Workshop Proceedings

1.1. Introduction

1.1.1. Workshop Time and Place

The SEDAR 12 Assessment Workshop was held October 16 - 20, 2006, in Miami FL.

1.1.2. Terms of Reference

1. 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. Provide justification for any deviations from Data Workshop recommendations.
2. Provide estimates of stock parameters (fishing mortality, abundance, biomass, selectivity, stock-recruitment relationship, etc); include appropriate and representative measures of precision for parameter estimates and measures of model ‘goodness of fit’.
3. Characterize uncertainty in the assessment and estimated values, considering components such as input data, modeling approach, and model configuration.
4. Provide yield-per-recruit, spawner-per-recruit, and stock-recruitment evaluations.
5. Provide estimates for SFA criteria. This may include evaluating existing SFA benchmarks or estimating alternative SFA benchmarks (SFA benchmarks include MSY, Fmsy, Bmsy, MSST, and MFMT); recommend proxy values where necessary.
6. Provide declarations of stock status relative to SFA benchmarks.
7. Estimate an Allowable Biological Catch (ABC) range.
8. 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:
        - i. F=0, F=current, F=Fmsy, Ftarget (OY),
        - ii. F=Frebuild (max that rebuild in allowed time)
    - B) If stock is overfishing
        - i. F=Fcurrent, F=Fmsy, F= Ftarget (OY)
    - C) If stock is neither overfished nor overfishing
        - i. F=Fcurrent, F=Fmsy, F=Ftarget (OY)
9. Evaluate the results of past management actions and, if appropriate, probable impacts of current management actions with emphasis on determining progress toward stated management goals.
10. Provide recommendations for future research and data collection (field and assessment); be as specific as practicable in describing sampling design and sampling intensity.
11. Complete the Assessment Workshop Report (Section III of the SEDAR Stock Assessment Report).

IMPORTANT NOTES:

The SEDAR Steering Committee requires use of validated models such as those included in the National Fisheries Toolbox or documented through bodies such as ICCAT or ICES. See the SEDAR Guidelines for further details or validation requirements of new or custom models.

Reports are to be finalized within 6 weeks of the conclusion of the Assessment Workshop.

If final assessment results are not available for review by workshop panelists during the workshop, the panel shall determine deadlines and methods for distribution and review of the final results and completion of the workshop report.

1.1.3. List of Participants

Appointed Panelists

Craig Brown .... SEFSC/Miami
Shannon Cass-Calay .... SEFSC/Miami
Mark Fisher .... GMFMC FSAP/TX PWD
Walter Ingram .... SEFSC/Pascagoula
Linda Lombardi-Carlson .... SEFSC/Panama City
Kevin McCarthy .... SEFSC/Miami
Russ Nelson .... GMFMC/NGO
Dennis O'Hern .... GMFMC / Reef Fish AP
Clay Porch .... SEFSC/Miami
Tom Turke .... GMFMC Reef Fish AP
Steve Turner .... SEFSC/Miami
John Walter .... SEFSC/Miami
Carl Walters .... GMFMC FSAP/Univ. BC
Bob Zales .... GMFMC/Reef Fish AP

Council Representation

Roy Williams .... GMFMC/ FL FWC

Observers

Jim Berkson .... SEFSC/Miami
Liz Brooks .... SEFSC/Miami
Ching Ping Chih .... SEFSC/Miami
Guillermo Diaz .... SEFSC/Miami
Tomas Jamir .... SEFSC/Miami
Albert Jones .... GMFMC SSC

Staff

John Carmichael .... SEDAR Coordinator/Chair
Tyree Davis .... SEFSC/Miami
Stu Kennedy .... GMFMC
Tina Trezza .... GMFMC

1.1.4. Documents

The following documents were available for consideration by the Assessment Workshop Panel.

SEDAR12-AW01	<<< NOT USED >>>>>	
SEDAR12-AW02	STANDARDIZED CATCH RATES OF RED GROUPER (/EPINEPHELUS MORIO/) FROM THE U.S. HEADBOAT FISHERY IN THE GULF OF MEXICO, 1986-2005. SFD-2006-036.	Cass-Calay, S
SEDAR12-AW03	STANDARDIZED CATCH RATES OF RED GROUPER (/EPINEPHELUS MORIO/) FROM THE U.S. RECREATIONAL FISHERY IN THE GULF OF MEXICO, 1986-2005. SFD-2006-037.	Cass-Calay, S
SEDAR12-AW04	Discard Calculations	McCarthy, K.
SEDAR12-AW05	Construction of a fisheries independent index of red grouper using data from the Dry Tortugas National Park, 1994-2004	anon
SEDAR12-AW06	Derived and observed catch at age from the Gulf of Mexico red grouper stock	Nowlis, J. S. & 5 co-authors
SEDAR12-AW07	Age data evaluation	Lombardi-Carlson, L
SEDAR12-AW08	Comparison of ALK and RAS methods for deriving age frequency distributions of red grouper caught by commercial fisheries in the Gulf of Mexico	Chih, C-P.
SEDAR12-RD06 ICCAT SCRS/1998/058	A flexible forward age-structured assessment program	Legault, C. M. and V. R. Restrepo
SEDAR12-RD07 MIA 92/93-75. 1993.	The red grouper fishery of the Gulf of Mexico.	Goodyear, C. P. and M. J. Schirripa.
SEDAR12-RD08 MIA 93/94-60. 1994	Biological reference points for red grouper: uncertainty about growth.	Goodyear, C. P

2. Proceedings and Recommendations of the SEDAR 12 Assessment Workshop Panel

2.1. Data review and Update

2.1.1. Life History

There were no significant change in the life history data following the data workshop. The assessment panel suggested considering regional catch curves (completed during the AW, results provided in this report). The panel noted that while some fisheries have inadequate age samples, samples from the longline fishery were so numerous that they were subsampled for age determination. The panel suggested developing better allocation strategies. Discard rates by depth were discussed, but there was no progress on this issue following the data workshop.

2.1.2. Recreational data

MRFSS estimated landings from the keys are assigned to the Gulf, per MRFSS design which treats Monroe County as part of the Gulf. Headboat landings are assigned to the Atlantic based on the belief that Keys headboats operate primarily in Atlantic waters.

The DW recommended calculating discard rates by depth. However, as noted above, little work has been done on this issue between the workshops. The AP will attempt to address the issue during the assessment workshop, but is skeptical that sufficient data exist.

MRFSS sampling data are considered inadequate for estimating weight, largely due to low sample sizes and high uncertainty. The Goodyear probabilistic method provides an alternative, but the AP will need to determine how to proceed.

2.1.3. Commercial

Large year to year variability in the Cuban data was discussed, and considered likely realistic based on various events that would affect fishing activity. For example, after the revolution boats did not leave Cuba. Landings also drop off with beginning of World War II, then ageing. during 1961-62, coinciding with the Bay of Pigs incident and missle crisis. One question is the lack of response in US landings to cuban changes. However, commercial exploitation rates overall commercial are not all that high, so the lack of a noticeable US landings response to cuban trends is not unreasonable.

It was noted that landings are fairly high in the initial year recommended by the DW (1937). Using this year will not allow the model to start at a time prior to exploitation, which is a primary advantage of moving back in time.

Additional commercial discard estimates were prepared following the Data workshop (Addendum to SEDAR12-DW17). Concerns remain as to the magnitude of estimated discards that will be discussed further during the workshop.

2.1.4. Indices

No significant changes were made to the indices following the data workshop. One concern expressed by the AP is the effect of including multiple indices with conflicting trends. In such instance the model typically tracks between the two trends, thus providing results that are 'wrong' either way. It is also likely that reference point values will be sensitive to index selection.

The AP agreed to omit the Tortugas index, based on a short time series and no discernible trend. This index may have promise in the future as the time series increases and should be continued.

2.2. Assessment methods considered

The assessment panel (AP) reviewed three modeling approaches including a surplus production model (ASPIC, Prager 1994), a forward projection age-structured model (ASAP, Legault and Restrepo 1999), a stochastic stock reduction analysis (SRA, Walters et al. 2006) for assessment of the Gulf red grouper. VPA runs were made to examine temporal changes in catchability (q) and gear selectivity.

Exploratory VPA runs indicated little change in q while exhibiting some dome-shaped vulnerability at age. ASPIC model results were deemed uninformative due to the short time series and model difficulties reconciling the simultaneous increase in catch and CPUE data. Moreover, ASPIC productivity estimates were deemed excessive, with MSY estimates approximately 10-100X the maximum observed catch (Appendix 4). The AP concluded that the production model approach did not produce satisfactory results, and focused attention on developing a forward projection catch-age model using the ASAP program. The AP includes SRA analysis for portraying uncertainty in stock parameters (Appendix 3). The long time series SRA analysis is also critical to determining whether ASAP estimates based on recent, short time series data that are more comprehensive provide productivity estimates that are consistent with long term data consisting primarily of catch records of unknown accuracy.

2.3. Preferred model and configuration recommendations

The AP agreed that ASAP should be used as the primary method for the Gulf red grouper assessment. The ASAP model projects population numbers at age forward from the initial year to create a time series of predicted stock sizes and total fishery catches. Predicted stock size and total fishery catch are compared to observed catch and population indices using statistical methods. Such statistical, age-structured models account for errors associated with observed catch at age and allow selectivity and catchability to vary over time and age. Previous stock assessments of the Gulf red grouper (Schirripa et al., 1999 and NMFS-SEFSC 2002) have been based on ASAP. The AP adopted a sequential approach to developing the stock assessment: 1) develop a ASAP continuity run with only updated catch, catch at age, and indices; 2) develop a new ASAP base run with new fishery data and life history parameter estimates; and 3) conduct a series of sensitivity and retrospective runs.

2.4. Issues Discussed

2.4.1. Catch time series and fishery data

Catch time series

The AP discussed the pros and cons of several different catch time series, with particular emphasis on the danger of starting estimation at a point where the stock is already heavily exploited. Based on availability of various catch and fishery sampling data sources, options included 1986-2005, 1978-2005, 1937-2005, and 1880-2005.

The 1937-2005 series was the Data Workshop Report (DWR) recommendation, but AP recommended running the ASAP model with the short time series (1986-2005) as the base run and the long catch time series (starting in 1880) as a sensitivity run. Uncertainty associated with age distribution is minimized with the short time series due to more extensive age and length sampling over this period, whereas the longer time series could provide greater contrast and therefore more information on virgin biomass, recruitment levels, and reference points. However, the primary difficulty with the long time series is the lack of reliable age composition data prior to the early 1990s. Accordingly, one must either assume that fleet selectivity patterns have not changed since 1880 or make the even less satisfying assumption that the age or size composition of the catch did not change from 1880-1990 (i.e., implying constant selection and recruitment).

ASAP model runs including a base configuration and sensitivities for the 1986+ catch series were prepared and reviewed by the AP and documented in this report. Runs based on the 1880+ time series were not completed in time for consideration by the AP and will be provided to the SEDAR 12 review panel as additional sensitivity analyses. The SRA model was developed with an 1880-forward time series.

Age composition

Twenty ages were used in the assessment, starting at age 1 and ending with a plus group (20+). Catch age composition is available from two approaches: 1) direct evaluation based on otolith samples from landed catches, and 2) relative age composition derived through a probabilistic modeling approach (Goodyear 1997). The ASAP model allows incorporation of both sources of age composition if desired. The model will also function in the absence of age composition information for portions of the catch time series. Age composition from the Goodyear approach and the associated otolith samples are presented graphically in Appendix 5.

The relative age composition of the catch (by fishery and by season) was derived from the sampled lengths using the Goodyear probabilistic method (Goodyear 1997; initial results presented in SEDAR12-AW06) and the growth parameters estimated using size-modified von Bertalanffy model (described in DW report). The AP noted that catch age composition results were substantially different from those reported in 2002, largely as a result of using the updated growth curve. An analysis prepared during the assessment workshop to explore this in greater detail is included as Appendix 1. The AP concluded that the proportional representation of each age class in the derived age composition was, on average, similar to that observed from sampled otoliths. However, inter-annual trends in the proportional representation of any given age class were quite different, probably because the probabilistic method used to derive age from length did not include information on year class strength. Although this method could provide age composition information for the 1986-forward time period, the concerns noted here led the AP to reject use of the probabilistically-derived fishery age compositions in the model.

On the other hand, there was some concern that the otoliths were not always randomly sampled, particularly during the early 1990s when there were noticeable discrepancies between the distributions of length from the otolith samples and the distribution of length from all length samples. The AP agreed that much of this discrepancy in length distributions may be more apparent than real owing to the rather low pre-2000 otolith sample sizes. The AP therefore recommended using only the direct age information for evaluating age composition of the landed catch (rather than using both the derived and sampled age composition as was done in 2002).

The Goodyear probabilistic method also provides an estimate of discard age composition. Inasmuch as otoliths were not sampled from the discarded catch, the age composition was inferred from the expected proportion of each age class that was below the size limit. Discard age compositions as used in the assessment are presented in tables in Appendix 5.

Selectivity

Sufficient otolith samples to adequately evaluate selectivity trends were available only from 1991-2005. Therefore it was necessary to assume that selectivity patterns for each fishery were constant over time. However, the effect of size limits on the proportion of the catch that was landed was modeled explicitly using estimates of the proportion of each age class expected to be below the size limit. The AP recommended estimating age-specific selectivity parameters to age 15 for the commercial fisheries and to age 10 for the recreational fishery owing to the rarity of older fish in the samples. It was also observed that the commercial fishery tended to operate in deeper waters and catch somewhat older fish than the recreational fishery.

Discards and release mortality

For the estimates of commercial discards, The AP chose to apply the same method used in the 2002 assessment using size frequency distributions from catch-at-size for two periods: no size limit (1880/1986-1989) and 20” minimum size limit (1990-2005). The AP agreed with using the B2 portion of MRFSS estimates for the recreational discards. The AP reviewed data on discard mortality rates and agreed upon 10% release mortality for the recreational, handline and trap fisheries and 45% for the longline fishery. The AP discussed the depth-discard mortality relationship approach and agreed that this approach was not feasible for red grouper because of limited data (i.e., small sample sizes, high variability and sample design concerns).

2.4.2. Biological Parameter Estimates

Natural mortality estimates

Previous assessments assumed a constant natural mortality M=0.2 based on maximum observed age of 18. This value persisted through numerous assessments, in spite of repeated reviews suggesting that 0.2 was possibly excessive. The DW recommended M = 0.14 based on new age composition data that included a single fish aged at 29 years. The AP believed a fair amount of uncertainty existed around the determination of maximum age and was not convinced by the information in the DW report that age 29 and the resultant M=0.14 was the most appropriate value.

The AP discussed the observed maximum age extensively, including further evaluation of history of age determinations for the fish aged at 29 as well as a tabulation of the frequency of occurrence of the older ages (Table 1). It was pointed out that, because of the difficulty in ageing older red grouper, the ages of some animals will likely be overestimated and therefore the oldest age observed in any sufficiently large sample will likely be artificial. Only one fish was aged at 29, and various readers aged the particular otolith in question at ages ranging from 18 - 30. Thirteen fish were aged at 25. On the other hand, it was also pointed out that these samples came from an exploited population and that the maximum age for an unfished population might be considerably older. Ultimately the AP concluded that considerable uncertainty was associated with the maximum age determination of 29, and that a maximum age of 25 seemed a reasonable compromise based on the evidence discussed above.

The AP decided to assume M=0.167 for the base run, consistent with a maximum age of 25. The AP agreed with using the Lorenzen method for estimating age-specific M; scaling it such that the cumulative natural mortality on all age groups was the same as for a constant M of 0.167.

Total mortality estimates

The AP reviewed Z estimates from catch curve analyses provided by the data workshop. The catch curve estimate of Z was 0.32 for ages 5-19 in the Gulf, but regional estimates (above and below 28 degrees latitude) varied from 0.27 in the south to 0.47 in the north. Differences may be due to recruitment or fishing pressure or both. The AP discussed using the catch curve Z estimates from current and historical studies for evaluating the magnitude of mortality estimates generated from the more complex ASAP or SRA models.

Maturity vector

The AP agreed to use the updated maturity schedule suggested by the DW in the base run and recommended sensitivity runs including the old maturity schedule and a combined old and new maturity schedules.

Fecundity

Gonad weight at age is used as a proxy for fecundity. The AW recommended using observed gonad weight at age data for ages 2-9 (where the trend with age was fairly smooth) and a fitted multiplicative function for ages 10+ (to smooth out the fluctuations associated with small samples of older age classes). See Appendix 2 for further details.

Sex composition

The AW recommended using combined NMFS-Panama City and Koenig (reported in Schirripa et al. 1999) data for % females at age for 1990-2005 and Moe's data (1969) for the period prior to 1990. The female-based run assumes males are not limiting in red grouper reproduction. Initial ASAP runs show *F*30% to be higher than *F*max and *F*msy, indicating that no gain could be achieved from reduced harvest of females as they will switch to males. It is believed that red grouper spawn in pairs (unlike aggregate spawners such as gag or red snapper) and it is possible that reduction in males would be more limiting for red grouper. AW recommended a sensitivity run using combined mature biomass as a measure of fecundity (as was used in the South Atlantic gag grouper assessment). No major differences were found between the female-based and combined sex models.

2.4.3. Indices of abundance

The AP reviewed both fishery dependent and fishery independent time series. Fishery dependent indices were partitioned by size limit phases and included commercial handline, longline, headboat, and MRFSS. The fishery independent indices examined included the SEAMAP video, Dry Tortugas visual survey and NMFS experimental longline survey. The AP recommended using the former, but not the latter two surveys as they were highly variable and short in duration. In general, all indices exhibited a similar trend of increased relative abundance in recent years. There was an extended discussion concerning the reliability of MRFSS index which ultimately tended more toward inclusion than exclusion given low weights assigned to the MRFSS index (as a result of high CV values). In ASAP, the weights assigned to each component of the likelihood function correspond to the inverse of the variance associated with that component.

2.4.4. Stock and recruitment relationships

The AP was satisfied with the Beverton-Holt spawner/recruit model used in ASAP. Spawning stock and recruitment data generated from the base run showed high uncertainly in the relationship, perhaps due to the short time series. To address the uncertainty in the spawner-recruit relationship, the AP recommended a sensitivity run including a longer catch time series and sensitivity runs evaluating a range of steepness values from 0.6 to 0.9.

2.5. Model runs

The AP made following recommendations for the base and sensitivity runs:

Base run- The ASAP base run consisted of landing and discard statistics from the commercial (longline, handline, and trap) and recreational fisheries beginning in 1986, five fishery-dependent indices (commercial handline, commercial longline, NMFS Headboat Survey 1986-1990, NMFS Headboat Survey 1990-2005, and MRFSS Recreational) and one fishery-independent index (SEAMAP video survey), a new age-specific M vector (constant over time), new fecundity-at-age vectors, new weight-at-age vectors (adjusted for biological age rather than calendar age), new age composition (in the case of landed catch, from additional otolith samples, and in the case of discards, inferred from new growth models), selectivity estimated to age 12, equally weighted indices, down weighted lambda for discards, age composition were weighted using observed sample size, a slight modification to the effective sample size for age composition (modified to account for the fraction of the catch sampled), one catchability per fleet and not allowing it change by year, and steepness was estimated (with a triangular distribution ranging from 0.6 to 0.9 and centered at 0.8). Initial results showed generally good fits to the age composition, total recreational and commercial catch, indices of abundance (except for the MRFSS CPUE) (see assessment report). Initial runs showed that the fits were improved by increasing recruitment deviation (from the average value) from 0.25 to 0.5.

Sensitivity runs 1-4 address uncertainty associated with spawner-recruit relationship by using a range of steepness values from 0.6 to 0.9.

Sensitivity runs 5-6 address the effects of various indices using the SEAMAP video survey and commercial longline only (5) and removing the commercial longline index from the mix (6).

Sensitivity runs 7-8 address potential differences between a spawning stock biomass-based model vs. a fecundity-based model (7) and differences between the old and new fecundity vectors (8).

Sensitivity runs 9-10 address the uncertainty associated with *M* estimates. The AP recommended sensitivity runs with the Lorenzen *M* proposed by the DW (average M==0.14) as the lower limit and *M*=0.2 (used in the 2002 assessment) as the upper limit.

Sensitivity run 11 addresses potential increase in the catchability rate with new technologies at a rate of 2% per year beginning in 1986.

Sensitivity run 12 addresses uncertainty associated with spawner-recruit relationship using long catch time series beginning in 1880(commercial catch 1880-2005 and recreational catch 1945-2005, assuming constant catchability and constant fleet-specific selection patterns).

The continuity run addresses potential changes in stock condition using the 2002 ASAP model with only updated catch, catch at age, and indices.

A retrospective run intended to address retrospective bias by sequentially removing up to 5 of the most recent years of both catch and indices of abundance data was not prepared in time for review by the assessment panel.

2.6. Stock Condition

Results from the base and sensitivity runs are summarized in **Error! Reference source not found.**.

Fishing mortality for the terminal year (2005) is estimated at F=0.145 in the base run, with a range from 0.06 - 0.182 across the sensitivity runs . Fishing mortality has declined in the commercial longline, handline, and trap fisheries in recent years when compared to values estimated during the early to mid 1990s. Recreational fishing mortality declined sharply from 1992 to 1996, increased during 1997-2000, and has stayed fairly constant in recent years. Overall, F_{2005} (0.145) was lower than F_{MSY} (0.160) and $F_{30\%SPR}$ (0.222). The F/F_{MSY} ratio was less than 1 (indicating no overfishing) in 1998, 2003, and 2005 (Figure 1). The F/F_{MSY} ratio ranged from 0.26 (for the sensitivity run with M=0.20) to 1.46 (for the sensitivity run with fixed steepness of 0.6). Spawning stock estimates increase in recent years, reflecting increasing abundance and declining fishing mortality. The SS/SS_{MSY} ratio was less than 1 (indicating an overfished status) for the entire base run time series except for 2005, when SS_{2005}/SS_{MSY} was estimated at slightly above 1 (1.035) (**Error! Reference source not found.**). The SS_{2005}/SS_{MSY} for sensitivity runs ranged from 0.52 (for the sensitivity run with fixed steepness of 0.6) to 1.91 (for the sensitivity run with M=0.2) (Table 1). If F/F_{MSY} and SS/SS_{MSY} are chosen as preferred benchmarks, the Gulf red grouper stock is not overfished nor is overfishing occurring given the 2005 stock condition estimated in the base run.

Stochastic SRA model results were in general agreement with ASAP runs concerning unfished and current stock size, Umsy, and MSY. SRA model results indicate wide uncertainty (plus or minus 50%) on historical (unfished) average biomass and on the extent of depletion following major fishery development beginning in the 1930s (Appendix 3, Figures 4, 5 and 6). The most probable current stock size is estimated at between 20% and 30% of average unfished biomass. The model attributes recent increases in catch rate to positive recruitment anomalies, and predicts some decline in recruitment and exploitable biomass over the next few years if current exploitation rates (averaging around 15-20% on fully vulnerable ages) continue. It suggests that the decline could be largely prevented by moving to a somewhat lower (10%) exploitation rate target.

The AP was satisfied with the continuity run. Results were consistent with the new ASAP base run.

2.7. Management benchmarks

The AP discussed benchmarks estimates from two S/R relationships; one based on recent time series (1986-2005) representing period with positive recruitment anomalies, and another based on historical time series representing average recruitment. Several members of the AP agreed that the more recent recruitment estimates were better determined as they were based on actual indices and age composition during that period. Others argued that it was uncertain whether the higher recruitment values after the 1980's reflected a true regime shift that will persist into the future, or fortuitous recruitments that will not persist, or simply a modeling artifact (i.e., the apparently lower recruitment estimates for the earlier years may be poorly estimated). Therefore, the AP agreed that MSST-related reference points, which depend on the S/R relationship, may not be well determined and that a range of possibilities should be presented. Due to great uncertainty in MSY based benchmarks, the AP recommended considering YPR and SPR approaches for estimating benchmarks. It should be noted that while YPR and SPR calculations themselves don't require knowledge of the spawner-recruit relationship, a biomass reference point based on those concepts does.

2.7.1. Management Benchmark Recommendations

The AP agreed that management benchmark point estimates should be determined from the base model configuration (**Error! Reference source not found.**).

2.7.2. ABC Recommendations

Acceptable biological catch (ABC) values were selected based on the projection of F_{OY} during 2008-2015. (Fcurrent was projected during 2006 and 2007). Projected yield was used as a basis to estimate ABC. These values, in pounds gutted weight, are listed below.

YEAR	Projected Yield at F_{OY}
2008	7,094,290
2009	7,325,190
2010	7,508,810
2011	7,664,670
2012	7,796,410
2013	7,909,230
2014	8,011,650
2015	8,102,010

NOTE : Measures of uncertainty for the estimates will be provided at the Review Workshop.

2.8. Research Recommendations

1) Refine sampling for age determination to provide sufficient spatial and temporal coverage across all fisheries. Ensure some fisheries are not sampled excessively, necessitating subsampling for age determination.

2) Quantify temporal and spatial changes in catchability rate

3) Develop methods to evaluate the impact of natural events such as red tide in modeling M and the overall assessment.

4) Develop and expand fishery-independent indices for tuning assessment models and evaluation of management measures

5) Increase at-sea observation of discards by fishery to provide numbers of discards, fate of discards, and size/age composition of discarsd.

6) Quantify release mortality rates by fishery by depth

7) Improved the MRFSS survey and estimates of recreational fishing effort, especially to improve spatial resolution. Develop methods to obtain age samples from the recreational fishery and improve estimation of fish weight from recreational sampling.

8) Support research to better describe and understand dolphin predation of red grouper.

2.9. Assessment Workshop Panel Figures and Tables

Table 1 Annual composition of age data for red grouper collected in the Gulf of Mexico: 1991-2005. Data includes red grouper collected from fishery dependent (commercial and recreational) and fishery independent sources (see 2006 SEDAR 12-DW-03 for further details.)

Age	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	n
1													4	4		8
2			1								7		3	53	4	68
3	2	1	3	8		1	1	2	3	8	6	23	21	12	51	142
4	7	5	45	79	16	8	9	20	10	142	71	68	205	129	22	836
5	19	48	52	125	92	86	19	48	86	67	738	197	127	866	231	2801
6	17	54	114	71	159	138	42	61	104	139	236	639	269	219	1046	3308
7	14	63	120	89	97	97	51	73	130	95	339	306	438	382	178	2472
8	9	43	86	58	65	32	21	42	211	90	164	261	221	408	250	1961
9	16	20	35	36	40	42	3	25	165	84	81	169	199	218	248	1381
10	15	16	15	23	23	18	2	10	79	59	134	97	121	180	135	927
11	3	7	8	9	11	3	3	8	46	52	92	101	87	103	72	605
12	5	8	3	6	8	2	1	5	23	21	50	87	89	70	49	427
13	3	3	3	7	6	1	3	1	13	13	31	61	69	56	29	299
14			1	3	4		1	2	6	7	24	33	40	57	24	202
15	1		1	1		1	1	2	3	6	16	26	37	36	14	145
16	2		1		2		2		2	3	13	18	21	18	14	96
17		2				1			1	1	9	10	23	17	7	71
18		1	2						1	1	3	12	14	18	6	58
19	2									2	3	5	10	10	4	36
20									1	2	4	2	5	9	5	28
21	1			1	2					1	2	7	2	3	7	26
22					1								2	2	1	6
23	1				1					1		1	1	2	2	9
24	2		1	1		1					2	4	5	1		17
25			1	1	1							3	3	1	3	13
26												2				2
27				1							1	2		2		6
28									1			1				2
29		1														1
n	119	272	492	519	528	431	159	299	885	794	2026	2135	2016	2876	2402	15953

Table 2. Red grouper assessment base and sensitivity runs reference points generated by the ASAP model

NAME	BASE	SENS-1	SENS-2	SENS-3	SENS-4	SENS-5	SENS-6	SENS-7	SENS-8	SENS-9	SENS-10	SENS-11	SENS-12	SENS-13
Description	Base Run Lorenzen M @ 0.167	Fix Steepness = 0.6	Fix Steepness = 0.7	Fix Steepness = 0.8	Fix Steepness = 0.9	SEAMAP VIDEO and COM-LL Indices Only	No COM-LL Index	Substitute Mature Biomass for Fecundity	Use 2002 Fecundity Series	Use Lorenzen M @ 0.14	M = 0.2 all ages	Decrement Indices by 2% (Annual Increse in Q)	NMFS_LL Survey Age Comp	Start Catch Series in 1880
F-REFS														
F0.1	0.103	0.105	0.104	0.103	0.102	0.103	0.103	0.103	0.103	0.087	0.164	0.103		
Fmax	0.190	0.192	0.191	0.191	0.190	0.190	0.190	0.190	0.190	0.162	0.276	0.190		
F30%SPR	0.222	0.221	0.222	0.222	0.222	0.221	0.222	0.177	0.191	0.178	0.400	0.222		
F40%SPR	0.142	0.142	0.142	0.142	0.142	0.141	0.142	0.116	0.125	0.115	0.261	0.142		
Fmsy	0.160	0.102	0.124	0.146	0.168	0.160	0.160	0.153	0.155	0.137	0.239	0.159		
Foy	0.120	0.076	0.093	0.109	0.126	0.120	0.120	0.115	0.116	0.103	0.180	0.120		
Fcurrent	0.145	0.149	0.146	0.145	0.145	0.165	0.141	0.146	0.146	0.158	0.062	0.182		
SSB-REFS														
SS_F0.1	9.79E+11	1.38E+12	1.16E+12	1.03E+12	9.54E+11	9.12E+11	9.91E+11	1.16E+11	1.77E+12	1.11E+12	1.07E+12	8.88E+11		
SS_Fmax	6.52E+11	7.32E+11	7.00E+11	6.67E+11	6.44E+11	6.08E+11	6.60E+11	7.26E+10	1.12E+12	7.30E+11	7.75E+11	5.91E+11		
SSmsy	7.40E+11	1.42E+12	1.02E+12	8.18E+11	7.03E+11	6.90E+11	7.49E+11	8.68E+10	1.33E+12	8.27E+11	8.55E+11	6.72E+11		
SSoy	8.93E+11	1.75E+12	1.24E+12	9.92E+11	8.47E+11	8.34E+11	9.04E+11	1.08E+11	1.63E+12	1.00E+12	1.02E+12	8.11E+11		
YIELD REFS														
Y F0.1	8.40E+06	1.20E+07	9.95E+06	8.85E+06	8.19E+06	7.83E+06	8.51E+06	8.50E+06	8.48E+06	8.84E+06	1.15E+07	7.62E+06		
Y Fmax	8.75E+06	9.86E+06	9.41E+06	8.96E+06	8.64E+06	8.15E+06	8.87E+06	8.75E+06	8.76E+06	9.23E+06	1.19E+07	7.93E+06		
MSY	8.82E+06	1.20E+07	1.01E+07	9.14E+06	8.68E+06	8.22E+06	8.93E+06	8.86E+06	8.86E+06	9.29E+06	1.20E+07	7.99E+06		
OY	8.64E+06	1.16E+07	9.80E+06	8.94E+06	8.51E+06	8.05E+06	8.75E+06	8.67E+06	8.67E+06	9.10E+06	1.17E+07	7.83E+06		
SRR Parameters														
virgin	2.14E+12	3.74E+12	2.78E+12	2.32E+12	2.05E+12	2.00E+12	2.16E+12	2.85E+11	4.12E+12	2.47E+12	2.17E+12	1.94E+12		
steepness	0.863	0.600	0.700	0.800	0.900	0.864	0.863	0.867	0.863	0.875	0.847	0.862		
Current Status														
F/F_{MSY}	0.909	1.464	1.181	0.996	0.865	1.037	0.880	0.950	0.942	1.149	0.261	1.141		
SS/SS_{MSY}	1.035	0.522	0.747	0.935	1.088	0.973	1.051	0.932	0.937	0.845	1.912	0.925		
F/F_{OY}	1.212	1.952	1.575	1.328	1.154	1.382	1.174	1.267	1.256	1.533	0.348	1.521		

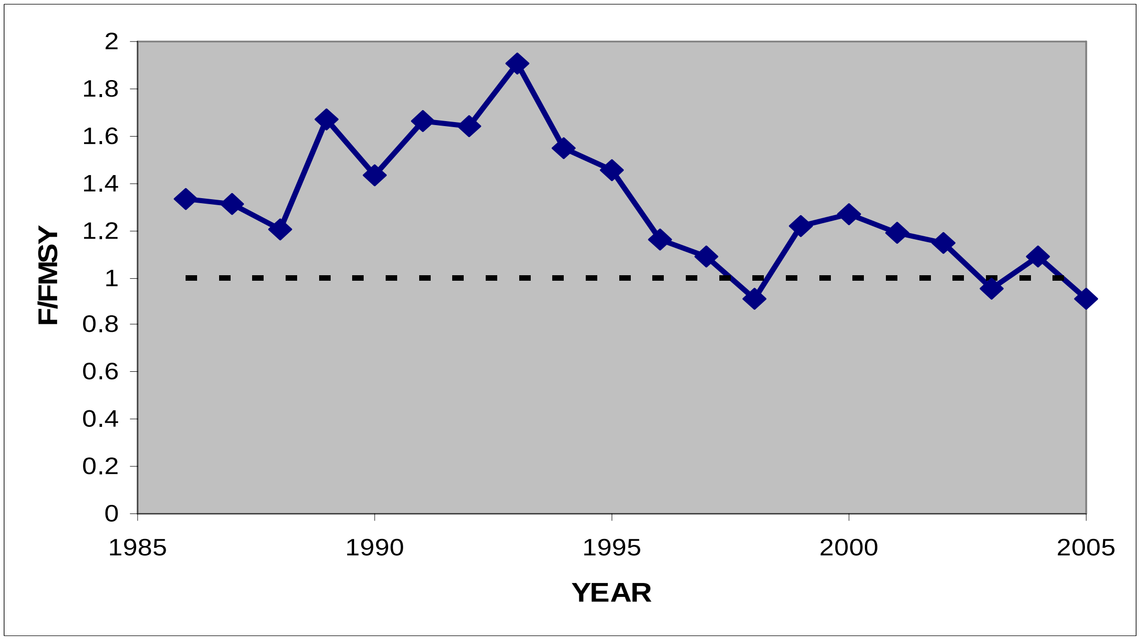


Figure 1 Time series trajectory of estimated F/FMSY generated from the ASAP base run

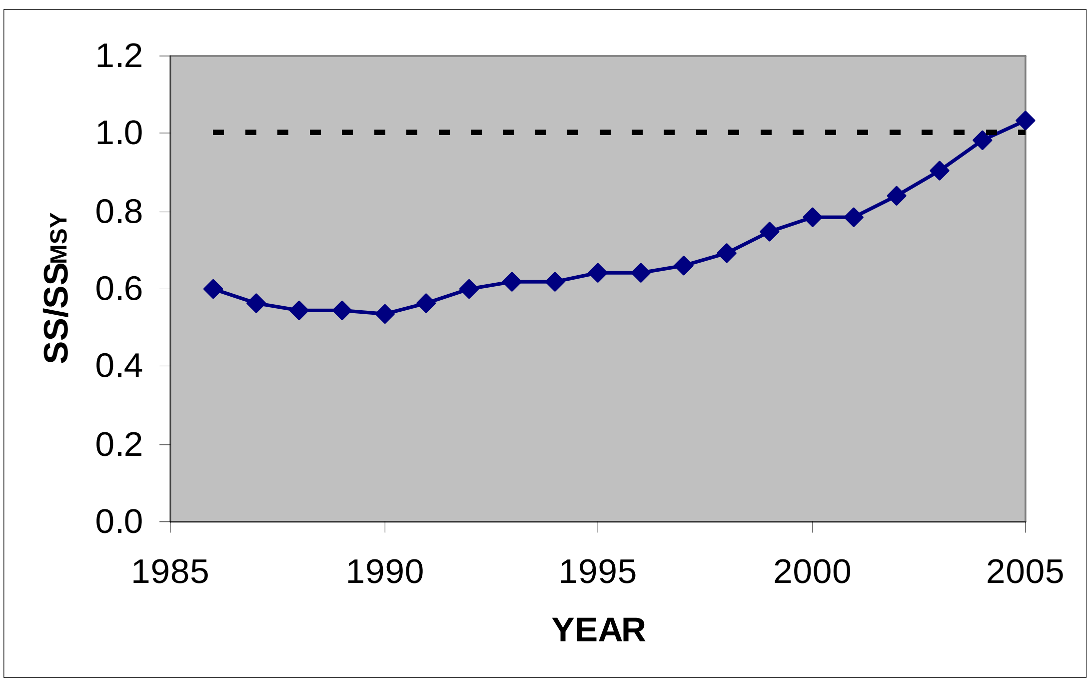


Figure 2. Time series trajectory of SS/Ssmsy for the base run.

2.10. Appendices

2.10.1. Appendix 1. Comparison of the effects of the old versus the new growth curves on predicted age compositions

Given the scarcity of age composition data relative to length composition samples, it was necessary to convert lengths into ages for several purposes. We employ the Goodyear (1997) probabilistic method of converting lengths into ages, however this method requires a Von Bertalanffy growth model. Two growth models exist, an “old” model used in assessments prior to the current SEDAR 12 and a “new” model presented in the SEDAR-12 Data Workshop with the following parameters; $L_{inf,}$= 854 , t_o = -0.19, k = 0.16. The old growth model (Goodyear 1994) used in the 2002 and 1999 assessments and in the continuity model run for 2006 has the following parameters; L_{inf} = 808 , K = 0.21, to = -.3. We explore the impact of using the new versus the old growth model on the predicted age composition in the commercial fishery (Figures A1 and A2). The new growth model generally shifts the ages one year older so that the four-year olds under the old model become five year olds under the new model.

Figure A.1. Predicted age distributions using the old Von Bertalanffy growth model and the new mortality estimate.

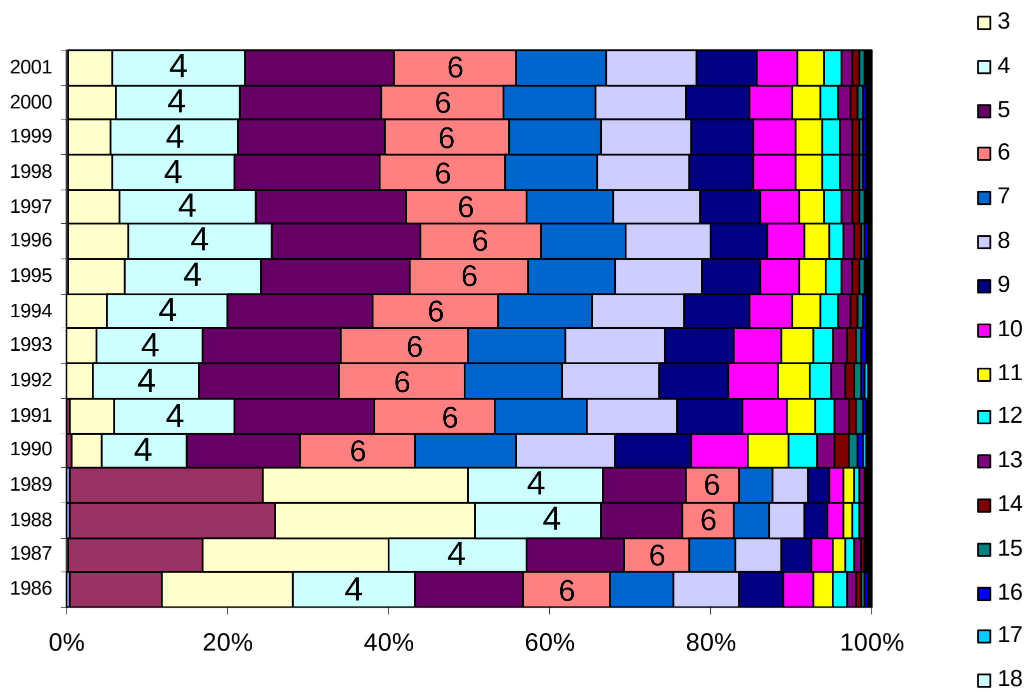
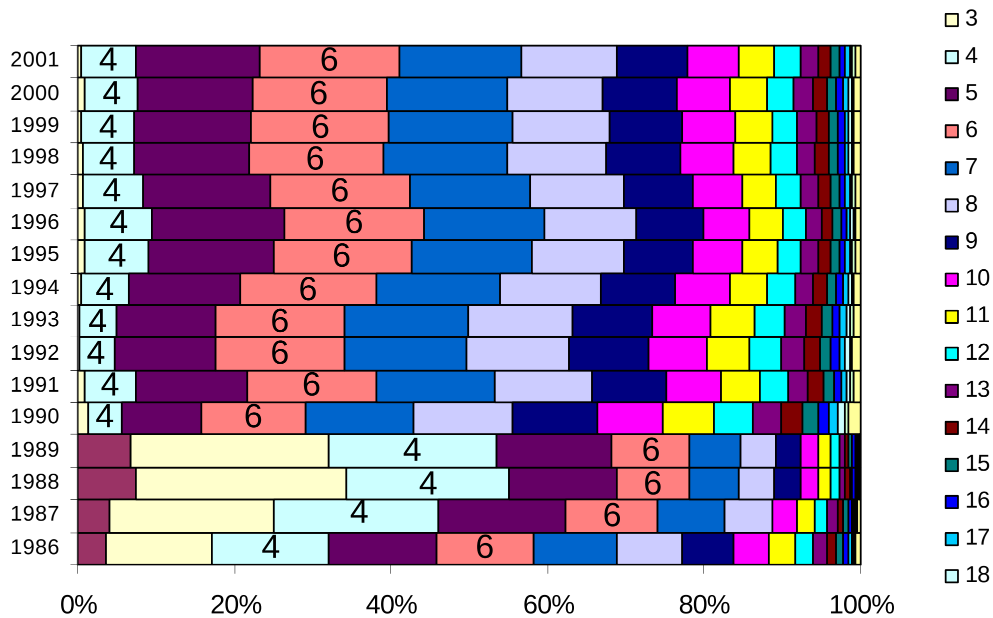


Figure A.2. Predicted age distributions using the new Von Bertalanffy growth model and the new mortality estimate.



We then examine whether the predicted age composition using the new growth curve reflects the age samples from commercial fishery for all gears combined for the years 1991-2005 for which age composition data exists (Figures A3 and A4). Averaged over all years, the predicted age compositions appear to reflect the age composition of the fishery, indicating that the new growth model adequately allocates lengths to ages. It does not, however, capture critical recruitment effects and produces a highly smoothed age distribution. For this reason, the Assessment Workshop participants decided to use the actual and not the predicted age composition for the years that age-composition data was available (1991-2005).

Figure A3. Predicted age distributions using the new Von Bertalanffy growth model and the new mortality estimate.

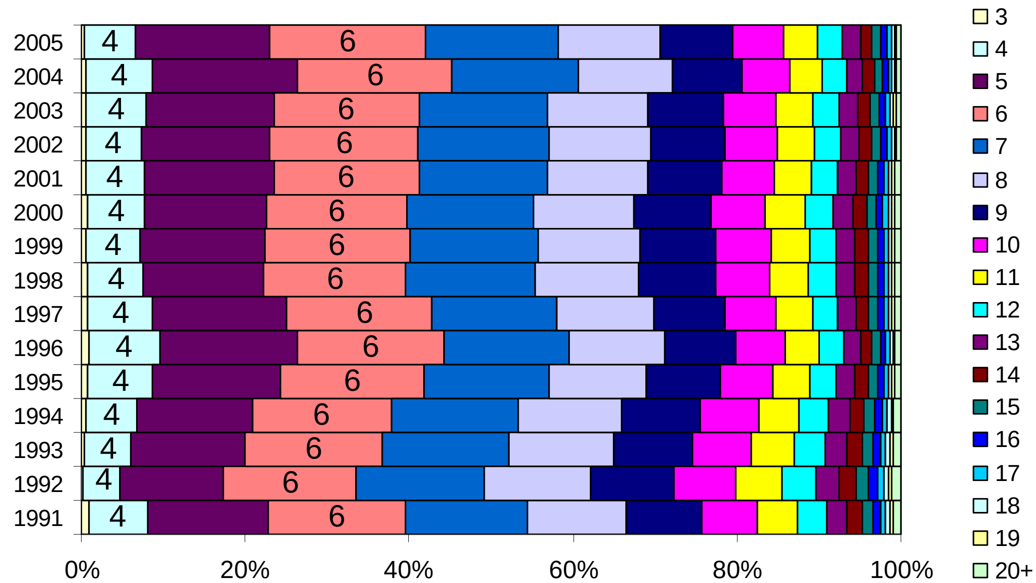
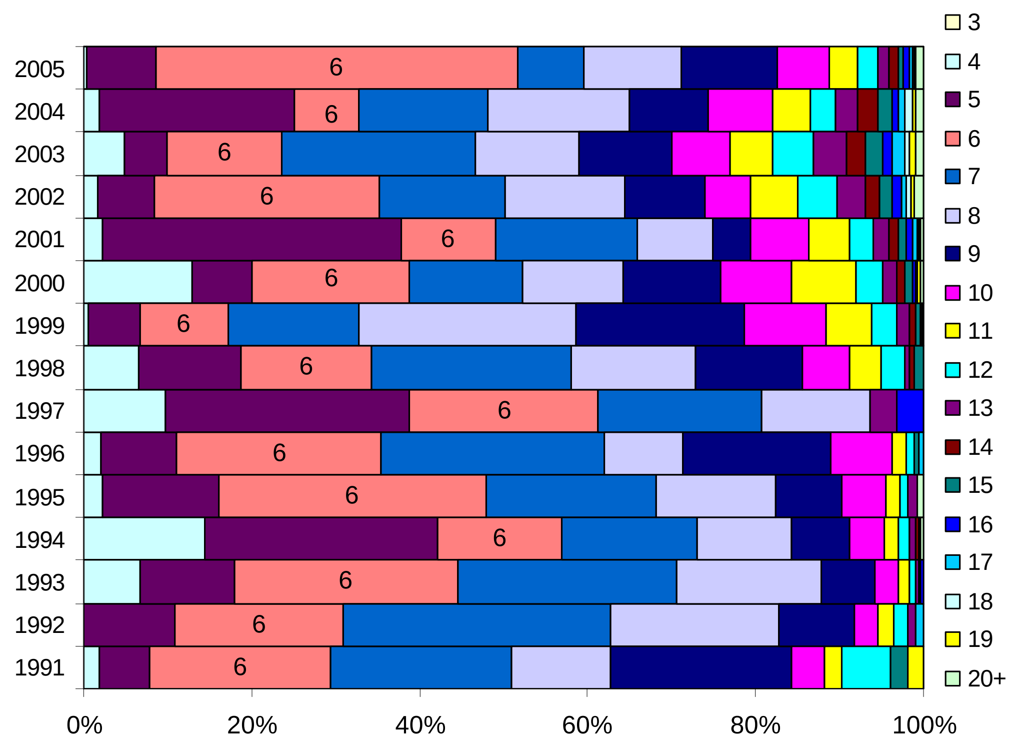


Figure A4. Age samples from commercial fishery for all gears combined.



References

Goodyear, C.P. 1994. Biological reference points for red grouper: effects of uncertainty about growth.

Goodyear, C. P. 1997. Fish age determined from length: an evaluation of three methods using simulated red snapper data. Fishery Bulletin. 95: 39-46.

2.10.2. Appendix 2. Reproductive Output

Red Grouper Reproduction
r
-Clay E. Porch

METHODS AND RESULTS:

The maturity, percent female, and relative fecundity (gonad weight) of each age class was derived from the data sets recommended by the DW. Maturity for the base run was derived set to the observed proportion of females identified as definitely mature by NMFS Panama City (SEDAR-DW-04) and Moe (1969). The former was used in all of the 1986-2004 model runs and the latter calculated for possible use with models that used longer time series for the period prior to 1980 (Table 1).

The percentage of the population that are female at each age were interpolated from the combined data in Koenig (unpublished, reported in Schirripa et al. 1999) and Fitzhugh et al. 2006 (Figure 1, Table 1) by use of a linear regression except that an average value was used for age 16 and older owing to sparse sampling (the linear regression would have indicated no females beyond age 20, but the data indicate that females make up a substantial percentage of these older age classes). The Moe (1969) data were interpolated by fitting with a logistic curve assuming additive errors (for possible use in the long time series runs for the period prior to 1980). Note that the interpolating routines were used in this case merely to smooth the data.

Gonad weight data from (Fitzhugh et al. 2006, SEDAR12-DW-04) was used to develop a proxy for the relative fecundity at age. The arithmetic mean values of gonad weight were used for ages 2-9. Owing to sparse sampling of older ages, expected gonad weights for ages 10-20 were interpolated from the data by use of a bias-corrected power function, assuming a multiplicative error structure owing to increasing variance in gonad weight with age (Figure 2).

RECOMMENDATIONS:

The DW recommended against incorporating a relationship between spawning frequency at age, noting a high degree of uncertainty in the fits that statistically would not be significant by age (SEDAR12-DW-04). Therefore, the relative reproductive contribution of each age class was computed as the product of maturity, percentage female and gonad weight. The final vectors are shown in Table 1.

Table 1. Final age-specific vectors used in calculations of reproductive output. Relative fecundity is the product of percent female, percent mature and gonad weight. Early and late refer to the periods before and after 1980, respectively.

age	Percent female		Percent mature		Gonad	Relative fecundity	
	early	late	early	late	weight	early	late
1	1.00	1.00	0.00	0.00	0.0	0.0	0.0
2	0.98	0.95	0.00	0.14	2.3	0.0	0.3
3	0.95	0.90	0.00	0.75	11.0	0.1	7.4
4	0.93	0.85	0.03	0.91	32.6	1.0	25.1
5	0.90	0.80	0.19	0.95	54.3	9.3	41.1
6	0.88	0.75	0.62	0.98	83.4	45.2	60.8
7	0.86	0.70	0.92	0.96	83.4	65.5	55.9
8	0.83	0.64	0.99	0.99	115.5	94.9	73.6
9	0.81	0.59	1.00	1.00	161.1	129.8	95.6
10	0.78	0.54	1.00	1.00	181.4	142.1	98.5
11	0.76	0.49	1.00	1.00	209.2	159.0	103.0
12	0.74	0.44	1.00	1.00	238.4	175.4	105.2
13	0.71	0.39	1.00	1.00	268.8	191.3	105.0
14	0.69	0.34	1.00	1.00	300.4	206.6	102.1
15	0.66	0.29	1.00	1.00	333.2	221.1	96.3
16	0.64	0.23	1.00	1.00	367.0	234.7	83.3
17	0.62	0.23	1.00	1.00	402.0	247.4	91.2
18	0.59	0.23	1.00	1.00	438.0	259.1	99.4
19	0.57	0.23	1.00	1.00	474.9	269.5	107.8
20	0.54	0.23	1.00	1.00	512.9	278.7	116.4

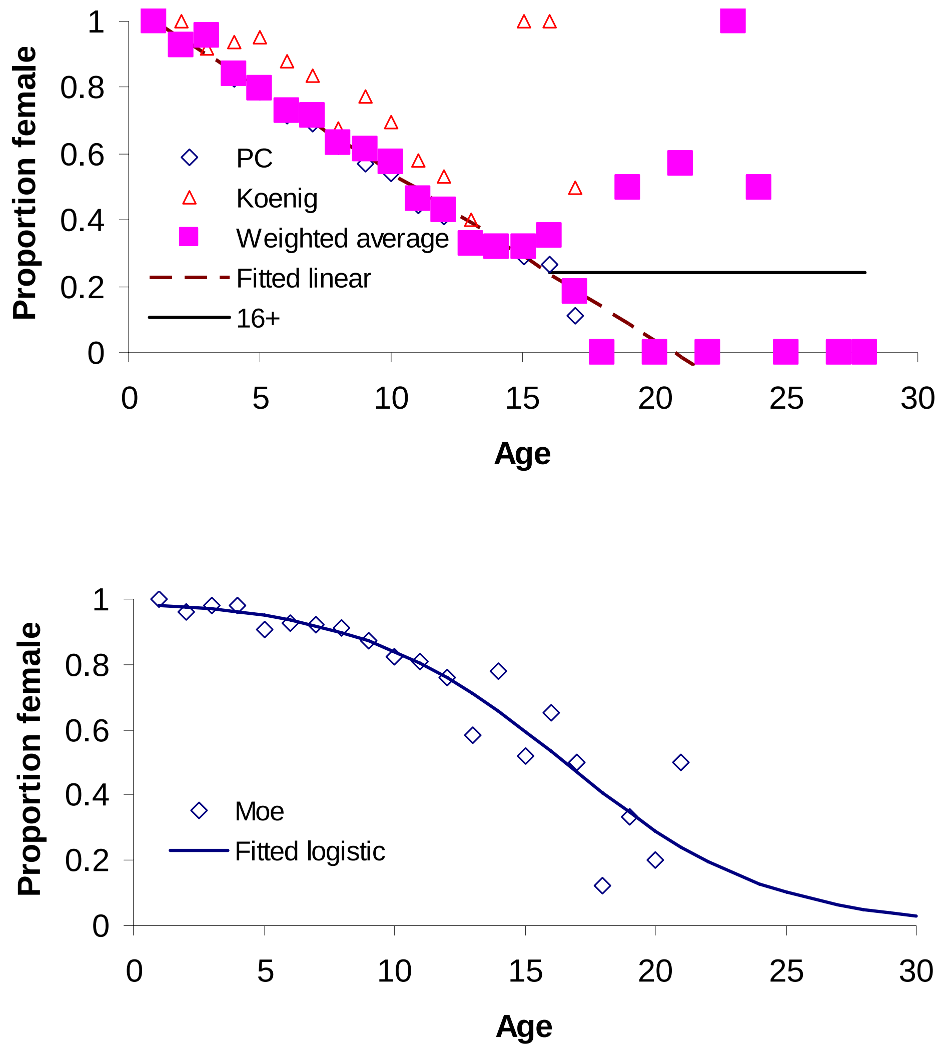


Figure 1. Estimated proportion of the stock that is female from several data sources with curvilinear interpolations.

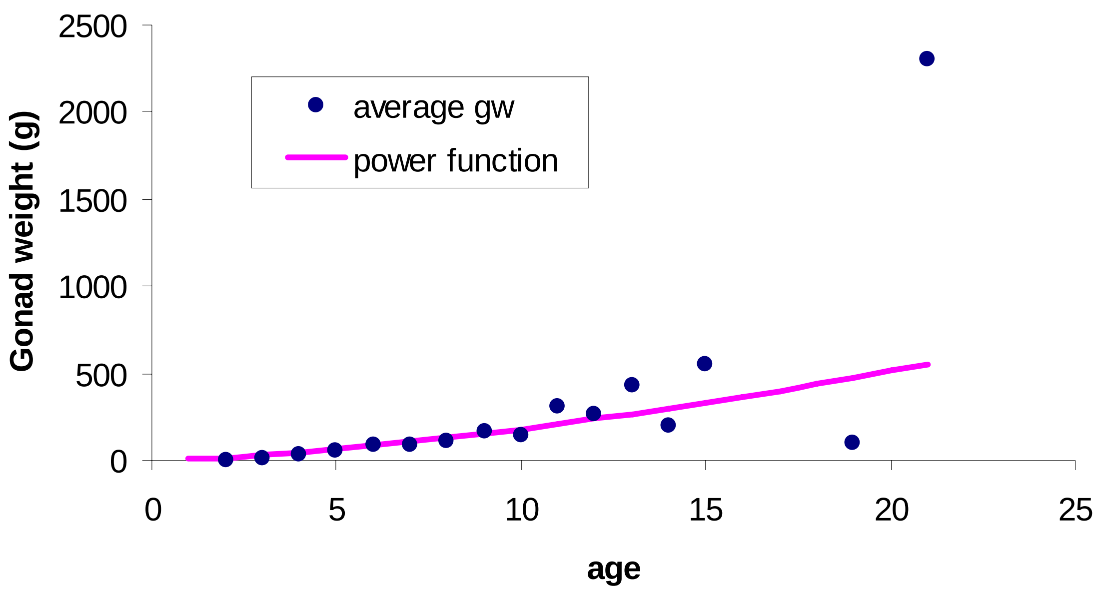


Figure 2. Average gonad weight for red grouper from age 2 to age 21 with fitted power function (bias-corrected curve shown). Curve was fitted to actual observations (not the average values) assuming a multiplicative error structure).

2.10.3. Appendix-3, SRA Model

STOCK REDUCTION ANALYSIS (SRA) MODEL

For comparison with the NMFS assessment models, we also ran a stochastic stock reduction analysis (SRA, Walters et al. 2006) on long-term catches (1880-2005), as was done for gag grouper in SEDAR 10. In this approach, an age structured population model with Beverton-Holt stock-recruitment function is simulated forward in time from the start of the fishery, with exploitation rates calculated each year from observed catch divided by modeled vulnerable population (sum of vulnerabilities at age multiplied by modeled numbers at age). In Stochastic SRA, recruitment is assumed to have had log-normally distributed annual anomalies (with variance estimated from VPA estimates of recent recruitment variability), and to account for the effects of these a very large number of simulation runs is made with anomaly sequences chosen from normal prior distributions (with or without autocorrelation). The resulting sample of possible historical stock trajectories is re-sampled using importance re-sampling (SIR), or a large sample is taken using MCMC. Summing frequencies of occurrence of different values of leading population parameter values over this sample amounts to solving the full state-space estimation problem for the leading parameters (i.e. find marginal probability distribution for the leading population parameters integrated over the probability distribution of historical state trajectories implied by recruitment process errors and by the likelihood of observed population trend indices).

The stochastic SRA is parameterized by taking Umsy (annual exploitation rate producing MSY at equilibrium) and MSY as leading parameters, then calculating the Beverton-Holt stock-recruit parameters from these and from per-recruit fished and unfished eggs and vulnerable biomasses. Under this parameterization, we effectively assume a uniform Bayes prior for Umsy and MSY, rather than a uniform prior for the stock-recruitment parameters. This is an age-structured version of the stock-recruitment parameterization in terms of policy parameters suggested by Schnute and Kronlund (1996).

Natural mortality rate was treated as age-independent, and was sampled for each simulation trial from a uniform prior distribution with M ranging from 0.1 to 0.17. Vulnerability at age schedules were estimated for the pre-1995 and post-1995 period from a VPA assessment using age composition data provided by Linda Lombardi (SEDAR 12-DW-03), along with total catches by gear type (longline, handline, recreational) provided in SEDAR 12 data reports. Probable changes in vulnerability changes before 1990 were not included in the simulations. Fecundity at age was adjusted to match the product of mean proportion of fish mature times fecundity at age estimated for ASAP model runs (fecundity approximately linear with age, with an intercept between age 4 and 5, resulting in maximum egg production considering survivorship to age coming from ages 6-10).

The SRA model results indicate wide uncertainty (plus or minus 50%) on historical (unfished) average biomass and on the extent of depletion since major development of the fishery beginning in the 1930s (Figures 4,5, and 6). The most probable current stock size is estimated to be between 20 and 30% of average unfished biomass. The model attributes recent increases in catch rate to positive recruitment anomalies, and predicts some decline in recruitment and exploitable biomass within the next few years if current exploitation rates (averaging around 15-20% on fully vulnerable ages) continue. It suggests that the decline could be largely prevented by moving to a somewhat lower (10%) exploitation rate target.

The SRA results are in general agreement with ASAP runs concerning unfished and current stock size, Umsy, and MSY.

The model also indicates considerable uncertainty about Umsy (90% credibility limits 10% to 30% per year) and somewhat lower uncertainty about MSY (90% credibility limits 10,000,000 to 14,000,000 pounds). Under all parameter and historical catch reconstruction scenarios (e.g. varying discard mortality rates and estimates of early Cuban catches), the model indicates that recent (post 1990) harvests have been below MSY, while peak period harvests between 1960 and 1990 sometimes exceeded MSY.

We caution that these results are based largely on an instrumental (reconstructed, not raw data) time series of total catches estimated from a variety of sources. There is particularly high uncertainty about recreational catches prior to 1980, and commercial catches (including impact of Cuban fishing) prior to 1970. We caution also that the model does not fully represent changes in vulnerability at age and discarding that likely took place even before size limits began to be imposed.

REFERENCE:

Goodyear,C. P. 1997. Fish age determination from length: an evaluation of three methods using simulated snapper data. Fish. Bull. 95:39-46.

Legault, C.M and V. Restrepo. 1998. A flexible forward age structured assessment program. ICCAT. Col. Vol. Sci. Pap. 49:246-253.

Prager, M. H. 1994. A suite of extensions to a nonequilibrium surplus-production model. Fishery Bulletin 92: 374-389.

Schirripa, M.J., C.M. Legault and M. Ortiz. 1999. The red grouper fishery of the Gulf of Mexico: Assessment 3.0. NMFS, Sustainable Fisheries Division. Miami, SFD-98/99-56.

Schnute, J.T. and A.R. Kronlund. 1996. A management oriented approach to stock recruitment analysis. Canadian Journal of Fisheries and Aquatic Sciences 53:1281-1293.

Walters, C.J., Korman, J., and Martell, S.J. 2006. A stochastic approach to stock reduction analysis. Canadian Journal of Fisheries and Aquatic Sciences 63:212-223.

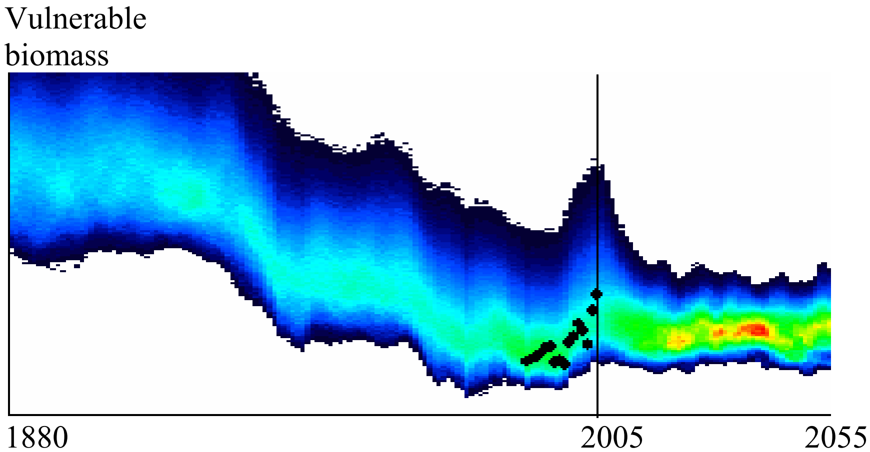


Figure 4. Probability distribution for vulnerable biomass of red grouper, Gulf of Mexico, 1880-2055 based on stochastic stock reduction analysis model. Increase in 1990s (just prior to vertical line indicating 2005) due to estimated recruitment anomalies. Future decline to lower stable level based on assuming annual exploitation rate of 20%. Age-specific catches calculated from average vulnerability schedule for dropline, longline, and recreational fishing. Only reported Cuban catches included, and discard mortality rates of 10% and 30% for recreational and commercial fisheries respectively.

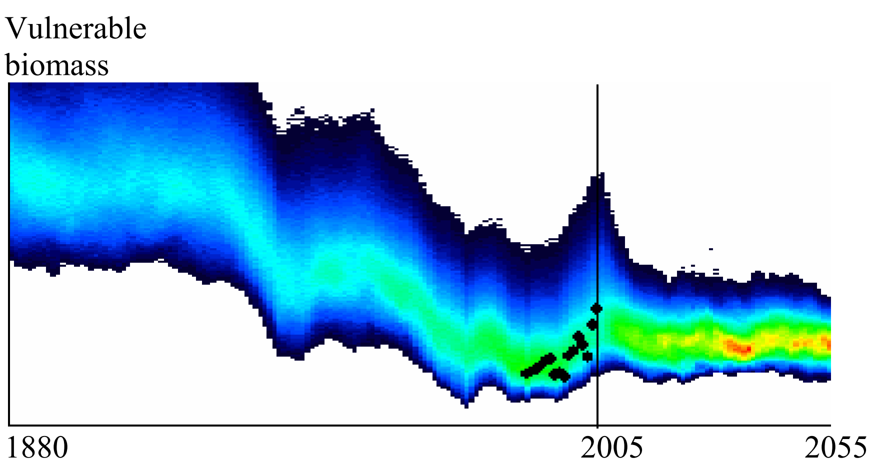


Figure 5. Probability distribution for red grouper stock size, calculated with corrected Cuban catches (assume fishery started earlier).

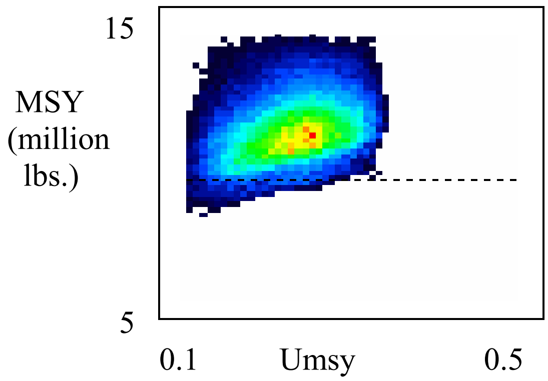


Figure 6. Probability distribution for MSY an Umsy corresponding to the stock dynamics in Figure 1. Recent (1990-2005) mean catch shown as dotted line, indicating high probability that recent mean catches have been below MSY.

2.10.4. Appendix 4. ASPIC production model

ASPIC Application to Red Grouper

-Liz Brooks and Guillermo Diaz

Model Runs.

The production model ASPIC (Prager 1994) was applied to fisheries data for red grouper. Two data configurations were constructed, a "continuity run" and a "long time series run." The purpose of the continuity run was to use the same fishery inputs as were available at the time of the last assessment (SEFSC Staff, 2002). The data spanned the years 1986-2001, and three sets of fisheries landings were paired with their respective CPUE (Figure 1):

- Handline, Cuban, and Trap landings were paired with the Handline Index
- Longline landings were paired with the Longline Index
- Recreational and Headboat landings were paired with the MRFSS Index

The long time series run spanned the years 1937-2005, and made the same three pairings of landings with CPUEs as in the continuity run (Figure 2). In both Figure 1 and 2, the pattern of increasing catches with corresponding increases in CPUE is evident for all three fisheries.

Results.

As might be expected given the lack of contrast in the data (Figures 1, 2), the model could only explain the observed fishery trends as either coming from a stock that had barely been impacted by fishing (long time series run) or from a stock that was fully depleted at the start of the data (continuity run). Figure 3 shows the trajectories of F/F_{MSY} and B/B_{MSY} for each of the model runs.

No conclusions regarding current stock status could be made from these model runs given the lack of contrast in the data, and consequently, no projections were pursued.

References.

Prager, M. H. 1994. A suite of extensions to a nonequilibrium surplus–production model. Fishery Bulletin 92: 374–389.

SESFC Staff. 2002. Status of red grouper in United States waters of the Gulf of Mexico during 1986-2001.NOAA Fisheries, Southeast Fisheries Science Center, Sustainable Fisheries Division, Miami FL. SFD-01/02-175.

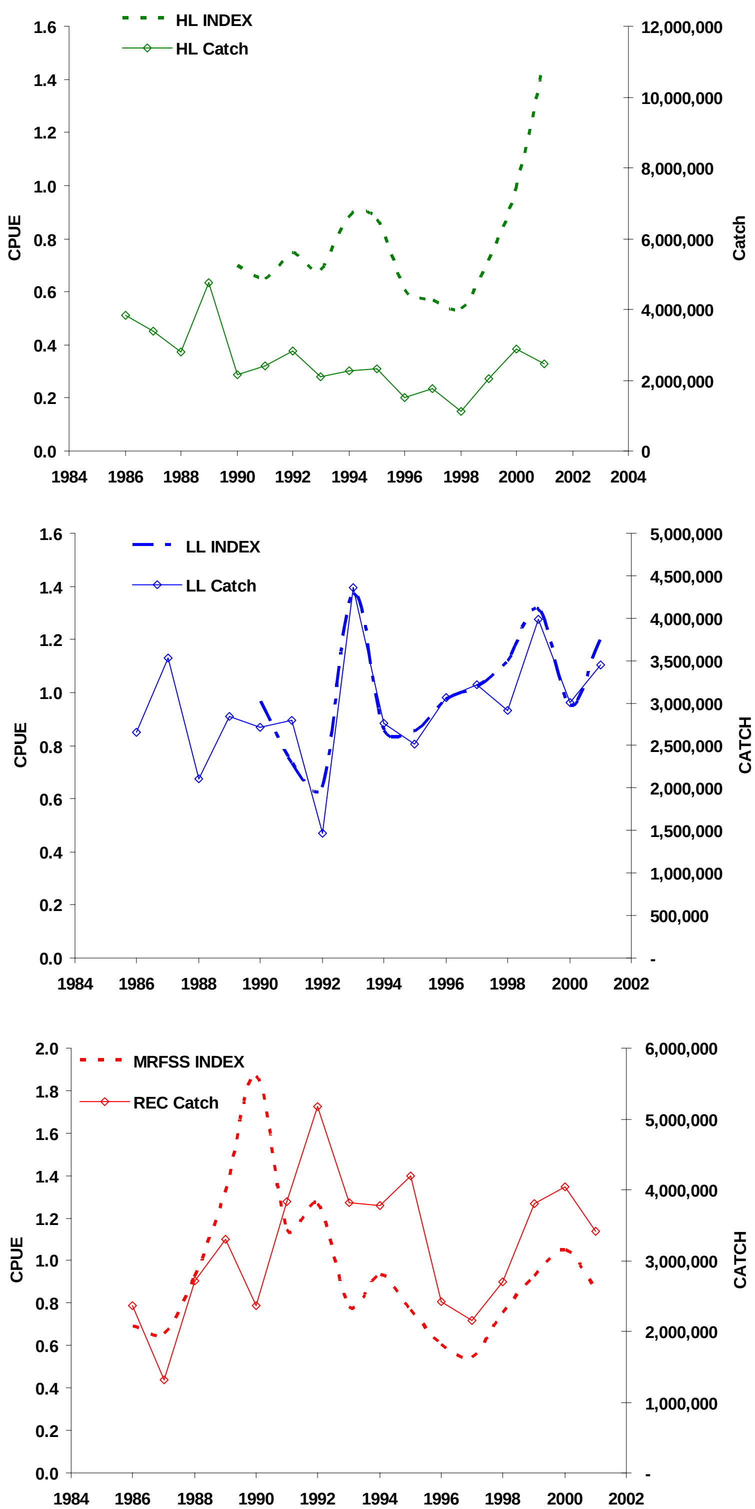


Figure 1. Catches (solid lines) and indices (broken lines) for the handline (HL), longline (LL), and recreational (REC) fleets used in the production model continuity run.

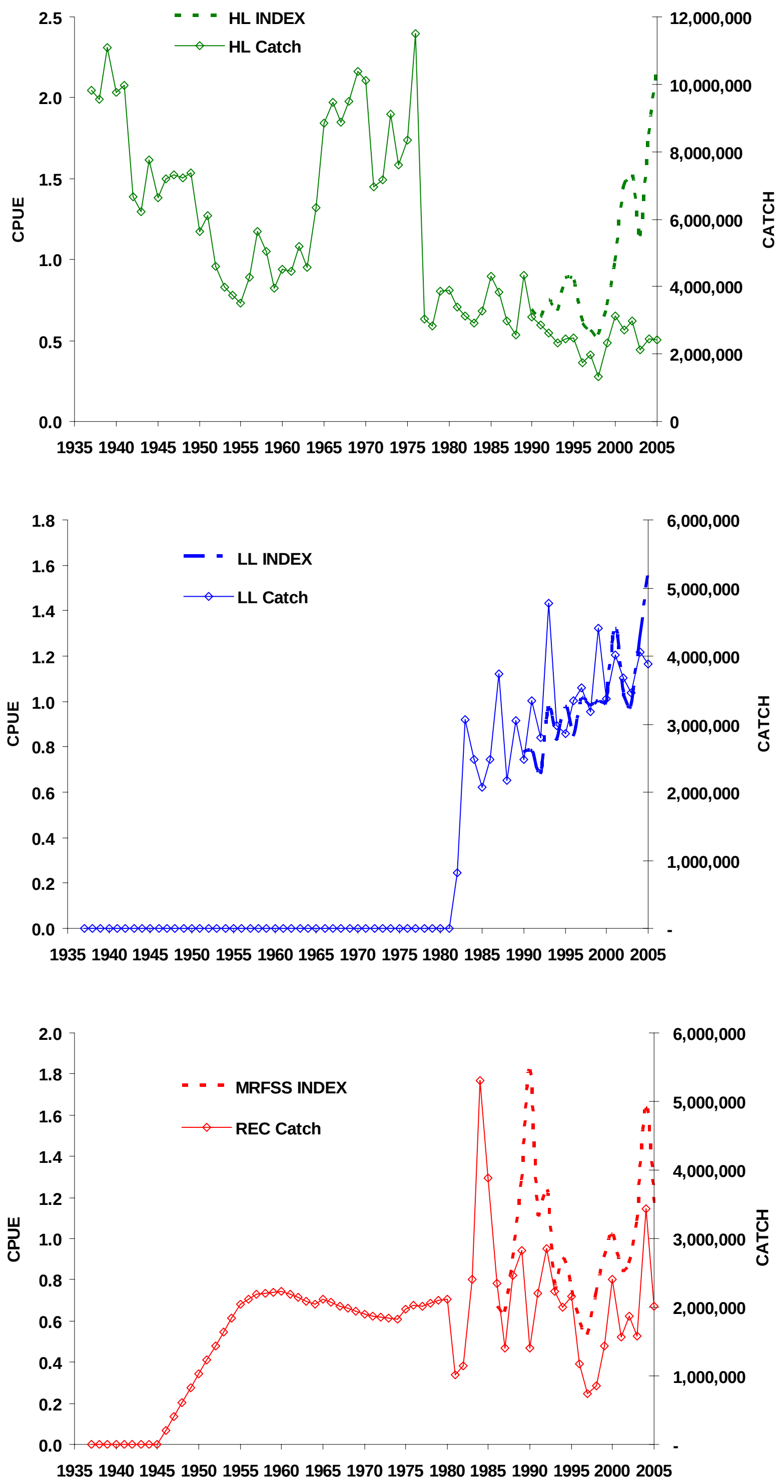


Figure 2. Catches (solid lines) and indices (broken lines) for the handline (HL), longline (LL), and recreational (REC) fleets used in the production model long time series run.

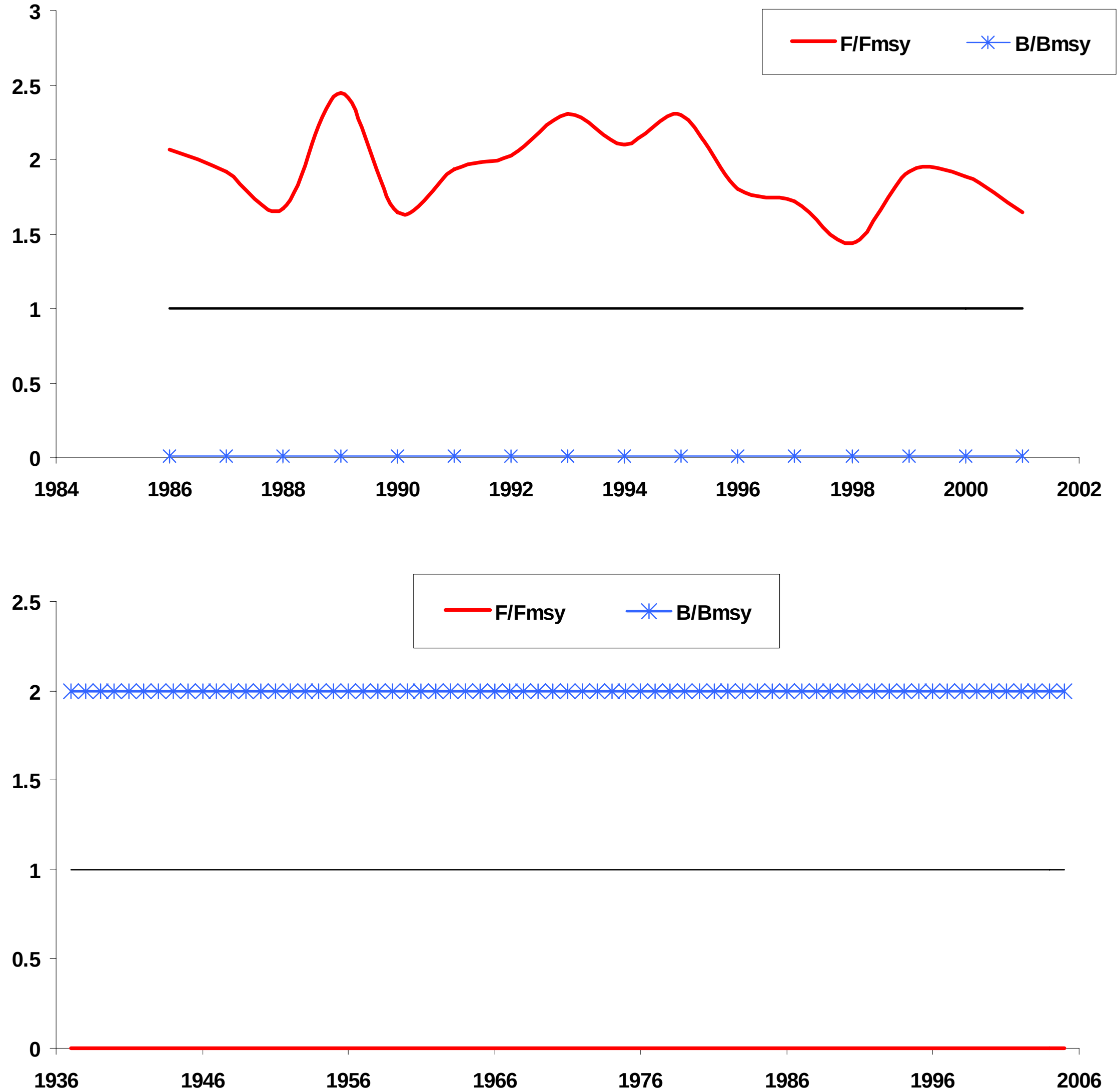
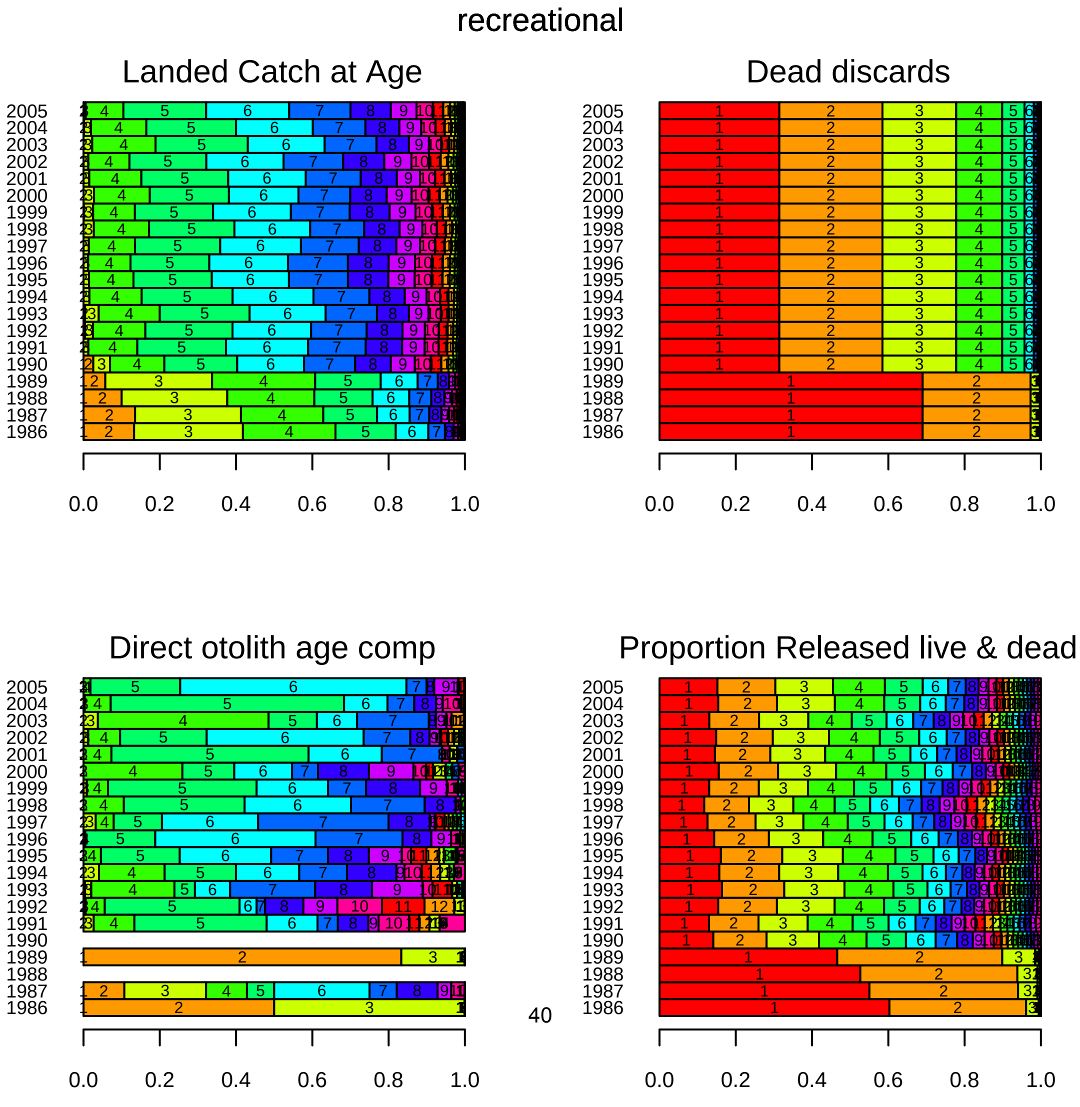
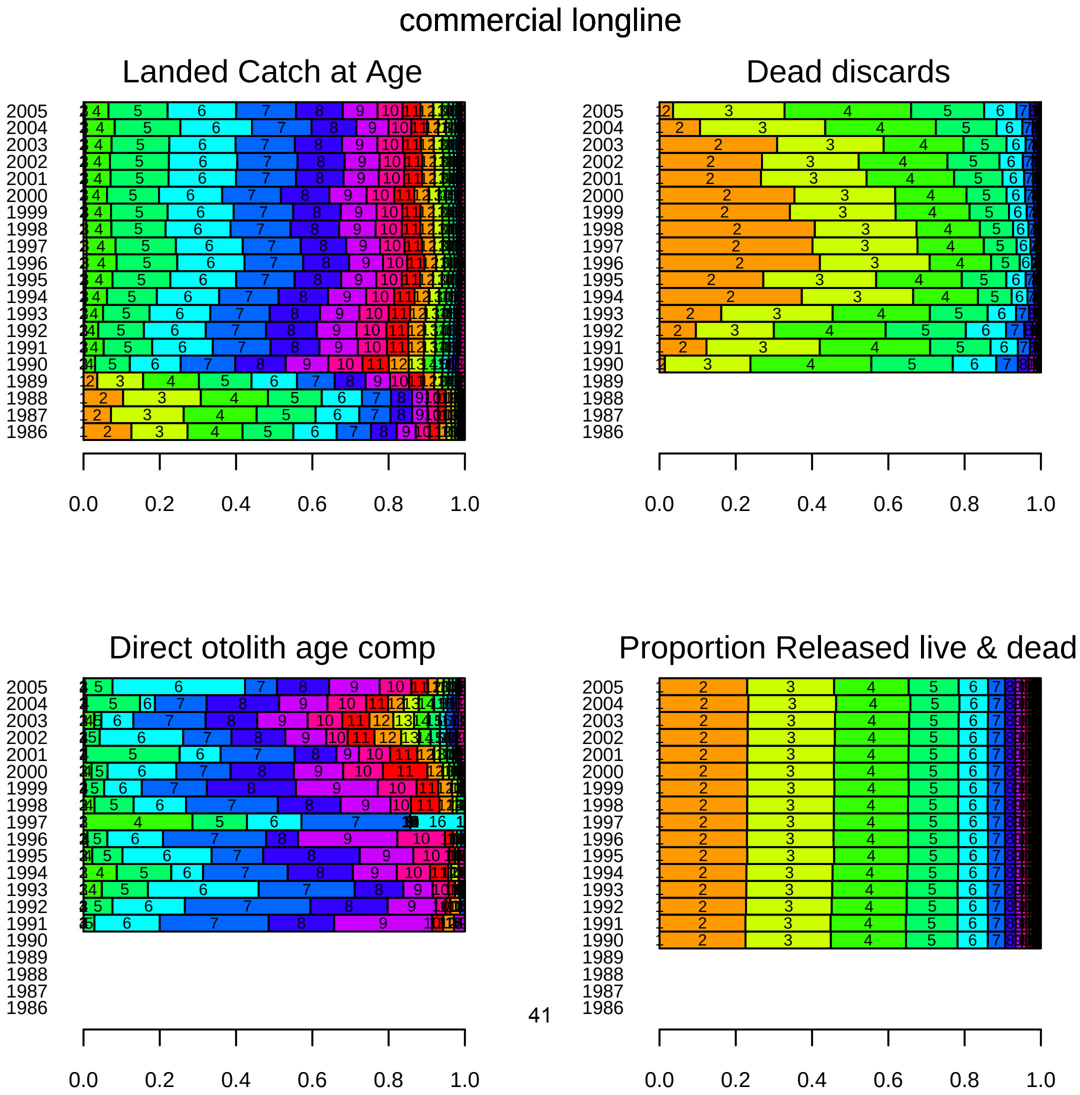


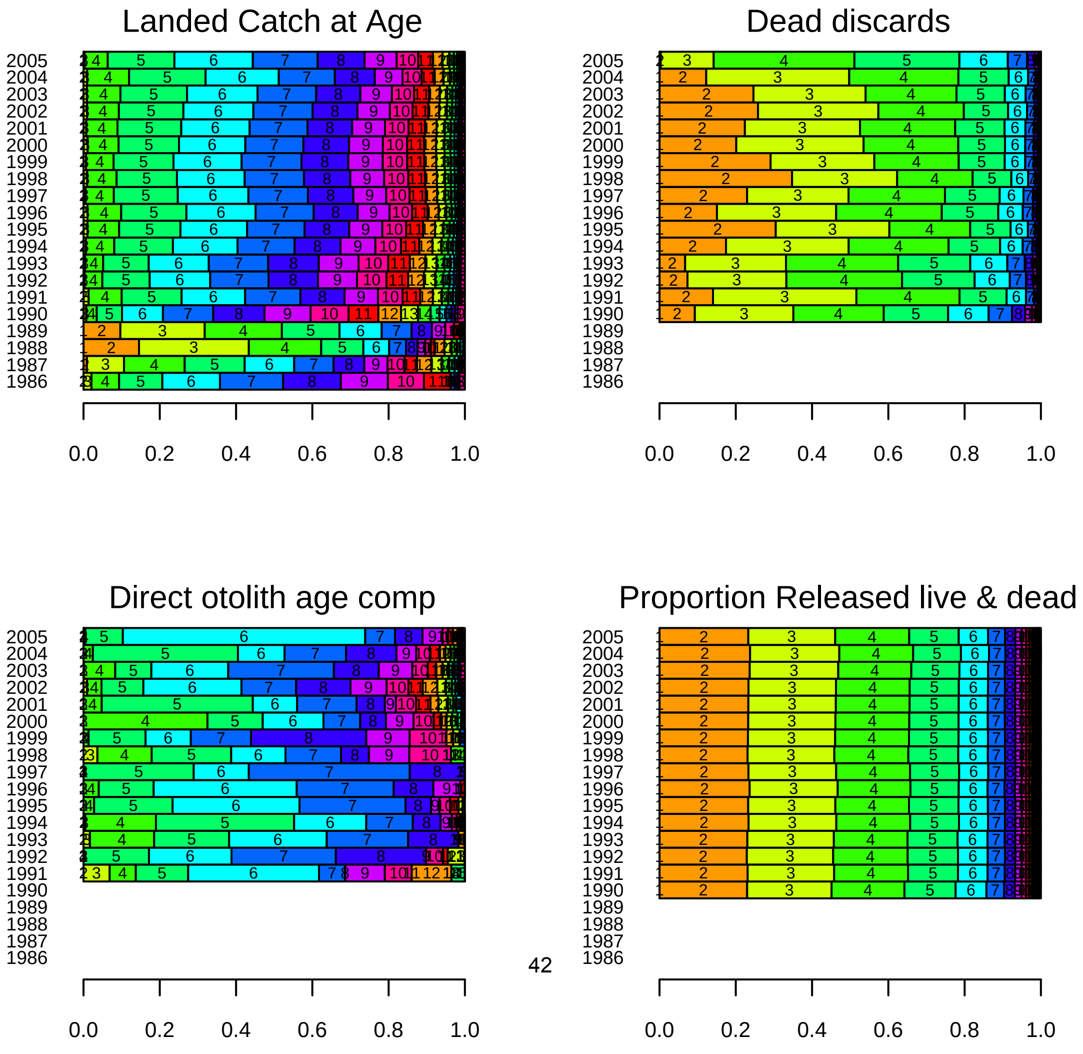
Figure 3. Trajectories of F/Fmsy (solid) and B/Bmsy (line with symbol) for the continuity run (top) and long time series run (bottom).

2.10.5. Appendix 5. ASAP Age Composition

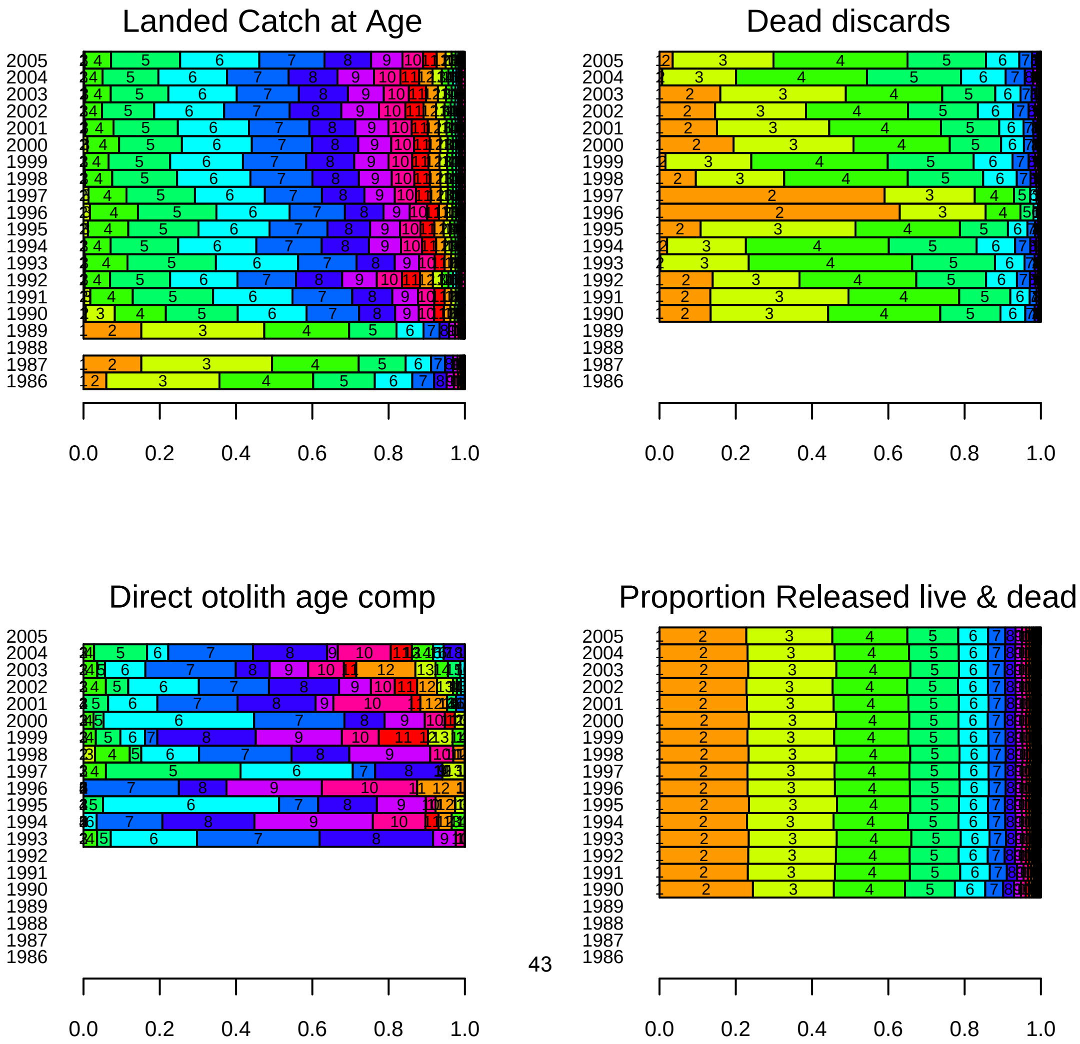

recreational
Landed Catch at Age
Dead discards
Direct otolith age comp
Proportion Released live & dead
2005
2004
2003
2002
2001
2000
1999
1998
1997
1996
1995
1994
1993
1992
1991
1990
1989
1988
1987
1986
0.0
0.2
0.4
0.6
0.8
1.0


commercial longline
Landed Catch at Age
Dead discards
Direct otolith age comp
Proportion Released live & dead
2005
2004
2003
2002
2001
2000
1999
1998
1997
1996
1995
1994
1993
1992
1991
1990
1989
1988
1987
1986
0.0
0.2
0.4
0.6
0.8
1.0

commercial handline



commercial trap



3. STOCK ASSESSMENT MODEL AND RESULTS

An age-structured assessment program (ASAP) was used to examine the status of red grouper in the U.S. Gulf of Mexico. This assessment workshop report includes two ASAP models, a continuity case intended to update the 2002 assessment of red grouper (SEFSC Staff, 2002), and a new ASAP base run developed by the SEDAR12 assessment model workshop participants. A production model was also developed and presented to the SEDAR12 AW, but it was ultimately rejected due to lack of convergence.

3.1. Model 1: ASAP Continuity Case

3.1.1. Methods

3.1.1.1. Overview

The continuity case is intended to update the base model approved by the Reef Fish Stock Assessment Panel (RFSAP) in 2002. It uses the most recent data as recommended by the SEDAR12 data workshop, but the 2002 model structure, parameter weightings and natural mortality assumption.

3.1.1.2. Data Sources

The continuity model replicated the structure and assumptions of the 2002 assessment, and included:

3 Fleets:

1. Commercial Longline
2. Commercial HL+Trap+Other
3. Recreational

6 Fisheries-dependent Indices:

1.	Commercial Longline	1990-2005
2.	Commercial Handline	1990-2005
3.	Commercial Trap	1990-2005
4.	MRFSS Recreational	1986-2005
5.	MOTE Tagging Index	1991-2001
6.	US Historical Index	1986-1997

Ages: 1 to 20+
Years: 1986-2005

Release Mortality:

1.	Commercial Longline	= 0.33
2.	Commercial Handline + Trap	= 0.33
3.	Recreational	= 0.10

A growth equation and natural mortality function were used to develop catch-at-age and discard-at-age matrices (SEDAR12-AW-06). For the continuity case (and the base run), the

Von Bertalanffy growth parameters used during this procedure were: L_∞=33.6 (854 mm); k=0.16; t_0=-0.19. A calendar year adjustment was also applied using a birth date of June 1st.

Revised/updated estimates of catch-at-age, discards-at-age and direct observations of catch-at-age (from otolith readings) were developed using methods recommended by the SEDAR12 Data Workshop. The fisheries dependent indices were also updated following the recommendations of the SEDAR12-DW. The Mote Tagging Index and U.S. Historical Index were reviewed during and after SEDAR12 DW, but it was decided that they would not be updated, nor included in the ASAP base run. Therefore, for the purposes of the continuity case, they were included unchanged from the series used during the 2002 red grouper assessment.
The data, parameter input, projection setup and output files pertaining to the continuity case were provided to the SEDAR Program Manager, and should be obtained directly from the SEDAR office[1].
All other versions of the files should be considered preliminary and are not appropriate for use.

3.1.1.3. Model Configuration and Equations

Much of this description is taken from the manuscript by Legault and Restrepo (1998).

ASAP is a flexible, age-structured "forward-computing" model that allows the assumption of separability of gear specific fishing mortality into year and age components to be relaxed and change over time (Legault and Restrepo, 1998). Likewise, catchability coefficients for observed indices of abundance are also allowed to vary over time. This increased flexibility may improve the fit of the model without relying on assumptions that may be unrealistic (i.e. exact fit to catch-at-age, invariant Q). ASAP is implemented using the AD Model Builder software package.

ASAP was used previously for stock assessments red grouper in the U.S. Gulf of Mexico (Schirripa et al., 1999; SEFSC Staff, 2002) and for western bluefin tuna (Legault and Restrepo, 1998). A different version of ASAP, which permits recruitment at age 0, has been used to assess red snapper in the U.S. Gulf of Mexico (Schirripa and Legault, 1999; Cass-Calay and Diaz, 2005; Cass-Calay et al., 2005; Ortiz and Cass-Calay, 2005.).

3.1.1.3.1. Population Dynamics

The population dynamics model of ASAP uses the standard equations common to forward-projection methods (Fournier and Archibald, 1982; Deriso et al., 1985; Methot, 1998; Ianelli and Fornier (1998). Unlike some forward-projection models, fleet specific catch and fishing mortality can be accommodated.

For the following description, let:

a = age	1…A
y = year	1…Y
g = fleet	1…G

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u = index 1…U

Age-specific selectivity coefficients were estimated subject to the following penalties used to constrain the amount of curvature allowed in the fleet-specific selectivity patterns by age:

(Eq. 1) $$\rho_{selA} = \lambda_{\rho 1} \sum_{y} \sum_{g} \sum_{a(g_{start})}^{a(g_{end})-2} \left(S_{a,y,g} - 2S_{a+1,y,g} + S_{a+2,y,g} \right)^2$$

and over time:

(Eq. 2) $$\rho_{selY} = \lambda_{\rho 2} \sum_{a} \sum_{g} \sum_{Y=1}^{Y-2} \left(S_{a,y,g} - 2S_{a,y+1,g} + S_{a,y+2,g} \right)^2$$

where the weightings of the penalties, λ_{p1} and λ_{p2}, were 1000 (CV = 0.03) and 100 (CV = 0.1), respectively.
An additional penalty is used in early phases of the estimation procedure to keep the average fishing mortality rate close to the natural mortality rate. This penalty ensures that the population abundance estimates do not get exceedingly large during the early phases of minimization. Ages $a(g_{start})$ and $a(g_{end})$ are the starting and endings ages for the gear selectivity. For the continuity case, ages 1 to 20+ were included in the selectivity vector for each fleet. However, selectivity was estimated for ages 1 to 10 only. Ages 11 to 20+ were fixed at 1.0. This causes a constant selectivity from ages 11 to 20+, and forces selectivity at younger ages to be estimated relative to that constant value.

Directed fishing mortality (*dirF*) is calculated as follows:

(Eq. 3) $$dirF_{a,y,g} = S_{a,y,g} * Fmult_{y,g} * (1.0 - PropRel_{a,y,g})$$

where *Sa,y,g* is the selectivity by age, year and fleet; $Fmult_{y,g}$ is the annual fleet-specific fishing mortality multiplier, and $PropRel_{a,y,g}$ is the proportion of fish released by age, year and fleet.

Discard fishing mortality (discF) is calculated as follows:

(Eq. 4) $$discF_{a,y,g} = S_{a,y,g} * Fmult_{y,g} * PropRel_{a,y,g} * RelMort_{g}$$

where $S_{a,y,g}$ is the selectivity by age, year and fleet; $Fmult_{y,g}$ is the annual fleet-specific fishing mortality multiplier, $PropRel_{a,y,g}$ is the proportion of fish released by age, year and fleet and $RelMort_g$ is the fleet-specific release mortality rate.

Total fishing mortality at age and year is the sum of the fleet-specific directed and discard fishing mortality rates.

(Eq. 5) $$Ftot_{a,y} = \sum_{g} dirF_{a,y,g} + discF_{a,y,g}$$

Total mortality is the sum of the total fishing mortality and the natural mortality (*M*).

$$Z_{a,y} = Ftot_{a,y} + M_{a,y}$$

(Eq. 6)

For the continuity case, *M* was assumed to equal 0.2 at all ages.

Catch-at-age, by year and fleet, is calculated as:

$$C_{a,y,g} = \frac{N_{a,y} * dirF_{a,y,g} * \left(1 - e^{-Z_{a,y}}\right)}{Z_{a,y}}$$

(Eq. 7)

where *N* is the population abundance at the start of the year. Discards-at-age, by year and fleet, are calculated in a similar fashion.

$$D_{a,y,g} = \frac{N_{a,y} * discF_{a,y,g} * \left(1 - e^{-Z_{a,y}}\right)}{Z_{a,y}}$$

(Eq. 8)

The landings and discards (in weight) by age, year and fleet are calculated

(Eq. 9)
$$Y_{a,y,g} = C_{a,y,g} * W_{a,y} \quad or \quad discY_{a,y,g} = D_{a,y,g} * W_{a,y}$$

where $W_{a,y}$ is the weight of a fish of age a in year y. The same weight-at-age matrix is used to calculate both catch-at-age and discards-at-age in weight. However, it is important to note that the inputted discards (in weight) were derived from the discards in numbers using the same weight-at-age matrix. Therefore, the model is effectively fitting numbers of discards, avoiding concerns that the average weight of discarded fish is than that of landed fish.

The proportion of catch-at-age (or discards-at-age) within a year by a fleet is:

(Eq. 10)
$$P_{CAA1_{a,y,g}} = \frac{C_{a,y,g}}{\sum_a C_{a,y,g}} \qquad \text{for the modeled catch} - \text{at} - \text{age}$$
$$P_{CAA2_{a,y,g}} = \frac{C_{a,y,g}}{\sum_a C_{a,y,g}} \qquad \text{for the direct observed catch} - \text{at} - \text{age}$$
$$or \quad P_{DAA_{a,y,g}} = \frac{D_{a,y,g}}{\sum_a D_{a,y,g}} \qquad \text{for the modeled discards} - \text{at} - \text{age}$$

Note: There are two catch-at-age matrices, the modeled CAA estimated using the Goodyear approach (CAA1), and the directly observed otolith observations (CAA2).

The recruitment in the first year is estimated as deviations from the predicted virgin recruitment

(Eq. 11)
$$N_{1,y} = \overline{N_o} e^{v_y}$$

where $v_y \sim N(0, \sigma_{Ny}^2)$. For the continuity case, deviations from the average value were assigned a CV equal to 0.25.

The population age structure in year 1 is estimated as deviations from equilibrium at unfished (virgin) condition.

(Eq. 12)
$$N_{a,1} = N_{1,1} e^{-\sum_{i=1}^{a-1} M_{i,1}} e^{\psi_a} \qquad for \ a < A$$
$$N_{a,1} = \frac{N_{1,1} e^{-\sum_{i=1}^{a-1} M_{i,1}}}{1 - e^{-M_{A,1}}} e^{\psi_a} \qquad for \ a = A$$

where $\psi_a \sim N(0,\sigma_{Na}^2)$. The remaining population abundance at age and year is then computed using the recursion:

$$N_{a,y} = N_{a-1,y-1}e^{-Z_{a-1,y-1}} \qquad for\ a < A$$

(Eq. 13)
$$N_{a,y} = N_{a-1,y-1}e^{-Z_{a-1,y-1}} + N_{a,y-1}e^{-Z_{a,y-1}} \qquad for\ a = A$$

where Z is the total mortality (Eq. 6).

Predicted indices of abundance ($\hat{I}$) are a measure of the population scaled by catchability coefficients (*q*) and selectivity at age (*S*)

(Eq. 14)
$$\hat{I}_{u,y} = q_{u,y} \sum_{a(u_{start})}^{a(u_{end})} S_{u,a,y} N^*_{a,y}$$

Where $a(u_{start})$ and $a(u_{end})$ are the starting and ending ages for the index, and N* is the population abundance, which can be expressed either in weight or numbers. The abundance index selectivity at age can be linked to that of a fleet, or input directly. If the latter is chosen, the age range can be smaller that that of the fleet and the annual selectivity values are rescaled to equal 1.0 for a specified age (a_{ref}) such that the catchability coefficient (*q*) is linked to this age.

(Eq. 15)
$$S_{u,a,y} = \frac{S_{a,y,g}}{Sa_{ref}, y, g}$$

The settings used for the indices during the continuity case are listed below. In each case, the index selectivities were linked to the age composition of a fleet.

INDEX	START AGE	END AGE	a_{ref}	Selectivity linked to fleet
COM LL	1	20	3	COM LL
COM HL	1	20	3	COM HL+TRAP
COM TRAP	1	20	3	COM HL+TRAP
MRFSS	1	20	3	REC
MOTE TAGGING	1	7	3	REC
US HISTORICAL	1	20	5	COM HL + TRAP

3.1.1.3.2. Time-Varying Parameters

The ASAP modeling framework allows time varying fleet-specific selectivity and catchability parameters. Changes in selectivity can occur each year (or time step τ_g) through a random walk for every age in a given fleet:

$$S_{a,y+\tau,g} = S_{a,y,g} e^{\varepsilon_{a,y,g}}$$

(Eq. 16)

where $\varepsilon_{a,y,g} \sim N(0,S_g^2)$ and are then rescaled to average 1.0 following equation (1). For the continuity case, the selectivity was allowed to change modestly (CV= 0.1) each year.

Deviations in the catchability coefficients are also modeled using a random walk

$$q_{u,y+1} = q_{u,y} e^{\omega_{u,y}}$$

(Eq. 17)

as do the fleet-specific fishing mortality rate multipliers

$$Fmult_{y+1,g} = Fmult_{y,g} e^{\eta_{y,g}}$$

(Eq. 18)

where $\omega_{u,y} \sim N(0,\sigma_{q,u}^2)$ and $\eta_{y,g} \sim N(0,\sigma_{Fg}^2)$.

Changes in catchability were permitted during the continuity run, however they were strongly constrained (CV = 0.01).

3.1.1.4. Parameter Estimation

The number of parameters estimated depends on the value of the time-step (τ_g) and whether changes in selectivity and/or catchability are allowed. For the continuity case, which allowed time-varying selectivity and catchability, the ***765*** estimated parameters included:

1) 20 Recruitment (1986-2005)
2) 19 Population abundance in Year 1 (Ages -1)
3) 60 Fishing mortality rate multipliers (20 Years * 3 Fleets)
4) 30 Selectivities (10 estimated ages* 3 Fleets)
5) 6 Catchabilities (6 indices)
6) 1 Stock Recruitment parameters (R_0 - steepness fixed at 0.7)
7) 540 additional selectivity estimates due to time-variant selectivity
8) 89 additional catchability estimates due to time-variant selectivity

The likelihood function to be minimized includes the following components (excluding constants). Variables with a hat ($\wedge$) are estimated by the model and variables without a hat are input as observations. The weighting (λ) assigned to each component of the likelihood function are essentially equivalent to the inverse of the variance assumed to be associated with that component ($\lambda = 1/\sigma^2$) where $\sigma^2 = \ln(CV^2 + 1)$.

Total catch in weight by fleet (lognormally distributed)

(Eq. 19) $$L_{TotalCatch} = \lambda_1 \left[\ln\left(\sum_a Y_{a,y,g} \right) - \ln\left(\sum_a \hat{Y}_{a,y,g} \right) \right]^2$$

where λ_1 is a weighting component assumed to equal 100.5 (CV = 0.1).

Total discards in weight by fleet (lognormally distributed)

(Eq. 20) $$L_{TotalDiscards} = \lambda_2 \left[\ln\left(\sum_a discY_{a,y,g} \right) - \ln\left(\sum_a disc\hat{Y}_{a,y,g} \right) \right]^2$$

where λ_2 is a weighting component assumed to equal 25 (CV = 0.2).

Two matrices of catch-at-age and one discard-at-age matrix are included in the red grouper ASAP model runs, the modeled catch-at-age (CAA1) and discards-at-age matrices (DAA) were estimated using the Goodyear approach (SEDAR12-AW-06). The second catch-at-age matrix (CAA2) is the direct otolith observations. A separate likelihood component was included for each. These were assumed to be multinomially distributed and were calculated:

(Eq. 21 $$L_{CAA_1} = -\sum_y \sum_g \lambda_{3,y,g} \sum_a P_{a,y,g} \left[\ln\left(\hat{P}_{CAA1\,a,y,g} \right) - \ln\left(P_{CAA1\,a,y,g} \right) \right]$$

(Eq. 22) $$L_{CAA2} = -\sum_y \sum_g \lambda_{4,y,g} \sum_a P_{a,y,g} \left[\ln\left(\hat{P}_{CAA2\,a,y,g} \right) - \ln\left(P_{CAA2\,a,y,g} \right) \right]$$

(Eq. 23) $$L_{DAA} = -\sum_y \sum_g \lambda_{5,y,g} \sum_a P_{a,y,g} \left[\ln\left(\hat{P}_{DAA\,a,y,g} \right) - \ln\left(P_{DAA\,a,y,g} \right) \right]$$

The second terms in equations 20-22 cause the likelihoods to equal zero for a perfect fit. The weighting components (λ_3, λ_4 and λ_5) are year and fleet specific, and are set to the effective sample sizes as summarized below. Setting λ=0 will assign a weight of zero to a given year/fleet combination. When this occurs, only total catch (or discards) in weight will be incorporated into the objective function for that fleet and year.

	λ_3 modeled catch-at-age			λ_4 direct observed catch-at-age			λ_5 modeled discards-at-age		
YEAR	Com LL	Com HL+ TRAP	Rec	ComL L	Com HL+ TRAP	Rec	Com LL	Com HL+ TRAP	Rec
1986	100	200	150	0	0	0	0	0	100
1987	100	200	150	0	0	2	0	0	100
1988	100	200	150	0	0	0	0	0	100
1989	100	200	150	0	0	0	0	0	100
1990	100	200	150	0	0	0	25	25	100
1991	100	200	150	5	9	1	25	25	100
1992	100	200	150	75	16	4	25	25	100
1993	100	200	150	151	29	7	25	25	100

1994	100	200	150	51	101	7	25	25	100
1995	100	200	150	100	83	19	25	25	100
1996	100	200	150	74	37	24	25	25	100
1997	100	200	150	5	3	22	25	25	100
1998	100	200	150	76	13	19	25	25	100
1999	100	200	150	200	30	21	25	25	100
2000	100	200	150	200	96	20	25	25	100
2001	100	200	150	200	200	13	25	25	100
2002	100	200	150	200	111	58	25	25	100
2003	100	200	150	200	127	72	25	25	100
2004	100	200	150	200	200	57	25	25	100
2005	100	200	150	200	182	29	25	25	100

Note: λ = 400; CV $\cong$ 0.050 λ = 100; CV $\cong$ 0.100 λ = 25; CV $\cong$ 0.200
λ = 12; CV $\cong$ 0.300 λ = 6.74; CV $\cong$ 0.400 λ = 4.48; CV $\cong$ 0.500
λ = 3.24; CV $\cong$ 0.600 λ = 2.50; CV $\cong$ 0.700 λ = 1.44; CV $\cong$ 1.000

The likelihood component for the indices of abundance (lognormally distributed) was calculated:

$$L_{Indices} = \sum_g \lambda_{6,g} \sum_y \left[\ln\left(I_{y,g}\right) - \ln\left(\hat{I}_{y,g}\right)\right]^2 / 2\sigma^2_{y,g} + \ln\left(\sigma_{y,g}\right)$$
(Eq. 24)

where λ_6 is a weighting component. For the continuity case, λ_6 = 25 (CV = 0.2) for all indices. The sigmas (σ) in equation 23 can be set equal to 1.0, or input. For the continuity case, the sigmas were input using the annual CVs for each index. These values are summarized in the table below.

	Index of Abundance											
	COM LL		COM HL		COM TRAP		MRFSS		MOTE TAGGING		US HIST	
YEAR	Value	SD (σ)	Value	SD (σ)	Value	SD (σ)	Value	SD (σ)	Value	SD (σ)	Value	SD (σ)
1986	-	-	-	-	-	-	0.688	0.549	-	-	0.620	1.000
1987	-	-	-	-	-	-	0.658	0.564	-	-	0.486	1.000
1988	-	-	-	-	-	-	0.925	0.466	-	-	0.408	1.000
1989	-	-	-	-	-	-	1.318	0.435	-	-	0.680	1.000
1990	0.774	0.133	0.696	0.228	0.821	0.177	1.869	0.453	-	-	0.271	1.000
1991	0.779	0.120	0.648	0.212	0.943	0.167	1.148	0.500	1.790	0.130	0.296	1.000
1992	0.680	0.133	0.748	0.196	1.029	0.165	1.267	0.423	1.420	0.080	0.356	1.000
1993	0.973	0.106	0.683	0.175	0.948	0.163	0.781	0.480	0.955	0.110	0.378	1.000
1994	0.832	0.104	0.882	0.166	1.121	0.164	0.932	0.447	1.202	0.190	0.324	1.000
1995	0.977	0.103	0.871	0.164	1.059	0.168	0.769	0.502	1.066	0.220	0.252	1.000
1996	0.844	0.103	0.608	0.170	0.794	0.177	0.605	0.514	0.720	0.300	0.168	1.000
1997	1.012	0.099	0.566	0.175	0.768	0.182	0.545	0.538	0.510	0.110	0.203	1.000
1998	0.982	0.101	0.537	0.175	0.660	0.193	0.755	0.445	0.696	0.100	-	-
1999	1.002	0.105	0.717	0.164	1.302	0.175	0.930	0.402	1.028	0.140	-	-
2000	0.994	0.101	0.987	0.158	1.273	0.166	1.047	0.397	0.875	0.130	-	-
2001	1.319	0.097	1.453	0.155	1.009	0.180	0.869	0.397	0.738	0.170	-	-
2002	1.025	0.101	1.522	0.152	0.953	0.178	0.903	0.392	-	-	-	-
2003	0.978	0.101	1.140	0.151	0.846	0.185	1.113	0.361	-	-	-	-

2004	1.278	0.098	1.773	0.148	1.246	0.178	1.676	0.305	-	-	-	-
2005	1.553	0.098	2.169	0.149	1.230	0.181	1.204	0.338	-	-	-	-

Therefore, annual index values were weighted by their CVs, and individual indices were weighted by their associated variance, and an additional weighting term (λ_6) which further down weighted the indices compared to the catch and discards series.

Priors for the time-varying parameters are also included in the likelihood by setting λ equal to the inverse of the assumed variance for each component:

(Eq. 25)
$$L_{sel} = \sum_g \lambda_{7,g} \sum_a \sum_y \varepsilon^2_{a,y,g} \qquad (selectivity)$$

(Eq. 26)
$$L_q = \sum_u \lambda_{8,u} \sum_y \omega^2_{u,y} \qquad (catchability)$$

(Eq. 27)
$$L_{Fmult} = \sum_g \lambda_{9,g} \sum_y \eta^2_{y,g} \qquad (F\ multipliers)$$

(Eq. 28)
$$L_R = \lambda_{10} \sum_y \nu^2_y \qquad (recruitment)$$

(Eq. 29)
$$L_{N_1} = \lambda_{11} \sum_y \psi^2_y \qquad (N\ year\ 1)$$

where

Selectivity Deviations:	λ_7 = 1000;	CV ≅ 0.03
Catchability Deviations:	λ_8 = 10000;	CV ≅ 0.01 (applied to all indices)
F_{Mult} Deviations (by Fleet):		
Commercial LL:	λ_9 = 7;	CV ≅ 0.39
Commercial HL+Trap	λ_9 = 11;	CV ≅ 0.29
Recreational	λ_9 = 11;	CV ≅ 0.29
Recruitment Deviations	λ_{10} = 4.48	CV ≅ 0.50
N_{Year1} Deviations	λ_{11} = 4.48	CV ≅ 0.50

In addition, there is a prior for fitting a Beverton and Holt type stock-recruitment relationship

(Eq. 30)
$$L_{SR} = \lambda_{12} \sum_y \left[\ln\left(N_{1,y}\right) - \ln\left(\frac{\alpha SS_{y-1}}{\beta + SS_{y-1}}\right)\right]^2$$

where SS is the spawning stock reproductive potential, α and β are parameters to be estimated, and λ_{12} is the inverse of variance assigned to virgin stock size. For the continuity case, $\lambda_{12} = 0$. This setting causes the virgin stock size to be estimated as a free parameter. Note: ASAP estimates alpha and beta, but uses the reparameterized inputs virgin reproductive potential (or biomass) and steepness. For the continuity case, steepness was fixed at 0.7, as recommended by the Reef Fish Stock Assessment Panel during the 2002 red grouper assessment, while virgin reproductive potential was estimated as a free parameter.

The function to be minimized is the sum of the likelihoods and penalties.

$$L = L_{TotalCatch} + L_{TotalDiscards} + L_{CAA1} + L_{CAA2} + L_{DAA} + L_{Indices} + L_{Sel} + L_{Q} + L_{FMult} + L_{R} + L_{NYear1} + L_{SR} + \rho_{SelA} + \rho_{SelY} \quad \text{(Eq. 31)}$$

3.1.1.5. Uncertainty and Measures of Precision

Each component of the objective function is reported to the output file (*.rep) along with the corresponding number of observations, weight assigned to that component, and the residual sum of squared deviations (when appropriate). The ASAP output includes an estimate of the standard deviation of each parameter. Standard deviations were derived by taking the inverse of the Hessian matrix at the maximum likelihood estimate, a capability of the AD-Model Builder software.

3.1.1.6. Benchmark / Reference points methods

Each fleet can be designated as "directed" or "non-directed" for the F reference point calculations. For red grouper, all fleets were considered directed. The directed fleets are combined to estimate an overall selectivity pattern that is used to solve for the common fishing mortality rate reference points ($F_{0.1}$, F_{MAX}, $F_{30\%SPR}$, $F_{40\%SPR}$, F_{MSY}, F_{OY}) and compared to the terminal year F estimate (F Current)

3.1.1.7. Projection methods

No projections were run for the continuity case.

3.1.2. Model 1 Results

3.1.2.1. Measures of Overall Model Fit

The objective function value, likelihood components and residual sums of squares are tabulated in Table 3.1.2.1.1. Model fits to the catch series are summarized in Table 3.1.2.1.2. The fits to the catch series for the 2002 base run and the 2006 continuity run are shown in Figure 3.1.2.1.1. In general, the fits to the catch series were better for the 2006 continuity run. However, an examination of the 2006 continuity case results reveals a notable lack of fit in the 1986-1989 catch estimates from the commercial HL&TRAP fleet.

The predicted discard series for the commercial fleets were estimated with a greater assumed variance (λ = 25.5; CV=0.2) because these are modeled inputs, and the assessment panel had less confidence in their precision. As a result, the fits are allowed to deviate from the expected values to a greater extent than the fits to the catch series (λ = 100; CV=0.1). The fits to the discard series for the 2002 base run and the 2006 continuity run are shown in Figure 3.1.2.1.2. The fits to the discard series were improved for the 2006 continuity run.

The index CVs were used to weight the annual estimates within each series. In addition, the mean variance and an additional index variance parameter (λ = 25.5; CV=0.2) was used to further downweight the indices with regard to the catch series. The fits to the indices of abundance for the 2002 base run and the 2006 continuity case are summarized in Table

3.1.2.1.4 and Figure 3.1.2.1.3. In general, the fits to the indices reflect the annual trends. The fits to the indices are generally tighter for the 2002 base run. This is due to the inclusion of year interaction terms during standardization of the 2006 CPUE series. Year interaction terms were modeled as random effects, a procedure which increases the variance estimates.

3.1.2.2. Parameter estimates

As discussed in Section 3.1.1.4, the 2006 continuity case included 765 estimated parameters. A selection of important parameters is summarized, and compared to the 2002 base case in Table 3.1.2.2.1. The other estimated parameters include annual estimates of fleet-specific selectivity-at-age, annual estimates of catchability, recruitment and F_{MULT} deviations. These can be found in the parameter output file (ASAP2002.std).

3.1.2.3. Stock Abundance and Recruitment

According to the 2006 continuity case, abundance has generally increased since 1986 (Table 3.1.2.3.1; Figure 3.1.2.3.1). The highest estimated abundance occurred in 2004. Recruitment has deviated without obvious trend throughout the time series. There is some indication of a large year-class in 1999 (Figure 3.1.2.3.2). The stock-recruitment relationship (Beverton and Holt) is shown in Figure 3.1.2.3.3.

The abundance-at-age is shown in Figure 3.1.2.3.4. and Table 3.1.2.3.1. According to these results, the stock is comprised mostly of individuals less than 10 years old. The oldest animals were declining in abundance from 1986 until the mid-1990s. After that time, the number of older individuals began to increase as younger animals progressed through the age structure.

The results from the 2006 continuity case are very similar to the 2002 base case (Figures 3.1.2.3.1 to 3.1.2.3.4).

3.1.2.4. Spawning Stock Biomass

Because reproductive potential (eggs per spawning event) was used as a fecundity proxy, ASAP does not produce estimates of spawning stock biomass. Instead, ASAP estimates spawning stock reproductive potential (SS; eggs per spawning event). According to the 2006 continuity case, spawning reproductive potential has generally increased since 1990 (Figure 3.1.2.4.1 and Table 3.1.2.4.1). At that time, SS as a fraction of SS at maximum sustainable yield (MSY) was 61%. In 2005, SS/SS_{MSY} was estimated at 1.07, indicating that, according to this model configuration, the red grouper stock in the Gulf of Mexico is no longer overfished.

The 2006 continuity case was compared to the 2002 base case in Figures 3.1.2.4.1 and 3.1.2.4.2. The 2002 model results are very similar to the continuity case. For the 2002 base model, SS_{2001}/SS_{MSY} was 0.80. For the 2006 continuity case, SS_{2001}/SS_{MSY} was 0.85. Both results indicate that the stock was not overfished in 2001, assuming a threshold of 1-M where M=0.2.

3.1.2.5. Fishery Selectivity

The 2002 base model and 2006 continuity case allowed annual variation in fleet-specific selectivity. After the estimation, the Age-1 selectivity was fixed at zero for the commercial fleets after 1990. This was done because there were very few observations of age-1 individuals in the commercial catch-at-age.

The estimated selectivity vectors are shown in Figures 3.1.2.5.1 to 3.1.2.5.3. The selectivity vectors estimated by the 2002 base model and the 2006 continuity case are very similar. Both models indicate that older individuals (Ages 9-20+) are fully selected for by the commercial fisheries, while younger individuals (Ages 1-6) are selected for by recreational fleet.

3.1.2.6. Fishing Mortality

Fleet-specific fishing mortality rates are summarized in Figure 3.1.2.6.1 to 3.1.2.6.2 and Table 3.1.2.6.1. Without exception, fishing mortality rates resulting from directed landings are higher than those from discards. The highest fishing mortality rates are due to the recreational fleet, while the lowest are due to the commercial handline and trap fleets

The annual fishing mortality estimates of the recreational fishery differ considerably between the 2002 base run and the 2006 continuity case (Figures 3.1.2.6.1 and 3.1.2.6.2). Specifically, the recreational fishing mortality series estimated by the 2002 base run are substantially higher. The fishing mortality estimates for the commercial fleets are roughly similar.

Annual estimates of apical F and F/F_{MSY} indicate that fishing mortality has generally declined since the mid 1990s (Figure 3.1.2.6.3 and 3.1.2.6.4 and Table 3.1.2.6.2). Although the estimated directed fishing mortality of the 2002 base run and 2006 continuity case differ substantially during 1986-1999, they are quite similar after 1990. Discard fishing mortality is most dissimilar during 1991-1995.

For the 2002 base case and 2006 continuity case, the estimates of directed F_{1990}/F_{MSY} were 1.11 and 1.23, respectively, indicating that overfishing was occurring at that time. Directed F/F_{MSY} began to decline after the mid 1990s. By 2001, estimates of directed F/F_{MSY} were 1.08 and 1.06, respectively. The 2006 continuity case results indicate that the stock is currently not overfished (F_{2005}/F_{MSY}= 0.78).

Fishing mortality-at-age is summarized in Table 3.1.2.6.3. These estimates indicate low directed F on ages 1-2, particularly after 1989. Maximal directed F occurs on ages 11-20 during the 18” minimum size limit (1986-1990), and the plus group (20+) after the 20” minimum size limit (1990-2005). Discard F-at-age also changes in association with the increase in legal minimum size. Before 1990, maximal discard mortality occurred at age-1. After 1990, maximal discard F occurred on ages 2-3.

3.1.2.7. Stock-Recruitment Parameters

Steepness was fixed at 0.7 for both the 2006 continuity case and the 2002 base run. Therefore, only one stock recruitment parameter was estimated, the virgin reproductive potential. (Number of fish* Proportion Female * Proportion Mature * eggs per female) This was estimated as a free parameter (no prior was used). For the 2006 continuity case, the estimated virgin reproductive potential was 2.67 trillion eggs per spawning event. This is very similar to the result of the 2002 base run which estimated 2.3 trillion eggs per spawning event.

3.1.2.8. Measures of Parameter Uncertainty

See sections 3.1.2.2 and 3.1.2.10.

3.1.2.9. Retrospective and Sensitivity Analyses

No retrospective or sensitivity analyses were made for the continuity case. This run was performed to compare with the previous assessment, and was not intended to be a base run.

3.1.2.10. Benchmarks / Reference Points / ABC values

The benchmarks/reference points for the 2002 base run and the 2006 continuity case are shown in Table 3.1.2.10.1. The current management plan for red grouper stipulates the use of MSY-based reference points. A phase/control rule diagram is provided to facilitate comparison of the model runs (Figure 3.2.2.10.1). The results of the 2002 base run and the 2006 continuity case are very similar. In 2001 (the terminal year of the 2002 run), SS/SS_{MSY} was estimated at 0.84 (SD= 0.025) and 0.80, respectively. The fishing mortality ratio (F_{2001}/F_{MSY}) was estimated at 1.03 (SD= 0.056) and 1.06, respectively. These results suggest that in 2001, the population was undergoing overfishing, but was not overfished if one assumed a threshold of 1-M where M=0.2.

The 2006 continuity case provides estimates of current status. In 2005, SS/SS_{MSY} = 1.07 (SD=0.034) and F/F_{MSY} = 0.78 (SD=0.045). These results indicate that the stock is no longer overfished, and is not currently undergoing overfishing. Management reference points are listed below.

Reference Point	2002 Base Case	2006 Continuity Case
F_{OY}	0.229	0.220
MFMT (=F_{MSY})	0.306	0.293
MSST [(1-M)*SSB_{MSY}]	6.72E+11	7.40E+11

No ABC recommendations were made based on the results of the continuity case.

3.1.2.11. Projections

No projections were made for the continuity case. This run was performed to compare with the previous assessment, and was not intended to be a base run.

3.1.3. Discussion

The continuity case was intended to replicate the 2002 red grouper assessment selected by the Reef Fish Stock Assessment Panel. The results are very similar to those of the 2002 assessment. In 2001 (the terminal year of the 2001 assessment, then stock was not overfished, but was undergoing overfishing. This was also the result of the 2001 assessment. Furthermore, according to the continuity case, in 2005, the stock was not overfished, and was also not undergoing overfishing.

3.2. Model 2: ASAP Base Case

3.2.1. Methods

3.2.1.1. Overview

The base case is the model constructed during the SEDAR12 assessment workshop, and recommended for review. Except where noted, the base model uses the data, indices and life history parameters (growth, maturity, fecundity and natural mortality etc.) provided to, reviewed and recommended by the SEDAR12-DW panel. ***Deviations from the recommendations of the SEDAR12-DW panel are summarized in section 3.2.1.2.***

3.2.1.1.1. Data Sources

As recommended by the DW panel, the base model structure included 4 fleets:
1. Commercial Longline
2. Commercial HL
3. Commercial Trap
4. Recreational

The DW panel recommended the use of 5 indices,
1. Commercial Longline
2. Commercial Handline
3. MRFSS Recreational
4. SEAMAP Video Survey
5. NMFS Longline Survey

and requested that the AW panel review three additional indices, and make a recommendation regarding their use.
1. Dry Tortugas Visual Census
2. NMFS Headboat Survey (1986-1990) 18” minimum size limit
3. NMFS Headboat Survey (1990-2005) 20” minimum size limit

The final recommendation of the SEDAR12-AW panel was to include 6 indices in the base run.
1. Commercial Longline (Fisheries-dependent; 1990-2005)
2. Commercial Handline (Fisheries-dependent; 1990-2005)
3. MRFSS Recreational (Fisheries-dependent; 1986-2005)
4. NMFS Headboat Survey (MSL18”) (Fisheries-dependent; 1986-1990)
5. NMFS Headboat Survey (MSL 20”) (Fisheries-dependent; 1990-2005)
6. SEAMAP Video Survey (Fisheries-independent; 1993-1997,2002,2004,2005)

The NMFS Longline Survey was removed from the base run on the grounds that it was short, highly variable and largely without trend.

Consistent with the advice of the SEDAR12-DW panel, the ASAP base run included:
Ages: 1 to 20+
Years: 1986-2005

The DW panel recommended an age-varying natural mortality (M) developed using the method of Lorenzen (1996). This approach inversely relates the natural mortality-at-age to the mean weight-at-age by a power function, $M = 3W^{-0.288}$, incorporating a scaling parameter. Lorenzen (1996) provided point estimates and 90% confidence intervals of the power and scaling parameters for oceanic fishes, which are used for initial parameterization. The Lorenzen function was re-scaled to the oldest observed age (29; SEDAR12-DW-03) such that the cumulative natural mortality through this age was equivalent to that with a constant M of 0.14 for all ages from the Hoenig (1983) method.
The AW panel reviewed this recommendation, and noted that the maximum age of 29 was based on a single observation aged by three readers who had estimated the age from 19-29 years. Consequently, the AW panel felt that a maximum age of 25 was more defensible as several fish (n=13) have been observed at this age, with better reader agreement. The base model used a revised Lorenzen M function developed at the assessment workshop such that the cumulative natural mortality through this age was equivalent to a constant M of 0.167 (T_{max} = 25) for all ages from the Hoenig (1983) method. The following table is summarizes the difference between the data (DW) and assessment panel (AW) recommendations.

AGE	Natural Mortality DW Panel (T_{max} = 29)	Natural Mortality AW Panel (T_{max} = 25)
1	0.343	0.409
2	0.221	0.263
3	0.171	0.204
4	0.144	0.171
5	0.127	0.151
6	0.115	0.137
7	0.107	0.128
8	0.101	0.120
9	0.096	0.115
10	0.093	0.111
11	0.090	0.107
12	0.088	0.104
13	0.086	0.102
14	0.084	0.100
15	0.083	0.099
16	0.082	0.098
17	0.081	0.097
18	0.080	0.096
19	0.080	0.095
20+	0.080	0.095

The DW panel recommended that depth-related functions be used to develop fleet-specific release mortality estimates. However, it became apparent during DW discussions that red grouper release mortality estimates appropriate for the development of a depth-function were scarce compared to those available for gag grouper (SEDAR 10). The AW panel also reviewed the available data, and agreed that it was insufficient to develop suitable depth-related release mortality functions. However, based on the best available data, including average depth by fleet, the AW provided the following fleet-specific release mortality estimates:

1. Commercial Longline = 0.45
2. Commercial Handline = 0.10
3. Commercial Trap = 0.10
4. Recreational = 0.10

The base model used the growth function as recommended by the SEDAR12-DW panel (L_∞ = 854 mm; K = 0.16; t_0 = -0.19 yr).

The base model used the maturity and fecundity series developed using the recommendations of the SEDAR12-DW panel.

The data, parameter input, projection setup and output files pertaining to the continuity case were provided to the SEDAR Program Manager, and should be obtained directly from the SEDAR office[2].
All other versions of the files should be considered preliminary and are not appropriate for use.

3.2.1.2. Model Configuration and Equations

The base model used the same assessment method (ASAP) as the continuity case (Section 3.1). The equations are identical to those described in Section 3.1.1.3.

3.2.1.2.1. Population Dynamics

The base model equations are identical to those described in Section 3.1.1.3. All differences in weighting components and variances are summarized below.

Differences between continuity case and base run

1) Recall that selectivity (*S*) at age in year *y* can be limited to a range of ages. For the base run, ages 1 to 20+ were included in the selectivity vector for each fleet. However, the age range for which selectivity was estimated varied by fleet. Selectivity was estimated for ages 1 to 15 for the commercial handline and longline fleets, ages 1 to 12 for the commercial trap fleet, and ages 1 to 10 for the recreational fleet. All other selectivities were fixed at 1.0. This causes a constant selectivity when age is greater than the last estimated age, and forces selectivity at younger ages to be estimated relative to that constant value.

2) Recruitment in year 1 is estimated as deviations from the predicted virgin recruitment (Eq. 12). For the continuity case, deviations from the average value were assigned a CV equal to 0.25. For the base case, a CV of 0.5 was assigned.

3) The abundance index selectivity at age can be linked to a fleet, or input directly. The settings for the indices used for the base run are listed below. Selectivities for all indices except the SEAMAP video were linked to that of the corresponding fleet. For the SEAMAP Video Survey, a fixed selectivity vector based on the age composition was input (Relative selectivity at age 1 = 0; age 2 = 0; age 3 = 0.5; ages 4 to 20+ = 1.0).

INDEX	START AGE	END AGE	a_{ref}	Selectivity linked to fleet?
SEAMAP Video	3	20	4	FIXED

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COM LL	4	20	4	COM LL
COM HL	4	20	4	COM HL
HB 1986-1990	4	20	4	REC
HB 1990-2005	4	20	4	REC
MRFSS	1	20	4	REC

4) The ASAP modeling framework allows time varying fleet-specific selectivity and catchability parameters. Changes in selectivity can occur each year (or time step τ_g) through a random walk for every age in a given fleet (Eq. 16). For the base run, the selectivity was estimated over the entire time period (1986-2005) without annual deviations. ***It should be noted that although time-invariant selectivity functions were estimated, the discard fractions are estimated directly, and do vary annually. Therefore, although management actions (such as increasing the minimum size limit) will not modify the selectivity vector, they may cause changes the proportion of the catch discarded.***

5) Unlike the continuity case, no annual deviations in the catchability coefficients were allowed. However, one sensitivity run examined the effect of increasing Q by 2% annually.

3.2.1.3. Parameter Estimation

The base run did not estimate time-varying selectivity and catchability parameters. Therefore, a reduced number of parameters were estimated (179) including:

1) 20 Recruitment (1986-2005)
2) 19 Population abundance in Year 1 (Ages -1)
3) 80 Fishing mortality rate multipliers (20 Years * 4 Fleets)
4) 52 Selectivity-at-age
5) 6 Catchabilities (6 indices)
6) 2 Stock Recruitment parameters (Virgin reproductive potential - steepness also estimated)

The likelihood function to be minimized was identical to that described in Section 3.1.1.4., with the exception of the following weighting components.

		Weighting	
Likelihood Component	Name	Continuity Case	Base Run
Total Catch in Weight	λ_1	100.5 (CV=0.1)	100.5 (CV=0.1)
Total Discards in Weight	λ_2	25 (CV = 0.2)	11.6 (CV = 0.3)
Indices Relative Weights (λ)	λ_6	25 (CV = 0.2)	25 (CV = 0.2)
Index Interannual Weightings (σ)	σ	Used Index CVs	Fixed = 1.0 (equal weight)
Selectivity	λ_7	1000 (CV = 0.03)	No deviations allowed
Catchability	λ_8	10000 (CV = 0.01)	No deviations allowed

F Multipliers Com LL Com HL Com Trap Com HL + Trap Recreational	λ_9	 7 (CV = 0.39) not used notused 11 (CV = 0.29 11 (CV = 0.29	 11 (CV = 0.29) 11 (CV = 0.29) 11 (CV = 0.29 not used 11 (CV = 0.29)
Recruitment	λ_{10}	4.48 (CV = 0.5)	4.48 (CV = 0.5)
N in Year1	λ_{11}	4.48 (CV = 0.5)	4.48 (CV = 0.5)
Stock-Recruitment	λ_{12}	0 (free parameter)	0 (free parameter)
Penalty for Curvature of Selectivity by Year	$\lambda_{\rho 1}$	1000 (CV = 0.03)	400 (CV = 0.05)
Penalty for Curvature of Selectivity by Age	$\lambda_{\rho 2}$	100 (CV = 0.1)	100 (CV = 0.1)

The weighting components for the catch-at-age and discards-at-age matrices (λ_3, λ_4 and λ_5) are year and fleet specific, and were assumed equal to the effective sample sizes as summarized below.

	λ_3 modeled catch-at-age	λ_4 direct observed catch-at-age				λ_5 modeled discards-at-age			
YEAR	ALL FLEETS	COM LL	COM HL	COM TRAP	REC	COM LL	COM HL	COM TRAP	REC
1986	0	0	0	0	0	0	0	0	11.6
1987	0	0	0	0	2	0	0	0	11.6
1988	0	0	0	0	0	0	0	0	11.6
1989	0	0	0	0	0	0	0	0	11.6
1990	0	0	0	0	0	11.6	11.6	11.6	11.6
1991	0	5	10	0	1	11.6	11.6	11.6	11.6
1992	0	75	17	0	4	11.6	11.6	11.6	11.6
1993	0	151	32	46	7	11.6	11.6	11.6	11.6
1994	0	51	124	11	7	11.6	11.6	11.6	11.6
1995	0	100	93	17	19	11.6	11.6	11.6	11.6
1996	0	74	40	4	24	11.6	11.6	11.6	11.6
1997	0	5	4	8	22	11.6	11.6	11.6	11.6
1998	0	76	14	18	19	11.6	11.6	11.6	11.6
1999	0	200	33	13	21	11.6	11.6	11.6	11.6
2000	0	200	104	15	20	11.6	11.6	11.6	11.6
2001	0	200	200	15	13	11.6	11.6	11.6	11.6
2002	0	200	117	37	58	11.6	11.6	11.6	11.6
2003	0	200	135	31	72	11.6	11.6	11.6	11.6
2004	0	200	200	18	57	11.6	11.6	11.6	11.6
2005	0	200	187	0	29	11.6	11.6	11.6	11.6

Note: $\lambda = 400$; CV $\cong 0.050$ $\lambda = 178$; CV $\cong 0.075$ $\lambda = 100$; CV $\cong 0.100$
$\lambda = 45$; CV $\cong 0.150$ $\lambda = 25$; CV $\cong 0.200$ $\lambda = 16$; CV $\cong 0.250$
$\lambda = 12$; CV $\cong 0.300$ $\lambda = 6.74$; CV $\cong 0.400$ $\lambda = 4.48$; CV $\cong 0.500$
$\lambda = 3.24$; CV $\cong 0.600$ $\lambda = 2.50$; CV $\cong 0.700$ $\lambda = 1.44$; CV $\cong 1.000$

It should be noted that, unlike the continuity case, the base run does not use the fit to the modeled age composition ($\lambda_3 = 0$) in the objective function. The fit to the catch-at-age is determined solely by the directly observed age composition from otolith analysis. These observations are weighted by their effective sample sizes (λ_4). It was necessary to use the modeled discard age composition (λ_5) since there are no available direct observations. However, these were generally weighted lower than other data sources (λ_5.= 11.6; CV = 0.3).

3.2.1.4. Uncertainty and Measures of Precision

Same as section 3.1.1.5.

3.2.1.5. Benchmark / Reference points methods

Same as section 3.1.1.6.

3.2.1.6. Projection methods

The projections for each successive year can be made using a variety of assumptions: an input yield in weight, an input F, $F_{SPR30\%}$, $F_{SPR40\%}$, F_{MSY}, F_{OY} or $F_{Current}$. An additional option exists to modify the non-directed F in the projection years, but no non-directed fleets were specified in the red grouper ASAP model runs, therefore this option was not used.

Five projections were made from the base run. Projection settings are summarized below. F is the fishing mortality ($F_{CURRENT}$ = 0.145; F_{MSY} = 0.16; F_{OY} = 0.12). In all cases, it was assumed that management changes would not occur until 2008. Therefore, $F_{CURRENT}$ was maintained during 2006 and 2007. Recruitment was estimated from the stock-recruitment relationship. The projection settings are summarized below.

	PROJECTION									
	Current F		FMSY		FOY		OY		Evaluate Management	
YEAR	Fix?	Value	Fix?	Value	Fix?	Value	Fix?	Value	Fix?	Value
2006	F	0.145	F	0.145	F	0.145	F	0.145	F	0.145
2007	F	0.145	F	0.145	F	0.145	F	0.145	F	0.145
2008	F	0.145	F	0.160	F	0.120	Yield	8.64 mp	Yield	7.22 mp
2009	F	0.145	F	0.160	F	0.120	Yield	8.64 mp	Yield	7.33 mp
2010	F	0.145	F	0.160	F	0.120	Yield	8.64 mp	Yield	7.33 mp
2011	F	0.145	F	0.160	F	0.120	Yield	8.64 mp	Yield	7.33 mp
2012	F	0.145	F	0.160	F	0.120	Yield	8.64 mp	Yield	7.39 mp
2013	F	0.145	F	0.160	F	0.120	Yield	8.64 mp	Yield	7.39 mp
2014	F	0.145	F	0.160	F	0.120	Yield	8.64 mp	Yield	7.39 mp
2015	F	0.145	F	0.160	F	0.120	Yield	8.64 mp	Yield	7.39 mp
2016	F	0.145	F	0.160	F	0.120	Yield	8.64 mp	Yield	7.39 mp
2017	F	0.145	F	0.160	F	0.120	Yield	8.64 mp	Yield	7.39 mp
2018	F	0.145	F	0.160	F	0.120	Yield	8.64 mp	Yield	7.39 mp
2019	F	0.145	F	0.160	F	0.120	Yield	8.64 mp	Yield	7.39 mp

3.2.2. Model 1 Results

3.2.2.1. Measures of Overall Model Fit

The objective function value, likelihood components and residual sums of squares are tabulated in Table 3.2.2.1.1. Model fits to the catch series were good, as was expected given the weighting of this component (λ = 100; CV=0.1; Table 3.2.2.1.2 and Figure 3.2.2.1.1). Residuals seldom exceeded 10% of the total annual catch.

The predicted discard series were estimated with a greater assumed variance (λ = 11.6; CV=0.3). Therefore, the fits were less precise, but acceptable. Residuals were generally 20-40% of the annual discards in weight, with the exception of the trap fleet for which residuals often exceeded 150% of the annual discards (Table 3.2.2.1.3 and Figure 3.2.2.1.2).

The predicted index values were assigned moderate variance (λ = 25; CV=0.2). The six indices were equally weighted, and the yearly estimates of each index were also assigned an equal weighting. The fits to the indices of abundance are summarized in Table 3.2.2.1.4 and Figures 3.2.2.1.3 and 3.2.2.1.4. In general, the fits to the indices reflect the annual trends. The fits to the SEAMAP Video and COM LL indices are very precise throughout the time series. During recent years, the predicted index values are lower than the observed values for the COM HL and HB 20" minimum size limit (1990-2005) indices. The MRFSS index deviates from the predicted values primarily during the middle of the time series 1988-1992, and in 2004.

Fits to the age composition are generally acceptable (Figures 3.2.2.1.5 to 3.2.2.1.8). There are no observations for the commercial fisheries until 1991. Likewise, there are no observations for the trap fishery in 2005. Lack of fit is generally caused by low effective sample sizes (See section 3.2.1.4).

3.2.2.2. Parameter estimates

As discussed in Section 3.2.1.3, the base run included 179 estimated parameters. Many of these are summarized in Table 3.2.2.2.1. The other estimated parameters include recruitment and F_{MULT} deviations. These can be found in the report file (ASAP2002..std).

3.2.2.3. Stock Abundance and Recruitment

Abundance has generally increased since 1986 (Table 3.2.2.3.1; Figure 3.2.2.3.1). The highest estimated abundance occurred in 2000, as a result of a strong year class in 1999 (Figure 3.2.2.3.2; Table 3.2.2.3.1). Recruitment has deviated without obvious trend throughout the time series. Large year-classes are evident in 1996 and 1999 (Figure 3.2.2.3.2). The stock-recruitment relationship (Beverton and Holt) is shown in Figure 3.2.2.3.3.

The abundance-at-age is shown in Figure 3.2.2.3.4. and Table 3.2.2.3.1. According to these results, the stock is comprised mostly of individuals less than 10 years old. The oldest animals were declining in abundance from 1986 until the mid-1990s. After that time, the number of older individuals began to increase as younger animals progressed through the age structure.

3.2.2.4. Stock Biomass (total and spawning stock)

Because reproductive potential (eggs per spawning event) was used as a fecundity proxy, ASAP does not produce estimates of spawning stock biomass. Instead, ASAP estimates spawning stock reproductive potential (SS; eggs per spawning event). Spawning stock reproductive potential (SS) has increased since 1990 (Figure 3.2.2.4.1 and Table 3.2.2.4.1). At that time, SS as a fraction of SS at maximum sustainable yield (MSY) was 53%. In 2005, SS/SS_{MSY} was estimated at 1.04, indicating that the red grouper stock in the Gulf of Mexico is no longer overfished.

3.2.2.5. Fishery Selectivity

Selectivity-at-age was estimated for each fleet. After the estimation, the Age-1 selectivity was set to zero for the commercial fleets. This was done because there were very few observations of age-1 individuals in the commercial catch-at-age. The selectivity vectors are summarized in Figure 3.2.2.5.1 and Table 3.2.2.5.1. According to these results, older individuals (Ages 9-20+) are selected for by the commercial trap fishery, while individuals Ages 9-15 are predominate in the commercial longline landings. Ages 2-10 are selected for by the commercial handline fleet. The recreational fishery selects for younger age classes (Ages < 10).

3.2.2.6. Fishing Mortality

Fleet-specific fishing mortality rates are summarized in Figure 3.2.2.6.1 and Table 3.2.2.6.1. Without exception, fishing mortality rates resulting from directed landings are higher than those from discards. The highest fishing mortality rates are due to the commercial longline and recreational fleets, while the lowest are due to the commercial trap fleet

Annual estimates of apical F and F/F_{MSY} indicate that fishing mortality has generally declined since 1993 (Figure 3.2.2.6.2 and Table 3.2.2.6.2). In the initial year, 1986, F/F_{MSY} was 1.3, indicating that overfishing was occurring. F/F_{MSY} increased until 1993 ($F_{1993}/F_{MSY} = 1.9$) and then began to decline. In 2005, F/F_{MSY} was 0.91. If F/F_{MSY} is the selected recovery benchmark, this implies that overfishing is no longer occurring. However, F_{2005} (0.14) remains greater than F_{OY} (0.12) in 2005.

Fishing mortality-at-age is summarized in Table 3.2.2.6.3. These estimates indicate low directed F on ages 1-3. Maximal directed F occurs on ages 6-8 during the 18” minimum size limit (1986-1990), and ages 9-12 after the 20” minimum size limit (1990-2005). Discard F-at-age shows similar changes in association with the increase in legal minimum size. Before 1990, maximal discard mortality occurred at age-1. After 1990, maximal discard F occurred on ages 3-4.

3.2.2.7. Stock-Recruitment Parameters

Two stock recruitment parameters were estimated during the base run, steepness and virgin reproductive potential. Steepness was estimated using a triangular prior (as recommended by the 2002 Reef Fish Stock Assessment Panel) with a maximum probability at 0.7, and zero probability of steepness < 0.3 or >0.9. The assessment panel reviewed this prior, and agreed with the 2002 RFSAP that steepness values greater than 0.9 are not likely to be realistic for red grouper.

Estimated steepness was 0.863 (SD = 0.033). It is likely that steepness would have been higher if the prior allowed a greater probability of steepness > 0.863. The virgin stock size was estimated as a free parameter (no prior was used). The estimated value was 2.14 trillion eggs per spawning event.

3.2.2.8. Measures of Parameter Uncertainty

See sections 3.2.2.2 and 3.2.2.10.

3.2.2.9. Retrospective and Sensitivity Analyses

No retrospective analyses were preformed.

Numerous sensitivity analyses were requested by SEDAR12-AW panel, including:

1) Steepness fixed at 0.6
2) Steepness fixed at 0.7
3) Steepness fixed at 0.8
4) Steepness fixed at 0.9

5) VIDEO and LL indices only, ESTIMATE STEEPNESS
6) ALL indices except LL, ESTIMATE STEEPNESS

7) Base Run: except use “old” mature biomass rather than SEDAR12 fecundity vector. (Note: Leave datafile switch “isfecund” set to 1)

AGE	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Mat Bio.	0.00	0.11	1.24	2.54	3.89	5.34	6.59	8.06	9.41	10.6	11.6	12.6	13.4	14.2	14.8	15.4	15.9	16.4	16.7	17.9

8) Base Run: except use 2002 fecundity vector.

AGE	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Fecundity	0	0	24.9	40.2	57.9	77.6	98.6	120.4	142	164	184	203	219	233	243	250	253	252	249	220

9) Base Run: except Lorenzen M @0.14 (See Section 3.2.1.2).
10) M = 0.2 at all ages
11) Decrement indices to account for 2% annual increase in catchability
12) Add NMFS Longline Survey age composition data.
13) Begin data series in 1880.

The results of the sensitivity runs are summarized in section 3.2.2.10.

3.2.2.10. Benchmarks / Reference Points / ABC values

The benchmarks/reference points for the base and sensitivity runs are shown in Table 3.2.2.10.1.
The current management plan for red grouper stipulates the use of MSY-based reference points. A phase/control rule diagram is provided to facilitate comparison of the model runs (Figure 3.2.2.10.1). The base run is designated by the large red filled circle. The results of the base run indicate that in 2005, the stock was not overfished , SS_{2005}/SS_{MSY}=1.04, (SD=0.071)and was not undergoing overfishing, F_{2005}/F_{MSY} = 0.91 (SD= 0.085). For the base run, F_{OY} = 0.120, MFMT = F_{MSY} = 0.160 and MSST = (1-M) * SS_{MSY} = 6.16E+11, where M = 0.167 (Table 3.2.2.10.1).

The sensitivity runs can be separated into three categories: those that indicate a healthy stock status (SS_{2005}/SS_{MSY} > 1-M and F_{2005}/F_{MSY} < 1.0), a stock that is undergoing overfishing

(SS_{2005}/SS_{MSY} > 1-M and F_{2005}/F_{MSY} > 1.0), and a stock that is both undergoing overfishing and is currently overfished (SS_{2005}/SS_{MSY} < 1-M and F_{2005}/F_{MSY} > 1.0). ***Note: 1-M = 0.833 using the assumptions of the base run, 0.86 at M = 0.14 and 0.8 at M = 0.2.***

The runs that indicated a healthy stock status in 2005 included:

1) Base run
2) Runs with steepness fixed at values ≥ 0.80.
3) Run using Mature Biomass as a proxy for fecundity
4) Run using the 2002 fecundity series.
5) Run that excluded the Commercial Longline index.
6) Run at constant M = 0.2.

Runs that indicated a stock undergoing overfishing, but not currently overfished included:

1) Run using a 2% annual increase in catchability (Q).
2) Run that used only the "flatter" indices (VIDEO and LL)

Runs that indicated a current stock status that was currently overfished and undergoing overfishing included:

1) Run with steepness fixed at 0.6.
2) Run with steepness fixed at 0.7.
3) Run using a Lorenzen M @ 0.14.

Acceptable biological catch (ABC) values were selected based on the projection of F_{OY} during 2008-2015. (Fcurrent was projected during 2006 and 2007). Projected yield was used as a basis to estimate ABC. These values, in pounds gutted weight, are listed below.

YEAR	Projected Yield at F_{OY}
2008	7,094,290
2009	7,325,190
2010	7,508,810
2011	7,664,670
2012	7,796,410
2013	7,909,230
2014	8,011,650
2015	8,102,010

3.2.2.11. Projections

The projection results are summarized in Figures 3.2.2.11.1 to 3.2.2.11.13, and Tables 3.2.2.11.1 to 3.2.2.11.6. Assuming no changes to the base run, all projections indicate that the stock will remain at or above SS_{MSY} throughout the time series (Figure 3.2.2.11.11 and Table 3.2.2.11.5) and that fishing mortality will remain at or below F_{MSY} (Figure 3.2.2.11.5 and Table 3.2.2.11.4). Only two projection runs reduce fishing mortality to F_{OY} by 2015: the F_{OY} projection, which by definition, reduces F to F_{OY} in 2008, and the "Current Management" projection which reduces F to less than F_{OY} in 2010 (Figure 3.2.2.11.6 and Table 3.2.2.11.4).

3.3. References

Cass-Calay, S.L. et al. 2005. Revised assessments of Gulf of Mexico red snapper during 1962-2003 using a gulfwide implementation of an age-structured-assessment-program (ASAP).

NOAA Fisheries, Southeast Fisheries Science Center, Sustainable Fisheries Division, Miami FL. SFD-2005-004.

Cass-Calay, S.L. and G. A. Diaz. 2005. Revised assessments of Gulf of Mexico red snapper during 1984-2003 using a gulfwide implementation of ASAP. NOAA Fisheries, Southeast Fisheries Science Center, Sustainable Fisheries Division, Miami FL. SFD-2005-003.

Deriso, R.B., T.J. Quinn and P.R. Neal. 1985. Catch-at-age analysis with auxillary information. Can. J. Fish. Aquat. Sci. 42: 815-824.

Fourier, D. and C.P. Archibald. 1982. A general theory for analyzing catch at age data. Can. J. Fish. Aquat. Sci. 39: 1195-1207.

Goodyear, C.P. 1997. Fish age determination from length: an evaluation of three methods using simulated red snapper data. Fish. Bull. 95: 39-46.

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

Ianelli, J.N. and D.A. Fournier. 1998. Alternative age-structured analyses of the NRC simulated stock assessment data. NOAA Tech. Memo. NMFS-F/SPO-30. pp. 81-96.

Legault, C.M. and V.R. Restrepo. 1998. A flexible forward age-structured assessment program. ICCAT. Col. Vol. Sci. Pap.49: 246-253.

Lombardi-Carlson, L.A., G.R. Fitzhugh and J.J. Mikulas. 2002. Red grouper (*Epinephelus morio*) age length structure and description of growth from the eastern Gulf of Mexico: 1992-2001. 121p. National Marine Fisheries Service, Panama City, FL Contribution Series 2002-06. 42p.

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

Methot. R. 1998. Application of stock synthesis to NRC test data sets. NOAA Tech, Memo. NMFS-F/SPO-30. pp. 59-80.

Ortiz, M. and S.L. Cass-Calay. 2005. Assessments of red snapper stocks in the eastern and western Gulf of Mexico using an age-structured-assessment-procedure. NOAA Fisheries, Southeast Fisheries Science Center, Sustainable Fisheries Division, Miami FL. SFD-2005-005.

Schirripa, M.J., C.M. Legault and M. Ortiz. 1999. The red grouper fishery of the Gulf of Mexico: Assessment 3.0. National Marine Fisheries Service, Sustainable Fisheries Division. Miami, SFD-98/99-56.

SESFC Staff. 2002. Status of red grouper in United States waters of the Gulf of Mexico during 1986-2001.NOAA Fisheries, Southeast Fisheries Science Center, Sustainable Fisheries Division, Miami FL. SFD-01/02-175.

Table 3.1.2.1.1 The objective function value, likelihood components and residual sums of squares for the **2006 continuity case.**

Component	**RSS**	**nobs**	**Lambda**	**Likelihood**
Catch_Fleet_COM_LL	0.354	20	100.5	35.575
Catch_Fleet_COM_HL_TRAP	6.331	20	100.5	636.300
Catch_Fleet_REC	0.152	20	100.5	15.281
Catch_Fleet_Total	6.837	60	100.5	687.157
Discard_Fleet_COM_LL	2.087	20	25	52.166
Discard_Fleet_COM_HL_TRAP	115.102	20	25	2877.540
Discard_Fleet_REC	0.892	20	25	22.288
Discard_Fleet_Total	118.080	60	25	2952.000
CAA_proportions		1200		1469.890
CAA2_proportions		1200		1023.370
Discard_proportions		1200		181.530
Index_Fit_COM_LL	0.120	16	25.5	-319.857
Index_Fit_COM_HL	0.505	16	25.5	-123.674
Index_Fit_COM_TRAP	0.441	16	25.5	-174.268
Index_Fit_MRFSS	0.610	20	25.5	-176.584
Index_Fit_MOTE_TAG	0.378	15	25.5	-11.917
Index_Fit_US_HIST	0.983	12	25.5	-9.961
Index_Fit_Total	3.037	95	153	-816.260
Fmult_fleet_1	1.149	19	7	8.040
Fmult_fleet_2	2.348	19	11	25.829
Fmult_fleet_3	1.660	19	11	18.260
Fmult_fleet_Total	5.157	57	29	52.129
N_year_1	6.349	19	4.48	28.442
Stock-Recruit_Fit	1.384	20	4.48	-11.645
Recruit_devs	1.384	20	4.48	6.201
SRR_steepness	0.000	1	1.000	0.000
SRR_virgin_stock	44.972	1	0.000	0.000
Curvature_over_age	0.320	972	1000	320.387
Curvature_over_time	0.102	1080	100.5	10.219
F_penalty	0.009	400	0.001	0.000
Mean_Sel_year1_pen	0.000	60	1000	0.000
Max_Sel_penalty	2.718	1	100	0.000
Fmult_Max_penalty	0.000	NA	100	0.000
Objective Function				***6331.410***

Table 3.1.2.1.2. Fits to the catch series for the **2006 continuity case.**

	COM LL			COM HL&TRAP			REC		
YEAR	OBS	PRED	RESID	OBS	PRED	RESID	OBS	PRED	RES
1986	2,482,090	2,661,800	-179,710	3,830,900	1,123,590	2,707,310	2,241,560	2,413,390	-171,830
1987	3,742,400	3,831,000	-88,600	2,975,490	896,944	2,078,546	1,375,480	1,574,320	-198,840
1988	2,172,240	2,445,810	-273,570	2,570,250	781,283	1,788,967	2,314,830	2,299,860	14,970
1989	3,048,280	3,369,400	-321,120	4,319,630	1,171,740	3,147,890	2,593,910	2,710,310	-116,400
1990	2,015,800	2,486,280	-470,480	2,793,480	3,057,610	-264,130	1,056,210	1,141,430	-85,220
1991	2,588,380	2,760,970	-172,590	2,506,120	2,646,140	-140,020	1,668,200	1,583,380	84,820
1992	2,408,440	2,355,630	52,810	2,054,840	2,338,390	-283,550	2,491,380	2,332,030	159,350
1993	4,302,810	3,803,120	499,690	2,076,820	2,118,990	-42,170	1,962,150	2,091,740	-129,590
1994	2,703,460	2,892,710	-189,250	2,199,400	2,385,440	-186,040	1,696,240	1,910,340	-214,100
1995	2,466,020	3,349,260	-883,240	2,280,120	2,635,430	-355,310	1,741,610	1,960,270	-218,660
1996	2,992,830	4,030,540	-1,037,710	1,461,320	2,011,210	-549,890	835,528	955,327	-119,799
1997	3,135,750	3,680,390	-544,640	1,712,740	1,974,130	-261,390	525,936	592,099	-66,163
1998	2,843,510	2,893,240	-49,730	1,105,060	1,388,440	-283,380	601,824	642,492	-40,668
1999	3,944,720	3,388,430	556,290	2,029,990	2,050,170	-20,180	1,080,470	1,060,410	20,060
2000	2,989,420	2,868,260	121,160	2,848,880	2,567,360	281,520	1,968,710	1,765,260	203,450
2001	3,535,000	3,559,700	-24,700	2,429,500	2,571,180	-141,680	1,242,400	1,298,470	-56,070
2002	3,207,540	3,674,190	-466,650	2,699,710	2,888,180	-188,470	1,505,210	1,506,130	-920
2003	3,067,680	3,138,300	-70,620	1,870,290	2,103,220	-232,930	1,196,230	1,265,000	-68,770
2004	3,533,880	3,344,730	189,150	2,215,160	2,152,310	62,850	2,809,250	2,383,680	425,570
2005	3,304,300	3,400,640	-96,340	2,106,290	2,263,890	-157,600	1,530,220	1,564,770	-34,550

Table 3.1.2.1.3. Fits to the discard series for the **2006 continuity case.**

	COM LL			COM HL&TRAP			REC		
YEAR	OBS	PRED	RESID	OBS	PRED	RESID	OBS	PRED	RES
1986	0	0	0	0	147	-147	22,884	15,027	7,857
1987	0	0	0	0	146	-146	21,069	16,125	4,944
1988	0	0	0	0	177	-177	38,503	30,859	7,643
1989	0	0	0	0	343	-343	90,447	56,745	33,702
1990	451,732	262,034	189,698	282,539	170,550	111,989	280,393	238,548	41,845
1991	772,337	373,123	399,214	370,184	201,535	168,649	499,753	422,316	77,437
1992	408,090	351,340	56,750	578,891	214,901	363,990	437,484	448,333	-10,849
1993	502,310	543,785	-41,475	247,601	214,385	33,216	287,301	316,073	-28,772
1994	317,238	368,209	-50,971	243,143	230,130	13,013	275,955	282,763	-6,808
1995	435,314	366,656	68,658	205,419	227,173	-21,754	276,153	282,491	-6,338
1996	414,270	417,370	-3,100	290,593	164,212	126,381	196,003	178,823	17,180
1997	473,077	360,395	112,682	280,508	162,971	117,537	183,015	147,021	35,994
1998	419,691	280,356	139,335	256,565	114,014	142,551	255,707	183,526	72,181
1999	541,100	331,817	209,283	336,621	164,125	172,496	347,792	259,753	88,039
2000	452,703	288,402	164,301	297,878	204,354	93,524	368,104	318,060	50,044
2001	535,964	378,562	157,402	318,229	210,485	107,744	274,471	268,244	6,227
2002	526,692	416,606	110,086	296,955	247,693	49,262	319,796	329,134	-9,338
2003	451,378	363,423	87,955	285,113	183,319	101,794	348,080	309,225	38,855
2004	568,602	379,681	188,921	239,223	184,047	55,176	517,428	444,500	72,928
2005	544,670	387,930	156,740	308,513	198,270	110,243	298,722	302,850	-4,128

Table 3.1.2.1.4. Fits to the indices of abundance for the **2006 continuity case.**

	COM_LL			COM_HL			COM_TRAP			MRFSS		
YEAR	OBS	PRED	RESID	OBS	PRED	RESID	OBS	PRED	RESID	OBS	PRED	RESID
1986	-	-	-	-	-	-	-	-	-	0.688	0.729	-0.041
1987	-	-	-	-	-	-	-	-	-	0.658	0.843	-0.186
1988	-	-	-	-	-	-	-	-	-	0.925	0.975	-0.051
1989	-	-	-	-	-	-	-	-	-	1.318	1.137	0.182
1990	0.774	0.799	-0.026	0.696	0.833	-0.137	0.821	1.020	-0.199	1.869	1.282	0.587
1991	0.779	0.774	0.005	0.648	0.745	-0.098	0.943	0.917	0.026	1.147	1.361	-0.214
1992	0.680	0.789	-0.109	0.748	0.739	0.008	1.029	0.909	0.120	1.267	1.247	0.020
1993	0.973	0.850	0.123	0.683	0.756	-0.073	0.948	0.923	0.024	0.781	1.037	-0.257
1994	0.832	0.871	-0.039	0.882	0.796	0.087	1.121	0.960	0.162	0.932	0.956	-0.024
1995	0.977	0.911	0.066	0.871	0.783	0.089	1.059	0.930	0.128	0.769	0.880	-0.111
1996	0.844	0.911	-0.068	0.608	0.713	-0.106	0.794	0.835	-0.041	0.605	0.793	-0.188
1997	1.012	0.953	0.059	0.566	0.693	-0.127	0.768	0.794	-0.026	0.545	0.791	-0.246
1998	0.982	0.990	-0.007	0.537	0.738	-0.201	0.660	0.823	-0.163	0.755	0.851	-0.097
1999	1.002	1.028	-0.026	0.718	0.869	-0.152	1.302	0.937	0.365	0.929	0.919	0.010
2000	0.994	1.054	-0.060	0.987	1.005	-0.018	1.273	1.023	0.250	1.047	1.028	0.020
2001	1.319	1.121	0.198	1.453	1.129	0.324	1.009	1.074	-0.065	0.869	1.019	-0.150
2002	1.025	1.091	-0.066	1.522	1.209	0.313	0.953	1.091	-0.138	0.903	1.039	-0.136
2003	0.978	1.126	-0.149	1.140	1.298	-0.158	0.846	1.133	-0.287	1.113	1.061	0.051
2004	1.278	1.285	-0.007	1.773	1.529	0.245	1.246	1.295	-0.050	1.675	1.086	0.589
2005	1.553	1.425	0.128	2.169	1.698	0.472	1.230	1.410	-0.181	1.204	1.061	0.143

	MOTE_TAG			US_HIST		
YEAR	OBS	PRED	RESID	OBS	PRED	RESID
1986	-	-	-	1.676	1.581	0.095
1987	-	-	-	1.313	1.341	-0.028
1988	-	-	-	1.102	1.163	-0.061
1989	-	-	-	1.837	1.017	0.820
1990	-	-	-	0.731	0.870	-0.138
1991	1.790	1.450	0.340	0.800	0.777	0.023
1992	1.420	1.309	0.111	0.961	0.755	0.206
1993	0.955	1.060	-0.105	1.021	0.769	0.252
1994	1.202	0.953	0.249	0.877	0.792	0.085
1995	1.066	0.846	0.220	0.680	0.800	-0.119
1996	0.720	0.732	-0.012	0.453	0.782	-0.329
1997	0.510	0.698	-0.188	0.548	0.778	-0.230
1998	0.696	0.740	-0.044	-	-	-
1999	1.028	0.800	0.228	-	-	-
2000	0.875	0.894	-0.019	-	-	-
2001	0.738	0.906	-0.169	-	-	-
2002	-	-	-	-	-	-
2003	-	-	-	-	-	-
2004	-	-	-	-	-	-
2005	-	-	-	-	-	-

Table 3.1.2.2.1. Selected parameter estimates for the 2002 base case and the 2006 continuity case.

		2002 BASE RUN		**2006 CONT CASE**	
Parameter Name	**Description**	**Value**	**Std Dev**	**Value**	**Std Dev**
SRR_Virgin	Virgin Reproductive Potential (eggs per spawning event)	2.297E+12		2.672E+12	
Fmult_year1	1986, CM-LL	0.160	7.61E-02	0.078	7.68E-02
Fmult_year1	1986, CM-HL&TRAP	0.163	7.70E-02	0.036	7.17E-02
Fmult_year1	1986, REC	0.046	6.80E-02	0.040	6.63E-02
MSY		7,559,000	153,650	9,280,000	177,790
SS_{2001}/SS_{MSY}		0.840	0.025	0.799	
F_{2001}/F_{MSY}		1.031	0.057	1.060	
SS_{2005}/SS_{MSY}				1.066	0.034
F_{2005}/F_{MSY}				0.777	0.045
Steepness	Fixed at 0.7	0.7	0.000 (Fixed)	0.7	0.000 (Fixed)

Table. 3.1.2.3.1. Number-at-age for the **2006 continuity case.**. Note: recruitment occurs at Age-1. The sum is total abundance.

YEAR	AGE 1	AGE 2	AGE 3	AGE 4	AGE 5	AGE 6	AGE 7	AGE 8	AGE 9	AGE 10	AGE 11	AGE 12	AGE 13	AGE 14	AGE 15	AGE 16	AGE 17	AGE 18	AGE 19	AGE 20	SUM
1986	3.45E+06	2.35E+06	1.88E+06	1.35E+06	9.94E+05	7.06E+05	5.70E+05	3.96E+05	3.61E+05	2.85E+05	2.38E+05	1.91E+05	1.59E+05	1.36E+05	1.16E+05	9.98E+04	8.77E+04	7.66E+04	6.66E+04	1.75E+05	1.37E+07
1987	4.54E+06	2.75E+06	1.75E+06	1.38E+06	9.91E+05	7.30E+05	5.14E+05	4.12E+05	2.83E+05	2.56E+05	2.01E+05	1.67E+05	1.34E+05	1.12E+05	9.56E+04	8.15E+04	7.00E+04	6.15E+04	5.37E+04	1.69E+05	1.47E+07
1988	5.06E+06	3.60E+06	2.08E+06	1.30E+06	1.02E+06	7.25E+05	5.26E+05	3.65E+05	2.88E+05	1.96E+05	1.75E+05	1.37E+05	1.14E+05	9.10E+04	7.60E+04	6.50E+04	5.54E+04	4.76E+04	4.18E+04	1.52E+05	1.61E+07
1989	5.88E+06	4.02E+06	2.70E+06	1.52E+06	9.53E+05	7.46E+05	5.27E+05	3.79E+05	2.61E+05	2.04E+05	1.37E+05	1.22E+05	9.54E+04	7.93E+04	6.35E+04	5.30E+04	4.53E+04	3.87E+04	3.32E+04	1.35E+05	1.80E+07
1990	6.11E+06	4.64E+06	3.01E+06	1.92E+06	1.08E+06	6.69E+05	5.17E+05	3.60E+05	2.55E+05	1.73E+05	1.34E+05	8.94E+04	7.96E+04	6.20E+04	5.15E+04	4.13E+04	3.45E+04	2.95E+04	2.51E+04	1.09E+05	1.94E+07
1991	5.85E+06	4.92E+06	3.70E+06	2.37E+06	1.45E+06	7.70E+05	4.52E+05	3.34E+05	2.25E+05	1.55E+05	1.03E+05	7.69E+04	5.12E+04	4.56E+04	3.55E+04	2.95E+04	2.36E+04	1.97E+04	1.68E+04	7.68E+04	2.07E+07
1992	4.78E+06	4.67E+06	3.89E+06	2.88E+06	1.75E+06	1.00E+06	5.02E+05	2.82E+05	2.01E+05	1.31E+05	8.82E+04	5.63E+04	4.20E+04	2.80E+04	2.48E+04	1.93E+04	1.60E+04	1.28E+04	1.07E+04	5.08E+04	2.04E+07
1993	3.87E+06	3.81E+06	3.69E+06	3.00E+06	2.10E+06	1.20E+06	6.54E+05	3.16E+05	1.72E+05	1.20E+05	7.65E+04	4.95E+04	3.15E+04	2.35E+04	1.56E+04	1.39E+04	1.08E+04	8.95E+03	7.15E+03	3.43E+04	1.92E+07
1994	4.45E+06	3.11E+06	3.00E+06	2.83E+06	2.18E+06	1.43E+06	7.69E+05	4.00E+05	1.86E+05	9.81E+04	6.68E+04	4.11E+04	2.65E+04	1.69E+04	1.26E+04	8.35E+03	7.40E+03	5.76E+03	4.78E+03	2.21E+04	1.87E+07
1995	4.51E+06	3.58E+06	2.47E+06	2.34E+06	2.09E+06	1.52E+06	9.49E+05	4.94E+05	2.49E+05	1.13E+05	5.85E+04	3.82E+04	2.35E+04	1.51E+04	9.63E+03	7.17E+03	4.76E+03	4.22E+03	3.28E+03	1.53E+04	1.85E+07
1996	4.11E+06	3.63E+06	2.84E+06	1.92E+06	1.71E+06	1.44E+06	9.98E+05	6.03E+05	3.04E+05	1.49E+05	6.62E+04	3.28E+04	2.14E+04	1.31E+04	8.46E+03	5.37E+03	4.00E+03	2.65E+03	2.35E+03	1.03E+04	1.79E+07
1997	5.33E+06	3.34E+06	2.90E+06	2.23E+06	1.44E+06	1.22E+06	9.81E+05	6.53E+05	3.80E+05	1.86E+05	8.96E+04	3.83E+04	1.89E+04	1.24E+04	7.57E+03	4.88E+03	3.10E+03	2.31E+03	1.53E+03	7.31E+03	1.88E+07
1998	5.36E+06	4.34E+06	2.68E+06	2.29E+06	1.69E+06	1.05E+06	8.53E+05	6.61E+05	4.25E+05	2.41E+05	1.16E+05	5.38E+04	2.30E+04	1.14E+04	7.40E+03	4.53E+03	2.92E+03	1.85E+03	1.38E+03	5.28E+03	1.98E+07
1999	5.37E+06	4.36E+06	3.49E+06	2.12E+06	1.77E+06	1.27E+06	7.60E+05	6.04E+05	4.56E+05	2.88E+05	1.61E+05	7.54E+04	3.50E+04	1.49E+04	7.37E+03	4.80E+03	2.94E+03	1.89E+03	1.20E+03	4.32E+03	2.08E+07
2000	7.71E+06	4.36E+06	3.49E+06	2.75E+06	1.61E+06	1.29E+06	8.91E+05	5.18E+05	4.00E+05	2.95E+05	1.83E+05	9.90E+04	4.63E+04	2.15E+04	9.16E+03	4.52E+03	2.94E+03	1.80E+03	1.16E+03	3.38E+03	2.37E+07
2001	6.01E+06	6.24E+06	3.48E+06	2.72E+06	2.06E+06	1.16E+06	8.91E+05	6.01E+05	3.41E+05	2.58E+05	1.88E+05	1.12E+05	6.02E+04	2.82E+04	1.30E+04	5.57E+03	2.75E+03	1.79E+03	1.09E+03	2.75E+03	2.42E+07
2002	7.65E+06	4.88E+06	4.99E+06	2.73E+06	2.05E+06	1.48E+06	7.99E+05	5.97E+05	3.91E+05	2.17E+05	1.61E+05	1.13E+05	6.72E+04	3.62E+04	1.69E+04	7.83E+03	3.34E+03	1.65E+03	1.07E+03	2.31E+03	2.62E+07
2003	8.83E+06	6.21E+06	3.90E+06	3.91E+06	2.05E+06	1.46E+06	1.01E+06	5.29E+05	3.83E+05	2.45E+05	1.33E+05	9.52E+04	6.66E+04	3.96E+04	2.13E+04	9.95E+03	4.61E+03	1.96E+03	9.68E+02	1.98E+03	2.89E+07
2004	8.07E+06	7.17E+06	4.98E+06	3.07E+06	2.99E+06	1.51E+06	1.05E+06	7.05E+05	3.60E+05	2.55E+05	1.61E+05	8.53E+04	6.08E+04	4.25E+04	2.52E+04	1.36E+04	6.34E+03	2.93E+03	1.25E+03	1.88E+03	3.06E+07
2005	6.28E+06	6.53E+06	5.73E+06	3.89E+06	2.31E+06	2.17E+06	1.07E+06	7.22E+05	4.75E+05	2.38E+05	1.67E+05	1.02E+05	5.41E+04	3.85E+04	2.69E+04	1.60E+04	8.59E+03	4.01E+03	1.86E+03	1.98E+03	2.98E+07

Table 3.1.2.4.1. Spawning stock reproductive potential (SS; eggs per spawning event), SS at maximum sustainable yield (MSY) and SS/SS_{MSY} for the **2006 continuity case.**

YEAR	SS	SS_{MSY}	SS/SS_{MSY}
1986	7.14E+11	9.25E+11	0.772
1987	6.49E+11	9.25E+11	0.702
1988	5.99E+11	9.25E+11	0.647
1989	5.87E+11	9.25E+11	0.634
1990	5.69E+11	9.25E+11	0.615
1991	5.77E+11	9.25E+11	0.624
1992	6.00E+11	9.25E+11	0.649
1993	6.32E+11	9.25E+11	0.683
1994	6.37E+11	9.25E+11	0.688
1995	6.38E+11	9.25E+11	0.690
1996	6.32E+11	9.25E+11	0.683
1997	6.37E+11	9.25E+11	0.689
1998	6.47E+11	9.25E+11	0.699
1999	6.94E+11	9.25E+11	0.750
2000	7.20E+11	9.25E+11	0.779
2001	7.39E+11	9.25E+11	0.799
2002	7.93E+11	9.25E+11	0.857
2003	8.22E+11	9.25E+11	0.888
2004	9.02E+11	9.25E+11	0.974
2005	9.86E+11	9.25E+11	1.066

Table 3.1.2.6.1. Fleet-specific fishing mortality rates from the directed landings and the discards from the directed fleets for the **2006 continuity case.**

	DIRECTED F			DISCARD F		
YEAR	COM LL	COM HL&TRAP	REC	COM LL	COM HL&TRAP	REC
1986	0.078	0.036	0.110	0.00E+00	3.68E-05	1.04E-02
1987	0.125	0.033	0.080	0.00E+00	3.30E-05	7.91E-03
1988	0.086	0.032	0.124	0.00E+00	3.24E-05	1.23E-02
1989	0.127	0.053	0.156	0.00E+00	5.55E-05	1.56E-02
1990	0.135	0.181	0.163	1.21E-02	7.51E-03	1.62E-02
1991	0.167	0.178	0.252	1.49E-02	7.96E-03	2.52E-02
1992	0.146	0.163	0.269	1.27E-02	7.52E-03	2.69E-02
1993	0.228	0.143	0.188	1.89E-02	7.11E-03	1.88E-02
1994	0.163	0.150	0.162	1.36E-02	7.63E-03	1.62E-02
1995	0.175	0.156	0.159	1.43E-02	8.07E-03	1.59E-02
1996	0.204	0.118	0.096	1.70E-02	6.50E-03	9.13E-03
1997	0.180	0.115	0.075	1.46E-02	6.66E-03	7.20E-03
1998	0.135	0.077	0.086	1.10E-02	4.54E-03	8.25E-03
1999	0.152	0.106	0.118	1.23E-02	6.21E-03	1.13E-02
2000	0.128	0.127	0.153	1.03E-02	7.15E-03	1.38E-02
2001	0.159	0.123	0.116	1.22E-02	6.93E-03	1.07E-02
2002	0.162	0.134	0.129	1.29E-02	7.57E-03	1.21E-02
2003	0.132	0.092	0.108	1.07E-02	5.00E-03	9.98E-03
2004	0.130	0.085	0.154	9.95E-03	4.64E-03	1.39E-02
2005	0.120	0.082	0.096	9.39E-03	4.61E-03	9.09E-03

Table 3.1.2.6.2. Annual estimates of apical fishing mortality, F_{MSY} and F/F_{MSY} for the directed landings and the discards for the **2006 continuity case.**

	F (DIRECTED LANDINGS)			F (DISCARDS)		
YEAR	Apical F	F_{MSY}	F/F_{MSY}	Apical F	F_{MSY}	F/F_{MSY}
1986	0.155	0.293	0.527	0.010	0.293	0.035
1987	0.186	0.293	0.634	0.008	0.293	0.027
1988	0.160	0.293	0.546	0.012	0.293	0.042
1989	0.230	0.293	0.785	0.016	0.293	0.053
1990	0.360	0.293	1.227	0.026	0.293	0.089
1991	0.408	0.293	1.391	0.035	0.293	0.118
1992	0.383	0.293	1.307	0.035	0.293	0.118
1993	0.428	0.293	1.458	0.036	0.293	0.122
1994	0.363	0.293	1.239	0.031	0.293	0.104
1995	0.384	0.293	1.309	0.033	0.293	0.113
1996	0.351	0.293	1.197	0.030	0.293	0.102
1997	0.313	0.293	1.069	0.026	0.293	0.088
1998	0.233	0.293	0.795	0.022	0.293	0.075
1999	0.290	0.293	0.988	0.027	0.293	0.092
2000	0.299	0.293	1.019	0.028	0.293	0.095
2001	0.311	0.293	1.060	0.027	0.293	0.091
2002	0.331	0.293	1.128	0.029	0.293	0.098
2003	0.251	0.293	0.857	0.023	0.293	0.080
2004	0.257	0.293	0.877	0.026	0.293	0.090
2005	0.228	0.293	0.777	0.021	0.293	0.071

Table 3.1.2.6.3. Fishing mortality-at-age for the directed landings (**A**) and the discards (**B**) for the **2006 continuity case**. Apical F is noted by cell shading.

A)

YEAR	AGE 1	AGE 2	AGE 3	AGE 4	AGE 5	AGE 6	AGE 7	AGE 8	AGE 9	AGE 10	AGE 11	AGE 12	AGE 13	AGE 14	AGE 15	AGE 16	AGE 17	AGE 18	AGE 19	AGE 20
1986	0.019	0.093	0.106	0.106	0.109	0.116	0.125	0.135	0.143	0.150	0.155	0.155	0.155	0.155	0.155	0.155	0.155	0.155	0.155	0.155
1987	0.022	0.076	0.095	0.102	0.112	0.126	0.142	0.157	0.170	0.180	0.186	0.186	0.186	0.186	0.186	0.186	0.186	0.186	0.186	0.186
1988	0.016	0.086	0.111	0.111	0.114	0.120	0.129	0.138	0.147	0.154	0.160	0.160	0.160	0.160	0.160	0.160	0.160	0.160	0.160	0.160
1989	0.022	0.083	0.140	0.145	0.153	0.166	0.180	0.195	0.209	0.219	0.230	0.230	0.230	0.230	0.230	0.230	0.230	0.230	0.230	0.230
1990	0.001	0.002	0.014	0.057	0.119	0.180	0.227	0.265	0.295	0.317	0.351	0.353	0.355	0.356	0.357	0.358	0.358	0.359	0.359	0.360
1991	0.000	0.000	0.015	0.071	0.146	0.211	0.261	0.301	0.333	0.357	0.397	0.400	0.402	0.404	0.405	0.406	0.406	0.408	0.408	0.408
1992	0.000	0.001	0.024	0.088	0.158	0.214	0.254	0.287	0.313	0.334	0.374	0.377	0.378	0.380	0.380	0.381	0.381	0.382	0.382	0.383
1993	0.000	0.002	0.029	0.093	0.166	0.229	0.280	0.323	0.356	0.378	0.418	0.420	0.422	0.423	0.424	0.425	0.425	0.426	0.426	0.428
1994	0.000	0.001	0.021	0.080	0.143	0.195	0.234	0.267	0.294	0.313	0.355	0.357	0.358	0.359	0.360	0.360	0.361	0.361	0.361	0.363
1995	0.000	0.000	0.022	0.082	0.151	0.205	0.246	0.281	0.309	0.330	0.376	0.378	0.379	0.380	0.381	0.382	0.382	0.382	0.382	0.384
1996	0.000	0.000	0.014	0.062	0.121	0.173	0.216	0.255	0.286	0.306	0.343	0.345	0.346	0.347	0.348	0.349	0.349	0.349	0.349	0.351
1997	0.000	0.000	0.011	0.051	0.102	0.149	0.188	0.224	0.251	0.270	0.306	0.308	0.309	0.310	0.311	0.312	0.312	0.312	0.312	0.313
1998	0.000	0.000	0.010	0.039	0.077	0.111	0.140	0.167	0.187	0.201	0.227	0.229	0.230	0.230	0.231	0.231	0.232	0.232	0.232	0.233
1999	0.000	0.000	0.011	0.051	0.101	0.143	0.177	0.207	0.231	0.247	0.283	0.284	0.286	0.287	0.287	0.288	0.288	0.289	0.288	0.290
2000	0.000	0.001	0.021	0.066	0.117	0.159	0.187	0.213	0.234	0.250	0.292	0.294	0.295	0.296	0.297	0.297	0.298	0.298	0.298	0.299
2001	0.000	0.000	0.015	0.060	0.113	0.159	0.193	0.225	0.249	0.266	0.304	0.306	0.307	0.308	0.308	0.309	0.309	0.310	0.310	0.311
2002	0.000	0.000	0.015	0.062	0.121	0.171	0.206	0.238	0.263	0.281	0.324	0.326	0.327	0.328	0.329	0.329	0.330	0.330	0.330	0.331
2003	0.000	0.000	0.014	0.050	0.090	0.127	0.154	0.180	0.201	0.215	0.245	0.246	0.248	0.248	0.249	0.249	0.250	0.250	0.250	0.251
2004	0.000	0.001	0.020	0.065	0.107	0.141	0.165	0.190	0.209	0.223	0.251	0.253	0.254	0.255	0.255	0.256	0.256	0.256	0.257	0.257
2005	0.000	0.000	0.010	0.046	0.086	0.120	0.144	0.167	0.185	0.197	0.222	0.224	0.225	0.225	0.226	0.226	0.227	0.226	0.226	0.228

B)

YEAR	AGE 1	AGE 2	AGE 3	AGE 4	AGE 5	AGE 6	AGE 7	AGE 8	AGE 9	AGE 10	AGE 11	AGE 12	AGE 13	AGE 14	AGE 15	AGE 16	AGE 17	AGE 18	AGE 19	AGE 20
1986	0.010	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1987	0.008	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1988	0.012	0.004	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1989	0.016	0.007	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1990	0.016	0.025	0.026	0.024	0.019	0.013	0.009	0.007	0.005	0.004	0.004	0.003	0.003	0.002	0.002	0.002	0.002	0.002	0.002	0.001
1991	0.025	0.034	0.035	0.031	0.023	0.016	0.011	0.008	0.006	0.005	0.005	0.004	0.004	0.003	0.003	0.003	0.003	0.002	0.002	0.002
1992	0.027	0.035	0.034	0.028	0.020	0.014	0.009	0.007	0.005	0.004	0.004	0.003	0.003	0.003	0.002	0.002	0.002	0.002	0.002	0.002
1993	0.019	0.035	0.036	0.030	0.021	0.015	0.010	0.008	0.006	0.005	0.004	0.003	0.003	0.003	0.002	0.002	0.002	0.002	0.002	0.002
1994	0.016	0.029	0.031	0.026	0.018	0.012	0.009	0.006	0.005	0.004	0.004	0.003	0.003	0.002	0.002	0.002	0.002	0.002	0.002	0.001
1995	0.016	0.030	0.033	0.027	0.019	0.013	0.009	0.006	0.005	0.004	0.004	0.003	0.003	0.002	0.002	0.002	0.002	0.002	0.002	0.001
1996	0.008	0.026	0.030	0.025	0.017	0.012	0.008	0.006	0.005	0.004	0.003	0.003	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.001
1997	0.006	0.021	0.026	0.022	0.016	0.011	0.007	0.006	0.004	0.003	0.003	0.003	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.001
1998	0.006	0.019	0.022	0.018	0.013	0.009	0.006	0.004	0.003	0.003	0.003	0.002	0.002	0.002	0.002	0.002	0.001	0.002	0.001	0.001
1999	0.009	0.023	0.027	0.022	0.016	0.010	0.007	0.005	0.004	0.003	0.003	0.003	0.002	0.002	0.002	0.002	0.002	0.001	0.002	0.001
2000	0.011	0.024	0.028	0.023	0.016	0.010	0.007	0.005	0.004	0.003	0.003	0.002	0.002	0.002	0.002	0.002	0.001	0.001	0.001	0.001
2001	0.008	0.023	0.027	0.022	0.016	0.011	0.007	0.005	0.004	0.003	0.003	0.003	0.002	0.002	0.002	0.002	0.002	0.001	0.001	0.001
2002	0.009	0.025	0.029	0.024	0.017	0.011	0.008	0.006	0.004	0.003	0.003	0.003	0.002	0.002	0.002	0.002	0.002	0.002	0.001	0.001
2003	0.008	0.021	0.023	0.018	0.013	0.009	0.006	0.005	0.004	0.003	0.003	0.002	0.002	0.002	0.002	0.002	0.002	0.001	0.001	0.001
2004	0.012	0.024	0.026	0.019	0.013	0.009	0.006	0.004	0.003	0.003	0.002	0.002	0.002	0.002	0.002	0.001	0.001	0.001	0.001	0.001
2005	0.007	0.018	0.021	0.016	0.011	0.008	0.005	0.004	0.003	0.002	0.002	0.002	0.002	0.001	0.001	0.001	0.001	0.001	0.001	0.001

Table 3.1.2.10.1. Reference points and benchmarks for the 2002 red grouper base run and the 2006 continuity case. Spawning stock (SS) references are reproductive potential (eggs per spawning event)

REFERENCE POINTS	2002 BASE CASE	2006 CONT CASE
Virgin Stock Parameters		
Virgin SPR	372.959	372.959
Virgin R	6.158E+06	7.16E+06
F-REFS		
F0.1	0.238	0.233
Fmax	0.476	0.494
F30%SPR	0.563	0.510
F40%SPR	0.354	0.315
Fmsy	0.306	0.293
Foy	0.229	0.220
Fcurrent	0.315	0.228
Spawning Stock-REFS		
SS_F0.1	9.93E+11	1.09E+12
SS_Fmax	5.86E+11	5.96E+11
SSmsy	8.40E+11	9.25E+11
SSoy	1.01E+12	1.13E+12
YIELD REFS		
Y F0.1	7.424E+06	9.14E+06
Y Fmax	7.101E+06	8.53E+06
MSY	7.559E+06	9.28E+06
OY	7.386E+06	9.07E+06
SRR Parameters		
virgin	2.30E+12	2.67E+12
steepness	0.700	0.700
2001 Status		
F_{2001}/F_{MSY}	1.031	1.060
SS_{2001}/SS_{MSY}	0.840	0.799
2005 Status		
F_{2005}/F_{MSY}	-	0.777
SS_{2005}/SS_{MSY}	-	1.066
Management Reference Points		
F_{OY}	0.229	0.230
MFMT (=F_{MSY})	0.306	0.293
MSST [(1-M)*SS_{MSY}]	6.72E+11	7.40E+11

Table 3.2.2.1.1 The objective function value, likelihood components and residual sums of squares for the base run.

Component	RSS	nobs	Lambda	Likelihood
Catch_Fleet_1	0.061	20	100.5	6.157
Catch_Fleet_2	0.052	20	100.5	5.194
Catch_Fleet_3	0.297	20	100.5	29.844
Catch_Fleet_4	0.066	20	100.5	6.596
Catch_Fleet_Total	***0.476***	***80***	***100.5***	***47.791***
Discard_Fleet_1	1.765	20	11.6	20.478
Discard_Fleet_2	1.351	20	11.6	15.669
Discard_Fleet_3	15.116	20	11.6	175.344
Discard_Fleet_4	0.941	20	11.6	10.913
Discard_Fleet_Total	***19.173***	***80***	***11.6***	***222.404***
CAA_proportions		1600		0.000
CAA2_proportions		1600		603.792
Discard_proportions		1600		118.740
Index_Fit_1	0.095	8	25.5	1.209
Index_Fit_2	0.229	16	25.5	2.914
Index_Fit_3	1.280	16	25.5	16.325
Index_Fit_4	0.291	5	25.5	3.704
Index_Fit_5	1.002	16	25.5	12.780
Index_Fit_6	1.864	20	25.5	23.770
Index_Fit_Total	***4.761***	***81***	***153***	***60.702***
Fmult_fleet_1	0.905	19	11	9.955
Fmult_fleet_2	0.916	19	11	10.073
Fmult_fleet_3	2.010	19	11	22.111
Fmult_fleet_4	1.851	19	11	20.356
Fmult_fleet_Total	5.681	76	44	62.495
N_year_1	12.817	19	4.48	57.419
Stock-Recruit_Fit	1.939	20	4.48	-14.136
Recruit_devs	1.939	20	4.48	8.686
SRR_steepness	0.004	1	1	0.006
SRR_virgin_stock	42.015	1	0	0.000
Curvature_over_age	0.135	72	400	53.814
Curvature_over_time	0.000	1440	100.5	0.000
F_penalty	0.014	400	0.001	0.000
Mean_Sel_year1_pen	0.000	80	1000	0.000
Max_Sel_penalty	2.718	1	100	0.000
Fmult_Max_penalty	0.000		100	0.000
Objective Function				***1230.870***

Table 3.2.2.1.2. Fits to the catch series.

	COM LL			COM HL			COM TRAP			REC		
YEAR	OBS	PRED	RESID	OBS	PRED	RESID	OBS	PRED	RES	OBS	PRED	RESID
1986	2,482,090	2,676,230	-194,140	3,116,270	3,160,580	-44,310	714,626	700,993	13,633	2,478,550	2,407,400	71,150
1987	3,742,400	3,565,420	176,980	2,531,260	2,545,270	-14,010	444,230	473,145	-28,915	1,510,900	1,653,100	-142,200
1988	2,172,240	2,363,340	-191,100	2,035,090	2,165,720	-130,630	535,166	535,860	-694	2,559,360	2,395,440	163,920
1989	3,048,280	3,012,720	35,560	3,740,150	3,502,740	237,410	579,481	562,562	16,919	2,848,310	2,823,470	24,840
1990	2,015,800	2,245,350	-229,550	2,454,250	2,262,290	191,960	339,232	383,617	-44,385	1,170,570	1,247,440	-76,870
1991	2,588,380	2,737,860	-149,480	2,131,680	1,984,970	146,710	374,441	427,828	-53,387	1,834,660	1,806,200	28,460
1992	2,408,440	2,556,130	-147,690	1,452,930	1,518,730	-65,800	601,907	653,277	-51,370	2,750,670	2,620,460	130,210
1993	4,302,810	3,881,450	421,360	1,359,830	1,329,080	30,750	716,986	689,927	27,059	2,162,450	2,205,310	-42,860
1994	2,703,460	2,722,060	-18,600	1,283,180	1,261,610	21,570	916,222	821,730	94,492	1,871,100	1,911,420	-40,320
1995	2,466,020	2,629,460	-163,440	1,222,420	1,179,670	42,750	1,057,700	867,723	189,977	1,927,480	1,864,120	63,360
1996	2,992,830	3,042,170	-49,340	902,576	987,318	-84,742	558,740	515,634	43,106	925,086	978,354	-53,268
1997	3,135,750	3,199,860	-64,110	1,005,510	1,026,230	-20,720	707,226	563,467	143,759	582,162	638,359	-56,197
1998	2,843,510	2,958,460	-114,950	791,642	864,835	-73,193	313,414	340,879	-27,465	665,569	714,554	-48,985
1999	3,944,720	3,753,700	191,020	1,257,120	1,263,400	-6,280	772,866	671,629	101,237	1,192,010	1,217,600	-25,590
2000	2,989,420	3,115,540	-126,120	1,792,080	1,687,480	104,600	1,056,800	865,879	190,921	2,179,170	2,047,620	131,550
2001	3,535,000	3,500,490	34,510	1,661,760	1,638,540	23,220	767,746	706,781	60,965	1,373,780	1,449,730	-75,950
2002	3,207,540	3,274,100	-66,560	1,749,860	1,642,290	107,570	949,848	812,731	137,117	1,667,060	1,638,270	28,790
2003	3,067,680	3,144,560	-76,880	1,147,240	1,207,360	-60,120	723,050	654,290	68,760	1,320,110	1,430,770	-110,660
2004	3,533,880	3,607,890	-74,010	1,439,550	1,413,500	26,050	775,609	669,467	106,142	3,102,650	2,863,150	239,500
2005	3,304,300	3,544,210	-239,910	1,495,960	1,527,090	-31,130	610,334	546,357	63,977	1,684,450	1,825,950	-141,500

Table 3.2.2.1.3. Fits to the discard series.

	COM LL			COM HL			COM TRAP			REC		
YEAR	OBS	PRED	RESID	OBS	PRED	RESID	OBS	PRED	RES	OBS	PRED	RESID
1986	0	0	0	0	0	0	0	0	0	21,363	22,701	-1,338
1987	0	0	0	0	0	0	0	0	0	19,670	18,256	1,414
1988	0	0	0	0	0	0	0	0	0	35,946	40,287	-4,341
1989	0	0	0	0	0	0	0	0	0	84,442	55,709	28,733
1990	657,819	361,937	295,882	90,478	153,272	-62,795	3,522	1,990	1,532	251,526	220,091	31,435
1991	1,080,000	520,852	559,148	103,895	151,545	-47,650	6,679	2,990	3,690	448,299	376,289	72,010
1992	564,272	512,893	51,379	162,089	119,096	42,993	15,945	5,743	10,202	392,439	398,081	-5,642
1993	678,466	774,039	-95,573	73,749	98,945	-25,196	4,585	6,928	-2,343	257,719	277,251	-19,532
1994	389,357	509,778	-120,421	69,739	84,383	-14,644	4,602	9,472	-4,870	247,541	243,181	4,360
1995	564,953	433,322	131,631	55,367	71,528	-16,161	3,249	9,819	-6,569	247,722	225,868	21,854
1996	499,556	456,950	42,606	86,618	52,774	33,844	1,633	5,632	-3,999	175,821	140,079	35,742
1997	567,228	443,280	123,948	79,608	54,482	25,126	1,452	5,818	-4,366	164,172	115,312	48,860
1998	496,779	409,921	86,858	66,070	49,303	16,768	2,196	3,260	-1,064	229,377	150,096	79,281
1999	670,271	528,422	141,849	90,455	75,123	15,332	2,910	6,283	-3,373	311,983	222,136	89,847
2000	557,982	450,133	107,849	86,225	100,635	-14,410	2,325	7,801	-5,476	330,202	284,444	45,758
2001	691,080	535,050	156,030	90,882	101,547	-10,665	2,510	6,583	-4,073	246,215	223,504	22,711
2002	667,657	519,123	148,534	83,482	105,862	-22,380	3,088	7,796	-4,708	286,868	267,264	19,604
2003	564,179	512,768	51,411	80,725	78,178	2,548	2,182	6,294	-4,112	312,239	258,526	53,713
2004	758,557	545,852	212,705	75,331	81,958	-6,627	2,284	6,547	-4,264	464,151	352,368	111,783
2005	818,140	494,957	323,183	96,393	79,554	16,839	1,541	5,253	-3,711	267,966	208,564	59,402

Table 3.2.2.1.4. Fits to the indices of abundance.

SEAMAP VIDEO				COM_LL				COM_HL			
YEAR	OBS	PRED	RESID	YEAR	OBS	PRED	RESID	YEAR	OBS	PRED	RESID
1993	0.887878	0.864208	0.02367	1990	0.773695	0.718848	0.054847	1990	0.6959	0.652186	0.043714
1994	0.855679	0.860783	-0.005104	1991	0.778595	0.731349	0.047246	1991	0.6475	0.711063	-0.063563
1995	0.648084	0.835399	-0.187315	1992	0.680396	0.742142	-0.061746	1992	0.7476	0.743213	0.004387
1996	0.919877	0.816909	0.102968	1993	0.972894	0.770089	0.202805	1993	0.6832	0.781209	-0.098009
1997	0.944476	0.848407	0.096069	1994	0.831695	0.808569	0.023126	1994	0.8822	0.810891	0.071309
2002	1.11637	1.16184	-0.04547	1995	0.976894	0.861637	0.115257	1995	0.8712	0.837724	0.033476
2004	1.29117	1.29445	-0.00328	1996	0.843695	0.912599	-0.068904	1996	0.6078	0.846183	-0.238383
2005	1.33647	1.27219	0.06428	1997	1.01189	0.966847	0.045043	1997	0.5657	0.857409	-0.291709
-	-	-	-	1998	0.982494	1.03004	-0.047546	1998	0.5366	0.895686	-0.359086
-	-	-	-	1999	1.00219	1.06025	-0.05806	1999	0.7175	0.9121	-0.1946
-	-	-	-	2000	0.994194	1.0983	-0.104106	2000	0.9867	0.984795	0.001905
-	-	-	-	2001	1.31859	1.11609	0.2025	2001	1.4534	1.01181	0.44159
-	-	-	-	2002	1.02459	1.1351	-0.11051	2002	1.5219	1.01078	0.51112
-	-	-	-	2003	0.977594	1.27376	-0.296166	2003	1.14	1.19548	-0.05548
-	-	-	-	2004	1.27769	1.36488	-0.08719	2004	1.7734	1.28189	0.49151
-	-	-	-	2005	1.55289	1.45412	0.09877	2005	2.1694	1.33971	0.82969

HB18				HB20				MRFSS			
YEAR	OBS	PRED	RESID	YEAR	OBS	PRED	RESID	YEAR	OBS	PRED	RESID
1986	0.7449	0.852896	-0.107996	1990	0.848105	0.678007	0.170098	1986	0.687697	0.665188	0.022509
1987	1.1838	0.915745	0.268055	1991	0.942306	0.810854	0.131452	1987	0.657597	0.823829	-0.166232
1988	1.0426	1.08243	-0.03983	1992	0.795505	0.804121	-0.008616	1988	0.924695	0.906138	0.018557
1989	1.2184	0.925077	0.293323	1993	0.763505	0.865086	-0.101581	1989	1.31829	0.856323	0.461967
1990	0.8103	1.16059	-0.35029	1994	0.803305	0.873642	-0.070337	1990	1.86929	0.918598	0.950692
-	-	-	-	1995	0.919006	0.850969	0.068037	1991	1.14749	0.94091	0.20658
-	-	-	-	1996	0.741705	0.791182	-0.049477	1992	1.26729	0.91014	0.35715
-	-	-	-	1997	0.569104	0.778862	-0.209758	1993	0.780896	0.830423	-0.049527
-	-	-	-	1998	0.634604	0.849854	-0.21525	1994	0.931895	0.792249	0.139646
-	-	-	-	1999	0.631204	0.84329	-0.212086	1995	0.769096	0.82578	-0.056684
-	-	-	-	2000	0.873405	1.04775	-0.174345	1996	0.604597	0.807187	-0.20259
-	-	-	-	2001	0.844405	0.99089	-0.146485	1997	0.544797	0.997123	-0.452326
-	-	-	-	2002	0.927006	0.894761	0.032245	1998	0.754596	0.961844	-0.207248
-	-	-	-	2003	1.37531	1.39474	-0.01943	1999	0.929495	0.897502	0.031993
-	-	-	-	2004	2.01431	1.31316	0.70115	2000	1.04719	1.32379	-0.2766
-	-	-	-	2005	2.31721	1.24484	1.07237	2001	0.869096	1.23433	-0.365234
-	-	-	-	-	-	-	-	2002	0.903195	1.19901	-0.295815
-	-	-	-	-	-	-	-	2003	1.11279	1.16839	-0.0556
-	-	-	-	-	-	-	-	2004	1.67549	1.12371	0.55178
-	-	-	-	-	-	-	-	2005	1.20449	1.10139	0.1031

Table 3.2.2.2.1. Selected parameter estimates for the base run.

Name	Description	Value	Std Dev
Selectivity	Age 1, COM LL	0.272	0.203
Selectivity	Age 2, COM LL	0.347	0.167
Selectivity	Age 3, COM LL	0.442	0.145
Selectivity	Age 4, COM LL	0.566	0.134
Selectivity	Age 5, COM LL	0.740	0.130
Selectivity	Age 6, COM LL	0.974	0.128
Selectivity	Age 7, COM LL	1.235	0.127
Selectivity	Age 8, COM LL	1.444	0.125
Selectivity	Age 8, COM LL	1.540	0.122
Selectivity	Age 9, COM LL	1.520	0.117
Selectivity	Age 10, COM LL	1.428	0.109
Selectivity	Age 11, COM LL	1.306	0.096
Selectivity	Age 12, COM LL	1.191	0.079
Selectivity	Age 13, COM LL	1.100	0.056
Selectivity	Age 14, COM LL	1.036	0.029
Selectivity	Age 1, COM HL	0.729	0.207
Selectivity	Age 2, COM HL	0.949	0.179
Selectivity	Age 3, COM HL	1.234	0.165
Selectivity	Age 4, COM HL	1.563	0.160
Selectivity	Age 5, COM HL	1.857	0.160
Selectivity	Age 6, COM HL	1.966	0.160
Selectivity	Age 7, COM HL	1.850	0.160
Selectivity	Age 8, COM HL	1.622	0.158
Selectivity	Age 8, COM HL	1.397	0.154
Selectivity	Age 9, COM HL	1.226	0.145
Selectivity	Age 10, COM HL	1.110	0.131
Selectivity	Age 11, COM HL	1.041	0.112
Selectivity	Age 12, COM HL	1.006	0.088
Selectivity	Age 13, COM HL	0.993	0.060
Selectivity	Age 14, COM HL	0.995	0.031
Selectivity	Age 1, COM TRAP	0.007	0.203
Selectivity	Age 2, COM TRAP	0.012	0.161
Selectivity	Age 3, COM TRAP	0.020	0.133
Selectivity	Age 4, COM TRAP	0.033	0.118
Selectivity	Age 5, COM TRAP	0.056	0.110
Selectivity	Age 6, COM TRAP	0.094	0.106
Selectivity	Age 7, COM TRAP	0.158	0.103
Selectivity	Age 8, COM TRAP	0.259	0.098
Selectivity	Age 8, COM TRAP	0.398	0.089
Selectivity	Age 9, COM TRAP	0.571	0.075
Selectivity	Age 1, REC	0.753	0.054
Selectivity	Age 2, REC	0.910	0.029
Selectivity	Age 3, REC	2.718	0.002
Selectivity	Age 4, REC	2.718	0.000
Selectivity	Age 5, REC	2.716	0.026
Selectivity	Age 6, REC	2.621	0.046
Selectivity	Age 7, REC	2.380	0.060
Selectivity	Age 8, REC	2.009	0.067
Selectivity	Age 8, REC	1.631	0.067
Selectivity	Age 9, REC	1.336	0.060
Selectivity	Age 10, REC	1.144	0.047
Selectivity	Age 11, REC	1.040	0.027

Name	Description	Value	Std Dev
F MULT	1986 COM LL	0.050	0.119
F MULT	1986 COM HL	0.048	0.138
F MULT	1986 COM TRAP	0.023	0.095
F MULT	1986 REC	0.033	0.073
Q	SEAMAP VIDEO	1.001E-07	0.081
Q	COM LL	8.325E-09	0.094
Q	COM HL	1.509E-08	0.086
Q	HB 18	2.654E-07	0.100
Q	HB 20	1.550E-07	0.071
Q	MRFSS	5.527E-08	0.056
Virgin Stock		2.136E+12	*CHECK THIS*
Steepness		0.863	0.033

Name	Value	Std Dev
MSY	8,818,000	338,600
SS_{2005}/SS_{MSY}	1.035	0.071
F_{2005}/F_{MSY}	0.909	0.085

Table. 3.2.2.3.1. Number-at-age from base case. Note: recruitment occurs at Age-1. The sum is total abundance.

YEAR	AGE 1	AGE 2	AGE 3	AGE 4	AGE 5	AGE 6	AGE 7	AGE 8	AGE 9	AGE 10	AGE 11	AGE 12	AGE 13	AGE 14	AGE 15	AGE 16	AGE 17	AGE 18	AGE 19	AGE 20	SUM
1986	3,624,600	4,581,670	2,414,240	1,199,970	869,467	538,321	478,042	330,779	306,162	270,022	260,652	227,743	212,311	196,836	182,410	168,547	159,143	149,582	140,536	411,862	16,722,895
1987	8,248,940	2,385,850	3,167,530	1,663,620	834,462	607,286	379,029	341,152	239,721	225,208	201,253	196,391	173,089	162,593	151,796	141,326	130,942	123,759	116,430	430,460	19,920,837
1988	7,681,060	5,444,890	1,679,070	2,240,800	1,185,210	594,471	432,516	270,757	245,259	174,036	165,516	149,815	147,942	131,775	124,909	117,337	109,640	101,686	96,195	425,580	21,518,464
1989	5,589,540	5,054,400	3,863,900	1,175,210	1,583,870	844,354	427,540	314,796	199,521	182,916	131,251	126,034	115,000	114,409	102,621	97,742	92,081	86,127	79,950	410,732	20,591,993
1990	7,249,810	3,671,310	3,524,540	2,590,370	781,372	1,052,110	563,724	288,893	215,958	139,066	129,438	94,119	91,381	84,206	84,520	76,262	72,883	68,731	64,344	367,026	21,210,064
1991	6,431,590	4,762,260	2,737,970	2,764,380	2,037,390	592,650	762,946	398,130	202,615	152,182	98,986	93,174	68,451	67,088	62,334	62,913	56,934	54,445	51,379	322,631	21,780,447
1992	5,548,200	4,200,350	3,528,440	2,136,420	2,154,540	1,512,080	417,715	522,000	269,621	137,505	104,182	68,504	65,168	48,373	47,867	44,763	45,343	41,047	39,276	269,826	21,201,217
1993	4,370,410	3,614,010	3,111,180	2,750,860	1,652,220	1,583,550	1,063,290	287,094	355,999	184,011	94,293	71,855	47,522	45,544	34,115	33,969	31,876	32,308	29,267	220,465	19,613,837
1994	4,691,150	2,860,910	2,673,490	2,414,140	2,112,340	1,209,540	1,105,870	717,731	189,845	233,498	120,858	62,334	47,923	32,047	31,105	23,508	23,523	22,092	22,402	173,197	18,767,503
1995	5,960,720	3,076,140	2,135,970	2,104,290	1,898,870	1,600,400	885,430	791,789	507,344	133,359	163,663	84,689	43,738	33,790	22,800	22,267	16,889	16,913	15,890	140,780	19,655,731
1996	4,922,220	3,910,950	2,302,340	1,686,420	1,668,550	1,459,960	1,191,220	645,480	570,510	363,315	95,201	116,618	60,327	31,266	24,350	16,522	16,192	12,290	12,314	114,142	19,220,185
1997	9,206,980	3,246,640	2,942,110	1,828,830	1,357,610	1,319,780	1,125,290	899,158	480,876	422,760	269,400	70,871	87,305	45,492	23,781	18,632	12,689	12,445	9,452	97,318	23,477,417
1998	5,385,610	6,084,730	2,448,000	2,343,510	1,480,680	1,084,550	1,030,070	860,498	678,267	360,570	317,042	202,768	53,636	66,539	34,963	18,386	14,455	9,852	9,669	83,011	22,566,807
1999	4,399,820	3,556,230	4,593,140	1,952,850	1,903,890	1,193,080	858,512	802,521	663,896	521,893	278,270	246,151	158,558	42,258	52,816	27,900	14,719	11,580	7,899	74,348	21,360,331
2000	15,038,700	2,896,900	2,668,630	3,637,760	1,567,780	1,498,100	911,518	640,853	590,900	486,426	382,941	205,156	182,613	118,527	31,866	40,072	21,243	11,215	8,828	62,743	31,002,771
2001	6,599,250	9,871,100	2,170,370	2,107,630	2,885,050	1,209,970	1,122,720	670,517	467,508	430,384	354,960	280,292	150,700	134,866	88,198	23,836	30,065	15,949	8,426	53,805	28,675,595
2002	6,729,120	4,346,940	7,415,990	1,721,200	1,686,690	2,255,060	919,733	836,988	494,847	344,174	317,682	263,329	209,189	113,279	102,207	67,223	18,228	23,007	12,213	47,689	27,924,787
2003	6,534,020	4,428,920	3,267,360	5,886,620	1,381,450	1,323,670	1,721,350	689,453	622,058	367,062	255,809	236,976	197,302	157,656	86,016	78,015	51,471	13,967	17,641	45,963	27,362,779
2004	6,277,450	4,305,450	3,338,940	2,602,480	4,750,340	1,100,360	1,035,830	1,329,370	528,628	476,102	281,522	196,965	183,332	153,523	123,513	67,713	61,594	40,666	11,042	50,315	26,915,134
2005	6,602,750	4,118,150	3,229,350	2,643,890	2,070,890	3,687,600	835,931	777,530	993,083	395,057	357,115	212,200	149,242	139,778	117,879	95,313	52,409	47,708	31,521	47,585	26,604,981

Table 3.2.2.4.1. Spawning stock reproductive potential (SS; eggs per spawning event), SS at maximum sustainable yield (MSY) and SS/SS_{MSY}.

YEAR	SS	SS_{MSY}	SS/SS_{MSY}
1986	4.42E+11	7.40E+11	0.598
1987	4.18E+11	7.40E+11	0.565
1988	4.03E+11	7.40E+11	0.546
1989	4.02E+11	7.40E+11	0.544
1990	3.94E+11	7.40E+11	0.533
1991	4.16E+11	7.40E+11	0.563
1992	4.44E+11	7.40E+11	0.601
1993	4.58E+11	7.40E+11	0.619
1994	4.57E+11	7.40E+11	0.617
1995	4.73E+11	7.40E+11	0.640
1996	4.75E+11	7.40E+11	0.642
1997	4.89E+11	7.40E+11	0.661
1998	5.11E+11	7.40E+11	0.691
1999	5.52E+11	7.40E+11	0.746
2000	5.80E+11	7.40E+11	0.784
2001	5.81E+11	7.40E+11	0.785
2002	6.20E+11	7.40E+11	0.839
2003	6.69E+11	7.40E+11	0.905
2004	7.25E+11	7.40E+11	0.981
2005	7.65E+11	7.40E+11	1.035

Table 3.2.2.5.1. Estimated selectivity-at-age by fleet.

FLEET	COM LL	COM HL	COM TRAP	REC
Age 1	0.000	0.000	0.000	1.000
Age 2	0.225	0.483	0.012	1.000
Age 3	0.287	0.628	0.020	0.999
Age 4	0.368	0.795	0.033	0.964
Age 5	0.480	0.944	0.056	0.876
Age 6	0.633	1.000	0.094	0.739
Age 7	0.802	0.941	0.158	0.600
Age 8	0.938	0.825	0.259	0.491
Age 9	1.000	0.711	0.398	0.421
Age 10	0.987	0.624	0.571	0.383
Age 11	0.927	0.564	0.753	0.368
Age 12	0.848	0.529	0.910	0.368
Age 13	0.773	0.512	1.000	0.368
Age 14	0.714	0.505	1.000	0.368
Age 15	0.673	0.506	1.000	0.368
Age 16	0.649	0.509	1.000	0.368
Age 17	0.649	0.509	1.000	0.368
Age 18	0.649	0.509	1.000	0.368
Age 19	0.649	0.509	1.000	0.368
Age 20	0.649	0.509	1.000	0.368

Table 3.2.2.6.1. Fleet-specific fishing mortality rates from the directed landings and the discards from the directed fleets.

	F (DIRECTED LANDINGS)				F (DISCARDS)			
YEAR	COM LL	COM HL	COM TRAP	REC	COM LL	COM HL	COM TRAP	REC
1986	0.077	0.095	0.023	0.091	0.000	0.000	0.0E+00	0.009
1987	0.114	0.081	0.017	0.064	0.000	0.000	0.0E+00	0.006
1988	0.080	0.069	0.022	0.095	0.000	0.000	0.0E+00	0.009
1989	0.108	0.112	0.027	0.113	0.000	0.000	0.0E+00	0.011
1990	0.114	0.120	0.022	0.112	0.016	0.008	6.6E-05	0.011
1991	0.144	0.104	0.029	0.170	0.021	0.007	9.1E-05	0.017
1992	0.133	0.076	0.051	0.195	0.019	0.005	1.6E-04	0.019
1993	0.197	0.064	0.060	0.147	0.028	0.004	1.8E-04	0.015
1994	0.131	0.057	0.076	0.130	0.019	0.004	2.4E-04	0.013
1995	0.116	0.050	0.079	0.124	0.016	0.003	2.4E-04	0.012
1996	0.123	0.039	0.043	0.071	0.017	0.003	1.4E-04	0.007
1997	0.119	0.040	0.043	0.052	0.017	0.003	1.3E-04	0.005
1998	0.103	0.033	0.023	0.060	0.014	0.002	7.0E-05	0.006
1999	0.126	0.047	0.041	0.089	0.018	0.003	1.3E-04	0.009
2000	0.104	0.061	0.050	0.120	0.015	0.004	1.6E-04	0.012
2001	0.115	0.056	0.040	0.085	0.016	0.004	1.3E-04	0.008
2002	0.103	0.054	0.044	0.093	0.014	0.004	1.4E-04	0.009
2003	0.093	0.037	0.034	0.081	0.013	0.002	1.0E-04	0.008
2004	0.098	0.039	0.033	0.126	0.014	0.003	1.0E-04	0.013
2005	0.089	0.039	0.025	0.077	0.013	0.003	8.1E-05	0.008

Table 3.2.2.6.2. Annual estimates of apical fishing mortality and F/F_{MSY} for the directed landings and the discards.

	F (DIRECTED LANDINGS)			F (DISCARDS)		
YEAR	Apical F	F_{MSY}	F/F_{MSY}	Apical F	F_{MSY}	F/F_{MSY}
1986	0.213	0.160	1.336	0.009	0.160	0.057
1987	0.210	0.160	1.312	0.006	0.160	0.040
1988	0.192	0.160	1.203	0.009	0.160	0.059
1989	0.267	0.160	1.669	0.011	0.160	0.071
1990	0.229	0.160	1.436	0.034	0.160	0.212
1991	0.265	0.160	1.661	0.043	0.160	0.268
1992	0.262	0.160	1.641	0.041	0.160	0.257
1993	0.304	0.160	1.904	0.044	0.160	0.272
1994	0.248	0.160	1.551	0.033	0.160	0.208
1995	0.233	0.160	1.458	0.030	0.160	0.189
1996	0.185	0.160	1.161	0.026	0.160	0.164
1997	0.174	0.160	1.092	0.024	0.160	0.151
1998	0.145	0.160	0.910	0.022	0.160	0.138
1999	0.195	0.160	1.221	0.029	0.160	0.180
2000	0.202	0.160	1.268	0.029	0.160	0.181
2001	0.190	0.160	1.187	0.027	0.160	0.169
2002	0.184	0.160	1.150	0.026	0.160	0.163
2003	0.152	0.160	0.951	0.022	0.160	0.139
2004	0.174	0.160	1.088	0.027	0.160	0.171
2005	0.145	0.160	0.909	0.022	0.160	0.136

Table 3.2.2.6.3. Fishing mortality-at-age for the directed landings (**A**) and the discards (**B**). Apical F is noted by cell shading and bold font.

A)

YEAR	AGE 1	AGE 2	AGE 3	AGE 4	AGE 5	AGE 6	AGE 7	AGE 8	AGE 9	AGE 10	AGE 11	AGE 12	AGE 13	AGE 14	AGE 15	AGE 16	AGE 17	AGE 18	AGE 19	AGE 20
1986	0.000	0.101	0.168	0.192	0.208	**0.213**	0.210	0.201	0.192	0.183	0.176	0.170	0.165	0.159	0.156	0.155	0.155	0.155	0.155	0.155
1987	0.000	0.084	0.142	0.168	0.188	0.202	0.209	**0.210**	0.205	0.197	0.188	0.179	0.170	0.163	0.158	0.156	0.156	0.156	0.156	0.156
1988	0.000	0.072	0.152	0.176	0.188	**0.192**	0.190	0.185	0.178	0.171	0.165	0.160	0.155	0.150	0.146	0.145	0.145	0.145	0.145	0.145
1989	0.000	0.087	0.194	0.237	0.258	**0.267**	0.264	0.256	0.246	0.235	0.225	0.217	0.209	0.202	0.198	0.196	0.196	0.196	0.196	0.196
1990	0.000	0.002	0.007	0.035	0.097	0.164	0.207	0.226	**0.229**	0.226	0.219	0.212	0.205	0.199	0.195	0.194	0.194	0.194	0.195	0.195
1991	0.000	0.000	0.003	0.035	0.112	0.188	0.235	0.258	**0.265**	0.263	0.257	0.250	0.243	0.235	0.231	0.228	0.229	0.229	0.230	0.231
1992	0.000	0.000	0.004	0.046	0.125	0.193	0.233	0.253	0.261	**0.262**	0.261	0.259	0.254	0.247	0.243	0.241	0.241	0.241	0.242	0.243
1993	0.000	0.001	0.007	0.050	0.125	0.196	0.247	0.281	0.299	**0.304**	0.303	0.298	0.290	0.279	0.272	0.268	0.269	0.269	0.270	0.271
1994	0.000	0.000	0.003	0.036	0.100	0.156	0.194	0.218	0.232	0.241	0.245	**0.248**	0.245	0.239	0.234	0.232	0.232	0.233	0.233	0.234
1995	0.000	0.000	0.003	0.031	0.088	0.141	0.177	0.200	0.214	0.223	0.229	**0.233**	0.232	0.226	0.222	0.220	0.220	0.221	0.221	0.222
1996	0.000	0.000	0.001	0.020	0.062	0.107	0.143	0.166	0.180	0.185	**0.185**	0.183	0.179	0.172	0.168	0.165	0.166	0.166	0.166	0.167
1997	0.000	0.000	0.001	0.016	0.053	0.095	0.130	0.154	0.168	0.174	**0.174**	0.172	0.168	0.162	0.157	0.155	0.156	0.156	0.156	0.157
1998	0.000	0.000	0.001	0.015	0.046	0.082	0.112	0.132	0.143	**0.145**	0.144	0.140	0.135	0.129	0.126	0.124	0.124	0.124	0.125	0.125
1999	0.000	0.000	0.002	0.020	0.065	0.114	0.153	0.177	0.191	**0.195**	0.195	0.192	0.187	0.181	0.176	0.174	0.174	0.175	0.175	0.175
2000	0.000	0.000	0.004	0.032	0.085	0.135	0.168	0.188	0.197	0.201	**0.202**	0.202	0.200	0.194	0.191	0.189	0.189	0.189	0.190	0.190
2001	0.000	0.000	0.002	0.025	0.073	0.121	0.155	0.176	0.186	**0.190**	0.189	0.186	0.182	0.176	0.172	0.170	0.170	0.170	0.170	0.171
2002	0.000	0.000	0.002	0.023	0.070	0.118	0.150	0.169	0.179	0.183	**0.184**	0.183	0.179	0.174	0.170	0.168	0.169	0.169	0.169	0.170
2003	0.000	0.000	0.002	0.021	0.058	0.095	0.121	0.139	0.148	0.152	**0.152**	0.151	0.147	0.143	0.139	0.138	0.138	0.138	0.139	0.139
2004	0.000	0.000	0.003	0.031	0.082	0.123	0.149	0.165	0.172	**0.174**	0.173	0.171	0.168	0.163	0.159	0.158	0.158	0.158	0.159	0.159
2005	0.000	0.000	0.001	0.018	0.059	0.097	0.122	0.137	0.144	**0.145**	0.144	0.141	0.137	0.132	0.129	0.127	0.128	0.128	0.128	0.129

B)

YEAR	AGE 1	AGE 2	AGE 3	AGE 4	AGE 5	AGE 6	AGE 7	AGE 8	AGE 9	AGE 10	AGE 11	AGE 12	AGE 13	AGE 14	AGE 15	AGE 16	AGE 17	AGE 18	AGE 19	AGE 20
1986	**0.009**	0.005	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1987	**0.006**	0.005	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1988	**0.009**	0.007	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1989	**0.011**	0.011	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1990	0.011	0.028	0.033	**0.034**	0.029	0.020	0.013	0.009	0.006	0.004	0.003	0.002	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
1991	0.017	0.037	0.042	**0.043**	0.035	0.025	0.017	0.011	0.007	0.005	0.004	0.003	0.002	0.002	0.002	0.001	0.001	0.001	0.001	0.001
1992	0.019	0.037	**0.041**	0.040	0.032	0.022	0.015	0.010	0.006	0.004	0.003	0.002	0.002	0.002	0.001	0.001	0.001	0.001	0.001	0.001
1993	0.015	0.038	0.043	**0.044**	0.036	0.026	0.018	0.012	0.008	0.006	0.004	0.003	0.002	0.002	0.001	0.001	0.001	0.001	0.001	0.001
1994	0.013	0.029	**0.033**	0.033	0.026	0.019	0.013	0.009	0.006	0.004	0.003	0.002	0.002	0.001	0.001	0.001	0.001	0.001	0.001	0.001
1995	0.012	0.027	**0.030**	0.030	0.024	0.017	0.011	0.008	0.005	0.003	0.002	0.002	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
1996	0.007	0.022	0.025	**0.026**	0.022	0.016	0.011	0.007	0.005	0.003	0.002	0.002	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.000
1997	0.005	0.019	0.023	**0.024**	0.020	0.015	0.011	0.007	0.005	0.003	0.002	0.002	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.000
1998	0.006	0.018	0.021	**0.022**	0.019	0.014	0.010	0.007	0.005	0.003	0.002	0.002	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
1999	0.009	0.024	0.028	**0.029**	0.024	0.018	0.012	0.008	0.006	0.004	0.003	0.002	0.002	0.001	0.001	0.001	0.001	0.001	0.001	0.001
2000	0.012	0.026	**0.029**	0.029	0.023	0.016	0.011	0.007	0.005	0.003	0.002	0.002	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.000
2001	0.008	0.023	0.027	**0.027**	0.022	0.016	0.011	0.007	0.005	0.003	0.002	0.002	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.000
2002	0.009	0.022	0.026	**0.026**	0.021	0.015	0.010	0.007	0.005	0.003	0.002	0.002	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.000
2003	0.008	0.019	0.022	**0.022**	0.018	0.013	0.009	0.006	0.004	0.003	0.002	0.002	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
2004	0.013	0.024	**0.027**	0.026	0.020	0.014	0.010	0.007	0.004	0.003	0.002	0.002	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.000
2005	0.008	0.019	0.021	**0.022**	0.017	0.012	0.008	0.006	0.004	0.003	0.002	0.001	0.001	0.001	0.001	0.001	0.001	0.000	0.000	0.000

Table 3.2.2.10.1. Reference points and benchmarks for the red grouper base and sensitivity runs.

NAME	BASE	SENS-1	SENS-2	SENS-3	SENS-4	SENS-5	SENS-6	SENS-7	SENS-8	SENS-9	SENS-10	SENS-11	SENS-12	SENS-13
Description	Base Run Lorenzen M @ 0.167	Fix Steepness = 0.6	Fix Steepness = 0.7	Fix Steepness = 0.8	Fix Steepness = 0.9	SEAMAP VIDEO and COM-LL Indices Only	No COM-LL Index	Substitute Mature Biomass for Fecundity	Use 2002 Fecundity Series	Use Lorenzen M @ 0.14	M = 0.2 all ages	Decrement Indices by 2% (Annual Increse in Q)	NMFS_LL Survey Age Comp	Start Catch Series in 1880
F-REFS														
F0.1	0.103	0.105	0.104	0.103	0.102	0.103	0.103	0.103	0.103	0.087	0.164	0.103		
Fmax	0.190	0.192	0.191	0.191	0.190	0.190	0.190	0.190	0.190	0.162	0.276	0.190		
F30%SPR	0.222	0.221	0.222	0.222	0.222	0.221	0.222	0.177	0.191	0.178	0.400	0.222		
F40%SPR	0.142	0.142	0.142	0.142	0.142	0.141	0.142	0.116	0.125	0.115	0.261	0.142		
Fmsy	0.160	0.102	0.124	0.146	0.168	0.160	0.160	0.153	0.155	0.137	0.239	0.159		
Foy	0.120	0.076	0.093	0.109	0.126	0.120	0.120	0.115	0.116	0.103	0.180	0.120		
Fcurrent	0.145	0.149	0.146	0.145	0.145	0.165	0.141	0.146	0.146	0.158	0.062	0.182		
SSB-REFS														
SS_F0.1	9.79E+11	1.38E+12	1.16E+12	1.03E+12	9.54E+11	9.12E+11	9.91E+11	1.16E+11	1.77E+12	1.11E+12	1.07E+12	8.88E+11		
SS_Fmax	6.52E+11	7.32E+11	7.00E+11	6.67E+11	6.44E+11	6.08E+11	6.60E+11	7.26E+10	1.12E+12	7.30E+11	7.75E+11	5.91E+11		
SSmsy	7.40E+11	1.42E+12	1.02E+12	8.18E+11	7.03E+11	6.90E+11	7.49E+11	8.68E+10	1.33E+12	8.27E+11	8.55E+11	6.72E+11		
SSoy	8.93E+11	1.75E+12	1.24E+12	9.92E+11	8.47E+11	8.34E+11	9.04E+11	1.08E+11	1.63E+12	1.00E+12	1.02E+12	8.11E+11		
YIELD REFS														
Y F0.1	8.40E+06	1.20E+07	9.95E+06	8.85E+06	8.19E+06	7.83E+06	8.51E+06	8.50E+06	8.48E+06	8.84E+06	1.15E+07	7.62E+06		
Y Fmax	8.75E+06	9.86E+06	9.41E+06	8.96E+06	8.64E+06	8.15E+06	8.87E+06	8.75E+06	8.76E+06	9.23E+06	1.19E+07	7.93E+06		
MSY	8.82E+06	1.20E+07	1.01E+07	9.14E+06	8.68E+06	8.22E+06	8.93E+06	8.86E+06	8.86E+06	9.29E+06	1.20E+07	7.99E+06		
OY	8.64E+06	1.16E+07	9.80E+06	8.94E+06	8.51E+06	8.05E+06	8.75E+06	8.67E+06	8.67E+06	9.10E+06	1.17E+07	7.83E+06		
SRR Parameters														
virgin	2.14E+12	3.74E+12	2.78E+12	2.32E+12	2.05E+12	2.00E+12	2.16E+12	2.85E+11	4.12E+12	2.47E+12	2.17E+12	1.94E+12		
steepness	0.863	0.600	0.700	0.800	0.900	0.864	0.863	0.867	0.863	0.875	0.847	0.862		
Current Status														
F/F_{MSY}	0.909	1.464	1.181	0.996	0.865	1.037	0.880	0.950	0.942	1.149	0.261	1.141		
SS/SS_{MSY}	1.035	0.522	0.747	0.935	1.088	0.973	1.051	0.932	0.937	0.845	1.912	0.925		
F/F_{OY}	1.212	1.952	1.575	1.328	1.154	1.382	1.174	1.267	1.256	1.533	0.348	1.521		

Table 3.2.2.11.1. Projected abundance (numbers) for the five projections .

YEAR	OY	FOY	FMSY	Fcurrent	Cur Mngmt
2006	26,568,207	26,568,207	26,568,207	26,568,207	26,568,207
2007	26,505,610	26,505,610	26,505,610	26,505,610	26,505,610
2008	26,474,330	26,474,330	26,474,330	26,474,330	26,474,330
2009	26,450,757	26,674,795	26,355,241	26,470,113	26,656,611
2010	26,442,687	26,846,891	26,258,257	26,468,072	26,828,665
2011	26,446,475	26,997,560	26,183,693	26,471,663	27,004,935
2012	26,454,910	27,126,497	26,123,782	26,476,284	27,179,705
2013	26,465,204	27,236,141	26,074,709	26,480,682	27,342,702
2014	26,478,161	27,330,929	26,035,716	26,486,166	27,503,620
2015	26,492,611	27,411,737	26,003,417	26,491,032	27,661,307

Table 3.2.2.11.2. Projected yield (lbs gutted weight) for the five projections .

YEAR	OY	FOY	FMSY	Fcurrent	Cur Mngmt
2006	7,982,450	7,982,450	7,982,450	7,982,450	7,982,450
2007	8,323,950	8,323,950	8,323,950	8,323,950	8,323,950
2008	8,638,440	7,094,290	9,294,510	8,505,340	7,220,000
2009	8,638,440	7,325,190	9,274,160	8,592,630	7,330,000
2010	8,638,440	7,508,810	9,216,610	8,635,470	7,330,000
2011	8,638,440	7,664,670	9,154,390	8,661,900	7,330,000
2012	8,638,440	7,796,410	9,094,840	8,678,360	7,390,000
2013	8,638,440	7,909,230	9,043,950	8,691,100	7,390,000
2014	8,638,440	8,011,650	9,007,800	8,707,750	7,390,000
2015	8,638,440	8,102,010	8,980,260	8,724,270	7,390,000

Table 3.2.2.11.3. Projected discards (lbs gutted weight) for the five projections .

YEAR	OY	FOY	FMSY	Fcurrent	Cur Mngmt
2006	761,052	761,052	761,052	761,052	761,052
2007	739,269	739,269	739,269	739,269	739,269
2008	737,941	602,953	795,733	726,249	613,890
2009	724,399	603,507	783,964	719,601	604,559
2010	718,131	605,317	777,551	716,578	591,340
2011	715,007	607,505	774,251	715,524	580,378
2012	713,381	609,572	772,531	715,342	575,466
2013	712,192	611,400	771,501	715,470	566,677
2014	710,557	612,952	770,704	715,626	558,020
2015	708,696	614,205	769,948	715,686	549,644

Table 3.2.2.11.4. Projected fishing mortality F, F/F_{MSY} and F/F_{OY} for the five projections.

	OY			FOY			FMSY			Fcurrent			Cur Mngmt		
YEAR	Apical F	F/F_{MSY}	F/F_{OY}	Apical F	F/F_{MSY}	F/F_{OY}	Apical F	F/F_{MSY}	F/F_{OY}	Apical F	F/F_{MSY}	F/F_{OY}	Apical F	F/F_{MSY}	F/F_{OY}
2006	0.145	0.909	1.212	0.145	0.909	1.212	0.145	0.909	1.212	0.145	0.909	1.212	0.145	0.909	1.212
2007	0.145	0.909	1.212	0.145	0.909	1.212	0.145	0.909	1.212	0.145	0.909	1.212	0.145	0.909	1.212
2008	0.148	0.925	1.233	0.120	0.750	1.000	0.160	1.000	1.333	0.145	0.909	1.212	0.122	0.764	1.019
2009	0.146	0.917	1.222	0.120	0.750	1.000	0.160	1.000	1.333	0.145	0.909	1.212	0.120	0.752	1.003
2010	0.146	0.912	1.217	0.120	0.750	1.000	0.160	1.000	1.333	0.145	0.909	1.212	0.117	0.733	0.977
2011	0.145	0.910	1.213	0.120	0.750	1.000	0.160	1.000	1.333	0.145	0.909	1.212	0.114	0.715	0.953
2012	0.145	0.907	1.210	0.120	0.750	1.000	0.160	1.000	1.333	0.145	0.909	1.212	0.113	0.705	0.940
2013	0.145	0.905	1.207	0.120	0.750	1.000	0.160	1.000	1.333	0.145	0.909	1.212	0.110	0.690	0.920
2014	0.144	0.903	1.204	0.120	0.750	1.000	0.160	1.000	1.333	0.145	0.909	1.212	0.108	0.676	0.901
2015	0.144	0.900	1.200	0.120	0.750	1.000	0.160	1.000	1.333	0.145	0.909	1.212	0.106	0.662	0.883

Table 3.2.2.11.5. Projected spawning stock reproductive potential (SS; eggs per spawning event), SS/SS_{MSY} and SS/SS_{OY} for the five projections**.**

	OY			FOY			FMSY		
YEAR	SS	SS/SS_{MSY}	SS/SS_{OY}	SS	SS/SS_{MSY}	SS/SS_{OY}	SS	SS/SS_{MSY}	SS/SS_{OY}
2006	7.493E+11	1.013	0.839	7.493E+11	1.013	0.839	7.493E+11	1.013	0.839
2007	7.698E+11	1.041	0.862	7.698E+11	1.041	0.862	7.698E+11	1.041	0.862
2008	7.897E+11	1.068	0.884	7.897E+11	1.068	0.884	7.897E+11	1.068	0.884
2009	7.857E+11	1.062	0.880	8.017E+11	1.084	0.898	7.789E+11	1.053	0.872
2010	7.861E+11	1.063	0.880	8.156E+11	1.103	0.913	7.727E+11	1.045	0.865
2011	7.844E+11	1.061	0.879	8.251E+11	1.116	0.924	7.652E+11	1.035	0.857
2012	7.826E+11	1.058	0.877	8.325E+11	1.126	0.932	7.584E+11	1.025	0.849
2013	7.833E+11	1.059	0.877	8.407E+11	1.137	0.942	7.548E+11	1.021	0.845
2014	7.836E+11	1.059	0.878	8.471E+11	1.145	0.949	7.514E+11	1.016	0.842
2015	7.825E+11	1.058	0.876	8.506E+11	1.150	0.953	7.471E+11	1.010	0.837

	Fcurrent			Cur Mngmt		
YEAR	SS	SS/SS_{MSY}	SS/SS_{OY}	SS	SS/SS_{MSY}	SS/SS_{OY}
2006	7.49E+11	1.013	0.839	7.493E+11	1.013	0.839
2007	7.70E+11	1.041	0.862	7.698E+11	1.041	0.862
2008	7.90E+11	1.068	0.884	7.897E+11	1.068	0.884
2009	7.87E+11	1.064	0.882	8.004E+11	1.082	0.896
2010	7.88E+11	1.065	0.882	8.142E+11	1.101	0.912
2011	7.86E+11	1.063	0.881	8.256E+11	1.116	0.925
2012	7.84E+11	1.060	0.878	8.363E+11	1.131	0.937
2013	7.84E+11	1.061	0.879	8.486E+11	1.147	0.950
2014	7.84E+11	1.060	0.878	8.600E+11	1.163	0.963
2015	7.82E+11	1.058	0.876	8.692E+11	1.175	0.974

Table 3.2.2.11.6. Projected recruitment (numbers) for the five projections**.**

YEAR	OY	FOY	FMSY	Fcurrent	Cur Mngmt
2006	6,563,470	6,563,470	6,563,470	6,563,470	6,563,470
2007	6,548,950	6,548,950	6,548,950	6,548,950	6,548,950
2008	6,567,330	6,567,330	6,567,330	6,567,330	6,567,330
2009	6,584,410	6,584,410	6,584,410	6,584,410	6,584,410
2010	6,581,080	6,594,410	6,575,270	6,582,250	6,593,350
2011	6,581,380	6,605,550	6,569,890	6,582,950	6,604,470
2012	6,579,960	6,613,020	6,563,290	6,581,540	6,613,380
2013	6,578,450	6,618,670	6,557,230	6,579,810	6,621,580
2014	6,579,050	6,624,930	6,553,940	6,580,040	6,630,770
2015	6,579,300	6,629,700	6,550,830	6,579,820	6,639,080

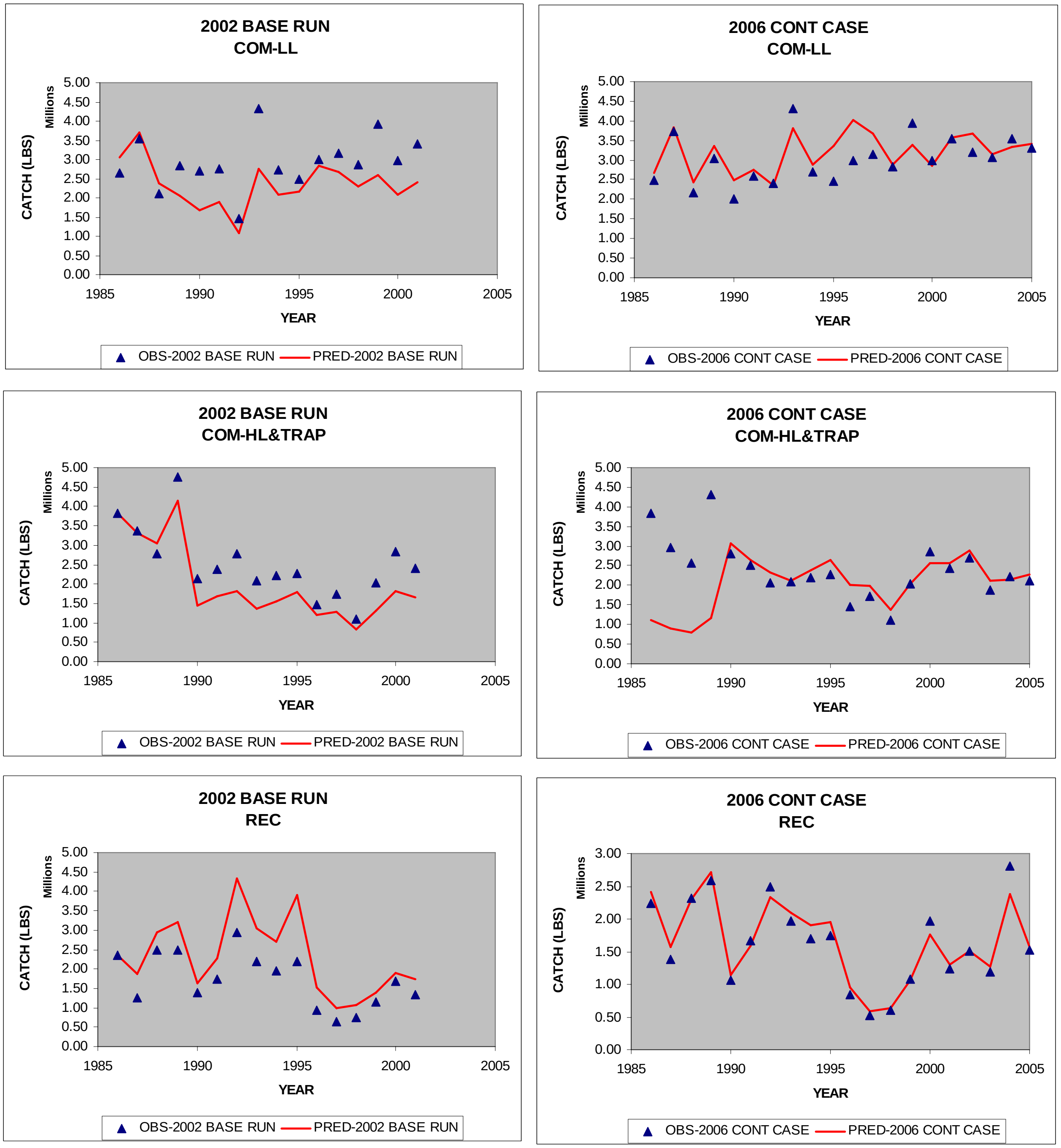


Figure 3.1.2.1.1 Fits to the catch series for the 2002 base run (left hand panels) and the 2006 continuity run (right hand panels)..

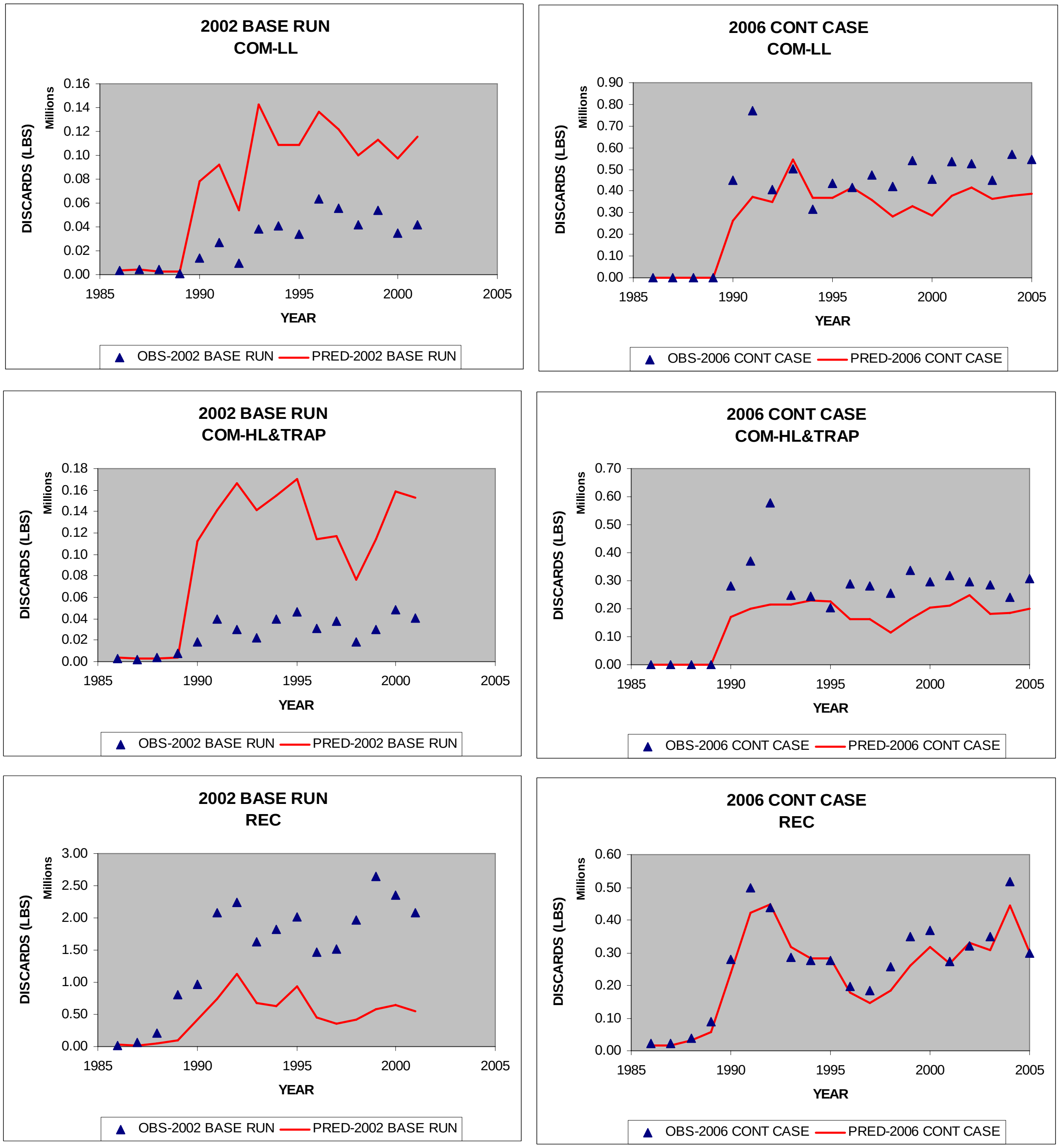


Figure 3.1.2.1.2 Fits to the discard series for the 2002 base run (left hand panels) and the 2006 continuity run (right hand panels)..

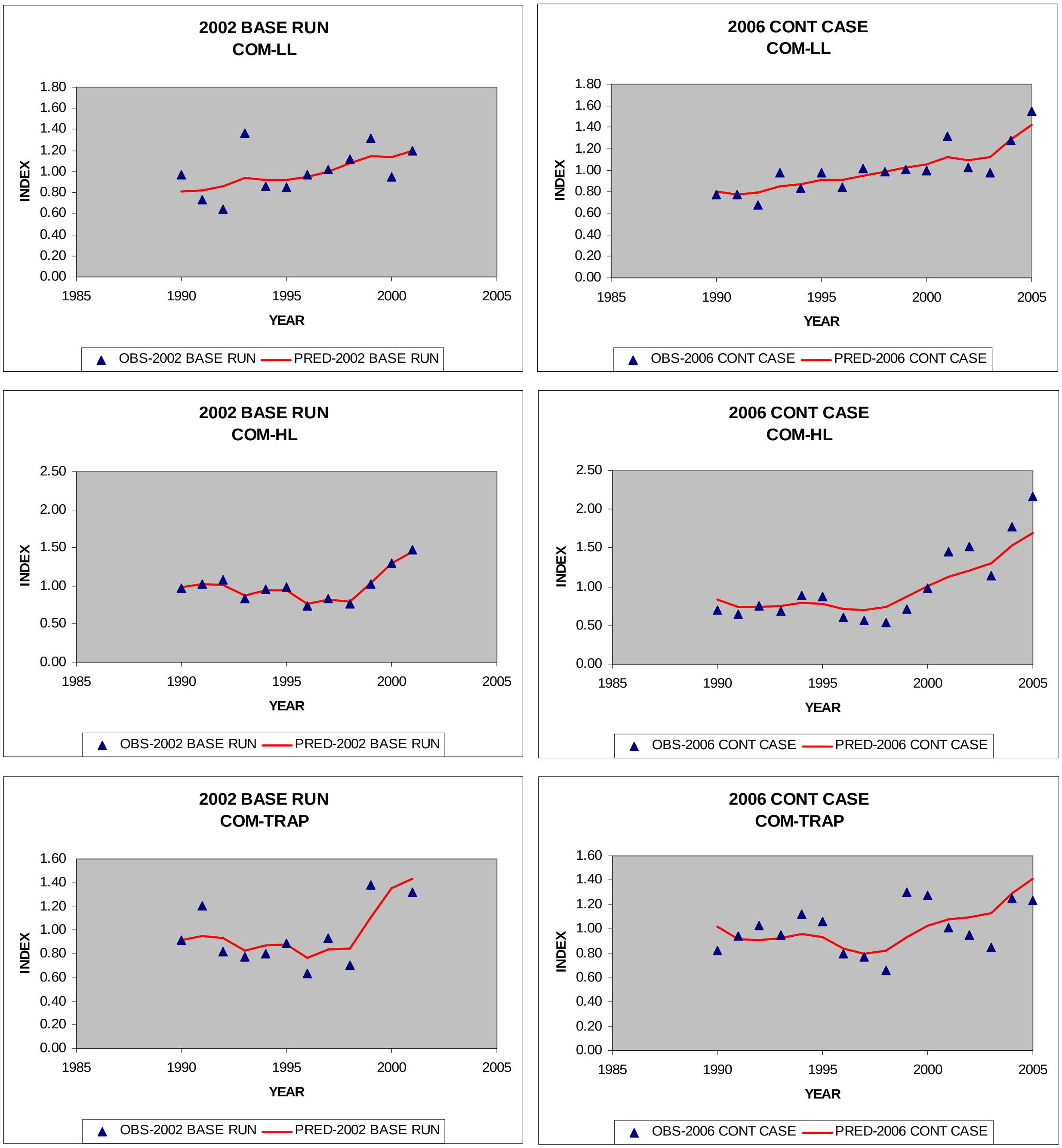


Figure 3.1.2.1.3 Fits to the indices of abundance for the 2002 base run (left hand panels) and the 2006 continuity run (right hand panels). ***CONTINUED ON NEXT PAGE***.

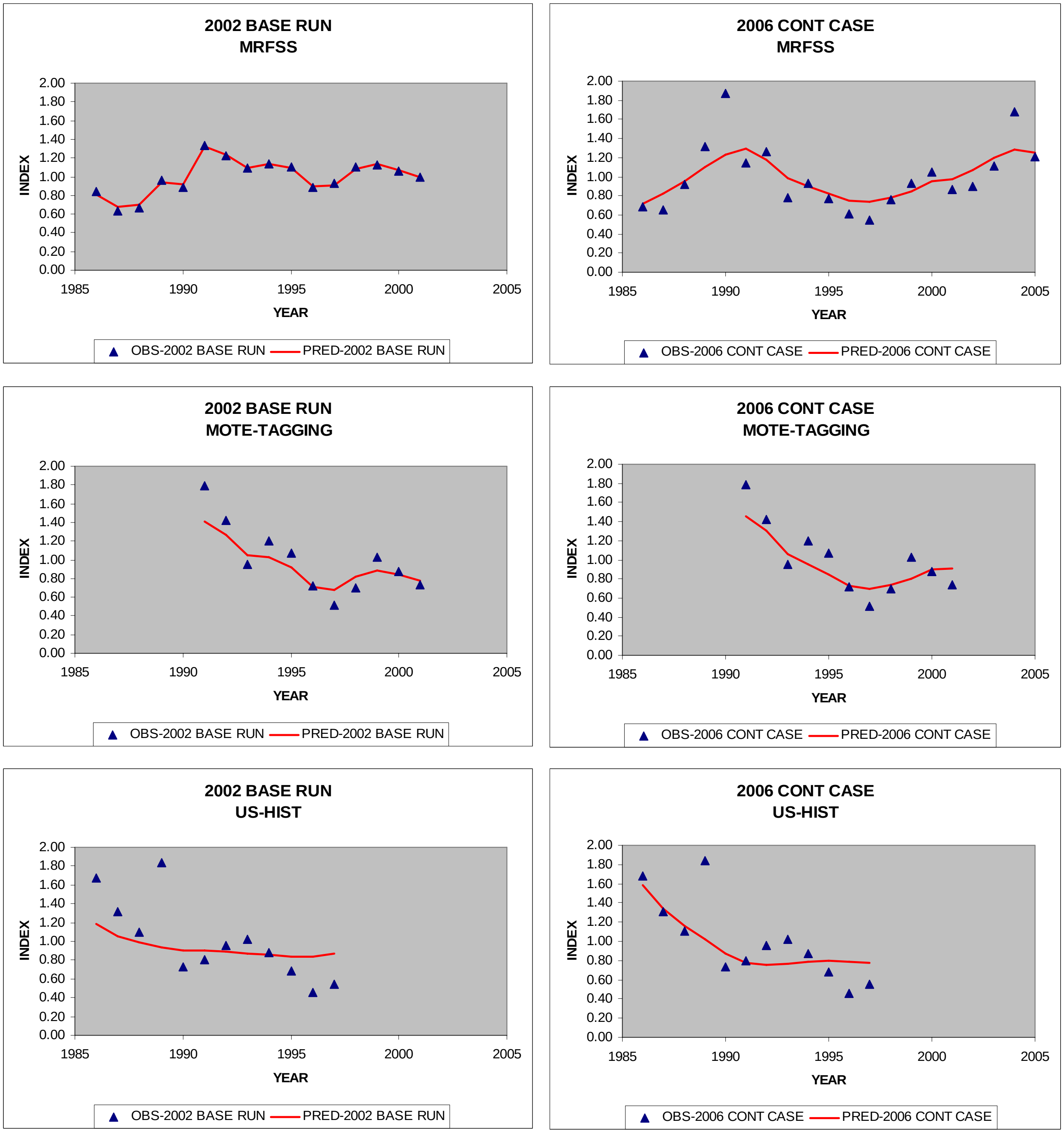


Figure 3.1.2.1.3 (*CONTINUED*) Fits to the indices of abundance for the 2002 base run (left hand panels) and the 2006 continuity run (right hand panels).

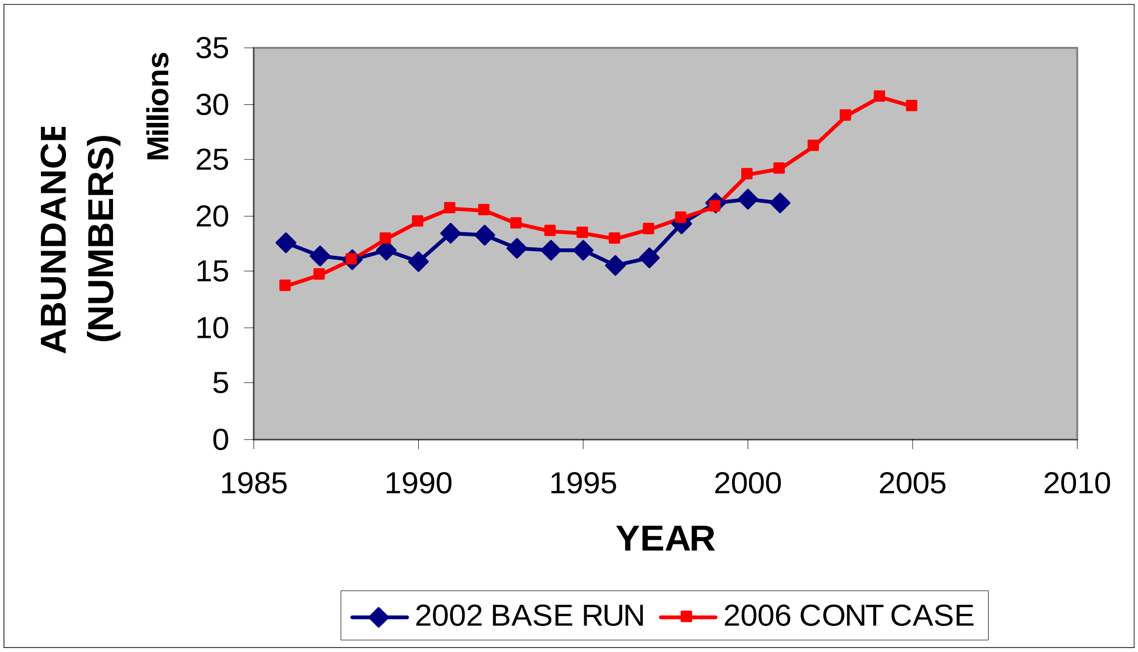


Figure 3.1.2.3.1. Abundance of red grouper (numbers) for the 2006 continuity case and the 2002 base run.

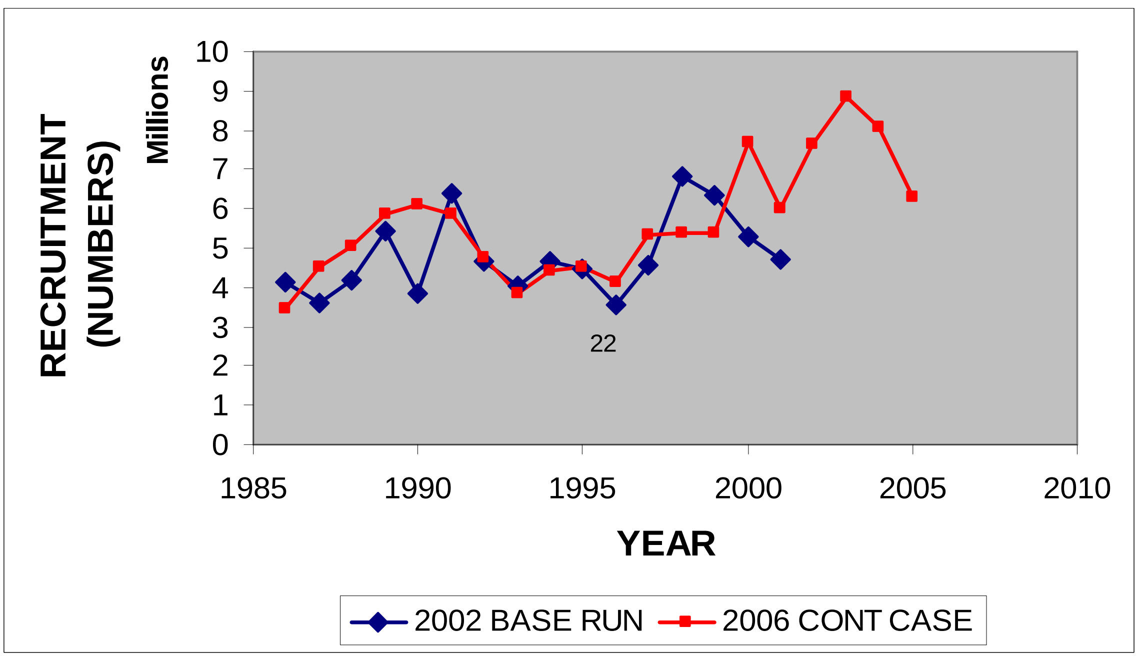
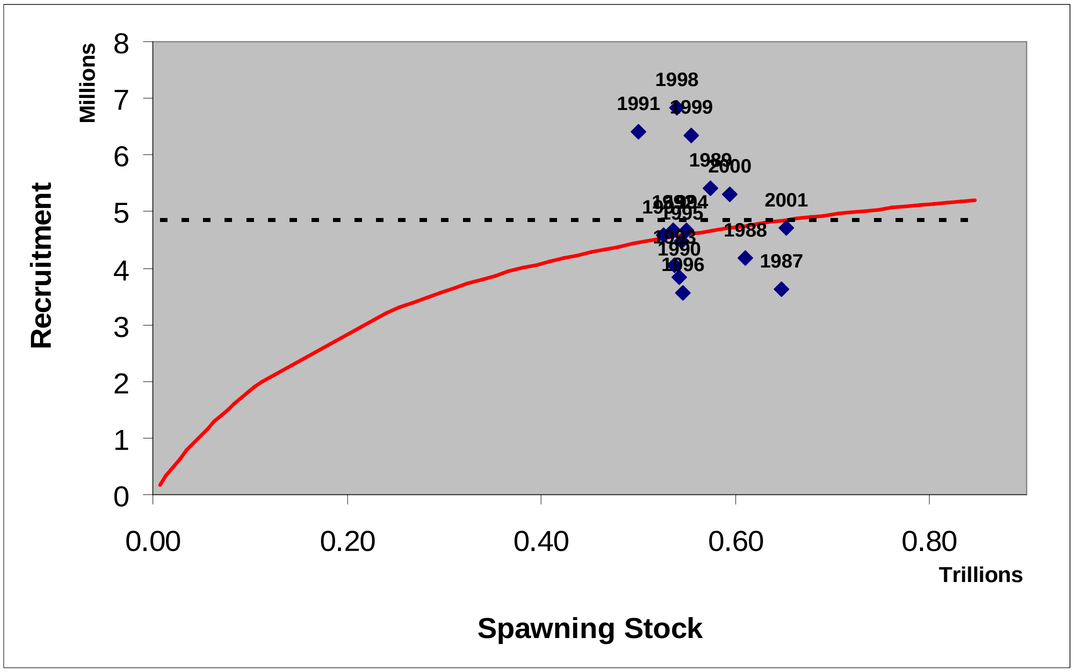


Figure 3.1.2.3.2. Annual recruitment estimates in numbers (Age 1) and the predicted recruitment from the Stock-Recruitment relationship for the 2006 continuity case and the 2002 base run.

A)



B)

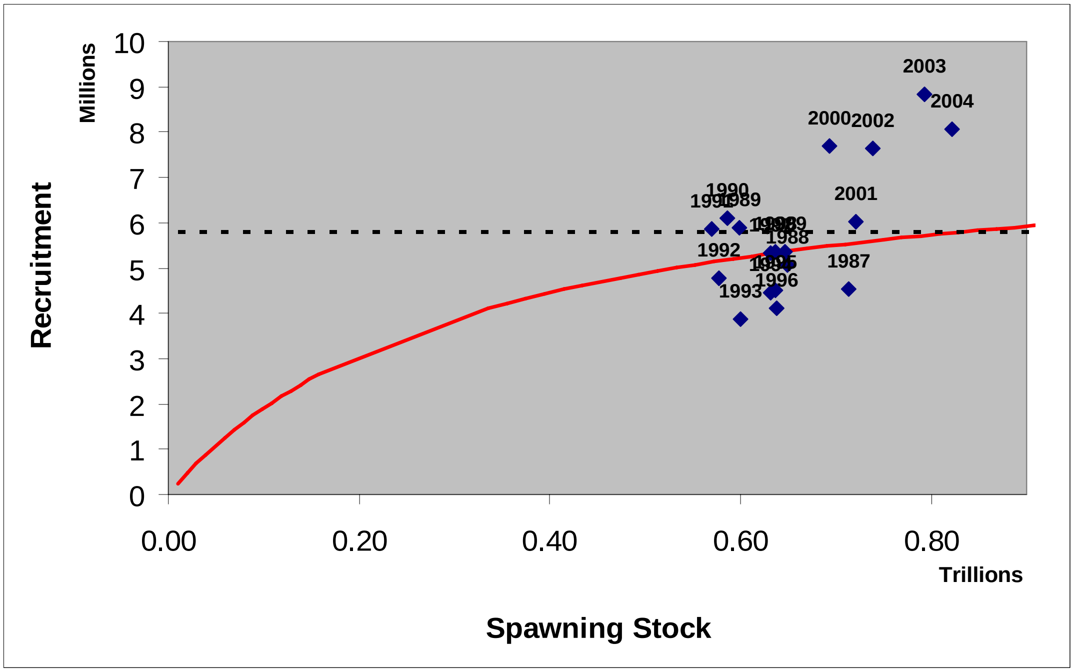
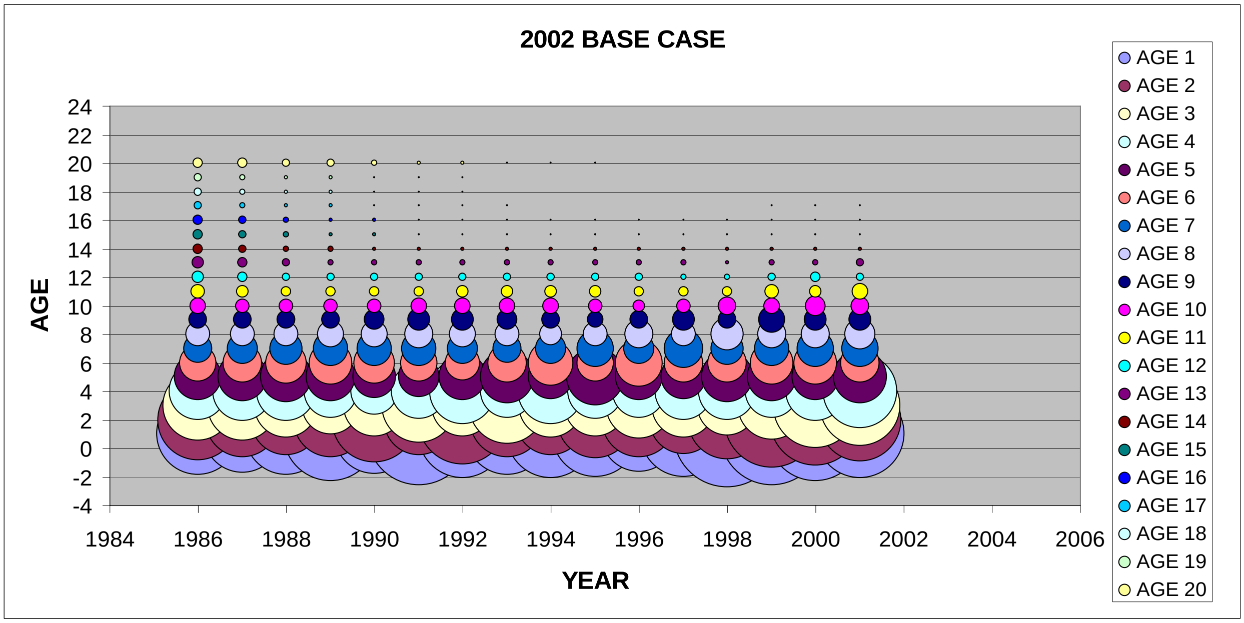


Figure 3.1.2.3.3. Stock-recruitment estimates with Beverton and Holt fit to the stock-recruitment estimates for the 2002 base run (**A**) and the 2006 continuity case (**B**). NOTE: Recruitment occurs at age-1.

A)



B)

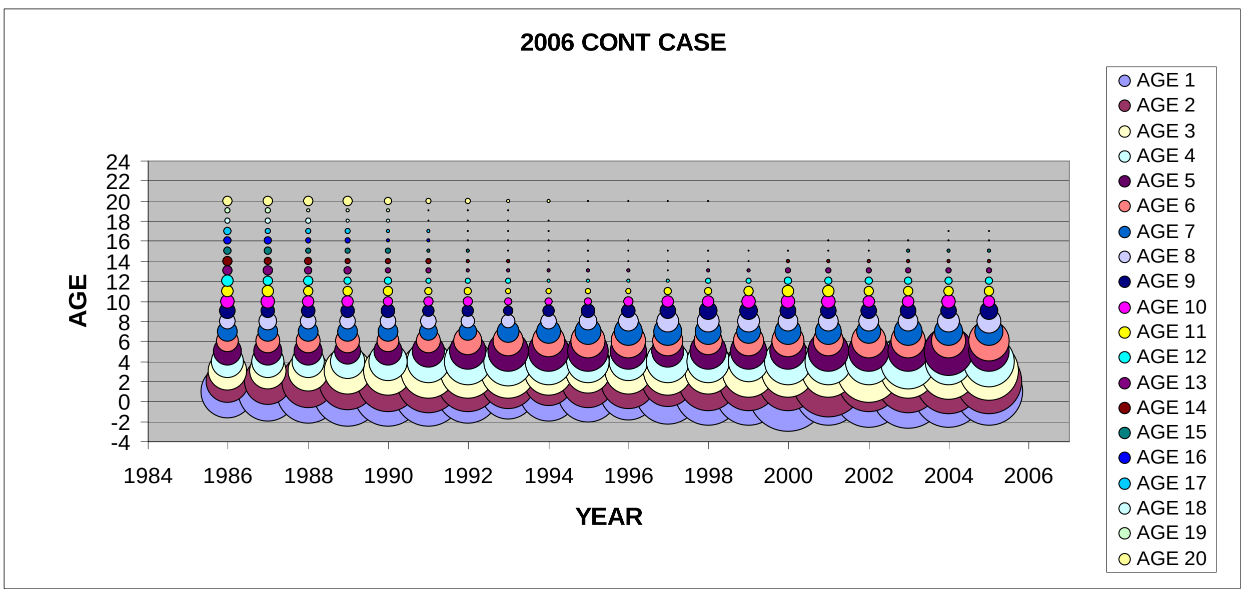
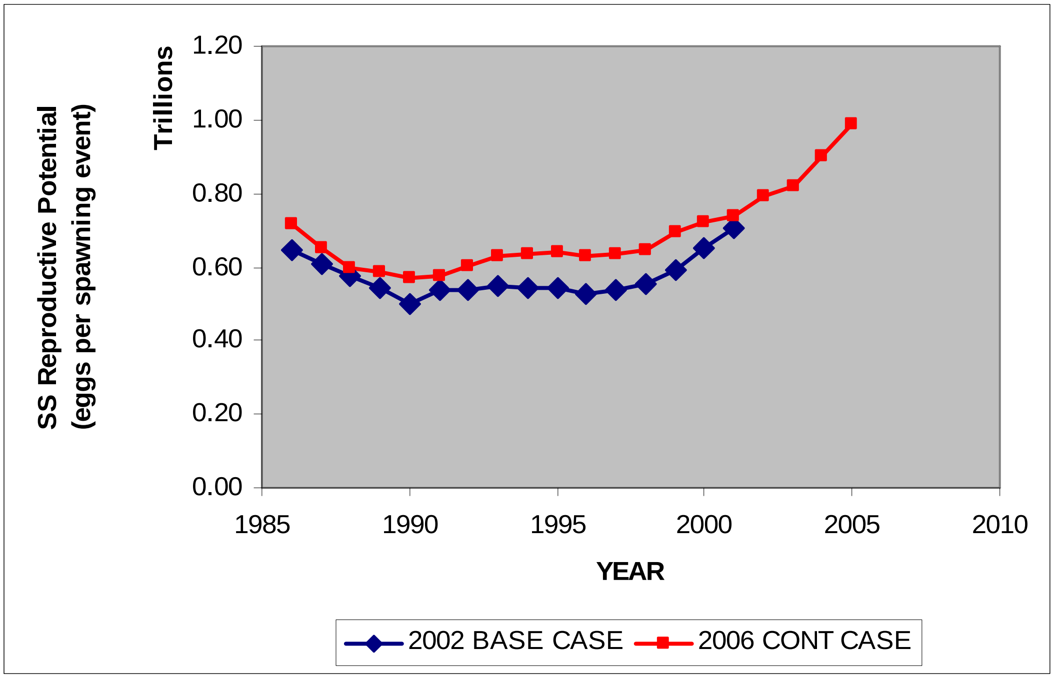


Figure 3.1.2.3.4. Abundance-at-age (numbers) for the 2002 base run (**A**) and the 2006 continuity case (**B**).

A)



B)

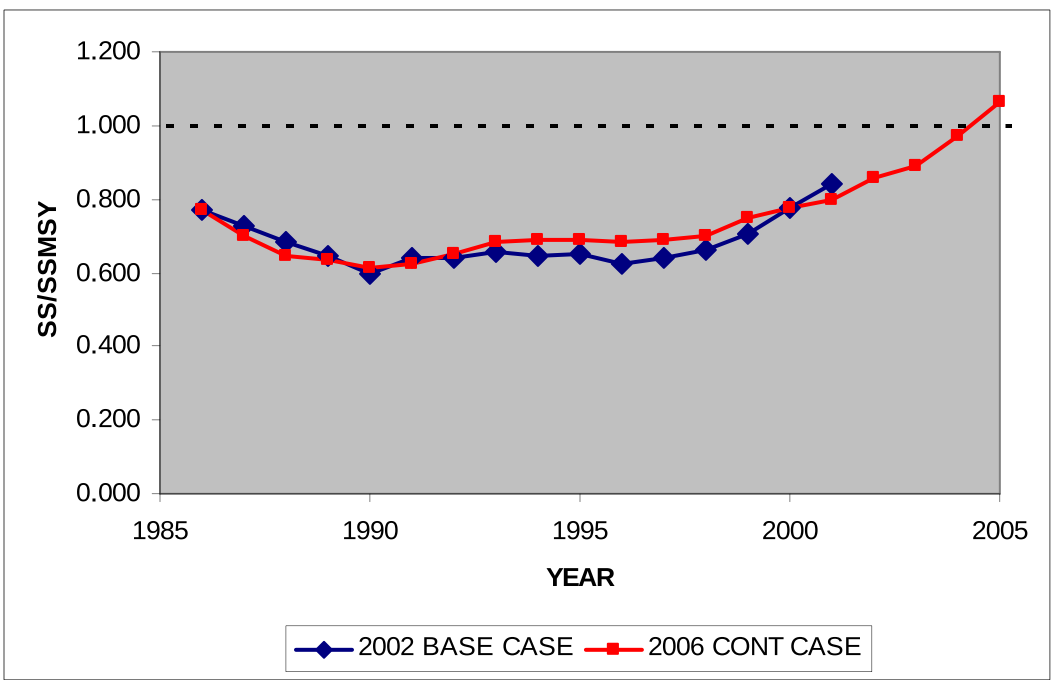


Figure 3.1.2.4.1. A) Spawning stock reproductive potential (SS; eggs per spawning event) and **B)** SS as a fraction of SS at maximum sustainable yield for the 2006 continuity case and the 2002 base run.

A) B)

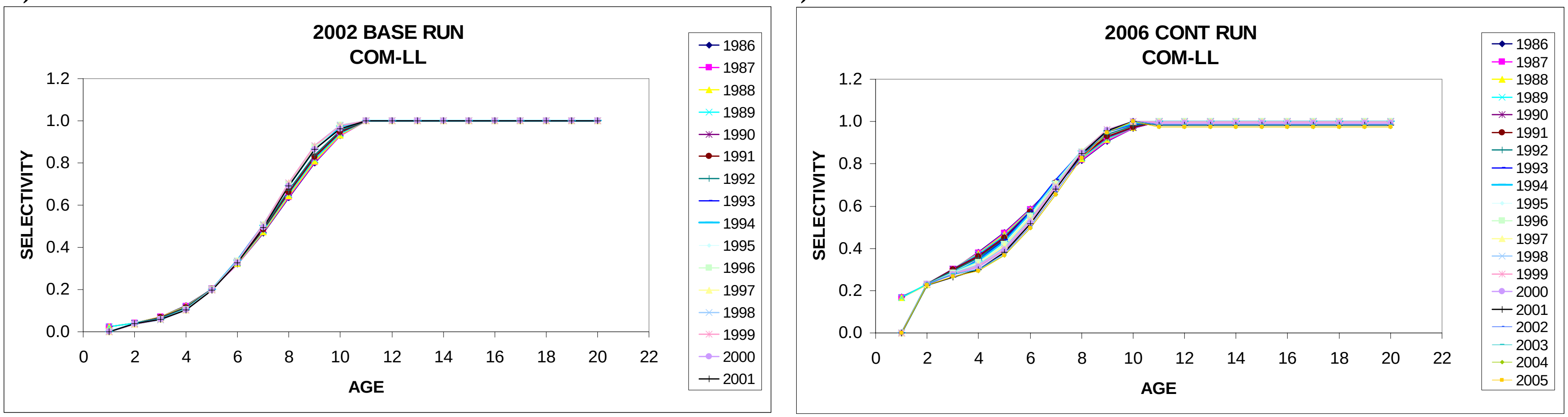


Figure 3.1.2.5.1. Estimated selectivity-at-age for the commercial longline fleet for the 2002 base run (**A**) and the 2006 continuity case (**B**).

A) B)

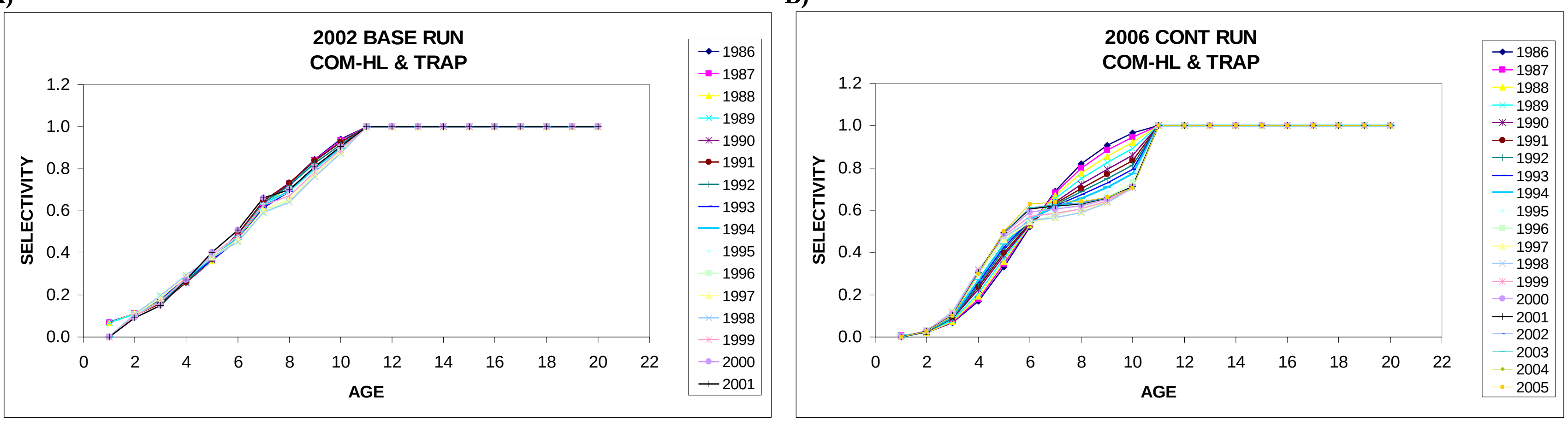
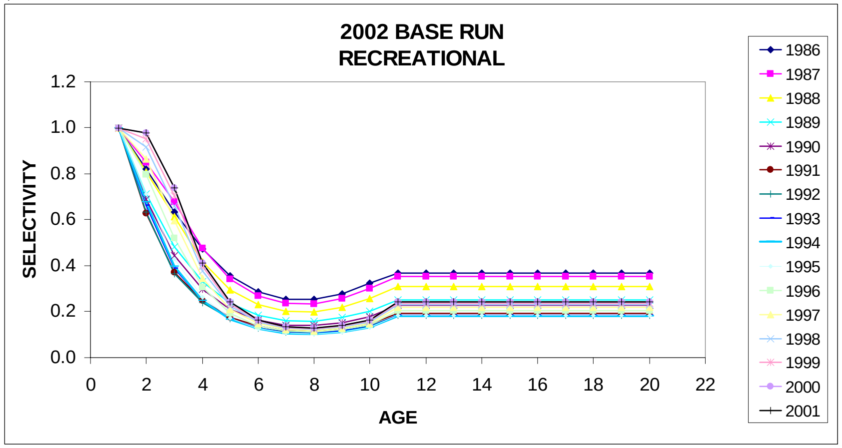


Figure 3.1.2.5.2. Estimated selectivity-at-age for the commercial handline and trap fleets for the 2002 base run (**A**) and the 2006 continuity case (**B**).

A)



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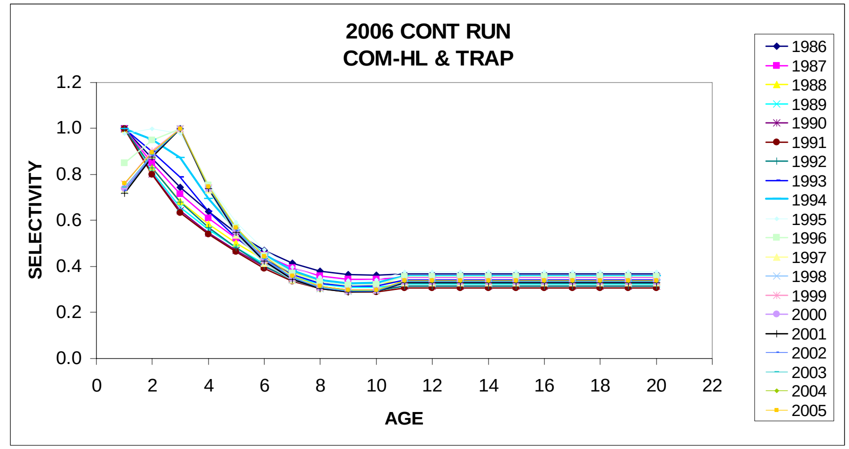
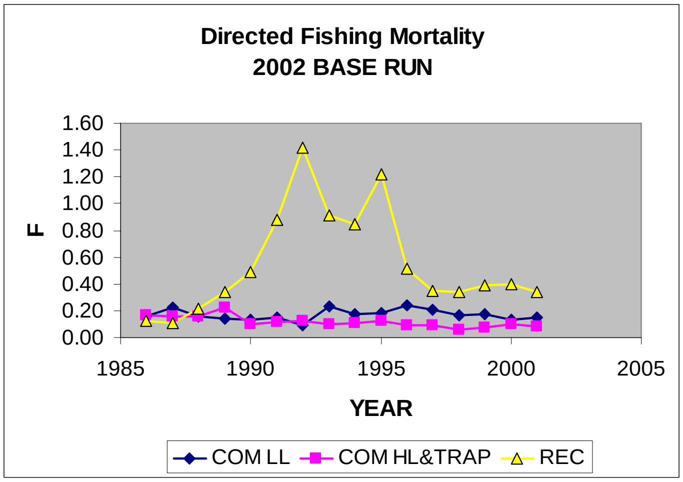


Figure 3.1.2.5.3. Estimated selectivity-at-age for the recreational fleet for the 2002 base run (**A**) and the 2006 continuity case (**B**).

A)



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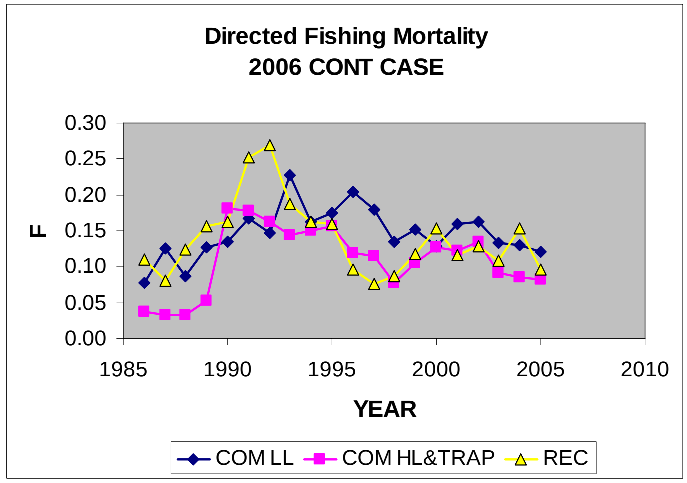
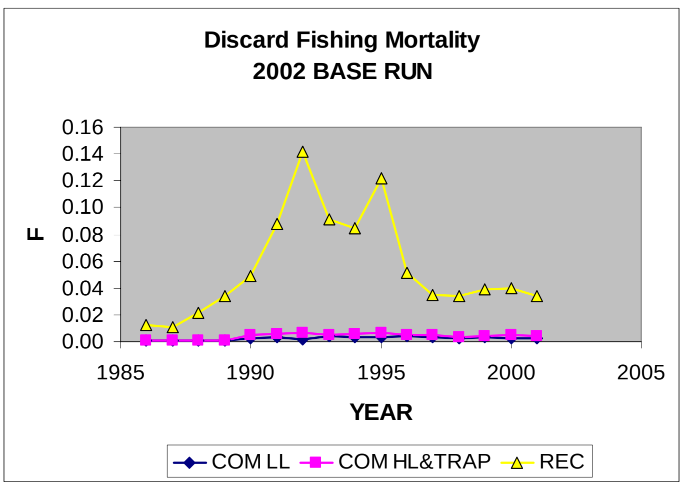


Figure 3.1.2.6.1. Fleet-specific fishing directed mortality rates for the 2002 base run (**A**) and the 2006 continuity case (**B**).

A)



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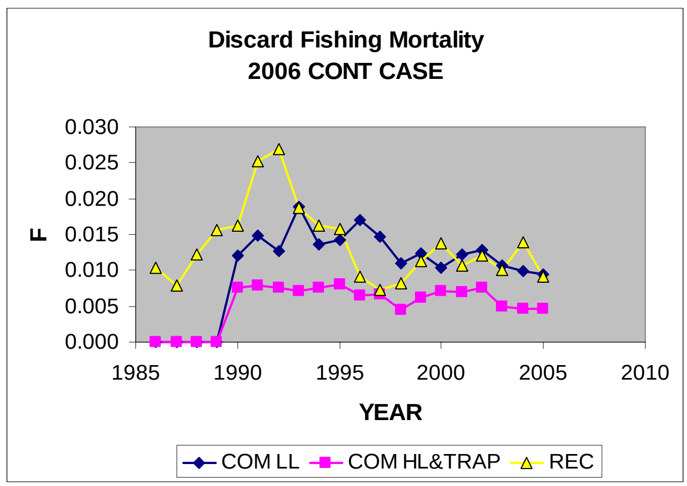


Figure 3.1.2.6.2. Fleet-specific discard fishing mortality rates for the 2002 base run (**A**) and the 2006 continuity case (**B**).

A) B)

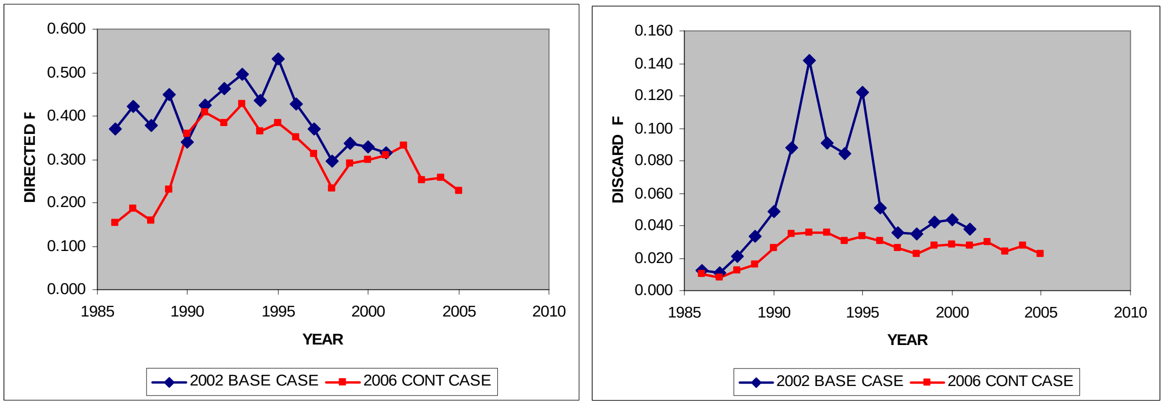


Figure 3.1.2.6.3. Total fishing mortality (F) for the directed landings (**A**) and the discards from the directed fleets (**B**) for the 2006 continuity case and the 2002 base run.

A) B)

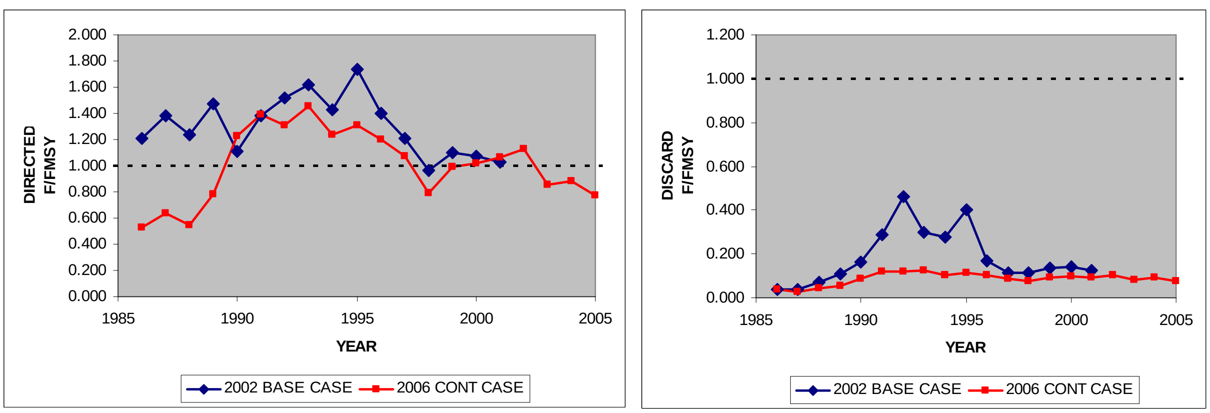


Figure 3.1.2.6.4. Total fishing mortality as a fraction of F_{MSY} for the directed landings (**A**) and the discards from the directed fleets (**B**) for the 2006 continuity case and the 2002 base run.

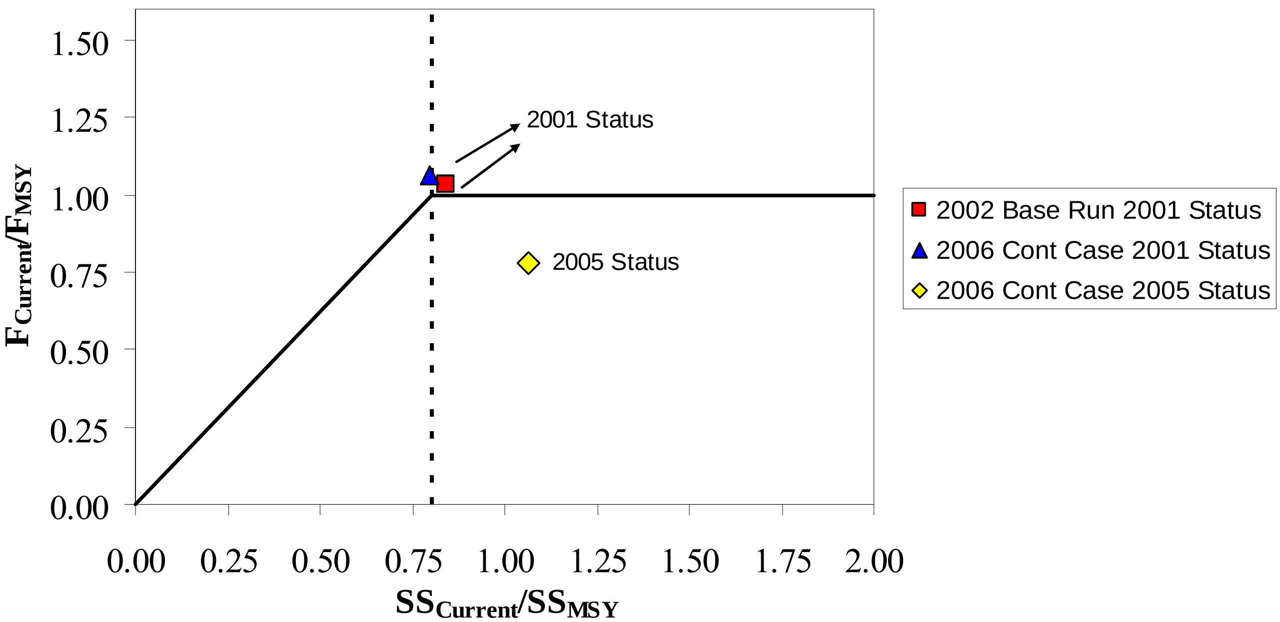


Figure 3.1.2.10.1. Control rules plots for the 2006 continuity case and the 2002 base run. The SS/SB_{MSY} reference line is at 1-M where M is the natural mortality rate. Values < 1-M indicate an overfished population. The F/F_{MSY} reference line is at 1.0. Values > 1.0 indicate overfishing.

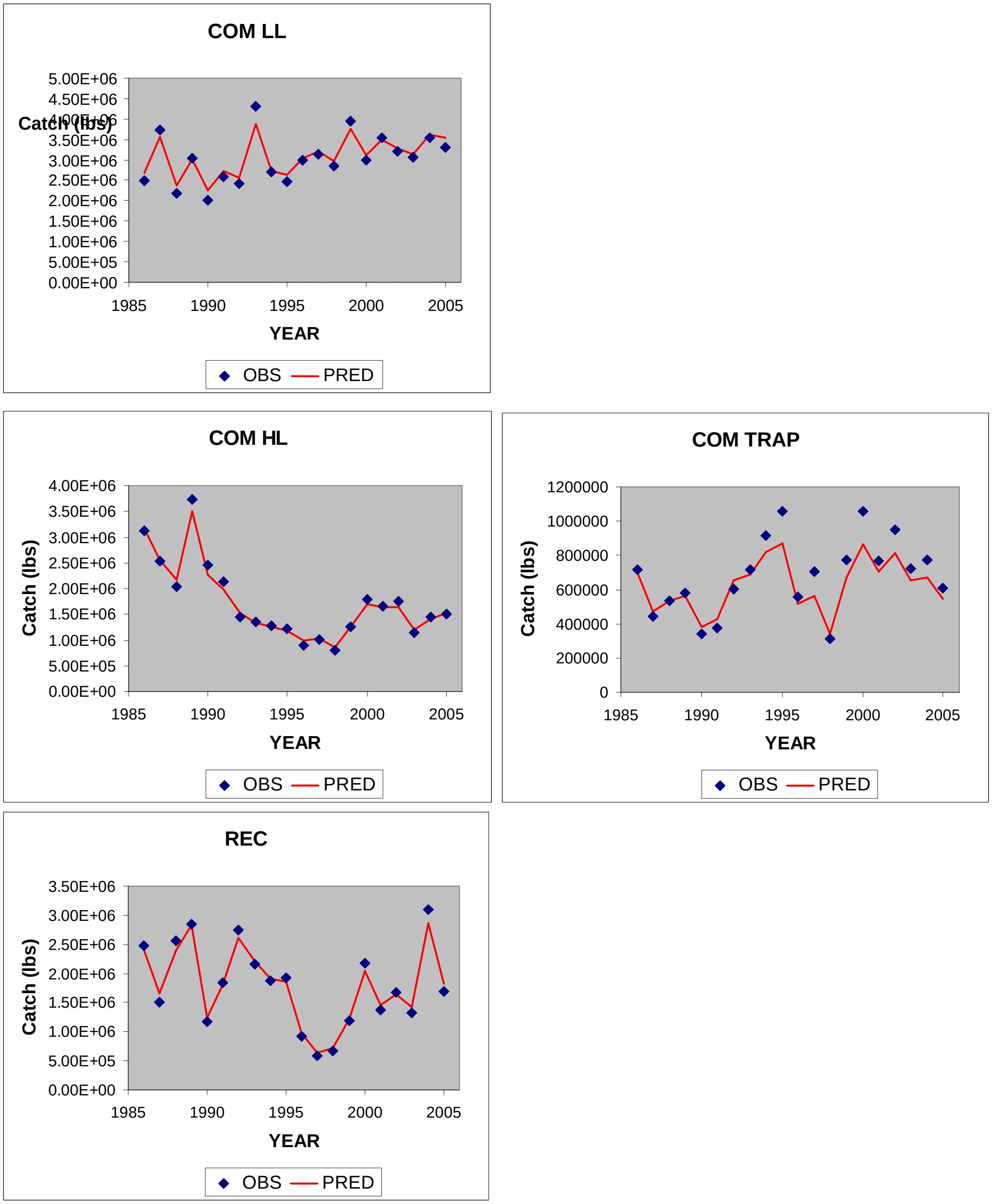


Figure 3.2.2.1.1 Fits to the catch series.

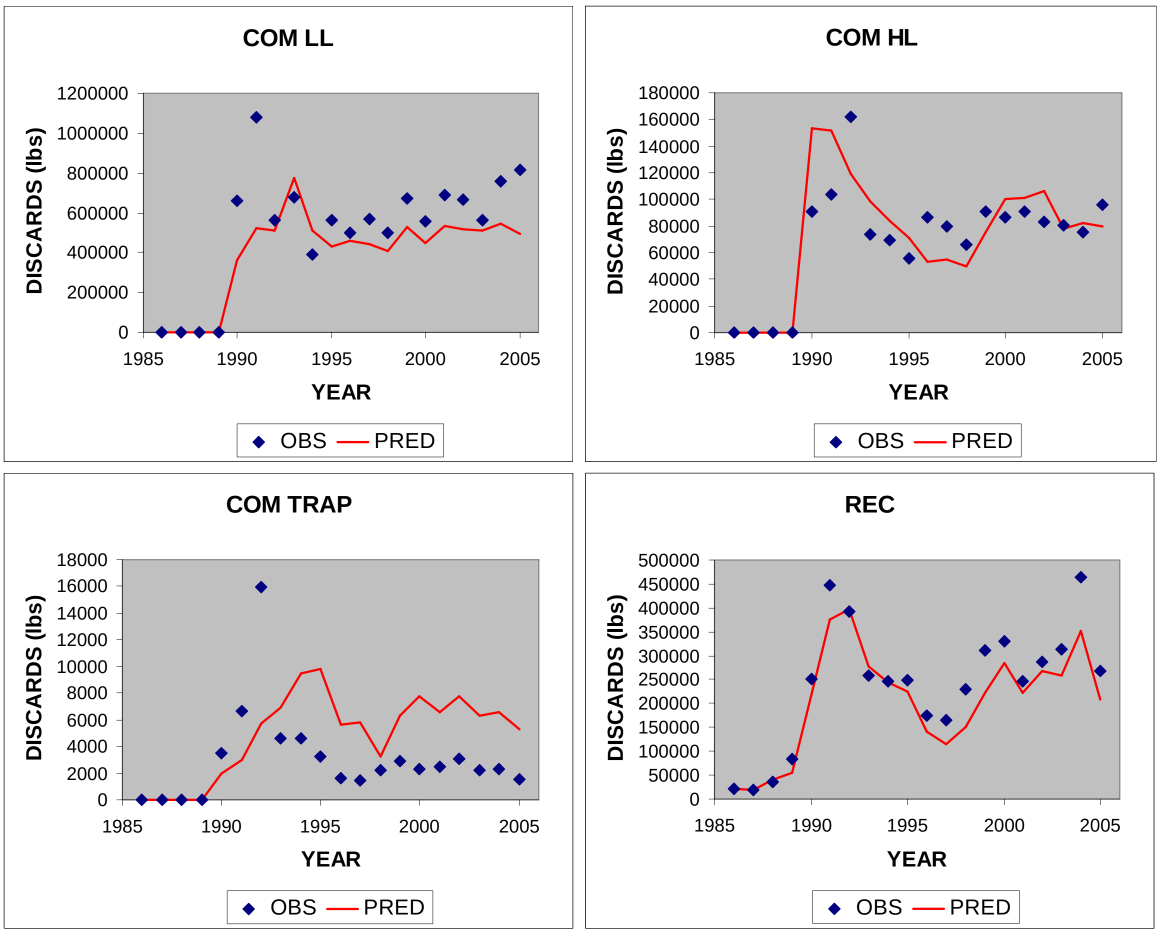


Figure 3.2.2.1.2 Fits to the discard series.

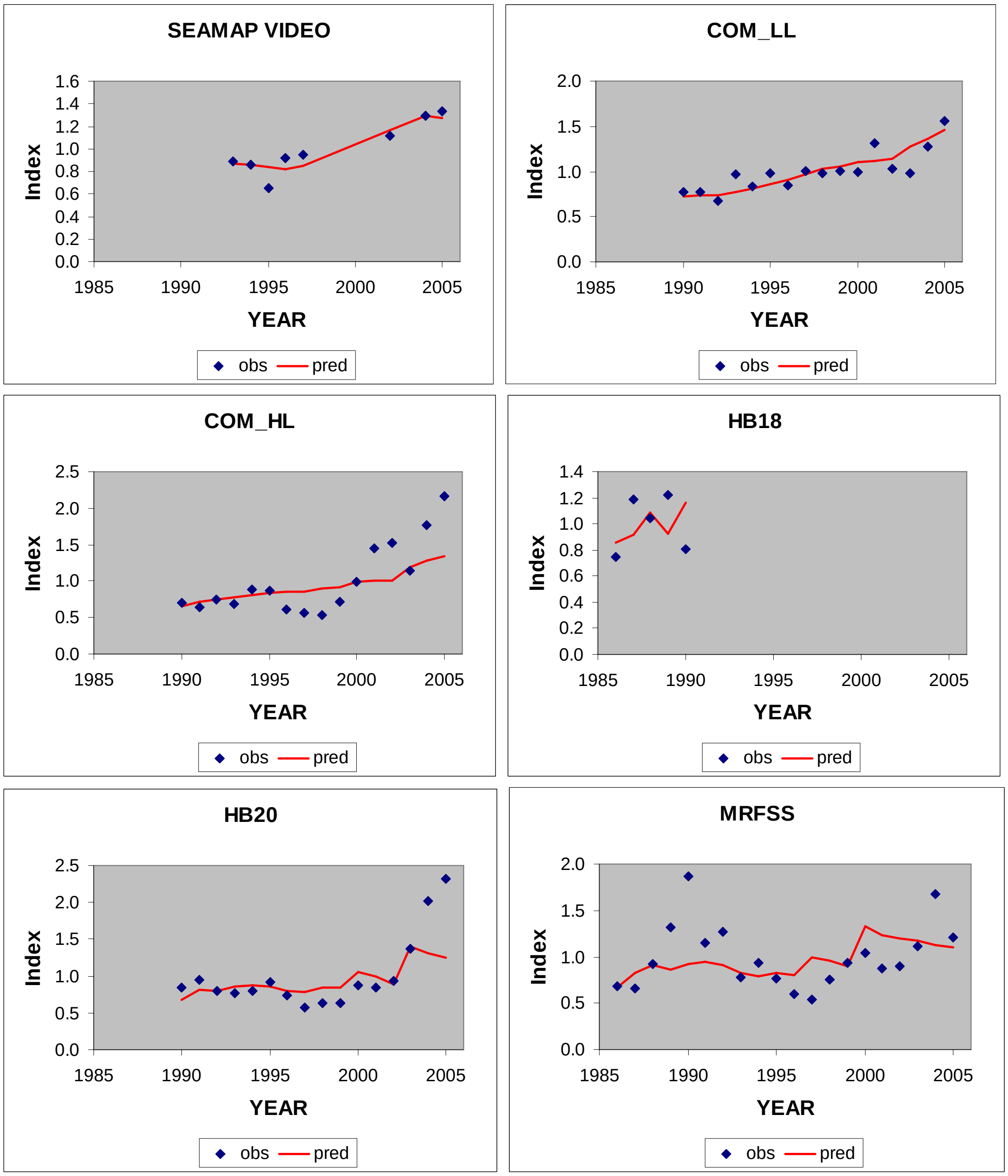


Figure 3.2.2.1.3 Fits to the indices of abundance..

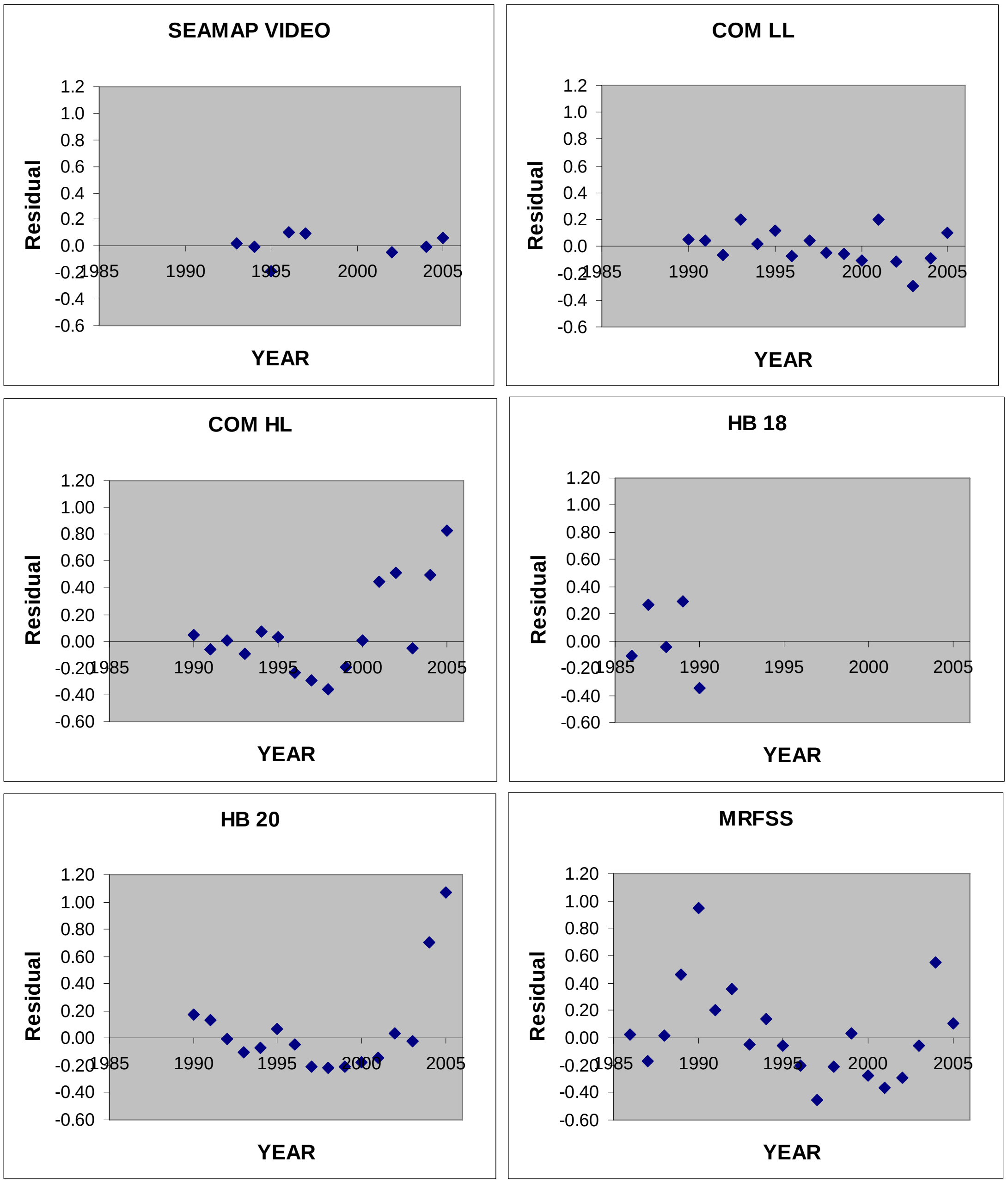


Figure 3.2.2.1.4 Residuals of the fits to the indices of abundance..

FITS TO AGE COMPOSITION – COMMERCIAL LONGLINE

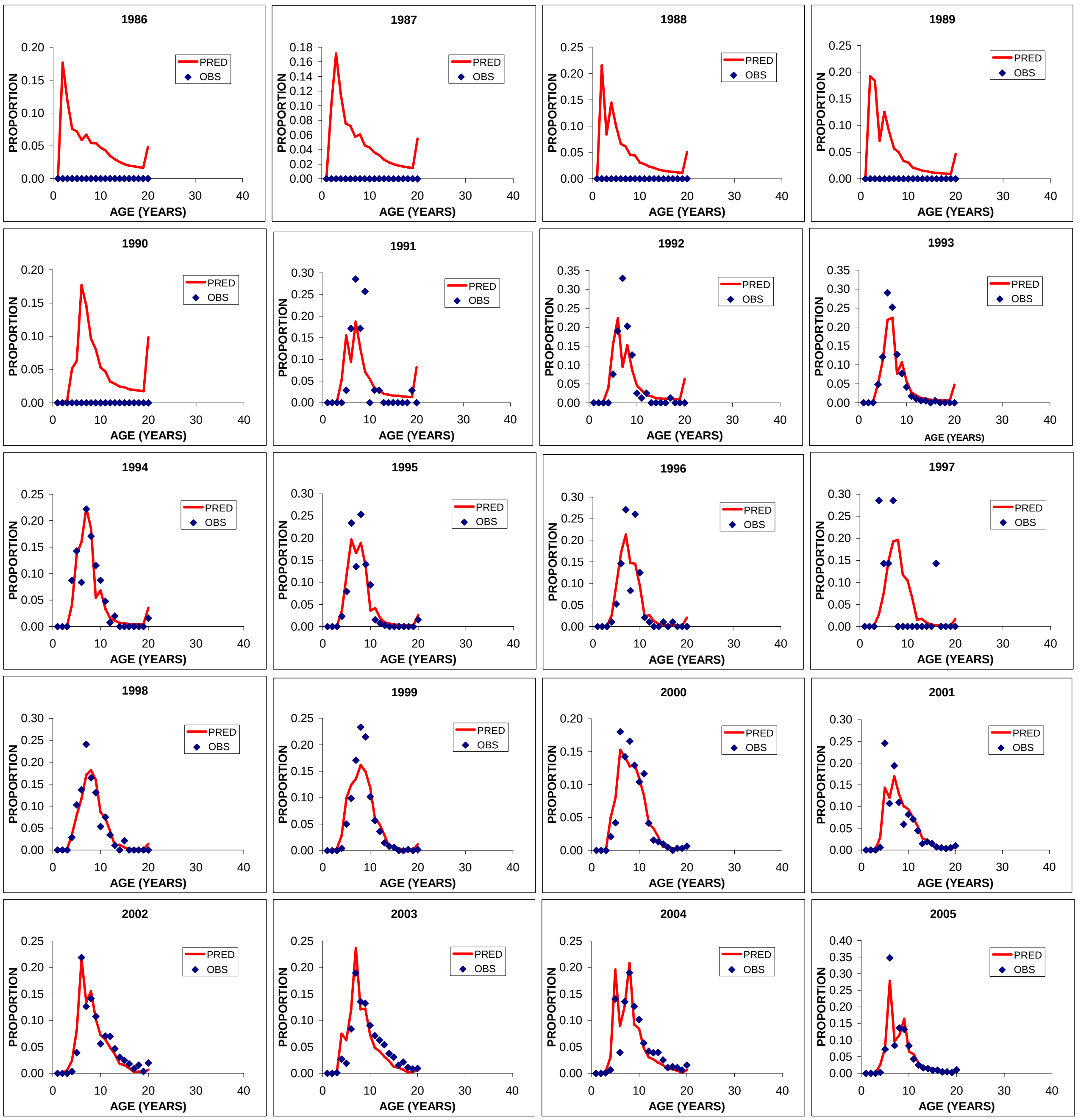


Figure 3.2.2.1.5. Fits to the observed age composition (otoliths) for the commercial longline fleet.

FITS TO AGE COMPOSITION – COMMERCIAL HANDLINE

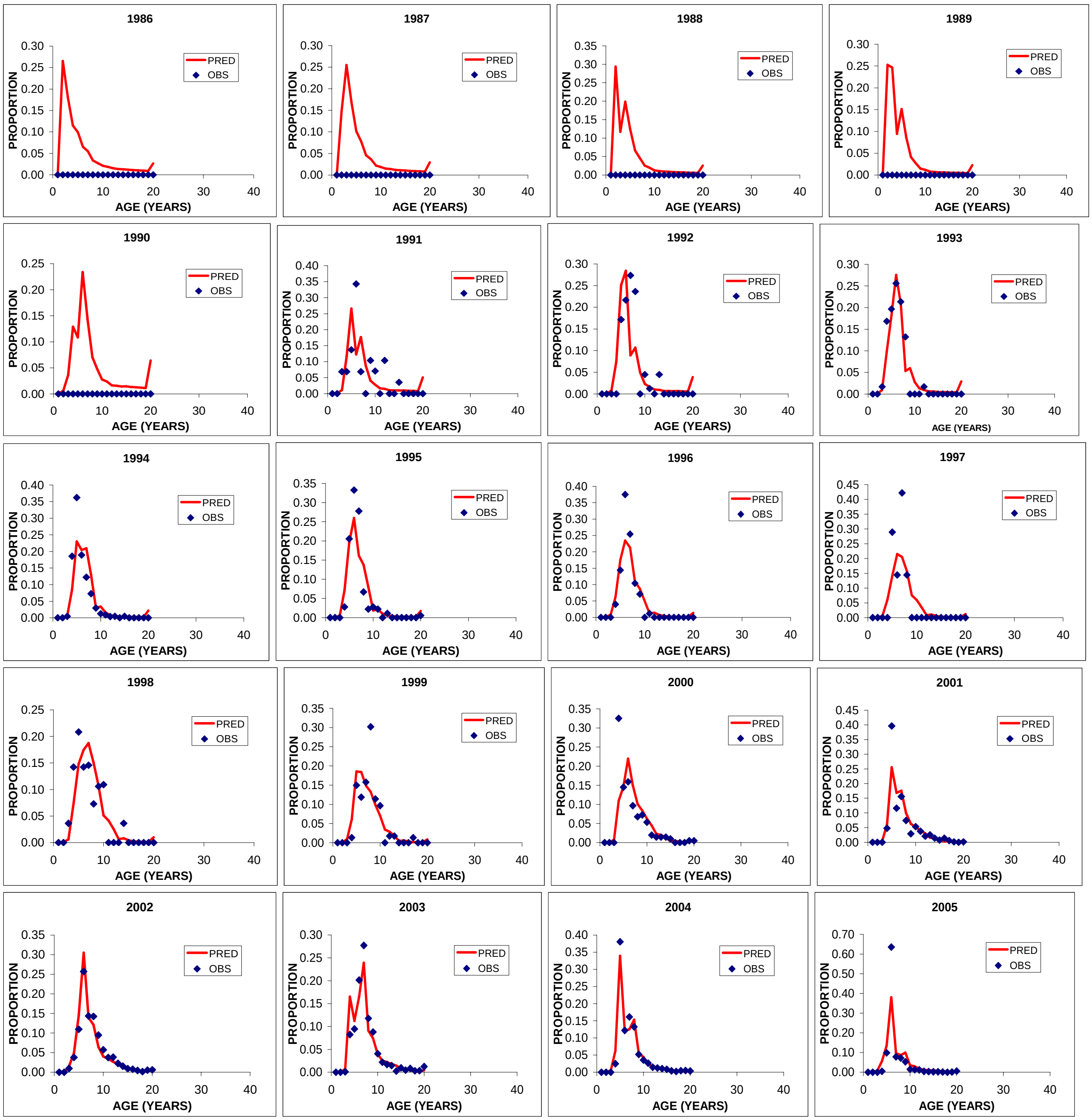


Figure 3.2.2.1.6. Fits to the observed age composition (otoliths) for the commercial handline fleet.

FITS TO AGE COMPOSITION – COMMERCIAL TRAP

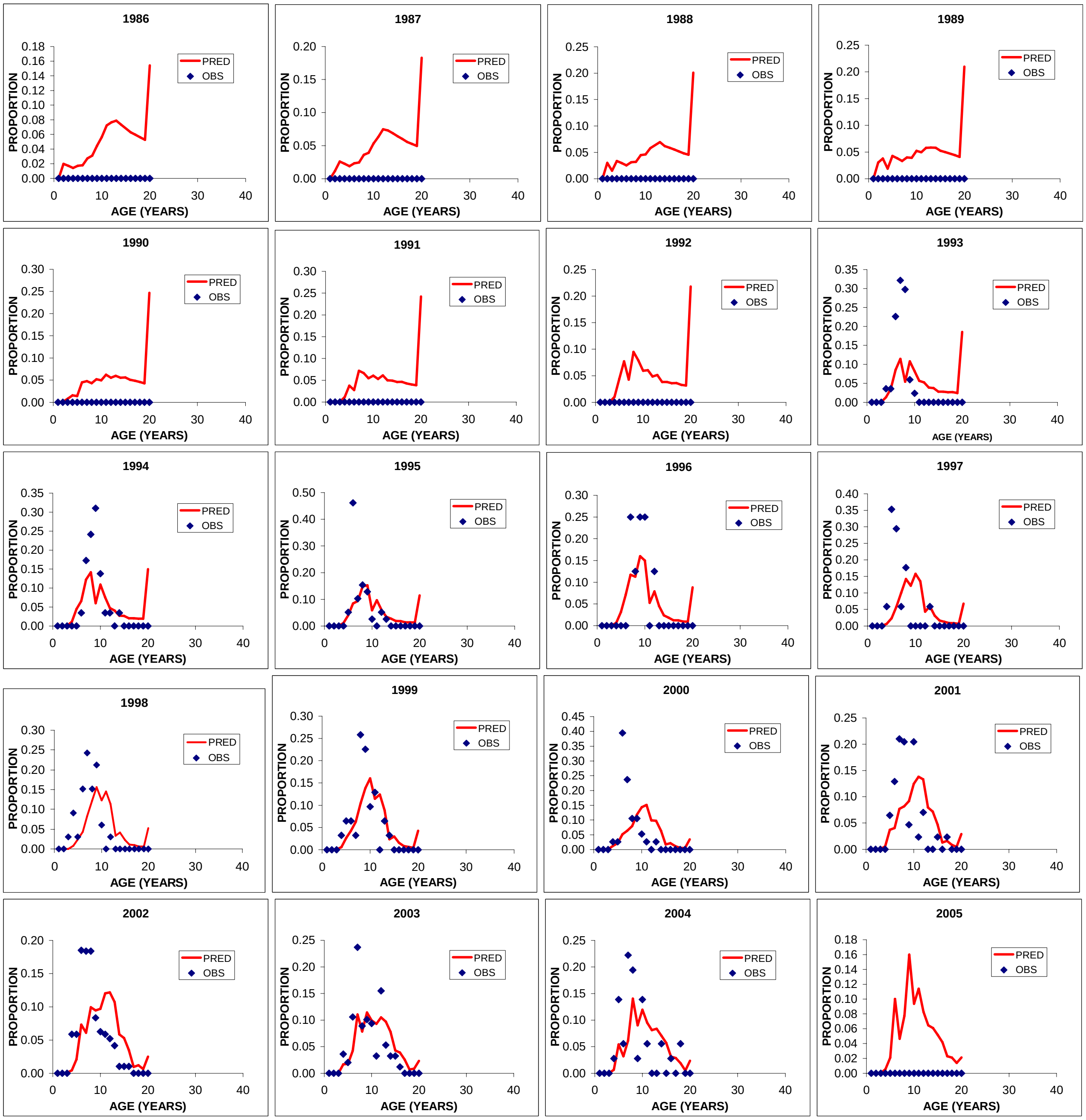


Figure 3.2.2.1.7. Fits to the observed age composition (otoliths) for the commercial trap fleet.

FITS TO AGE COMPOSITION – RECREATIONAL

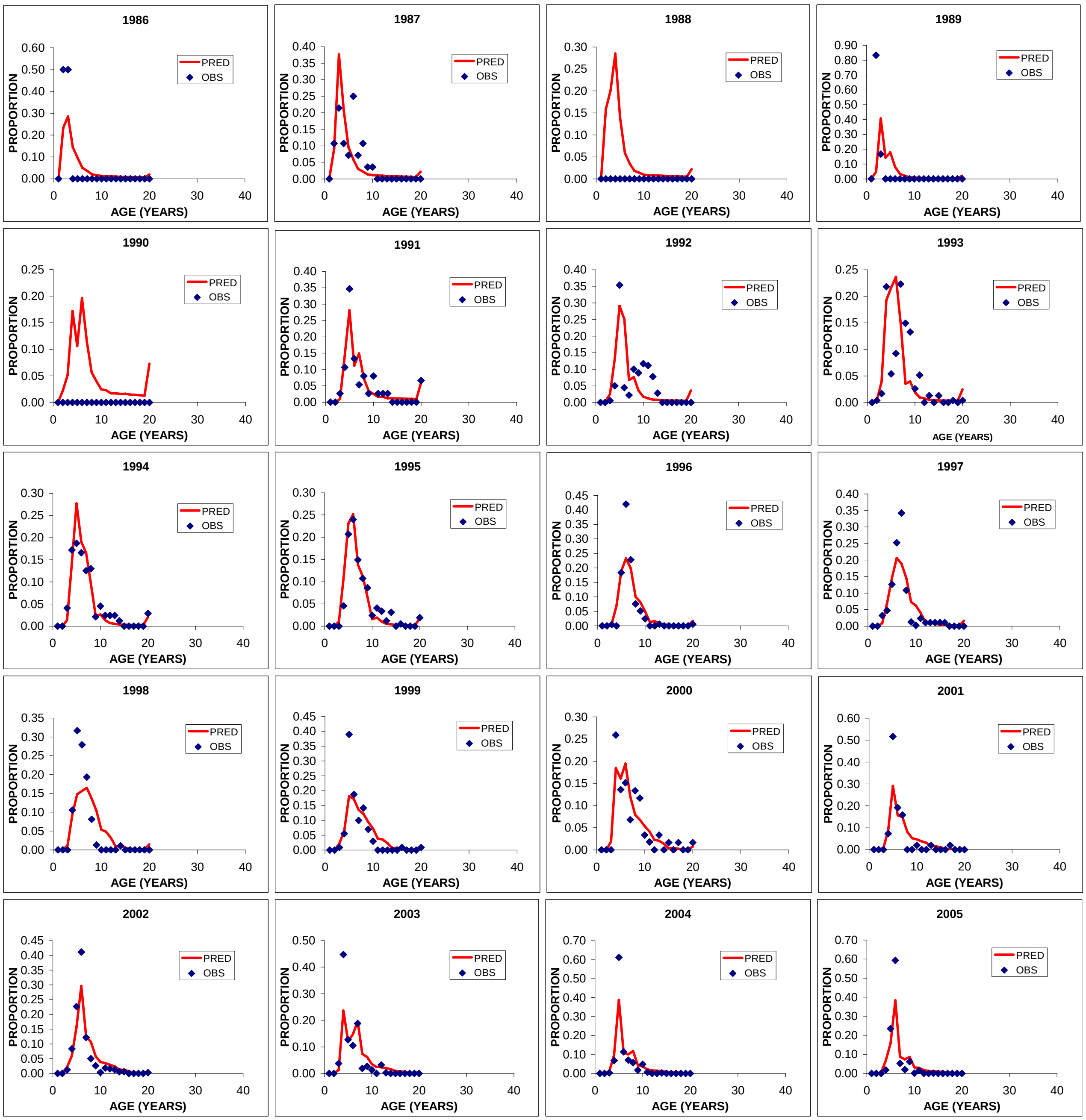


Figure 3.2.2.1.8. Fits to the observed age composition (otoliths) for the recreational fleet.

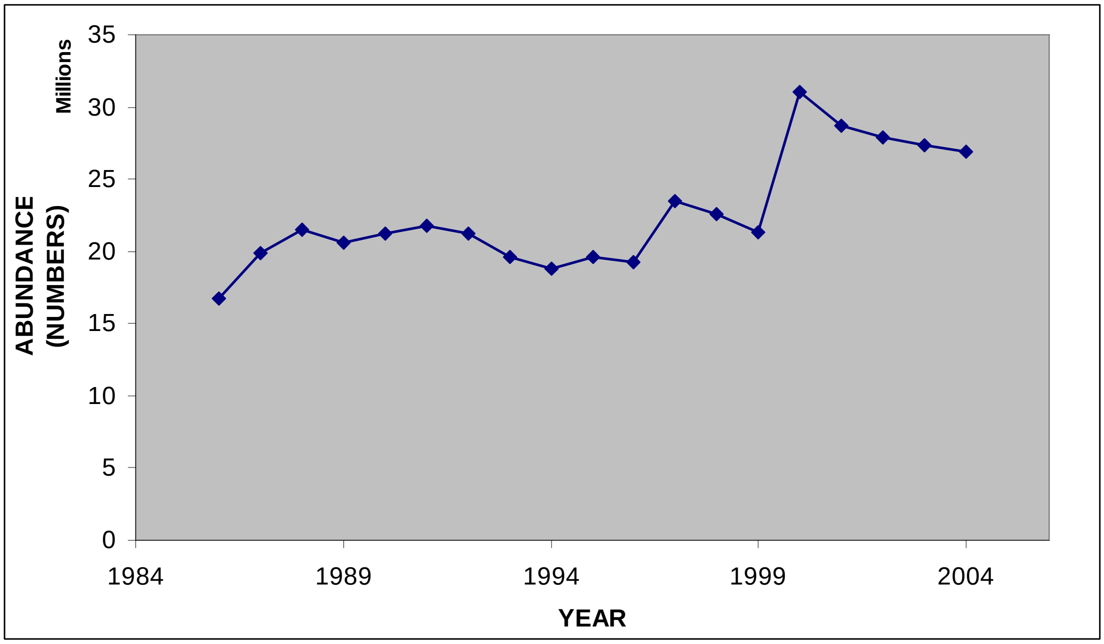


Figure 3.2.2.3.1. Abundance of red grouper (numbers).

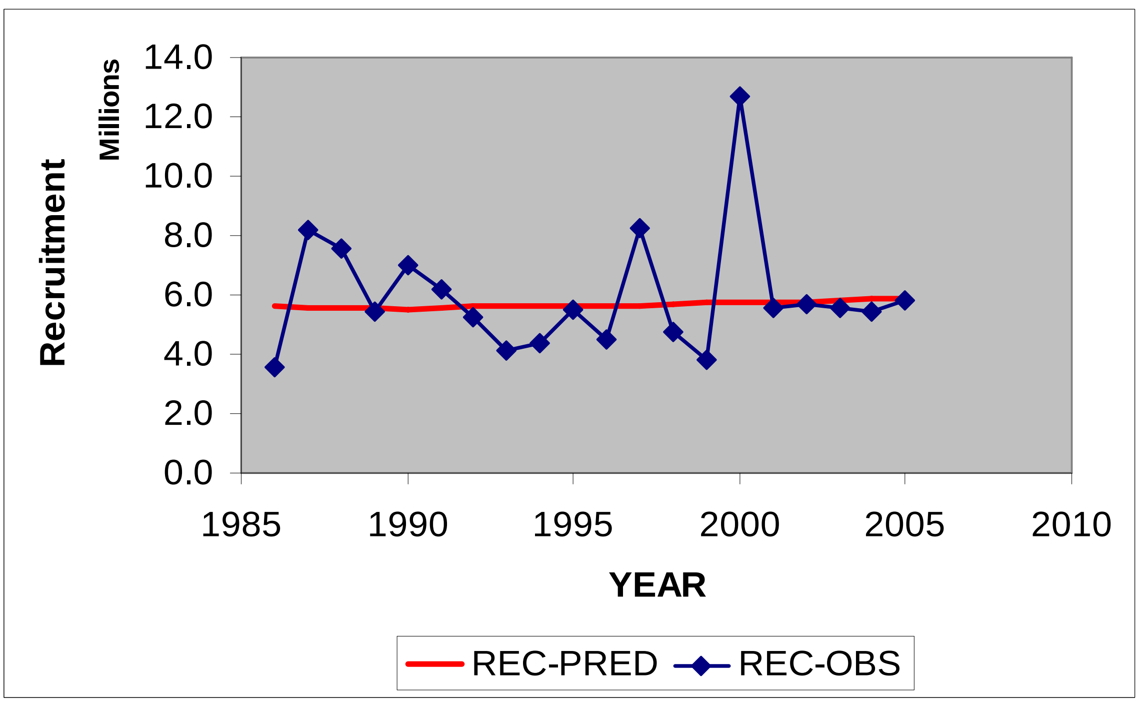


Figure 3.2.2.3.2. Annual recruitment estimates in numbers (Age 1) and the predicted recruitment from the Stock-Recruitment relationship

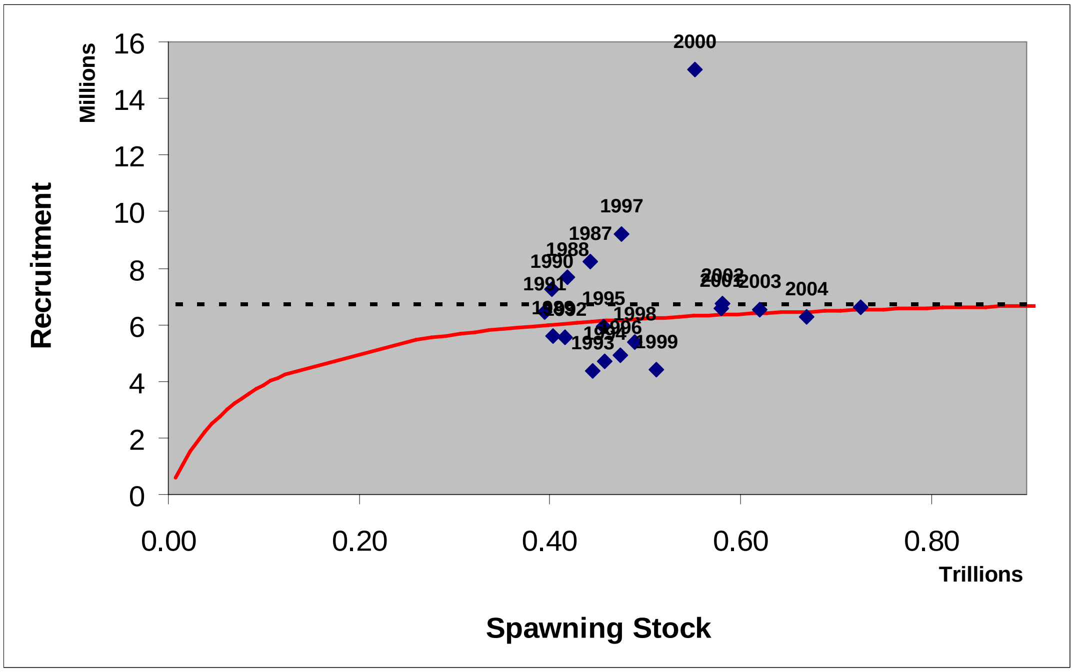


Figure 3.2.2.3.3. Stock-recruitment estimates with Beverton and Holt fit to the stock-recruitment estimates. Note the large year-class in 1999 (Age-1 in 2000).

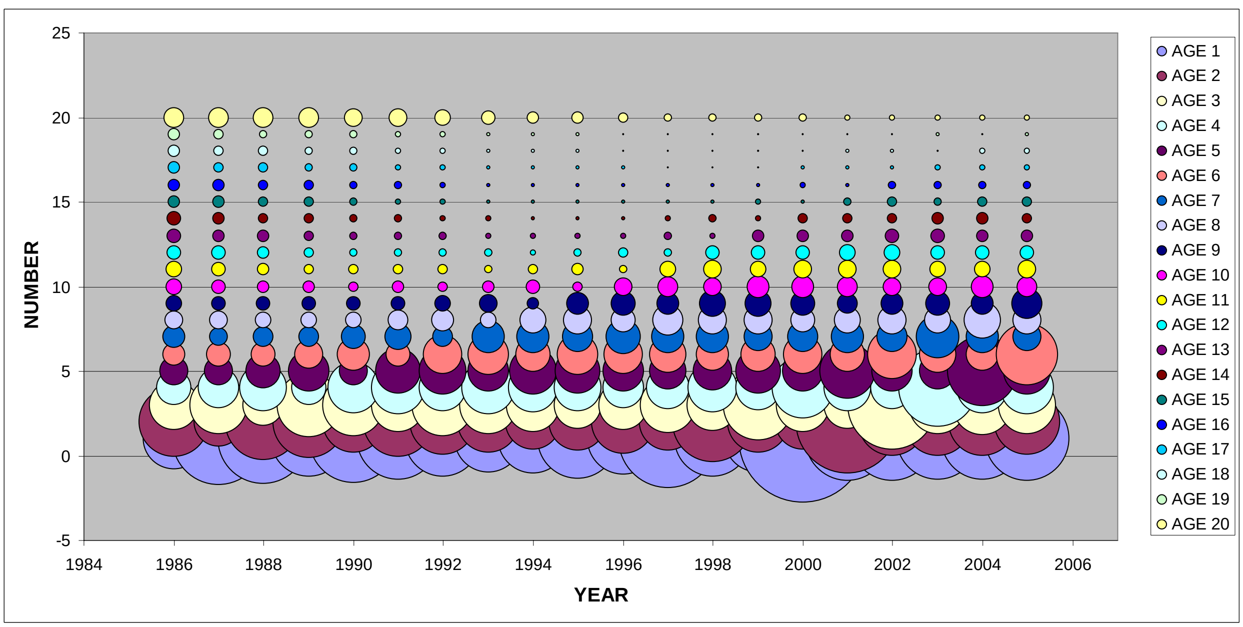
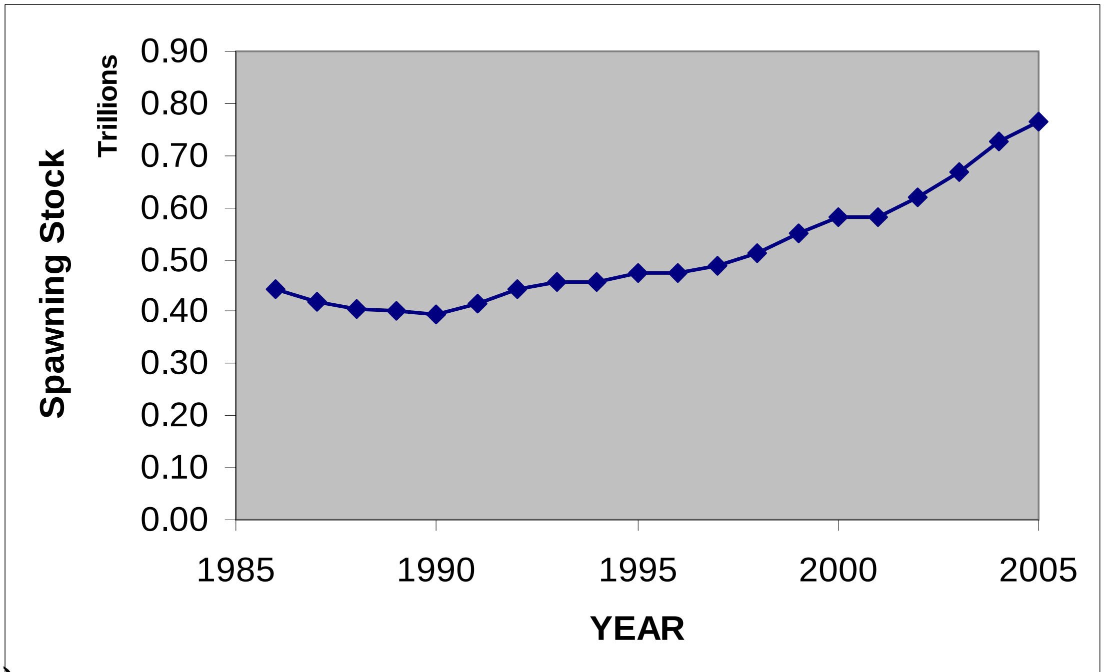


Figure 3.2.2.3.4. Abundance-at-age (numbers).

A)



B)

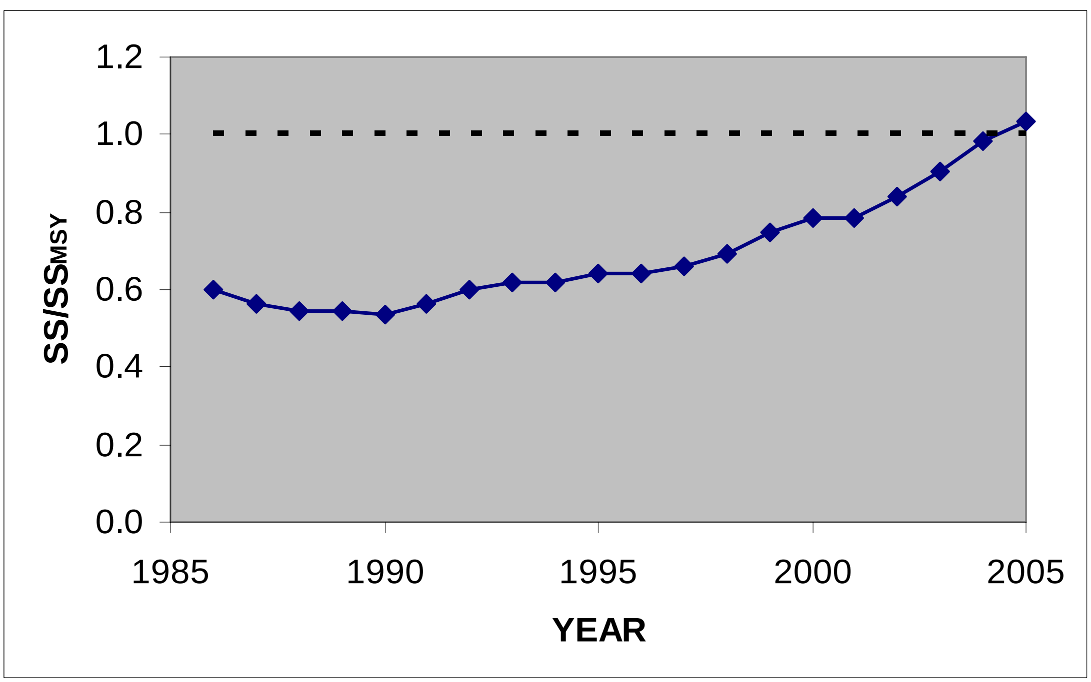


Figure 3.2.2.4.1. A) Spawning stock reproductive potential (SS; eggs per spawning event) and **B)** SS as a fraction of SS at maximum sustainable yield.

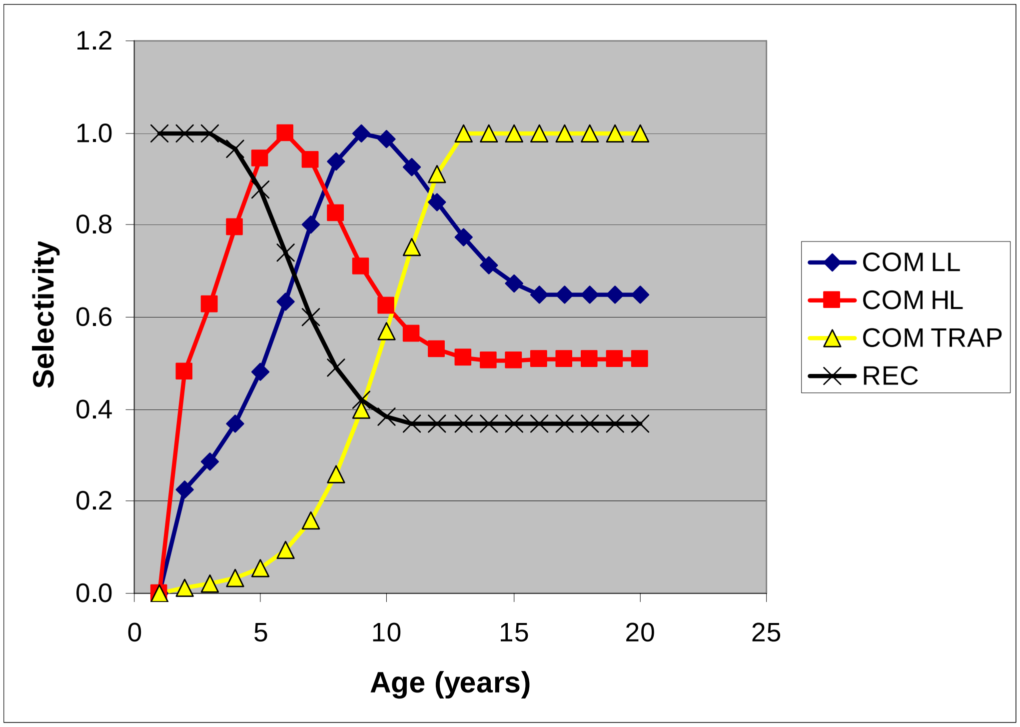
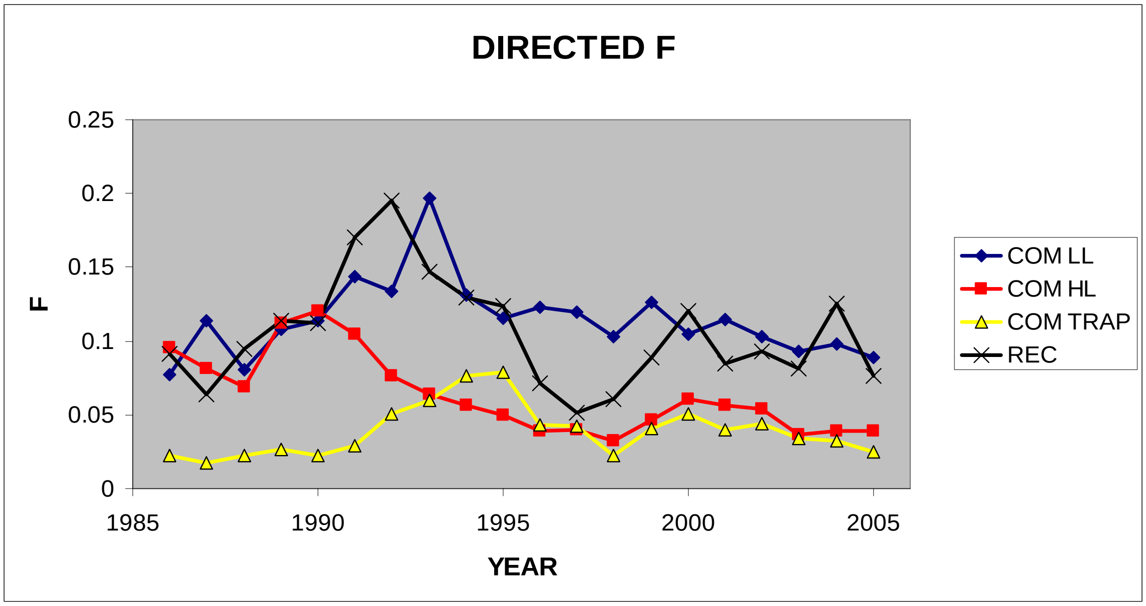


Figure 3.2.2.5.1. Estimated selectivity-at-age by fleet.

A)



B)

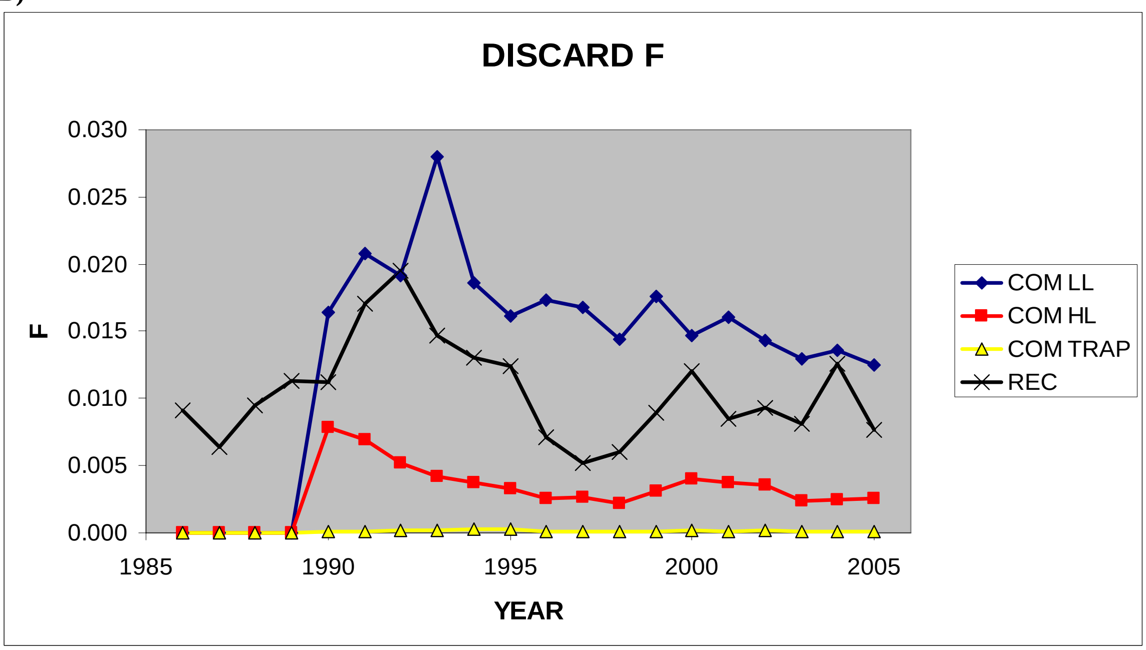
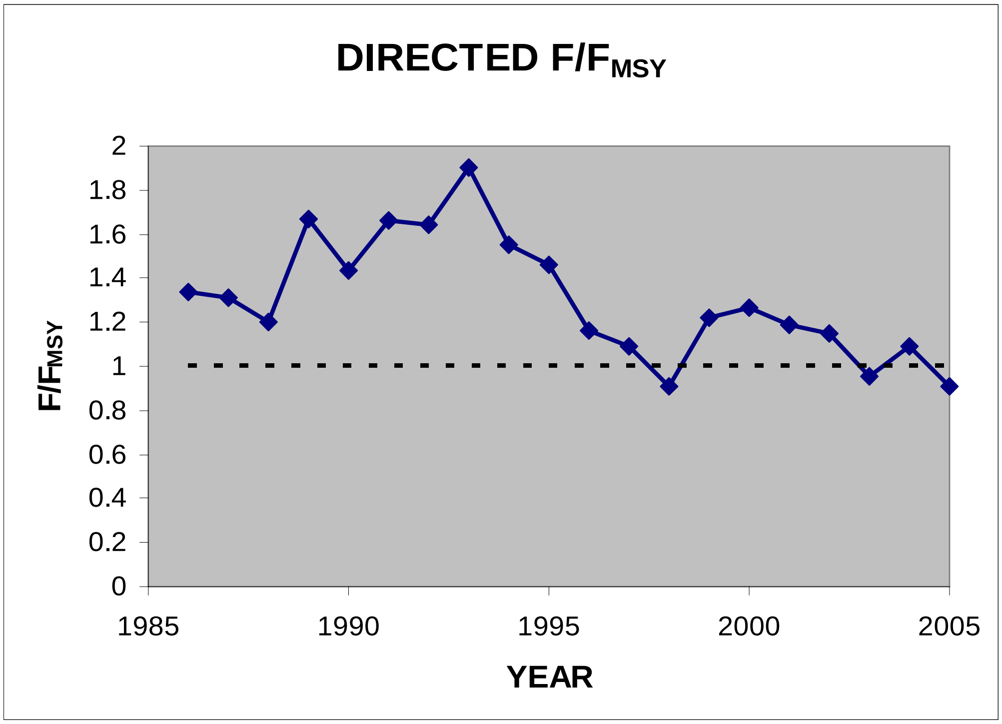


Figure 3.2.2.6.1. Fleet-specific fishing mortality rates from the directed landings (**A**) and the discards from the directed fleets (**B**).

A)



B)

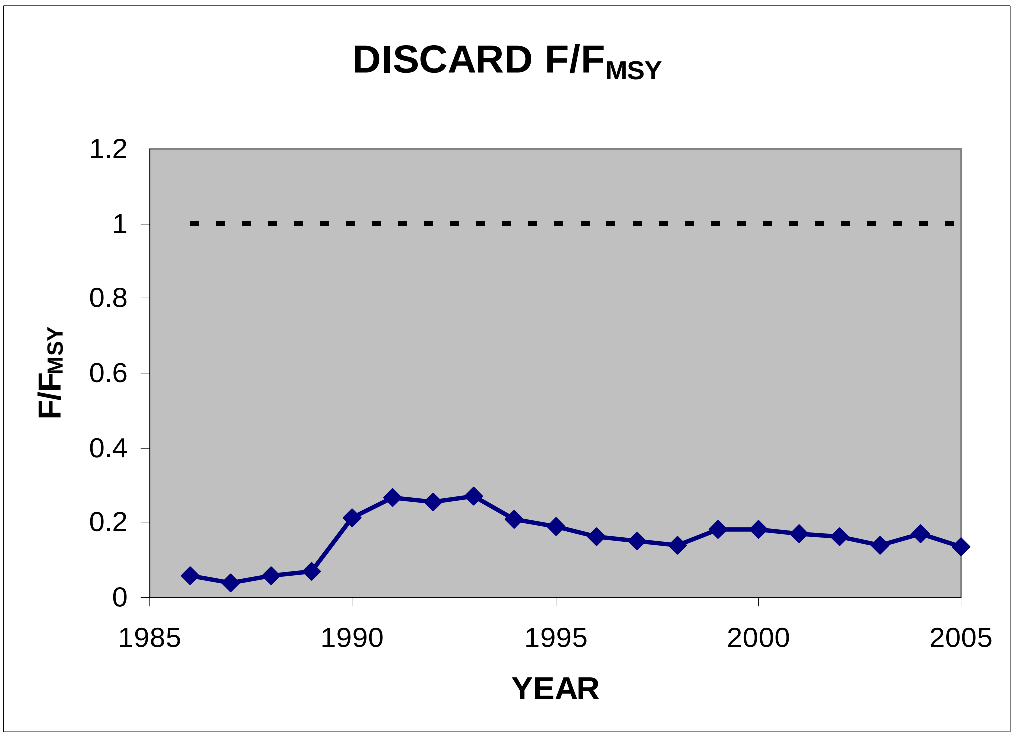
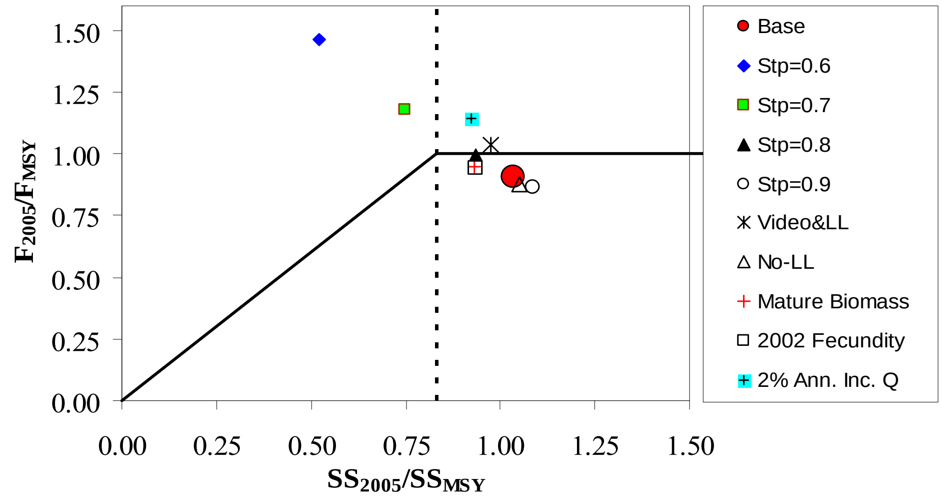
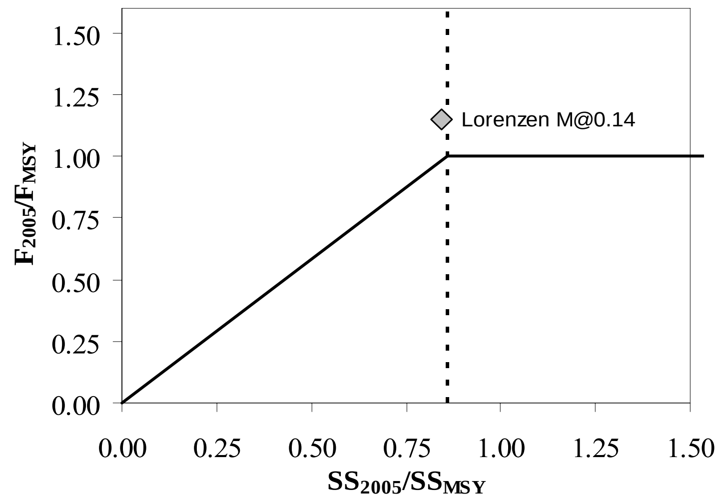


Figure 3.2.2.6.2. Total fishing mortality as a fraction of F_{MSY} for the directed landings (**A**) and the discards from the directed fleets (**B**).

A)



B)



C)

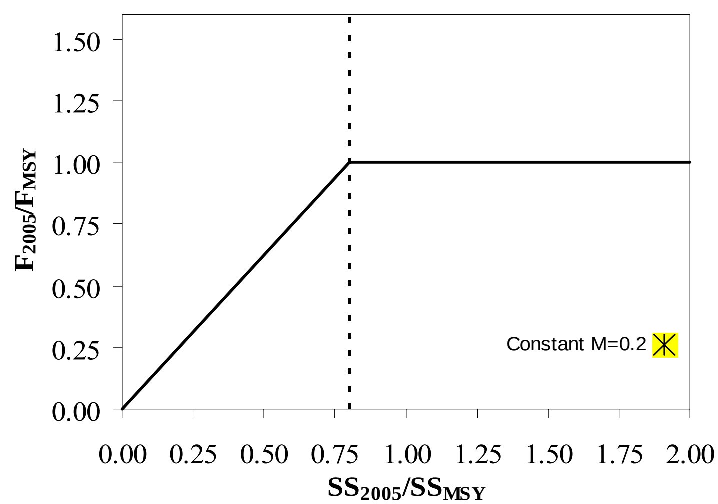


Figure 3.2.2.10.1. Control rules plots for the base (panel A. large red circle) and sensitivity runs. The SS/SS_{MSY} reference line is at 1-M where M is the natural mortality rate. Values < 1-M indicate an overfished population. The F/F_{MSY} reference line is at 1.0. Values > 1.0 indicate overfishing. The panels are A) runs using Lorenzen M@0.167; B) run using Lorenzen M@0.14; C) run using a constant M = 0.2.

A) B)

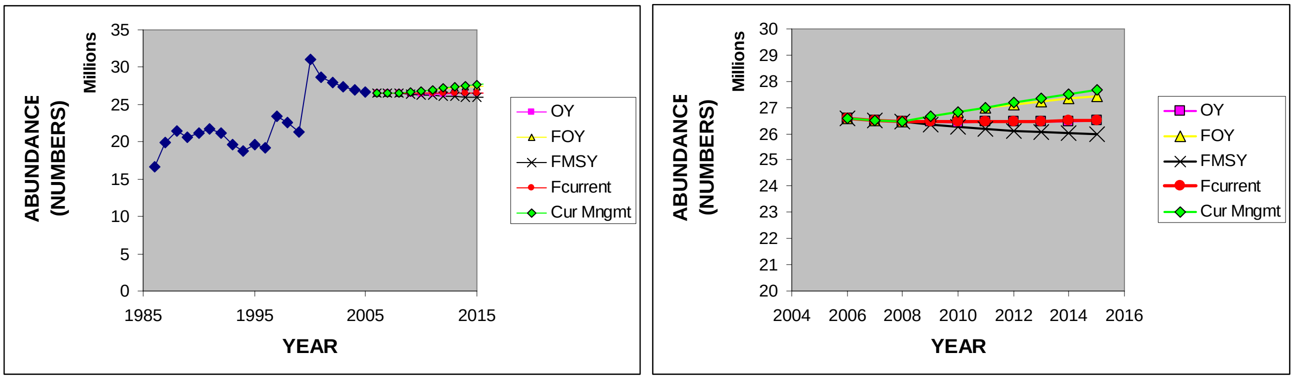


Figure 3.2.2.11.1. Abundance estimates from the base run and projected abundance for the five projections **A)** 1986-2015 and **B)** 2006-2015.

A) B)

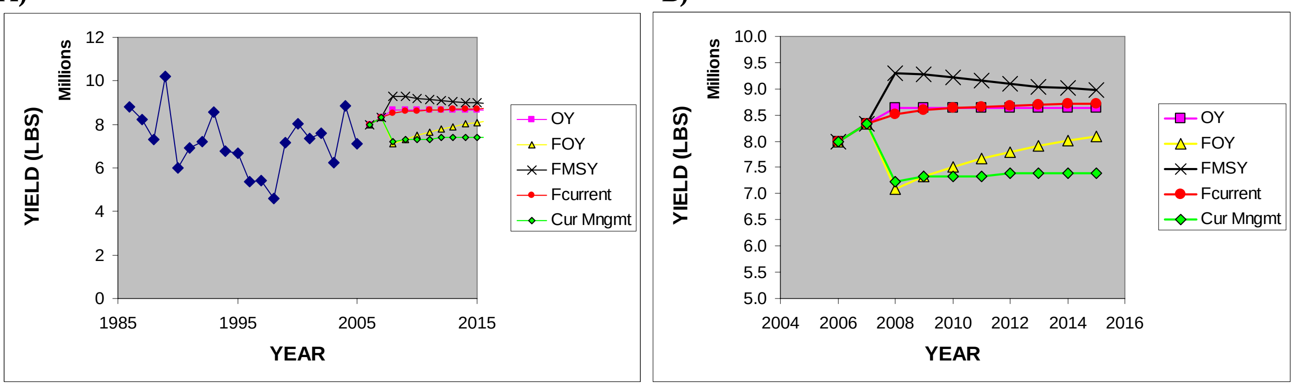


Figure 3.2.2.11.2. Yield estimates from the base run and projected yield for the five projections **A)** 1986-2015 and **B)** 2006-2015.

A) B)

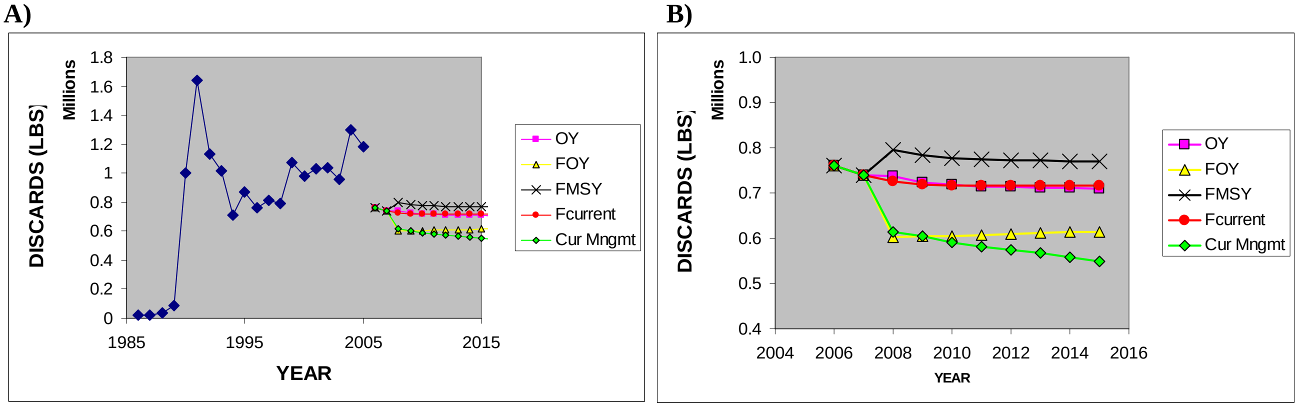


Figure 3.2.2.11.3. Discard estimates from the base run and projected discards for the five projections **A)** 1986-2015 and **B)** 2006-2015.

A) B)

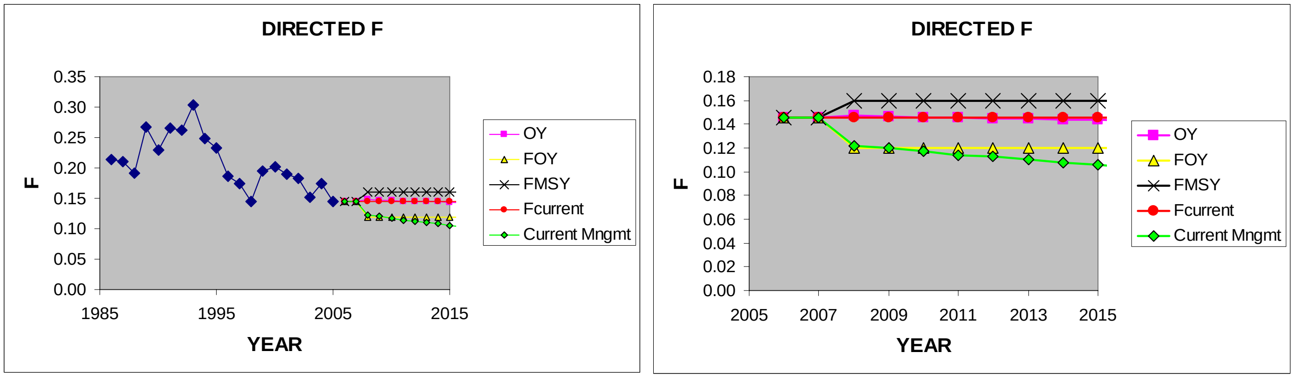


Figure 3.2.2.11.4. Directed fishing mortality estimates from the base run and projected directed fishing mortality for the five projections **A)** 1986-2015 and **B)** 2006-2015.

A) B)

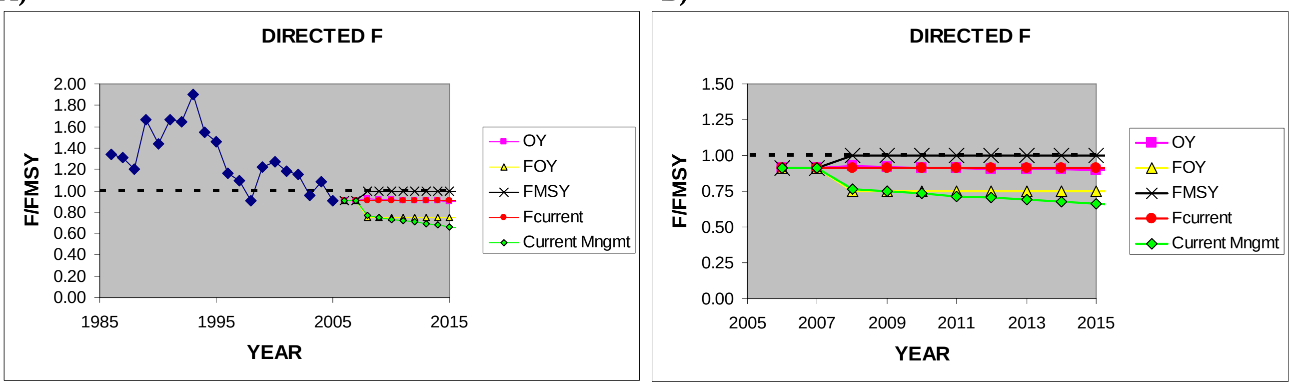


Figure 3.2.2.11.5. Directed F/F_{MSY} estimates from the base run and projected directed F/F_{MSY} for the five projections **A)** 1986-2015 and **B)** 2006-2015.

A) B)

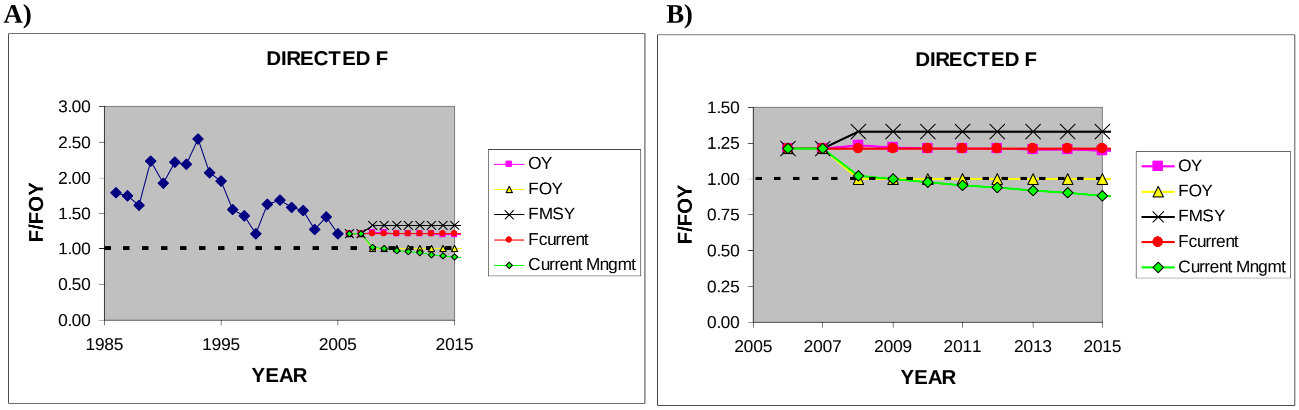


Figure 3.2.2.11.6. Directed F/F_{OY} estimates from the base run and projected directed F/F_{OY} for the five projections **A)** 1986-2015 and **B)** 2006-2015.

A) B)

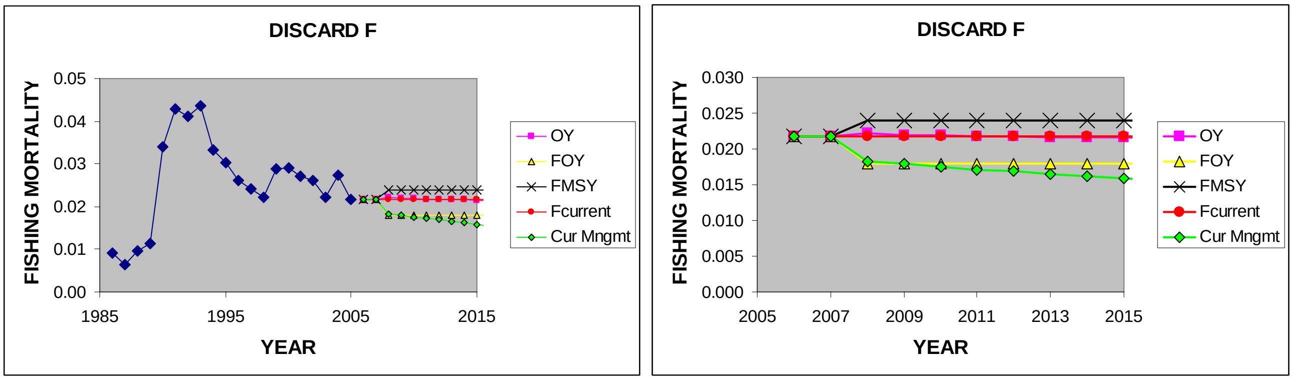


Figure 3.2.2.11.7. Discard fishing mortality estimates from the base run and projected discard fishing mortality for the five projections **A)** 1986-2015 and **B)** 2006-2015.

A) B)

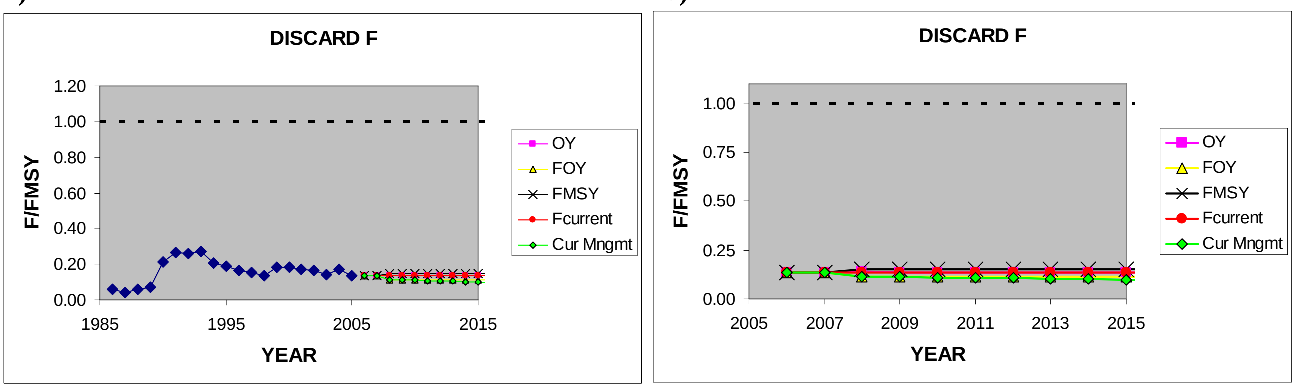


Figure 3.2.2.11.8. Discard F/F_{MSY} estimates from the base run and projected discard F/F_{MSY} for the five projections **A)** 1986-2015 and **B)** 2006-2015.

A) B)

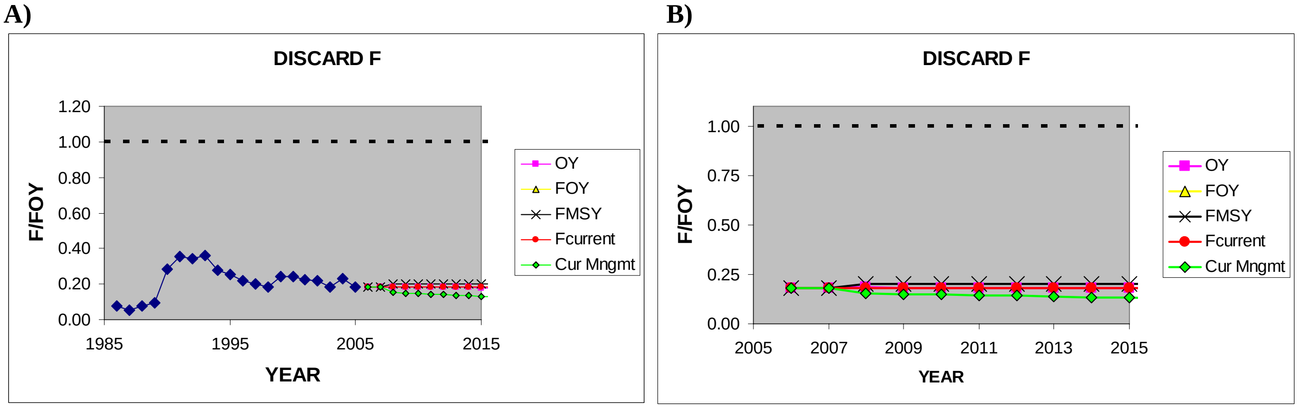
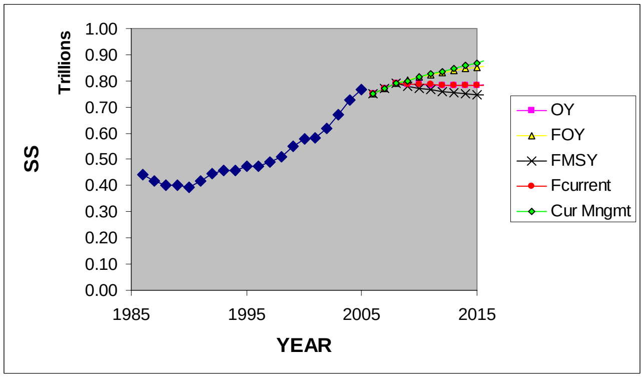


Figure 3.2.2.11.9. Discard F/F_{OY} estimates from the base run and projected discard F/F_{OY} for the five projections **A)** 1986-2015 and **B)** 2006-2015.

A)



B)

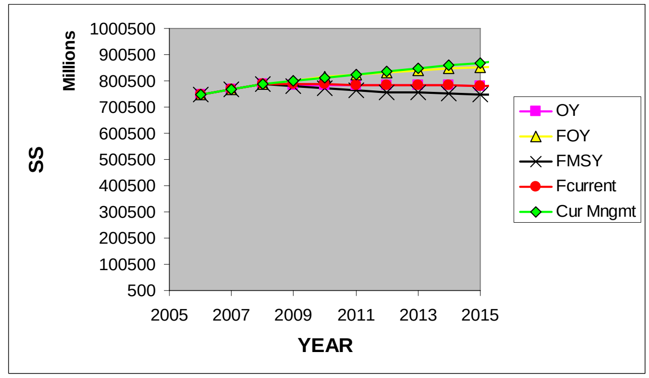
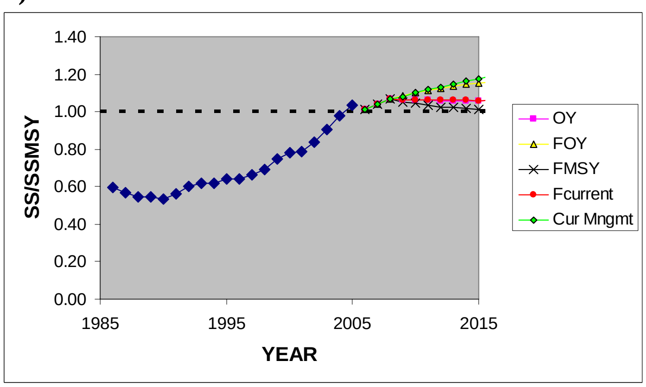


Figure 3.2.2.11.10. Spawning stock reproductive potential (SS; eggs per spawning event) from the base run and projected SS for the five projections **A)** 1986-2015 and **B)** 2006-2015.

A)



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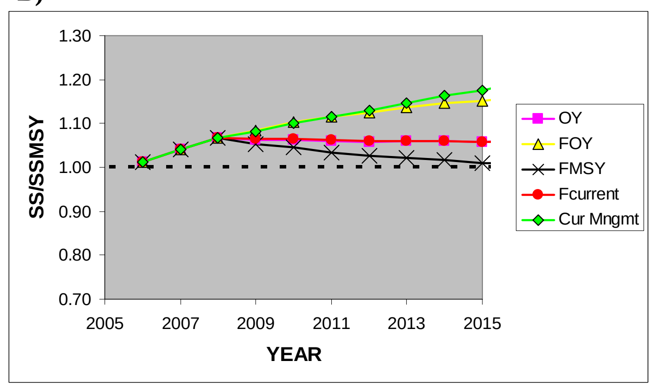
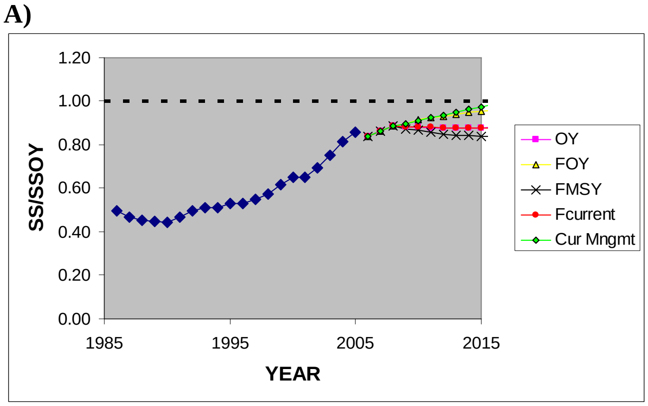


Figure 3.2.2.11.11. SS/SS$_{MSY}$ estimates from the base run and SS/SS$_{MSY}$ for the five projections **A)** 1986-2015 and **B)** 2006-2015.

A)



B)

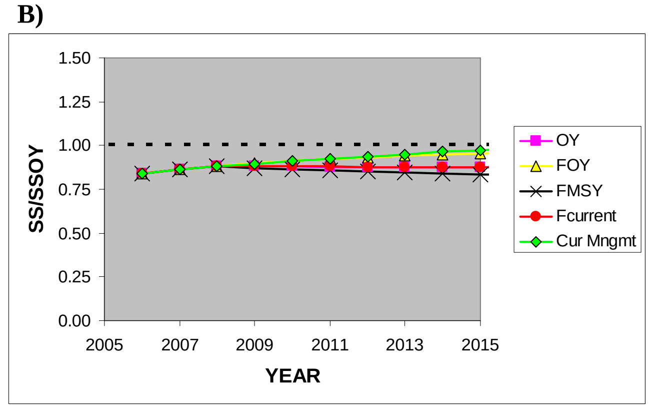
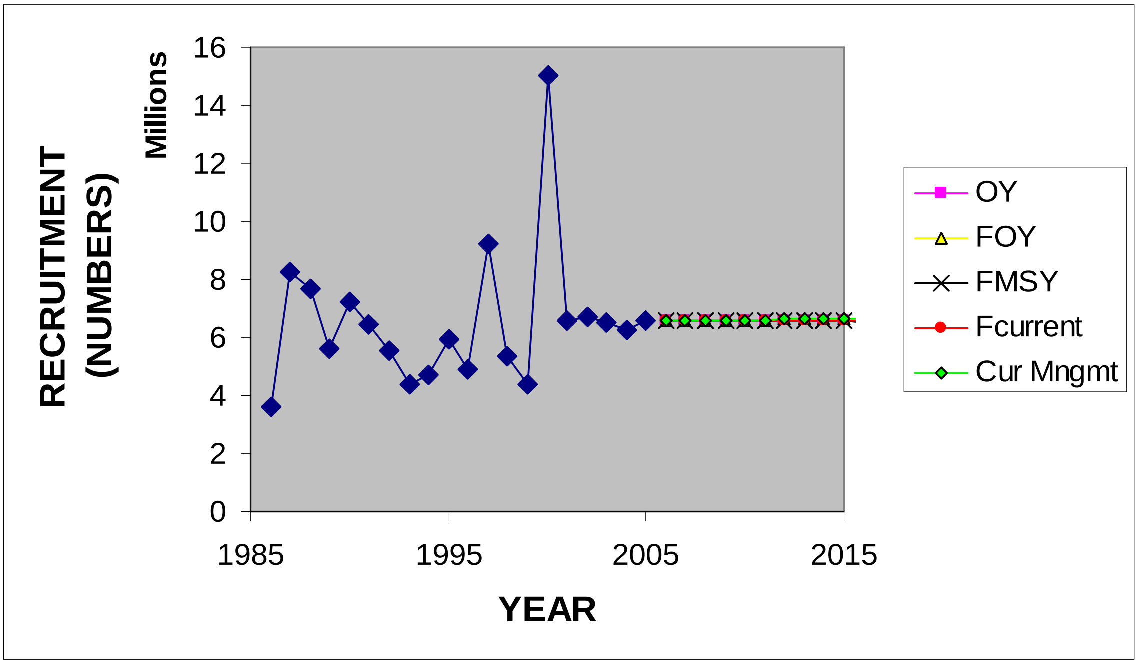


Figure 3.2.2.11.12. SS/SS$_{OY}$ estimates from the base run and SS/SS$_{OY}$ for the five projections **A)** 1986-2015 and **B)** 2006-2015.

A)



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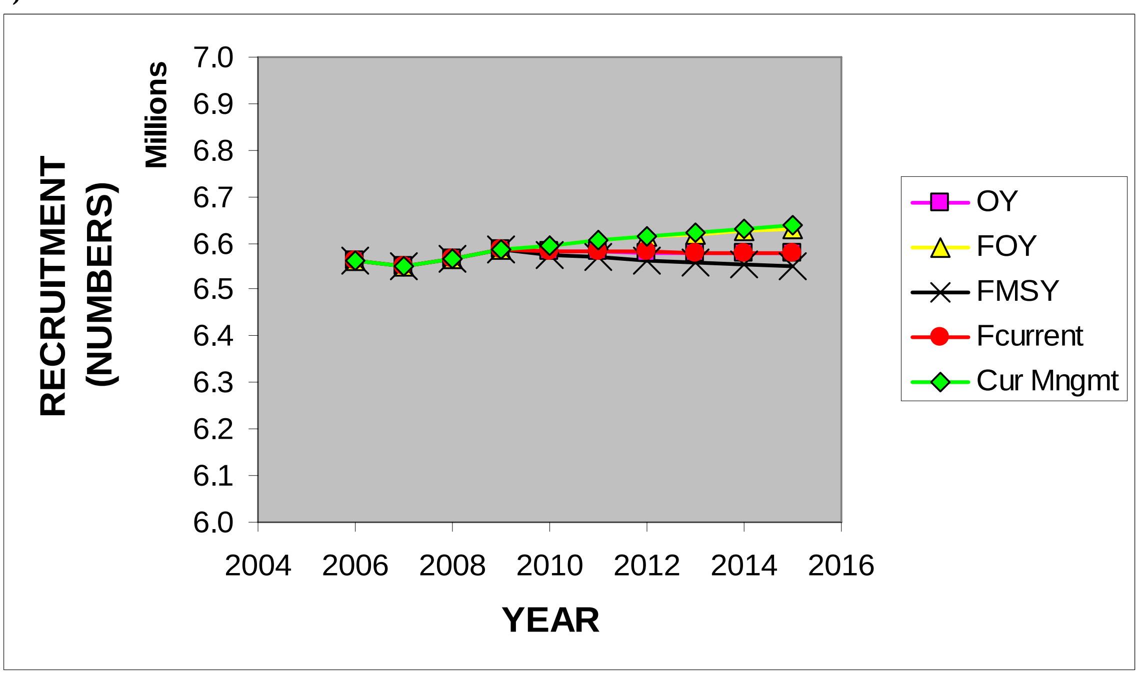

Figure 3.2.2.11.13. Recruitment estimates from the base run and for the five projections **A)** 1986-2015 and **B)** 2006-2015.

SEDAR 12

Stock Assessment Report 1

Gulf of Mexico Red Grouper

SECTION IV. Review Workshop

SEDAR
1 Southpark Circle # 306
Charleston, SC 29414

SEDAR 12 Review Workshop

Review Panel Consensus Summary

Table of Contents

1. Introduction

1.1. Workshop Time and Place

The SEDAR 12 Review Workshop was held January 29 - February 2, 2007, in Atlanta, Georgia.

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*); provide estimated values for management benchmarks, a range of ABC, 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. Identify any Terms of Reference which were inadequately addressed by the Data or Assessment Workshops; identify any additional information or assistance which will improve Review Workshops; suggest improvements or identify aspects requiring clarification.
9. Review the research recommendations provided by the Data and Assessment workshops and make any additional recommendations warranted. Clearly indicate the research and monitoring needs that may appreciably improve the reliability of future assessments. Recommend an appropriate interval for the next assessment.
10. Prepare a Peer Review Consensus Summary summarizing the Panel's evaluation of the stock assessment and addressing each Term of Reference. Prepare an Advisory Report summarizing key assessment results. (Reports to be drafted by the Panel during the review workshop with a final report due two weeks after the workshop ends.)

* 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. Workshop Participants

Review Panel

Richard Methot .... Chair/NOAA Fisheries NWFSC
John Casey .... CIE/CEFAS
Stewart Frusher ....CIE/University of Tasmania
Paul Medley ....CIE

Council Appointed Observers

Martin Fisher... GMFMC AP
Bob Muller .... GMFMC FSAP/FL FWC
Dennis O'Hearn .... GMFMC AP

Analytical Team

Craig Brown... NOAA Fisheries SEFSC
Shannon Cass-Calay .... NOAA Fisheries SEFSC
Steve Turner... NOAA Fisheries SEFSC
John Walter .... NOAA Fisheries SEFSC

Council Representative

William Teehan..GMFMC/ FL FWC

SERO Representative

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1.4. Review Workshop Working Papers & Documents

Working Papers:

SEDAR12-RW01	Gulf Council RFSAP report excerpts regarding red grouper assessments, 1999-2002.	anon.

Reference Documents:

SEDAR12-RD09 SFD 98/99-57 1999	Trends in red grouper mortality rate estimated from tagging data	Legault et al
SEDAR12-RD10 unpub. SEFSC manu. no date	Red grouper mean size at age: An evaluation of sampling strategies using simulated data	Goodyear, C. P.
SEDAR12-RD11 SEFSC Pan. City Lab. Cont. # 2002-07 2002	Characterization of red grouper reproduction from the Eastern Gulf of Mexico.	Collins, L. A. and 5 co-authors.
SEDAR12-RD12 FL FWCC/FWRI	Effects of the 2005 red tide event on recreational fisheries in Southwest Florida	Barbieri, L. and J. Landsberg
SEDAR12-RD13 J. Fish. Bio. 49:627-647. 1996	The relationship between body weight and natural mortality in juvenile and adult fish: a comparison of natural systems and aquaculture.	Lorenzen, K.
SEDAR12-RD14 2005 Phil. Trans. Royal Soc. London. Fisheries theme issue 2004	Population dynamics and potential of fisheries stock enhancement: practical theory for assessment and policy analysis	Lorenzen, K.

2. Review Panel Consensus

Executive Summary

The SEDAR 12 assessment team did an outstanding job responding to the recommendations from past review panels and updating the assessment. They were highly responsive to requests from the Review Panel (RP). The SEDAR process itself was well organized and well implemented by the SEDAR chair. In addition, the RP thanks the fishery representatives who attended the meeting and made a very positive contribution to the success of the review.

The RP finds that the red grouper assessment in 2006 is a significant improvement over the assessment conducted in 2002. In particular, the addition of longer time series of indices has improved estimates of long term trends, direct age composition data has greatly improved estimates of year-to-year changes in recruitment and has allowed modification of the estimated level of natural mortality. As expected from an assessment update, the assessment is now able to track more recent recruitments, notably the large recruitment from the 1999 year class. However, lack of a pre-recruit survey prevents detection of recruitment fluctuations past 2002. Some revision of historical stock status estimates has occurred, and the RP finds that the magnitude of these changes is not unexpected given the degree of uncertainty in the estimates.

The stock in 2006 is estimated to be at a sustainable level of abundance and the current level of total catch is consistent with keeping the stock near this level of abundance. The stock is estimated to be fully rebuilt and overfishing is not occurring. Management measures and other factors that influence the level of fishing activity, and therefore fishing mortality (F), have resulted in recent levels of F that are quite close to the F level that would produce optimum yield (OY). This F level is set to 75% of the overfishing level (MFMT) in the FMP covering red grouper. This conclusion is derived from model results that are clearly supported by the stable or upward trends in the fishery CPUE and survey indicator data, and in the fishery age composition data which indicate a broad age distribution with an increasing number of older fish appearing in the fishery and continued occurrence of new recruits.

Principal changes in the data inputs and model structure include: using direct observations of age composition in the fishery and survey, rather than blurred age estimates derived from sizes of fish; reducing the level of natural mortality from the constant level of 0.2 to a more reasonable lower value that reflects the maximum age of fish occurring in the fishery; refining the estimate of reproductive output to be used as the basis for tracking the spawning potential of the stock; refining the calculation of discards and discard mortality for the different sectors of the commercial and recreational fishing fleets; inclusion of fishery-independent surveys that can track trends in stock abundance without the confounding effect of drift in catchability that is commonly associated with the CPUE of fishery data.

Major future recommendations include: investigate trends in fishery catchability, refine estimates of natural mortality and other life history factors, continuation of NMFS longline survey, continued work on discard estimates and discard mortality, and migrate the analysis to a more flexible assessment modeling framework.

2.1. Statements addressing each TOR

1) Evaluate the adequacy, appropriateness, and application of data used in the assessment.

Life History

In general the RP was impressed at the amount of data available and the extent of analysis. The addition of ages obtained directly from red grouper otoliths has significantly improved the assessment. The RP had some concern that the reproductive data did not cover the entire spectrum of sizes/ages well because these data are typically collected opportunistically rather than through a specifically designed program to sample for life history characteristics. The fact that this species is a protogynous hermaphrodite accentuates the need for improved sampling.

Growth and reproduction- The RP considered that there could be refinements in the growth and reproductive metrics although more data would be required. It is unlikely that they will make significant changes to the outcome of the model, but should improve the description of both metrics. Further discussion on growth and reproduction can be found in the research recommendations section.

Natural Mortality
Previously, natural mortality (M) was assigned a value of 0.2 in the red grouper assessment model. Direct age data now available show a number of fish aged beyond 25, thus a lower value of M is indicated. Although the AP recommended a value of 0.167 based on a maximum age of 25 and the Hoenig (1983) approach, the RP considered the gradual tail-off of fish beyond age 25 and out to age 29 to be consistent with a value of 0.14 for M. The RP concurs with the use of an age-dependent pattern in M that is scaled to body weight based on the Lorenzen (2000) method. However, the RP finds that the scaling recommended by the AP produced an underestimate of the natural mortality level for older fish because it included the youngest (age 0, 1, 2) groups in the calculation of the average natural mortality. A revised scaling based on age 5-29 is recommended because this is the age range of samples used to derive the average M of 0.14. Revised base models were conducted with this revised scaling.

Spatial data (and movement):
The RP concurs with the assessment of red grouper in the Gulf of Mexico as a single stock principally found along the west-central coast of Florida. Within this area the spatial patterns described in the Data Workshop report (p. 16) were mentioned during the RP workshop: shallow to deep movements of cohorts, movements associated with hurricanes. Similarly ontogenetic movement from north to south was also suggested from the age composition of the northern and southern NMFS long-line survey catches and fishery catch-at-age. In addition to these movements there was a suggestion that there had been a recent range expansion in the northern regions. This was supported by the increased occurrence of red grouper in the northwest FL recreational fishery data and an associated small but increasing CPUE over the last 4-5 years in this NW area. Causes for

the range expansion were uncertain and suggestions included a response to the increasing frequency of hurricanes and the increased abundance due to the 1999 recruitment peak.

Fishery Data

Catches

Retained catch data seem generally reliable for the modeled time period 1986-2005. Catches are recorded in weight for the commercial fishery and numbers for the recreational fishery. Conversion between catch and weight occurs within the model as necessary and does not appear to be a significant source of uncertainty.

Discards

The discard information is one of the most uncertain of the data inputs. Not all discarded fish die, and mortality in the recreational and trap catches is thought to be low. Discard mortality in numbers is currently estimated to be about a third of the total catch split relatively evenly between the commercial longline and the recreational discards. Several changes in the estimation of gear-specific discard and discard mortality rates were recommended by the DW and AP. The RP concurs with these recommended changes, but notes that there are several components of discard mortality that could be improved through improved data collection and analysis. In particular, the longline discard rate is based on information from the handline fishery, the discard rate from the recreational fleet is self-reported, and all estimates of discard mortality rate could be improved. More detailed recommendations are found in the recommendations section.

Age Compositions

The age composition data is important to the assessment and has been made more reliable by using direct, randomly sampled age observations rather than age inferred from length. The RP strongly supports the continued use of direct age estimation in the assessment. In the research recommendations, the RP discusses some possible methods to use some of the historical length data and possible length-stratified sampling for age determination to increase the precision of the estimates for the less common older fish.

Spatial Structure

There appears to have been an increase in recreational fishing activity in the NW area associated with higher catch rates in that area. However, the majority of the total catch occurs in the southern areas, and it is assumed that the majority of the stock resides there. Some north-south differences in growth and consistent differences in age composition between north and south indicate that whatever mixing occurs between north and south it is insufficient to homogenize these patterns. However, there was insufficient information to consider whether the areas could or should be treated separately. The catch data could, if considered necessary in future, be split between North and South stock areas.

Extending Catch Time Series Back

The full catch time series, which goes back to 1880, was not used. The RP believes that the full catch time series has been reasonably derived, but the historical catch data certainly is less reliable. For example, before 1986 the grouper landings are not differentiated among grouper species, but a fixed proportion by gear is applied to estimate red grouper. Most species are either gag or red grouper. The Cuban aggregated data is not necessarily accurate and shows great shifts, which are attributed to political changes during the period. A model that incorporates such a long time series could be informative because it could test whether the productivity implied by the current assessment could support the exploitation history. Such a model should be designed to acknowledge the greater uncertainty in the early catches.

Indices of Abundance

The review panel considered that the DW and AW had been rigorous and conscientious in developing the available stock abundance indices. In general, the approach used to standardize the indices was adequate and after standardization, the indices chosen indicated a general upward trend since the mid-1990s. The RP accepted the indices used by the AP with a recommendation on potential lack of constancy in the catchability of the fishery catch rate series.

The panel discussed the utility of the NMFS long-line survey for model calibration and concluded that in principle, this series probably has the greatest potential for reflecting trends in the stock. At present however, the time series is short and survey coverage in two of the six years was poor and restricted to the northern part of the survey area. The AW did not include the survey in its base run on the grounds that it was a short time series, highly variable and largely without trend. The RP did not feel that these were good reasons to exclude the index. Because of its potential to reflect stock trends, the panel felt that it should be used excluding the data for the years 2000 and 2002 when coverage was poor. The RP recommended that the nominal indices would be appropriate for the Fishery Independent NMFS Bottom Long-line Survey because it is has, by design, good coverage of the stock's area and there is no obvious benefit to be obtained from the application of a Generalized Linear Model. The nominal indices were not available during the workshop.

The RP identified a number of issues that it considered should be investigated for future assessments. These issues are documented in the research recommendations.

2) Evaluate the adequacy, appropriateness, and application of methods used to assess the stock.

The Gulf of Mexico red grouper stock was assessed using the Age-Structured Assessment Program (ASAP). This program, developed in 1998 by Legault and Restrepo, is adequate and appropriate for this assessment. It was designed to assess stocks with data comparable to the data available for red grouper and to provide management advice in terms that meet the needs of the Gulf of Mexico Fishery Management Council. In particular, ASAP can explicitly deal with the fact that a substantial portion of the total fishery caused mortality is not attributable to the retained catch. The ASAP program has been included in the NMFS Stock Assessment Toolbox as one of the core assessment programs, thus reinforcing the confidence that ASAP is an adequate and appropriate assessment program. The version of ASAP used to conduct the red grouper assessment is fundamentally similar to the version included in the Toolbox, and has appropriate modifications to address the particular needs of this assessment.

Although the RP found that the ASAP model is adequate and appropriate for this assessment, it does have limitations. In particular, it could not be configured to work with a long time series dating to the earliest years of the fishery (circa 1880), and some of the model inputs require substantial pre-processing such that the estimates of uncertainty in model results are not able to incorporate this additional uncertainty due to the pre-processing steps. The future recommendations section identifies the recent availability of more comprehensive and flexible models that may be applicable for future red grouper assessments.

The RP identified four factors that were adjusted in a revised base model. These factors are: natural mortality, trend in catchability for the fishery catch per effort indices, inclusion of the NMFS bottom long-line survey, and the level of emphasis to place on the age composition estimates for the discarded component of the catch.

Natural mortality – As described in TOR-1, the RP concurs with the DW and AW in using a level of natural mortality that is scaled to body weight and consistent with new evidence of the longevity of red grouper, but recommends a more appropriate scaling of the natural mortality. The RP finds that the level of natural mortality is an influential, but difficult to estimate, parameter as it is in most other assessments. The level being used here is consistent with available information, but there is uncertainty. The RP cannot bracket this uncertainty with a quantitative confidence interval on natural mortality. The sensitivity analyses with respect to natural mortality undertaken during the workshop are intended specifically to demonstrate the degree to which the assessment results are influenced by the level of natural mortality. The sensitivity analyses should not be interpreted as a confidence interval around the best estimate being used in the revised base model.

Fishery catchability – Commercial and recreational fishery CPUE have been included in the red grouper model as plausible indexes of the trend in stock abundance. However, the RP recognizes that it is not possible to standardize the units of fishery effort over time to the same degree that the units of effort in a fishery-independent survey (such as the bottom longline survey and the video survey) are held highly constant. The panel agreed that it would be unrealistic to assume constant fishery catchability over 20 years and requested that an annual 2% increase in catchability be incorporated in the base run to reflect increased fishing power (efficiency) principally due to technology innovations (GPS, GIS, cell phone communication, etc.) that cannot be quantitatively included in the standardization. This means that over a 15-year period, a 35% increase in observed fishery CPUE would be expected from a stock that was level in its abundance. The representatives of the fishing industry attending the meeting agreed that 2% per year was within a likely range. The RP finds that the direct information to calculate the historical drift in catchability does not exist and makes some research recommendations in TOR-9. For sensitivity analyses, the RP recommends model runs based on 0% and 4% per year trend in catchability.

NMFS Bottom Longline survey – Although the bottom longline survey has not yet been conducted for enough years to describe long-term trends in red grouper abundance, the RP finds that this survey has the appropriate characteristics to be a very useful indicator for red grouper: In most years it has covered the principal range of red grouper, it is highly standardized, and it provides size and age composition data. Although the RP does not expect the bottom longline survey to be influential in the current assessment's results because of its short duration, we recommend including it in the model to reinforce our conclusion that this survey has high merit, should be continued and, be included in future red grouper assessments.

Discard age composition – The RP recommends reducing the influence of the derived discard age composition data in the base model. There are no direct otolith age observations collected from discarded fish and the age composition estimates derived from the length composition data do not contain the recruitment signal apparent in other model data. The RP recommends reducing the influence (e.g. effective sample size) of each discard age composition from the level of 11.6, which would be as or more influential than 12 of the direct otolith age composition observations, to a level of 1, which would be the same as the lowest influence level for the direct age observations. For comparison, the most heavily sampled of the direct age composition samples had an influence level of 200. As expected, with the reduced influence of the discard age composition information, the ASAP model produces a slightly larger range in estimated year-to-year changes in recruitment.

3) Recommend appropriate estimates of stock abundance, biomass, and exploitation.

The time series of estimated stock abundance, biomass and exploitation was calculated from the base model as revised according to the RP recommendations. These estimates are presented in the advisory report.

4) Evaluate the methods used to estimate population benchmarks and management parameters (*e.g., MSY, Fmsy, Bmsy, MSST, MFMT, or their proxies*); provide estimated values for management benchmarks, a range of ABC, and declarations of stock status.

The estimates of population benchmarks and management parameters have been calculated using standard, routine procedures. These values are tabulated in the advisory report.

The exact values of these parameters are related to various factors estimated in the assessment, particularly the level of natural mortality and spawner-recruitment steepness. Both of these factors will be subject to revision as subsequent assessments are conducted with more data, so some modification of these management parameters is to be expected in the future.

On the basis of these estimated parameters, the RP finds that the Gulf of Mexico red grouper stock is not experiencing overfishing and it has fully rebuilt from previous low levels of abundance. In fact, its abundance is at approximately the exact level to be expected from a stock fished at 75% of Fmsy. Current fishing mortality rate is very close to 75% of Fmsy, so efforts over the past few years to curtail the pace of the fisheries have resulted in the fishing mortality being at the target level. Continued fishing at 75% of Fmsy would produce an ABC near the status quo level as documented in the advisory report. This ABC is calculated for landed catch and it takes into account the effect on the stock of associated discard mortality.

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).

The RP finds that the method used to project future stock status is adequate and appropriate. The method is based on calculation of the fishing mortality rate (F) that would produce long-term maximum sustainable yield (MSY), then applying this and other F levels into the future using: the estimated current stock abundance, expected mean and variability of future recruitment levels, expected catch for the 2006 and 2007 fishing years based on management measures currently in place and recent fishery performance. Such an approach is similar to the approach used in other regions and is adequate for providing technical advice for the management of red grouper. Use of the target reference point at 0.75 Fmsy is appropriate as it provides a degree of precaution for the fishery given the uncertainty in the assessment and in the fishery associated with recruitment variability, discard survival and limited fishery independent indices.

Caveats:

The recent status has improved with the large 2000 year class, but no recruitment information is available since 2002 due to the gap between settlement and recruitment to the fishery. Recruitment since 2002 is only an average of past recruitment. The MSY-based benchmarks are solely from the Beverton-Holt stock-recruitment model. The parameters of this stock-recruitment model are not precisely estimated, partly because the assessment model begins after historical fishing had already reduced the stock abundance. In addition, there is an argument that the Ricker curve might be more appropriate where there is significant habitat limitation on recruitment and stock size.

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.

Some uncertainty is to be expected. More sophisticated models with extensive sets of appropriate data can reduce uncertainty, but uncertainty cannot be eliminated altogether. The RP finds that the degree of uncertainty in the red grouper stock assessment is not so high as to interfere with the use of these results as the technical basis for management of this stock.

Although we are confident in this conclusion, there are some factors that would cause the quantitative estimate of uncertainty to underestimate the possible range of uncertainty. The ASAP assessment model routinely provides estimates of uncertainty in model parameters and stock factors such as recruitment, abundance and fishing mortality. These estimates of uncertainty are based upon the degree to which the currently configured model can fit the data. The 95% confidence interval on current stock status is approximately +- 14% of the mean estimate, although this estimate of the confidence interval does not include all potential factors that could contribute to the uncertainty. These estimates of uncertainty have been supplemented with sensitivity analyses for alternative model configurations. The RP finds that the level of natural mortality and the degree of drift in fishery catchability are influential aspects of the model configuration and appropriate sensitivity analyses to alternative levels of these configuration factors have been provided. The RP notes that a plausible +- 10% change in the level of natural mortality causes a comparable change in the current stock status, and a similar sensitivity is found for the drift in catchability.

A more complete quantification of uncertainty is beyond currently available technical methods, but such an ideal quantification would encompass natural mortality, fishery catchability, recent recruitment levels and even the influence of ecosystem factors on the productivity of the stock. The current management plan sets the target level of the fishery at 75% of the best estimate of the fishing mortality limit. Such a buffer is consistent with the degree of uncertainty in this assessment.

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 RP recommended modifications to the base model and sensitivity analyses as described in TOR 2. The results of these modifications are documented in an addendum and summarized in the Advisory Report.

8) Evaluate the SEDAR Process. Identify any Terms of Reference which were inadequately addressed by the Data or Assessment Workshops; identify any additional information or assistance which will improve Review Workshops; suggest improvements or identify aspects requiring clarification.

The RP was pleased by the smooth operation of the SEDAR process. All participants contributed to its success.

The breadth of experience of reviewers selected for this SEDAR workshop improved the review and provided insight in many areas which otherwise would not have been given.

Future SEDAR review workshops should consider having a representative of the data community in attendance. While models and analyses tend to be broadly consistent between stock assessments, data can have peculiarities which can only be elucidated from the inside knowledge of those who collect and/or manage the data. While the DW report contains much of the necessary information, a representative of the DW would be useful to highlight important issues and provide insight on the provenance and accuracy of data.

The RP was surprised that there was no ecosystem/environmental perspective provided during the DW, AW or RW given the increasing requirement globally to address fisheries in an ecosystem context (ecosystem based fishery management). Environmental data could assist in interpretation of recruitment trends, range expansions and changes in catch rates. Similarly it was also surprising that information on similar species that occur within this region (e.g. Gag grouper) were not used to compare similarities in recruitment or fishing patterns.

Concentrating on one species allowed more in depth review and improved the quality of the results from the SEDAR process. It was recognized that this makes the process more expensive, but it is preferred compared to trying to cover several assessments in the same meeting. To contain costs, it is reasonable to conduct full reviews, like this SEDAR 12, less frequently and triggered by specific criteria so that interim stock assessment updates can be conducted more frequently without repeating the entire review process. Criteria could include significant change to the scientific advice to managers, changes to the overfishing or overfished status of the stock, availability of significant new data or assessment methods, request from the assessment or data workshops to adjudicate on issues for which they could not reach a consensus and objections from stakeholder groups which require arbitration.

9) Review the research recommendations provided by the Data and Assessment workshops and make any additional recommendations warranted. Clearly indicate the research and monitoring needs that may appreciably improve the reliability of future assessments. Recommend an appropriate interval for the next assessment.

The RP was not able to examine and comment on the research recommendations of the DW and AW item by item, but our recommendations broadly mirror those made by the DW and AW. The RP recommendations below are split into a set that is of high priority to address in the next major assessment and a set of other recommendations that are of interest but are not expected to be feasible soon or are not expected to make a substantial change to the assessment result. Finally, the RP provides some additional discussion on these research topics.

HIGH PRIORITY RESEARCH RECOMMENDATIONS

LIFE HISTORY

- Verify and improve the estimate of age-dependent natural mortality.
- Improve the metric of reproductive output. This will involve expanded sampling to get adequate coverage in season, geography, and size/age range and the collection of relevant abiotic factors associated with the samples. It will also involve special consideration of this species' female to male gender change.

FISHERY

- Expand at-sea sampling to improve estimates of discard for each fishery sector
- Conduct special studies to improve estimates of discard mortality for each fishery sector and in association with various fishery and environmental factors

INDICES

- Conduct NMFS longline survey annually with full spatial coverage; consider the feasibility of a cooperative survey with industry to expand cost-effective coverage.

- A pre-recruit survey is needed if future management is to be more responsive to recruitment fluctuations.
- Collect additional data (expanded logbooks, fisher interviews, historical personal logbooks) relevant to the standardization of fishery catchability in order to refine the current recommendation for a 2% per year inflation in fishery catchability.
- Improve the statistical model (GLM – Generalized Linear Model) used to derive an annual index from the fishery catch per effort data. The model should be more explicit with regard the included factors and covariates. Currently some factors affect catchability and some are related to spatial/temporal patterns in fish density. The form of the GLM needs more justification than statistical significant inference. The focus of the model needs to be creating an index that will be proportional to the total stock abundance.

MODEL

- The ASAP model used for this assessment provides an adequate means to interpret most data and produce estimates of stock status with associated estimates of uncertainty. In the time since ASAP was developed (1998), there have been continued advancements in the models available to conduct such analyses. The current generation of integrated analysis models are able to incorporate both age and length data, to extend over long time periods with limited data, to incorporate environmental information where relevant, and to include more factors in estimating the confidence interval around stock status and projections. Transition to such a model is recommended for the next major red grouper assessment.

ADDITIONAL REVIEW PANEL RESEARCH RECOMMENDATION

LIFE HISTORY

- Investigate a two-gender growth model that explicitly addresses maturation and protogynous hermaphroditic gender change;
- Use tagging to further evaluate north-south connectivity;
- Explore temporal and/or density-dependent changes in growth and reproduction, including investigation of possible abiotic effects such as temperature;
- Publish a technical document about the application of Lorenzen method to convert conventional constant M to age-dependent M (avoid problem with the maximum age over which average has been developed).

FISHERY

- Support ongoing work to evaluate and reduce possible bias and precision of recreational catch estimates;
- Evaluate sampling design for fishery length and age composition sampling for optimum cost, precision, analytical flexibility;
- Include more documentation of patterns in the fishery (seasonal, geographic, quota attainments, etc.) in the next assessment report.

INDICES

- Evaluate the mix of surveys (longline, trap, SEAMAP video survey) to achieve best coverage of recruits and pre-recruits across relevant habitats and geographic and depth ranges.

MODEL

- Consider extending the model over different time periods. One sensitivity option would limit the assessment to the period after 1990 when the new 20 inch minimum size came into affect. Prior to 1990, data are different due to the size limit change so consider discarding pre-1990 data and fit the model to this shorter time series. Another option would be to complete the investigation of model performance and inference when the entire time series since 1880 is included. Such a long time series would have uncertainties due to assumptions about fishery characteristics in the early years, but could provide a check on the consistency between estimates of stock productivity and the cumulative removals over the entire time period.

ADDITIONAL DISCUSSION ON RESEARCH RECOMMENDATIONS

The comments below expand upon the recommendations above and provide an expanded exploration of the topics. In places these exploratory comments may appear to contradict recommendations made in the previous section. Such apparent contradictions are a manifestation of the constant scientific inquiry in the SEDAR review process. They are an indication that all findings have some associated uncertainty and room for improvement, but they do not negate the basic finding of a sound assessment.

LIFE HISTORY

The topic of stock definition was not discussed in detail at the review workshop. The Data Working Group suggested that research aimed at identifying recruitment peaks in each of the main fishing regions be explored with the assumption that similarity in peaks would suggest common recruitment patterns and a single spawning stock. The age composition provided through the NMFS Bottom Longline Survey suggested a similar 1999 recruitment peak. Continuation of this survey ensuring adequate north and south coverage is important. The age structure tends to suggest that there could be movement of younger fish from north to south, or a higher total mortality rate (Z) in the north. However, the Mote Tagging Database did not exhibit directed north to south movement. A more comprehensive tagging program may help elucidate the connectivity between north and south regions. There was also concern that there was spatial heterogeneity in the data that was not being captured in the descriptions. There were differences in the length-age data for depth, sector (commercial vs. recreational) and region.

The RP considered alternative methods for estimating natural mortality (M). A promising approach would be to use sampling and experiments in the Dry Tortugas Marine Reserve, where fishing mortality might be considered negligible. If scientific/experimental fishing was allowed, it may be possible to use both catch curve and tagging studies (multi-period models) to obtain an estimate of M and to determine if the natural mortality followed the form proposed by Lorenzen (1996, 2005).

The RP supports necessary continued work to calibrate and standardize otolith age determinations, as recommended by the DW.

Although the VB growth curve was a reasonable fit to the data there appeared to be a distinctive pattern in the residuals. The younger and older fish were underestimated and the middle aged fish a mixture of both. Because of the energy demands on a species that changes sex, a normal VB curve maybe inappropriate. It appears possible that the growth curve is a mixture of 3 separate events: female growth, transitional growth and male growth. The higher values for the start of the VB curve could be associated with faster female growth (pre-maturity), the flatter middle section of the curve with transitional growth (females use majority of energy for transition) and, the higher values at the end of the growth curve associated with male growth which would be relatively faster as gonad development requires less energy. The current growth curve estimates L_{inf} at 854mm although fish up to 1007mm have been caught. Size frequency tables in DW-03 indicate that fish in the length class 900 were consistently present in the fishery.

Relative fecundity is a product of percent female, percent of females mature and gonad weight. The power function used to describe reproduction (Figure 2, page 28, Section 3 of Stock Assessment Report) is based on the 0-9 year data set as this is associated with the majority of the data. A bias corrected power function was then used to estimate the mean gonad weight for ages 10-20. Although based on small sample sizes the average gonad weight for the ages 11-15 are above the power function suggesting that this function may be underestimating gonad weight for the larger animals. While the majority of the catch is currently below 10 years of age, a greater number of 10+ aged fish are beginning to appear in the catch. With rebuilding of the stock the number of 10+ fish is expected to increase. Any change in the reproductive relationship that increases the reproductive output for larger fish may therefore have a greater impact in the future.

Another possible explanation for the low gonad weights for very large fish is that these fish are in the sex transition phase and have reducing ovaries. As the rate of sex transition is unknown, it is uncertain if a range of gonad weight for an expected age will result from different stages of transition (i.e., if sex transition occurs over 2 seasons there could be 3 different gonad conditions: full female – female with reduced ovary – full male). It is also possible that these fish are periodically skipping spawning periods. Annual reproduction should not include skip spawners in either the percentage mature or in the gonad weight relationship (Figure 14, DW 4), but should be estimated as a separate component. Future analyses should consider the ‘transitional fish’ and how they contribute to spawning biomass. In the dataset provided there were a number of females that had sperm or plugs (indicator of skip spawning) present that mainly contribute to the model variance. Whether these should be included as females in the proportion female is uncertain, and their contribution to annual egg production should be considered in greater detail.

FISHERY

Discards are not directly observed but estimated from various sources. Long-line discards form the majority of the discard mortality. However, because discard rates for the long-line fishery based on observer data were thought to be biased underestimates, these were inferred from reported hand-line discard rates. As the hook sizes are the same, selectivity for hand-line and long-line are thought to be approximately the same, despite long-line being set a little deeper. The recreational fishery tends to target smaller fish, so a high proportion of the catch is below the minimum size. The recreational bag limits do not appear to be a major cause of discarding.

The assumed long-line discard rate based on reported discarding from hand-line logbooks suggests that one fish is discarded per 5lbs landed. It was suggested at the meeting by one of the participating fishermen that this is probably an underestimate by as much as a factor of 2. The lack of direct observations makes the assumed values highly uncertain.

Once released, fish mortality due to fishing probably depends upon the depth caught, ascent time, time on deck, predators present and other stress factors. These effects have been confounded across previous studies making interpretation for estimating the gear-based discard mortality difficult. Most fish are killed through baro-trauma, where the swim bladder’s expansion causes physical stress on internal organs. Although venting the swim bladder can relieve the stress, it requires some skill. Increased predation on discarded fish may also contribute to post release mortality. Cetaceans and barracuda were reported as being the major observed predators of discarded fish.

Release mortality among red grouper of less than 20 inches total length is not precisely known. Release mortality in a small sample of 21 red groupers caught by hook and line from a depth of 44 m was 29%. Anecdotal evidence from fishermen suggests significant numbers of released red grouper do not survive after release.

The data workshop panel explored the issue of estimating the mortality based on fishing depth, but was unable to estimate depth for all catches. In any case, it appears that attributing mortality to depth alone would only be partially successful, and a more detailed understanding of the causes of mortality is required.

All gears were assumed to have a discard mortality of 10% except long-line, which was allocated a discard mortality of 45%. Long-line discard mortality is thought to be much higher due to the greater depth fished, and possible stress from being hooked on the line for longer periods. Discard mortality in the longline fishery contributes significantly to the total fishing mortality for this mode of fishing. Based on the available data, accurate estimates are not possible, but general indicators were provided. Long-line probably has the highest discard mortality based on reports from fishermen, and consistent with the deeper sets. Recreational discards probably have the lowest discard mortality due to their treatment on deck and relatively low depth. Trap gears will be discontinued, and in any case only forms a small proportion of the total catch. However, there was some concern that the discard mortality of 10% maybe too low for the recreational sector.

Focus improvements in data collection on discards and discard mortality, perhaps using observer program and directed research on contributions to discard mortality from depth, exposure etc as suggested by the Data Workshop panel. Pre-release mortality would be recorded by observers and should be estimated by the observer program. Post-release mortality can only be estimated by directed research. Rather than link post-release mortality only to explanatory variables such as catch depth, time on deck and so on, which may prove complex, attempts might be made to link post release mortality to variables collected by observers or through a tagging program. For example, size and subjectively-assessed release condition could be recorded routinely by observers and linked to mortality through a research project.

Discards are caused by the management controls that are implemented in the fishery. Further changes to management controls could require modification of the way that discarded catch is included in the model. Where discarding changes significantly, trends may be produced, which are due to changing errors in the discard estimates rather than real changes in the stock.

Reducing discarding generally will reduce sensitivity to the issue of discard mortality. Management controls which discourage discarding, but achieve similar aims of the minimum size through gear selectivity would be preferred if possible.

The current assessment depends on random age sampling to obtain age frequencies necessary for input to the ASAP model. The available length composition data is not used. The recommendation from the data workshop, supported by this RP, is to develop an ALK or similar approach so that length compositions can be used particularly for the younger animals. Direct use of length frequency data may also be integrated into the stock assessment model in future.

For the years before 1990, very little age composition data is available. For these years, lengths are the only information. Conversion of length to age, with appropriate uncertainty, could improve recruitment estimates for years 1986-1989.

INDICES

The RP strongly supported continuation of the NMFS bottom longline survey. It is well-standardized, covers the relevant geographic range, and provides age and size samples. The fact that the time series is short means that the survey cannot exert substantial influence on the model results. However, the RP strongly endorses development of fishery-independent surveys and recommended inclusion of the longline survey in the current model so that it is available for future model updates.

With regard to the SEAMAP video survey, the coverage is largely restricted to an area straddling the 100m-depth contour, which does not coincide with the main distributional area of the stock of red grouper off the west-central coast of Florida. Hence the panel concluded that while the index may be indicative of the trend in the stock, the relationship may not be linear. Nevertheless, the index was retained for the accepted base run.

Fishery catch rate series were treated as abundance indices by the assessment model when most are strictly indices of relative density as interpreted by the GLM standardizations. The RP considered that there is a need to strengthen the GLM approach, since there appeared to be insufficient thought given to the inclusion of all explanatory variables and confounding of variables that affect catchability with variables that describe spatial differences in density.

The RP was not able to discuss the possibility that factors such as storms and red tides affect catch rates. If direct evidence of such effects is found, then it may be possible to include these factors in the GLM models.

The introduction of a 20" minimum landing size in 1990 had a big effect on the size composition of the retained catch. While this is adequately accounted for in the development of the stock abundance indices, the potential changes in fishing behavior should be investigated.

The panel also considered that the data from the NMFS long-line survey should be investigated in order to derive catchability estimates for long-line, which could be used to guide an analysis of possible changes in catchability in the commercial long-line fishery. Because detailed information on a per-set basis can be obtained from the survey longline, it offers many more covariates for GLM standardization. Appropriate covariates can be identified for the commercial longline, which specifically deal with changes in catchability rather than other factors such as density.

The panel also discussed the utility of the MRFSS index and agreed that since it is based on the results of interviews, its ability to accurately reflect stock trends may be limited and conceivably may be biased. However it was recognized that the MRFSS index included observations on discards, which other indices did not.

The review panel suggested that an expanded log-book program to obtain information on standardized catch per unit effort should be explored. This could be for a selected sub-sample of enthusiastic participants, if not the entire fleet. The panel noted that some fishers keep detailed personal log-book records which potentially contain valuable historical information on catch and effort. Some fishers may be willing to make such records available especially after they have retired from the industry. The panel suggests that the possibility to obtain such records be investigated.

In order to obtain an estimate for the annual change in catchability, the panel suggested that a survey of fishers be undertaken to obtain an estimate of how their fishing power (efficiency) has increased over time. The result could be used to derive an informed estimate and range for annual increases in catchability.

The RP acknowledged that obtaining catchability estimates to describe how fishing power has impacted on catchability is problematic and there are few examples. The following reference may be considered: Fernandez, J.A., Cross, J.M. and Caputi, N. (1997). The impact of technology on fishing power in the western rock lobster (*Panulirus cygnus*) fishery. Proceedings of the

International Congress on Modelling and Simulation, Hobart, Tasmania, December 1997, vol. 4.

CRITERIA FOR NEW ASSESSMENT and REVIEW

With current model and data streams, it should be possible to update normal data streams (catch, catch age composition, survey and fishery CPUE indices) and re-run the assessment model to extend the time series of abundance, recruitment and mortality estimates. Such updates could be conducted every 1-3 years, subjected to an expedited review and the results could be used to update annual catch limits and other management measures. In the course of such updates, detection of a recruitment event is simply the process working as expected and not necessarily a need for new review. Criteria for determining whether a benchmark assessment and full review could be:

- There are significant changes to the treatment of the data;
- There are significant changes to the model structure, inputs and assumptions. Such factors include natural mortality, catchability, changes in fish-independent index, major revision of GLMs;
- There is a change in the status of the stock or a significant change in scientific management advice;
- There is some other substantial dispute among stakeholders over the assessment, which can only be resolved through an independent review process.

10) Prepare a Peer Review Consensus Summary summarizing the Panel's evaluation of the stock assessment and addressing each Term of Reference. Prepare an Advisory Report summarizing key assessment results. (Reports to be drafted by the Panel during the review workshop with a final report due two weeks after the workshop ends.)

The required reports were prepared and have been included in appropriate sections of this document.

2.2. Analyses and Evaluations

The RP provided no additional analyses and evaluations beyond those documented in TOR 1 and 2 above.

2.3. Additional Comments

The RP has no comments to add beyond those included in other sections of this document.

2.4. Reviewer Statements

The RP consisted of a chair appointed by NMFS and three independent reviewers appointed by the Center for Independent Experts. The consensus summary reported in this document represents the joint work of all members of the RP. The conclusions, findings and recommendations of the RP are agreed to by its members.

3. Written Comment submitted to the Review Panel

3.1 Statement submitted by Tom Marvel, GMFMC appointed observer.

January 29th, 2007

Statement of Concern

I have been fishing for grouper commercially, full time, since 1979. I have continuously used the same gear type. What mystifies me is that when I go to sea, drop baits to the bottom , I catch very little. I catch less than I did in 1980. What is mystifying is that the grouper stocks (read densities) are basically given a clean bill of health. Yes we might be slightly overfishing one year or slightly overfished another, but the basic assessment is that of a generally healthy stock. One could pull up my old logs and counter that the actual weights of grouper I landed in 1979-1982 were similar to present landings (roughly 2000 lbs for a week at sea) so that it would appear my catches are stable. Nothing could be further from the truth. My vessel in 1979 was 31', presently it is 43'. In 1979 I used one paper fathometer, presently two color fathometers. When I started fishing I used 300 lbs/test leaders with one Spanish sardine as bait. Today I use 150 lbs/test leaders with a whole boston mackerel or live bait. My 1979 navigation tool was a loran C whose coordinates randomly jumped a distance of 200' from the vessels' actual position. Currently I use a GPS chart plotter with consistent accuracy of 10'. My 1979 loran book, this is the most significant, was two pages thick. Today's is in files that conservatively weigh five pounds. Certainly you get my point. The effort I expend today is probably greater by a factor of ten. I suspect that I am not alone in this regard.

My concern is that if , in a general sense, commercial landings are roughly the same as they were 25 years ago and the fleet as a whole has ramped up efficiency to the degree I have, then the implications for the standing biomass, stock assessments notwithstanding, are not good. I am truly concerned that very few people have a handle on how much effort we are currently expending to catch what we caught with relative ease 25 years ago.

Tom Marvel
Owner/operator
F/V Sea Marvel
Naples, Florida

SEDAR 12

Stock Assessment Report 1

Gulf of Mexico Red Grouper

SECTION V. Addenda

SEDAR
1 Southpark Circle # 306
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Addenda 1. Red grouper assessment configuration and results based on Review Workshop Panel recommendations.

Stock Assessment of Red Grouper (*Epinephelus morio*) in the U.S. Gulf of Mexico

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Sustainable Fisheries Division Contribution No. SFD-2007-003

1. ABSTRACT

A revised base model was developed at the SEDAR12 review workshop in Atlanta, Georgia. After a comprehensive review, this model was accepted by the review panel, and was used to determine the current status of red grouper in the U.S. Gulf of Mexico, and to prepare management recommendations. According to the base model, red grouper were not overfished in 2005 (SS_{2005}/SS_{MSY} = 1.27) and were not undergoing overfishing (F_{2005}/F_{MSY} = 0.73). Furthermore, in 2005, the estimated spawning stock exceeded SS_{MSY} and SS_{OY} (SS_{2005}/SS_{OY} = 1.07). These results indicate that by 2005, the red grouper stock had fully recovered.

2. INTRODUCTION

This report describes the stock assessment of red grouper that was developed and reviewed by the SEDAR12 data, assessment and review workshops. This is a description of the final base case, sensitivity runs, projections and retrospective analyses accepted by the SEDAR12 Review Panel (Jan.29th –Feb 2nd, 2007; Atlanta, GA).

3. METHODS

3.1. Model Overview

To model the population dynamics of red grouper, we used a forward-computing age-structured model (ASAP: Age-Structured Assessment Program) developed by Legault and Restrepo (1998). ASAP allows the assumption of separability of gear specific fishing mortality into year and age components that can change over time. Likewise, catchability coefficients for observed indices of abundance can also be allowed to vary over time. This increased flexibility may improve the fit of the model without relying on assumptions that may be unrealistic (i.e. exact fit to catch-at-age, invariant Q). ASAP is implemented using the AD Model Builder software package.

ASAP was used previously for stock assessments of red grouper in the U.S. Gulf of Mexico (Schirripa et al., 1999; SEFSC Staff, 2002) and for western bluefin tuna (Legault and Restrepo, 1998). A different version of ASAP, which permits recruitment at age 0, has been used to assess red snapper in the U.S. Gulf of Mexico (Schirripa and Legault, 1999; Cass-Calay and Diaz, 2005; Cass-Calay et al., 2005; Ortiz and Cass-Calay, 2005.).

3.2. Data Sources

The data inputs are summarized within this document. A complete description of the development of the data inputs can be found in the data and assessment workshop reports[1],

[1] SEDAR12 Stock Assessment Report 1: Gulf of Mexico Red Grouper. 2007.

and in the SEDAR 12 working papers. All are available on the SEDAR website, http://www.sefsc.noaa.gov/sedar/, or by contacting the SEDAR coordinator[1].

The ASAP model was developed using the time period 1986-2005. Ages 1 – 20+ were considered. The model structure included 4 fleets:

1) Commercial Longline
2) Commercial HL
3) Commercial Trap
4) Recreational

and 6 indices of abundance:

1.	Commercial Longline	(Fisheries-dependent; 1990-2005)
2.	Commercial Handline	(Fisheries-dependent; 1990-2005)
3.	MRFSS Recreational	(Fisheries-dependent; 1986-2005)
4.	NMFS Headboat Survey (MSL18")	(Fisheries-dependent; 1986-1990)
5.	NMFS Headboat Survey (MSL 20")	(Fisheries-dependent; 1990-2005)
6.	SEAMAP Video Survey	(Fisheries-independent; 1993-1997,2002,2004,2005)

The SEDAR12 panels recommended an age-varying natural mortality (M) developed using the method of Lorenzen (1996). This approach inversely relates the natural mortality-at-age to the mean weight-at-age by a power function, $M = 3W^{-0.288}$, incorporating a scaling parameter. The final Lorenzen function was developed at the review workshop. It used a maximum age of 25[2] such that the cumulative natural mortality of the exploited age classes (5-25) was equal to 0.14 (Table 3.2.1; Figure 3.2.1).

Although the DW panel had recommended that depth-related functions be used to develop fleet-specific release mortality estimates, the AW panel reviewed the available data, and determined that it was not sufficient to develop suitable depth-related release mortality functions. Based on the best available data, including average depth by fleet, the AW provided the following fleet-specific release mortality estimates:

1. Commercial Longline = 0.45
2. Commercial Handline = 0.10
3. Commercial Trap = 0.10
4. Recreational = 0.10

The base model used the age-specific life history functions specified by the SEDAR12 Data and Assessment Workshop panels. The weight-at-age matrix was developed using the

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[1] SEDAR Coordinator: John Carmichael, South Atlantic Fishery Management Council, 4055 Faber Place, Suite 201, North Charleston, SC 29405. (843)571-4366

[2] SEDAR12 Stock Assessment Report 1: Gulf of Mexico Red Grouper. 2007.

Chapman and Richards generalization of the von Bertalanffy growth equation where L_∞ = 854 mm; K = 0.16; t_0 = -0.19 yr, α = 7.00e-8 and β = 2.76 and m = 1. An offset of 135 days was used to calculate weight-at-age at the peak of the spawning season (May 15). Although weight-at-age was calculated in millimeters and kilograms, it was converted to pounds gutted weight (Table 3.2.2; Figure 3.2.2).

Maturity and fecundity series were developed according to the recommendations of the SEDAR12 DW and AW panels. A proxy for fecundity was developed such that fecundity is equal to Proportion Mature * Proportion Female * Gonad Weight (Table 3.2.3; Figure 3.2.3). Therefore, estimates of spawning stock abundance are in units of mature female gonad weight (g).

Landings in weight (gutted lbs) are summarized in Table 3.2.4. The landings of the commercial fisheries are reported in weight; therefore, no conversions were necessary. The recreational landings are reported in numbers. We used the derived proportion-at-age (SEDAR12-AW-06) for the recreational sector and the weight-at-age matrix to convert recreational landings (MRFSS AB1 + HB) to pounds gutted weight (Table 3.2.5).

Total discards were reported (or estimated) in numbers (Tables 3.2.6-Table 3.2.9). Because ASAP requires annual estimates of discards in weight, these were estimated using the derived proportion-at-age (SEDAR12-AW-06) and weight-at-age matrices (Tables 3.2.6-3.2.9). Since only one weight-at-age matrix is available (based on landed animals) and this matrix was used to estimate the weight of the discards and was also input to the model, the model is effectively fitting to discards in numbers. This method eliminates the need to obtain a weight-at-age function for discarded fish. However, the reader should be aware that the model may overestimate discards in weight because discarded animals are likely to be smaller at a given age than landed animals.

Catch-at-age and discards at age were modeled using an approach developed by Goodyear (1997), and described in SEDAR12-AW-06. The final inputs differ from those reported in SEDAR12-AW-06 because the model results depend on the natural mortality function, which was altered during the review workshop. The SEDAR12 AW and RW workshops agreed not to use the derived (modeled) catch-at-age because direct observations were available. However, there are no direct observations of the age composition of discarded fish. Therefore, we used the derived discard age composition with a very low weighting of (CV = 1.3). The age composition of the discards is summarized in Tables 3.2.6A, 3.2.7A, 3.2.8A and 3.2.9A.

Direct observations of catch-at-age were available from otolith analysis (SEDAR12-DW-03). Observations (by year and age) were stratified by region (North and South of 28°N), gear (LL, HL, Electric Reel, Trap) and mode (Headboat, Charterboat, Private). Four aggregated strata (Commercial LL, Commercial HL + Electric Reel, Commercial Trap and Recreational) were constructed by weighting the individual components by the corresponding landings fractions (Table 3.2.10). The effective sample sizes (Table 3.2.10) were used to weight the direct observed catch-at-age (by year and fleet). A maximum value of 200 was used to prevent excessive weighting of this data.

ASAP also requires estimates of the proportion of animals released (alive or dead) by age and year. These matrices were developed from the derived age composition (SEDAR12-AW-06), and are summarized in Table 3.2.11.

The review workshop panel assumed a 2% annual increase in catchability (q). To accommodate this assumption, the fisheries dependent indices were decremented by dividing the annual index values by a q-scalar equal to 1.0 in the initial year, and increasing 2% annually. The rescaled indices are summarized in Table 3.2.12.

3.3. Model Configuration and Equations

3.3.1. Population Dynamics

The population dynamics model of ASAP uses the standard equations common to forward-projection methods (Fournier and Archibald, 1982; Deriso et al., 1985; Methot, 1998; Ianelli and Fornier (1998). Unlike some forward-projection models, fleet specific catch and fishing mortality can be accommodated. For the following description, let:

a = age	1…A
y = year	1…Y
g = fleet	1…G
u = index	1…U

Age-specific selectivity coefficients were estimated subject to the following penalties used to constrain the amount of curvature allowed in the fleet-specific selectivity patterns by age:

$$\rho_{selA} = \lambda_{\rho 1} \sum_{y} \sum_{g} \sum_{a(g_{start})}^{a(g_{end})-2} \left(S_{a,y,g} - 2S_{a+1,y,g} + S_{a+2,y,g}\right)^2 \qquad \text{(Eq. 1)}$$

and over time:

$$\rho_{selY} = \lambda_{\rho 2} \sum_{a} \sum_{g} \sum_{Y=1}^{Y-2} \left(S_{a,y,g} - 2S_{a,y+1,g} + S_{a,y+2,g}\right)^2 \qquad \text{(Eq. 2)}$$

where the weighting of the penalty λ_{p1} was 400 (CV = 0.05). The base model did not allow annual deviations fleet-specific selectivity. Therefore, selectivity was estimated over the entire time period (1986-2005). However, it is important to note that although time-invariant selectivity functions were estimated, the discard fractions are estimated directly, and do vary annually. Therefore, although management actions (such as increasing the minimum size limit) will not modify the selectivity vector, they may cause changes the proportion of the catch discarded.

An additional penalty is used in early phases of the estimation procedure to keep the average fishing mortality rate close to the natural mortality rate. This penalty ensures that the population abundance estimates do not get exceedingly large during the early phases of minimization.

Directed fishing mortality (*dirF*) is calculated as follows:

$$dirF_{a,y,g} = S_{a,y,g} * Fmult_{y,g} * (1.0 - PropRel_{a,y,g}) \quad \text{(Eq. 3)}$$

where $S_{a,y,g}$ is the selectivity by age, year and fleet; $Fmult_{y,g}$ is the annual fleet-specific fishing mortality multiplier, and $PropRel_{a,y,g}$ is the proportion of fish released by age, year and fleet.

Discard fishing mortality (discF) is calculated as follows:

$$discF_{a,y,g} = S_{a,y,g} * Fmult_{y,g} * PropRel_{a,y,g} * RelMort_{g} \quad \text{(Eq. 4)}$$

where $S_{a,y,g}$ is the selectivity by age, year and fleet; $Fmult_{y,g}$ is the annual fleet-specific fishing mortality multiplier, $PropRel_{a,y,g}$ is the proportion of fish released by age, year and fleet and $RelMort_g$ is the fleet-specific release mortality rate.

Total fishing mortality at age and year is the sum of the fleet-specific directed and discard fishing mortality rates.

$$Ftot_{a,y} = \sum_{g} dirF_{a,y,g} + discF_{a,y,g} \quad \text{(Eq. 5)}$$

Total mortality is the sum of the total fishing mortality and the natural mortality (*M*).

$$Z_{a,y} = Ftot_{a,y} + M_{a,y} \quad \text{(Eq. 6)}$$

Catch-at-age, by year and fleet, is calculated as:

$$C_{a,y,g} = \frac{N_{a,y} * dirF_{a,y,g} * \left(1 - e^{-Z_{a,y}}\right)}{Z_{a,y}} \quad \text{(Eq. 7)}$$

where *N* is the population abundance at the start of the year. Discards-at-age, by year and fleet, are calculated in a similar fashion.

$$D_{a,y,g} = \frac{N_{a,y} * discF_{a,y,g} * \left(1 - e^{-Z_{a,y}}\right)}{Z_{a,y}} \quad \text{(Eq. 8)}$$

The landings and discards (in weight) by age, year and fleet are calculated

$$Y_{a,y,g} = C_{a,y,g} * W_{a,y} \quad or \quad discY_{a,y,g} = D_{a,y,g} * W_{a,y} \qquad \text{(Eq. 9)}$$

where $W_{a,y}$ is the weight of a fish of age *a* in year *y*.

The proportion of catch-at-age (or discards-at-age) within a year by a fleet is:

$$P_{CAA1_{a,y,g}} = \frac{C_{a,y,g}}{\sum_a C_{a,y,g}} \qquad \text{for the modeled catch – at – age}$$

$$P_{CAA2_{a,y,g}} = \frac{C_{a,y,g}}{\sum_a C_{a,y,g}} \qquad \text{for the direct observed catch – at – age} \qquad \text{(Eq. 10)}$$

$$or \quad P_{DAA_{a,y,g}} = \frac{D_{a,y,g}}{\sum_a D_{a,y,g}} \qquad \text{for the modeled discards – at – age}$$

Note: There are two catch-at-age matrices, the modeled CAA estimated using the Goodyear approach (CAA1), and the directly observed otolith observations (CAA2).

The recruitment in the first year is estimated as deviations from the predicted virgin recruitment

$$N_{1,y} = \overline{N_o} e^{v_y} \qquad \text{(Eq. 11)}$$

where $\nu_y \sim N(0,\sigma_{Ny}^2)$. For the base case, deviations from the average value were assigned a CV equal to 0.5.

The population age structure in year 1 is estimated as deviations from equilibrium at unfished (virgin) condition.

$$N_{a,1} = N_{1,1} e^{-\sum_{i=1}^{a-1} M_{i,1}} e^{\psi_a} \qquad for \;\; a < A$$

$$N_{a,1} = \frac{N_{1,1} e^{-\sum_{i=1}^{a-1} M_{i,1}}}{1 - e^{-M_{A,1}}} e^{\psi_a} \qquad for \;\; a = A \qquad \text{(Eq. 12)}$$

where $\psi_a \sim N(0,\sigma_{Na}^2)$. The remaining population abundance at age and year is then computed using the recursion:

$$N_{a,y} = N_{a-1,y-1}e^{-Z_{a-1,y-1}} \qquad for\ a < A$$
$$N_{a,y} = N_{a-1,y-1}e^{-Z_{a-1,y-1}} + N_{a,y-1}e^{-Z_{a,y-1}} \qquad for\ a = A \qquad \text{(Eq. 13)}$$

where Z is the total mortality (Eq. 6).

Predicted indices of abundance ($\hat{I}$) are a measure of the population scaled by catchability coefficients (q) and selectivity at age (S)

$$\hat{I}_{u,y} = q_{u,y} \sum_{a(u_{start})}^{a(u_{end})} S_{u,a,y} N^{*}_{a,y} \qquad \text{(Eq. 14)}$$

Where $a(u_{start})$ and $a(u_{end})$ are the starting and ending ages for the index, and N* is the population abundance, which can be expressed either in weight or numbers. The abundance index selectivity at age can be linked to that of a fleet, or input directly. If the latter is chosen, the age range can be smaller that that of the fleet and the annual selectivity values are rescaled to equal 1.0 for a specified age (a_{ref}) such that the catchability coefficient (q) is linked to this age.

$$S_{u,a,y} = \frac{S_{a,y,g}}{Sa_{ref}, y, g} \qquad \text{(Eq. 15)}$$

The settings used for the indices listed below. Selectivities for all indices except the SEAMAP video were linked to that of the corresponding fleet. For the SEAMAP Video Survey, a fixed selectivity vector based on the age composition was input (Relative selectivity at age 1 = 0; age 2 = 0; age 3 = 0.5; ages 4 to 20+ = 1.0).

INDEX	START AGE	END AGE	a_{ref}	Selectivity linked to fleet?
SEAMAP Video	3	20	4	FIXED
COM LL	4	20	4	COM LL
COM HL	4	20	4	COM HL
HB 1986-1990	4	20	4	REC
HB 1990-2005	4	20	4	REC
MRFSS	1	20	4	REC

3.3.2. Time-Varying Parameters

The ASAP modeling framework allows time varying fleet-specific selectivity and catchability parameters. Changes in selectivity can occur each year (or time step τ_g) through a random walk for every age in a given fleet:

$$S_{a,y+\tau,g} = S_{a,y,g} e^{\varepsilon_{a,y,g}} \quad \text{(Eq. 16)}$$

where $\varepsilon_{a,y,g} \sim N(0,S_g^2)$ and are then rescaled to average 1.0 following equation (1). The base model did not allow annual deviations fleet-specific selectivity. Instead, selectivity was estimated over the entire time period (1986-2005).

Deviations in the catchability coefficients can be modeled using a random walk

$$q_{u,y+1} = q_{u,y} e^{\omega_{u,y}} \quad \text{(Eq. 17)}$$

as are the fleet-specific fishing mortality rate multipliers

$$Fmult_{y+1,g} = Fmult_{y,g} e^{\eta_{y,g}} \quad \text{(Eq. 18)}$$

where $\omega_{u,y} \sim N(0,\sigma_{q,u}^2)$ and $\eta_{y,g}, \sim N(0,\sigma_{Fg}^2)$.

Although catchability can be allowed to vary using a random walk, these changes were not permitted during any final ASAP model. Instead, a 2% annual increase in catchability was applied to the base case. Sensitivity analyses examined alternative assumptions regarding catchability.

3.3.3. Parameter Estimation

ASAP requires initial guesses for certain parameters ($S_{g,a}$, $F_{g,1}$, $Q_{u,1}$, steepness, virgin stock size) which are estimated in early estimation phases. These initial guesses scale the parameters to biologically reasonable values, and facilitate the evaluation of parameters estimated in subsequent phases (F deviations, recruitment deviations, selectivity deviations etc.) All parameters are re-estimated in the final phase. The initial guesses are summarized in Table 3.3.3.1.

A total of 179 parameters were estimated during the ASAP base run, including:

1) 20 Recruitment (1986-2005)
2) 19 Population abundance in Year 1 (Ages -1)
3) 80 Fishing mortality rate multipliers (20 Years * 4 Fleets)
4) 52 Selectivity-at-age
5) 6 Catchabilities (6 indices)
6) 2 Stock Recruitment parameters (Virgin reproductive potential -steepness)

The likelihood function to be minimized includes the following components (excluding constants). Variables with a hat (∧) are estimated by the model and variables without a hat are input as observations. The weighting (λ) assigned to each component of the likelihood function are essentially equivalent to the inverse of the variance assumed to be associated with that component ($\lambda = 1/\sigma^2$) where $\sigma^2 = \ln(CV^2 + 1)$.

Total catch in weight by fleet (lognormally distributed)

$$L_{TotalCatch} = \lambda_1 \left[\ln\left(\sum_a Y_{a,y,g} \right) - \ln\left(\sum_a \hat{Y}_{a,y,g} \right) \right]^2 \qquad \text{(Eq. 19)}$$

where λ_1 is a weighting component assumed to equal 100.5 (CV = 0.1).

Total discards in weight by fleet (lognormally distributed)

$$L_{TotalDiscards} = \lambda_2 \left[\ln\left(\sum_a discY_{a,y,g} \right) - \ln\left(\sum_a disc\hat{Y}_{a,y,g} \right) \right]^2 \qquad \text{(Eq. 20)}$$

where λ_2 is a weighting component assumed to equal 11.6 (CV = 0.3).

Two matrices of catch-at-age and one discard-at-age matrix are included in the red grouper ASAP model runs, the modeled catch-at-age (CAA1) and discards-at-age matrices (DAA) were estimated using the Goodyear approach (SEDAR12-AW-06). The second catch-at-age matrix (CAA2) is the direct otolith observations. A separate likelihood component was included for each. These were assumed to be multinomially distributed and were calculated:

$$L_{CAA_1} = -\sum_y \sum_g \lambda_{3,y,g} \sum_a P_{a,y,g} \left[\ln\left(\hat{P}_{CAA1\,a,y,g} \right) - \ln\left(P_{CAA1\,a,y,g} \right) \right] \qquad \text{(Eq. 21)}$$

$$L_{CAA2} = -\sum_y \sum_g \lambda_{4,y,g} \sum_a P_{a,y,g} \left[\ln\left(\hat{P}_{CAA2\,a,y,g} \right) - \ln\left(P_{CAA2\,a,y,g} \right) \right] \qquad \text{(Eq. 22)}$$

$$L_{DAA} = -\sum_y \sum_g \lambda_{5,y,g} \sum_a P_{a,y,g} \left[\ln\left(\hat{P}_{DAA\,a,y,g} \right) - \ln\left(P_{DAA\,a,y,g} \right) \right] \qquad \text{(Eq. 23)}$$

The weighting components (λ_3, λ_4 and λ_5) are year and fleet specific. Setting λ=0 will assign a weight of zero to a given year/fleet combination. When this occurs, only total catch (or discards) in weight will be incorporated into the objective function for that fleet and year. During the ASAP base run, the derived catch-at-age (CAA1) was not used because direct observations of age composition were available. Therefore, λ_3 was set equal to 0 for all years and fleets. The weighting components, λ_4, for the direct observations of age composition (CAA2; from otolith analysis) were set to the effective sample sizes (Table 3.2 10; ***Note: maximum effective sample size capped at 200 to avoid excessive weighting***). The RW panel chose to downweight the discard age composition substantially, with regard to other model components (λ_5 = 1; CV=1.3) because they had little confidence in this model component.

The likelihood component for the indices of abundance (lognormally distributed) was calculated:

$$L_{Indices} = \sum_g \lambda_{6,g} \sum_y \left[\ln\left(I_{y,g}\right) - \ln\left(\hat{I}_{y,g}\right) \right]^2 / 2\sigma^2_{y,g} + \ln\left(\sigma_{y,g}\right) \qquad \text{(Eq. 24)}$$

where λ_6 is a weighting component assumed equal to 25 (CV = 0.2) for all indices. The sigmas (σ) in equation 23 can be set equal to 1.0, or input. For the ASAP base run, the indices were equally weighted, and all CVs were assumed to equal 0.2.

Priors for the time-varying parameters are also included in the likelihood by setting λ equal to the inverse of the assumed variance for each component:

$$L_{sel} = \sum_g \lambda_{7,g} \sum_a \sum_y \varepsilon^2_{a,y,g} \qquad (selectivity) \qquad \text{(Eq. 25)}$$

$$L_q = \sum_u \lambda_{8,u} \sum_y \omega^2_{u,y} \qquad (catchability) \qquad \text{(Eq. 26)}$$

$$L_{Fmult} = \sum_g \lambda_{9,g} \sum_y \eta^2_{y,g} \qquad (F\ multipliers) \qquad \text{(Eq. 27)}$$

$$L_R = \lambda_{10} \sum_y \nu^2_y \qquad (recruitment) \qquad \text{(Eq. 28)}$$

$$L_{N_1} = \lambda_{11} \sum_y \psi^2_y \qquad (N\ year\ 1) \qquad \text{(Eq. 29)}$$

where

Selectivity Deviations:	λ_7 = N/A;	None estimated
Catchability Deviations:	λ_8 = N/A;	None estimated
F_{Mult} Deviations (by Fleet):		
Commercial LL:	λ_9 = 11;	CV $\cong$ 0.29
Commercial HL	λ_9 = 11;	CV $\cong$ 0.29
Commercial Trap	λ_9 = 11;	CV $\cong$ 0.29
Recreational	λ_9 = 11;	CV $\cong$ 0.29
Recruitment Deviations	λ_{10} = 4.48	CV $\cong$ 0.50
N_{Year1} Deviations	λ_{11} = 4.48	CV $\cong$ 0.50

In addition, there is a prior for fitting a Beverton and Holt type stock-recruitment relationship

$$L_{SR} = \lambda_{12} \sum_y \left[\ln\left(N_{1,y}\right) - \ln\left(\frac{\alpha SS_{y-1}}{\beta + SS_{y-1}}\right) \right]^2 \qquad \text{(Eq. 30)}$$

where *SS* is the spawning stock reproductive potential, α and β are parameters to be estimated, and λ_{12} is the inverse of variance assigned to virgin stock size. For the base case, $\lambda_{12} = 0$. This setting causes the virgin stock size to be estimated as a free parameter. Note: ASAP estimates alpha and beta, but uses the re-parameterized inputs virgin reproductive potential (or biomass) and steepness.

The function to be minimized is the sum of the likelihoods and penalties.

$$L = L_{TotalCatch} + L_{TotalDiscards} + L_{CAA1} + L_{CAA2} + L_{DAA} + L_{Indices} + L_{Sel} + L_{Q} + \\ L_{FMult} + L_{R} + L_{NYear1} + L_{SR} + \rho_{SelA} + \rho_{SelY} \qquad \text{(Eq. 31)}$$

The component weightings recommended by the review workshop are summarized in Table 3.3.3.2.

3.4. Uncertainty and Measures of Precision

Each component of the objective function is reported to the output file (*.rep) along with the corresponding number of observations, weight assigned to that component, and the residual sum of squared deviations (when appropriate). The ASAP output includes an estimate of the standard deviation of each parameter. Standard deviations were derived by taking the inverse of the Hessian matrix at the maximum likelihood estimate, a capability of the AD-Model Builder software.

3.5. Methods for Benchmarks / Reference Points

Each fleet can be designated as “directed” or “non-directed” for the F reference point calculations. For red grouper, all fleets were considered directed. The directed fleets are combined to estimate an overall selectivity pattern that is used to solve for the common fishing mortality rate reference points ($F_{0.1}$, F_{MAX}, $F_{30\%SPR}$, $F_{40\%SPR}$, F_{MSY}, F_{OY}) and compared to the terminal year F estimate (F Current)

3.6. Projection Methods

Projections were run to 2015 using the projection software PRO-2BOX (Porch, 2002b). To estimate the variance of the projections, 500 bootstraps were run off the deterministic results of ASAP. This method does not take into account the inherent variability in the parameter estimates. Instead, the bootstrap variable was simply the recruitment deviations (std dev = 0.4). Five projections were made from the base run.

1) Project at F_{MSY}	2008-2015
2) Project at F_{OY}	2008-2015
3) Project at $F_{Current}$	2008-2015
4) Project at OY	2008-2015
5) Project Current Management Plan	2008-2015

The projection settings are summarized below:

	PROJECTION									
	F_{MSY}		F_{OY}		$F_{CURRENT}$		OY		Current Management	
YEAR	Fix?	Value	Fix?	Value	Fix?	Value	Fix?	Value	Fix?	Value
2006	Yield	7.28mp	Yield	7.28mp	Yield	7.28mp	Yield	7.28 mp	Yield	7.28 mp
2007	F	0.158	F	0.158	F	0.158	F	0.156	F	0.156
2008	F	0.22	F	0.16	F	0.158	Yield	7.57 mp	Yield	7.22 mp
2009	F	0.22	F	0.16	F	0.158	Yield	7.57 mp	Yield	7.33 mp
2010	F	0.22	F	0.16	F	0.158	Yield	7.57 mp	Yield	7.33 mp
2011	F	0.22	F	0.16	F	0.158	Yield	7.57 mp	Yield	7.33 mp
2012	F	0.22	F	0.16	F	0.158	Yield	7.57 mp	Yield	7.39 mp
2013	F	0.22	F	0.16	F	0.158	Yield	7.57 mp	Yield	7.39 mp
2014	F	0.22	F	0.16	F	0.158	Yield	7.57 mp	Yield	7.39 mp
2015	F	0.22	F	0.16	F	0.158	Yield	7.57 mp	Yield	7.39 mp

where F is the fishing mortality ($F_{CURRENT}$ = 0.158; F_{MSY} = 0.22; F_{OY} = 0.16). In all cases, it was assumed that management changes would not occur until 2008. Therefore, for 2006, a quota of 7.28 mp (5.31 mp + geometric mean of recreational yield 2003-2005) was applied, and for 2007, $F_{Current}$ was applied. Recruitment was estimated from the stock-recruitment relationship, but allowed to vary with a standard deviation equal to 0.4.

4. RESULTS

4.1. Measures of Overall Model Fit

The objective function value, likelihood components and residual sums of squares are tabulated in Table 4.1.1.

Model fits to the catch series were good, as was expected given the weighting of this component (λ = 100.5; CV=0.1; Table 4.1.2 and Figure 4.1.1).Residuals seldom exceeded 10% of the total annual catch.

The predicted discard series were estimated with a greater assumed variance (λ = 11.6; CV=0.3). Therefore, the fits were less precise, but acceptable. Residuals were generally 20-40% of the annual discards in weight, with the exception of the trap fleet for which residuals often exceeded 100% of the annual discards (Table 4.1.3 and Figure 4.1.2).

The predicted index values were assigned moderate variance (λ = 25; CV=0.2). The six indices were equally weighted, and the yearly estimates of each index were also assigned an equal weighting (CV = 0.2). The fits to the indices of abundance are summarized in Table 4.1.4 and Figure 4.1.3. During recent years, the predicted index values are lower than the observed values for the COM HL and HB 20" minimum size limit (1990-2005) indices. The MRFSS index deviates from the predicted values primarily during the middle of the time series (1988-1992) and in 2004.

Fits to the catch-at-age are generally acceptable (Figures 4.1.4 A-D). There are no observations for the commercial fisheries until 1991. Likewise, there are no observations for the trap fishery in 2005. Lack of fit is generally caused by low effective sample sizes (See Table 3.2.10A-D).

The derived discards-at-age were given a very low weighting (CV = 1.3) to reflect little confidence in their accuracy. Nevertheless, the fits to these modeled inputs are quite acceptable (Figures 4.1.5 A-D).

4.2. Parameter Estimates

As discussed in Section 3.3.3, the base run included 179 estimated parameters. Some of these are summarized in Table 4.2.1. The others, including selectivity-at-age, recruitment and FMULT deviations can be found in the report file (ASAP2002.std).

4.3. Stock Abundance and Recruitment

Abundance has generally increased since 1986 (Table 4.3.1; Figure 4.3.1). The highest estimated abundance occurred in 2000, as a result of a strong year class in 1999 (Figure 4.3.2; Table 4.3.1). Recruitment has deviated without obvious trend throughout the time series. Large year-classes are evident in 1996 and 1999 (Figure 4.3.2). The stock recruitment relationship is shown in Figure 4.3.3. The abundance-at-age is shown in Figure 4.3.4. and Table 4.3.1. According to these results, the stock is comprised mostly of individuals less than 10 years old. The oldest animals were declining in abundance from 1986 until the mid-1990s. After that time, the number of older individuals began to increase as younger animals progressed through the age structure.

4.4. Spawning Stock Biomass

Because reproductive potential {mature female gonad weight (g)} was used as a fecundity proxy, ASAP does not produce estimates of spawning stock biomass. Instead, ASAP estimates spawning stock reproductive potential (SS). Spawning stock reproductive potential (SS) has generally increased since 1986 (Figure 4.4.1and Table 4.4.1). At that time, SS as a fraction of SS at maximum sustainable yield (MSY) was 86% and SS as a fraction of SS at optimal yield (OY) was 72%. In 2005, SS/SS_{MSY} was estimated at 1.27 and SS/SS_{OY} was 1.07. These results indicate that the red grouper stock in the Gulf of Mexico is no longer overfished, and has fully recovered to both the SS at MSY and OY levels.

4.5. Fishery Selectivity

A single selectivity-at-age vector was estimated for each fleet. Each vector applies to the total catch (landed and released animals). After the estimation, the Age-1 selectivity was set to zero for the commercial fleets. This was done because there were very few observations of age-1 individuals in the commercial catch-at-age (either landed or discarded). The selectivity vectors are summarized in Figure 4.5.1 and Table 4.5.1. According to these results, older individuals (Ages 9- 20+) are selected for by the commercial trap fishery, while individuals Ages 9-15 are predominate in the commercial longline landings. Ages 2-10 are selected for by the commercial handline fleet. The recreational fishery selects for younger age classes (Ages < 10). ***Note: recall that many of the young fish that are caught are subsequently discarded.***

4.6. Fishing Mortality

Fleet-specific total fishing mortality rates (landings + discards) are summarized in Figure 4.6.1 and Table 4.6.1. The highest fishing mortality rates are due to the commercial longline and recreational fleets, while the lowest are due to the commercial trap fleet.

Annual estimates of apical F (landings + discards) indicate that fishing mortality generally increased during 1986-1993, and then declined (Figure 4.6.2 and Table 4.6.2). In 2005, apical F was equal to 0.158. In 1986, F/F_{MSY} was 0.83, indicating that overfishing was not occurring. Values of F/F_{MSY} greater than 1.0 (indicating overfishing) occurred in 1989, 1991, 1992, 1993 and 1994. The highest F occurred in 1993 (F_{1993}/F_{MSY} = 1.25). Since then, F/F_{MSY} has decreased. In 2005, F/F_{MSY} was 0.73. When F/F_{MSY} is the selected overfishing threshold, this implies that overfishing is no longer occurring. In addition, F_{2005} is very close to F_{OY} (F_{2005}/F_{OY} = 0.97), the management goal designated after the 2002 assessment.

Total fishing mortality-at-age (landings + discards) is summarized in Table 4.6.3. These estimates indicate low F on animals younger than 2. Maximal F occurred on animals aged 7-8 during the 18" minimum size limit (1986-1990), and 9-12 years old after the 20" minimum size limit (1990-2005).

4.7. Stock-Recruitment Parameters

Two stock recruitment parameters were estimated during the base run, steepness and virgin reproductive potential. Steepness was estimated using a triangular prior (as recommended by the 2002 Reef Fish Stock Assessment Panel) with a maximum probability at 0.7, and zero probability of steepness < 0.3 or >0.9. The assessment panel reviewed this prior, and agreed with the 2002 RFSAP that steepness values greater than 0.9 are not likely to be realistic for red grouper.

Estimated steepness was 0.84 (SD = 0.06). It is likely that steepness would have been higher if the prior allowed a greater probability of steepness > 0.84. The virgin spawning stock size was estimated as a free parameter (no prior was used). The estimated value was 1.62E+09 (grams mature female gonads).

4.8. Measures of Parameter Uncertainty

Uncertainty values are tabulated within each section when available.

4.9. Retrospective Analyses

Retrospective analyses were made to examine the effect of the most recent years of data (Figure 4.9.1 and Table 4.9.1). Generally, as years were removed from the SEDAR 12 base model, the result became more pessimistic. When the model was restricted to 1986-2001, SS_{2001}/SS_{MSY} = 0.93 and F_{2001}/F_{MSY} = 1.31. This result is similar to the 2002 base case at steepness 0.7 (SS_{2001}/SS_{MSY} = 0.84, F_{2001}/F_{MSY} = 1.03). Both results indicate a stock that was undergoing overfishing in 2001. In both cases, the stock had not yet recovered to SS_{MSY} as of 2001 (SS/SS_{MSY} < 1.0) but neither was the stock overfished (SS/SS_{MSY} > 1 - Natural Mortality).

The retrospective analyses also underscore the importance of the strong 1999 year class. As each recent year is removed from the model, the number of recruits (at age 1) estimated in 2000 declines. The 1999 year class is no longer apparent when the model is terminated in 2002 or 2001 (Figure 4.9.1). This result suggests that the 2005 stock status is enhanced by the strong 1999 year class which has recently recruited to the directed fisheries. These young fish were not available to the fisheries before 2002, and had only partially recruited by 2003. Therefore, the addition of 4 years of data (2002-2005) including a large recruitment event is the primary reason for the improved 2005 status. Changes in modeling assumptions appear to be secondary influences.

4.10. Sensitivity Analyses

Five sensitivity runs were requested by the SEDAR 12 Review Panel, including:

1) Increase natural mortality-at-age vector by 10% (multiply vector by 1.1).
2) Decrease natural mortality-at-age vector by 10% (multiply vector by 0.9).
3) Assume constant catchability (do not decrement fisheries dependent indices).
4) Assume a 4% annual increase in catchability (decrement fisheries dependent indices).
5) Reduce the variance allowed in the discards series (by weight) to CV = 0.15. Previously, the CV was equal to 0.3.

All of the SEDAR12 Review Panel sensitivity runs indicated that the stock was fully recovered (SS/SS_{MSY} > 1) and that overfishing was not occurring (F/F_{MSY} < 1). The most optimistic sensitivity runs used constant catchability or a higher natural mortality vector ($M_{AGE*} = M_{AGE} * 1.1$). The most pessimistic runs used a 4% increase in catchability or a lower natural mortality vector ($M_{AGE*} = M_{AGE} * 0.9$). The base run used a 2% increase in catchability. The results of the sensitivity runs are summarized in Table 4.10.1 and Figure 4.10.1.

4.11. Benchmarks / Reference Points / ABC Values

The results of the base run indicate that in 2005, the stock was not overfished , SS_{2005}/SS_{MSY}=1.27, (SD=0.089)and was not undergoing overfishing, F_{2005}/F_{MSY} = 0.73 (SD= 0.071). Furthermore, in 2005, F/F_{OY} = 0.97 and SS/SS_{OY} = 1.07, indicating the stock has recovered to both MSY and OY based reference levels. Management reference points are as follows MFMT = F_{MSY} = 0.22 and MSST = (1-M) * SS_{MSY} = 5.09E+08, where M = 0.14.

A complete summary of the benchmarks and reference points can be found in Table 4.10.1. Uncertainty values, if available, are summarized in Table 4.2.1.

Acceptable biological catch (ABC) values were selected based on the projection of F_{OY} during 2008-2015. Projected yield was used as a basis to estimate ABC. These values, in pounds gutted weight, are listed below. Also reported are the upper and lower 80% confidence intervals.

	ABC (millions of lbs) Based on F_{OY} Projection		
YEAR	**Lower 80% CI**	**Median Yield**	**Upper 80% CI**
2008	7.33	7.33	7.33
2009	7.28	7.28	7.28
2010	7.73	7.73	7.73
2011	7.97	7.97	7.97
2012	7.88	7.94	8.03
2013	7.68	7.91	8.26
2014	7.43	7.90	8.52
2015	7.21	7.92	8.83

4.12. Projections

Projections results, with 80% confidence intervals, are summarized in Figures 4.12.1 to 4.12.7 and Tables 4.12.1 to 4.12.7. Assuming no changes to the base run, all projections indicate that yield is sustainable at or somewhat above 2005 levels (7.33 million pounds, Figure 4.12.1, Table 4.12.1). Discards are generally projected to be 680-750 thousand pounds, with the exception of the F_{MSY} projection which estimates higher discards (1 million pounds, Figure 4.12.2, Table 4.12.2). All projections indicate that the stock will remain at or above SS_{MSY} throughout the time series (Figure 4.12.3 and Table 4.12.4) and that fishing mortality will remain at or below F_{MSY} (Figure 4.12.5 and Table 4.12.6). Only one projection run fails to sustain fishing mortality rates at or below F_{OY}, the F_{MSY} projection, which by definition, increases F to F_{MSY} beginning in 2008 (Figure 4.12.6, Table 4.12.6). The most conservative projection is the “Current Management” projection which reduces F to less than F_{OY} in 2010 (Figure 4.12.6 and Table 4.12.6), and continues to reduce fishing mortality throughout the projection interval. The projected recruitment does not vary greatly between projections (Table 4.12.7, Figure 4.12.7). Instead, recruitment is projected to be close to the 1986-2005 average of 9.6 million. The actual level of future recruitment will greatly influence the accuracy of these projections.

5. REFERENCES

Cass-Calay, S.L. et al. 2005. Revised assessments of Gulf of Mexico red snapper during 1962-2003 using a gulfwide implementation of an age-structured-assessment-program (ASAP). NOAA Fisheries, Southeast Fisheries Science Center, Sustainable Fisheries Division, Miami FL. SFD-2005-004.

Cass-Calay, S.L. and G. A. Diaz. 2005. Revised assessments of Gulf of Mexico red snapper during 1984-2003 using a gulfwide implementation of ASAP. NOAA Fisheries, Southeast Fisheries Science Center, Sustainable Fisheries Division, Miami FL. SFD-2005-003.

Deriso, R.B., T.J. Quinn and P.R. Neal. 1985. Catch-at-age analysis with auxillary information. Can. J. Fish. Aquat. Sci. 42: 815-824.

Fourier, D. and C.P. Archibald. 1982. A general theory for analyzing catch at age data. Can. J. Fish. Aquat. Sci. 39: 1195-1207.

Goodyear, C.P. 1997. Fish age determination from length: an evaluation of three methods using simulated red snapper data. Fish. Bull. 95: 39-46.

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

Ianelli, J.N. and D.A. Fournier. 1998. Alternative age-structured analyses of the NRC simulated stock assessment data. NOAA Tech. Memo. NMFS-F/SPO-30. pp. 81-96.

Legault, C.M. and V.R. Restrepo. 1998. A flexible forward age-structured assessment program. ICCAT. Col. Vol. Sci. Pap.49: 246-253.

Lombardi-Carlson, L.A., G.R. Fitzhugh and J.J. Mikulas. 2002. Red grouper (*Epinephelus morio*) age length structure and description of growth from the eastern Gulf of Mexico: 1992-2001. 121p. National Marine Fisheries Service, Panama City, FL Contribution Series 2002-06. 42p.

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

Methot. R. 1998. Application of stock synthesis to NRC test data sets. NOAA Tech, Memo. NMFS-F/SPO-30. pp. 59-80.

Ortiz, M. and S.L. Cass-Calay. 2005. Assessments of red snapper stocks in the eastern and western Gulf of Mexico using an age-structured-assessment-procedure. NOAA Fisheries, Southeast Fisheries Science Center, Sustainable Fisheries Division, Miami FL. SFD-2005-005.

Schirripa, M.J., C.M. Legault and M. Ortiz. 1999. The red grouper fishery of the Gulf of Mexico: Assessment 3.0. National Marine Fisheries Service, Sustainable Fisheries Division. Miami, SFD-98/99-56.

SESFC Staff. 2002. Status of red grouper in United States waters of the Gulf of Mexico during 1986-2001.NOAA Fisheries, Southeast Fisheries Science Center, Sustainable Fisheries Division, Miami FL. SFD-01/02-175.

Table 3.2.1. Natural mortality-at-age used for the SEDAR12 RW base run.

Age	Natural Mortality	Age	Natural Mortality
1	0.4943	11	0.1438
2	0.3391	12	0.1401
3	0.2681	13	0.1371
4	0.2277	14	0.1347
5	0.2018	15	0.1327
6	0.1840	16	0.1310
7	0.1712	17	0.1296
8	0.1616	18	0.1284
9	0.1542	19	0.1274
10	0.1484	20+	0.1266

Table 3.2.2. Weight-at-age used for the SEDAR12 RW base run.

Age	Gutted Weight (lbs)	Age	Gutted Weight (lbs)
1	0.1956	11	11.6234
2	0.7515	12	12.5739
3	1.6473	13	13.4218
4	2.7935	14	14.1724
5	4.0928	15	14.8327
6	5.4607	16	15.4106
7	6.8315	17	15.9143
8	8.1583	18	16.3516
9	9.4100	19	16.7303
10	10.5680	20+	17.8160

Table 3.2.3. Derivation of the fecundity proxy used for the SEDAR12 RW base run (Prop. Mature * Prop. Female * Gonad Weight).

Age	Proportion Mature	Proportion Female	Gonad Weight (g)	Fecundity Proxy for Model
1	0.000	1.000	0.0	0.00
2	0.143	0.949	2.3	0.31
3	0.750	0.898	11.0	7.41
4	0.907	0.848	32.6	25.06
5	0.950	0.797	54.3	41.10
6	0.977	0.746	83.4	60.79
7	0.965	0.695	83.4	55.93
8	0.988	0.645	115.5	73.58
9	1.000	0.594	161.1	95.63
10	1.000	0.543	181.4	98.49
11	1.000	0.492	209.2	103.00
12	1.000	0.441	238.4	105.25
13	1.000	0.391	268.8	105.02
14	1.000	0.340	300.4	102.12
15	1.000	0.289	333.2	96.33
16	1.000	0.240	367.0	88.09
17	1.000	0.240	402.0	96.47
18	1.000	0.240	438.0	105.11
19	1.000	0.240	474.9	113.99
20+	1.000	0.240	512.9	123.10

Table 3.2.4. Landings in weight (gutted pounds).

YEAR	COM LL	COM HL	COM TRAP	COM TOTAL	REC (MRFSS AB1+HB)	TOTAL (REC + COM)
1986	2,482,092	3,116,270	714,626	6,312,988	2,400,381	8,713,369
1987	3,742,403	2,531,263	444,230	6,717,896	1,464,707	8,182,602
1988	2,172,243	2,035,089	535,166	4,742,498	2,476,065	7,218,563
1989	3,048,280	3,740,154	579,481	7,367,915	2,761,149	10,129,064
1990	2,015,801	2,454,250	339,232	4,809,283	1,131,711	5,940,994
1991	2,588,385	2,131,682	374,441	5,094,507	1,775,109	6,869,617
1992	2,408,439	1,452,933	601,907	4,463,278	2,658,180	7,121,458
1993	4,302,811	1,359,833	716,986	6,379,630	2,091,164	8,470,794
1994	2,703,457	1,283,178	916,222	4,902,857	1,808,242	6,711,099
1995	2,466,024	1,222,425	1,057,700	4,746,149	1,862,567	6,608,716
1996	2,992,831	902,576	558,740	4,454,147	893,755	5,347,902
1997	3,135,748	1,005,510	707,226	4,848,484	562,328	5,410,812
1998	2,843,515	791,642	313,414	3,948,571	643,058	4,591,629
1999	3,944,719	1,257,123	772,866	5,974,708	1,152,807	7,127,515
2000	2,989,417	1,792,076	1,056,800	5,838,293	2,107,730	7,946,023
2001	3,534,997	1,661,758	767,746	5,964,501	1,327,773	7,292,274
2002	3,207,535	1,749,860	949,848	5,907,243	1,611,114	7,518,357
2003	3,067,675	1,147,243	723,050	4,937,969	1,275,833	6,213,802
2004	3,533,882	1,439,555	775,609	5,749,046	3,000,138	8,749,183
2005	3,304,299	1,495,955	610,334	5,410,588	1,630,136	7,040,724

Table 3.2.5. Calculation of recreational landings in weight (gutted pounds).

A) Multiply number landed (MRFSS AB1 + HB) by derived age comp to estimate number-at-age

		PROPORTION AT AGE (DERIVED)																			
YEAR	NUMBER LANDED	AGE 1	AGE 2	AGE 3	AGE 4	AGE 5	AGE 6	AGE 7	AGE 8	AGE 9	AGE 10	AGE 11	AGE 12	AGE 13	AGE 14	AGE 15	AGE 16	AGE 17	AGE 18	AGE 19	AGE 20+
1986	781,222	0.001	0.138	0.292	0.246	0.156	0.082	0.040	0.020	0.010	0.006	0.003	0.002	0.001	0.001	0.001	0.000	0.000	0.000	0.000	0.000
1987	428,978	0.000	0.141	0.283	0.218	0.140	0.084	0.050	0.030	0.019	0.012	0.008	0.005	0.003	0.002	0.002	0.001	0.001	0.000	0.000	0.001
1988	711,926	0.000	0.105	0.284	0.231	0.152	0.094	0.055	0.032	0.018	0.011	0.006	0.004	0.002	0.002	0.001	0.001	0.000	0.000	0.000	0.000
1989	801,267	0.000	0.061	0.289	0.274	0.170	0.094	0.050	0.027	0.015	0.008	0.005	0.003	0.002	0.001	0.001	0.000	0.000	0.000	0.000	0.000
1990	190,750	0.000	0.026	0.047	0.151	0.199	0.179	0.134	0.091	0.060	0.039	0.025	0.016	0.011	0.007	0.005	0.003	0.002	0.002	0.001	0.003
1991	297,158	0.000	0.000	0.014	0.139	0.244	0.219	0.149	0.091	0.055	0.033	0.020	0.013	0.008	0.005	0.003	0.002	0.002	0.001	0.001	0.002
1992	451,980	0.002	0.002	0.023	0.148	0.239	0.209	0.144	0.090	0.054	0.033	0.020	0.013	0.008	0.005	0.003	0.002	0.002	0.001	0.001	0.002
1993	371,007	0.000	0.004	0.039	0.171	0.245	0.201	0.131	0.080	0.048	0.029	0.018	0.011	0.007	0.005	0.003	0.002	0.002	0.001	0.001	0.002
1994	308,169	0.000	0.000	0.017	0.148	0.250	0.215	0.144	0.088	0.053	0.032	0.019	0.012	0.007	0.005	0.003	0.002	0.001	0.001	0.001	0.001
1995	296,934	0.000	0.000	0.016	0.126	0.216	0.207	0.154	0.102	0.065	0.041	0.025	0.016	0.010	0.007	0.004	0.003	0.002	0.001	0.001	0.002
1996	142,070	0.000	0.000	0.014	0.121	0.218	0.211	0.157	0.103	0.065	0.040	0.025	0.016	0.010	0.007	0.004	0.003	0.002	0.001	0.001	0.002
1997	92,254	0.000	0.000	0.016	0.132	0.235	0.215	0.150	0.094	0.058	0.036	0.022	0.014	0.009	0.006	0.004	0.003	0.002	0.001	0.001	0.002
1998	108,890	0.000	0.000	0.030	0.156	0.234	0.202	0.140	0.089	0.055	0.034	0.021	0.014	0.009	0.006	0.004	0.002	0.002	0.001	0.001	0.002
1999	184,929	0.000	0.001	0.026	0.118	0.216	0.209	0.154	0.101	0.064	0.040	0.025	0.016	0.010	0.007	0.004	0.003	0.002	0.001	0.001	0.002
2000	342,540	0.000	0.000	0.030	0.156	0.216	0.185	0.135	0.093	0.062	0.041	0.027	0.018	0.012	0.008	0.005	0.004	0.002	0.002	0.001	0.003
2001	220,359	0.000	0.000	0.017	0.148	0.238	0.206	0.142	0.091	0.057	0.036	0.023	0.014	0.009	0.006	0.004	0.003	0.002	0.001	0.001	0.002
2002	252,359	0.000	0.000	0.014	0.117	0.213	0.208	0.156	0.105	0.067	0.043	0.027	0.017	0.011	0.007	0.005	0.003	0.002	0.002	0.001	0.002
2003	224,877	0.000	0.000	0.026	0.178	0.251	0.203	0.133	0.081	0.048	0.029	0.018	0.011	0.007	0.005	0.003	0.002	0.001	0.001	0.001	0.002
2004	506,241	0.000	0.001	0.020	0.157	0.245	0.203	0.135	0.085	0.054	0.034	0.022	0.014	0.009	0.006	0.004	0.003	0.002	0.001	0.001	0.002
2005	258,115	0.000	0.000	0.006	0.108	0.229	0.223	0.159	0.102	0.063	0.039	0.024	0.015	0.010	0.007	0.004	0.003	0.002	0.001	0.001	0.002

B) Multiply number-at-age by weight-at-age to estimate total landings (MRFSS AB1 + HB) in weight.

	NUMBER AT AGE (DERIVED)																				
YEAR	AGE 1	AGE 2	AGE 3	AGE 4	AGE 5	AGE 6	AGE 7	AGE 8	AGE 9	AGE 10	AGE 11	AGE 12	AGE 13	AGE 14	AGE 15	AGE 16	AGE 17	AGE 18	AGE 19	AGE 20+	**Total Weight (gutted lbs)**
1986	412	108,056	227,822	191,825	122,243	64,085	31,576	15,733	8,162	4,445	2,538	1,514	939	601	396	266	182	126	88	212	**2,400,381**
1987	16	60,507	121,271	93,477	60,219	35,869	21,239	12,930	8,108	5,190	3,369	2,211	1,465	980	661	450	309	213	148	345	**1,464,707**
1988	28	74,854	202,276	164,120	108,508	67,138	39,447	22,655	13,029	7,605	4,533	2,763	1,721	1,094	708	465	310	209	143	319	**2,476,065**
1989	8	48,497	231,811	219,170	136,580	75,284	40,064	21,398	11,692	6,588	3,832	2,297	1,415	892	574	376	250	168	115	257	**2,761,149**
1990	6	4,963	8,915	28,795	37,975	34,139	25,486	17,349	11,355	7,351	4,774	3,129	2,073	1,389	940	643	443	307	214	504	**1,131,711**
1991	0	1	4,204	41,326	72,428	64,972	44,189	27,106	16,210	9,762	5,990	3,754	2,400	1,563	1,034	693	470	322	222	513	**1,775,109**
1992	737	988	10,482	67,034	108,042	94,492	64,878	40,530	24,559	14,863	9,101	5,667	3,592	2,317	1,517	1,008	678	461	316	719	**2,658,180**
1993	0	1,610	14,345	63,536	90,843	74,543	48,766	29,517	17,666	10,741	6,684	4,255	2,764	1,825	1,222	828	567	391	272	633	**2,091,164**
1994	0	39	5,277	45,743	76,946	66,201	44,375	27,210	16,274	9,754	5,926	3,665	2,309	1,481	965	639	428	290	198	448	**1,808,242**
1995	0	3	4,811	37,405	64,177	61,521	45,817	30,433	19,280	12,047	7,546	4,774	3,060	1,988	1,309	873	588	400	275	627	**1,862,567**
1996	0	1	1,923	17,124	30,980	30,042	22,246	14,665	9,233	5,740	3,580	2,257	1,442	934	614	408	275	187	128	292	**893,755**
1997	0	6	1,438	12,153	21,715	19,867	13,794	8,682	5,337	3,297	2,066	1,316	851	559	371	250	170	116	80	186	**562,328**
1998	0	21	3,216	16,936	25,442	21,947	15,215	9,714	6,037	3,740	2,334	1,475	944	613	404	269	181	123	85	194	**643,058**
1999	0	194	4,840	21,796	39,950	38,625	28,429	18,715	11,807	7,371	4,623	2,931	1,884	1,228	811	542	366	250	172	394	**1,152,807**
2000	0	62	10,339	53,529	73,844	63,385	46,332	31,898	21,346	14,082	9,244	6,076	4,015	2,673	1,794	1,215	829	570	395	913	**2,107,730**
2001	0	4	3,753	32,532	52,501	45,432	31,338	20,024	12,537	7,856	4,966	3,177	2,059	1,351	898	603	409	280	193	444	**1,327,773**
2002	0	18	3,542	29,534	53,676	52,446	39,348	26,388	16,934	10,733	6,817	4,368	2,830	1,856	1,232	826	560	383	264	606	**1,611,114**
2003	0	5	5,755	40,116	56,519	45,581	29,870	18,170	10,871	6,561	4,033	2,531	1,619	1,054	697	467	317	217	149	345	**1,275,833**
2004	0	757	10,274	79,273	124,202	102,806	68,511	43,201	27,160	17,241	11,071	7,190	4,722	3,134	2,101	1,422	971	668	463	1,074	**3,000,138**
2005	0	-	1,636	27,911	59,204	57,481	41,155	26,307	16,265	10,052	6,288	3,996	2,580	1,691	1,123	755	513	352	243	562	**1,630,136**
Weight-at-Age	0.196	0.752	1.647	2.793	4.093	5.461	6.832	8.158	9.410	10.568	11.623	12.574	13.422	14.172	14.833	15.411	15.914	16.352	16.730	17.816	

Table 3.2.6. Calculation of ***commercial longline*** dead discards in weight (gutted pounds).

A) multiply number discarded dead by derived age comp to estimate number-at-age

		PROPORTION DISCARDED DEAD AT AGE (DERIVED)																			
YEAR	NUMBER DISCARDED DEAD	AGE 1	AGE 2	AGE 3	AGE 4	AGE 5	AGE 6	AGE 7	AGE 8	AGE 9	AGE 10	AGE 11	AGE 12	AGE 13	AGE 14	AGE 15	AGE 16	AGE 17	AGE 18	AGE 19	AGE 20
1986	0	0.000	0.863	0.118	0.015	0.003	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1987	0	0.000	0.737	0.228	0.029	0.005	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1988	0	0.000	0.794	0.182	0.020	0.003	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1989	0	0.000	0.682	0.266	0.041	0.008	0.002	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1990	176,590	0.000	0.016	0.236	0.320	0.210	0.110	0.054	0.026	0.013	0.007	0.004	0.002	0.001	0.001	0.000	0.000	0.000	0.000	0.000	0.000
1991	370,445	0.000	0.133	0.307	0.287	0.152	0.067	0.029	0.013	0.006	0.003	0.001	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1992	166,007	0.000	0.104	0.213	0.295	0.205	0.100	0.045	0.020	0.009	0.004	0.002	0.001	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1993	236,771	0.000	0.174	0.299	0.252	0.146	0.070	0.031	0.014	0.006	0.003	0.002	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1994	184,877	0.000	0.393	0.292	0.163	0.083	0.038	0.017	0.007	0.003	0.002	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1995	236,200	0.000	0.290	0.299	0.219	0.110	0.047	0.019	0.008	0.004	0.002	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1996	261,744	0.000	0.441	0.286	0.154	0.070	0.029	0.012	0.005	0.002	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1997	282,439	0.000	0.422	0.275	0.167	0.080	0.033	0.013	0.006	0.002	0.001	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1998	242,831	0.000	0.428	0.266	0.160	0.082	0.037	0.016	0.007	0.003	0.001	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1999	300,867	0.000	0.362	0.279	0.187	0.097	0.043	0.018	0.008	0.003	0.002	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2000	248,017	0.000	0.374	0.265	0.181	0.099	0.045	0.020	0.009	0.004	0.002	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2001	279,119	0.000	0.284	0.281	0.224	0.120	0.052	0.022	0.009	0.004	0.002	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2002	262,996	0.000	0.287	0.257	0.228	0.129	0.057	0.024	0.010	0.004	0.002	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2003	242,103	0.000	0.328	0.282	0.203	0.106	0.046	0.020	0.008	0.004	0.002	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2004	267,521	0.000	0.116	0.339	0.287	0.152	0.063	0.025	0.010	0.004	0.002	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2005	256,386	0.000	0.039	0.305	0.332	0.186	0.080	0.033	0.014	0.006	0.003	0.001	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

B) multiply number-at-age by weight-at-age to estimate total landings in weight.

	NUMBER DISCARDED DEAD AT AGE (DERIVED)																				
YEAR	AGE 1	AGE 2	AGE 3	AGE 4	AGE 5	AGE 6	AGE 7	AGE 8	AGE 9	AGE 10	AGE 11	AGE 12	AGE 13	AGE 14	AGE 15	AGE 16	AGE 17	AGE 18	AGE 19	AGE 20	DISCARDS (GUTTED LBS)
1986	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1987	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1988	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1989	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1990	0	2,741	41,659	56,588	37,097	19,379	9,507	4,646	2,315	1,186	629	345	195	114	69	43	27	17	12	22	642,444
1991	0	49,307	113,609	106,239	56,348	24,864	10,766	4,798	2,223	1,076	543	287	157	89	52	31	20	12	9	15	1,047,817
1992	0	17,293	35,383	48,910	33,982	16,615	7,412	3,316	1,532	737	370	195	106	60	35	22	13	9	5	10	548,134
1993	0	41,299	70,902	59,655	34,489	16,559	7,444	3,337	1,536	735	368	192	104	59	34	21	13	8	5	9	656,707
1994	0	72,708	53,934	30,188	15,313	7,028	3,100	1,371	623	294	145	75	40	23	13	8	5	3	2	4	374,239
1995	0	68,454	70,729	51,635	26,006	11,079	4,605	1,967	877	410	201	104	56	31	18	11	7	4	2	4	544,782
1996	0	115,388	74,935	40,293	18,245	7,497	3,044	1,271	554	254	123	62	33	18	10	6	4	2	1	3	480,720
1997	0	119,090	77,583	47,176	22,573	9,307	3,764	1,578	696	324	159	82	44	25	14	9	5	3	2	4	545,266
1998	0	103,813	64,557	38,798	19,791	8,939	3,849	1,657	734	339	164	83	44	25	14	9	5	3	2	4	477,339
1999	0	108,799	83,808	56,398	29,213	12,859	5,437	2,330	1,035	480	234	120	64	36	21	12	8	5	3	6	644,556
2000	0	92,669	65,805	44,905	24,496	11,170	4,864	2,147	981	467	233	121	66	37	22	13	8	5	3	5	536,157
2001	0	79,241	78,392	62,531	33,476	14,603	6,089	2,580	1,135	524	254	129	69	38	22	13	8	5	3	6	665,925
2002	0	75,465	67,715	59,872	34,002	14,935	6,181	2,602	1,143	528	256	131	70	39	22	13	8	5	3	6	643,022
2003	0	79,292	68,184	49,232	25,670	11,213	4,728	2,026	899	417	203	104	56	31	18	11	7	4	3	5	543,031
2004	0	30,918	90,575	76,824	40,702	16,890	6,657	2,709	1,165	530	256	130	69	39	22	13	8	5	3	6	736,977
2005	0	10,048	78,221	85,182	47,579	20,485	8,344	3,494	1,541	718	353	182	98	55	32	19	12	7	5	8	798,363
Weight-at-age	0.196	0.752	1.647	2.793	4.093	5.461	6.832	8.158	9.410	10.568	11.623	12.574	13.422	14.172	14.833	15.411	15.914	16.352	16.730	17.816	

Table 3.2.7. Calculation of ***commercial handline*** dead discards in weight (gutted pounds).

A) multiply number discarded dead by derived age comp to estimate number-at-age

		PROPORTION DISCARDED DEAD AT AGE (DERIVED)																			
YEAR	NUMBER DISCARDED DEAD	AGE 1	AGE 2	AGE 3	AGE 4	AGE 5	AGE 6	AGE 7	AGE 8	AGE 9	AGE 10	AGE 11	AGE 12	AGE 13	AGE 14	AGE 15	AGE 16	AGE 17	AGE 18	AGE 19	AGE 20
1986	0	0.000	0.024	0.575	0.253	0.084	0.035	0.015	0.008	0.005	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1987	0	0.000	0.382	0.488	0.101	0.021	0.005	0.002	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1988	0	0.000	0.800	0.183	0.015	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1989	0	0.000	0.766	0.205	0.024	0.004	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1990	25,308	0.000	0.101	0.266	0.237	0.166	0.103	0.059	0.032	0.017	0.009	0.005	0.003	0.001	0.001	0.001	0.000	0.000	0.000	0.000	0.000
1991	40,345	0.000	0.151	0.385	0.265	0.117	0.047	0.019	0.008	0.004	0.002	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1992	49,571	0.000	0.080	0.270	0.304	0.185	0.088	0.039	0.018	0.008	0.004	0.002	0.001	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1993	22,206	0.000	0.073	0.275	0.294	0.184	0.093	0.043	0.019	0.009	0.004	0.002	0.001	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1994	26,310	0.000	0.188	0.329	0.257	0.129	0.055	0.023	0.010	0.005	0.002	0.001	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1995	24,454	0.000	0.323	0.300	0.205	0.100	0.042	0.017	0.007	0.003	0.001	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1996	31,677	0.000	0.163	0.321	0.273	0.141	0.060	0.024	0.010	0.004	0.002	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1997	30,548	0.000	0.246	0.271	0.248	0.136	0.058	0.023	0.009	0.004	0.002	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1998	30,190	0.000	0.367	0.277	0.191	0.095	0.040	0.017	0.007	0.003	0.001	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1999	37,722	0.000	0.310	0.275	0.216	0.114	0.049	0.020	0.009	0.004	0.002	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2000	34,325	0.000	0.216	0.340	0.243	0.116	0.049	0.020	0.009	0.004	0.002	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2001	36,165	0.000	0.240	0.307	0.244	0.123	0.050	0.020	0.008	0.004	0.002	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2002	35,183	0.000	0.276	0.319	0.218	0.109	0.046	0.018	0.007	0.003	0.001	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2003	32,717	0.000	0.263	0.299	0.233	0.120	0.050	0.020	0.008	0.004	0.002	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2004	29,090	0.000	0.133	0.385	0.281	0.125	0.047	0.017	0.007	0.003	0.001	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2005	25,643	0.000	0.003	0.148	0.377	0.271	0.121	0.047	0.018	0.007	0.003	0.001	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

B) multiply number-at-age by weight-at-age to estimate total landings in weight.

	NUMBER DISCARDED DEAD AT AGE (DERIVED)																				
YEAR	AGE 1	AGE 2	AGE 3	AGE 4	AGE 5	AGE 6	AGE 7	AGE 8	AGE 9	AGE 10	AGE 11	AGE 12	AGE 13	AGE 14	AGE 15	AGE 16	AGE 17	AGE 18	AGE 19	AGE 20	DISCARDS (GUTTED LBS)
1986	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1987	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1988	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1989	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1990	0	2,550	6,743	6,000	4,197	2,604	1,486	802	423	223	120	66	37	22	13	8	5	3	2	4	87,807
1991	0	6,105	15,521	10,687	4,726	1,899	777	333	149	71	35	18	10	5	3	2	1	1	1	1	100,877
1992	0	3,975	13,372	15,056	9,149	4,344	1,951	884	413	200	102	53	29	17	10	6	4	2	2	2	157,670
1993	0	1,630	6,104	6,537	4,095	2,056	950	432	200	96	48	25	14	8	4	3	2	1	1	1	71,785
1994	0	4,936	8,652	6,765	3,385	1,449	614	268	121	57	28	15	8	4	3	2	1	1	0	1	67,541
1995	0	7,905	7,340	5,025	2,436	1,015	412	172	76	35	17	9	5	3	2	1	1	0	0	0	53,364
1996	0	5,156	10,167	8,645	4,479	1,891	762	314	136	62	30	15	8	4	3	1	1	1	0	1	83,943
1997	0	7,523	8,279	7,585	4,164	1,760	705	290	125	57	28	14	7	4	2	1	1	1	0	0	76,849
1998	0	11,081	8,357	5,776	2,877	1,218	499	208	90	41	20	10	5	3	2	1	1	0	0	0	63,582
1999	0	11,679	10,377	8,132	4,301	1,866	771	323	141	64	31	16	8	5	3	2	1	1	0	1	87,131
2000	0	7,404	11,665	8,329	3,989	1,688	701	296	130	60	29	15	8	4	3	1	1	1	0	1	83,444
2001	0	8,666	11,112	8,830	4,434	1,825	733	306	134	62	30	15	8	4	3	2	1	1	0	1	87,823
2002	0	9,697	11,235	7,671	3,852	1,607	643	263	113	51	24	12	6	4	2	1	1	0	0	0	80,549
2003	0	8,607	9,771	7,614	3,925	1,648	661	270	116	52	25	13	7	4	2	1	1	0	0	0	77,922
2004	0	3,856	11,189	8,183	3,641	1,364	504	197	82	37	18	9	5	3	1	1	1	0	0	0	73,220
2005	0	88	3,800	9,667	6,956	3,109	1,205	466	189	82	38	19	10	5	3	2	1	1	0	0	94,460
Weight-at-age	0.196	0.752	1.647	2.793	4.093	5.461	6.832	8.158	9.410	10.568	11.623	12.574	13.422	14.172	14.833	15.411	15.914	16.352	16.730	17.816	

Table 3.2.8. Calculation of ***commercial trap*** dead discards in weight (gutted pounds).

A) multiply number discarded dead by derived age comp to estimate number-at-age

		PROPORTION DISCARDED DEAD AT AGE (DERIVED)																			
YEAR	NUMBER DISCARDED DEAD	AGE 1	AGE 2	AGE 3	AGE 4	AGE 5	AGE 6	AGE 7	AGE 8	AGE 9	AGE 10	AGE 11	AGE 12	AGE 13	AGE 14	AGE 15	AGE 16	AGE 17	AGE 18	AGE 19	AGE 20
1986	0	0.000	0.610	0.348	0.036	0.005	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1987	0	0.000	0.777	0.204	0.017	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1988	0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1989	0	0.000	0.787	0.193	0.017	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1990	1,282	0.000	0.145	0.317	0.291	0.151	0.060	0.022	0.008	0.003	0.001	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1991	2,610	0.000	0.144	0.371	0.286	0.127	0.046	0.016	0.006	0.002	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1992	5,268	0.000	0.151	0.235	0.305	0.176	0.076	0.031	0.013	0.006	0.003	0.001	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1993	1,423	0.000	0.003	0.246	0.432	0.209	0.072	0.024	0.008	0.003	0.001	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1994	1,345	0.000	0.022	0.218	0.379	0.225	0.096	0.037	0.014	0.006	0.002	0.001	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1995	1,256	0.000	0.117	0.416	0.269	0.120	0.047	0.018	0.007	0.003	0.001	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1996	1,199	0.000	0.648	0.219	0.085	0.031	0.011	0.004	0.001	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1997	985	0.000	0.609	0.231	0.097	0.039	0.015	0.006	0.002	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1998	698	0.000	0.104	0.241	0.324	0.191	0.083	0.033	0.013	0.006	0.002	0.001	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1999	845	0.000	0.017	0.237	0.361	0.220	0.097	0.039	0.016	0.007	0.003	0.001	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2000	895	0.000	0.209	0.321	0.247	0.128	0.056	0.023	0.009	0.004	0.002	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2001	913	0.000	0.163	0.303	0.289	0.146	0.059	0.023	0.009	0.004	0.002	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2002	1,003	0.000	0.158	0.246	0.266	0.177	0.087	0.037	0.016	0.007	0.003	0.001	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2003	802	0.000	0.172	0.336	0.249	0.133	0.062	0.027	0.011	0.005	0.002	0.001	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2004	623	0.000	0.008	0.205	0.349	0.242	0.112	0.047	0.020	0.009	0.004	0.002	0.001	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2005	482	0.000	0.038	0.276	0.353	0.200	0.082	0.031	0.012	0.005	0.002	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

B) multiply number-at-age by weight-at-age to estimate total landings in weight.

	NUMBER DISCARDED DEAD AT AGE (DERIVED)																				
YEAR	AGE 1	AGE 2	AGE 3	AGE 4	AGE 5	AGE 6	AGE 7	AGE 8	AGE 9	AGE 10	AGE 11	AGE 12	AGE 13	AGE 14	AGE 15	AGE 16	AGE 17	AGE 18	AGE 19	AGE 20	DISCARDS (GUTTED LBS)
1986	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1987	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1988	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1989	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1990	0	186	406	373	194	77	28	10	4	2	1	0	0	0	0	0	0	0	0	0	3,420
1991	0	376	969	745	332	121	42	15	6	2	1	0	0	0	0	0	0	0	0	0	6,488
1992	0	798	1,240	1,606	927	399	165	70	31	15	7	4	2	1	1	0	0	0	0	0	15,460
1993	0	4	349	615	298	103	34	12	5	2	1	0	0	0	0	0	0	0	0	0	4,491
1994	0	30	293	510	303	129	49	19	7	3	1	1	0	0	0	0	0	0	0	0	4,500
1995	0	147	522	338	151	60	23	9	4	2	1	0	0	0	0	0	0	0	0	0	3,162
1996	0	777	263	102	37	13	4	2	1	0	0	0	0	0	0	0	0	0	0	0	1,580
1997	0	600	227	95	38	14	6	2	1	0	0	0	0	0	0	0	0	0	0	0	1,401
1998	0	72	168	226	134	58	23	9	4	2	1	0	0	0	0	0	0	0	0	0	2,136
1999	0	15	200	305	186	82	33	13	6	2	1	1	0	0	0	0	0	0	0	0	2,845
2000	0	187	287	222	115	50	20	8	4	2	1	0	0	0	0	0	0	0	0	0	2,250
2001	0	148	277	264	133	54	21	9	4	2	1	0	0	0	0	0	0	0	0	0	2,434
2002	0	159	246	267	178	87	37	16	7	3	1	1	0	0	0	0	0	0	0	0	2,989
2003	0	138	269	199	107	50	22	9	4	2	1	0	0	0	0	0	0	0	0	0	2,115
2004	0	5	127	217	151	70	29	13	6	3	1	1	0	0	0	0	0	0	0	0	2,235
2005	0	18	133	170	96	40	15	6	2	1	0	0	0	0	0	0	0	0	0	0	1,505
Weight-at-age	0.196	0.752	1.647	2.793	4.093	5.461	6.832	8.158	9.410	10.568	11.623	12.574	13.422	14.172	14.833	15.411	15.914	16.352	16.730	17.816	

Table 3.2.9. Calculation of ***recreational*** dead discards in weight (gutted pounds).

A) multiply number discarded dead by derived age comp to estimate number-at-age

		PROPORTION DISCARDED DEAD AT AGE (DERIVED)																			
YEAR	NUMBER DISCARDED DEAD	AGE 1	AGE 2	AGE 3	AGE 4	AGE 5	AGE 6	AGE 7	AGE 8	AGE 9	AGE 10	AGE 11	AGE 12	AGE 13	AGE 14	AGE 15	AGE 16	AGE 17	AGE 18	AGE 19	AGE 20
1986	53,966	0.707	0.269	0.022	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1987	49,690	0.707	0.269	0.022	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1988	90,804	0.707	0.269	0.022	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1989	213,305	0.707	0.269	0.022	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1990	174,523	0.346	0.276	0.185	0.109	0.050	0.020	0.008	0.003	0.001	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1991	311,055	0.346	0.276	0.185	0.109	0.050	0.020	0.008	0.003	0.001	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1992	272,299	0.346	0.276	0.185	0.109	0.050	0.020	0.008	0.003	0.001	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1993	178,823	0.346	0.276	0.185	0.109	0.050	0.020	0.008	0.003	0.001	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1994	171,760	0.346	0.276	0.185	0.109	0.050	0.020	0.008	0.003	0.001	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1995	171,885	0.346	0.276	0.185	0.109	0.050	0.020	0.008	0.003	0.001	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1996	121,994	0.346	0.276	0.185	0.109	0.050	0.020	0.008	0.003	0.001	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1997	113,913	0.346	0.276	0.185	0.109	0.050	0.020	0.008	0.003	0.001	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1998	159,157	0.346	0.276	0.185	0.109	0.050	0.020	0.008	0.003	0.001	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1999	216,473	0.346	0.276	0.185	0.109	0.050	0.020	0.008	0.003	0.001	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2000	229,115	0.346	0.276	0.185	0.109	0.050	0.020	0.008	0.003	0.001	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2001	170,838	0.346	0.276	0.185	0.109	0.050	0.020	0.008	0.003	0.001	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2002	199,047	0.346	0.276	0.185	0.109	0.050	0.020	0.008	0.003	0.001	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2003	216,651	0.346	0.276	0.185	0.109	0.050	0.020	0.008	0.003	0.001	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2004	322,055	0.346	0.276	0.185	0.109	0.050	0.020	0.008	0.003	0.001	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2005	185,932	0.346	0.276	0.185	0.109	0.050	0.020	0.008	0.003	0.001	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

B) multiply number-at-age by weight-at-age to estimate total landings in weight.

	NUMBER DISCARDED DEAD AT AGE (DERIVED)																				
YEAR	AGE 1	AGE 2	AGE 3	AGE 4	AGE 5	AGE 6	AGE 7	AGE 8	AGE 9	AGE 10	AGE 11	AGE 12	AGE 13	AGE 14	AGE 15	AGE 16	AGE 17	AGE 18	AGE 19	AGE 20	DISCARDS (GUTTED LBS)
1986	38,168	14,514	1,167	99	14	3	1	0	0	0	0	0	0	0	0	0	0	0	0	0	20,657
1987	35,143	13,364	1,074	91	13	3	1	0	0	0	0	0	0	0	0	0	0	0	0	0	19,021
1988	64,221	24,422	1,963	167	24	5	2	1	0	0	0	0	0	0	0	0	0	0	0	0	34,758
1989	150,860	57,369	4,611	392	56	12	3	1	1	0	0	0	0	0	0	0	0	0	0	0	81,650
1990	60,383	48,152	32,277	19,018	8,764	3,488	1,369	565	250	119	60	32	18	11	6	4	3	2	1	2	228,556
1991	107,621	85,822	57,528	33,896	15,621	6,217	2,440	1,007	445	212	107	57	32	19	11	7	4	3	2	4	407,354
1992	94,212	75,129	50,360	29,673	13,674	5,443	2,136	881	390	185	94	50	28	16	10	6	4	3	2	4	356,598
1993	61,871	49,338	33,073	19,487	8,980	3,574	1,403	579	256	122	62	33	19	11	7	4	3	2	1	2	234,183
1994	59,427	47,389	31,766	18,717	8,625	3,433	1,347	556	246	117	59	32	18	10	6	4	2	2	1	2	224,934
1995	59,470	47,424	31,789	18,731	8,632	3,436	1,348	556	246	117	59	32	18	10	6	4	3	2	1	2	225,097
1996	42,209	33,659	22,562	13,294	6,126	2,438	957	395	175	83	42	22	13	7	4	3	2	1	1	2	159,758
1997	39,412	31,429	21,068	12,413	5,720	2,277	893	369	163	77	39	21	12	7	4	3	2	1	1	2	149,181
1998	55,066	43,912	29,435	17,344	7,992	3,181	1,248	515	228	108	55	29	16	10	6	4	2	1	1	2	208,428
1999	74,897	59,726	40,036	23,589	10,871	4,327	1,698	701	310	147	75	40	22	13	8	5	3	2	1	3	283,487
2000	79,271	63,214	42,374	24,967	11,506	4,579	1,797	741	328	156	79	42	24	14	8	5	3	2	1	3	300,042
2001	59,107	47,135	31,596	18,616	8,579	3,415	1,340	553	245	116	59	32	18	10	6	4	2	2	1	2	223,726
2002	68,867	54,918	36,813	21,690	9,996	3,979	1,561	644	285	135	69	37	21	12	7	5	3	2	1	3	260,670
2003	74,958	59,775	40,069	23,609	10,880	4,330	1,699	701	310	147	75	40	22	13	8	5	3	2	1	3	283,721
2004	111,427	88,857	59,563	35,095	16,173	6,437	2,526	1,042	461	219	111	59	33	19	12	7	5	3	2	4	421,755
2005	64,330	51,299	34,387	20,261	9,337	3,716	1,458	602	266	126	64	34	19	11	7	4	3	2	1	2	243,491
Weight-at-age	0.196	0.752	1.647	2.793	4.093	5.461	6.832	8.158	9.410	10.568	11.623	12.574	13.422	14.172	14.833	15.411	15.914	16.352	16.730	17.816	

Table 3.2.10. Direct observed catch-at-age from otolith analysis.

A) Commercial Longline

YEAR	AGE 1	AGE 2	AGE 3	AGE 4	AGE 5	AGE 6	AGE 7	AGE 8	AGE 9	AGE 10	AGE 11	AGE 12	AGE 13	AGE 14	AGE 15	AGE 16	AGE 17	AGE 18	AGE 19	AGE 20	Effective Sample Size
1986	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	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1987	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	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1988	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	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1989	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	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1990	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	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1991	0.0	0.0	0.0	0.0	0.1	0.8	1.3	0.8	1.2	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	4.6
1992	0.0	0.0	0.0	0.0	5.7	14.3	24.7	15.2	9.5	1.9	1.0	1.9	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	75.2
1993	0.0	0.0	0.0	7.3	18.2	43.8	38.0	19.2	11.6	6.3	2.6	1.6	0.8	0.8	0.0	0.8	0.0	0.0	0.0	0.0	150.9
1994	0.0	0.0	0.0	4.4	7.2	4.2	11.2	8.6	5.8	4.4	2.4	0.4	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.8	50.6
1995	0.0	0.0	0.0	2.3	7.9	23.3	13.5	25.2	14.0	9.4	1.5	0.8	0.2	0.0	0.0	0.0	0.0	0.0	0.0	1.5	99.5
1996	0.0	0.0	0.0	0.8	3.8	10.7	19.9	6.1	19.2	9.2	1.5	0.8	0.0	0.0	0.8	0.0	0.8	0.0	0.0	0.0	73.6
1997	0.0	0.0	0.0	1.5	0.7	0.7	1.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.7	0.0	0.0	0.0	0.0	5.1
1998	0.0	0.0	0.0	2.2	7.8	10.4	18.3	12.5	9.9	4.1	5.7	2.6	0.8	0.0	1.6	0.0	0.0	0.0	0.0	0.0	76.0
1999	0.0	0.0	0.0	1.6	19.6	38.6	66.8	91.4	84.2	39.8	22.2	14.1	5.7	3.3	2.5	0.0	0.0	0.8	0.0	0.8	391.6
2000	0.0	0.0	0.0	5.1	10.2	43.5	34.3	40.0	31.2	25.1	28.1	10.0	3.8	3.2	2.4	1.2	0.0	0.8	0.8	1.6	241.1
2001	0.0	0.0	0.0	2.8	107.2	46.8	84.7	47.9	25.9	35.7	31.1	19.4	6.5	8.4	6.6	3.1	2.3	1.5	2.3	4.3	436.4
2002	0.0	0.0	0.0	1.7	19.3	107.9	62.3	69.7	53.0	27.7	34.7	34.5	23.0	15.0	12.1	8.8	4.3	7.8	1.8	9.7	492.9
2003	0.0	0.0	0.8	19.2	13.4	59.8	135.1	96.6	94.4	64.7	50.9	44.7	38.7	26.9	21.8	10.8	15.2	8.0	5.8	6.6	713.4
2004	0.0	0.0	0.8	4.8	105.9	29.6	101.9	143.4	95.3	76.5	43.1	31.2	29.4	29.9	19.0	8.1	9.5	8.1	4.7	11.9	753.1
2005	0.0	0.0	0.0	2.7	63.2	301.4	72.8	118.5	115.2	71.8	37.4	21.9	14.2	12.5	8.1	8.1	4.1	4.1	2.0	9.5	867.5

B) Commercial Handline

YEAR	AGE 1	AGE 2	AGE 3	AGE 4	AGE 5	AGE 6	AGE 7	AGE 8	AGE 9	AGE 10	AGE 11	AGE 12	AGE 13	AGE 14	AGE 15	AGE 16	AGE 17	AGE 18	AGE 19	AGE 20	Effective Sample Size
1986	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	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1987	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	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1988	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	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1989	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	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1990	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	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1991	0.0	0.0	0.7	0.7	1.3	3.3	0.7	0.0	1.0	0.7	0.0	1.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0	9.6
1992	0.0	0.0	0.0	0.0	3.0	3.8	4.8	4.1	0.0	0.8	0.2	0.0	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	17.5
1993	0.0	0.0	0.5	5.4	6.3	8.3	6.9	4.3	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	32.3
1994	0.0	0.0	0.6	22.9	44.8	23.4	15.1	9.0	3.7	1.6	1.1	0.4	0.6	0.0	0.6	0.0	0.0	0.0	0.0	0.0	123.7
1995	0.0	0.0	0.0	2.6	19.1	30.9	25.8	6.2	2.1	2.6	2.1	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	92.8
1996	0.0	0.0	0.0	1.6	5.8	15.1	10.2	4.2	2.9	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	40.2
1997	0.0	0.0	0.0	0.0	1.0	0.5	1.5	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.6
1998	0.0	0.0	0.5	2.0	3.0	2.0	2.1	1.0	1.5	1.6	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	14.4
1999	0.0	0.0	0.0	0.4	4.9	3.9	5.1	9.8	3.7	3.1	0.0	0.6	0.6	0.0	0.0	0.0	0.4	0.0	0.0	0.0	32.5
2000	0.0	0.0	0.0	33.8	15.1	16.5	10.0	7.0	7.5	5.5	2.0	1.5	1.5	1.5	1.0	0.0	0.0	0.0	0.5	0.5	103.9
2001	0.0	0.0	0.0	14.1	117.4	34.4	46.1	22.0	8.6	15.7	11.1	6.1	7.4	4.1	2.3	4.1	1.7	0.4	0.0	0.4	296.2
2002	0.0	0.0	1.1	4.4	12.9	30.2	16.8	16.7	11.1	6.7	4.4	4.5	2.6	1.8	1.1	0.9	0.5	0.2	0.6	0.7	117.3
2003	0.0	0.0	0.1	11.1	12.7	27.1	37.3	15.8	11.8	5.5	2.9	2.3	2.0	0.3	1.3	0.6	1.1	0.4	0.5	1.7	134.5
2004	0.0	0.0	0.0	6.0	93.3	30.0	39.6	32.4	12.8	8.7	6.5	3.6	3.1	2.5	2.1	1.0	0.5	1.1	1.2	0.9	245.3
2005	0.0	0.0	0.0	0.9	18.4	118.7	14.6	13.4	9.8	2.7	2.3	2.2	0.8	0.6	0.4	0.4	0.2	0.0	0.2	1.1	186.8

Table 3.2.10 (*CONTINUED*). Direct observed catch-at-age from otolith analysis.

A) Commercial Trap

YEAR	AGE 1	AGE 2	AGE 3	AGE 4	AGE 5	AGE 6	AGE 7	AGE 8	AGE 9	AGE 10	AGE 11	AGE 12	AGE 13	AGE 14	AGE 15	AGE 16	AGE 17	AGE 18	AGE 19	AGE 20	Effective Sample Size
1986	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	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1987	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	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1988	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	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1989	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	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1990	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	0.0	0.0	0.0	0.0	0.0	0.0	0.0
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	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	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1993	0.0	0.0	0.0	1.6	1.6	10.4	14.8	13.7	2.7	1.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	46.0
1994	0.0	0.0	0.0	0.0	0.0	0.4	1.8	2.6	3.3	1.5	0.4	0.4	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	10.6
1995	0.0	0.0	0.0	0.0	0.9	7.8	1.7	2.6	2.2	0.4	0.0	0.9	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	16.9
1996	0.0	0.0	0.0	0.0	0.0	0.0	1.1	0.6	1.1	1.1	0.0	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.4
1997	0.0	0.0	0.0	0.5	3.0	2.5	0.5	1.5	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	8.4
1998	0.0	0.0	0.5	1.6	0.5	2.7	4.3	2.7	3.7	1.1	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	17.6
1999	0.0	0.0	0.0	0.4	0.8	0.8	0.4	3.2	2.8	1.2	1.6	0.0	0.8	0.4	0.0	0.0	0.0	0.0	0.0	0.0	12.5
2000	0.0	0.0	0.0	0.4	0.4	6.0	3.6	1.6	1.6	0.8	0.4	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	15.3
2001	0.0	0.0	0.0	0.0	1.0	2.0	3.3	3.2	0.7	3.2	0.4	1.1	0.0	0.0	0.4	0.0	0.4	0.0	0.0	0.0	15.5
2002	0.0	0.0	0.0	2.1	2.1	6.8	6.7	6.7	3.0	2.3	2.1	1.9	1.5	0.4	0.4	0.4	0.0	0.0	0.0	0.0	36.5
2003	0.0	0.0	0.0	1.1	0.6	3.3	7.3	2.7	3.1	2.9	1.0	4.8	1.6	1.0	1.0	0.4	0.0	0.0	0.0	0.0	30.8
2004	0.0	0.0	0.0	0.5	2.5	1.0	4.0	3.5	0.5	2.5	1.0	0.0	0.0	1.0	0.0	0.5	0.0	1.0	0.0	0.0	18.0
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	0.0	0.0	0.0	0.0	0.0	0.0	0.0

B) Recreational

YEAR	AGE 1	AGE 2	AGE 3	AGE 4	AGE 5	AGE 6	AGE 7	AGE 8	AGE 9	AGE 10	AGE 11	AGE 12	AGE 13	AGE 14	AGE 15	AGE 16	AGE 17	AGE 18	AGE 19	AGE 20	Effective Sample Size
1986	0.0	0.1	0.1	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	0.0	0.0	0.0	0.3
1987	0.0	0.2	0.4	0.2	0.1	0.4	0.1	0.2	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.7
1988	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	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1989	0.0	0.3	0.1	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	0.0	0.0	0.0	0.4
1990	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	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1991	0.0	0.0	0.0	0.1	0.4	0.2	0.1	0.1	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	1.2
1992	0.0	0.0	0.0	0.2	1.3	0.2	0.1	0.4	0.3	0.4	0.4	0.3	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.8
1993	0.0	0.0	0.1	1.4	0.4	0.6	1.5	1.0	0.9	0.2	0.3	0.0	0.1	0.0	0.1	0.0	0.0	0.0	0.0	0.0	6.6
1994	0.0	0.0	0.3	1.2	1.3	1.2	0.9	0.9	0.1	0.3	0.2	0.2	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.2	7.0
1995	0.0	0.0	0.0	0.9	4.0	4.7	2.9	2.1	1.7	0.5	0.8	0.7	0.2	0.6	0.0	0.1	0.0	0.0	0.0	0.4	19.5
1996	0.0	0.0	0.1	0.0	4.4	10.0	5.4	1.8	1.2	0.6	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.1	23.8
1997	0.0	0.0	0.7	1.1	2.8	5.6	7.6	2.4	0.3	0.1	0.5	0.2	0.2	0.2	0.2	0.2	0.0	0.0	0.0	0.0	22.3
1998	0.0	0.0	0.0	2.0	5.9	5.2	3.6	1.5	0.2	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	18.5
1999	0.0	0.0	0.2	1.1	8.0	3.9	2.1	2.9	1.4	0.6	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.2	20.6
2000	0.0	0.0	0.0	5.3	2.8	3.1	1.4	2.7	2.4	0.7	0.4	0.0	0.7	0.0	0.3	0.0	0.3	0.0	0.0	0.3	20.3
2001	0.0	0.0	0.0	1.0	6.9	2.6	2.1	0.0	0.0	0.3	0.0	0.0	0.3	0.0	0.0	0.0	0.3	0.0	0.0	0.0	13.3
2002	0.0	0.0	0.7	4.9	13.2	24.0	7.1	2.9	1.5	0.2	1.1	0.9	0.8	0.4	0.4	0.0	0.0	0.0	0.0	0.2	58.3
2003	0.0	0.0	2.7	32.0	9.1	7.5	13.5	1.4	1.9	1.0	0.0	2.3	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	71.6
2004	0.0	0.0	0.2	3.9	34.7	6.4	4.0	3.2	1.0	2.7	0.4	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	56.6
2005	0.0	0.0	0.0	0.5	6.9	17.4	1.6	0.6	1.8	0.1	0.4	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	29.4

Table 3.2.11. Proportion of red grouper released (dead or alive).

A) Commercial Longline

YEAR	Age 1	Age 2	Age 3	Age 4	Age 5	Age 6	Age 7	Age 8	Age 9	Age 10	Age 11	Age 12	Age 13	Age 14	Age 15	Age 16	Age 17	Age 18	Age 19	Age 20
1986	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1987	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1988	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1989	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1990	0.000	1.000	0.992	0.874	0.600	0.353	0.202	0.120	0.076	0.051	0.036	0.027	0.021	0.018	0.015	0.013	0.012	0.010	0.010	0.008
1991	0.000	1.000	0.992	0.876	0.602	0.353	0.202	0.120	0.076	0.051	0.036	0.027	0.022	0.018	0.015	0.013	0.011	0.009	0.010	0.007
1992	0.000	1.000	0.991	0.867	0.591	0.348	0.200	0.119	0.075	0.051	0.036	0.027	0.021	0.017	0.015	0.013	0.011	0.011	0.009	0.007
1993	0.000	1.000	0.990	0.859	0.587	0.347	0.200	0.119	0.075	0.051	0.036	0.027	0.021	0.017	0.015	0.013	0.011	0.010	0.009	0.007
1994	0.000	1.000	0.992	0.862	0.584	0.344	0.198	0.119	0.075	0.051	0.036	0.027	0.021	0.017	0.015	0.013	0.012	0.010	0.010	0.007
1995	0.000	1.000	0.989	0.847	0.571	0.338	0.196	0.117	0.075	0.050	0.036	0.027	0.021	0.017	0.015	0.013	0.012	0.010	0.009	0.006
1996	0.000	1.000	0.991	0.854	0.576	0.340	0.196	0.118	0.075	0.050	0.036	0.027	0.021	0.017	0.015	0.013	0.011	0.010	0.009	0.007
1997	0.000	1.000	0.989	0.850	0.573	0.338	0.196	0.117	0.075	0.050	0.036	0.027	0.021	0.018	0.015	0.013	0.011	0.010	0.009	0.007
1998	0.000	1.000	0.988	0.847	0.572	0.340	0.197	0.118	0.075	0.050	0.036	0.027	0.021	0.018	0.015	0.013	0.011	0.010	0.009	0.007
1999	0.000	1.000	0.989	0.847	0.568	0.336	0.195	0.117	0.074	0.050	0.036	0.027	0.021	0.018	0.015	0.013	0.011	0.010	0.010	0.008
2000	0.000	1.000	0.990	0.850	0.571	0.338	0.196	0.118	0.075	0.050	0.036	0.027	0.021	0.017	0.015	0.013	0.011	0.010	0.010	0.007
2001	0.000	1.000	0.988	0.847	0.569	0.337	0.195	0.117	0.074	0.050	0.036	0.027	0.021	0.017	0.015	0.013	0.012	0.010	0.009	0.007
2002	0.000	1.000	0.987	0.841	0.564	0.334	0.194	0.117	0.074	0.050	0.036	0.027	0.021	0.017	0.015	0.013	0.011	0.010	0.009	0.007
2003	0.000	1.000	0.989	0.842	0.563	0.333	0.194	0.117	0.074	0.050	0.036	0.027	0.021	0.017	0.015	0.013	0.011	0.011	0.009	0.007
2004	0.000	1.000	0.988	0.837	0.554	0.327	0.190	0.115	0.073	0.050	0.036	0.027	0.021	0.017	0.015	0.013	0.011	0.010	0.010	0.007
2005	0.000	1.000	0.990	0.852	0.571	0.336	0.195	0.117	0.074	0.050	0.036	0.027	0.021	0.018	0.015	0.013	0.011	0.010	0.009	0.007

B) Commercial Handline

YEAR	Age 1	Age 2	Age 3	Age 4	Age 5	Age 6	Age 7	Age 8	Age 9	Age 10	Age 11	Age 12	Age 13	Age 14	Age 15	Age 16	Age 17	Age 18	Age 19	Age 20
1986	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1987	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1988	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1989	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1990	0.000	0.991	0.957	0.828	0.581	0.349	0.201	0.120	0.076	0.051	0.036	0.027	0.022	0.018	0.015	0.013	0.011	0.010	0.009	0.007
1991	0.000	0.999	0.981	0.840	0.568	0.337	0.196	0.117	0.075	0.050	0.036	0.027	0.021	0.017	0.015	0.013	0.012	0.010	0.010	0.007
1992	0.000	0.999	0.988	0.854	0.578	0.342	0.198	0.118	0.075	0.051	0.036	0.027	0.021	0.018	0.015	0.013	0.011	0.009	0.010	0.006
1993	0.000	0.998	0.984	0.839	0.571	0.341	0.197	0.118	0.075	0.051	0.036	0.027	0.021	0.017	0.015	0.013	0.012	0.011	0.009	0.006
1994	0.000	1.000	0.986	0.831	0.551	0.328	0.192	0.116	0.074	0.050	0.036	0.027	0.021	0.017	0.015	0.013	0.012	0.011	0.011	0.006
1995	0.000	1.000	0.983	0.832	0.561	0.333	0.194	0.117	0.074	0.050	0.036	0.027	0.021	0.017	0.015	0.013	0.012	0.010	0.009	0.005
1996	0.000	0.999	0.977	0.809	0.539	0.322	0.189	0.115	0.073	0.050	0.036	0.027	0.021	0.017	0.015	0.012	0.011	0.009	0.009	0.006
1997	0.000	1.000	0.987	0.832	0.554	0.329	0.191	0.116	0.074	0.050	0.036	0.027	0.021	0.017	0.015	0.013	0.013	0.010	0.007	0.005
1998	0.000	0.999	0.985	0.841	0.569	0.337	0.195	0.117	0.074	0.050	0.036	0.027	0.022	0.018	0.015	0.013	0.012	0.010	0.010	0.004
1999	0.000	1.000	0.986	0.837	0.563	0.334	0.194	0.117	0.074	0.050	0.036	0.027	0.021	0.017	0.015	0.012	0.012	0.009	0.009	0.005
2000	0.000	0.999	0.982	0.833	0.557	0.331	0.193	0.116	0.074	0.050	0.036	0.027	0.021	0.017	0.015	0.012	0.012	0.011	0.009	0.006
2001	0.000	1.000	0.985	0.832	0.556	0.330	0.192	0.116	0.074	0.050	0.036	0.027	0.021	0.017	0.015	0.013	0.011	0.010	0.009	0.006
2002	0.000	1.000	0.984	0.830	0.555	0.329	0.192	0.116	0.074	0.050	0.036	0.027	0.021	0.018	0.015	0.014	0.012	0.010	0.010	0.004
2003	0.000	1.000	0.982	0.812	0.536	0.320	0.188	0.114	0.073	0.050	0.035	0.027	0.021	0.017	0.015	0.012	0.011	0.010	0.011	0.003
2004	0.000	1.000	0.985	0.817	0.530	0.312	0.183	0.112	0.072	0.049	0.035	0.027	0.021	0.018	0.014	0.013	0.011	0.011	0.006	0.003
2005	0.000	0.994	0.974	0.830	0.557	0.330	0.191	0.115	0.073	0.050	0.036	0.027	0.021	0.018	0.014	0.013	0.012	0.009	0.006	0.004

Table 3.2.11. (*CONTINUED)*. Percentage of red grouper released dead or alive.

A) Commercial Trap

YEAR	Age 1	Age 2	Age 3	Age 4	Age 5	Age 6	Age 7	Age 8	Age 9	Age 10	Age 11	Age 12	Age 13	Age 14	Age 15	Age 16	Age 17	Age 18	Age 19	Age 20
1986	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1987	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1988	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1989	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1990	0.000	0.970	0.851	0.746	0.522	0.317	0.187	0.113	0.072	0.049	0.036	0.026	0.021	0.016	0.015	0.014	0.010	0.014	0.000	0.000
1991	0.000	0.994	0.980	0.844	0.568	0.334	0.192	0.115	0.073	0.049	0.035	0.027	0.020	0.017	0.013	0.007	0.010	0.000	0.000	0.000
1992	0.000	1.000	0.987	0.832	0.554	0.329	0.192	0.116	0.074	0.050	0.036	0.027	0.021	0.017	0.015	0.013	0.011	0.012	0.006	0.005
1993	0.000	1.000	0.986	0.838	0.555	0.324	0.187	0.112	0.072	0.049	0.035	0.026	0.020	0.016	0.015	0.013	0.009	0.007	0.010	0.004
1994	0.000	1.000	0.989	0.852	0.577	0.341	0.196	0.117	0.074	0.050	0.036	0.027	0.022	0.017	0.015	0.011	0.008	0.012	0.017	0.000
1995	0.000	1.000	0.984	0.821	0.548	0.326	0.190	0.115	0.073	0.050	0.036	0.027	0.022	0.018	0.015	0.014	0.011	0.008	0.011	0.005
1996	0.000	1.000	0.991	0.851	0.567	0.332	0.192	0.115	0.073	0.050	0.035	0.027	0.022	0.017	0.016	0.014	0.010	0.014	0.010	0.000
1997	0.000	1.000	0.990	0.852	0.569	0.334	0.193	0.116	0.074	0.050	0.036	0.027	0.021	0.018	0.014	0.013	0.012	0.009	0.013	0.003
1998	0.000	1.000	0.985	0.830	0.556	0.330	0.192	0.115	0.074	0.050	0.035	0.027	0.021	0.017	0.013	0.009	0.014	0.020	0.000	0.000
1999	0.000	1.000	0.987	0.846	0.572	0.339	0.196	0.117	0.074	0.050	0.036	0.027	0.021	0.017	0.015	0.013	0.014	0.012	0.011	0.002
2000	0.000	1.000	0.980	0.822	0.554	0.331	0.193	0.116	0.074	0.050	0.036	0.027	0.022	0.017	0.015	0.012	0.012	0.009	0.008	0.004
2001	0.000	1.000	0.991	0.856	0.578	0.340	0.196	0.117	0.075	0.050	0.036	0.027	0.021	0.017	0.015	0.013	0.011	0.012	0.011	0.002
2002	0.000	1.000	0.991	0.859	0.585	0.345	0.199	0.118	0.075	0.051	0.036	0.027	0.022	0.018	0.015	0.014	0.010	0.009	0.008	0.005
2003	0.000	0.998	0.990	0.833	0.548	0.327	0.192	0.116	0.074	0.050	0.036	0.027	0.021	0.017	0.014	0.013	0.011	0.012	0.006	0.003
2004	0.000	1.000	0.989	0.846	0.566	0.334	0.194	0.117	0.074	0.050	0.036	0.027	0.022	0.018	0.015	0.013	0.010	0.009	0.008	0.005
2005	0.000	1.000	0.991	0.864	0.587	0.345	0.198	0.118	0.075	0.050	0.036	0.027	0.022	0.017	0.016	0.012	0.009	0.013	0.010	0.000

B) Recreational

YEAR	Age 1	Age 2	Age 3	Age 4	Age 5	Age 6	Age 7	Age 8	Age 9	Age 10	Age 11	Age 12	Age 13	Age 14	Age 15	Age 16	Age 17	Age 18	Age 19	Age 20
1986	0.999	0.571	0.048	0.005	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1987	1.000	0.689	0.081	0.010	0.002	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1988	1.000	0.764	0.088	0.010	0.002	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1989	1.000	0.921	0.164	0.017	0.004	0.002	0.001	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1990	1.000	0.990	0.972	0.865	0.692	0.499	0.343	0.241	0.176	0.136	0.109	0.091	0.078	0.069	0.062	0.056	0.053	0.050	0.049	0.042
1991	1.000	1.000	0.993	0.892	0.684	0.490	0.356	0.271	0.216	0.178	0.152	0.133	0.118	0.107	0.099	0.093	0.087	0.083	0.079	0.074
1992	0.999	0.999	0.980	0.816	0.559	0.366	0.248	0.179	0.137	0.111	0.094	0.082	0.073	0.066	0.062	0.058	0.054	0.053	0.051	0.048
1993	1.000	0.997	0.958	0.754	0.497	0.324	0.223	0.164	0.126	0.102	0.084	0.072	0.063	0.056	0.051	0.046	0.044	0.042	0.039	0.034
1994	1.000	1.000	0.984	0.804	0.529	0.342	0.233	0.170	0.131	0.107	0.091	0.080	0.072	0.066	0.061	0.058	0.055	0.052	0.053	0.047
1995	1.000	1.000	0.985	0.833	0.572	0.357	0.226	0.154	0.113	0.088	0.072	0.062	0.055	0.049	0.045	0.043	0.041	0.038	0.038	0.034
1996	1.000	1.000	0.991	0.885	0.663	0.446	0.299	0.211	0.158	0.126	0.104	0.090	0.080	0.072	0.067	0.062	0.058	0.056	0.052	0.049
1997	1.000	1.000	0.993	0.911	0.725	0.534	0.393	0.298	0.234	0.190	0.159	0.138	0.122	0.110	0.102	0.094	0.086	0.087	0.080	0.075
1998	1.000	1.000	0.989	0.911	0.759	0.592	0.451	0.347	0.274	0.225	0.190	0.166	0.149	0.135	0.126	0.118	0.113	0.109	0.105	0.093
1999	1.000	1.000	0.988	0.915	0.730	0.527	0.373	0.272	0.207	0.166	0.138	0.119	0.106	0.096	0.089	0.083	0.078	0.074	0.070	0.064
2000	1.000	1.000	0.976	0.822	0.607	0.417	0.278	0.187	0.132	0.099	0.078	0.065	0.055	0.049	0.044	0.041	0.038	0.036	0.034	0.030
2001	1.000	1.000	0.988	0.852	0.621	0.430	0.300	0.217	0.164	0.129	0.106	0.090	0.079	0.071	0.065	0.061	0.058	0.054	0.054	0.047
2002	1.000	1.000	0.990	0.880	0.650	0.430	0.283	0.195	0.143	0.112	0.091	0.077	0.068	0.061	0.055	0.052	0.049	0.047	0.043	0.041
2003	1.000	1.000	0.986	0.853	0.656	0.484	0.360	0.276	0.220	0.182	0.155	0.135	0.121	0.109	0.101	0.095	0.089	0.084	0.080	0.073
2004	1.000	0.999	0.983	0.816	0.565	0.385	0.269	0.194	0.145	0.113	0.091	0.076	0.066	0.058	0.053	0.049	0.045	0.043	0.041	0.037
2005	1.000	1.000	0.995	0.876	0.605	0.386	0.256	0.182	0.137	0.109	0.090	0.077	0.068	0.061	0.056	0.052	0.048	0.046	0.043	0.038

Table 3.2.12..Indices of abundance. Fisheries-dependent indices were modified to reflect a 2% annual increase in catchability, and rescaled to a mean value of 1.0. Indices were equally weighted (CVs not used).

	SEAMAP VIDEO		COM-LL		COM-HL		HB (18" MSL)		HB (20" MSL)		MRFSS	
YEAR	INDEX	CV	INDEX	CV	INDEX	CV	INDEX	CV	INDEX	CV	INDEX	CV
1986							0.775	0.611			0.828	0.549
1987							1.208	0.498			0.776	0.564
1988							1.043	0.514			1.070	0.466
1989							1.195	0.501			1.495	0.435
1990			0.908	0.133	0.831	0.228	0.779	0.646	1.006	0.545	2.079	0.453
1991			0.896	0.120	0.758	0.212			1.096	0.535	1.251	0.500
1992			0.768	0.133	0.858	0.196			0.907	0.558	1.355	0.423
1993	0.888	0.184	1.076	0.106	0.769	0.175			0.853	0.536	0.818	0.480
1994	0.856	0.153	0.902	0.104	0.973	0.166			0.880	0.543	0.957	0.447
1995	0.648	0.215	1.039	0.103	0.942	0.164			0.987	0.542	0.775	0.502
1996	0.920	0.160	0.879	0.103	0.644	0.170			0.781	0.570	0.597	0.514
1997	0.945	0.126	1.034	0.099	0.588	0.175			0.587	0.578	0.527	0.538
1998			0.984	0.101	0.547	0.175			0.642	0.575	0.716	0.445
1999			0.984	0.105	0.717	0.164			0.626	0.557	0.865	0.402
2000			0.957	0.101	0.966	0.158			0.850	0.550	0.955	0.397
2001			1.245	0.097	1.395	0.155			0.805	0.531	0.777	0.397
2002	1.116	0.101	0.948	0.101	1.433	0.152			0.867	0.530	0.792	0.392
2003			0.887	0.101	1.052	0.151			1.261	0.489	0.957	0.361
2004	1.291	0.087	1.137	0.098	1.604	0.148			1.810	0.470	1.412	0.305
2005	1.336	0.071	1.354	0.098	1.924	0.149			2.042	0.469	0.995	0.338

Table 3.3.3.1..Parameter initialization. All parameters are re-estimated in the final phase.

Parameter	Initial guess	Comments
Log(F-mult in Year 1)	-3	All Fleets
Log(Q in Year 1_	-16	
Log(Virgin Stock Size)	15	
Steepness	0.8	Triangular prior with bounds at 0.3 and 0.9.

Selectivity-at-age	COM-LL	COM-HL	COM-TRAP	REC	
Age 1	0.05	0.20	0.20	1.00	
Age 2	0.07	0.26	0.26	0.90	
Age 3	0.11	0.32	0.32	0.80	
Age 4	0.17	0.39	0.39	0.75	
Age 5	0.25	0.48	0.48	0.70	
Age 6	0.35	0.57	0.57	0.65	
Age 7	0.45	0.67	0.67	0.60	
Age 8	0.63	0.78	0.78	0.57	
Age 9	0.78	0.88	0.88	0.55	
Age 10	0.90	0.96	0.96	0.54	
Age 11	1	1	1	-	The symbol (-) indicates that selectivity-at-age is not estimated for this age. Instead it is fixed at the value estimated for the oldest estimated age (COM-LL and COM-HL = 15; COM-TRAP = 12; REC = 10).
Age 12	1	1	1	-	
Age 13	1	1	-	-	
Age 14	1	1	-	-	
Age 15	1	1	-	-	
Age 16	-	-	-	-	
Age 17	-	-	-	-	
Age 18	-	-	-	-	
Age 19	-	-	-	-	
Age 20+	-	-	-	-	

Table 3.3.3.2..Model component weightings and deviation terms expressed as coefficients of variation. (Note: the model generally requires inputs as λ where $\lambda = 1/[\ln(CV^2 + 1)]$.

Model Component	CV	Description/Comments
Indices of Abundance	0.2	Indices were equally weighted (CV used for all indices all years)
Total Landings (weight)	0.1	Used for all fleets and all years
Total Discards (weight)	0.3	Used for all fleets and all years
Derived Catch-at-Age (Goodyear, 1997)	0.0	NOT USED
Direct Observed Catch-at-Age (otoliths)	variable	Used effective sample sizes (Table 3.2.10) with a maximum effective sample size of 200 (CV = 0.07). This limit prevents the model from degrading the fits to other model components due to numerous otolith observations.
Derived Discards-at-Age (Goodyear, 1997)	1.3	The RW chose to downweight the discard age composition substantially (with regard to other model components) because they had little confidence in this model component.
F-Mult Deviations by Fleet	0.3	All fleets
N in Year 1 Deviation	0.5	Deviation from unfished condition
Recruitment Deviations	0.5	Deviation from stock-recruitment relationship. Applied to each year.
Curvature of Selectivity-at-age	0.05	Determines amount of deviation in selectivity by age
Curvature of Selectivity by year	N/A	NOT USED. Only one selectivity function estimated for each fleet for all years. Selectivity functions apply to the population (catch + discards). Annual discard fractions are estimated independently and will vary with changes in size limit.

Table 4.1.1. Base case likelihood component values and objective function estimate. RSS is the residual sum of squares.

Component	RSS	nobs	Likelihood	
Catch_COM_LL	0.058	20	5.817	
Catch_COM_HL	0.054	20	5.428	
Catch_COM_Trap	0.270	20	27.163	
Catch_REC	0.065	20	6.545	
Catch_Total	0.447	80	44.952	
Discards_COM_LL	1.632	20	18.930	
Discards_COM_HL	1.549	20	17.973	
Discards_COM_Trap	13.432	20	155.816	
Discards_REC	0.946	20	10.974	
Discards_Total	17.560	80	203.693	
CAA_proportions	N/A	1600	0.000	* Not Used
CAA2_proportions	N/A	1600	574.303	
Discard_proportions	N/A	1600	14.288	
Index_Fit_SEAMAP_VID	0.175	8	2.225	
Index_Fit_COM_LL	0.297	16	3.791	
Index_Fit_COM_HL	1.327	16	16.922	
Index_Fit_HB18	0.299	5	3.810	
Index_Fit_HB20	1.123	16	14.324	
Index_Fit_MRFSS	2.095	20	26.705	
Index_Fit_Total	5.316	81	67.777	
Fmult_fleet_COM_LL	0.887	19	9.762	
Fmult_fleet_COM_HL	0.913	19	10.047	
Fmult_fleet_COM_Trap	1.947	19	21.418	
Fmult_fleet_REC	1.863	19	20.491	
Fmult_fleet_Total	5.611	76	61.718	
N_year_1	8.290	19	37.139	
Stock-Recruit_Fit	2.064	20	-12.879	
Recruit_devs	2.064	20	9.247	
SRR_steepness	0.001	1	0.002	
SRR_virgin_stock	38.497	1	0.000	
Curvature_over_age	0.147	72	58.694	
Curvature_over_time	0.000	1440	0.000	
F_penalty	0.063	400	0.000	
Mean_Sel_year1_pen	0.000	80	0.000	
Max_Sel_penalty	2.718	1	0.000	

Objective Function =	***1068.11***

Table 4.1.2. Fits to the catch series (gutted lbs).

	COM LL			COM HL			COM TRAP			REC		
YEAR	OBS	PRED	RESID	OBS	PRED	RESID	OBS	PRED	RES	OBS	PRED	RESID
1986	2,482,090	2,657,390	175,300	3,116,270	3,136,590	20,320	714,626	700,093	-14,533	2,400,380	2,283,140	-117,240
1987	3,742,400	3,554,310	-188,090	2,531,260	2,545,520	14,260	444,230	472,513	28,283	1,464,710	1,576,160	111,450
1988	2,172,240	2,362,420	190,180	2,035,090	2,174,040	138,950	535,166	534,870	-296	2,476,070	2,306,290	-169,780
1989	3,048,280	3,015,870	-32,410	3,740,150	3,538,510	-201,640	579,481	561,294	-18,187	2,761,150	2,735,170	-25,980
1990	2,015,800	2,235,360	219,560	2,454,250	2,239,760	-214,490	339,232	382,000	42,768	1,131,710	1,194,440	62,730
1991	2,588,380	2,743,900	155,520	2,131,680	1,978,100	-153,580	374,441	428,450	54,009	1,775,110	1,744,670	-30,440
1992	2,408,440	2,569,270	160,830	1,452,930	1,512,170	59,240	601,907	655,979	54,072	2,658,180	2,527,500	-130,680
1993	4,302,810	3,899,380	-403,430	1,359,830	1,319,320	-40,510	716,986	695,387	-21,599	2,091,160	2,122,410	31,250
1994	2,703,460	2,722,230	18,770	1,283,180	1,251,280	-31,900	916,222	830,929	-85,293	1,808,240	1,843,670	35,430
1995	2,466,020	2,625,980	159,960	1,222,420	1,171,210	-51,210	1,057,700	876,404	-181,296	1,862,570	1,799,670	-62,900
1996	2,992,830	3,040,190	47,360	902,576	981,864	79,288	558,740	520,314	-38,426	893,755	947,300	53,545
1997	3,135,750	3,203,550	67,800	1,005,510	1,021,580	16,070	707,226	568,842	-138,384	562,328	618,526	56,198
1998	2,843,510	2,963,930	120,420	791,642	859,518	67,876	313,414	344,402	30,988	643,058	692,976	49,918
1999	3,944,720	3,752,520	-192,200	1,257,120	1,253,390	-3,730	772,866	679,550	-93,316	1,152,810	1,177,470	24,660
2000	2,989,420	3,104,350	114,930	1,792,080	1,673,060	-119,020	1,056,800	875,040	-181,760	2,107,730	1,971,130	-136,600
2001	3,535,000	3,478,530	-56,470	1,661,760	1,621,010	-40,750	767,746	714,179	-53,567	1,327,770	1,398,160	70,390
2002	3,207,540	3,251,680	44,140	1,749,860	1,622,930	-126,930	949,848	820,333	-129,515	1,611,110	1,574,720	-36,390
2003	3,067,680	3,125,730	58,050	1,147,240	1,195,590	48,350	723,050	660,110	-62,940	1,275,830	1,383,280	107,450
2004	3,533,880	3,591,360	57,480	1,439,550	1,403,730	-35,820	775,609	674,800	-100,809	3,000,140	2,767,130	-233,010
2005	3,304,300	3,521,130	216,830	1,495,960	1,511,400	15,440	610,334	548,064	-62,270	1,630,140	1,753,520	123,380

Table 4.1.3. Fits to the discard series (gutted lbs).

	COM LL			COM HL			COM TRAP			REC		
YEAR	OBS	PRED	RESID	OBS	PRED	RESID	OBS	PRED	RES	OBS	PRED	RESID
1986	0	0	0	0	0	0	0	0	0	20,657	25,196	4,539
1987	0	0	0	0	0	0	0	0	0	19,021	20,601	1,580
1988	0	0	0	0	0	0	0	0	0	34,758	43,897	9,139
1989	0	0	0	0	0	0	0	0	0	81,650	59,170	-22,479
1990	642,444	368,813	-273,631	87,807	164,762	76,955	3,420	1,985	-1,434	228,556	215,905	-12,651
1991	1,047,820	518,012	-529,808	100,877	159,049	58,172	6,488	2,833	-3,654	407,354	356,160	-51,194
1992	548,134	504,323	-43,811	157,670	123,726	-33,944	15,460	5,367	-10,093	356,598	373,309	16,711
1993	656,707	759,799	103,092	71,785	102,894	31,109	4,491	6,397	1,907	234,183	258,278	24,095
1994	374,239	498,794	124,555	67,541	87,369	19,828	4,500	8,588	4,088	224,934	222,650	-2,284
1995	544,782	423,440	-121,342	53,364	73,350	19,986	3,162	8,966	5,804	225,097	204,292	-20,805
1996	480,720	443,909	-36,811	83,943	53,917	-30,025	1,580	5,132	3,552	159,758	124,884	-34,874
1997	545,266	427,852	-117,414	76,849	55,133	-21,716	1,401	5,262	3,861	149,181	102,756	-46,425
1998	477,339	395,065	-82,274	63,582	50,285	-13,297	2,136	2,930	794	208,428	134,086	-74,342
1999	644,556	509,114	-135,442	87,131	76,765	-10,366	2,845	5,599	2,754	283,487	200,655	-82,832
2000	536,157	433,574	-102,583	83,444	102,154	18,710	2,250	6,948	4,699	300,042	262,501	-37,541
2001	665,925	519,967	-145,958	87,823	105,593	17,770	2,434	5,831	3,397	223,726	207,023	-16,703
2002	643,022	506,621	-136,401	80,549	110,622	30,073	2,989	6,917	3,927	260,670	249,018	-11,652
2003	543,031	502,289	-40,742	77,922	80,890	2,968	2,115	5,609	3,494	283,721	235,049	-48,672
2004	736,977	538,276	-198,701	73,220	84,156	10,936	2,235	5,936	3,701	421,755	319,586	-102,169
2005	798,363	494,819	-303,544	94,460	83,050	-11,410	1,505	4,849	3,343	243,491	195,759	-47,732

Table 4.1.4 Fits to the indices of abundance (rescaled to reflect a 2% increase in catchability).

	SEAMAP VIDEO			COM-LL			COM-HL			HB 18" MSL			HB 20" MSL			MRFSS		
YEAR	OBS	PRED	RES	OBS	PRED	RES	OBS	PRED	RES	OBS	PRED	RES	OBS	PRED	RES	OBS	PRED	RES
1986	-	-	-	-	-	-	-	-	-	0.775	0.845	0.070	-	-	-	0.828	0.721	-0.107
1987	-	-	-	-	-	-	-	-	-	1.208	0.918	-0.290	-	-	-	0.776	0.888	0.112
1988	-	-	-	-	-	-	-	-	-	1.043	1.078	0.035	-	-	-	1.070	0.971	-0.099
1989	-	-	-	-	-	-	-	-	-	1.195	0.939	-0.256	-	-	-	1.495	0.900	-0.596
1990	-	-	-	0.908	0.767	-0.142	0.831	0.719	-0.112	0.779	1.158	0.379	1.006	0.760	-0.246	2.079	0.980	-1.099
1991	-	-	-	0.896	0.784	-0.112	0.758	0.781	0.023	-	-	-	1.096	0.891	-0.204	1.251	0.999	-0.252
1992	-	-	-	0.768	0.798	0.030	0.858	0.808	-0.050	-	-	-	0.907	0.864	-0.043	1.355	0.959	-0.395
1993	0.888	0.936	0.048	1.076	0.831	-0.245	0.769	0.853	0.084	-	-	-	0.853	0.946	0.092	0.818	0.857	0.039
1994	0.856	0.932	0.076	0.902	0.874	-0.028	0.973	0.888	-0.085	-	-	-	0.880	0.960	0.080	0.957	0.810	-0.147
1995	0.648	0.892	0.244	1.039	0.928	-0.110	0.942	0.916	-0.026	-	-	-	0.987	0.931	-0.056	0.775	0.842	0.068
1996	0.920	0.857	-0.063	0.879	0.975	0.096	0.644	0.916	0.272	-	-	-	0.781	0.845	0.064	0.597	0.801	0.204
1997	0.944	0.876	-0.068	1.034	1.020	-0.015	0.588	0.915	0.327	-	-	-	0.588	0.815	0.228	0.527	1.013	0.486
1998	-	-	-	0.984	1.066	0.082	0.547	0.938	0.391	-	-	-	0.642	0.876	0.233	0.716	0.936	0.220
1999	-	-	-	0.984	1.073	0.089	0.717	0.932	0.215	-	-	-	0.626	0.843	0.217	0.865	0.831	-0.034
2000	-	-	-	0.957	1.091	0.133	0.966	0.995	0.029	-	-	-	0.850	1.060	0.211	0.955	1.322	0.366
2001	-	-	-	1.245	1.084	-0.161	1.395	0.998	-0.397	-	-	-	0.805	0.968	0.163	0.777	1.145	0.368
2002	1.116	1.118	0.002	0.948	1.074	0.125	1.433	0.967	-0.465	-	-	-	0.867	0.833	-0.034	0.792	1.044	0.252
2003	-	-	-	0.887	1.181	0.294	1.052	1.142	0.090	-	-	-	1.261	1.369	0.109	0.957	1.044	0.087
2004	1.291	1.146	-0.145	1.137	1.229	0.092	1.604	1.183	-0.422	-	-	-	1.810	1.205	-0.605	1.412	1.043	-0.369
2005	1.336	1.101	-0.235	1.354	1.265	-0.090	1.924	1.184	-0.740	-	-	-	2.042	1.065	-0.977	0.995	1.015	0.020

Table 4.2.1. Selected parameter estimates with standard deviation. NOTE: F reference points include landings and discards.

Parameter Name	Value	Standard Deviation
F_Mult_1986 COM_LL	0.048	0.125
F_Mult_1986 COM_HL	0.043	0.147
F_Mult_1986 COM_TRAP	0.023	0.101
F_Mult_1986 REC	0.027	0.075
Q_Index SEAMAP VIDEO	8.88E-08	8.23E-02
Q_Index COM_LL	6.56E-09	1.07E-01
Q_Index COM_HL	1.38E-08	9.04E-02
Q_Index HB_18	2.13E-07	1.01E-01
Q_Index HB_20	1.40E-07	7.32E-02
Q_Index MRFSS	4.30E-08	5.76E-02
Virgin Reproductive Potential	1.62E+09	5.31E-02
Steepness	0.836	0.056
F_{MSY}	0.213	0.021
F_{OY}	0.160	0.015
$F_{CURRENT}$	0.158	0.015
SS_{MSY}	5.91E+08	5.16E+07
SS_{OY}	7.04E+08	5.82E+07
OY	7.57E+06	2.28E+05
MSY	7.72E+06	2.78E+05
SS_{2005}/SS_{MSY}	1.271	0.089
F_{2005}/F_{MSY}	0.730	0.071

Table 4.3.1. Number-at-age, recruitment (Age 1) and total abundance (sum) by year.

YEAR	AGE 1	AGE 2	AGE 3	AGE 4	AGE 5	AGE 6	AGE 7	AGE 8	AGE 9	AGE 10	AGE 11
1986	6,066,880	6,474,380	3,338,640	1,638,500	1,154,350	687,632	594,675	394,469	358,250	305,899	287,375
1987	12,454,100	3,673,440	4,221,710	2,225,660	1,116,580	795,556	478,358	418,448	281,182	258,732	223,622
1988	11,770,800	7,557,930	2,434,430	2,877,010	1,547,050	781,700	558,119	336,368	295,735	200,460	186,570
1989	8,353,940	7,125,500	5,040,670	1,644,560	1,988,260	1,084,450	553,935	399,680	243,449	216,354	148,186
1990	11,516,300	5,049,760	4,687,270	3,287,380	1,082,470	1,317,540	722,981	372,674	272,080	167,944	151,267
1991	10,171,600	6,962,810	3,514,500	3,475,640	2,475,100	796,851	937,482	503,601	258,150	189,357	118,005
1992	8,705,560	6,123,040	4,823,890	2,597,120	2,598,350	1,789,820	554,030	636,311	338,886	174,098	128,766
1993	6,531,860	5,230,250	4,241,890	3,562,330	1,928,260	1,864,580	1,244,260	378,441	431,860	230,162	118,778
1994	7,018,580	3,939,460	3,622,180	3,122,470	2,632,320	1,381,450	1,290,140	837,203	250,061	283,246	151,143
1995	8,867,940	4,238,840	2,746,680	2,695,920	2,352,390	1,939,810	994,635	913,385	586,422	174,217	197,020
1996	6,973,290	5,358,070	2,960,620	2,048,980	2,044,410	1,753,830	1,415,390	714,809	650,346	415,472	123,165
1997	13,807,300	4,230,330	3,757,000	2,218,970	1,573,300	1,559,820	1,315,790	1,045,650	522,801	473,925	303,261
1998	7,400,070	8,388,520	2,970,910	2,821,250	1,711,210	1,209,540	1,181,090	980,964	771,201	383,919	348,434
1999	5,595,530	4,492,540	5,894,380	2,232,700	2,180,430	1,323,600	925,388	893,123	736,480	578,383	289,082
2000	22,335,000	3,388,490	3,140,970	4,402,220	1,707,190	1,649,770	979,463	671,817	640,920	526,555	414,472
2001	7,984,390	13,488,000	2,364,330	2,338,300	3,324,790	1,267,330	1,197,550	700,147	476,865	454,534	374,408
2002	7,722,450	4,835,470	9,430,980	1,765,860	1,779,210	2,492,860	929,623	863,748	500,378	340,135	325,240
2003	9,649,700	4,672,670	3,380,560	7,044,890	1,345,650	1,335,770	1,829,830	671,573	619,024	358,023	243,974
2004	10,026,300	5,844,050	3,274,040	2,531,590	5,389,890	1,022,810	1,001,270	1,355,490	494,112	454,801	263,742
2005	9,331,480	6,046,490	4,073,970	2,437,070	1,907,850	3,985,940	742,738	718,940	968,463	353,201	326,485

YEAR	AGE 11	AGE 12	AGE 13	AGE 14	AGE 15	AGE 16	AGE 17	AGE 18	AGE 19	AGE 20	SUM
1986	287,375	247,973	221,283	203,192	180,641	164,575	151,120	138,099	126,087	380,119	23,114,139
1987	223,622	212,297	184,768	166,159	153,628	137,219	125,389	115,300	105,492	387,301	27,734,941
1988	186,570	163,228	156,733	137,814	125,004	116,265	104,232	95,379	87,810	375,911	29,908,547
1989	148,186	139,220	122,778	118,780	105,158	95,841	89,416	80,274	73,544	358,151	27,982,145
1990	151,267	104,890	99,577	88,656	86,495	77,014	70,437	65,807	59,150	318,626	29,598,319
1991	118,005	107,445	75,248	72,097	64,700	63,462	56,687	51,904	48,542	278,941	30,222,122
1992	128,766	81,086	74,580	52,752	51,000	46,047	45,325	40,531	37,133	234,549	29,132,874
1993	118,778	88,366	55,978	51,872	37,000	35,982	32,603	32,124	28,758	192,941	26,318,294
1994	151,143	78,486	58,884	37,695	35,326	25,399	24,815	22,509	22,197	153,352	24,986,916
1995	197,020	105,201	54,760	41,310	26,661	25,131	18,131	17,734	16,106	125,700	26,137,993
1996	123,165	139,225	74,431	38,917	29,581	19,192	18,154	13,111	12,834	102,750	24,906,576
1997	303,261	90,324	102,734	55,332	29,162	22,294	14,516	13,746	9,940	87,713	31,233,907
1998	348,434	223,959	67,115	76,898	41,746	22,126	16,974	11,065	10,489	74,606	28,712,086
1999	289,082	264,127	171,063	51,663	59,622	32,533	17,300	13,290	8,674	66,765	25,826,672
2000	414,472	208,317	191,659	125,132	38,110	44,244	24,231	12,901	9,919	56,367	40,567,747
2001	374,408	295,921	149,429	138,346	91,002	27,862	32,452	17,794	9,483	48,776	34,781,708
2002	325,240	269,468	214,433	109,125	101,857	67,386	20,706	24,144	13,253	43,436	31,849,761
2003	243,974	234,340	195,197	156,382	80,198	75,261	49,962	15,368	17,939	42,167	32,018,477
2004	263,742	180,591	174,448	146,285	118,040	60,844	57,287	38,072	11,723	45,892	32,491,277
2005	326,485	190,453	131,224	127,683	107,886	87,524	45,268	42,668	28,386	43,005	31,696,724

Table 4.4.1 Spawning stock (SS) reproductive potential (mature female gonad weight (g)), and SS as a function of maximum sustainable yield (MSY) and optimal yield (OY).

YEAR	SS	SS_{MSY}	SS_{OY}	SS/SS_{MSY}	SS/SS_{OY}
1986	5.06E+08	5.91E+08	7.040E+08	0.855	0.718
1987	4.85E+08	5.91E+08	7.040E+08	0.820	0.689
1988	4.73E+08	5.91E+08	7.040E+08	0.800	0.672
1989	4.76E+08	5.91E+08	7.040E+08	0.806	0.677
1990	4.75E+08	5.91E+08	7.040E+08	0.803	0.674
1991	5.00E+08	5.91E+08	7.040E+08	0.845	0.710
1992	5.31E+08	5.91E+08	7.040E+08	0.899	0.755
1993	5.49E+08	5.91E+08	7.040E+08	0.929	0.780
1994	5.50E+08	5.91E+08	7.040E+08	0.930	0.781
1995	5.67E+08	5.91E+08	7.040E+08	0.959	0.805
1996	5.61E+08	5.91E+08	7.040E+08	0.949	0.797
1997	5.68E+08	5.91E+08	7.040E+08	0.961	0.807
1998	5.82E+08	5.91E+08	7.040E+08	0.985	0.827
1999	6.18E+08	5.91E+08	7.040E+08	1.044	0.877
2000	6.39E+08	5.91E+08	7.040E+08	1.081	0.908
2001	6.26E+08	5.91E+08	7.040E+08	1.058	0.889
2002	6.60E+08	5.91E+08	7.040E+08	1.116	0.937
2003	7.00E+08	5.91E+08	7.040E+08	1.184	0.994
2004	7.34E+08	5.91E+08	7.040E+08	1.241	1.042
2005	7.52E+08	5.91E+08	7.040E+08	1.271	1.068

Table 4.5.1 Selectivity-at-age by fleet. Note: these selectivity vectors apply to the total catch (landed + released).

	FLEET			
	COM LL	COM HL	COM TRAP	REC
Age 1	0.00	0.00	0.00	1.00
Age 2	0.18	0.50	0.00	1.00
Age 3	0.24	0.63	0.01	1.00
Age 4	0.32	0.78	0.02	0.96
Age 5	0.44	0.93	0.04	0.87
Age 6	0.61	1.00	0.08	0.74
Age 7	0.79	0.96	0.15	0.61
Age 8	0.93	0.86	0.26	0.50
Age 9	1.00	0.75	0.42	0.43
Age 10	0.99	0.66	0.60	0.39
Age 11	0.94	0.60	0.78	0.37
Age 12	0.86	0.57	0.92	0.37
Age 13	0.79	0.55	1.00	0.37
Age 14	0.74	0.54	1.00	0.37
Age 15	0.70	0.54	1.00	0.37
Age 16	0.68	0.54	1.00	0.37
Age 17	0.68	0.54	1.00	0.37
Age 18	0.68	0.54	1.00	0.37
Age 19	0.68	0.54	1.00	0.37
Age 20	0.68	0.54	1.00	0.37

Table 4.6.1 Fishing mortality (due to landings and discards) by year and fleet.

YEAR	COM LL	COM HL	COM TRAP	REC
1986	0.071	0.080	0.023	0.081
1987	0.104	0.068	0.017	0.057
1988	0.073	0.058	0.022	0.084
1989	0.097	0.093	0.027	0.100
1990	0.114	0.107	0.022	0.098
1991	0.144	0.093	0.028	0.146
1992	0.132	0.068	0.049	0.166
1993	0.194	0.057	0.056	0.125
1994	0.129	0.050	0.070	0.110
1995	0.114	0.045	0.071	0.105
1996	0.122	0.035	0.039	0.061
1997	0.120	0.036	0.038	0.044
1998	0.106	0.030	0.021	0.052
1999	0.132	0.044	0.038	0.080
2000	0.111	0.058	0.048	0.111
2001	0.124	0.055	0.039	0.079
2002	0.114	0.054	0.045	0.089
2003	0.106	0.038	0.035	0.079
2004	0.115	0.041	0.035	0.126
2005	0.108	0.042	0.028	0.079

Table 4.6.2. Annual estimates of total fishing mortality (landings + discards) expressed as Apical F (maximum annual F at any age), F as a fraction of F at maximum sustainable yield (F_{MSY}) and F as a fraction of F at optimal yield (F_{OY}).

YEAR	Apical F	F_{MSY}	F_{OY}	F/F_{MSY}	F/F_{OY}
1986	0.18	0.22	0.16	0.83	1.11
1987	0.19	0.22	0.16	0.85	1.14
1988	0.16	0.22	0.16	0.75	1.00
1989	0.23	0.22	0.16	1.04	1.38
1990	0.21	0.22	0.16	0.96	1.28
1991	0.24	0.22	0.16	1.10	1.47
1992	0.23	0.22	0.16	1.08	1.44
1993	0.27	0.22	0.16	1.25	1.67
1994	0.22	0.22	0.16	1.01	1.35
1995	0.21	0.22	0.16	0.95	1.27
1996	0.17	0.22	0.16	0.77	1.02
1997	0.16	0.22	0.16	0.73	0.98
1998	0.14	0.22	0.16	0.62	0.83
1999	0.18	0.22	0.16	0.85	1.14
2000	0.19	0.22	0.16	0.89	1.19
2001	0.19	0.22	0.16	0.86	1.14
2002	0.18	0.22	0.16	0.85	1.13
2003	0.16	0.22	0.16	0.72	0.97
2004	0.18	0.22	0.16	0.84	1.12
2005	0.16	0.22	0.16	0.73	0.97

Table 4.6.3. Total fishing mortality (due to landings and discards) by age and year.

YEAR	AGE 1	AGE 2	AGE 3	AGE 4	AGE 5	AGE 6	AGE 7	AGE 8	AGE 9	AGE 10	AGE 11	AGE 12	AGE 13	AGE 14	AGE 15	AGE 16	AGE 17	AGE 18	AGE 19	AGE 20
1986	0.007	0.089	0.137	0.156	0.170	0.179	**0.180**	0.177	0.171	0.165	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1987	0.005	0.072	0.115	0.136	0.155	0.170	0.181	**0.185**	0.184	0.179	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1988	0.008	0.066	0.124	0.142	0.153	0.160	**0.163**	0.162	0.158	0.154	0.149	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1989	0.009	0.080	0.159	0.191	0.210	0.221	**0.225**	0.223	0.217	0.209	0.202	0.195	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1990	0.009	0.023	0.031	0.056	0.105	0.156	0.190	0.206	**0.208**	0.205	0.198	0.192	0.186	0.180	0.177	0.175	0.176	0.176	0.176	0.177
1991	0.013	0.028	0.034	0.063	0.122	0.179	0.216	0.235	**0.240**	0.237	0.231	0.225	0.218	0.211	0.207	0.206	0.206	0.206	0.207	0.207
1992	0.015	0.028	0.035	0.070	0.130	0.180	0.210	0.226	0.233	**0.234**	0.233	0.230	0.226	0.220	0.216	0.214	0.215	0.215	0.215	0.216
1993	0.011	0.028	0.038	0.075	0.132	0.184	0.225	0.253	0.268	**0.272**	0.271	0.266	0.258	0.249	0.244	0.241	0.241	0.241	0.241	0.242
1994	0.010	0.022	0.027	0.055	0.103	0.145	0.174	0.194	0.207	0.215	0.219	**0.220**	0.217	0.212	0.208	0.206	0.206	0.206	0.206	0.208
1995	0.010	0.020	0.025	0.049	0.092	0.131	0.159	0.178	0.190	0.198	0.203	**0.206**	0.204	0.199	0.196	0.194	0.195	0.195	0.195	0.196
1996	0.006	0.016	0.020	0.036	0.069	0.103	0.132	0.151	0.162	**0.166**	0.166	0.164	0.159	0.154	0.150	0.148	0.149	0.149	0.149	0.149
1997	0.004	0.014	0.018	0.032	0.061	0.094	0.122	0.143	0.155	0.159	**0.159**	0.157	0.153	0.147	0.143	0.142	0.142	0.142	0.142	0.143
1998	0.005	0.014	0.018	0.030	0.055	0.084	0.108	0.125	0.134	**0.135**	0.133	0.129	0.125	0.120	0.117	0.115	0.115	0.115	0.116	0.116
1999	0.007	0.019	0.024	0.041	0.077	0.117	0.149	0.170	0.181	**0.185**	0.184	0.181	0.176	0.170	0.166	0.164	0.164	0.164	0.164	0.165
2000	0.010	0.021	0.027	0.053	0.096	0.136	0.165	0.181	0.189	0.193	**0.193**	0.192	0.189	0.184	0.181	0.179	0.179	0.179	0.180	0.180
2001	0.007	0.019	0.024	0.046	0.086	0.126	0.156	0.174	0.184	**0.186**	0.185	0.182	0.177	0.171	0.168	0.166	0.166	0.166	0.166	0.167
2002	0.008	0.019	0.024	0.044	0.085	0.125	0.154	0.172	0.181	0.184	**0.184**	0.182	0.179	0.173	0.170	0.168	0.169	0.169	0.169	0.169
2003	0.007	0.017	0.021	0.040	0.073	0.104	0.129	0.145	0.154	**0.157**	0.157	0.155	0.151	0.147	0.143	0.142	0.142	0.142	0.143	0.143
2004	0.011	0.022	0.027	0.055	0.100	0.136	0.160	0.175	0.182	**0.183**	0.182	0.179	0.175	0.170	0.166	0.165	0.165	0.165	0.165	0.166
2005	0.007	0.017	0.021	0.039	0.077	0.111	0.136	0.151	0.157	**0.158**	0.156	0.153	0.148	0.143	0.140	0.138	0.139	0.139	0.139	0.139

Table 4.9.1. Retrospective analyses. The effect of removing the most recent years of data on SS/SS_{MSY}, F/F_{MSY} and recruitment.

	Recruitment (Millions)					F/F_{MSY}					SS/SS_{MSY}				
YEAR	to 2005	to 2004	to 2003	to 2002	to 2001	to 2005	to 2004	to 2003	to 2002	to 2001	to 2005	to 2004	to 2003	to 2002	to 2001
1986	6.07	6.02	5.91	5.85	5.67	0.83	0.84	0.78	0.78	0.80	0.85	0.87	0.92	0.95	0.99
1987	12.45	12.38	12.01	11.69	11.17	0.85	0.89	0.84	0.85	0.89	0.82	0.83	0.87	0.90	0.93
1988	11.77	11.73	11.51	11.41	10.91	0.75	0.77	0.73	0.74	0.78	0.80	0.81	0.84	0.87	0.89
1989	8.35	8.28	8.08	7.86	7.44	1.04	1.07	1.02	1.03	1.09	0.81	0.81	0.84	0.86	0.88
1990	11.52	11.38	11.08	11.00	10.45	0.96	1.01	0.97	0.98	1.04	0.80	0.81	0.83	0.85	0.86
1991	10.17	10.02	9.61	9.41	8.76	1.10	1.18	1.14	1.15	1.24	0.84	0.85	0.87	0.89	0.90
1992	8.71	8.54	8.21	7.89	7.38	1.08	1.18	1.15	1.16	1.26	0.90	0.91	0.92	0.94	0.94
1993	6.53	6.41	6.11	5.96	5.60	1.25	1.38	1.34	1.35	1.48	0.93	0.93	0.95	0.96	0.95
1994	7.02	6.89	6.50	6.29	5.65	1.01	1.13	1.11	1.10	1.23	0.93	0.93	0.94	0.95	0.93
1995	8.87	8.80	8.24	8.05	7.28	0.95	1.06	1.05	1.05	1.18	0.96	0.96	0.96	0.97	0.94
1996	6.97	6.81	6.27	6.01	5.09	0.77	0.85	0.85	0.85	0.97	0.95	0.95	0.94	0.95	0.91
1997	13.81	13.96	13.60	14.12	13.07	0.73	0.82	0.82	0.83	0.95	0.96	0.96	0.95	0.95	0.90
1998	7.40	7.16	6.18	6.04	5.55	0.62	0.68	0.69	0.71	0.82	0.98	0.98	0.96	0.96	0.90
1999	5.60	5.57	5.51	6.76	6.70	0.85	0.94	0.96	0.99	1.17	1.04	1.04	1.02	1.02	0.94
2000	22.34	16.84	11.27	8.08	7.37	0.89	1.00	1.03	1.07	1.30	1.08	1.08	1.05	1.05	0.96
2001	7.98	7.49	8.17	7.79	7.27	0.86	0.96	1.01	1.04	1.31	1.06	1.06	1.01	1.02	0.93
2002	7.72	8.79	8.29	7.89		0.85	0.96	1.03	1.07	-	1.12	1.09	1.01	1.02	-
2003	9.65	9.36	8.41	-	-	0.72	0.83	0.89	-	-	1.18	1.11	0.99	-	-
2004	10.03	9.71	-	-	-	0.84	1.00	-	-	-	1.24	1.15	-	-	-
2005	9.33	-	-	-	-	0.73	-	-	-	-	1.27	-	-	-	-

Table 4.10.1 Reference points and benchmarks for the red grouper base run and sensitivity analyses.

BENCHMARKS	BASE (2% Increase in Q)	LM * 1.1	LM * 0.9	Constant Q	4% Annual Increase in Q	CV Discards 0.15
Virgin Stock Parameters						
Virgin SPR	163.4	127.5	212.2	163.4	163.4	163.4
Virgin R	9.91E+06	1.23E+07	8.06E+06	1.10E+07	9.10E+06	1.06E+07
F-REFS						
F_{MSY}	0.22	0.23	0.19	0.21	0.21	0.20
F_{OY}	0.16	0.18	0.14	0.16	0.16	0.15
F_{2005}	0.16	0.14	0.17	0.13	0.19	0.13
SSB-REFS						
SS_{MSY}	5.91E+08	5.86E+08	6.11E+08	6.54E+08	5.44E+08	6.28E+08
SS_{OY}	7.04E+08	6.95E+08	7.30E+08	7.78E+08	6.48E+08	7.54E+08
SS_{2005}	7.52E+08	8.23E+08	6.93E+08	9.12E+08	6.27E+08	8.47E+08
YIELD REFS						
MSY	7.72E+06	7.84E+06	7.73E+06	8.54E+06	7.06E+06	8.03E+06
OY	7.57E+06	7.68E+06	7.58E+06	8.37E+06	6.92E+06	7.87E+06
SRR Parameters						
virgin	1.62E+09	1.57E+09	1.71E+09	1.79E+09	1.49E+09	1.73E+09
steepness	0.84	0.82	0.85	0.83	0.83	0.85
Current Status						
F/F_{MSY}	0.73	0.61	0.87	0.59	0.90	0.67
SS/SS_{MSY}	1.27	1.40	1.13	1.40	1.15	1.35
F/F_{OY}	0.97	0.81	1.17	0.79	1.19	0.90
SS/SS_{OY}	1.07	1.18	0.95	1.17	0.97	1.12
MFMT = F_{MSY}	***0.22***	***0.23***	***0.19***	***0.21***	***0.21***	***0.20***
MSST = SS_{MSY} * (1-M) where M = 0.14	***5.09E+08***	***5.04E+08***	***5.25E+08***	***5.62E+08***	***4.68E+08***	***5.40E+08***

Table 4.12.1. Predicted yield (millions of lbs gutted weight) in 2005 and for the five projections (2006-2015) with 80% confidence intervals.

	F_{MSY}			F_{OY}			$F_{CURRENT}$			OY			Current Management		
YEAR	Lower 80% CI	Yield	Upper 80% CI	Lower 80% CI	Yield	Upper 80% CI	Lower 80% CI	Yield	Upper 80% CI	Lower 80% CI	Yield	Upper 80% CI	Lower 80% CI	Yield	Upper 80% CI
2005	7.33	7.33	7.33	7.33	7.33	7.33	7.33	7.33	7.33	7.33	7.33	7.33	7.33	7.33	7.33
2006	7.28	7.28	7.28	7.28	7.28	7.28	7.28	7.28	7.28	7.28	7.28	7.28	7.28	7.28	7.28
2007	7.73	7.73	7.73	7.73	7.73	7.73	7.73	7.73	7.73	7.73	7.73	7.73	7.73	7.73	7.73
2008	10.38	10.39	10.39	7.97	7.97	7.97	7.76	7.77	7.77	7.57	7.57	7.57	7.22	7.22	7.22
2009	9.83	9.91	10.03	7.88	7.94	8.03	7.71	7.76	7.86	7.57	7.57	7.57	7.33	7.33	7.33
2010	9.21	9.50	9.96	7.68	7.91	8.26	7.54	7.76	8.10	7.57	7.57	7.57	7.33	7.33	7.33
2011	8.61	9.20	9.98	7.43	7.90	8.52	7.32	7.77	8.38	7.57	7.57	7.57	7.33	7.33	7.33
2012	8.11	8.98	10.12	7.21	7.92	8.83	7.12	7.81	8.70	7.57	7.57	7.57	7.39	7.39	7.39
2013	7.81	8.85	10.18	7.09	7.97	9.06	7.01	7.87	8.94	7.57	7.57	7.57	7.39	7.39	7.39
2014	7.63	8.72	10.14	7.02	7.98	9.20	6.95	7.89	9.09	7.57	7.57	7.57	7.39	7.39	7.39
2015	7.50	8.66	10.17	7.01	8.02	9.34	6.95	7.94	9.24	7.57	7.57	7.57	7.39	7.39	7.39

Table 4.12.2. Predicted discards (thousands of lbs gutted weight) in 2005 and for the five projections (2006-2015).

	F_{MSY}	F_{OY}	$F_{CURRENT}$	OY	Current Management
YEAR	Discards (1000s of lbs)	Discards (1000s of lbs)	Discards (1000s of lbs)	Discards (1000s of lbs)	Discards (1000s of lbs)
2005	778.5	778.5	778.5	778.5	778.5
2006	727.5	727.5	727.5	727.5	727.5
2007	750.1	750.1	750.1	750.1	750.1
2008	1003.2	721.9	741.5	721.9	687.8
2009	975.0	714.6	735.2	714.6	689.0
2010	956.4	710.9	731.0	710.9	683.4
2011	944.6	709.4	728.4	709.4	679.8
2012	937.0	709.4	727.0	709.4	683.4
2013	931.5	710.0	726.1	710.0	682.3
2014	927.0	710.4	725.4	710.4	681.2
2015	923.3	710.7	724.8	710.7	680.2

Table 4.12.3. Spawning stock (grams mature female gonad * 10^6) in 2005 and for the five projections (2006-2015) with 80% confidence intervals.

	F_{MSY}			F_{OY}			$F_{CURRENT}$			OY			Current Management		
YEAR	Lower 80% CI	SS	Upper 80% CI	Lower 80% CI	SS	Upper 80% CI	Lower 80% CI	SS	Upper 80% CI	Lower 80% CI	SS	Upper 80% CI	Lower 80% CI	SS	Upper 80% CI
2005	751.7	751.7	751.7	751.7	751.7	751.7	751.7	751.7	751.7	751.7	751.7	751.7	751.7	751.7	751.7
2006	714.7	714.7	714.7	714.7	714.7	714.7	714.7	714.7	714.7	714.7	714.7	714.7	714.7	714.7	714.7
2007	732.2	732.9	734.1	732.2	732.9	734.1	732.2	732.9	734.1	732.2	732.9	734.1	732.2	732.9	734.1
2008	737.3	749.8	770.4	737.3	749.8	770.4	737.3	749.8	770.4	737.3	749.8	770.4	737.3	749.8	770.4
2009	679.2	715.0	767.0	704.3	740.3	792.7	706.3	742.4	794.8	708.4	744.5	797.0	712.0	748.1	800.7
2010	631.7	691.0	770.1	675.7	736.3	816.9	679.5	740.1	820.8	683.0	744.3	826.5	688.8	750.2	832.6
2011	601.9	681.4	781.4	659.9	741.8	846.2	665.0	747.0	851.8	669.3	753.1	863.8	677.3	761.3	872.3
2012	585.7	670.4	773.7	653.6	741.6	852.6	659.6	747.9	859.4	660.3	757.1	875.1	670.5	767.6	885.7
2013	573.1	663.3	779.1	650.8	744.6	867.6	657.5	751.8	875.3	657.7	761.6	897.9	669.2	773.4	910.2
2014	561.0	660.5	779.3	644.8	749.9	879.0	652.1	757.8	887.8	648.4	771.9	925.1	661.2	785.1	938.7
2015	549.6	648.9	786.8	637.7	745.3	892.4	645.8	754.3	901.7	642.2	773.2	942.9	656.2	787.5	957.8

Table 4.12.4. SS/SS_{MSY} and SS/SS_{OY} in 2005 and for the five projections (2006-2015).

	F_{MSY}		F_{OY}		$F_{CURRENT}$		OY		Current Management	
YEAR	SS/SS_{MSY}	SS/SS_{OY}	SS/SS_{MSY}	SS/SS_{OY}	SS/SS_{MSY}	SS/SS_{OY}	SS/SS_{MSY}	SS/SS_{OY}	SS/SS_{MSY}	SS/SS_{OY}
2005	1.27	1.07	1.27	1.07	1.27	1.07	1.27	1.07	1.27	1.07
2006	1.21	1.02	1.21	1.02	1.21	1.02	1.21	1.02	1.21	1.02
2007	1.24	1.04	1.24	1.04	1.24	1.04	1.24	1.04	1.24	1.04
2008	1.27	1.06	1.27	1.06	1.27	1.06	1.27	1.06	1.27	1.06
2009	1.21	1.02	1.25	1.05	1.26	1.05	1.26	1.06	1.27	1.06
2010	1.17	0.98	1.25	1.05	1.25	1.05	1.26	1.06	1.27	1.07
2011	1.15	0.97	1.25	1.05	1.26	1.06	1.27	1.07	1.29	1.08
2012	1.13	0.95	1.25	1.05	1.26	1.06	1.28	1.08	1.30	1.09
2013	1.12	0.94	1.26	1.06	1.27	1.07	1.29	1.08	1.31	1.10
2014	1.12	0.94	1.27	1.07	1.28	1.08	1.31	1.10	1.33	1.12
2015	1.10	0.92	1.26	1.06	1.28	1.07	1.31	1.10	1.33	1.12

Table 4.12.5. Fishing mortality in 2005 and for the five projections (2006-2015) with 80% confidence intervals.

	F_{MSY}			F_{OY}			$F_{CURRENT}$			OY			Current Management		
YEAR	Lower 80% CI	F	Upper 80% CI	Lower 80% CI	F	Upper 80% CI	Lower 80% CI	F	Upper 80% CI	Lower 80% CI	F	Upper 80% CI	Lower 80% CI	F	Upper 80% CI
2005	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16
2006	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
2007	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16
2008	0.22	0.22	0.22	0.16	0.16	0.16	0.16	0.16	0.16	0.15	0.15	0.15	0.15	0.15	0.15
2009	0.22	0.22	0.22	0.16	0.16	0.16	0.16	0.16	0.16	0.15	0.15	0.15	0.15	0.15	0.15
2010	0.22	0.22	0.22	0.16	0.16	0.16	0.16	0.16	0.16	0.15	0.15	0.16	0.14	0.15	0.15
2011	0.22	0.22	0.22	0.16	0.16	0.16	0.16	0.16	0.16	0.14	0.15	0.16	0.13	0.14	0.16
2012	0.22	0.22	0.22	0.16	0.16	0.16	0.16	0.16	0.16	0.13	0.15	0.17	0.13	0.14	0.16
2013	0.22	0.22	0.22	0.16	0.16	0.16	0.16	0.16	0.16	0.13	0.15	0.17	0.12	0.14	0.16
2014	0.22	0.22	0.22	0.16	0.16	0.16	0.16	0.16	0.16	0.12	0.15	0.18	0.12	0.14	0.17
2015	0.22	0.22	0.22	0.16	0.16	0.16	0.16	0.16	0.16	0.12	0.15	0.18	0.11	0.14	0.17

Table 4.12.6. F/F_{MSY} and F/F_{OY} in 2005 and for the five projections (2006-2015).

	F_{MSY}		F_{OY}		$F_{CURRENT}$		OY		Current Management	
YEAR	F/F_{MSY}	F/F_{OY}	F/F_{MSY}	F/F_{OY}	F/F_{MSY}	F/F_{OY}	F/F_{MSY}	F/F_{OY}	F/F_{MSY}	F/F_{OY}
2005	0.73	0.97	0.73	0.97	0.73	0.97	0.73	0.97	0.73	0.97
2006	0.70	0.93	0.70	0.93	0.70	0.93	0.70	0.93	0.70	0.93
2007	0.73	0.97	0.73	0.97	0.73	0.97	0.73	0.97	0.73	0.97
2008	1.00	1.33	0.75	1.00	0.73	0.97	0.71	0.95	0.67	0.90
2009	1.00	1.33	0.75	1.00	0.73	0.97	0.71	0.94	0.68	0.91
2010	1.00	1.33	0.75	1.00	0.73	0.97	0.70	0.94	0.67	0.90
2011	1.00	1.33	0.75	1.00	0.73	0.97	0.70	0.93	0.67	0.89
2012	1.00	1.33	0.75	1.00	0.73	0.97	0.70	0.93	0.67	0.89
2013	1.00	1.33	0.75	1.00	0.73	0.97	0.69	0.91	0.65	0.87
2014	1.00	1.33	0.75	1.00	0.73	0.97	0.68	0.91	0.65	0.86
2015	1.00	1.33	0.75	1.00	0.73	0.97	0.67	0.90	0.64	0.85

Table 4.12.7. Recruitment (millions) in 2005 and for the five projections (2006-2015) with 80% confidence intervals.

	F_{MSY}			F_{OY}			$F_{CURRENT}$			OY			Current Management		
YEAR	Lower 80% CI	Recruits	Upper 80% CI	Lower 80% CI	Recruits	Upper 80% CI	Lower 80% CI	Recruits	Upper 80% CI	Lower 80% CI	Recruits	Upper 80% CI	Lower 80% CI	Recruits	Upper 80% CI
2005	9.33	9.33	9.33	9.33	9.33	9.33	9.33	9.33	9.33	9.33	9.33	9.33	9.33	9.33	9.33
2006	5.59	9.37	16.14	5.59	9.37	16.14	5.59	9.37	16.14	5.59	9.37	16.14	5.59	9.37	16.14
2007	5.76	9.19	14.47	5.76	9.19	14.47	5.76	9.19	14.47	5.76	9.19	14.47	5.76	9.19	14.47
2008	5.65	9.96	15.75	5.65	9.96	15.75	5.65	9.96	15.75	5.65	9.96	15.75	5.65	9.96	15.75
2009	5.56	9.48	16.03	5.56	9.48	16.03	5.56	9.48	16.03	5.56	9.48	16.03	5.56	9.48	16.03
2010	5.56	9.41	14.92	5.58	9.44	14.98	5.58	9.44	14.98	5.58	9.45	14.98	5.59	9.45	14.99
2011	5.71	9.54	15.51	5.75	9.61	15.61	5.75	9.61	15.62	5.76	9.62	15.63	5.76	9.63	15.64
2012	5.56	9.11	15.53	5.61	9.20	15.66	5.62	9.21	15.67	5.62	9.21	15.68	5.63	9.22	15.70
2013	5.34	8.96	15.28	5.38	9.07	15.42	5.39	9.08	15.44	5.40	9.08	15.45	5.40	9.10	15.47
2014	5.53	9.05	14.45	5.59	9.15	14.64	5.59	9.16	14.66	5.61	9.18	14.70	5.62	9.19	14.72
2015	5.61	9.46	15.67	5.68	9.57	15.95	5.69	9.58	15.97	5.70	9.59	15.96	5.70	9.60	16.00

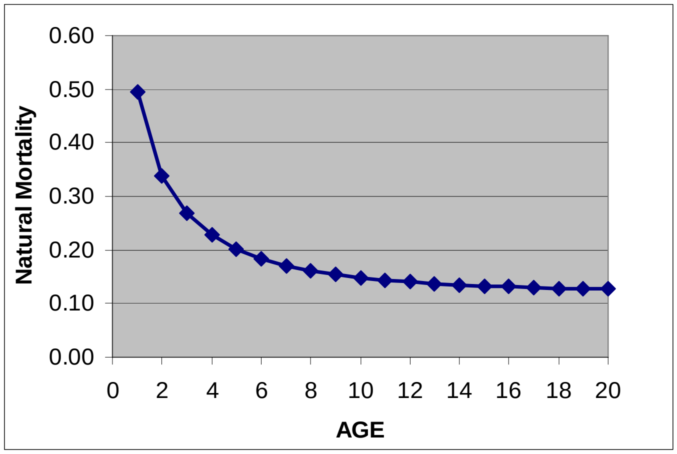


Figure 3.2.1. Natural mortality at age.

Figure 3.2.2 Gutted weight-at-age (lbs).

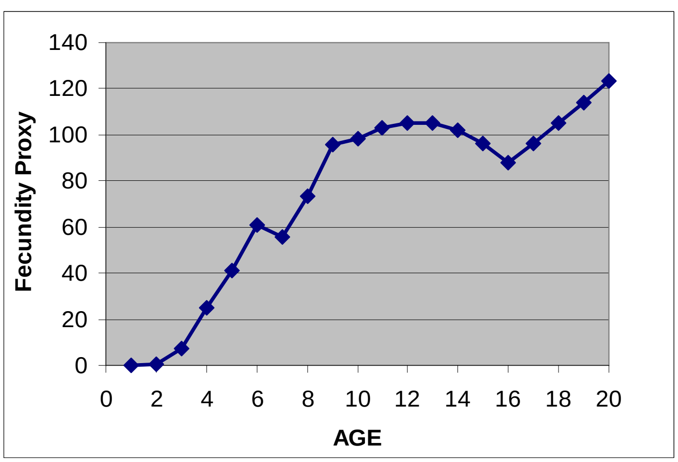


Figure 3.2.3 Fecundity-at-age (mature female gonad weight (g)).

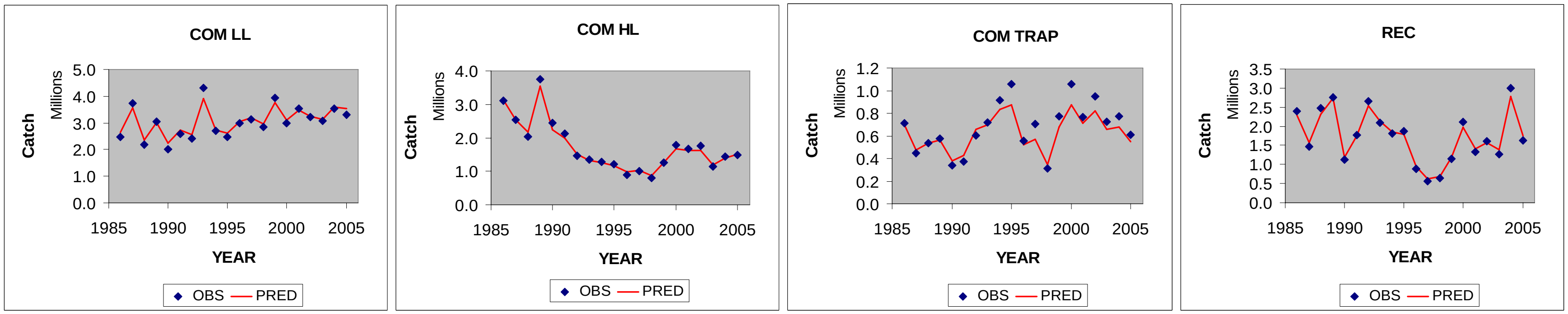


Figure 4.1.1. Fits to the catch series (gutted lbs).

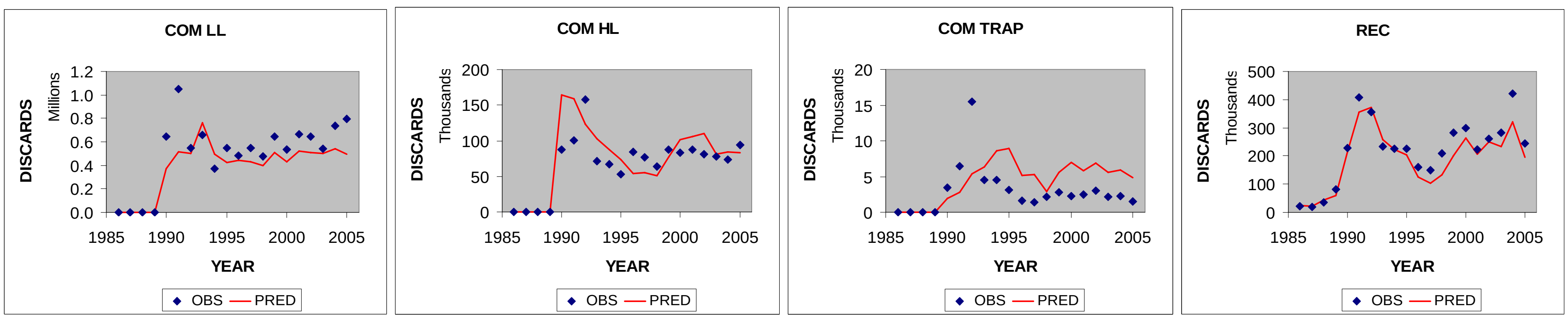


Figure 4.1.2. Fits to the discard series (gutted lbs).

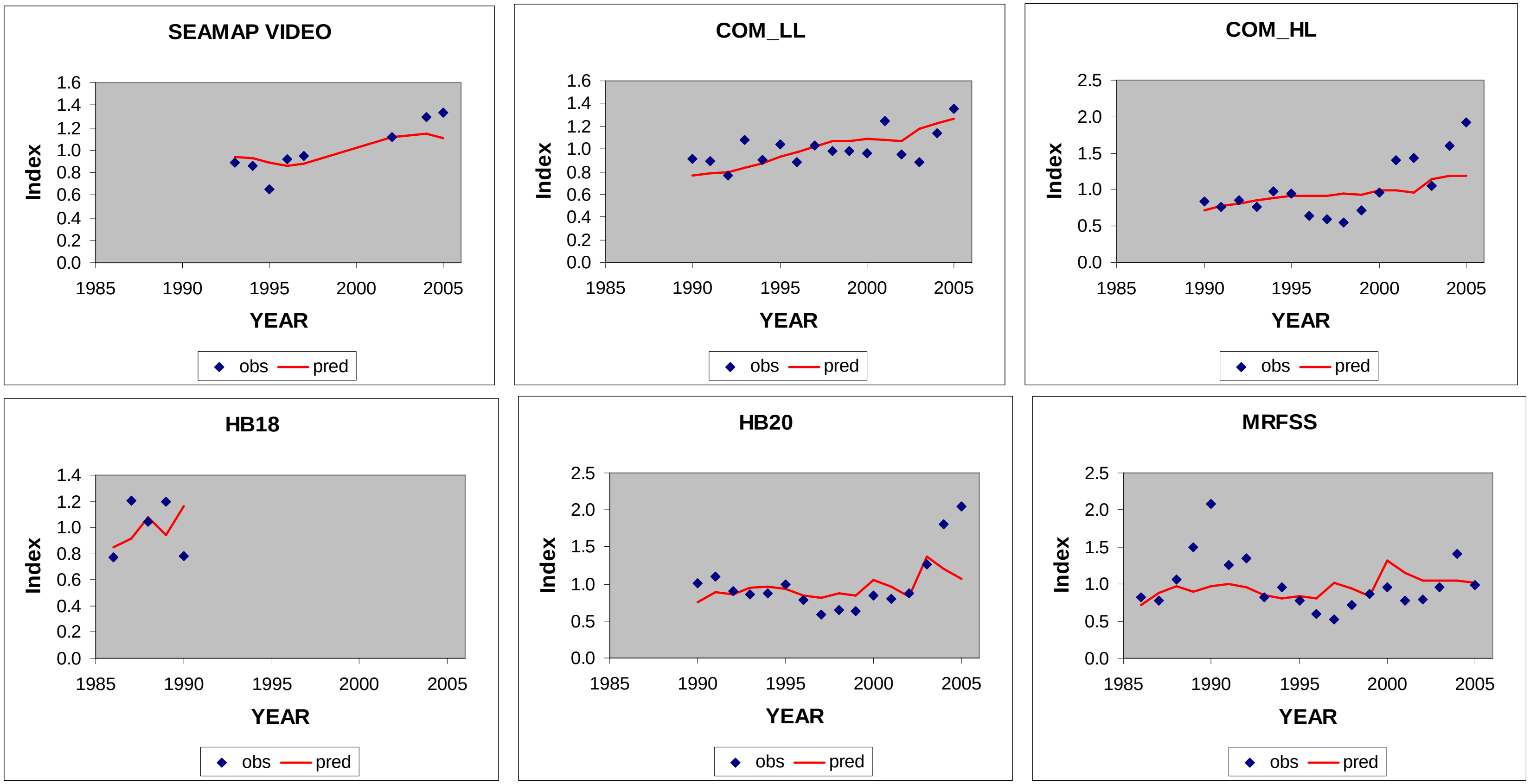


Figure 4.1.3. Fits to the indices of abundance.

A) FITS TO CATCH-AT-AGE - COMMERCIAL LONGLINE

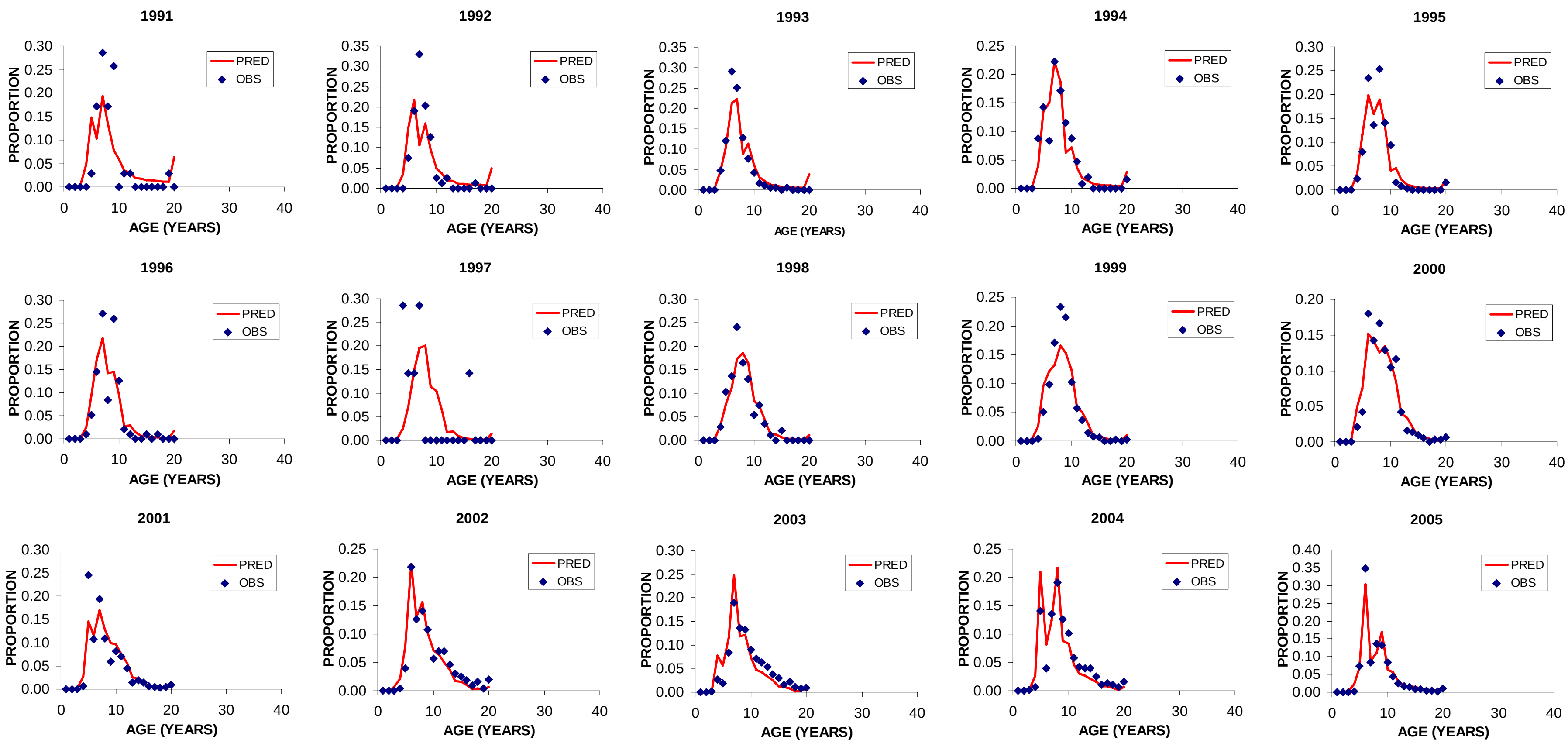


Figure 4.1.4 A. Fits to the direct observed catch-at-age for the commercial longline fleet. Note: there are no observations before 1991.

B) FITS TO CATCH-AT-AGE - COMMERCIAL HANDLINE

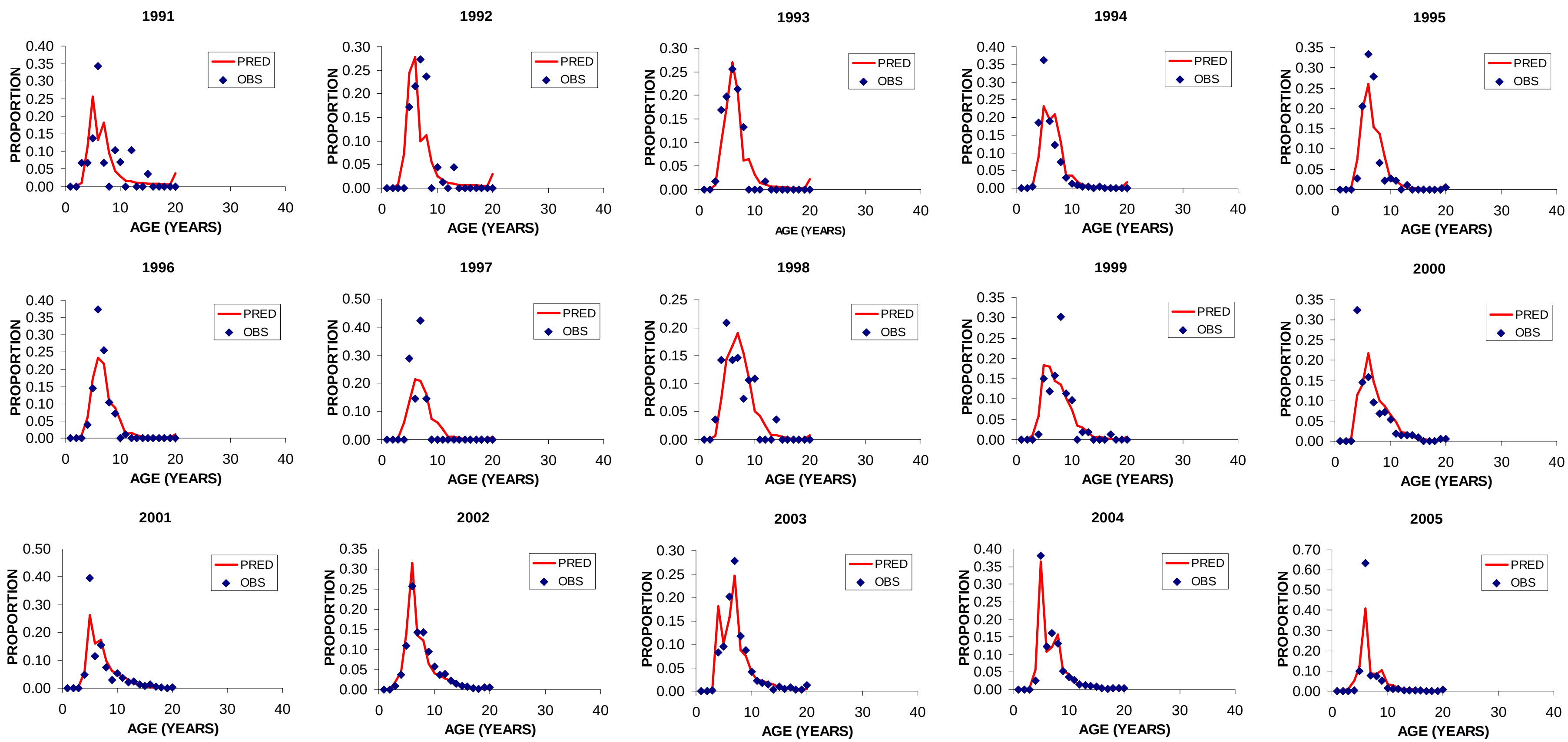


Figure 4.1.4 B. Fits to the direct observed catch-at-age for the commercial handline fleet. Note: there are no observations before 1991.

C) FITS TO CATCH-AT-AGE - COMMERCIAL TRAP

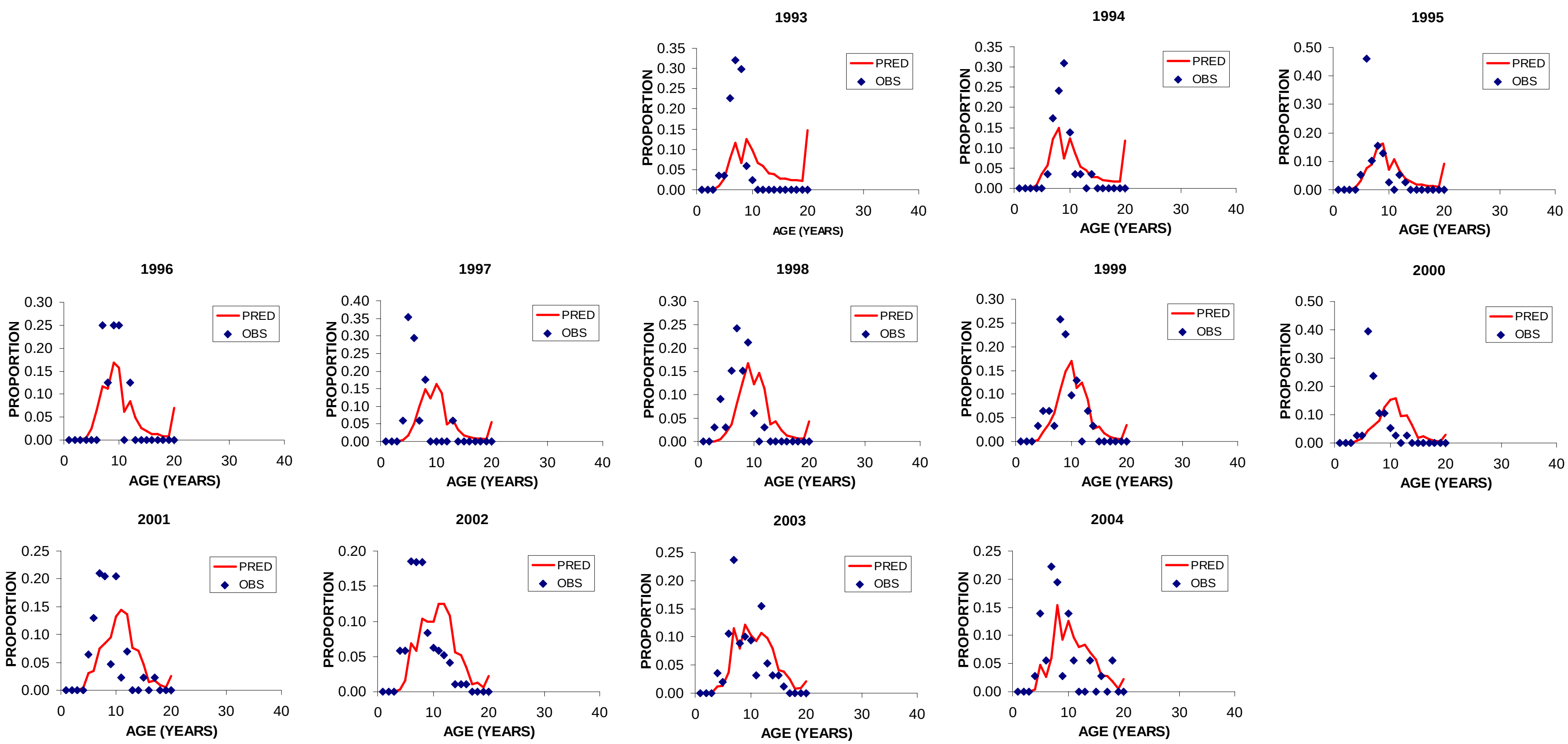


Figure 4.1.4 C. Fits to the direct observed catch-at-age for the commercial trap fleet. Note: there are no observations before 1993, and no observations in 2005.

D) FITS TO CATCH-AT-AGE - RECREATIONAL

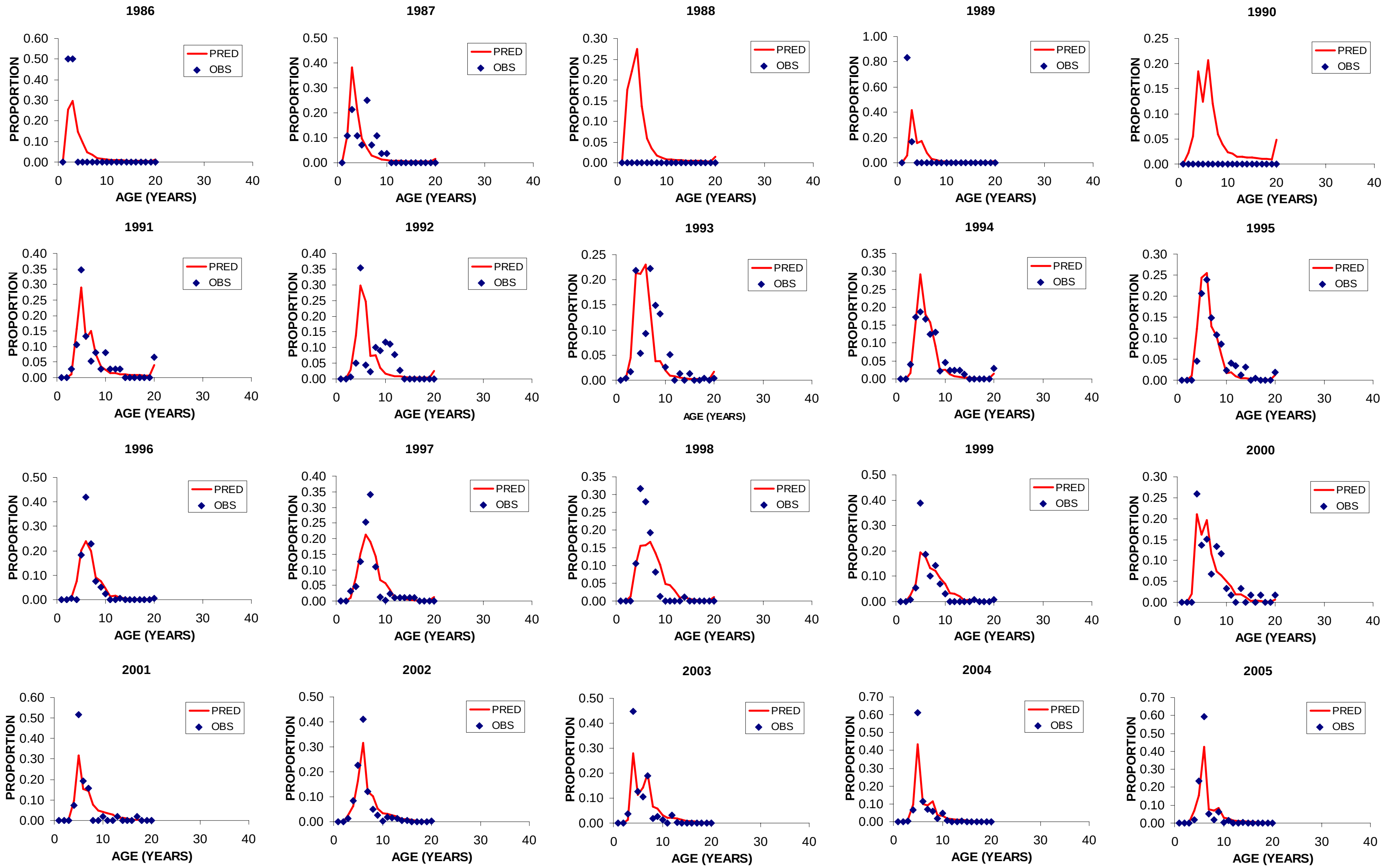


Figure 4.1.4 D. Fits to the direct observed catch-at-age for the recreational fleet. There were no observations in 1988 or 1990.

A) FITS TO DISCARDS-AT-AGE - COMMERCIAL LONGLINE

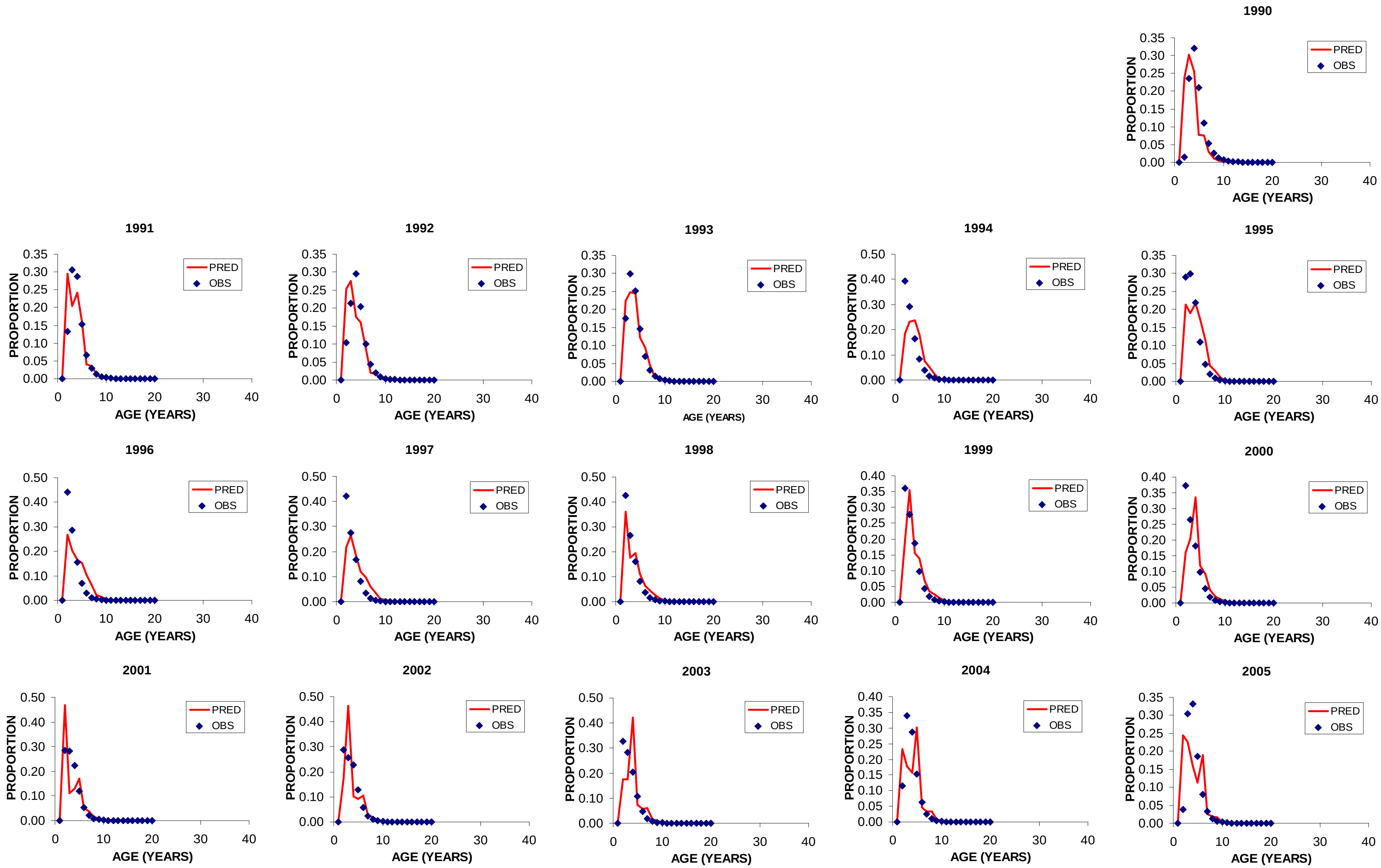


Figure 4.1.5 A. Fits to the modeled discards-at-age for the commercial longline fleet. Note: there are no estimates before 1990.

B) FITS TO DISCARDS-AT-AGE - COMMERCIAL HANDLINE

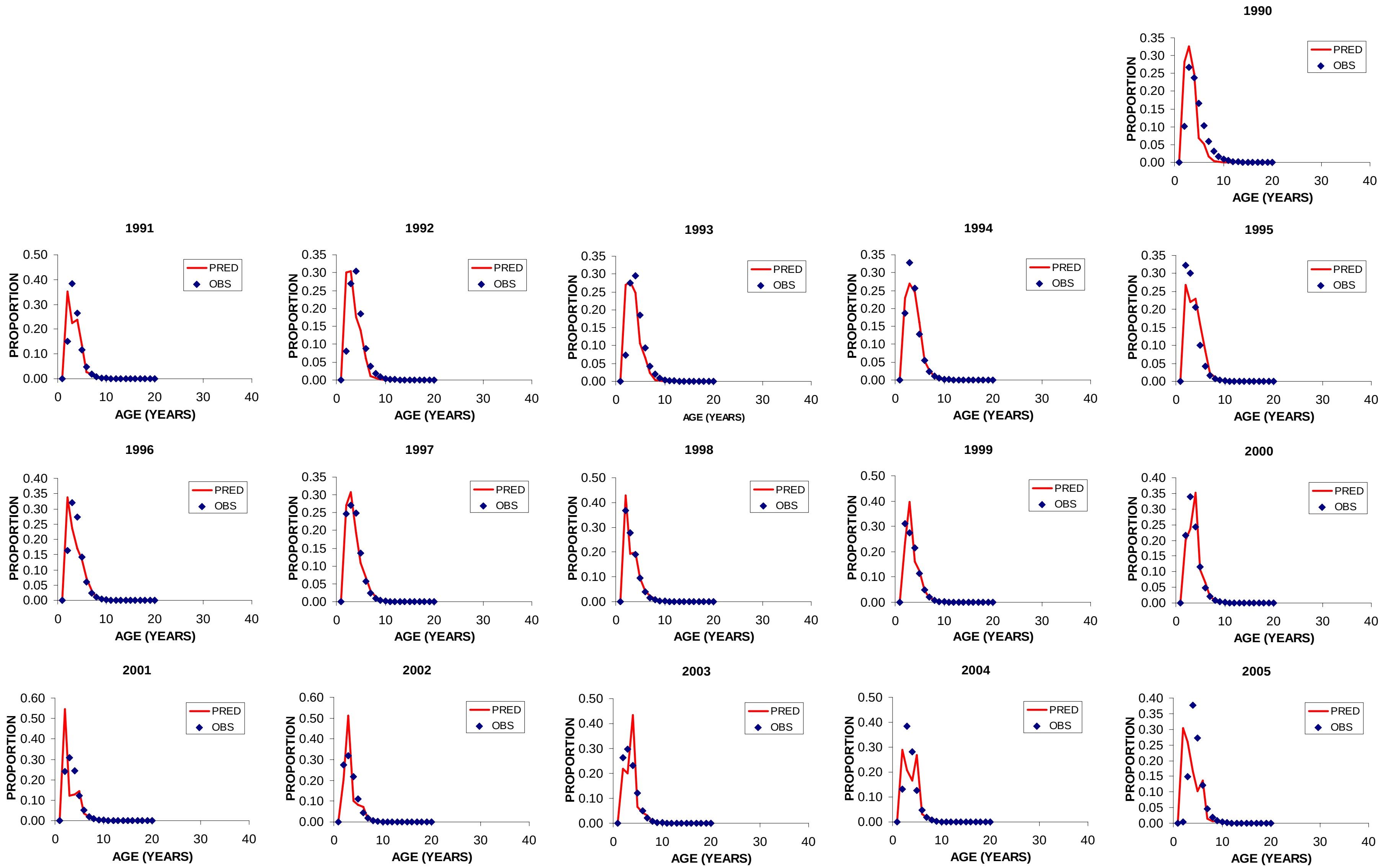


Figure 4.1.5 B. Fits to the modeled discards-at-age for the commercial handline fleet. Note: there are no estimates before 1990.

C) FITS TO DISCARDS-AT-AGE - COMMERCIAL TRAP

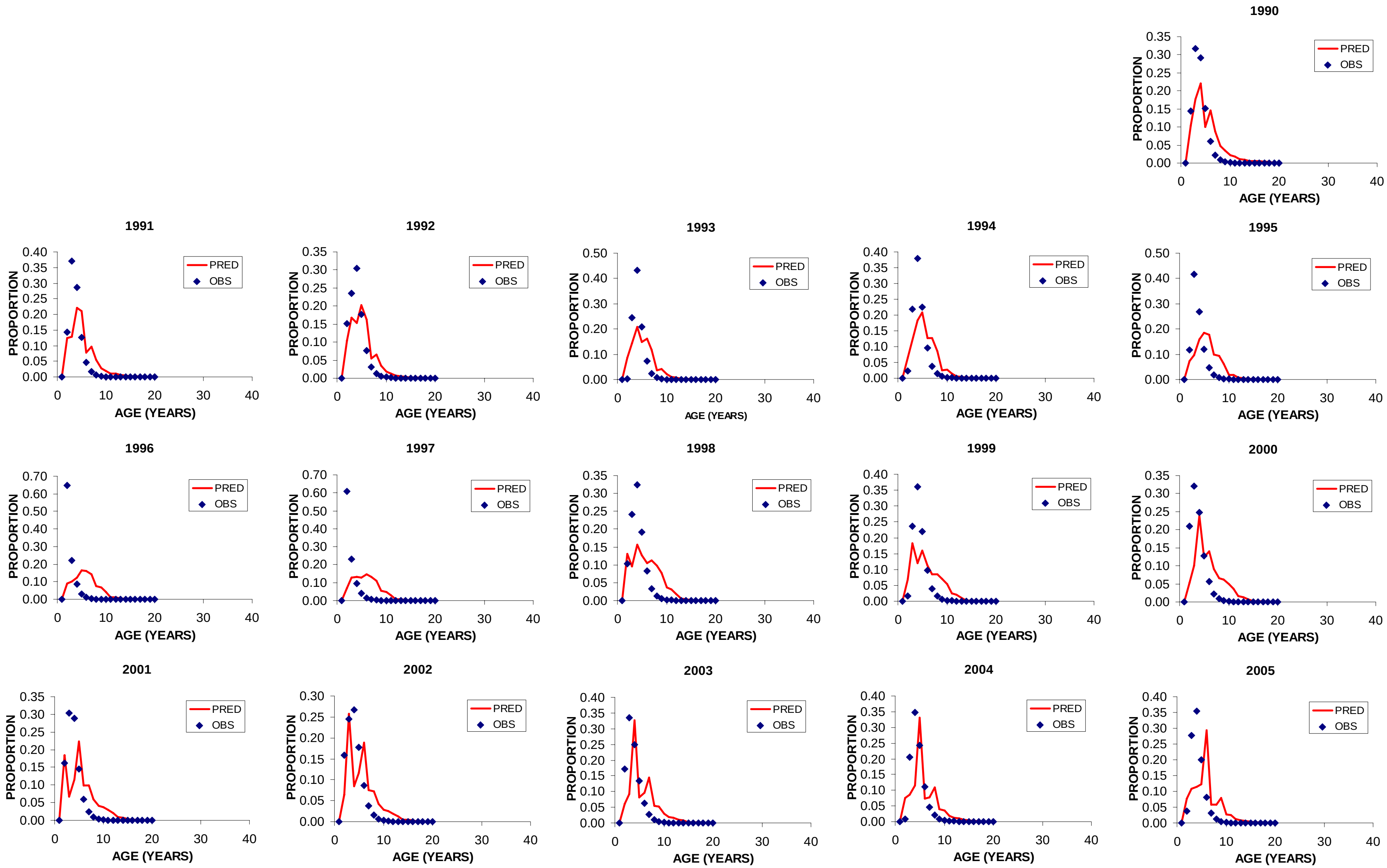


Figure 4.1.5 C. Fits to the modeled discards-at-age for the commercial trap fleet. Note: there are no estimates before 1990.

D) FITS TO DISCARDS-AT-AGE - RECREATIONAL

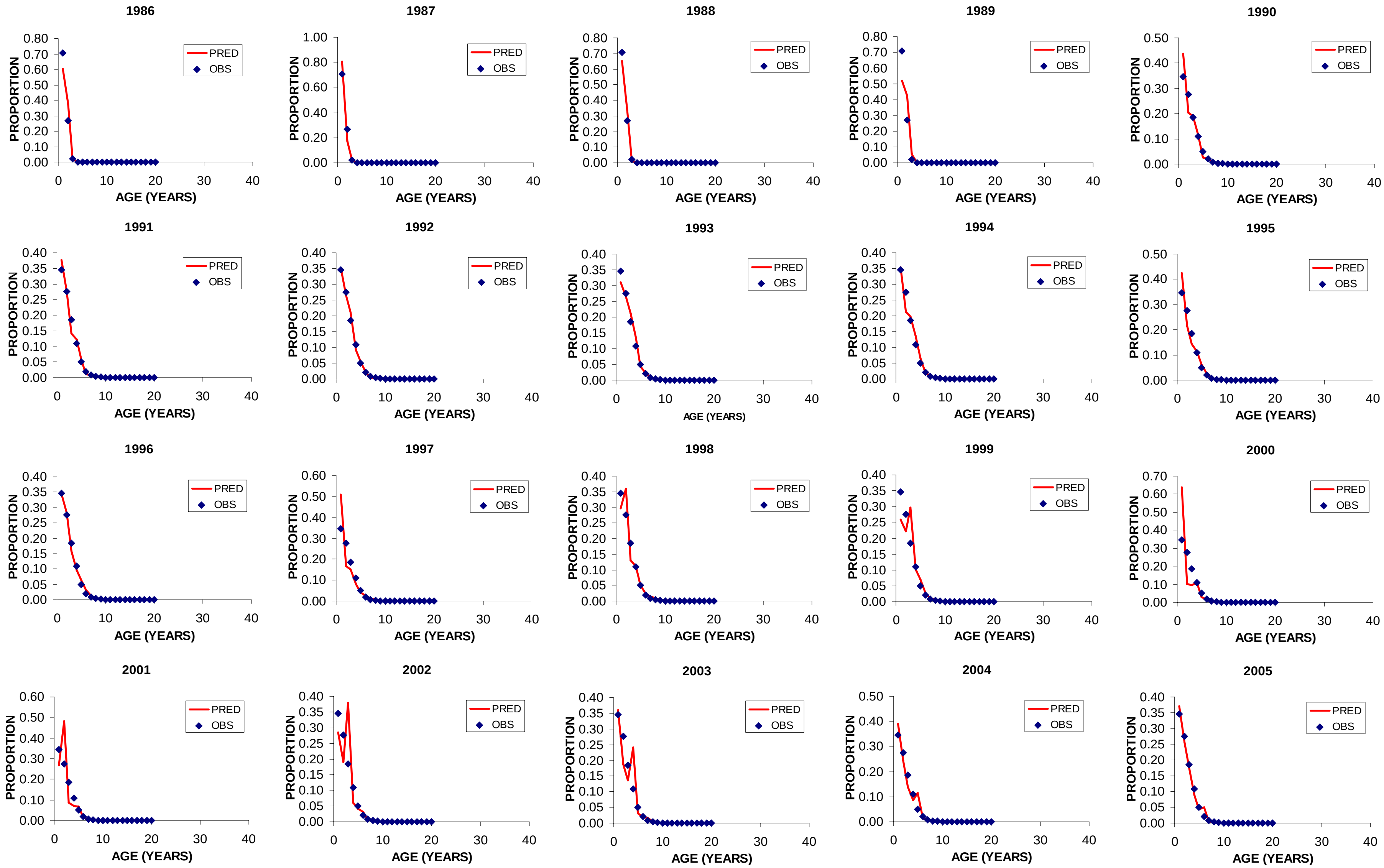


Figure 4.1.5 D. Fits to the modeled discards-at-age for the recreational fleet.

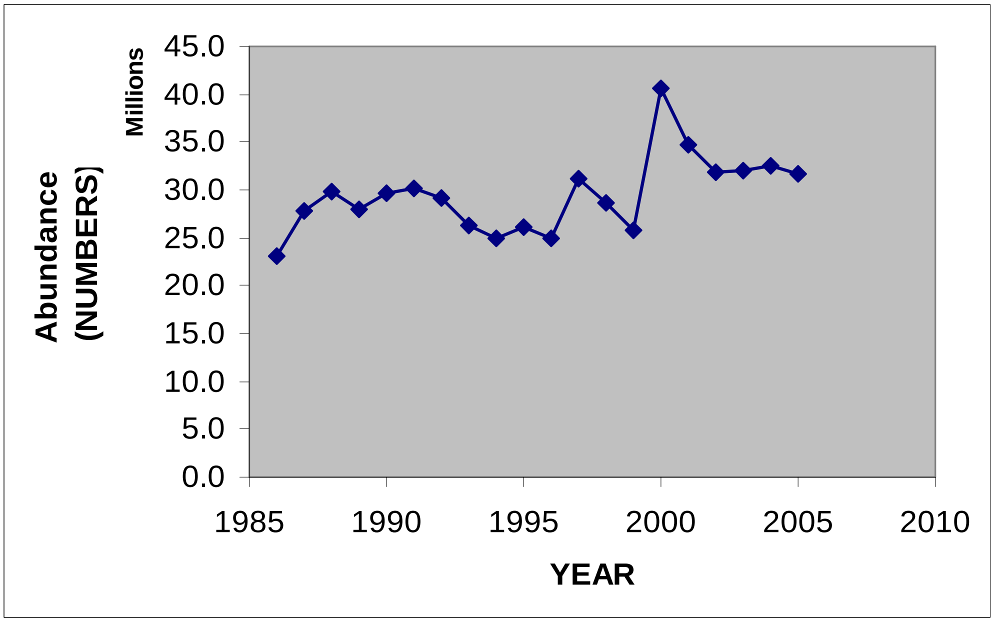


Figure 4.3.1 Annual abundance estimates.

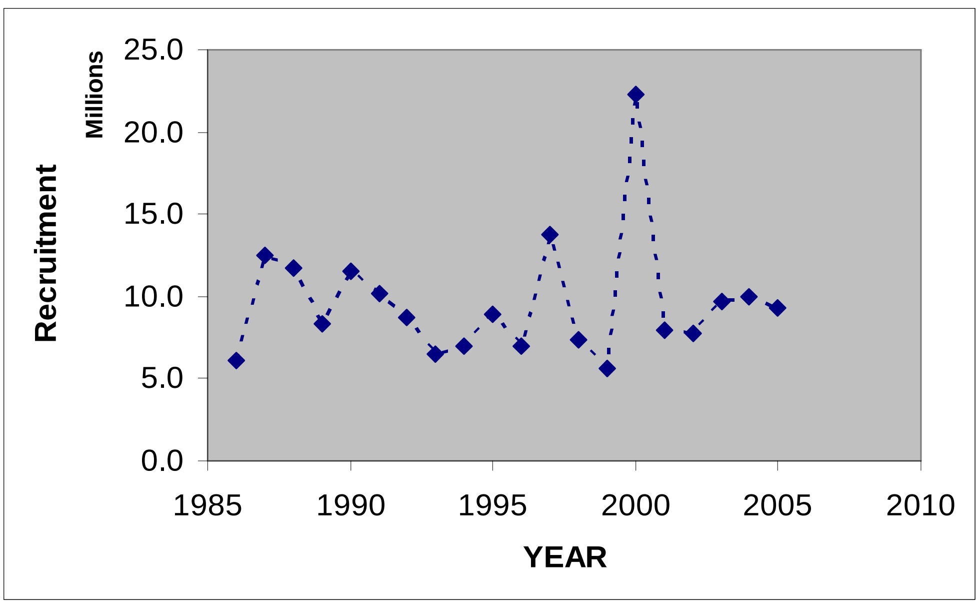


Figure 4.3.2. Annual estimates of recruitment (Age 1). Large year classes occurred in 1996 and 1999.

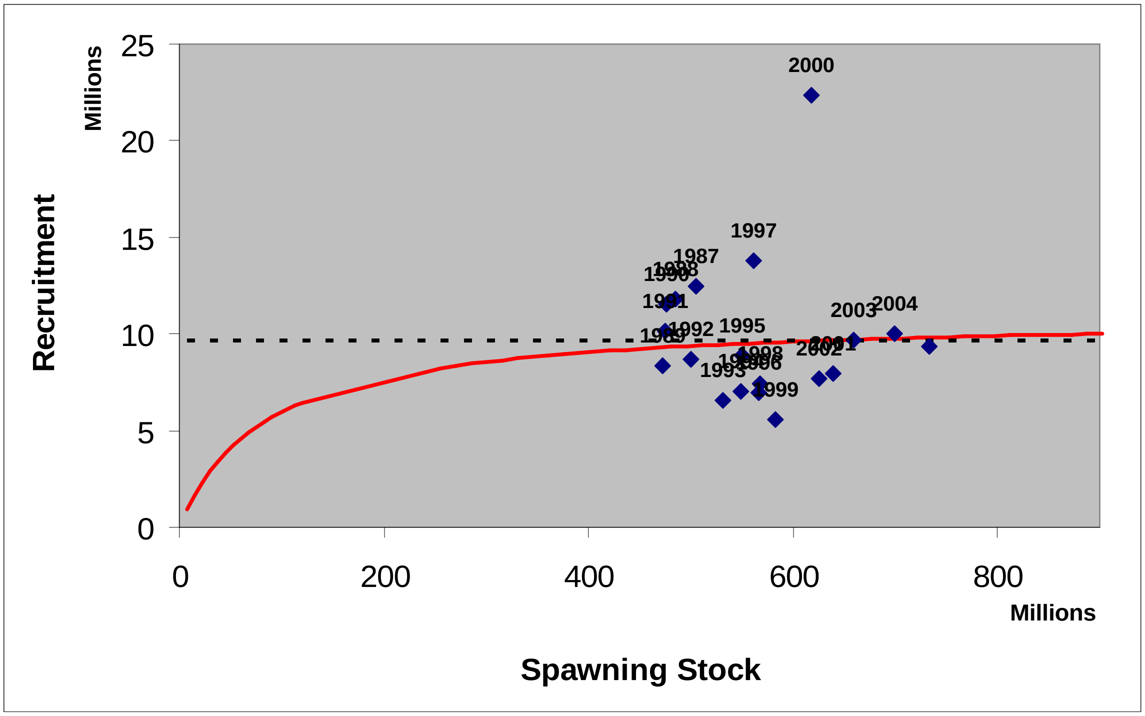


Figure 4.3.3. Beverton and Holt stock recruitment relationship (bias-corrected). The dotted line in the average recruitment (1986-2005).

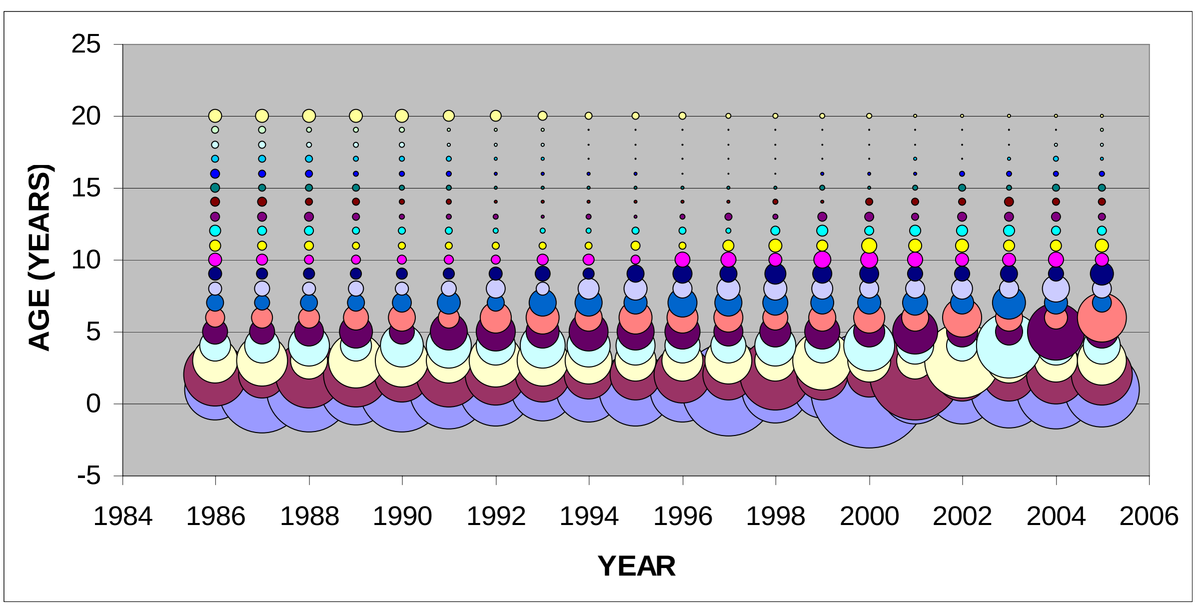
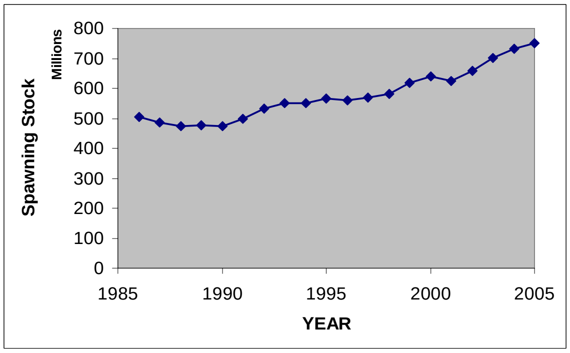
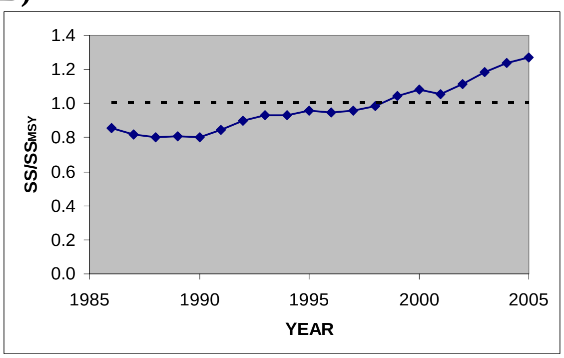


Figure 4.3.4. Number-at-age. The area of the circle is proportional to the number of fish at that age.

A)



B)



C)

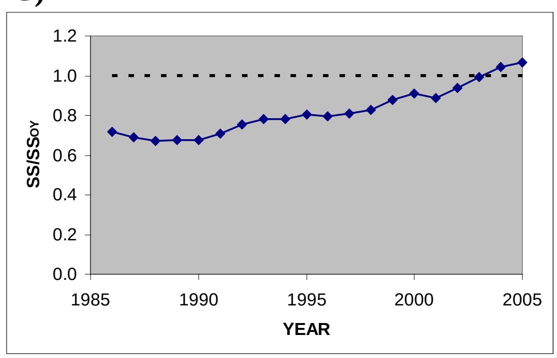


Figure 4.4.1. A) Spawning stock (SS) reproductive potential (grams mature female gonad weight), **B)** SS as a function of SS at maximum sustainable yield (SS_{MSY}) and **C)** optimal yield (SS_{OY})

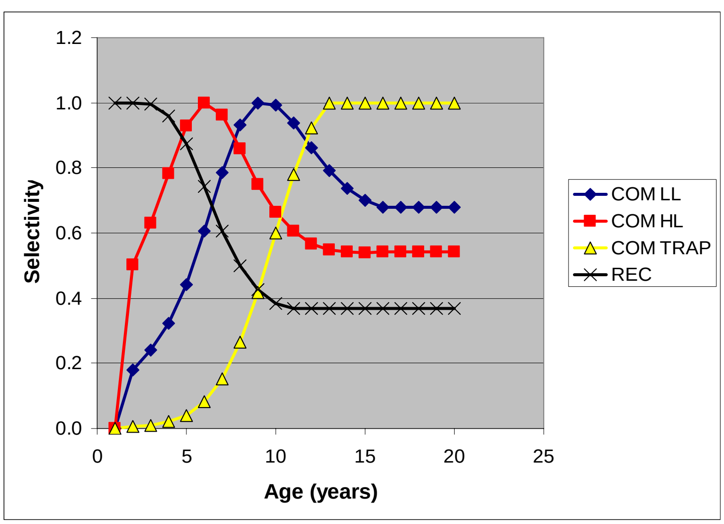


Figure 4.5.1 Selectivity-at-age by fleet. Note: these selectivity vectors apply to the total catch (landed + released).

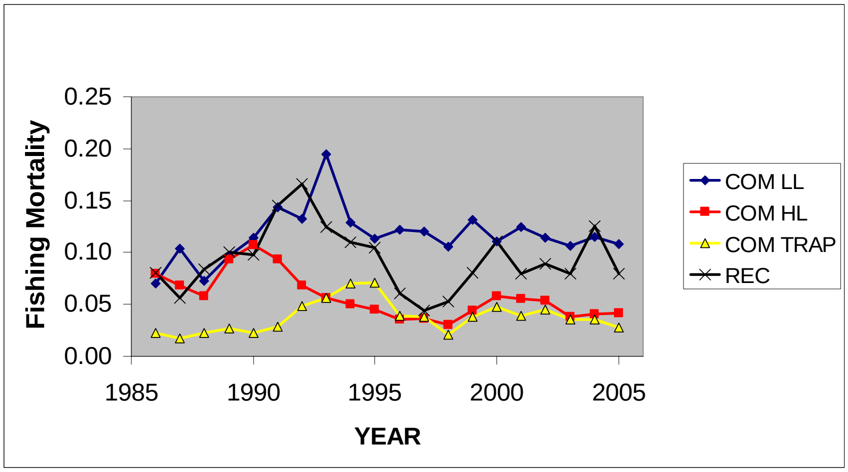
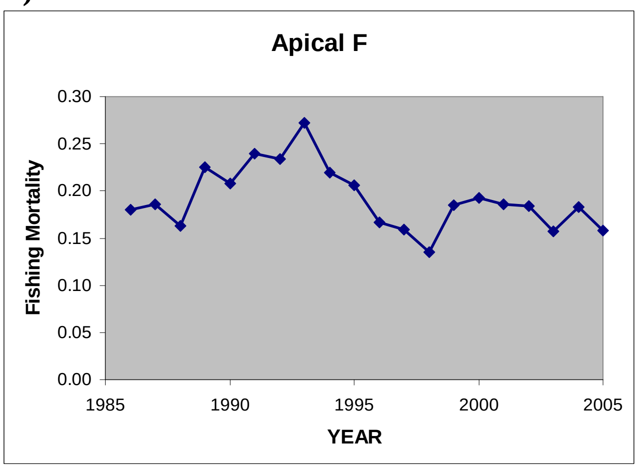
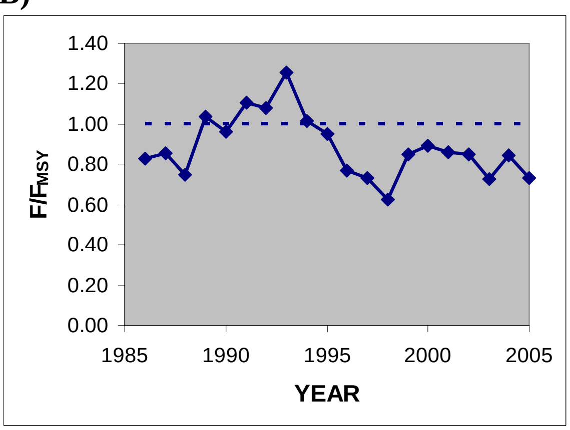


Figure 4.6.1 Fishing mortality (landings + discards) by year and fleet.

A)



B)



C)

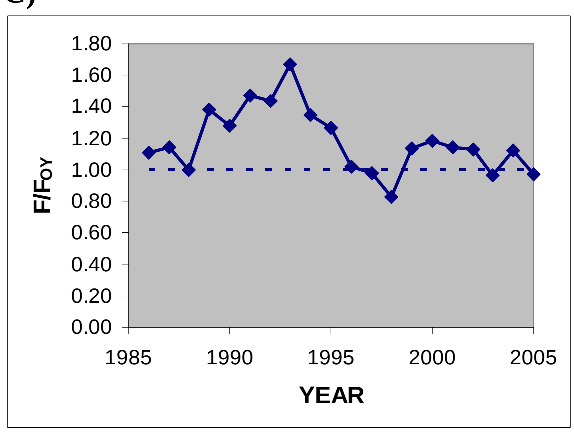


Figure 4.6.2. Annual estimates of total fishing mortality (landings +discards) expressed as **A)** Apical F (maximum annual F at any age), **B)** F as a fraction of F at maximum sustainable yield (F_{MSY}) and **C)** F as a fraction of F at optimal yield (F_{OY}).

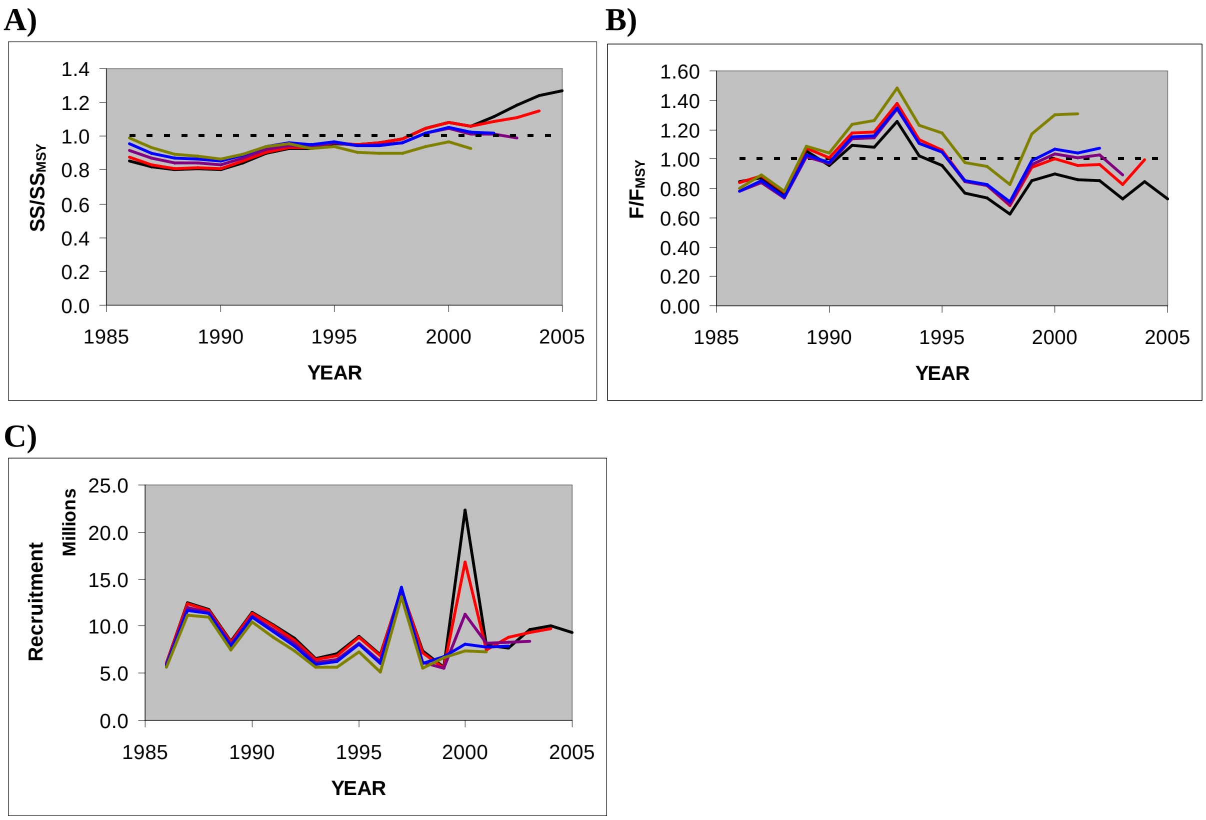


Figure 4.9.1. Results of retrospective analyses. The effect of removing the most recent years of data (2002-2005) on **A)** spawning stock ratio (SS/SS_{MSY}) **B)** fishing mortality ratio (F/F_{MSY}) and **C)** recruitment.

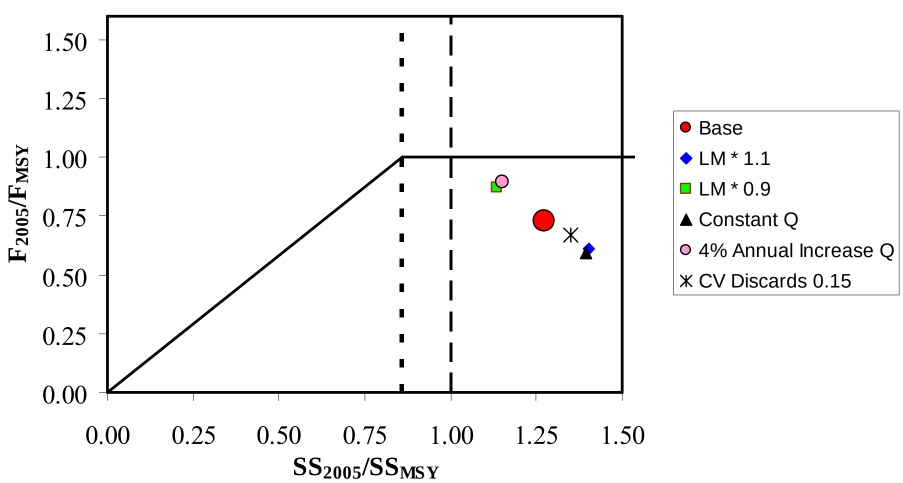


Figure 4.10.1. Control rules plots for the base (large red circle) and sensitivity runs. The SS/SS_{MSY} reference line is at 1-M where M is the natural mortality rate (0.14). Values of $SS/SS_{MSY} < 0.86$ indicate an overfished population. Values of $SS/SS_{MSY} \geq 1.0$ indicate recovery to SS at MSY. The F/F_{MSY} reference line is at 1.0. Values of $F/F_{MSY} > 1.0$ indicate overfishing.

A) B)

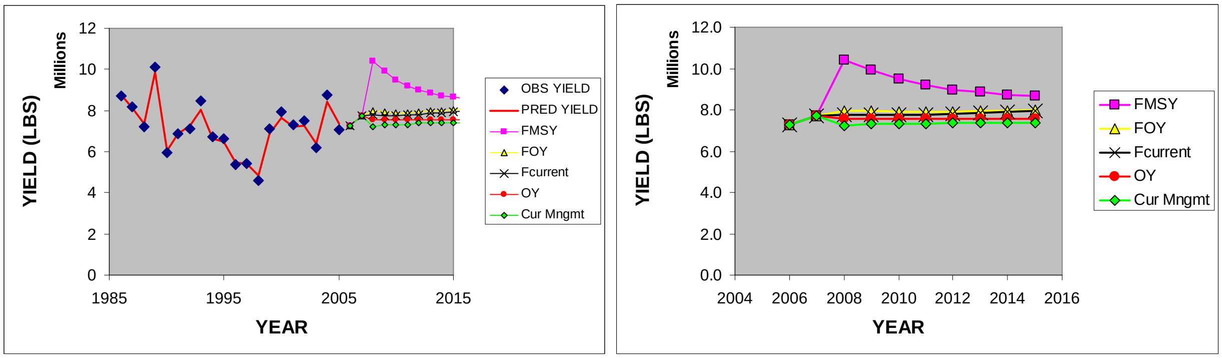


Figure 4.12.1. Yield estimates from the base run and projected yield for the five projections **A)** 1986-2015 and **B)** 2006-2015.

A) B)

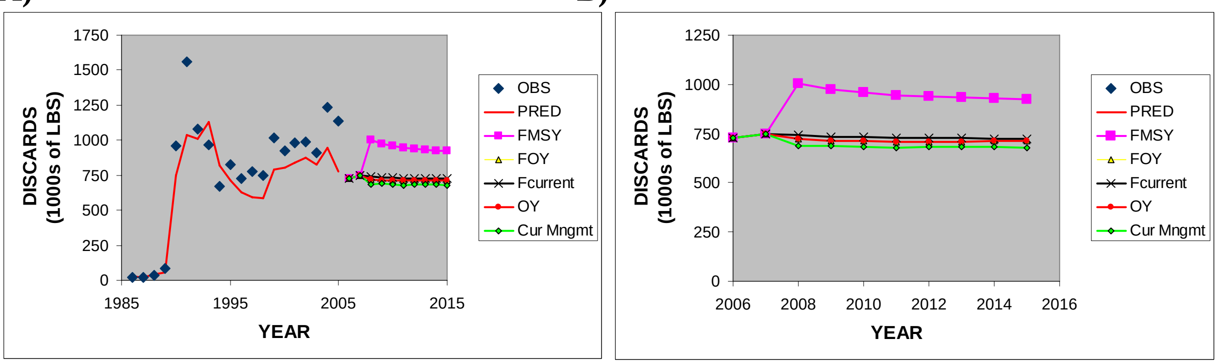


Figure 4.12.2. Discards estimates from the base run and projected yield for the five projections **A)** 1986-2015 and **B)** 2006-2015.

A) B)

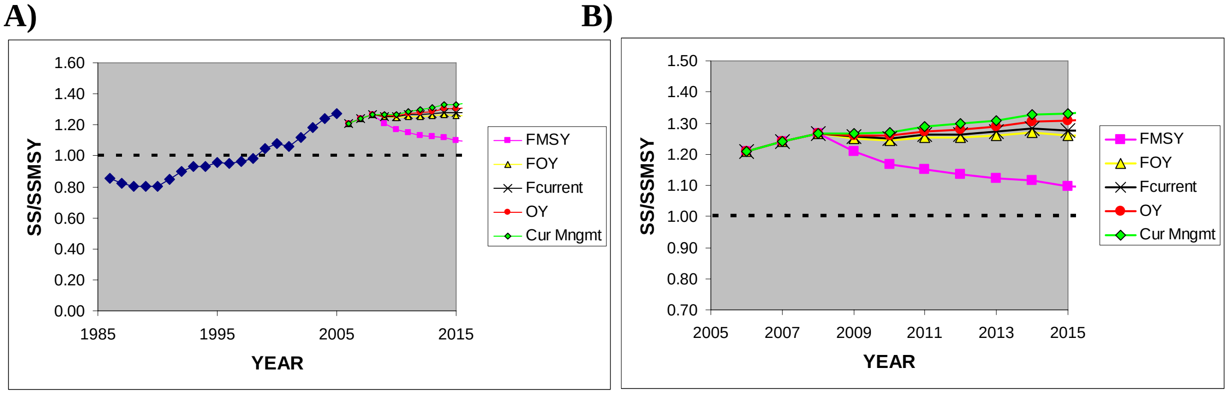


Figure 4.12.3. SS/SS_{MSY} estimates from the base run and for the five projections **A)** 1986-2015 and **B)** 2006-2015.

A) **B)**

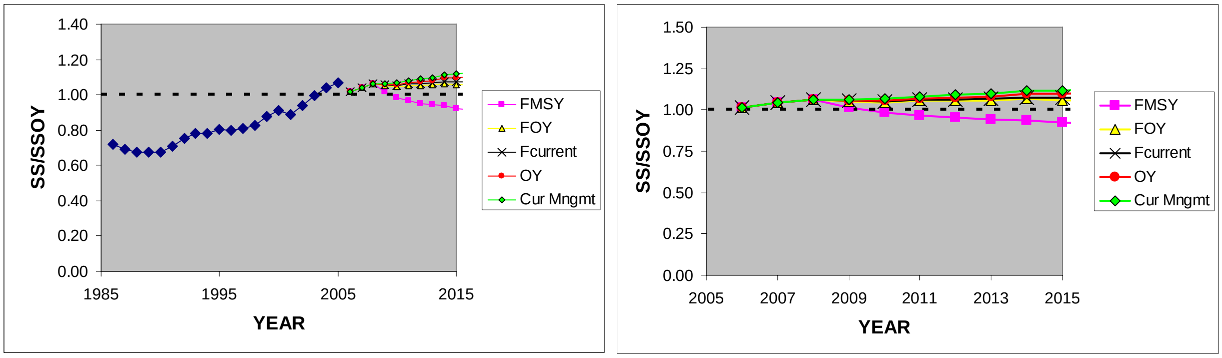


Figure 4.12.4. SS/SS$_{OY}$ estimates from the base run and for the five projections **A)** 1986-2015 and **B)** 2006-2015.

A) **B)**

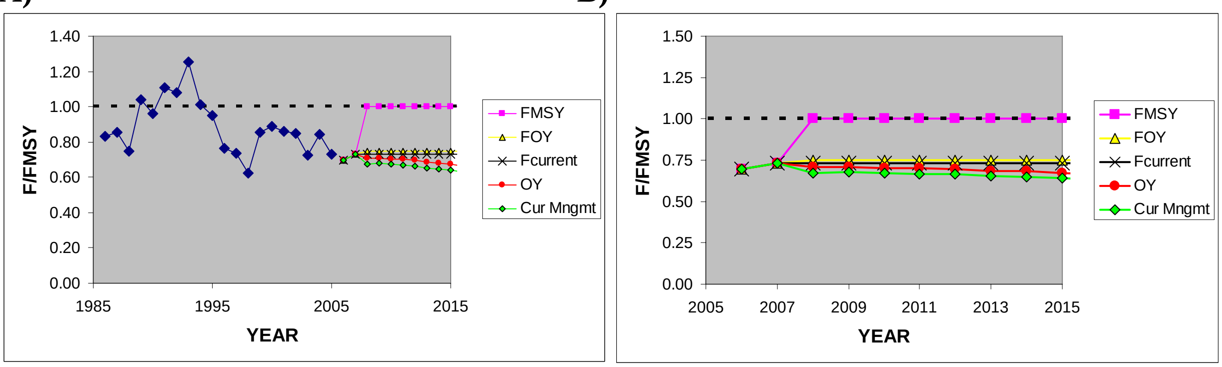


Figure 4.12.5. F/F$_{MSY}$ estimates from the base run and for the five projections **A)** 1986-2015 and **B)** 2006-2015.

A) **B)**

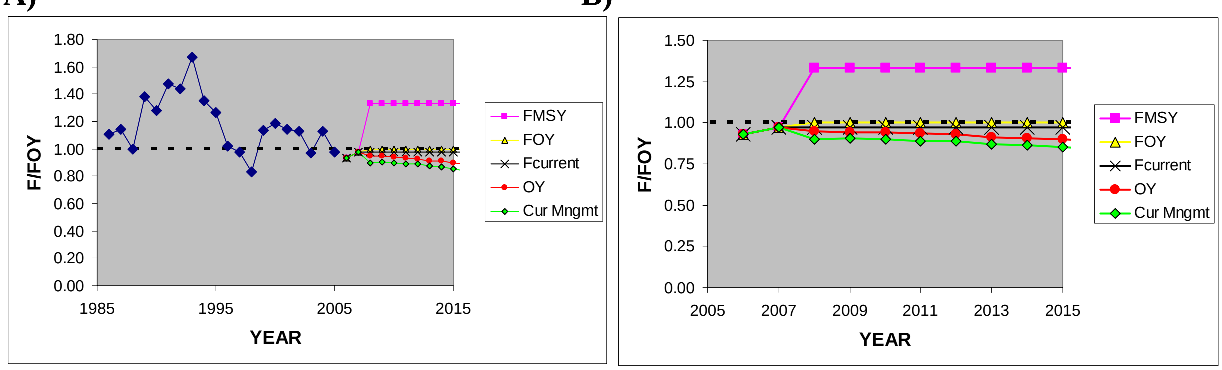


Figure 4.12.6. F/F$_{OY}$ estimates from the base run and for the five projections **A)** 1986-2015 and **B)** 2006-2015.

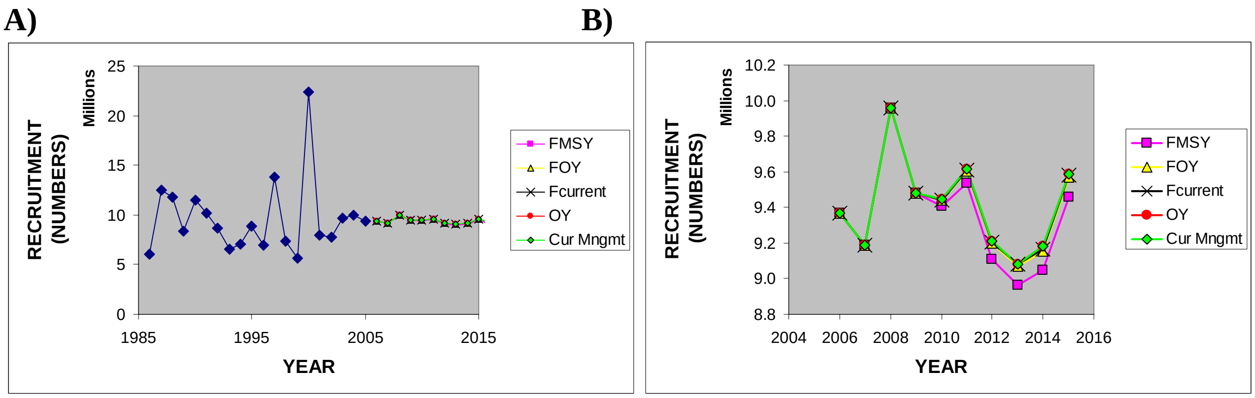


Figure 4.12.7. Recruitment estimates from the base run and for the five projections **A)** 1986-2015 and **B)** 2006-2015.