SEDAR

Southeast Data, Assessment, and Review

SEDAR 88

Stock Assessment Report

Gulf of Mexico Red Grouper

February 2025

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

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SECTION I: Introduction

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Overview

SEDAR 88 addressed the stock assessment for Gulf of Mexico red grouper. The assessment was conducted by the SEFSC. Two Topical Working Groups (TWG) was convened by SEDAR to review and provide recommendations on data and modeling modifications from SEDAR 61. One TWG focused its discussion and age and length composition data and met twice via webinar in October 2023 and March 2024. The second TWG focused on incorporating red tide into the assessment and meet five times: November 2023, January, May and November 2024, and January 2025.

The Stock Assessment Report is organized into 2 sections. Section I – Introduction contains a brief description of the SEDAR Process, Assessment and Management Histories for the species of interest, and the management specifications requested by the Cooperator. Section II is the Assessment Process report. This section details the assessment model, as well as documents any data recommendations that arise for new data sets presented during this assessment process, or changes to data sets used previously.

The final Stock Assessment Report (SAR) for Gulf of Mexico red grouper was disseminated to the public in September 2024. The Council's Scientific and Statistical Committee (SSC) will review the SAR for its stock. The SSCs are tasked with recommending whether the assessments represent Best Available Science, whether the results presented in the SARs are useful for providing management advice and developing fishing level recommendations for the Council. An SSC may request additional analyses be conducted or may use the information provided in the SAR as the basis for their Fishing Level Recommendations (e.g., Overfishing Limit and Acceptable Biological Catch). The Gulf of Mexico Fishery Management Council's SSC will review the assessment at its February 2025 meeting, followed by the Council receiving that information at its April 2025 meeting. Documentation on SSC recommendations is not part of the SEDAR process and is handled through each Council.

1 SEDAR PROCESS DESCRIPTION

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

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

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

2 MANAGEMENT OVERVIEW

2.1 Fishery Management Plans and Amendments

Original GMFMC FMP:

The Reef Fish Fishery Management Plan was implemented in November 1984. The regulations, designed to rebuild declining reef fish stocks, included: (1) prohibitions on the use of fish traps, roller trawls, and powerhead-equipped spear guns within an inshore stressed area; (2) a minimum size limit of 13 inches total length (TL) for red snapper with the exceptions that for- hire boats were exempted until 1987 and each angler could keep 5 undersize fish; and, (3) data reporting requirements.

GMFMC FMP Amendments affecting Red Grouper:

Description of Action	FMP/Amendment	Effective Date
Established a survival rate of biomass into the stock of spawning age fish to achieve at least 20% spawning stock biomass per recruit (SSBR). Set an 11.0 million-pound whole weight commercial quota for groupers, with the commercial quota divided into a 9.2 million pound whole weight shallow-water grouper quota and a 1.8 million-pound whole weight deepwater grouper quota. As a result of a change in the gutted to whole weight conversion ratio (from 1.18 to 1.05), these quotas were subsequently adjusted to 9.8 million pounds whole weight for all groupers, 8.2 million pounds whole weight shallow-water grouper, and 1.6 million pounds whole weight deep-water grouper. 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 shallow-water grouper quota is filled). Deep-water grouper were defined as misty grouper, snowy grouper, yellowedge grouper, warsaw grouper, and scamp once the shallow-water grouper quota is filled. Set a 20 inch total length minimum size limit and a five-grouper recreational daily bag limit. Limited trawl vessels to the recreational size and daily bag limits of reef fish.	Amendment 1	1990

Speckled hind moved from shallow-water grouper to deep-water grouper aggregate. Rebuilding target changed from 20% SSBR to 20% spawning potential ratio (SPR). The time frame to rebuild overfished stocks is specified as 1 ½ generation times.	Amendment 3	1991
Commercial reef fish permit moratorium established for three years	Amendment 4	1992
Fish trap endorsement and three year moratorium established	Amendment 5	1994
Extended commercial reef fish permit moratorium until January 1996	Amendment 9	1994
Commercial reef fish permit moratorium extended until December 30, 2000. Reef fish permit requirement established for headboats and charter vessels.	Amendment 11	1996
10-year phase-out of fish traps in EEZ established (February 7, 1997 – February 7, 2007).	Amendment 14	1997
Commercial reef fish permit moratorium extended until December 31, 2005.	Amendment 17	2000
(1) Prohibits vessels from retaining reef fish caught under recreational bag/possession limits when commercial quantities of Gulf reef fish are aboard, (2) adjusts the maximum crew size on charter vessels that also have a commercial reef fish permit and a USCG certificate of inspection (COI) to allow the minimum crew size specified by the COI when the vessel is fishing commercially for more than 12 hours, (3) prohibits the use of reef fish for bait except for sand perch or dwarf sand perch, and (4) requires electronic VMS aboard vessels with federal reef fish permits, including vessels with both commercial and charter vessel permits (implemented May 6, 2007).	Amendment 18A	2006
Also known as Generic Essential Fish Habitat (EFH) Amendment 2. Established two marine reserves off the Dry Tortugas where fishing for any species and anchoring by fishing vessels is prohibited.	Amendment 19	2002
3-year moratorium on reef fish charter/headboat permits established	Amendment 20	2002, but implementation deferred until June 16, 2003
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.	Amendment 21	2003
Permanent moratorium established for commercial reef fish permits.	Amendment 24	2005

Permanent moratorium established for charter and headboat reef fish permits, with periodic reviews at least every 10 years.	Amendment 25	2006
Addressed the use of non-stainless steel circle hooks when using natural baits to fish for Gulf reef fish effective June 1, 2008, and required the use of venting tools and dehooking devices when participating in the commercial or recreational reef fish fisheries effective June 1, 2008.	Amendment 27	2008
Established an individual fishing quota (IFQ) system for the commercial grouper and tilefish fisheries.	Amendment 29	2010
Sets interim allocations of gag and red grouper catches between recreational and commercial fisheries, and makes adjustments to the red grouper total allowable catch (TAC) to reflect the current status of the stock, which is currently at OY levels. Additionally, the amendment establishes annual catch limits (ACLs) and accountability measures (AMs) for the commercial and recreational red grouper fisheries and commercial aggregate shallow-water fishery. For the commercial sector, the amendment for 2009 reduces the aggregate shallow-water grouper quota from 8.80 mp to 7.8 mp, and increases the red grouper quota from 5.31 mp to 5.75 mp. Repeals the commercial closed season of February 15 to March 15 on gag, black and red grouper, and replaces it with a January through April seasonal area closure to all fishing at the Edges 40 fathom contour, a 390 nautical square mile gag spawning region northwest of Steamboat Lumps. Increases the red grouper recreational bag limit from one fish to two.	Amendment 30B	2009
Established additional restrictions on the use of bottom longline gear in the eastern Gulf of Mexico in order to reduce bycatch of endangered sea turtles, particularly loggerhead sea turtles. (1) Prohibits the use of bottom longline gear shoreward of a line approximating the 35-fathom contour from June through August; (2) reduces the number of longline vessels operating in the fishery through an endorsement provided only to vessel permits with a demonstrated history of landings, on average, of at least 40,000 pounds of reef fish annually with fish traps or longline gear during 1999-2007; and (3) restricts the total number of hooks that may be possessed onboard each reef fish bottom longline vessel to 1,000, only 750 of which may be rigged for fishing. The boundary line was initially moved from 20 to 50 fathoms by emergency rule effective May 18, 2009. That rule was replaced on	Amendment 31	2010

October 16, 2009 by a rule under the Endangered Species Act moving the boundary to 35 fathoms and implementing the maximum hook provisions.		
Set the commercial and recreational gag annual catch limits for 2012 through 2015 and beyond. Set the constant catch commercial red grouper annual catch limit at 6.03 mp and the recreational red grouper annual catch limit at 1.90 mp. Set the commercial and recreational gag annual catch targets for 2012 through 2015 and beyond. Implemented commercial gag quotas for 2012 through 2015 and beyond that included a 14% reduction from the annual catch target to account for additional dead discards of gag resulting from the reduced harvest. Modified grouper IFQ multi-use allocations. Simplified the commercial shallow-water grouper accountability measures by using the individual fishing quota program to reduce redundancy. Added an overage adjustment and in-season measures to the recreational gag and red grouper accountability measures to avoid exceeding the annual catch limit. Added an accountability measure for the red grouper bag limit that would reduce the four red grouper bag limit in the future to three red grouper, and then to two red grouper, if the red grouper recreational annual catch limit is exceeded.	Amendment 32	2012
Revised the post-season recreational accountability measure that reduces the length of the recreational season for all shallow-water grouper in the year following a year in which the ACL for gag or red grouper is exceeded. The modified accountability measure reduces the recreational season of only the species for which the ACL was exceeded. Modified the reef fish framework procedure to include accountability measures to the list of items that can be changed through the standard framework procedure.	Amendment 38	2013
Standardized the minimum stock size threshold for red grouper, equal to 50% of the biomass at maximum sustainable yield.	Amendment 44	2017
Modified the allocation of Gulf red grouper catch between the commercial and recreational sectors; and specified a new overfishing limit and acceptable biological catch. The sector allocation is revised from 76% commercial and 24% recreational, to 59.3% commercial and 40.7% recreational. The recreational annual catch target buffer is revised from 8% to 9%, and the overfishing limit, acceptable biological catch, sector	Amendment 53	2022

annual catch limits, and sector annual catch targets are as indicated in the Amendment.		

2.2 Generic Amendments

Generic Sustainable Fisheries Act Amendment: partially approved and implemented in **November 1999**, set the Maximum Fishing Mortality Threshold (MFMT) for most reef fish stocks at $F_{30\%}$ SPR. Estimates of maximum sustainable yield, Minimum Stock Size Threshold (MSST), and optimum yield were disapproved because they were based on SPR proxies rather than biomass based estimates.

Generic ACL/AM Amendment: Established in-season and post-season accountability measures for all stocks that did not already have such measures defined. This includes the "other shallow-water grouper species" complex. The accountability measure states that if an ACL is exceeded, in subsequent years an in-season accountability measure will be implemented that would close shallow-water grouper fishing (for all shallow-water grouper species combined) when the ACL is reached or projected to be reached.

2.3 Regulatory Amendments

July 1991: Implemented November 12, 1991, provided a one-time increase in the 1991 quota for shallow-water grouper from 9.2 mp ww to 9.9 mp ww to provide the commercial fishery an opportunity to harvest 0.7 MP that was not harvested in 1990 [56 FR 58188].

In 1991, the conversion factor used to convert grouper gutted weight to whole weight was changed from 1.18 to 1.05. Consequently, the base quotas for grouper were changed to 9.8 mp ww (all grouper), 8.2 mp ww (shallow-water grouper), and 1.6 mp ww (deep-water grouper). Since commercially harvested grouper are typically landed in gutted condition, this did not change the actual landings, only the whole weight equivalents.

November 1991: Implemented June 22, 1992, raised the 1992 commercial quota for shallow-water grouper to 9.8 mp ww after a red grouper stock assessment indicated that the red grouper SPR was substantially above the Council's minimum target of 20% [57 FR 21751].

August 1999: Implemented June 19, 2000, increased the commercial size limit for gag and black grouper from 20 to 24 inches TL, increased the recreational size limit for gag from 20 to 22 inches TL, implemented a seasonal closure on commercial harvest and 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) with a 4-year sunset clause that are closed year-round to fishing for all species under the Council's jurisdiction [65 FR 31827].

October 2005: Implemented January 1, 2006, established a 6,000 lb gw aggregate deepwater grouper and shallow-water grouper trip limit for the commercial grouper fishery, replacing the 10,000/7,500/5,500 step-down trip limit that had been implemented by emergency rule for 2005 [70 FR 77057].

March 2006: Implemented July 15, 2006, established a recreational red grouper bag limit of one fish per person per day as part of the five grouper per person aggregate bag limit, and prohibited for-hire vessel captains and crews from retaining bag limits of any grouper while under charter [71 FR 34534]. An additional provision established a recreational closed season for red grouper, gag and black grouper from February 15 to March 15 each year (matching a previously established commercial closed season) beginning with the 2007 season.

September 2010: Implemented January 1, 2011, reduced the total allowable catch for red grouper from 7.57 million pounds gutted weight to 5.68 million pounds gutted weight, based on the optimum yield projection from a March 2010 re-run of the projections from the 2009 red grouper update assessment. Although the stock was found to be neither overfished nor undergoing overfishing, the update assessment found that spawning stock biomass levels had decreased since 2005, apparently due to an episodic mortality even in 2005 which appeared to be related to an extensive red tide that year. Based on the 76%:34% commercial and recreational allocation of red grouper, the commercial quota was reduced from 5.75 to 4.32 million pounds gutted weight, and the recreational allocation was reduced from 1.82 to 1.36 million pounds gutted weight. No changes were made to the recreational fishing regulations as the recreational landings were already below the adjusted allocation in recent years.

August 2011: Increased the 2011 total allowable catch to 6.88 million pounds gutted weight and allowed the total allowable catch to increase from 2012 to 2015. The increases in TAC are contingent upon the TAC not being exceeded in previous years. If TAC is exceeded in a given year, it will remain at that year's level until the effects of the overage are evaluated by the Scientific and Statistical Committee. The amendment also increases the red grouper bag limit to 4 fish per person.

Framework Action - December 2012: Established the 2013 gag recreational fishing season to open on July 1 and remain open until the recreational annual catch target is projected to be taken. Also eliminated the February 1 through March 31 recreational shallow-water grouper closed season shoreward of 20 fathoms (except for gag). However, the closed season remains in effect beyond 20 fathoms to protect spawning aggregations of gag and other species that spawn offshore during that time.

Framework Action – May 2015: Reduced the recreational red grouper bag limit to 2 fish per day within the 4-fish aggregate grouper bag limit. Eliminated the accountability measure that automatically reduced the red grouper bag limit in the subsequent season if the recreational quota is exceeded in the current season. The fixed closed season of February 1 through March 31 in waters beyond the 20-fathom contour (which applies to red, black, scamp, yellowfin, and yellowmouth grouper) remains in place. The 3-fish red grouper bag limit that was implemented in April 2013 was the result of the automatic bag limit reduction accountability measure which is repealed. That bag limit was a temporary measure that expired on December 31, 2014. Consequently, on January 1, 2015, the red grouper bag limit in federal waters temporarily reverted to 4 fish until May 7, 2015, when this Framework Action was implemented.

Framework Action – October 2016: Increased the commercial and recreational allowable harvest for red grouper. The catch limits are as follows: Commercial annual catch limit (ACL) – 8,190,000 pounds, Commercial Quota – 7,780,000 pounds, Recreational ACL – 2,580,000 pounds, Recreational annual catch target (ACT) – 2,370,000 pounds. This final rule is effective October 12, 2016.

Framework Action – October 2019: Reduced the red grouper commercial and recreational annual catch limits and annual catch targets as follows:

Stock ACL	Commercial ACL	Commercial ACT	Recreational ACL	Recreational ACT
4,160,000	3,160,000	3,000,000	1,000,000	920,000

In October 2018, the Council requested an interim rule to reduce annual catch limits by setting them equal to the red grouper landings from 2017, and initiated work on this framework action. The interim rule published in May 2019, temporarily reduced the annual catch limits while this action was developed. This final rule is effective October 31, 2019.

Framework Action – August 2022: Increased the red grouper overfishing limit (OFL), acceptable biological catch (ABC), annual catch limits (ACLs), and annual catch targets (ACTs) in millions of pounds, gutted weight in MRIP-FES data units:

OFL	ABC	Total ACL	Comm ACL	Rec ACL	Comm ACT (Quota)	Rec ACT
5.99	4.96	4.96	2.94	2.02	2.79	1.84

This final rule is effective August 8, 2022.

2.4 Secretarial Amendments

Secretarial Amendment 1: Implemented July 15, 2004. Beginning with this amendment, all grouper TACs, quotas, and other catch levels are expressed in units of gutted weight rather than whole weight to avoid complications from the Accumulated Landings System using a different gutted-to-whole weight conversion factor than the Southeast Fisheries Science Center. Established a rebuilding plan, a 5.31 mp gutted weight (gw) commercial quota, and a 1.25 mp gw recreational target catch level for red grouper. Also reduced the commercial quota for shallow-water grouper from 9.35 to 8.8 mp gw and reduced the commercial quota for deep-water grouper from 1.35 to 1.02 mp gw. The recreational bag limit for red grouper was reduced to two fish per person per day.

2.5 Emergency and Interim Rules

Emergency Rule - Published February 15, 2005: established a series of trip limits for the commercial grouper fishery in order to extend the commercial fishing season. The trip limit was initially set at 10,000 lbs gw. If on or before August 1 the fishery is estimated to have landed more than 50% of either the shallow-water grouper or the red grouper quota, then a 7,500 lb gw trip limit takes effect (*took effect July 9, 2005*); and if on or before October 1 the fishery is estimated to have landed more than 75% of either the shallow-water grouper or the red grouper quota, then a 5,500 lb gw trip limit takes effect (*took effect August 4, 2005*) [70 FR 8037].

Interim Rule - Published July 25, 2005: proposed for the period August 9, 2005 through January 23, 2006, a temporary reduction in the recreational red grouper bag limit from two to one fish per person per day, in the aggregate grouper bag limit from five to three grouper per day, and a closure of the recreational fishery, from November - December 2005, for all grouper species [70 FR 42510]. These measures were proposed in response to an overharvest of the recreational allocation of red grouper under the Secretarial Amendment 1 red grouper rebuilding plan. The closed season was applied to all grouper in order to prevent effort shifting from red grouper to other grouper species and an increased bycatch mortality of incidentally caught red grouper. However, the rule was challenged by organizations representing recreational fishing interests. On October 31, 2005, a U.S. District Court judge ruled that an interim rule to end overfishing can only be applied to the species that is undergoing overfishing. Consequently, the reduction in the aggregate grouper bag limit and the application of the closed season to all grouper were overturned. The reduction in the red grouper bag limit to one per person and the November-December 2005 recreational closed season on red grouper only were allowed to proceed.

The approved measures were subsequently extended through July 22, 2006 by a temporary rule extension published January 19, 2006 [71 FR 3018].

Emergency Rule - Implemented May 18, 2009 through October 28, 2009: Prohibited the use of bottom longline gear to harvest reef fish east of 85°30′ W longitude in the portion of the exclusive economic zone (EEZ) shoreward of the coordinates established to approximate a line following the 50–fathom (91.4–m) contour as long as the 2009 deepwater grouper and tilefish quotas are unfilled. After the quotas have been filled, the use of bottom longline gear to harvest reef fish in water of all depths east of 85°30′ W longitude are prohibited [74 FR 20229].

Emergency Rule - Implemented May 3, 2010 through November 15, 2010: NMFS issued an emergency rule to temporarily close a portion of the Gulf of Mexico EEZ to all fishing [75 FR 24822] in response to an uncontrolled oil spill resulting from the explosion on April 20, 2010 and subsequent sinking of the Deepwater Horizon oil rig approximately 36 nautical miles (41 statute miles) off the Louisiana coast. The initial closed area extended from approximately the mouth of the Mississippi River to south of Pensacola, Florida and covered an area of 6,817 square statute miles. The coordinates of the closed area were subsequently modified periodically in response to changes in the size and location of the area affected by the spill. At its largest size on June 1, 2010, the closed area covered 88,522 square statute miles, or approximately 37 percent of the Gulf of Mexico EEZ. This closure was implemented for public safety.

Interim Rule - Published on December 1, 2010: [75 FR 74654] Reduced gag landings consistent with ending overfishing. This interim rule implemented conservative management measures while a rerun of the update stock assessment was being completed. At issue was the treatment of dead discarded fish in the assessment. The rule reduced the commercial quota to 100,000 pounds gutted weight, suspended the use of red grouper multi-use individual fishing quota allocation so it would not be used to harvest gag, and to temporarily halted the recreational harvest of gag until recreational fishing management measures being developed in Amendment 32 could be implemented to allow harvest at the appropriate levels.

Interim Rule – Effective from June 1, 2011 through November 27, 2011: Set the commercial gag quota at 430,000 pounds gutted weight (including the 100,000 pounds previously allowed) for the 2011 fishing year, and temporarily suspended the use of red grouper multi-use IFQ allocation so it cannot be used to harvest gag. It also set a two-month recreational gag fishing season from September 16 through November 15. This temporary rule can be extended for another 186 days [76 FR 31874].

Interim Rule – Effective from May 5, 2014 through December 31, 2014: Reduced the recreational bag limit for red grouper to three fish per person per day within the four fish per person daily aggregate grouper recreational bag limit [79 FR 24353]. This rule expired and the recreational bag limit for red grouper increased to four fish per person per day on January 1, 2015.

2.6 Management Program Specifications

Table 2.6.1. General Management Information

Species	Red Grouper
Management Unit	Gulf of Mexico
Management Unit Definition	Gulf of Mexico

Management Entity	Gulf of Mexico Fishery Management Council
Management Contacts SERO / Council	Ryan Rindone (GMFMC) Dan Luers (SERO)
Stock exploitation status (from SEDAR 61)	No overfishing
Stock biomass status (from SEDAR 61)	Not overfished

Table 2.6.2. Specific Management Criteria
(Provide details on the management criteria to be estimated in this assessment) Note: mp = million pounds; gw = gutted weight.

Criteria	Current- from SEDAR 61		Proposed	
	Definition	Value	Definition	Value
MSST	MSST = 0.5 *BMSY		Value from the most recent stock assessment based on MSST = 0.5 *BMSY	SEDAR 88
MFMT	F_{MSY} $F_{30\%SPR}$		F_{MSY} or proxy from the most recent stock assessment	SEDAR 88
MSY	Yield @ F_{MSY} $F_{30\%SPR}$		Yield at F_{MSY} , landings and discards, pounds and numbers	SEDAR 88
F_{MSY}	F_{MSY}			SEDAR 88
SSB_{MSY}	SSB @ $F_{30\%SPR}$		Spawning stock biomass (median from probabilistic analysis)	SEDAR 88
F Targets (i.e., F_{OY})	75% of F_{MSY}		75% F_{MSY}	SEDAR 88
Yield at F_{Target} (Equilibrium)	landings and discards, pounds and numbers		landings and discards, pounds and numbers	SEDAR 88
M	Natural Mortality, mean across ages		Natural Mortality, mean across ages	SEDAR 88
Terminal F	Exploitation (2017)		Exploitation (2022)	SEDAR 88
Terminal Biomass[1]	Biomass (2017)		Biomass (2022)	SEDAR 88
Exploitation Status	F/MFMT (2017)		F/MFMT (2022)	SEDAR 88
Biomass Status[1]	B/MSST (2017) B/B_{MSY} (2017)		B/MSST (2022) B/B_{MSY} (2022)	SEDAR 88
Generation Time				SEDAR 88
$T_{Rebuild}$ (if appropriate)	2032	-		SEDAR 88

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

Table 2.6.3. General projection information.
(This provides the basic information necessary to bridge the gap between the terminal year of the assessment and the year in which any changes may take place or specific alternative exploitation rates should be evaluated, and guidance for the information managers required from the projection analyses.)

Requested Information	Value
First Year of Management	2025 Fishing Year
Interim basis	- ACL, if ACL is met - Average exploitation, if ACL is not met
Projection Outputs	By stock and fishing year
Landings	pounds and numbers
Discards	pounds and numbers
Exploitation	F & Probability F>MFMT
Biomass (total or SSB, as appropriate)	SSB & Probability SSB>MSST (and Prob. SSB>B_{MSY} if under rebuilding plan)
Recruits	Number

Table 2.6.4. Base Run Projections Specifications. Long Term and Equilibrium conditions.

Criteria	Definition	If overfished	if overfishing	Not overfished, no overfishing
Projection Span	Years	$T_{Rebuild}$	10	10
Projection Values	$F_{Current}$	X	X	X
	F_{MSY} (proxy)	X	X	X
	75% F_{MSY}	X	X	X
	$F_{Rebuild}$	X		
	F=0	X		

NOTE: Exploitation rates for projections may be based on point estimates from the base run or the median of such values from evaluation of uncertainty. The objective is for projections to be based on the same criteria as the management specifications.

Table 2.6.5. P-Star Projections. Short term specifications for OFL and ABC recommendations. Additional P-star projections may be requested by the SSC once the ABC control rule is applied.

Criteria		Overfished	Not overfished
Projection Span	Years	10	10
Probability Values	50%	Probability of stock rebuild	Probability of overfishing
	27.5%[1]		

The following should be provided regardless of whether the stock is healthy or overfished:

- OFL: yield at F_{MSY} (or $F_{30\% SPR}$ proxy)
- OY: yield at 90% of MSY
- Equilibrium MSY and equilibrium OY

If the stock is overfished, the following should also be provided:

- $F_{REBUILD}$ and the yield at $F_{REBUILD}$ (where the rebuilding time frame is 10 years)
- A probability distribution function (PDF) that can be used along with the P* selected by the SSC to determine ABC. If multiple model runs are provided, this may need to wait until the SSC selects which model run to use for management.

The SSC typically recommends OFL and ABC yield streams for 3-5 years out. Yield streams provided by assessment scientists should go beyond five years. If a 10-year rebuilding plan is needed, yield streams should be provided for 10 years.

Table 2.6.6. Quota Calculation Details

Note: mp = million pounds; gw = gutted weight.

Current ACL Value (2023)	4.96 mp gw
Next Scheduled Quota Change	none
Annual or averaged quota?	Annual
Does the quota include bycatch/discard?	A+B1

Quotas are conditioned upon exploitation. Bycatch/discard estimates are considered in setting the quota; however, quota values are for landed fish only.

2.7 Federal Management and Regulatory Timelines for Red Grouper

Harvest Restrictions: Trip Limits (Trip limits do not apply during closures: if season is closed, then trip limit is 0)

First Yr In Effect	Last Yr In Effect	Effective Date	End Date	Fishery	Bag Limit Per Person/Day	Trip Limit Per Boat/Day	Region Affected	FRReference	FR Section	Amendment Number or Rule Type
2005	2005	3/3/05	6/8/05	Com	NA	10,000 lbs gw; DWG[1] & SWG[2]	Gulf of Mexico EEZ	70 FR 8037	622.44	Emergency Rule
2005	2005	6/9/05	8/3/05	Com	NA	7,500 lbs gw; DWG[1] & SWG[2]	Gulf of Mexico EEZ	70 FR 33033	622.44	Temporary Rule
2005	2005	8/4/05	12/31/05	Com	NA	5,500 lbs gw; SWG[2]	Gulf of Mexico EEZ	70 FR 42279	622.44	Temporary Rule
2006	2009	1/1/06	12/31/09	Com	NA	6,000 lbs gw; DWG[1] & SWG[2]	Gulf of Mexico EEZ	70 FR 77057	622.44	Reef Fish Regulatory Amendment
2010	Ongoing	1/1/10	Ongoing	Com	NA	IFQ	Gulf of Mexico EEZ	74 FR 44732	622.2	Reef Fish Amendment 29
1990	2004	4/23/90	7/14/04	Rec	5 grouper aggregate	NA	Gulf of Mexico EEZ	55 FR 2078	641.24	Reef Fish Amendment 1
2004	2005	7/15/04	8/8/05	Rec	2 per person within 5 grouper aggregate	NA	Gulf of Mexico EEZ	69 FR 33315	622.39	Secretarial Amendment 1
2005	2006	8/9/05	1/23/06	Rec	1 per person within 3 grouper aggregate	NA	Gulf of Mexico EEZ	70 FR 42510	622.39	Temporary Rule
2006	2009	1/24/06	5/17/09	Rec	1 per person within 5 grouper aggregate	NA	Gulf of Mexico EEZ	71 FR 3018 71 FR 34534	622.39	Temporary Rule Reef Fish Regulatory Amendment
2009	2011	5/18/09	11/1/11	Rec	2 per person within 4 grouper aggregate	NA	Gulf of Mexico EEZ	74 FR 17603	622.39	Reef Fish Amendment 30B
2011	2014	11/2/11	5/4/14	Rec	4 per person within 4 grouper aggregate	NA	Gulf of Mexico EEZ	76 FR 67618	622.39	Reef Fish Regulatory Amendment
2014	2014	5/5/14	12/31/14	Rec	3 per person within 4 grouper aggregate	NA	Gulf of Mexico EEZ	79 FR 24353	622.41	Temporary Rule
2015	2015	1/1/15	5/6/15	Rec	4 per person within 4 grouper aggregate	NA	Gulf of Mexico EEZ	79 FR 24353	622.38	Temporary Rule Expired
2015	Ongoing	5/7/15	Ongoing	Rec	2 per person within 4 grouper aggregate	NA	Gulf of Mexico EEZ	80 FR 18552	622.38	Reef Fish Framework Action

[1]DWG: deep-water grouper (misty grouper, snowy grouper, yellowedge grouper, warsaw grouper, and speckled hind)

[2]SWG: shallow-water grouper (black, gag, red, red hind, rock hind, scamp, yellowfin, and yellowmouth)

Harvest Restrictions: Size Limits (Size limits do not apply during closures)

First Yr In Effect	Last Yr In Effect	Effective Date	End Date	Fishery	Size Limit	Length Type	Region Affected	FR Reference	FR Section	Amendment Number or Rule Type
1990	2009	2/21/90	5/17/09	Com	20"	Minimum TL	Gulf of Mexico EEZ	55 FR 2078	641.21	Reef Fish Amendment 1
1990	Ongoing	2/21/90	Ongoing	Rec	20"	Minimum TL	Gulf of Mexico EEZ	55 FR 2078	641.21	Reef Fish Amendment 1
2009	Ongoing	5/18/09	Ongoing	Com	18"	Minimum TL	Gulf of Mexico EEZ	74 FR 17603	622.37	Reef Fish Amendment 30B

Harvest Restrictions: Fishery Closures (*Area specific regulations are documented under spatial restrictions)

First Yr In Effect	Last Year in Effect	Effective Date	End Date	Fishery	Closure Type	First Day Closed	Last Day Closed	Region Affected	FR Reference	FR Section	Amendment Number or Rule Type	Species Associated with Closure
2001	2009	6/19/00	12/31/09	Com	Seasonal	15-Feb	14-Mar[1]	Gulf of Mexico EEZ	65 FR 31827 74 FR 44732	622.34 622.2	Reef Fish Regulatory Amendment Reef Fish Amendment 29	Black, Red and Gag
2004	2004	11/15/04	12/31/04	Com	Quota	15-Nov	31-Dec	Gulf of Mexico EEZ	69 FR 65092	622.43	Notice of Closure	SWG: Black, Red, Gag, Scamp, Yellowfin, Rock Hind, Red Hind, and Yellowmouth
2005	2005	10/10/05	12/31/05	Com	Quota	10-Oct	31-Dec	Gulf of Mexico EEZ	70 FR 57802	622.43	Temporary Rule	SWG: Black, Red, Gag, Scamp, Yellowfin, Rock Hind, Red Hind, and Yellowmouth
2005	2005	8/9/05	1/23/06	Rec	Seasonal	1-Nov	31-Dec	Gulf of Mexico EEZ	70 FR 42510	622.34	Temporary Rule	Groupers
2007	2009	12/18/06	5/17/09	Rec	Seasonal	15-Feb	14-Mar[1]	Gulf of Mexico EEZ	71 FR 66878	622.34	Reef Fish Regulatory Amendment	Black, Red and Gag
2010	2013	5/18/09	7/4/13	Rec	Seasonal	1-Feb	31-Mar	Gulf of Mexico EEZ	74 FR 17603	622.34	Reef Fish Amendment 30B	SWG: Black, Red, Gag, Scamp, Yellowfin, Rock Hind, Red Hind, and Yellowmouth
2014	Ongong	7/5/13	Ongoing	Rec	Seasonal	1-Feb	31-Mar	Gulf of Mexico EEZ seaward of 20 fathoms	78 FR 33259	622.34	Reef Fish Framework Action	SWG: Black, Red, Gag, Yellowfin and Yellowmouth
2014	2014	9/16/14	12/31/14	Rec	Quota	4-Oct	31-Dec	Gulf of Mexico EEZ	79 FR 54668	622.41	Temporary Rule	Red Grouper
2015	2015	10/8/15	12/31/15	Rec	Quota	8-Oct	31-Dec	Gulf of Mexico EEZ	80 FR 59665	622.41	Temporary Rule	Red Grouper

[1]According to Fishery Bulletins, the 15-Feb to 15-Mar closures ended at 12:01 am 14-Mar, as such the last day closed is effectively 14-Mar (FB02-001, FB03-005, FB04-005, FB05-001, FB06-002, FB07-06, FB08-004, FB09-005)

Harvest Restrictions (Spatial Restrictions)

Area	First Yr In Effect	Effective Date	End Date	Fishery	First Day Closed	Last Day Closed	Restriction in Area	FR Reference	Amendment Number or Rule Type	FR Section	Amendment Number or Rule Type
Gulf of Mexico Stressed Areas	1984	11/8/84	Ongoing	Both	Year round		Prohibited powerheads for Reef FMP	49 FR 39548	Original Reef Fish FMP	641.7	Original Reef Fish FMP
	1984	11/8/84	Ongoing	Both	Year round		Prohibited pots and traps for Reef FMP	49 FR 39548	Original Reef Fish FMP	641.7	Original Reef Fish FMP
Alabama Special Management Zones	1994	2/7/94	Ongoing	Both	Year round		Allow only hook-and line gear with three or less hooks per line and spearfishing gear for fish in Reef FMP	59 FR 966	Reef Fish Amendment 5	641.23	Reef Fish Amendment 5
EEZ, inside 50 fathoms west of Cape San Blas, FL	1990	2/21/90	Ongoing	Both	Year round		Prohibited longline and buoy gear for Reef FMP	55 FR 2078	Reef Fish Amendment 1	641.7	Reef Fish Amendment 1
EEZ, inside 20 fathoms east of Cape San Blas, FL	1990	2/21/90	Ongoing	Both	Year round		Prohibited longline and buoy gear for Reef FMP	55 FR 2078	Reef Fish Amendment 1	NA	Reef Fish Amendment 1
EEZ, inside 50 fathoms east of Cape San Blas, FL	2009	5/18/09	10/15/09	Both	18-May	28-Oct	Prohibited bottom longline for Reef FMP	74 FR 20229	Emergency Rule	622.34	Emergency Rule
EEZ, inside 35 fathoms east of Cape San Blas, FL	2009	10/16/09	5/25/10	Both	Year round		Prohibited bottom longline for Reef FMP	74 FR 53889	Sea Turtle ESA Rule	223.206	Sea Turtle ESA Rule
	2010	5/26/10	Ongoing	Rec	Year round		Prohibited bottom longline for Reef FMP	75 FR 21512	Reef Fish Amendment 31	622.34	Reef Fish Amendment 31
	2010	5/26/10	Ongoing	Com	1-Jun	31-Aug	Prohibited bottom longline for Reef FMP	75 FR 21512	Reef Fish Amendment 31	622.34	Reef Fish Amendment 31
Madison-Swanson	2000	6/19/00	6/2/04	Both	Year round		Fishing prohibited except HMS[1]	65 FR 31827	Reef Fish Regulatory Amendment	622.34	Reef Fish Regulatory Amendment
	2004	6/3/04	8/19/21	Both	1-May	31-Oct	Fishing prohibited except surface trolling	70 FR 24532 74 FR 17603	Reef Fish Amendment 21 Reef Fish Amendment 30B	622.34 NA	Reef Fish Amendment 21 Reef Fish Amendment 30B
	2004	6/3/04	8/19/21	Both	1-Nov	30-Apr	Fishing prohibited	70 FR 24532 74 FR 17603	Reef Fish Amendment 21 Reef Fish Amendment 30B	622.34 NA	Reef Fish Amendment 21 Reef Fish Amendment 30B
	2021	8/20/21	Ongoing	Both	Year round		Fishing prohibited	86 FR 38416	RF Framework Action	622.34	Reef Fish Regulatory Amendment
Steamboat Lumps	2000	6/19/00	6/2/04	Both	Year round		Fishing prohibited except HMS[1]	65 FR 31827	Reef Fish Regulatory Amendment	622.34 NA	Reef Fish Amendment 21 Reef Fish Amendment 30B
	2004	6/3/04	Ongoing	Both	1-May	31-Oct	Fishing prohibited except surface trolling	70 FR 24532 74 FR 17603	Reef Fish Amendment 21 Reef Fish Amendment 30B	622.34 NA	Reef Fish Amendment 21 Reef Fish Amendment 30B
	2004	6/3/04	Ongoing	Both	1-Nov	30-Apr	Fishing prohibited	70 FR 24532 74 FR 17603	Reef Fish Amendment 21 Reef Fish Amendment 30B	622.34	Reef Fish Amendment 30B Supplement
	2021	8/20/21	Ongoing	Both	Year round		Fishing prohibited	86 FR 38416	RF Framework Action	622.34	Reef Fish Framework Action
The Edges	2010	7/24/09	Ongoing	Both	1-Jan	30-Apr	Fishing prohibited	74 FR 30001	Reef Fish Amendment 30B Supplement	934 622.34	Sanctuary Designation Essential Fish Habitat Amendment 3
20 Fathom Break	2014	7/5/13	Ongoing	Rec	1-Feb	31-Mar	Fishing for SWG prohibited[2]	78 FR 33259	Reef Fish Framework Action	641.23	Reef Fish Amendment 5
Flower Garden	1992	1/17/92	Ongoing	Both	Year round		Fishing with bottom gears prohibited[3]	56 FR 63634	Sanctuary Designation	635.71 622.34	Tortugas Amendment Essential Fish Habitat Amendment 3
Riley's Hump	1994	2/7/94	8/18/02	Both	1-May	30-Jun	Fishing prohibited	59 FR 966	Reef Fish Amendment 5	622.34	Essential Fish Habitat Amendment 3
Tortugas Reserves	2002	8/19/02	Ongoing	Both	Year round		Fishing prohibited	67 FR 47467	Tortugas Amendment	622.34	Essential Fish Habitat Amendment 3
Pulley Ridge	2006	1/23/06	Ongoing	Both	Year round		Fishing with bottom gears prohibited[3]	70 FR 76216	Essential Fish Habitat (EFH) Amendment 3	622.34	Essential Fish Habitat Amendment 3
McGrail Bank	2006	1/23/06	Ongoing	Both	Year round		Fishing with bottom gears prohibited[3]	70 FR 76216	Essential Fish Habitat (EFH) Amendment 3	622.34	Essential Fish Habitat Amendment 3
Stetson Bank	2006	1/23/06	Ongoing	Both	Year round		Fishing with bottom gears prohibited[3]	70 FR 76216	Essential Fish Habitat (EFH) Amendment 3	622.34	Essential Fish Habitat Amendment 3

[1]HMS: highly migratory species (tuna species, marlin, oceanic sharks, sailfishes, and swordfish)

[2]SWG: shallow-water grouper (black, gag, red, red hind, rock hind, scamp, yellowfin, and yellowmouth)

[3]Bottom gears: Bottom longline, bottom trawl, buoy gear, pot, or trap

Harvest Restrictions (Gear Restrictions*)
*Area specific gear regulations are documented under spatial restictions

Gear Type	First Yr In Effect	Last Yr In Effect	Effective Date	End Date	Gear/Harvesting Restrictions	Region Affected	FR Reference	FR Section	Amendment Number or Rule Type
Poison	1984	Ongoing	11/8/84	Ongoing	Prohibited for Reef FMP	Gulf of Mexico EEZ	49 FR 39548	641.24	Original Reef Fish FMP
Explosives	1984	Ongoing	11/8/84	Ongoing	Prohibited for Reef FMP	Gulf of Mexico EEZ	49 FR 39548	641.24	Original Reef Fish FMP
Pots and Traps	1984	1994	11/23/84	2/6/94	Established fish trap permit	Gulf of Mexico EEZ	49 FR 39548	641.4	Original Reef Fish FMP
	1984	1990	11/23/84	2/20/90	Set max number of traps fish by a vessel at 200	Gulf of Mexico EEZ	49 FR 39548	641.25	Original Reef Fish FMP
	1990	1994	2/21/90	2/6/94	Set max number of traps fish by a vessel at 100	Gulf of Mexico EEZ	55 FR 2078	641.22	Reef Fish Amendment 1
	1994	1997	2/7/94	2/7/97	Moratorium on additional commercial trap permits	Gulf of Mexico EEZ	59 FR 966	641.4	Reef Fish Amendment 5
	1997	2007	3/25/97	2/7/07	Phase out of fish traps begins	Gulf of Mexico EEZ	62 FR 13983	622.4	Reef Fish Amendment 14
	1997	2007	1/29/88	2/7/07	Prohibited harvest of reef fish from traps other than permited reef fish, stone crab, or spiny lobster traps.	Gulf of Mexico EEZ	62 FR 67714	622.39	Reef Fish Amendment 15
	2007	Ongoing	2/8/07	Ongoing	Traps prohibited	Gulf of Mexico EEZ	62 FR 13983	622.31	Reef Fish Amendment 14
All	1992	1995	5/8/92	12/31/95	Moratorium on commercial permits for Reef FMP	Gulf of Mexico EEZ	59 FR 11914 59 FR 39301	641.4 641.4	Reef Fish Amendment 4 Reef Fish Amendment 9
	1994	Ongoing	2/7/94	Ongoing	Finfish must have head and fins intact through landing, can be eviscerated, gilled, and scaled but must otherwise be whole (HMS and bait exceptions)	Gulf of Mexico EEZ	59 FR 966	641.21	Reef Fish Amendment 5
	1996	2005	7/1/96	12/31/05	Moratorium on commercial permits for Gulf reef fish	Gulf of Mexico EEZ	61 FR 34930 65 FR 41016	622.4 622.4	Interim Rule Reef Fish Amendment 17
	2006	Ongoing	9/8/06	Ongoing	Use of Gulf reef fish as bait prohibited[1]	Gulf of Mexico EEZ	71 FR 45428	622.31	Reef Fish Amendment 18A
Vertical Line	2008	Ongoing	6/1/08	Ongoing	Requires non-stainless steel circle hooks and dehooking devices	Gulf of Mexico EEZ	74 FR 5117	322.41	Reef Fish Amendment 27
	2008	2013	6/1/08	9/3/13	Requires venting tools	Gulf of Mexico EEZ	74 FR 5117 78 FR 46820	322.41 NA	Reef Fish Amendment 27 Framework Action
Bottom Longline	2010	Ongoing	5/26/10	Ongoing	Limited to 1,000 hooks of which no more than 750 hooks are rigged for fishing or fished	Gulf of Mexico EEZ	75 FR 21512	622.34	Reef Fish Amendment 31

[1]Except when, purchased from a fish processor, filleted carcasses may be used as bait crab and lobster traps.

Quota History - Commercial:

First Yr In Effect	Last YR In Effect	Effective Date	End Date	Species Affected	Quota	ACL	Units	Region Affected	FR Reference	FR Section	Amendment Number or Rule Type
1990	1991	2/21/1990	12/31/1991	All Groupers Excluding DWG[1] and Goliath	9.2		mp ww	Gulf of Mexico EEZ	55FR 2078	641.25	Reef Fish Amendment 1
1992	2003	6/22/1992	12/31/2003	All Groupers Including Scamp Excluding DWG[1] and Goliath	9.8		mp ww	Gulf of Mexico EEZ	57 FR 21752	641.25	Reef Fish Regulatory Amendment
2004	2008	7/15/2004	12/31/2008	All Groupers Including Scamp Excluding DWG[1], Goliath, and Nassau	8.8		mp gw	Gulf of Mexico EEZ	69 FR 33315	622.42	Secretarial Amendment 1
2009	2009	5/18/2009	12/31/2009	SWG[2]	7.48		mp gw	Gulf of Mexico EEZ	74 FR 17603	622.42	Reef Fish Amendment 30B
2010	2010	5/18/2009	12/31/2010	SWG[2]	7.57		mp gw	Gulf of Mexico EEZ	74 FR 17603	622.42	Reef Fish Amendment 30B
2011	2011	11/2/2011	12/31/2011	SWG[2]	6.07		mp gw	Gulf of Mexico EEZ	76 FR 67618	622.42	Reef Fish Regulatory Amendment
2012	2012	3/12/2012	12/31/2012	SWG[2]	6.347	8.04	mp gw	Gulf of Mexico EEZ	77 FR 6988	622.49	Reef Fish Amendment 32
2013	2013	3/12/2012	12/31/2013	SWG[2]	6.648	8.04	mp gw	Gulf of Mexico EEZ	77 FR 6988	622.49	Reef Fish Amendment 32
2014	2014	1/7/2015	12/31/2014	Other SWG[3]	0.523	0.545	mp gw	Gulf of Mexico EEZ	79 FR 72556	622.39	Reef Fish Framework Action
2015	Ongoing	1/7/2015	Ongoing	Other SWG[3]	0.525	0.547	mp gw	Gulf of Mexico EEZ	79 FR 72556	622.39	Reef Fish Framework Action
2004	2008	7/15/2004	12/31/2008	Red Grouper	5.31		mp gw	Gulf of Mexico EEZ	69 FR 33315	622.42	Secretarial Amendment 1
2009	2010	5/18/2009	12/31/2010	Red Grouper	5.75	5.87	mp gw	Gulf of Mexico EEZ	74 FR 17603	622.49	Reef Fish Amendment 30B
2011	2011	1/1/2011	11/1/2011	Red Grouper	4.32		mp gw	Gulf of Mexico EEZ	75 FR 74656	622.42	Reef Fish Regulatory Amendment
2011	2011	11/2/2011	12/31/2011	Red Grouper	5.23		mp gw	Gulf of Mexico EEZ	76 FR 67618	622.42	Reef Fish Regulatory Amendment
2012	2012	11/2/2011	12/31/2012	Red Grouper	5.37		mp gw	Gulf of Mexico EEZ	76 FR 67618	622.42	Reef Fish Regulatory Amendment
2012	2015	3/12/2012	12/31/2015	Red Grouper		6.03	mp gw	Gulf of Mexico EEZ	77 FR 6988	622.49	Reef Fish Amendment 32
2013	2013	11/2/2011	12/31/2013	Red Grouper	5.53		mp gw	Gulf of Mexico EEZ	76 FR 67618	622.42	Reef Fish Regulatory Amendment
2014	2014	11/2/2011	12/31/2014	Red Grouper	5.63		mp gw	Gulf of Mexico EEZ	76 FR 67618	622.42	Reef Fish Regulatory Amendment
2015	2015	11/2/2011	12/31/2015	Red Grouper	5.72		mp gw	Gulf of Mexico EEZ	76 FR 67618	622.42	Reef Fish Regulatory Amendment
2016	2016	10/12/2016	12/31/2016	Red Grouper	7.78	8.19	mp gw	Gulf of Mexico EEZ	81 FR 70365	622.41	Reef Fish Framework Action
2017	2017	1/1/2017	12/31/2017	Red Grouper	7.78	8.19	mp gw	Gulf of Mexico EEZ			
2018	2018	1/1/2018	12/31/2018	Red Grouper	7.78	8.19	mp gw	Gulf of Mexico EEZ			
2019	2019	1/1/2019	10/30/2019	Red Grouper	7.78	8.19	mp gw	Gulf of Mexico EEZ			
2019	2019	10/31/2019	12/31/2019	Red Grouper	3	3.16	mp gw	Gulf of Mexico EEZ			
2020	2020	1/1/2020	12/31/2020	Red Grouper	3	3.16	mp gw	Gulf of Mexico EEZ			
2021	2021	1/1/2021	12/31/2021	Red Grouper	3	3.16	mp gw	Gulf of Mexico EEZ			
2022	2022	1/1/2022	5/31/2022	Red Grouper	3	3.16	mp gw	Gulf of Mexico EEZ			
2022	2022	6/1/22	8/7/22	Red Grouper	2.4	2.53	mp gw	Gulf of Mexico EEZ			
2022	2022	8/8/2022	12/31/2022	Red Grouper	2.79	2.94	mp gw	Gulf of Mexico EEZ			
2023	2023	1/1/2023	12/31/2023	Red Grouper	2.79	2.94	mp gw	Gulf of Mexico EEZ			

[1]DWG: deep-water grouper (misty grouper, snowy grouper, yellowedge grouper, warsaw grouper)

[2]SWG: shallow-water grouper (black, gag, red, red hind, rock hind, scamp, yellowfin, and yellowmouth)

[3]Other SWG: other shallow-water grouper (black grouper, scamp, yellowmouth grouper, yellowfin grouper)

Quota History - Recreational:

First Yr In Effect	Last YR In Effect	Effective Date	End Date	ACL	ACT	Units	Region Affected	FR Reference	FR Section	Amendment Number or Rule Type
2009	2010	5/18/09	12/31/10	1.85	1.02	mp gw	Gulf of Mexico EEZ	74 FR 17603	622.49	Reef Fish Amendment 30B
2011	2011	11/2/11	12/31/11		1.65	mp gw	Gulf of Mexico EEZ	76 FR 67618		Reef Fish Regulatory Amendment
2012	2015	3/12/12	12/31/15	1.9	1.73	mp gw	Gulf of Mexico EEZ	77 FR 6988	622.49	Reef Fish Amendment 32
2016	2016	10/12/16	12/31/16	2.58	2.37	mp gw	Gulf of Mexico EEZ	81 FR 70365	622.41	Reef Fish Framework Action
2017	2017	1/1/2017	12/31/2017	2.58	2.37	mp gw	Gulf of Mexico EEZ			
2018	2018	1/1/2018	12/31/2018	2.58	2.37	mp gw	Gulf of Mexico EEZ			
2019	2019	1/1/2019	10/30/2019	2.58	2.37	mp gw	Gulf of Mexico EEZ			
2019	2019	10/31/2019	12/31/2019	1	0.92	mp gw	Gulf of Mexico EEZ			
2020	2020	1/1/2020	12/31/2020	1	0.92	mp gw	Gulf of Mexico EEZ			
2021	2021	1/1/2021	12/31/2021	1	0.92	mp gw	Gulf of Mexico EEZ			
2022	2022	1/1/2022	5/31/2022	1	0.92	mp gw	Gulf of Mexico EEZ			
2022	2022	6/1/22	8/7/22	1.73	1.57	mp gw	Gulf of Mexico EEZ			
2022	2022	8/8/2022	12/31/2022	2.02	1.84	mp gw	Gulf of Mexico EEZ			
2023	2023	1/1/2023	12/31/2023	2.02	1.84	mp gw	Gulf of Mexico EEZ			

3 ASSESSMENT HISTORY AND REVIEW

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 Scientific and Statistical 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 mid 1960'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 that 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 the 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.

In 2006, red grouper was assessed under the umbrella of the SEDAR process (SEDAR 2006). Two models were considered. The first was a model configured using the age-structured assessment program (ASAP, Legault and Restrepo 1998) and the second was a production model. The production model was ultimately rejected due to a lack of convergence; therefore, the ASAP model was used to evaluate stock status and provide management advice. The assessment time-series started in 1986 and ended in 2005. The age-structure of the population was assumed to start with age-1 recruits and the terminal age bin, age-20, represented a plus group. The main data inputs for the ASAP model included indices of abundance (commercial handline, commercial longline, MRFSS recreational, headboat survey (1986 – 1990, 18” TL size limit), headboat survey (1990 – 2005, 20” TL size limit), and SEAMAP video survey), catch-at-age, discards-at-age, catch in weight, and discards in weight. The catchabilities of the fishery-dependent indices were assumed to increase by 2% annually. Catch-at-age and discards-at-age were modeled using the Goodyear approach (Goodyear 1997). The results of the 2006 stock assessment indicated that the stock was not overfished ($SSB/SSB_{MSY} = 1.27$) and was not experiencing overfishing ($F/F_{MSY} = 0.73$).

The 2006 assessment was revisited in 2009 as an update assessment. The update assessment time-series started in 1986 and was extended by three years, ending in 2008. The basic model structure and data inputs were similar to the 2006 assessment. The main difference in the data inputs was the inclusion of observed discard lengths from the recreational (2005-2007) and commercial longline and handline fleets (2006-2008) that were converted to ages. The 2006 model was changed to include an episodic red tide mortality event in 2005 and no longer assumed an annually increasing catchability in the fishery-dependent indices. The results of the update assessment indicated that the stock was not overfished in 2008 and was not experiencing overfishing.

The SEDAR 42 benchmark assessment (SEDAR 2015) transitioned modeling environments from ASAP to Stock Synthesis (SS v. 3.24). After comparisons between modeling platforms (SS and ASAP) revealed similar results and management advice, Stock Synthesis was used to develop the base model through a terminal year of 2013. During the SEDAR 42 process, substantial discussion surrounded the treatment of the recreational fishery, the modeling of fecundity and hermaphroditism, the start year of the model, abundance indices recommended for use, estimation of commercial discards, and benchmarks. Ultimately, the base model recommended for use included substantial modifications included a start year of 1993 which coincided with the majority of informative data including composition and indices, the use of batch fecundity instead of gonad weight, a single continuous headboat index spanning 1986-2013 as opposed to two split indices, addition of fishery independent indices of abundance derived from the SEAMAP groundfish survey (notably for juvenile red grouper), NMFS bottom longline survey, and the combined video survey (incorporating SEAMAP, FWRI, and PC surveys), revised procedures for estimating commercial discards which resulted in much larger estimated discards, inclusion of length composition from fishery-independent surveys, and the treatment of red tide as a discard-only fishing fleet as opposed to episodic natural mortality. The SEDAR 42 benchmark assessment indicated that the stock was not overfished (SSB/MSST = 1.382) and was not experiencing overfishing (F/MFMT = 0.593), results of which were accepted by the GMFMC SSC.

The SEDAR 61standard assessment (SEDAR 2019) used Stock Synthesis (version 3.30) to develop a base model through a terminal year of 2017. During the SEDAR 61 Data Workshop and Assessment Workshop processes, several modifications were made to the base model developed during SEDAR 42. Significant changes were made to data inputs using new recommended methodologies. These included: recreational data inputs using revised MRIP data (landings, discards, CPUE and age composition), updating observed discards for the commercial vertical line and longline fisheries, an updated index of relative abundance and associated length composition for the Combined Video Survey combining the three video surveys, and finally, age and size composition sample sizes inputted as the square root of observed sample sizes rather than arbitrary caps. Additional data collection led to updates for data inputs including von Bertalanffy growth parameters, natural mortality, and the fecundity-at-age vector. New data inputs included an index of relative abundance and size composition from the FWRI Hook and Line Repetitive Time Drop Survey, which covered key Red Grouper habitat and provided information on size composition in the latter years of the assessment.

Other major changes to the assessment model included: 1.) starting the model in 1986 instead of 1993 to take advantage of the longest period of highly reliable landings, 2.) reconfiguring the red tide pseudo-fishing fleet to operate solely in years with severe events, 3.) using size-based selectivity for the fishing fleets rather than age-based selectivity, 4.) revising parameterization of retention, and 5.) implementing the Francis method for iterative reweighting of composition data.

The SEDAR61 Base Model indicated that the Gulf of Mexico Red Grouper stock, based on the definitions of MSST (0.5*SSBSPR30%) and MFMT, was not overfished and overfishing was not occurring (SSB2017 / MSSTNEW = 1.64; FCURRENT / MFMT = 0.784). An important caveat to these results was that under a previous definition of MSST ([1 – M]*SSBSPR30%,) the Red Grouper resource would have been considered overfished in 2017 (SSB2017 / MSSTOLD = 0.96). Based on the updated definition for MSST (0.5*SSBSPR30%) the Red Grouper stock has not been overfished at any point in the time series and the stock was undergoing overfishing in the late 1980's.

References

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. Undated. Red grouper mean size at age: an evaluation of sampling strategies using simulated data. Unpublished manuscript, Southeast Fisheries Science Center, Miami, FL. 8 pp.

Goodyear C. P. 1995. Mean size at age: An evaluation of sampling strategies with simulated red grouper data. Transactions of the American Fisheries Society 124: 746-755.

Legault, C. M., Restrepo, V.R. 1999. A flexible forward age-structured assessment program. ICCAT Coll. Vol. Sci. Pap. 49(2): 246-253.

SEDAR. 2006. SEDAR stock assessment report: Gulf of Mexico Red Grouper. SEDAR, Charleston, SC. SEDAR 12-SAR1.

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.

SEDAR. 2009. Stock assessment of red grouper in the Gulf of Mexico – SEDAR update assessment. SEDAR, Charleston, SC.

SEDAR. 2015. Stock assessment of red grouper in the Gulf of Mexico – SEDAR 42. SEDAR, Charleston, SC.

SEDAR. 2019. Stock assessment of red grouper in the Gulf of Mexico – SEDAR 61. SEDAR, Charleston, SC.

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.

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 REGIONAL MAPS

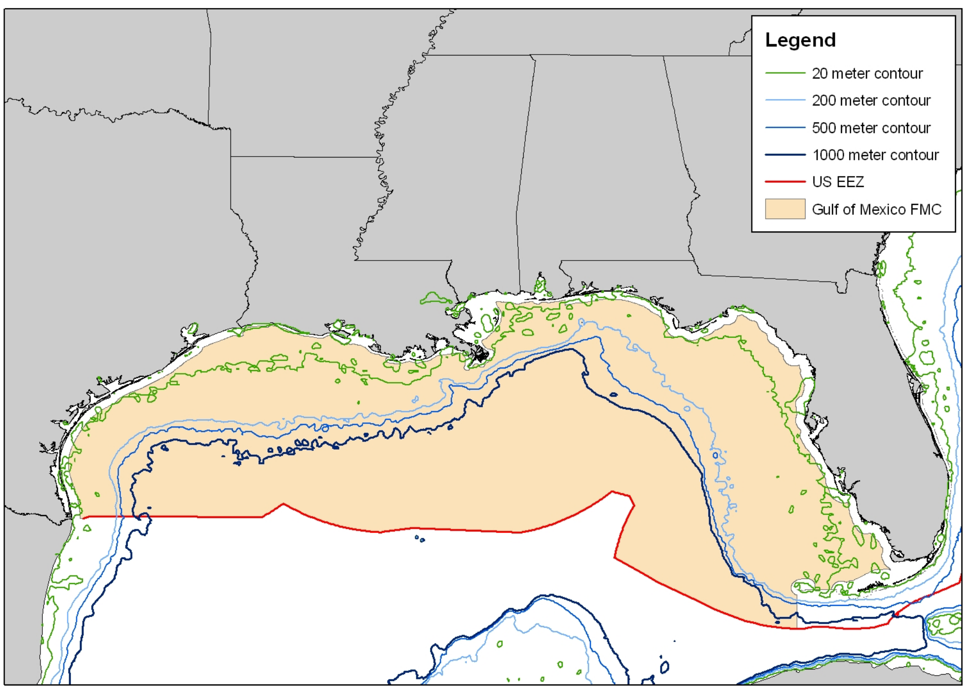


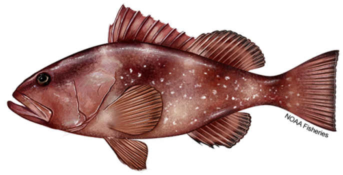
Figure 4.1 Gulf of Mexico Region including Council and EEZ Boundaries.

5 SEDAR ABBREVIATIONS

ABC	Acceptable Biological Catch
ACCSP	Atlantic Coastal Cooperative Statistics Program
ADMB	AD Model Builder (software program)
ALS	Accumulated Landings System: SEFSC fisheries data collection program

AMRD	Alabama Marine Resources Division
APAIS	Access Point Angler Intercept Survey
ASMFC	Atlantic States Marine Fisheries Commission
B	Biomass (stock) level
BAM	Beaufort Assessment Model
B_{msy}	B capable of producing MSY on a continuing basis
BSIA	Best Scientific Information Available
CHTS	Coastal Household Telephone Survey
CFMC	Caribbean Fishery Management Council
CIE	Center for Independent Experts
CPUE	Catch Per Unit Effort
EEZ	Exclusive Economic Zone
F	Fishing mortality (instantaneous)
FES	Fishing Effort Survey
FIN	Fisheries Information Network
F_{MSY}	F to produce MSY under equilibrium conditions
F_{OY}	F rate to produce OY under equilibrium
$F_{XX\%\ SPR}$	F rate resulting in retaining XX% of the maximum spawning production under equilibrium conditions
F_{max}	F maximizing the average weight yield per fish recruited to the fishery
F_o	F close to, but slightly less than, Fmax
FL FWCC	Florida Fish and Wildlife Conservation Commission
FWRI	Florida Fish and Wildlife Research Institute
GA DNR	Georgia Department of Natural Resources
GLM	General Linear Model
GMFMC	Gulf of Mexico Fishery Management Council
GSMFC	Gulf States Marine Fisheries Commission
GULF FIN	GSMFC Fisheries Information Network
HMS	Highly Migratory Species
LDWF	Louisiana Department of Wildlife and Fisheries
M	natural mortality (instantaneous)
MARFIN	Marine Fisheries Initiative
MARMAP	Marine Resources Monitoring, Assessment, and Prediction
MDMR	Mississippi Department of Marine Resources
MFMT	Maximum Fishing Mortality Threshold: value of F above which overfishing is deemed to be occurring
MRFSS	Marine Recreational Fisheries Statistics Survey: combines a telephone survey of households to estimate number of trips with creel surveys to estimate catch and effort per trip
MRIP	Marine Recreational Information Program

MSA	Magnuson Stevens Act
MSST	Minimum Stock Size Threshold: value of B below which the stock is deemed to be overfished
MSY	Maximum Sustainable Yield
NC DMF	North Carolina Division of Marine Fisheries
NMFS	National Marine Fisheries Service
NOAA	National Oceanographic and Atmospheric Administration
OST	Office of Science and Technology, NOAA
OY	Optimum Yield
SAFMC	South Atlantic Fishery Management Council
SC DNR	South Carolina Department of Natural Resources
SEAMAP	Southeast Area Monitoring and Assessment Program
SEDAR	Southeast Data, Assessment and Review
SEFIS	Southeast Fishery-Independent Survey
SEFSC	Southeast Fisheries Science Center, NMFS
SERFS	Southeast Reef Fish Survey
SERO	Southeast Regional Office, NMFS
SRFS	State Reef Fish Survey (Florida)
SRHS	Southeast Region Headboat Survey
SPR	Spawning Potential Ratio: B relative to an unfished state of the stock
SSB	Spawning Stock Biomass
SS	Stock Synthesis
SSC	Scientific and Statistical Committee
TIP	Trip Interview Program: biological data collection program of the SEFSC and Southeast States
TPWD	Texas Parks and Wildlife Department
Z	total mortality (M+F)



SEDAR 88 Gulf of Mexico Red Grouper Operational Assessment

Gulf Fisheries Branch
Sustainable Fisheries Division
NOAA Fisheries - Southeast Fisheries Science Center

February 05, 2025

Table of Contents

1. Introduction

This document summarizes the SEDAR 88 (Southeast Data Assessment and Review) Gulf of Mexico Red Grouper Operational Assessment (OA) as implemented in the Stock Synthesis (version 3.30.21.00) modeling framework (Methot and Wetzel 2013). The last assessment for Gulf of Mexico Red Grouper was the SEDAR 61 Standard Assessment with data through 2017 (SEDAR 2019).

Where practicable, the SEDAR 88 OA Base Model used the same data sets as the SEDAR 61 Standard Base Model with time series updated through 2022. However, notable changes to data sets and model configurations include:

- updating the time series of commercial discards using a refined catch per unit of effort (CPUE)-expansion approach
- updating the time series of Florida-caught private recreational landings and discards from the Marine Recreational Information Program Fishing Effort Survey (MRIP-FES)-based estimates to the Florida State Reef Fish Survey (SRFS)
- incorporating year-specific error in commercial and recreational landing estimates to better reflect uncertainties in landings
- using updated weighted length and age compositions for fisheries data to better represent compositions of the landings
- inputting and fitting to the mean length at age for the commercial and recreational fleets
- incorporating and fitting to the mean weight of the recreational landings
- reviewing composition data and excluding data which are not representative (e.g., fewer than 30 lengths for fisheries data)
- applying age-based selectivity to the commercial handline, longline fleets, and the recreational fleet
- setting the commercial longline fleet selectivity to logistic
- freely estimating the steepness parameter
- applying an updated natural mortality point estimate
- freely estimating the $L\infty$ growth parameter
- applying the Lorenzen scaling to the natural mortality estimate internally within SS to keep the scaling consistent with the internally estimated growth curve
- applying empirical selectivity-at-age for years with significant red tide events
- applying a Dirichlet-Multinomial internal re-weighting approach to age and length compositions
- extending the maximum age of the population from 21 to 29

These changes reflect improvements in data inputs and parameterization compared with SEDAR 61. A more comprehensive description of these changes is detailed in subsequent sections of the assessment report. Assessment methods, results, model diagnostics, stock status determination criteria and projections are also provided through this report.

1.1. Workshop Time and Place

The SEDAR 88 Operational Assessment (OA) process for Gulf of Mexico Red Grouper was conducted by the Southeast Fisheries Science Center (SEFSC). Two Topical Working Groups (TWG), Red Tide TWG and SRFS Data TWG, were convened by SEDAR to review and provide recommendations on data and modeling modifications from SEDAR 61. The Red Tide TWG met by webinar five times: November 2023, January, May and November 2024, and January 2025. The SRFS Data TWG met by webinar in October 2023 and March 2024.

1.2. Terms of Reference

The terms of reference approved by the Gulf of Mexico Fishery Management Council (GMFMC) are listed below.

1. Update the approved SEDAR 61 Gulf of Mexico Red Grouper base model with data through 2022.
    a. Use the State of Florida's State Reef Fish Survey (SRFS) to inform private recreational landings data, if historical SRFS landings have been calibrated and SRFS has been certified by the NOAA Office of Science and Technology.
    b. Document any changes or corrections made to model and input datasets and provide updated input data tables.
    c. Update life history data (e.g., growth, reproduction, mortality) if warranted.
    d. Provide a means to model projected discards in a manner that relaxes the assumption that discards would increase/decrease in proportion to changes in the landings.
    e. Consider the treatment of recreational harvest:
        i. Consider inputting recreational catch in weight (i.e., pounds) instead of in numbers of fish.
        ii. Re-evaluate error estimates for recreational landings.
        iii. Explore the effects of the changes in the mean weight estimation procedure between SEDAR 61 and the 2021 red grouper interim analysis. - If using numbers of fish as the input unit for recreational catch, compare the mean weights estimated by the model with that reported by the SERO ACL Monitoring Dataset, or explore fitting to the SERO mean weights.
2. Explore the potential effects of red tide with consideration of past red tide events, and more recent events in 2018 and thereafter. Explore age-specific episodic mortality of red grouper due to red tide.

3. Update model parameter estimates and their variances, model uncertainties, estimates of stock status and management benchmarks, and provide the probability of overfishing occurring at specified future harvest and exploitation levels. Provide commercial and recreational landings and discards in pounds and numbers.

    a. Use the following status determination criteria (SDC):
        i. MSY or MSY proxy = yield at F_{MSY}
        ii. If the stock is overfished, provide projections at $F_{Rebuild}$

iii. MSST = $0.5*B_{MSY}$
iv. MFMT = F_{MSY} (or proxy) and $F_{Rebuild}$ (if overfished)
v. OY = 75% of MSY or MSY proxy
vi. The current proxy for FMSY for red grouper is F30%SPR. Also provide estimates using an MSY proxy of $F_{40\%SPR}$.
vii. If different SDC are recommended, provide outputs for both the current and recommended SDC.

b. Unless otherwise recommended, use the geometric mean of the previous three years' fishing mortality to determine $F_{Current}$. If an alternative approach is recommended, provide justification and outputs for the current and alternative approach.
c. Provide yield and spawning stock biomass streams for the overfishing limit and acceptable biological catch in pounds:
   i. Annually for five years
   ii. Under a "constant catch" scenario for both three and five years
   iii. For the equilibrium yield at F_{MSY}, when estimable

4. Develop a stock assessment report to address these Terms of Reference and fully document the input data and results of the stock assessment model.

1.3. List of Participants

Topical Working Group Members
Francesca Forrestal (Lead analyst) .... NMFS SEFSC
Skyler Sagarese (Support analyst) .... NMFS SEFSC
Lisa Ailloud .... NMFS SEFSC
Luiz Barbieri .... SSC/FWC
Samantha Binion-Rock .... NMFS SEFSC
Armon Blair .... Industry
David Chagaris .... SSC/UFL
Tiffanie Cross .... FWC
Bill D'Antuono .... Industry
Patrick Neukam .... Industry
Matt Nuttall .... NMFS SEFSC
Steve Papen .... Industry
Beverly Sauls .... FWC
Eric Schmidt .... Industry
Katie Siegfried .... NMFS SEFSC
Ted Switzer .... FWC
Jim Tolan .... SSC/TPWD
Brendan Turley .... NOAA

Attendees
Manuel Coffill-Rivera ....
Chuanmin Hu .... USF

Max Lee .... Mote Marine Lab
Rich Malinoski..NOAA
Michaela Pawluk...NMFS SEFSC
Chloe Ramsay ....FWC
Ryan Rindone..GMFMC
Rebecca Scott...FWC
Nathan Vaughan...NMFS SEFSC

1.4. List of Working Papers and Reference Documents

Document #	Title	Authors	Date Submitted
Documents Prepared for the Operational Assessment			
SEDAR88-WP-01	Headboat Data for Red Grouper in the US Gulf of Mexico	Robin T. Cheshire, Kenneth Brennan, and Matthew E. Green	8 March 2024
SEDAR88-WP-02	General Recreational Survey Data for Red Grouper in the Gulf of Mexico	Matthew A. Nuttall and Samantha Binion-Rock	7 March 2024 Updated: 5 April 2024
SEDAR88-WP-03	Commercial Landings of Gulf of Mexico Red Grouper (*Epinephelus morio*) from 1986-2022	Micki Pawluk and Sarina Atkinson	11 March 2024 Updated: 15 April 2024
SEDAR88-WP-04	CPUE Expansion Estimation for Commercial Discards of Gulf of Mexico Red Grouper (*Epinephelus morio*)	Sarina Atkinson & Kevin Thompson	8 March 2024 Updated: 3 May 2024
SEDAR88-WP-05	Proxy Discard Estimates of Red Grouper (*Epinephelus morio*) from the US Gulf of Mexico Headboat Fishery	Matthew A. Nuttall	21 March 2024
SEDAR88-WP-06	Gulf of Mexico Red Grouper (**Epinephelus morio**) length and age compositions from the recreational fishery	Samantha M. Binion-Rock	22 March 2024
SEDAR88-WP-07	Size and age information Red Grouper, *Epinephelus morio*, collected in association with fishery-dependent	Maria McGirl, Jessica Carroll, and Bridget Cermak	4 March 2024

	projects along Florida's Gulf of Mexico coast		
SEDAR88-WP-08	Descriptions of Florida's Gulf of Mexico Red Grouper Recreational Fishery Assessed Using Fishery-Dependent Survey Data	Maria McGirl	4 March 2024
SEDAR88-WP-09	Gulf of Mexico Red Grouper (*Epinephelus morio*) Commercial Landings Length and Age Compositions	Michaela Pawluk	21 March 2024 Updated: 9 April 2024
SEDAR88-WP-10	Standardized Catch Per Unit Effort for Gulf of Mexico Red Grouper from the Southeast Region Headboat Survey	Matthew A. Nuttall, Kevin Thompson, and Michaela Pawluk	22 March 2024
SEDAR88-WP-11	A Review of the Gulf of Mexico Red Grouper (*Epinephelus morio*) Age-Length Data, 1978-2022	Chris Palmer, Laura Thornton, Steve Garner, and Beverly Barnett	22 March 2024
SEDAR88-WP-12	An Index of Relative Abundance for Red Grouper Captured During the NMFS Bottom Longline Survey in the Northern Gulf of Mexico	Adam G. Pollack, Kristin Hannan, William Driggers, and David S. Hanisko	27 March 2024
SEDAR88-WP-13	Red Grouper Abundance Indices from SEAMAP Groundfish Surveys in the Northern Gulf of Mexico	Adam G. Pollack and David S. Hanisko	27 March 2024
SEDAR88-WP-14	Electronic Monitoring Documentation of Red Grouper (*Epinephelus morio*) in the Eastern Gulf of Mexico Bottom Longline Fishery	Max Lee, Katie Harrington, Carole Neidig, and Ryan Schloesser	21 March 2024
SEDAR88-WP-15	A Summary of Gulf of Mexico Red Grouper Discard Length Data Collected from At-Sea Observers in Recreational Fishery Surveys in Florida	Ellie Corbett	21 March 2024
SEDAR88-WP-16	Combined indices of abundance for Red Grouper (*Epinephelus morio*) in the eastern Gulf of Mexico using data from three historic video surveys and unified G-FISHER program	Justin P. Lewis, Heather M. Christiansen, Theodore S. Switzer, Sean F. Keenan, Kate E.	28 March 2024

		Overly, Matthew D. Campbell	
SEDAR88-WP-17	A ratio-based method for calibrating estimates of total landings (numbers and pounds of fish), releases (numbers of fish), and total trips from MRIP-FCAL to SRFS for Red Grouper (*Epinephelus morio*) in the Gulf of Mexico	Chloe Ramsay, Tiffanie A. Cross, Colin P. Shea, and Beverly Sauls	28 June 2024 Updated: 23 July 2024
Final Stock Assessment Reports			
SEDAR88-SAR1	Gulf of Mexico Red Grouper	SEFSC	

2. Data Review and Update

A variety of data sources were used in the SEDAR 88 Operational Assessment (OA) following the SEDAR 61 Standard Assessment (terminal year of 2017). Where practicable, the SEDAR 88 OA Base Model used the same data sets as the SEDAR 61 Standard Base Model with an updated time series though 2022. However, there were a few new or revised data sets provided for consideration including:

1. An ageing error matrix accompanying the new age data since SEDAR 61 (2018-2022)
2. Commercial discard estimates
3. Annual estimates of uncertainty accompanying commercial and recreational landings estimates
4. Replacing Florida landings and discards estimates for the private mode from the National Marine Fisheries Service's (NMFS) Marine Recreational Information Program Fishing Effort Survey (MRIP-FES) with estimates from Florida State Reef Fish Survey (SRFS)
5. Weighted age compositions methods of Red Grouper landed by the commercial fleets
6. Mean body weight of recreational fleet landings
7. Mean length-at-age of Red Grouper landed by the commercial and recreational fleets
8. Updated natural mortality point estimate to the accepted best practice method

Additionally, two indices were removed from the model, the FWRI Hook and Line Repetitive Time Drop Survey (no longer operational) and the MRIP charter/private survey (no longer supported for indices of relative abundance).

The new data series were considered because they had not previously been available for the SEDAR 61 Standard Assessment or represented improved data inputs for use in the SEDAR 88 assessment. The data utilized in the SEDAR 88 OA Base Model are summarized below and illustrated in **Figure 1** along with their corresponding temporal scale. Comprehensive descriptions of individual data components are provided within each subsection below, with additional details provided in the SEDAR 61 Standard Assessment Report (SEDAR 2019).

1. Life history
    a. Meristics
    b. Age and growth
    c. Natural mortality
    d. Maturity
    e. Fecundity (incorporating sex transition)
2. Discard mortality rates (based on numbers of fish)
    a. Commercial Handline - 19.1%
    b. Commercial Longline - 41.5% pre-IFQ / 44.1% post-IFQ
    c. Commercial Trap - 10%
    d. Recreational - 11.6%
3. Landings
    a. Commercial Handline: 1986-2022 (metric tons gutted weight)
    b. Commercial Longline: 1986-2022 (metric tons gutted weight)
    c. Commercial Trap: 1986-2007 (metric tons gutted weight)
    d. Recreational: 1986-2022 (thousands of fish)
4. Discards
    a. Commercial Handline: 1993-2022 (thousands of fish)
    b. Commercial Longline: 1993-2022 (thousands of fish)
    c. Commercial Trap: 1990-2006 (thousands of fish)
    d. Recreational: 1986-2022 (thousands of fish)
5. Length composition of discards (2:96 cm Fork Length (cm FL), 2 cm FL bins)
    a. Commercial Handline: 2007-2022
    b. Commercial Longline: 2007-2022
    c. Recreational: 2005-2022
6. Age composition of landings (1-year age bins, plus group ages 20 and older)
    a. Commercial Handline (weighted): 1991-2022
    b. Commercial Longline (weighted): 1993-2022
    c. Commercial Trap (weighted): 1991-2006 (aggregated and treated as a super-period)
    d. Recreational (weighted): 1991-2022
7. Mean weight of recreational landings
    a. SRFS private mode: 1986-2022
8. Mean length-at-age of landings
    a. Commercial Handline: 1991-2022
    b. Commercial Longline: 1993-2022
    c. Recreational: 1991-2022
9. Abundance indices
    a. Fishery-independent:
        i. Combined Video Survey: 1993-2022
        ii. SEAMAP Summer Groundfish Survey: 2009-2022

iii. NMFS Bottom Longline: 2001-2022

b. Fishery-dependent:

i. Handline: 1993-2009

ii. Longline: 1993-2009

iii. Recreational (Headboat): 1986-2007

10. Length composition of surveys (2:96 cm FL, 2 cm FL bins)

a. Combined Video Survey: 2002-2022

b. SEAMAP Summer Groundfish Survey: 2009-2022

c. NMFS Bottom Longline: 2001-2022

Two Topical Working Groups (TWG) were needed to discuss the inclusion of recent red tides (Red Tide TWG) and the use of the Florida State Reef Fish Survey (SRFS) data and the associated length and age compositions (SRFS Data TWG).

A summary listing of all data sets included in the assessment, along with any revisions to the contact information for who provided the analysis, is compiled below. This will be the source of data information for the next assessment.

Primary Categories	Data Type	Contributing Organization	Data Providers	Contact Information
Life History	Raw age and length data	FWRI	Meagan Schrandt	meagan.schrandt@myfwc.com
	Raw age data	GulfFIN	Gregg Bray	gregg.bray@gsmfc.org
	Raw age and length data	SEFSC	Laura Thornton	laura.thornton@noaa.gov
	Ageing error matrix	SEFSC	Steve Garner	steven.garner@noaa.gov
Fishery Dependent	Raw recreational length data	FWRI		
	Raw recreational length data	SEFSC	Matt Nuttall Samantha Binion-Rock Drew Cathey	matthew.nuttall@noaa.gov samantha.binion-rock@noaa.gov andrew.cathey@noaa.gov
	Raw coastal logbook catch and effort	SEFSC	Sydney Alhale	sydney.alhale@noaa.gov
	Raw discard logbook discards	SEFSC	Sydney Alhale	sydney.alhale@noaa.gov
	Raw commercial observer program data	SEFSC	Gary Decossas	gary.decossas@noaa.gov

Primary Categories	Data Type	Contributing Organization	Data Providers	Contact Information
	Raw commercial length data and sample sizes	SEFSC	Larry Beerkircher	lawrence.r.beerkircher@noaa.gov
	Commercial landings estimates	SEFSC	Sarina Atkinson Michaela Pawluk	sarina.atkinson@noaa.gov michaela.pawluk@noaa.gov
	Commercial discards estimates and length composition	SEFSC	Sarina Atkinson Kevin Thompson	sarina.atkinson@noaa.gov kevin.thompson@noaa.gov
	Southeast Regional Headboat Survey effort, catch, and CV	SEFSC	Ken Brennan Rob Cheshire	kenneth.brennan@noaa.gov rob.cheshire@noaa.gov
	Recreational catch (landings+discards) estimates, MRIP CVs, and recreational effort estimates	SEFSC	Matt Nuttall Samantha Binion-Rock Drew Cathey	matthew.nuttall@noaa.gov samantha.binion-rock@noaa.gov andrew.cathey@noaa.gov
	SRFS recreational catch (landings+discards) estimates	FWRI	Chloe Ramsay	chloe.ramsay@myfwc.com
	Private mode recreational mean weight of landings	FWRI	Chloe Ramsay	chloe.ramsay@myfwc.com
	Commercial length compositions	SEFSC	Michaela Pawluk	michaela.pawluk@noaa.gov
	Commercial age compositions	SEFSC	Michaela Pawluk	michaela.pawluk@noaa.gov
	Commercial conditional age-at-length compositions	SEFSC	Michaela Pawluk	michaela.pawluk@noaa.gov
	Recreational length compositions	SEFSC	Samantha Binion-Rock	samantha.binion-rock@noaa.gov
	Recreational age compositions	SEFSC	Samantha Binion-Rock	samantha.binion-rock@noaa.gov
	Recreational conditional age-at-length compositions	SEFSC	Samantha Binion-Rock	samantha.binion-rock@noaa.gov

Primary Categories	Data Type	Contributing Organization	Data Providers	Contact Information
Fishery Independent	Combined Video Index	FWRI	Justin Lewis	justin.lewis@myfwc.com
	NMFS bottom longline index, length compositions	SEFSC	Adam Pollack	adam.pollack@noaa.gov
	SEAMAP groundfish trawl index, length compositions	SEFSC	Adam Pollack	adam.pollack@noaa.gov

2.1. Stock Structure and Management Unit

No new literature was identified during SEDAR 88 therefore, the stock definition was left unchanged from the SEDAR 61 Standard Assessment. The Gulf of Mexico Red Grouper stock was assumed to be a single unit stock due to the lack of information on stock structure. The management unit for Gulf of Mexico Red Grouper extends from the United States–Mexico border in the west through the northern Gulf waters and west of the Dry Tortugas and the Florida Keys (north of US Highway 1).

2.2. Life History Parameters

Life history data used in the assessment included length-length, weight-weight, and length-weight relationships, age and growth, natural mortality, maturity, and hermaphroditic transition rates. Some of the life history data were input to the population model (Stock Synthesis) as fixed values, while other life history parameters were estimated.

2.2.1. Morphometric and Conversion Factors

Morphometric and conversion factors developed during the SEDAR 42 Benchmark Assessment (SEDAR, 2015) were not updated during the SEDAR 88 OA. The relationship between gutted weight (in kilograms) and fork length (FL in centimeters; $gw = aFL^b$) for both sexes combined was used as a fixed model input (**Table 1**, **Figure 2**).

2.2.2. Age and Growth

As in SEDAR 61, some life history inputs in SEDAR 88 were fixed parameters (**Figure 2**). Input parameters for growth were not updated during SEDAR 88 and parameter initial estimates were based on starting values used for SEDAR 61 (**Table 2**). To account for uncertainty in the ageing process and for differences between time periods (e.g., due to different readers), standard deviations (SD)-at-age were calculated and used as a measure of ageing error in the assessment model for ages associated with each time period: (1) 1986-2017 (SEDAR 61) and (2) 2018-2022 (SEDAR 88). For the SEDAR 88 time period, the ageing error model parameters were re-estimated to inform ageing error. The best fit model based on Akaike's Information Criterion values assumed curvilinear coefficient of variation (CV) for both the reference set and primary readers (for a full discussion of methods and results see SEDAR88-WP-11). Uncertainty in age estimates increased with age (**Table 3**), with wider distributions of observed ages evident for older Red Grouper (**Figure 3**).

2.2.3. Natural Mortality

As in SEDAR 61, natural mortality (*M*) was modeled using a Lorenzen function, i.e. a size-dependent mortality schedule (Lorenzen 2000) in which the instantaneous mortality rate-at-age is inversely proportional to length-at-age. Parameters required for this approach include the age at full recruitment to the fishery (minage), an M_{target} point estimate for the species representing the cumulative mortality rate over the range of exploited ages, and growth curve parameter estimates.

During the SEDAR 42 Benchmark Assessment for Gulf of Mexico Red Grouper, the Life History Working Group (LHWG) recommended a maximum age (t_{max}) of 29 years. To account for uncertainty in maximum age (i.e., ageing error, limited sample size), the SEDAR 42 LHWG proposed a range of 24 to 34 years be used as the t_{max}, which directly translated into uncertainty about *M*. No updates to maximum age were made during the SEDAR 61 Standard Assessment (SEDAR 2019) or for SEDAR 88.

An updated point estimate for *M* was derived using the *M* estimator developed by Hamel and Cope (2022):

$$M = \frac{5.4}{t_{max}}$$

This study evaluated Then et al.'s (2015) updated dataset of *M* and t_{max} with a more appropriate transformation than was used by Then et al. (2015) (see Hamel and Cope 2022 for more detail on the approach).

Applying the Hamel and Cope (2022) estimator using a (t_{max}) of 29 years yielded an updated *M* point estimate of 0.186, an increase from the SEDAR 61 estimate of 0.14; this estimate was based on Hoenig (1983). For comparison, the *M* point estimate obtained using the Then et al.'s (2015) methodology was 0.180 (**Table 4; Figure 2**).

2.2.4. Maturity, Sexual Transition and Fecundity

Maturity parameters developed during the SEDAR 42 Benchmark Assessment were not updated during the SEDAR 88 OA as no new data were provided. Red Grouper are protogynous hermaphrodites (i.e., transition from female to male). The combined gender Stock Synthesis model treats males and females identically as in SEDAR 61 and SEDAR 42. New data informing the maturity and sexual transition schedules were presented at the SEDAR 61 DW/AW Workshop, however the data did not change the estimates of age and size at maturity or sexual transition that were used in SEDAR 42.

Hermaphroditism was accounted for in the fecundity vector in the model. To account for a decrease in fecundity as females transition and become males, total fecundity-at-age was calculated as the proportion female × proportion mature × batch fecundity. The SEDAR 61 DW/AW Panel recommended the use of batch fecundity as a function of length (rather than age as used in SEDAR 42) and to convert it to age using the growth curve. This decision was based on the relationship of fecundity-at-length being considered a better biological determinant given the sensitivity of the fecundity-at-age to a few older individuals observed during SEDAR 61 (**Figure 4B**).

2.2.5. Discard Mortality

Discard mortality estimates were unchanged from those recommended by the SEDAR 61 Standard Assessment. The commercial handline discard mortality was 19.0%. The discard mortality estimates for the pre- and post-Individual Fishing Quota (IFQ) commercial longline were 41.4% and 44.1%, respectively. The discard mortality rates for the commercial trap fishery and recreational fishery were unchanged from SEDAR 42 and were 10% and 11.6%, respectively.

2.3. Fishery-Dependent Data

2.3.1. Commercial Landings

Commercial landings data (1986-2022) used in the assessment are presented in **Table 5** and **Figure 5**. Commercial landings for Red Grouper were constructed using data housed in NOAA's Southeast Fisheries Science Center's (SEFSC) Accumulated Landings System (ALS) and from state trip ticket programs when available: Texas 2014+, Louisiana 2000+, Mississippi 2014+, Alabama 2002+, and Florida 1986+ (**Table 5**). For the assessment, as in SEDAR 61, commercial landings were partitioned into three fleets: (1) vertical line or handline, (2) longline, and (3) trap (**Section 3.1.6**). For SEDAR 88, landings by other gears (<0.58% overall; SEDAR88-WP-03) were lumped into the handline fleet so no landings were excluded (as in SEDAR 61). Landings have been predominantly captured by the longline gear (**Figure 6**).

Between SEDAR 61 and SEDAR 88 there have been updates to the standard gear groupings which resulted in some landings being shifted between gear groups (**Figure 5**, SEDAR88-WP-03).

Commercial landings were reported in pounds gutted weight and converted to metric tons for input into the assessment model. Uncertainty estimates for landings from the Gulf of Mexico were not provided during the SEDAR 61 Standard Assessment. Uncertainty estimates based on expert opinion were developed during the SEDAR 68 Gulf of Mexico Scamp and Yellowmouth Grouper Research Track Assessment by state (**Table 6**; SEDAR 2021). Since Red Grouper are caught across the Gulf of Mexico, but primarily in Florida, state-specific error estimates were multiplied by state landings to produce a weighted-error estimate for annual landings by fleet (**Figure 6**). These error estimates were used in the SEDAR 88 OA Base Model for 1986-2009, whereas an error of 0.01 was applied to landings beginning in 2010, corresponding to the implementation of the IFQ program in the Gulf of Mexico.

2.3.2. Recreational Landings

Recreational landings data (1986-2022) used in the assessment are presented in **Table 7** and **Figure 5**. Recreational landings of Red Grouper were estimated using fully calibrated estimates from the Marine Recreational Information Program (MRIP) using the Fishing Effort Survey (FES) and the redesigned Access Point Angler Intercept Survey (APAIS), Texas Parks and

Wildlife Department, Louisiana Creel survey (SEDAR88-WP-02), the Southeast Regional Headboat survey (SEDAR88-WP-01) and the Florida State Reef Fish Survey (SEDAR88-WP-08).

SEDAR 61 and SEDAR 88 fit to recreational landings in numbers of fish. Gulf assessments have traditionally fit to recreational landings in numbers as numbers are the native units of recreational monitoring surveys. A comparison between mean size of landed Red Grouper predicted by the SEDAR 61 assessment model and the ACL monitoring dataset revealed that the SEDAR 61 assessment model underpredicted the size of landed Red Grouper. The underestimation was caused by the growth curve, which was externally fit and fixed in the assessment model, and the assumed distribution regarding the variability-at-length (i.e., the coefficient of variation). The SEDAR 61 assessment model ultimately inferred the weights, which were lower than observed in the ACL monitoring dataset. For SEDAR 88, the mean weight of the recreational private mode landings was included to provide the model more information on the size of the recreational landings (**Table 8**).

Due to the fact that the vast majority of landings are captured off the west coast of Florida, the SRFS Data TWG supported the use of SRFS for a source of landings, discards, and compositions from the private boat mode when available (SEDAR88-WP-08).

SRFS TWG Recommendations:

The SRFS TWG recommended using the SRFS private mode estimates as replacement for the Florida MRIP private mode estimates for landings and discards. The associated length and age compositions were used when available, beginning in 2016. As there is a single recreational fleet in the Red Grouper model, these estimates were incorporated into the model only for Florida-caught private mode estimates (SEDAR88-WP-02; **Figure 7**). Variance estimates from different modes/surveys (e.g., MRIP vs. SRHS) were treated as independent and additively combined using the Variance Sum Law to produce uncertainty (CV) estimates for total recreational landings and discards (**Figure 8**).

2.3.3. Commercial Discards

Commercial discards (1993-2022) for the hand line and longline fisheries used in SEDAR 88 are presented in **Table 9** and **Figure 8**. The commercial discards for Gulf of Mexico Red Grouper were estimated using methods revised since SEDAR 61, which was the first to implement the CPUE-expansion approach. The improved methodology uses catch-per-unit-effort (CPUE) from the coastal observer program and total fishing effort from the commercial reef logbook program to estimate total catch. A full description of the discards and CPUE-expansion estimation procedures is given in SEDAR88-WP-04.

Commercial discards for Commercial Trap were unchanged from SEDAR 61.

2.3.4. Recreational Discards

Recreational discards in numbers of Red Grouper were estimated using fully calibrated estimates from MRIP using FES and the redesigned Access Point Angler Intercept Survey (SEDAR88-WP-02), Texas Parks and Wildlife Department, Louisiana Creel survey, and Southeast Regional Headboat survey SEDAR88-WP-01. For the Private fishing mode, Florida State Reef Fish

Survey (SRFS) estimates were used in place of the MRIP estimates (SEDAR88-WP-08, **Table 7** and **Figure 8**). The preferred super-ratio approach was evaluated as a suitable proxy method for SRHS discards, which rescales past (e.g., 1986-2007) discard rates of the MRIP charterboat mode (discards:landings) by the ratio of mean discard rates between the MRIP charterboat mode and SRHS headboat mode from recent years (e.g., 2008-2022). For more information, see SEDAR88-WP-05.

2.3.5. Commercial Size Compositions

The commercial data sources used to generate length compositions include length sample data collected by the Trip Interview Program (1986-2022). Annual length compositions were combined into 2-cm Fork Length interval bins (2:96 cm FL) following the SEDAR 61 Standard Assessment. A detailed description of length composition data can be found in SEDAR88-WP-09. As with SEDAR 61, length compositions of retained landings were not used within the model, rather they were incorporated to develop the weighted age compositions of landings. Retained length compositions from years without weighted age compositions were attempted to be included in the model, however in initial model building, these compositions had very poor fits due to low sample sizes and limited years available.

The Reef Fish Observer Program provides detailed information for each trip and each fish captured, including the size and disposition of Red Grouper caught. Length composition data of discarded fish from the commercial fishery were available and included in the model for the handline and longline fleets for 2007-2022.

Overall, length compositions of Red Grouper discarded by the Commercial Handline fishery peaked around 40 cm FL (**Figures 9-10**). Annual handline length compositions of Red Grouper discarded (2007-2022) are presented in **Figure 10**. Input sample sizes averaged 50 length observations (range: 10-158).

Overall, length compositions of Red Grouper discarded by the Commercial Longline fishery also peaked around 40 cm FL (**Figures 9-10**). Annual Longline length compositions of Red Grouper discarded (2007-2022) input sample sizes averaged 37 length observations (range: 14-81).

Length composition sample sizes in SEDAR 42 were input in numbers of length observations capped at a maximum effective sample size of 200 to prevent the length composition data from driving the model fitting process. For SEDAR 61, the sample sizes were input as the square root of observed sample sizes to prevent overfitting the composition data and to maintain the interannual differences in data quality that would otherwise be lost by an arbitrary cap. For SEDAR 88, the new Dirichlet-Multinomial likelihood was used to adjust input sample sizes, as such, capping the sample size was no longer necessary. The input sample size associated with each year/fleet was set as the number of trips with length observations.

2.3.6. Commercial Age Composition

The methodology used to weight commercial age compositions in SEDAR 88 was updated from SEDAR 61. Previously, nominal lengths were used to weight the nominal age compositions, after which the landings were used to combine the sub-regional weighted ages into a single age composition (Chih 2014). This differs from the current best practice of weighting the length compositions by the landings in each subregion. A full description of both methodologies and comparisons of the results can be found in SEDAR88-WP-09.

Overall, age compositions of Red Grouper landed by the Commercial Handline fishery peaked around 6 years (**Figures 11-12**). Input sample sizes averaged 136 trips (range: 10-425). Some cohorts were apparent in the Handline ages (**Figure 13**).

Overall, age compositions of Red Grouper landed by the Commercial Longline fishery peaked around 7 years (**Figures 11-12**). Input sample sizes averaged 131 trips (range: 11-370). Cohorts were apparent entering into the longline fishery around 2000, 2004 and 2010 (**Figure 14**).

Overall, age compositions of Red Grouper landed by the Commercial Trap fishery peaked around 6 years (**Figure 11**). Input sample sizes averaged 4 trips (range: 1-11). Due to the low sample sizes, the trap yearly age compositions were aggregated across years and entered as a super-period in Stock Synthesis.

Age composition sample sizes in SEDAR 42 were input in numbers of age observations capped at a maximum effective sample size of 100 to prevent the age composition data from driving the model fitting process. For SEDAR 61, the sample sizes were input as the square root of observed sample sizes to prevent overfitting the composition data and to maintain the interannual differences in data quality that would otherwise be lost by an arbitrary cap. For SEDAR 88, the new Dirichlet-Multinomial likelihood was used to adjust input sample sizes, and as such, capping the sample size was no longer necessary. The input sample size associated with each year/fleet was set as the number of trips with age observations.

A mean length-at-age vector for each year and fleet was included in the model for comparison between the model's expected length-at-age and the observed length-at-age. Initially this data was used for model checking but a very light lambda was applied during model building.

2.3.7. Commercial Catch Per Unit of Effort (CPUE) Indices of Abundance

Two commercial CPUE indices of relative abundance were used in the SEDAR 88 assessment. The pre-IFQ index for the Commercial Handline and Commercial Longline fleets were recommended for use because of their long and fairly consistent time series before the implementation of the IFQ program (i.e., 2010+). The standard errors, scaled to a mean of 0.3 (SEs, converted from CV, see **Section 3.2**) as well as all index values by source are presented in **Table 10**, and the indices are shown in **Figures 15-16**. These indices remain unchanged from SEDAR 61 and were not updated for SEDAR 88 because the implementation of the IFQ system is believed to have changed fishing behavior and catchability compared to the earlier years. Therefore, indices developed for IFQ years may not represent the relative abundance of the stock (see SEDAR 68 Gulf of Mexico Scamp and Yellowmouth Grouper Research Track Stock Assessment Report [SEDAR 2021] for further discussion).

2.3.8. Recreational Size Composition

Recreational length samples used in SEDAR 88 included new data sources as compared to SEDAR 61. Lengths from the Marine Recreational Information Program (MRIP) and Southeast Regional Headboat Survey (SRHS) were supplemented by opportunistic sampling from the Gulf States Marine Fisheries Commission Fisheries Information Network (GulfFIN) and Trip

Interview Program (TIP). Following SEDAR 61, one recreational fleet was defined combining fish sampled from private, charter boat, and headboat modes. Shore mode was excluded from analyses as only 30 Red Grouper were sampled for length, and none were sampled for age. The length composition included for analysis were updated for SEDAR 88 and did not include samples using WP_Size (a full description of these changes can be found in SEDAR88-WP-06). As with the commercial length compositions, the recreational length compositions of landings were not used explicitly within the model. Retained length compositions from years without weighted age compositions were attempted to be included in the model, however in initial model building, these compositions had very poor fits.

Discard length compositions were obtained from the FWRI (Florida Fish and Wildlife Research Institute) At-Sea Observer Program for the charter boat and headboat modes. Nominal length compositions of discarded Red Grouper were provided whereas headboat discard length compositions were weighted by trip length to correct for the fact that headboat trips were not sampled proportional to fishing effort (SEDAR88-WP-15). These compositions were combined by weighting using the proportion of discards provided by FWRI for each mode. The use of private mode discards was explored, however there was no effect to the final results. Sample sizes were obtained from the total sampled discard trip for the charter boat and headboat modes.

Overall, discard length compositions of Red Grouper discarded by the Recreational fishery peaked around 35 cm FL (**Figure 9**). Annual length compositions of Red Grouper discarded (2005-2022) input sample sizes averaged 166 trip observations (range: 46-288).

2.3.9. Recreational Age Composition

Age compositions of landings were weighted by length compositions and subregion. Overall, age compositions of Red Grouper landed by the Recreational fishery peaked around 5 years (**Figure 11**). Input sample sizes averaged 98 trips (range: 16-270).

Overall, age compositions of Red Grouper landed by the Recreational fishery peaked around 7 years (**Figures 11-12**). Input sample sizes averaged 131 trips (range: 11-370). Cohorts were apparent entering into the longline fishery around 2000, 2004 and 2010 (**Figure 17**).

A mean length-at-age vector for each year and fleet was included in the model for comparison between the model expected length-at-age and the observed length-at-age. Initially this data was used for model checking but a very light lambda was applied during model building.

2.3.10. Recreational Catch Per Unit of Effort (CPUE) Index of Abundance

One recreational CPUE index of relative abundance was used in the SEDAR 88 assessment as opposed to two in SEDAR 61. The MRIP charter/private survey was not used due to concerns that it does not track changes in abundance of recreationally caught species. An analysis by Fitzpatrick and Williams (2021) conducted on Gray Triggerfish concluded that "changing regulations, changing targeting, advances in fishing technology, and changing environmental conditions through time" render the proportionality between stock abundance and MRIP CPUE assumption invalid. While that analysis was conducted on Gray Triggerfish, recent assessments across the Southeast and the Gulf of Mexico have not included MRIP CPUE indices due the reasons outlined in the paper.

The Southeast Region Headboat Survey was updated for SEDAR 88. Most notably, records after 2007 were excluded from the standardization methods due to the effect of circle hooks on the catchability of Red Grouper. The switch from J hooks to circle hooks was mandated by Reef Fish Amendment 27 and went into effect in 2008. A similar filter excluding years with J-hooks was applied the NMFS Bottom Longline index for SEDAR 42. A full description of the standardization methodology can be found in SEDAR88-WP-10.

The standard errors (SEs, converted from CV, see **Section 3.2**) as well as all index values by source are presented in **Table 10**, and the indices are shown in **Figure 16**.

2.4. Fishery-Independent Surveys

2.4.1. Combined Video Survey

The Combined Video Survey used in SEDAR 61 represented three independent stationary video surveys that have historically been conducted in the northern Gulf of Mexico to derive fishery-independent abundance estimates of reef fish stocks. The longest running survey was the SEAMAP reef fish video (SRFV) survey initiated by the NMFS Mississippi Laboratory in 1992, followed in 2005 by the NMFS Panama City Laboratory (PC) survey, and finally the Florida Fish and Wildlife Research Institute (FWRI) video survey, which started in 2010. This survey has recently been updated to integrate the three surveys into a unified design beginning in 2020. This updated survey program is known as G-FISHER (Gulf Fishery Independent Survey of Habitat and Ecosystem Resources). A full description of this updated survey can be found in SEDAR88-WP-16.

Overall, length compositions of Red Grouper caught by the updated Combined Video Survey peaked around 40 cm FL (**Figure 9**). Input sample sizes for the averaged 128 length observations (range: 10-210). The standard errors (SEs, converted from CV, see **Section 3.2**) as well as all index values by source are presented in **Table 10**, and the indices are shown in **Figure 15**.

2.4.2. SEAMAP Groundfish

Standardized trawl surveys have been conducted in the Gulf of Mexico since 1972 and continued under the Southeast Area Monitoring and Assessment Program (SEAMAP) in 1982 and 1987 for the summer and fall, respectively. The primary objective of this trawl survey conducted semi-annually is to collect data on the abundance and distribution of demersal organisms in the northern Gulf of Mexico. Prior to 2009, the summer survey did not sample from Mobile Bay, Alabama eastward to Florida. Year 2020 was dropped due to the COVID-19 pandemic; full survey details can be found in SEDAR88-WP-13.

Overall, length compositions of Red Grouper caught by the SEAMPAP Groundfish Survey peaked around 20-30 cm FL (**Figure 9**). Survey length compositions of Red Grouper (2009-2022) input sample sizes for the survey averaged 33 station observations (range: 18-50). The standard errors (SEs, converted from CV, see **Section 3.2**) as well as all index values by source are presented in **Table 10**, and the index is shown in **Figure 16**.

2.4.3. NMFS Bottom Longline Survey

The NMFS Mississippi Laboratories have conducted standardized bottom longline surveys in the Gulf of Mexico, Caribbean, and Western North Atlantic since 1995. The objective of these surveys is to provide fisheries independent data for stock assessment purposes. These surveys are conducted annually and provide an important source of fishery independent information on large coastal sharks, snappers, and groupers from the Gulf of Mexico and Atlantic. In 2011, a Congressional Supplemental Sampling Program (CSSP) was conducted where high levels of survey effort were maintained from April through October. For this analysis, only Congressional Supplement Sampling Program data collected during the same time period as the annual survey were used to supplement missing data from the NMFS Bottom Longline Survey in 2011.

As in SEDAR 61 and SEDAR 42, a standardized index was developed using NMFS Bottom Longline Survey data and standard delta-lognormal methods (SEDAR88-WP-12). Data from 1995 – 2000 was not used due to the use of J-type hooks, which caught relatively few red grouper and an inconsistent survey design. When the hook type was changed to circle-hooks, red grouper catches increased by an order of magnitude (Ingram et al. 2005). Survey year 2002 was not included due to limited spatial coverage. The standard errors (SEs, converted from CV, see **Section 3.2**) as well as all index values by source are presented in **Table 10**, and the indices are shown in **Figure 16**.

Overall, length compositions of Red Grouper caught by the NMFS Bottom Longline Survey peaked around 45-50 cm FL (**Figure 9**). Survey length compositions of Red Grouper (2001-2022) input sample sizes for survey averaged 19 length observations (range: 7-72).

2.5. Environmental Considerations and Contributions from Stakeholders

2.5.1. Red Tide

Red tide blooms caused by the dinoflagellate *Karenia brevis* have been hypothesized to cause severe mortality for shallow-water grouper species such as Red Grouper (SEDAR 2019) and Gag Grouper (SEDAR 2021a). Although fish kill observations often originate from beach sightings, blooms can impact offshore species as well, as blooms generally start offshore at depth (Steidinger and Vargo 1988). The Red Tide TWG met to discuss how best to incorporate red tide mortality into the SEDAR 88 OA for Red Grouper. The TWG also discussed what years to explicitly include additional mortality due to red tide in the model structure. The Red Tide TWG recommended that the years 2018 and 2021 be entered as red tide years for the bycatch fleet within the model, in addition to 2005 and 2014 from SEDAR 61. For each year the bycatch fleet operated, a yearly fishing mortality parameter was estimated and an associated amounts of mortality in biomass and numbers was calculated. The magnitude for red tide mortality across ages and years for Red Grouper was estimated by the West Florida Shelf Ecospace model (**Table 11**; Vilas et al. 2023).

3. Stock Assessment Model Configuration and Methods

3.1. Stock Synthesis Model Configuration

The assessment model used was Stock Synthesis, version 3.30.21.00. Descriptions of algorithms and options are available in the User's Manual (Methot et al. 2023), the NOAA Fisheries Toolbox website (*http://nft.nefsc.noaa.gov/*), and Methot and Wetzel (2013). Stock Synthesis is a widely used integrated statistical catch-at-age model that has been tested for stock assessments in the United States (US), particularly on the West Coast and Southeast, and also throughout the world (see Dichmont et al. 2016 for review). Statistical catch-at-age models consist of three closely linked modules: the population dynamics module, an observation module, and a likelihood function. Input biological parameters (**Section 2.2**) are used to propagate abundance and biomass forward from initial conditions (population dynamics model) and Stock Synthesis develops expected data sets based on estimates of fishing mortality (*F*), selectivity, and catchability (the observation model). The observed and expected data are compared (the likelihood module) to determine best fit parameter estimates using a statistical maximum likelihood framework (detailed in Methot and Wetzel [2013]). Because many inputs are correlated, the concept behind Stock Synthesis is that processes should be modeled together, which helps to ensure that uncertainties in the input data are properly accounted for in the assessment.

The Stock Synthesis modeling framework provides estimates for key derived quantities including: time series of recruitment (units: 1,000s of age-0 recruits), abundance (units: 1,000s of fish), biomass (units: metric tons), SSB (units for Red Grouper: relative number of eggs), and exploitation or harvest rate (units for Red Grouper: total biomass killed all ages / total biomass age 0+). The r4ss software (Taylor et al. 2021) was utilized extensively to develop various graphics for model outputs and was also used to summarize various output files and perform diagnostic runs. The ss3diags software (Carvalho et al. 2021) was also used to perform additional diagnostics.

3.1.1. Initial Conditions

The Gulf of Mexico Red Grouper assessment begins in 1986 and has a terminal year of 2022. Since removals of Red Grouper are known to have occurred in the Gulf of Mexico prior to 1986 for both commercial and recreational fisheries, the stock was not assumed to be in virgin condition in 1986 and initial conditions had to be estimated. To estimate initial depletion at the start of the model (1986) a set of initial equilibrium catches for each fleet (from which a set of initial Fs was estimated) was specified using the initial equilibrium catches which were set equal to the average landings from the first 5 years of each fishing fleet. The initial F parameter values at the start of the model building were those used in the final SEDAR 61 base model. Changing the start year was not pursued during SEDAR 88 because multiple alternative start years were evaluated in detail during SEDAR 61 (SEDAR 2019) and SEDAR 42 (SEDAR 2015).

3.1.2. Temporal Structure

The Red Grouper population was modeled from age-0 (Stock Synthesis starts at age-0; Methot et al. 2023) through age-29, with data bins spanning age-0 through age-20+, with the last age representing a plus group. The population was modeled through the maximum age of 29 years, however, the vast majority of data available were for ages 20 and below. Data collection and fishing activities were assumed relatively continuous throughout the year; therefore, inclusion of a seasonal component to the removals was not deemed necessary. Within the model, the fishing season was assumed to be continuous and homogeneously distributed throughout the year.

3.1.3. Spatial Structure

A single area model was implemented where recruits are assumed to homogeneously settle across the entire Gulf of Mexico region.

3.1.4. Life History

A fixed length-weight relationship was used to convert body length (cm FL) to body weight (kg gutted weight; **Section 2.2.1; Table 1, Figure 2**). Stock Synthesis moves fish among age classes and length bins on January 1st of each modeled year starting from birth at age-0. Because the 'true' birth date often does not occur on January 1st, with peak spawning occurring around May 15th for Red Grouper in the Gulf of Mexico, some slight alterations in growth (t_0, or the age at length 0) and M parameters are required to account for the difference between true age and modeled age when parameters are input as fixed parameters instead of estimated within Stock Synthesis.

Growth within Stock Synthesis was modeled with a three parameter von Bertalanffy equation: (1) L_{Amin} (cm FL), the mean size at age-1 Red Grouper; (2) L_{Amax} (cm FL), the mean size at maximum aged Red Grouper (29 years); and (3) K (year^{-1}), the growth coefficient. In Stock Synthesis, when fish recruit at the real age of 0.0 they have a body size equal to the lower limit of the first population bin (fixed at 2 cm FL for Red Grouper). Fish then grow linearly until they reach a real age equal to the input value of A_{min} (growth age for L_{Amin}; age-1 for Red Grouper) and have a size equal to L_{Amin}. As they age further, they grow according to the von Bertalanffy growth equation (**Section 2.2.2; Figure 2**). L_{Amax} was specified as equivalent to $L\infty$. Two additional parameters are used to describe the variability in size-at-age and represent the CV in length-at-age at A_{min} (age-1) and A_{max} (age-29). For intermediate ages, a linear interpolation of the CV on mean size-at-age is used.

The SEDAR61 model estimated both the K and L_{Amin} after observing improved model fits to composition data, with starting values recommended by the Life History Working Group at the SEDAR 61 DW/AW Workshop. The availability of mean length-at-age data during SEDAR 88 allowed for the L_{max} parameter to be estimated.

The natural mortality rate (M) was assumed constant over time but decreasing with age. The Lorenzen (2005) age-specific vector of M was re-estimated for SEDAR 88 using the Hamel and Cope (2022) estimator (**Section 2.2.3**) (**Figure 2**) and scaled internally using the Lorenzen function over the range of fully recruited ages (5- 29) to derive an age-specific vector of M.

Red Grouper are protogynous hermaphrodites (female at birth, then a portion of the population transitions to male). The combined gender Stock Synthesis model treated males and females identically as in both SEDAR 61 and SEDAR 42. Immature females transitioned to mature females based on a fixed logistic function of age. Hermaphroditism was accounted for implicitly in the fecundity vector input into the assessment model. To account for a decrease in fecundity as females transition and become males, total fecundity-at-age was calculated as the proportion female (Section 2.2.4; unchanged from SEDAR61) × proportion mature × batch fecundity. The SEDAR61 DW/AW Panel recommended the use of batch fecundity as a function of length (rather than age as used in SEDAR42) and to convert it to age using the growth curve. This decision was based on the relationship of fecundity-at-length being considered a better biological determinant given the sensitivity of the fecundity-at-age to a few older individuals. As in SEDAR 61 and SEDAR 42, the combined fecundity-at-age vector was fixed within the Stock Synthesis model. Reproductive potential was defined as a relative number of eggs given its calculation above (**Section 2.2.4**; **Figure 4**).

3.1.5. Recruitment Dynamics

A Beverton-Holt stock-recruit function was used to parameterize the relationship between spawning output and resulting recruitment of age-0 fish. The stock-recruit function (representing the arithmetic mean stock-recruit levels) requires three parameters: (1) steepness characterizes the initial slope of the ascending limb (i.e., the fraction of virgin recruits produced at 20% of the equilibrium spawning biomass); (2) the virgin recruitment (R_0, estimated in log space; ln(R_0)) represents the asymptote or virgin recruitment levels; and (3) the variance or recruitment variability term (σR) which is the SD of the log of recruitment (it both penalizes deviations from the stock-recruit curve and defines the offset between the arithmetic mean stock-recruit curve and the expected geometric mean from which the deviations are calculated).

The SEDAR 61 Standard Base Model fixed steepness at 0.99 and freely estimated σR and ln(R_0). The parameterization of steepness was re-evaluated when building the SEDAR 88 OA Base Model. Steepness was initially fixed at a biologically plausible value of 0.78 however during later model building and diagnostics, steepness was determined to be estimable without the use of a prior (discussed in **Section 3.4.3**). The initial value of 0.78 was obtained from the FishLife R package (Thorson et al. 2023), an approach which was used during the SEDAR 68 to develop a biologically plausible value for steepness (SEDAR 2021). FishLife synthesizes life history data and produces estimates of life history inputs (such as steepness) based on available studies of the target species and congeners (Thorson et al. 2017a) and was strongly recommended by the CIE reviewers of that assessment as a best practice if steepness cannot be estimated.

Annual deviations from the stock-recruit function were estimated in Stock Synthesis as a vector of deviations forced to sum to zero and assuming a lognormal error structure. During model building, the constraint of forcing the deviations to sum to zero was explored by applying a slightly different stock recruitment function methodology. Red tide events in 2018 and 2021 were consistently very uncertain during model building and the use of this alternative method decreased some of the uncertainty around these recent red tide events. However this method has not been previously applied in the Gulf of Mexico and more research is needed to understand the effects on the model results (discussed in **Section 3.4.3**). A lognormal bias adjustment factor was applied to recruitment estimates as recommended by Methot et al. (2023).

For the SEDAR 88 OA Base Model, main period (i.e., data rich, when representative length or age composition data are available) recruitment deviations spanned 1993-2022. No recruitment deviations were estimated in the early period (i.e., pre-1993) because their estimation led to highly uncertain parameters (CV > 1), suggesting little information was available in the early composition data to inform the earlier age structure. Full bias adjustment was used only from

1996 to 2021. Bias adjustment was phased in linearly, from no bias adjustment prior to 1964 (note that the model starts in 1986) to full bias adjustment in 1996. Bias adjustment was phased out in 2021, decreasing from full bias adjustment to no bias adjustment by 2023. The years selected for full bias adjustment were estimated following the methods of Methot and Taylor (2011).

3.1.6. Fleet Structure and Surveys

Four fishing fleets were modeled and had associated length and/or age compositions. The fleets were: Commercial Handline (comm_HL_1), Commercial Longline (comm_LL_2), Commercial Trap (commTrap_3), and Recreational (Rec_4), which includes charter, private and headboat). Fleet structure was unchanged from SEDAR 61, where it was characterized by the availability of length and age composition data, comparisons of length distributions between gears, and resulting sample sizes. Fishing was assumed to be continuous and homogeneous across the entire year.

Three fishery-dependent CPUE indices were included in the SEDAR 88 OA Base Model: pre-IFQ Handline (units: biomass kept per hook hour), pre-IFQ Longline (units: biomass kept per hook) and recreational headboat derived from SRHS (units: numbers per angler hour). CPUE was treated as an index of biomass or abundance (depending on whether the corresponding catch was in weight or numbers) where the observed standardized CPUE time series was assumed to reflect annual variation in population trajectories. All three indices were of landings only, and the selectivity of each was assumed identical to the associated fleet.

Three fishery-independent survey indices of abundance were included and had associated length compositions. The surveys were: Combined Video Survey (Combined Video, units: MaxN), SEAMAP Summer Groundfish Survey (SEAMAP Summer Groundfish, units: fish per trawl hour), and NMFS Bottom Longline (NMFS Bottom Longline Survey, units: fish per 100 hook hour). For each survey, the length composition was fit directly based on the estimated length-based selectivity function.

Four bycatch fleets were included in the model to represent dead discards due to red tides; one bycatch fleet was used for each year (2005, 2014, 2018 and 2021) included for significant red tide events (**Section 2.5.1**).

3.1.7. Selectivity

Selectivity represents the probability of capture by age or length for a given fleet and represents the net result of multiple interrelated factors (e.g., gear type, targeting, and availability of fish due to spatial and temporal constraints). Stock Synthesis allows users to specify length-based selectivity, age-based selectivity, or both. The final selectivity curve governing each fleet/survey reflects the additive effect of both age- and length- based processes.

Unlike SEDAR 61 where only length-based selectivity was used, SEDAR 88 used both length and age-based selectivities. During initial model building, only length-based selectivities were used, however these model runs had poor agreement to the mean length at age across the fishing fleet compositions (**Section 4.6**) and the mean weight of recreational landings. Red Grouper in Gulf of Mexico presents a challenge as the length compositions for fishing fleets that are fit within the model are solely discarded fish while the age compositions fit within the model are all retained fish. Length compositions from retained fish are used to weight to the age compositions and so cannot be entered directly into the model. Several iterations were explored during model building, including: length and age-based selectivities for each fishing fleet, only age-based selectivity with length-based retention, age-based selectivity with age-based retention and hybrid age and length based selectivities (where smaller fish have length-based and larger fish have age-based selectivity). Model runs with age-based selectivity for the fleets with well-sampled age compositions (Commercial Handline, Commercial Longline and Recreational) and length based-retention had the best agreement with the mean length-at-age data and this is the approach used for SEDAR 88.

Selectivity patterns were assumed to be constant over time for each fleet and survey. The Red Grouper fishery has experienced changes in management regulation over time, which were assumed to influence the discard patterns more so than selectivity (**Figure 18**). As such, these changes were accounted for in the assessment model using time-varying retention patterns (**Section 3.1.8**) and modeling discards explicitly (**Section 3.1.10**).

3.1.7.1. Length-based Selectivity

Length-based selectivity patterns were specified for Commercial Trap and the three surveys and were characterized as one of two functional forms:

1. a two-parameter logistic function - a logistic curve implies that fish below a certain size range are not vulnerable, but then gradually increase in vulnerability with increasing size until all fish are fully vulnerable (asymptotic selectivity curve). Two parameters describe logistic selectivity: (1) the length at 50% selectivity, and (2) the difference between the length at 95% selectivity and the length at 50% selectivity.

2. the six-parameter double normal function - the double normal has the feature that it allows for domed or logistic selectivity and is a combination of two normal distributions; the first describes the ascending limb, while the second describes the descending limb. A line segment joins the maximum selectivity of the two functions. However, the double normal functional form can be more unstable than other selectivity functions due to the increased number of parameters. When robust length or age compositions are available with sufficient numbers of larger or older fish, it may be appropriate to freely estimate all parameters (especially the descending limb). If that is not the case, certain parameters can be fixed to improve model stability as long as fixing the parameter does not largely influence the point estimates of the remaining selectivity parameters. Unless strong evidence exists for domed selectivity, it is generally advisable to use the logistic function.

In the SEDAR 88 OA Base Model, length-based selectivity patterns were defined for: 1) Commercial Trap (double normal), 2) Combined Video Survey (logistic), 3) SEAMAP Summer Groundfish Survey (double normal), and the 4) NMFS Bottom Longline Survey (logistic). Logistic selectivity was modeled for the Combined Video Survey and the NMFS Bottom Longline Survey since both encountered Red Grouper throughout their size range. Dome-shaped selectivity was used for the SEAMAP Summer Groundfish Trawl Survey which surveys at the shallowest depths inhabited by Red Grouper and rarely captures large Red Grouper either due to gear avoidance, depth, or movement of Red Grouper into untrawlable habitat. All selectivity parameters were freely estimated with the exception of the Commercial Trap fishery due to data limitations (**Section 2.3.6**). Parameters for the Trap fleet were fixed at values used in SEDAR 61 except for the peak and top logit parameters which were estimated with no prior and a normal prior, respectively. The SEAMAP Summer Groundfish Trawl Survey parameters describing the ascending width as well as the starting and ending logits of the selectivity curve were poorly estimated and were fixed at values that allowed a realistic gradual increase and decrease. Overall, the SEAMAP Groundfish Summer Trawl Survey selectivity parameters were the most difficult to estimate; certain parameters were highly correlated with one another with large uncertainties. To help steer estimates towards a central value and stabilize the model, normal priors were used for those parameters.

3.1.7.2. Age-based Selectivity

Age-based selectivity was specified for Commercial Handline, Commercial Longline and Recreational using the six-parameter double normal function. The parameters were all freely estimated and if necessary due to uncertainties and correlations, normal priors were applied to parameters specifying the width and ascending limb of the plateaus. In the previous assessments of Red Grouper within the Gulf of Mexico, the double normal function was specified for Commercial Longline however, during model building it became apparent that this was not the appropriate selectivity, and a two-parameter logistic function was applied for Commercial Longline (discussed in **Section 3.4.3**). The NMFS Bottom Longline Survey is modeled using a logistic function; additionally, a logistic function is applied for the Commercial Longline in assessment models for other grouper species within the Gulf of Mexico. There is little evidence to suggest that Red Grouper are targeted differently by the Commercial Longline, necessitating a double normal function.

3.1.8. Retention

Each of the directed fleets was assumed to have regulatory discards based on selection (catch) of fish below the minimum size limit (**Figure 18**). Time-varying retention functions are commonly used in Gulf stock assessments to allow for varying discards at size due to the impacts of fishery minimum size limits and bag limits. For Red Grouper, time blocks were based on changes in the minimum size limits (federal and the state of Florida) and the implementation of the commercial IFQ program in 2010.

For each fleet, the retention function was specified as a logistic function consisting of four parameters: (1) the inflection point, (2) the slope, (3) the asymptote, and (4) the male offset inflection (not applicable to this model and assumed to be zero). Before the implementation of the federal size limit (i.e., pre-1990), all fish caught were assumed to be retained (i.e., landed) for the Commercial Handline, Commercial Longline, Commercial Trap and Recreational fleets. Beginning in 1990, all retention parameters for the Commercial Handline and Commercial Longline were estimated. Retention parameters for Commercial Trap were fixed and unchanged from SEDAR 61 due to a lack of data.

For the recreational fleet in SEDAR 61, the retention pattern for the 1986-1989 time block was assumed to be knife-edge at the size limit in Florida state waters where 100% of individuals were retained above the size limit. In SEDAR 88, the inflection point was re-estimated and fixed at this value because some recreational fishing occurs outside of Florida waters. The slope and asymptote parameters describing the retention pattern associated with the 1990 to 2022 time block were freely estimated which allowed for less than 100% retention due to bag limits and other restrictions.

The parameters for the time varying retention blocks for the commercial fleets were treated as:

Time Block	Inflection	Slope	Asymptote
pre-1990	0	Fixed at 0.25	Fixed at Maximum
1990-2009	Estimated; started at Federal size limit of 20 inches TL	Estimated	Estimated
2010-2022	Estimated; started at federal and Florida size limit of 18 inches TL	Estimated	Estimated

The parameters for the time varying retention blocks for the recreational fleets were treated as:

Time Block	Inflection	Slope	Asymptote
1986-1990	Fixed at updated estimate; Florida size limit of 18 inches TL used as initial value	Fixed at 0.5	Fixed at Maximum
1990-2022	Fixed at federal and Florida size limit of 20 inches TL	Estimated	Estimated

3.1.9. Landings and Age Compositions

Landings by fleet and associated length and age compositions were estimated using fleet-specific continuous fishing mortality rates and length-specific and age-specific selectivity curves following Baranov's catch equation.

The commercial landings were assumed the most representative and reliable data source in the model, especially over the most recent time period, because this information was collected in the form of a census as opposed to being collected as part of a survey. The commercial landings were assumed to have a lognormal error structure, with annual log-scale SEs obtained from regionally weighted estimates for the pre-IFQ period (1986-2009) and a log-scale SE of 0.01 assumed for the 2010+ post-IFQ period (**Section 2.3.1**). Annual CV estimates were provided and used for recreational landings.

A new feature available for fitting composition data in Stock Synthesis is the Dirichlet-Multinomial which differs from the standard multinomial in that it includes an estimable parameter (theta) which scales the input sample size (Thorson et al. 2017b; Methot et al. 2023). The Dirichlet-Multinomial is self-weighting, which avoids the potential for subjectivity as when the Francis re-weighting procedure is applied (Francis 2011). This approach also allows for observed zeros in the data, and the effective sample sizes calculated are directly interpretable.

The Dirichlet-Multinomial uses the input sample sizes directly, adjusted by an estimated variance inflation factor, which adjusts the overall weight of data for each fleet relative to one another based on model fit to reduce the potential for particular data sources to have a disproportionate effect on total model fit. The more positive the inflation factor, the more weight the data carry in the likelihood. The Dirichlet-Multinomial is considered an improved practice and recommended for use by the Stock Synthesis model developers and was first used in a Gulf stock assessment in 2020 for SEDAR 70 Gulf of Mexico Greater Amberjack. A normal prior was used on the Dirichlet-Multinomial parameters of 0 (SD = 1.813), which is recommended to counteract the effect of the logistic transformation between the Dirichlet-Multinomial parameter and the data weighting (Methot et al. 2023).

Because Stock Synthesis models the growth internally and tracks individual fish from birth, it virtually grows fish by length bins before eventually converting to age (based on the growth curve). As such, it is possible to fit both age and length compositions simultaneously. For SEDAR 88, the age and length composition data for each fleet/survey were assumed to follow a Dirichlet-Multinomial error structure where sample size represented the number trips, adjusted by an estimated variance inflation factor. The number of trips/sets was used as the number of observations for all fleets and surveys; this is preferred to using the number of lengths or ages as these can overestimate sample sizes in fisheries data (samples are rarely truly random or independent; Hulson et al. 2012). The final effective sample sizes for each year are provided on the figures illustrating the length and age compositions (given by N adj in each panel) in **Section 4.6.4-4.6.5**.

3.1.10. Discards

Discard data for each fleet were directly fit in the model using size-based retention functions, and a log-normal error structure was assumed. The model estimated total discards based on the selectivity and retention functions, then calculated dead discards based on the discard mortality rate (see **Section 2.2.5**). Two time-blocks were specified for the commercial longline discard mortality rates pre-IFQ (41.4%) and post-IFQ (44.1%) to more accurately implement these two rates recommended during SEDAR 61.

3.1.11. Indices

The indices are assumed to have a lognormal error structure. The CVs provided by the index standardization were converted to log-scale SEs required for input to Stock Synthesis for lognormal error structures (**Section 3.2**). For the pre-IFQ Commercial Handline and Commercial Longline CPUE indices (both landings only), the SEs were scaled to a mean SE of 0.3 (sensu Francis et al. 2003) across the entire time series, but the relative annual variation was maintained in the scaling. This is a more appropriate approach than using the output SE from the standardization routine directly in Stock Synthesis because CPUE indices can often have artificially low error estimates. The interannual variation for the fishery-independent indices were estimated through the index standardization techniques and were used to inform the error around the final observed index values.

3.1.12 Accounting for Mortality due to Red Tide

Mortality due to severe red tides has been included in Red Grouper assessments since SEDAR12 (SEDAR 2006), where an extra mortality term was estimated for 2005. Since SEDAR 42, red tide mortality has been parameterized as a bycatch fleet to model removals of Red Grouper by the red tides. All Red Grouper encountered were discarded with 100% mortality and therefore no catches were required as inputs. This approach was preferred because it allowed for the level of mortality to be estimated by the assessment model rather than input as a fixed parameter. In addition, the bycatch fleet approach gave similar results as the approach that used a fixed constant red tide mortality applied to all ages, and was thought to better represent model uncertainty due to red tide mortality events. Prior to SEDAR 88, selectivity of the red tide bycatch fleet was assumed constant at age (i.e. = 1) due to the lack of data on size-specific red tide mortality.

Two additional red tide events have occurred since the terminal year of SEDAR 61, one in 2018 and 2021, and these two years were treated as severe red tide years in the model. Constant and full selectivity-at-age was assumed during initial model building following SEDAR 61. No additional information was used as inputs to the model; rather, SS estimates mortality due to red tide solely on the contrast in other data. Modeling red tide mortality as a bycatch fleet allows for the level of mortality to be estimated by the assessment model rather than input as a fixed parameter. During the Red Tide TWG, other approaches for modeling red tide mortality were explored as the model exhibited considerable uncertainty in magnitude of the mortality for 2018 and 2021. The mortality observed in 2014 was far greater than 2005, which did not match observations nor other data (Vilas et al, 2023).

It was recommended to model red tide selectivity with empirical selectivity-at-age to provide information on differing effects on age classes across the years with observed red tide events. Empirical information for red tide events was obtained from an Ecospace module of the West Florida Shelf (WFS) Ecopath with Ecosim model (sensu SEDAR72-WP-01). Outputs from the Ecospace module provide information on mortality due to red tide events by age class for Red Grouper from ages 0-5+. This was used to derive a separate selectivity parameter for each age bin for each event. This allowed for differences in selectivities across ages in the different red tide years but necessitated the use of a separate bycatch fleets for each red tide year. The selectivity-at-age parameters were fixed and used the value from the WFS model scaled to the maximum value within a red tide year.

Stock Synthesis has been updated to model episodic environmental mortality events (such as red tide and fish kills) as a predator fleet which add mortality to the base natural mortality. Using a bycatch fleet to mimic these episodic events creates fishing mortality, which is included in total fishing mortality, however this F is not included in the MSY protocol. During the Red Tide TWG, it was recommended to model the red tide fleet as a predator fleet rather than a pseudo-fishing fleet. However, it is uncertain how this approach can be incorporated into the projection and catch allocation tools used for management of the Red Grouper in the Gulf of Mexico so while the predator approach was not used for this assessment, further research is warranted.

3.2. Goodness of Fit and Assumed Error Structure

A maximum likelihood approach was used to assess goodness of model fit to each of the data sources (e.g., catch, indices, compositions, etc.). For each separate data set, an assumed error distribution and an associated likelihood component was specified, the value of which was determined by the difference in observed and expected values along with the assumed variance of the error distribution. The total likelihood was the sum of each individual component. A nonlinear iterative search algorithm was used to minimize the total negative log-likelihood across the multidimensional parameter space to determine the parameter values that provide the best fit to the data. With this type of integrated modeling approach, data weighting (i.e., the variance associated with each data set) can affect model results, particularly if the various data sets indicate differing population trends.

Where lognormal error structures were used, annual CVs associated with each of the data sources were converted to log-scale SEs where necessary using the approximation (provided in Methot et al., 2023):

$$log_e(SE) = \sqrt{\left(log_e(1 + CV^2)\right)}$$

Weak penalty functions were implemented to keep parameter estimates from hitting their bounds (Methot et al. 2023). Parameter bounds were set to be relatively wide and were unlikely to truncate the search algorithm.

Uncertainty in parameter estimates was quantified by computing asymptotic SEs for each parameter. Asymptotic SEs are calculated by inverting the Hessian matrix (i.e., the matrix of second derivatives) after the model fitting process (Methot and Wetzel, 2013). Asymptotic SEs provide a minimum estimate of uncertainty in parameter values.

3.3. Estimated Parameters

In total, 422 parameters were estimated for the SEDAR 88 OA Base Model, of which 218 were active parameters (**Table 12**). These parameters include: the three von Bertalanffy growth parameters (L_{Amax}, L_{Amin} and K), three stock-recruit relationship parameters steepness, σR and (ln(R_0)), the stock-recruit deviations for the data-rich time period (1993-2022), year specific (1986-2022) F for each fleet, initial fishing mortality parameters for each fishing fleet, parameters informing length selectivity parameters for the Commercial Trap fleet and the three surveys, parameters informing age selectivity parameters for the Commercial Handline, Commercial Longline, and Recreational fleets, catchability parameters for each index, time-varying retention parameters for Commercial Handline, Commercial Longline, and Recreational, and 7 parameters informing the Dirichlet-Multinomial length and age composition weightings.

3.4. Model Diagnostics

3.4.1. Residual Analysis

The main approach used to address model fit and performance was residual analysis of model fit to each of the data sets (e.g., catch, indices, length/age compositions). Any temporal trends in model residuals (or trends with age or length for composition data) can be indicative of model misspecification and poor performance. It is not expected that any model will perfectly fit any of the observed data sets, but ideally, residuals will be randomly distributed and conform to the assumed error structure for that data source. Any extreme patterns of positive or negative residuals are indicative of poor model performance and potential unaccounted for process or observation error.

3.4.2. Correlation Analysis

High correlation among parameters can lead to flat likelihood response surfaces and poor model stability. By performing a correlation analysis, modeling assumptions that lead to inadequate model parameterizations can be highlighted. Because of the highly parameterized nature of stock assessment models, it is expected that some parameters will always be correlated (e.g., stock-recruit parameters or growth parameters). However, a large number of extremely correlated parameters warrant reconsideration of modeling assumptions and parameterization. A correlation analysis was carried out and correlations with an absolute value greater than 0.7 were reported.

3.4.3. Likelihood Profiles

Likelihood profiles are used to examine the change in negative log-likelihood for each data source to address the stability of a given parameter estimate, and to see how each individual data source influences the estimate. The analysis is performed by holding the given parameter at a constant value and rerunning the model. This is repeated for a range of reasonable parameter values. Ideally, the graph of negative log-likelihood values against parameter values will give a well-defined minimum, indicating that data sources agree. When a given parameter is not well-estimated, the profile plot may show conflicting signals across the data sources. The resulting total likelihood surface will often be flat, indicating that multiple parameter values are equally likely given the data. In such instances, the model assumptions may need to be reconsidered.

Typically, profiling is carried out for a few key parameters, particularly those defining the stock-recruit relationship. Profiles were carried out for the three growth parameters, $\ln(R_0)$, σR , steepness, and initial fishing mortality parameters.

3.4.4. Jitter Analysis

Jitter analysis can be used to assess model stability and to determine whether a global as opposed to a local minimum has been found by the search algorithm. The premise is that all the starting values are randomly altered (or 'jittered') by an input constant value and the model is rerun from the new starting values. If the resulting population trajectories across a number of runs converge to the same final solution, it can be reasonably assumed that a global minimum has been obtained. This process is not fault-proof, and no guarantee can be made that the 'true' solution has been found or that the model does not contain misspecification. However, if the jitter analysis results are consistent, it provides additional support that the model is performing well and has come to a stable, global solution.

For this assessment, a jitter value of 0.1 (10%) was applied to the starting values and 100 runs were completed.

3.4.5. Retrospective Analysis

Retrospective analysis evaluates the consistency of terminal year model estimates as it sequentially removes a year of data at a time and reruns the model. Mohn's Rho can be used to determine retrospective bias, with values between -0.15 to 0.2 considered acceptable for longer-lived species and values outside that range indicate of an undesirable retrospective pattern (Hurtado-Ferro et al. 2015; Carvalho et al. 2021). If the resulting estimates of derived quantities such as SSB or recruitment differ significantly, particularly if there is serial over- (+ Mohn's Rho) or underestimation (- Mohn's Rho) of any important quantities, it can indicate that the model has some unidentified process error, and requires reassessing model assumptions. It is expected that removing data will lead to slight differences between the new terminal year estimates and the updated estimates for that year in the model with the full data. Oftentimes additional data, especially composition data, will improve estimates in years prior to the new terminal year, because the information on cohort strength becomes more reliable. Therefore, slight differences are expected between model runs as more years of data are peeled away. Ideally, the difference in estimates will be slight and more or less randomly distributed above and below the estimates from the model with the complete data sets.

A five-year retrospective analysis was carried out. Retrospective forecasts were also evaluated to determine consistency between forward projections and subsequent updates with newly available data added one year at a time (Carvalho et al. 2021).

3.4.6. Additional Diagnostics

Additional diagnostics using the R package 'SS3Diags' are presented following the recommendations of Carvalho et al. (2021). Joint residual plots were used to assess goodness of model fit by identifying conflicting time series and auto-correlation of residual patterns via a Loess smoother (Winker et al. 2018; Carvalho et al. 2021). Undesirably high root mean squared error (RMSE) were values which exceeded 30%. Model misspecification was evaluated by exploring patterns in residuals of indices and compositions using a runs test, which indicates the presence of nonrandom variation (Carvalho et al. 2021). In addition, outlier data points were identified via the 3-sigma limit, where any points beyond this limit would be unlikely given random process error in the observed residual distribution (Carvalho et al. 2021).

The prediction skill of the model was tested using the hindcasting cross-validation approach of Kell et al. (2021). The mean absolute scaled error (MASE; Hyndman and Koehler 2006) was calculated for a 5-year period for each data input where available. The mean absolute scaled error scales the mean absolute error of forecasts (i.e., prediction residuals) to the mean absolute error of a naïve in-sample prediction (Carvalho et al. 2021). A skilled model would improve the model forecast compared to the baseline (i.e., random walk), with a mean absolute scaled error value of 0.5 indicative of a forecast being twice as accurate as the baseline and values >1 indicative of average model forecasts worse than the baseline (Carvalho et al. 2021; Kell et al. 2021).

3.4.7. SEDAR 61 Standard Base Model Sensitivity Runs

Sensitivity runs were first conducted with the SEDAR 61 Standard Base Model to understand how changes in data inputs provided for SEDAR 88, either due to improvements in methodology or corrections, would have influenced model results. The following data inputs were included in this analysis:

1. *Use the SRFS private mode estimates in the recreational fleet*. This run used the landings and discards estimates for the private fishing mode in Florida submitted for SEDAR 88, which included new data sources (e.g., SRFS).
2. *Update the Combined Video Index with the newer methodology used in SEDAR 88*. These runs explored the effect of replacing the original Combined Video Index with the updated methodology used in SEDAR 88 and the updated associated length compositions. The length composition sample sizes were obtained by taking the square root of the sample sizes to replicate the method used in SEDAR 61.
3. *Updating M vector with S88 M vector*. Replace natural mortality point estimate used in SEDAR 61 base model with one recommended for SEDAR 88.

3.4.8. SEDAR 88 OA Base Model Sensitivity Runs

Sensitivity runs were conducted with the SEDAR 88 OA Base Model to investigate critical uncertainty in data and reactivity to modeling assumptions. An exhaustive evaluation of model uncertainty was not carried out, but the aspects of model uncertainty judged to be the most important for model performance and accuracy were investigated.

Only the most important sensitivity runs are presented below, but many additional exploratory runs were also implemented. The order in which they are presented is not intended to reflect their importance; each run included here provided important information for developing or evaluating the base case model and alternate states of nature. Focus of the sensitivity runs was on population trajectories, improvements in fit and important parameter estimates (e.g., recruitment).

Natural Mortality - Implementing the updated natural mortality point estimate from Hamel and Cope (2022) increased stock size estimates from SEDAR 61, therefore three sensitivity runs were conducted:

1. *Low M estimate*. This run used the natural mortality point estimate with the higher maximum age of 34 (base maximum age is 29).
2. *High M estimate*. This run used the natural mortality point estimate with the lower maximum age of 24 (base maximum age is 29).
3. *S88 with S61 M*. This run used the natural mortality vector from the SEDAR 61 base model which was based on the Hoenig (1983) estimator for teleosts.
4. *S88 with S61 M and S61* ($L\infty$). This run used the natural mortality vector from the SEDAR 61 base model in the SEDAR 88 model and the externally estimated $L\infty$ value.

Steepness - Steepness is generally one of the most uncertain parameters estimated in a stock assessment model and is a critical quantity to stock assessment. To examine the effect of the estimated steepness parameter in the SEDAR 88 OA Base Model we conducted three sensitivity runs:

1. *Fix steepness at the upper bound*. Fixing steepness at the upper bound is a computational convenience to estimate average recruitment deviations rather than those from a stock-recruit curve (used for both SEDAR 61 and SEDAR 42). It is not fixed at the upper bound because we think there is perfect compensation in the population.
2. *Fix steepness at the FishLife value*.

Red tide mortality - Two sensitivity runs were conducted:

1. *Full and constant selectivity across ages (including age-0)*. This run demonstrates the selectivity approach used in SEDAR 61.
2. *No red tide mortality*. This run did not include the bycatch fleet to model red tide mortality

Growth - Two sensitivity runs were conducted:

1. *Estimate L∞ with the use of platoons*. The use of platoons mimics the effect of size selectivity on the distribution of size-at-age fish surviving the fishery.

2. *Fix L∞ at the value from the externally estimated growth curve*

Recruitment deviation method - remove constraint of forcing the recruitment deviations to sum to zero.

G-FISHER time block: applied a time block starting in 2020 to account for the updated survey methodology.

Jackknife of indices of abundance - The goal of these sensitivity runs was to determine if any single index of abundance was having undue influence on the model and causing tension with other data in terms of estimating parameters. The approach can be especially useful for identifying indices that may be giving conflicting abundance trend signals compared to the other indices. If removing a data set leads to dramatically different results, it suggests that the data set should be reexamined to determine if the sampling procedures are consistent and appropriate (e.g., an index may only be sampling a sub-unit of the stock and resulting abundance signals may only reflect a local sub-population and not the trend in the entire stock). Each index was removed and the model rerun. Other data sets (i.e., landings and composition data) were deemed fundamentally necessary to stabilize the assessment and therefore their exclusion was not included in the jack-knife analysis (i.e., a full jackknife was not conducted).

4. Stock Assessment Model - Results

4.1. Estimated Parameters

Most parameter estimates and variances were reasonably well estimated (i.e., CV < 1) for the SEDAR 88 OA Base Model (**Table 12**. Of the 218 active parameters, 6 exhibited CVs above 1 and were poorly estimated, including 4 recruitment deviations, and the two recent red tide years' fishing mortality estimates. No parameters were estimated near bounds.

Parameter distribution plots along with starting values and priors are shown in **Figure 19**.

None of the Dirichlet-Multinomial parameters were estimated at the upper bound of 5 (i.e. a weight of >99% through inverse logit transformation), therefore input sample sizes were down-weighted for all fleets and surveys:

- Commercial Fleets: length (97%) and age (82%) compositions
- Recreational length (83%) and age (42%) compositions
- Combined Video Survey length (90%) compositions
- SEAMAP Groundfish Survey (96%) compositions
- NMFS Bottom Longline length (98%) compositions.

4.2. Fishing Mortality

The exploitation rate (total biomass killed all ages / total biomass age 0+) for the entire stock are provided in **Table 13** and **Figure 20**. Since 1986, the exploitation rate for the stock has averaged around 0.136, and ranged between 0.058 in 2019 to 0.321 in 2014.

Overall, the exploitation rate declined slightly over the time frame of the assessment. Exploitation rates decreased from 1993 to 1998, then increased in 1999 and steadily declined until 2004. The exploitation rates for 2005, 2014, 2018 and 2021 include the mortality from the Red Tide fleets. The rate dropped after 2005 but then increased again peaking in 2014, and decreased over the remainder of the time series, with increases in 2018 and 2021. The terminal year (2022) exploitation rate for the entire stock was 0.059, which is below the time series mean. Similar trends in exploitation rates were observed for SEDAR 61, although higher overall exploitation rates were estimated overall (**Table 13**; **Figure 20**).

The exploitation rate for the stock was driven largely by the Recreational fleet and Commercial Longline fleet throughout the time series (**Table 14**; **Figure 21**). Commercial Handline fleet had relatively higher exploitation rates earlier in the time series (1980s) before decreasing in the 1990's. Commercial Longline exploitation rates were relatively stable across the time series with the exception in the late 2000's when a decline was observed. The exploitation rate the near the terminal year of the assessment was the lowest across the time series for Commercial Longline. Across the entire time series Recreational exploitation rates have been highly variable, ranging from a low of 0.02 to a high of 0.1. The terminal year (2022) fishing mortality rates for the Commercial Handline, Commercial Longline, and Recreational fleets were 0.012, 0.025, and 0.022, respectively (**Table 14**). Predicted dead discards with landings and discards are shown in **Figure 22**.

4.3. Selectivity

Selectivity parameters for all fleets and surveys appeared well estimated (CV < 1; **Table 12**, Label prefix "Size_"). Length-based selectivity curves estimated in Stock Synthesis for the Commercial Trap fleet were similar between assessments except for the ascending limb (**Figure 23**). Length based selectivities for the other fleets are not comparable as length-based selectivity was not used in SEDAR 88.

The Commercial Trap fleet reached 50% selection around 40 cm FL (**Table 12**), with full selection by 48 cm FL (**Figure 23**). The selectivity function estimated in SEDAR 88 slightly shifted towards smaller Red Grouper potentially due to pooling the data for SEDAR 88.

Derived age-based selectivity patterns were used to compare the ages selected between SEDAR 88 and SEDAR 61. Across all four fleets, younger fish were selected as compared to SEDAR 61 (**Figure 24**). The Commercial Handline fleet selected younger fish (50% selection by 5+ years), with the Commercial Longline fleet generally selecting Red Grouper 5+ years and Commercial Trap fleet selecting Red Grouper 5+ years. Age-based selectivity for the Recreational fleet shifted to much younger Red Grouper as compared to SEDAR 61, selecting Red Grouper 3+ years.

The Commercial Handline fleet peaked around age-5, and then declined slightly for older fish. Selectivity for the Commercial Longline fleet peaked around age-7 and remained constant for older Red Grouper (**Figure 24**). Selectivity for the Commercial Trap fleet peaked around age-7, and then declined slightly for older Red Grouper. Selectivity for the Recreational fleet peaked at 92.8% around age-3, and then significantly declined for older Red Grouper before leveling off starting at age-8.

The selectivity functions for the fishery-independent surveys estimated in SEDAR 88 shifted towards smaller and younger Red Grouper with the addition of new data. Selectivity for the Combined Video Survey reached 50% selection around 42 cm FL (**Table 12**), with full selection above 58 cm FL (**Figure 25**). This translated into full selection by 11 year (**Figure 26**). Selectivity for the SEAMAP Groundfish Survey reached 50% selection around 14 cm FL (**Table 12**), with full selection above 14 cm FL (**Figure 25**). This translated into 50% selection by 1 years, and reduced selection thereafter (**Figure 26**).

Selectivity for the NMFS Bottom Longline Survey reached 50% selection around 46 cm FL (**Table 12**), with full selection above 58 cm FL (**Figure 25**). This translated into 50% selection by 6 years, and full selection by 12 years (**Figure 26**).

Selectivity for the red tide bycatch fleets followed the fixed parameters used in the empirical selection-at-age values obtained from Vilas et al (2023); **Section 2.5.1** (**Figure 27**). Years 2014 and 2021 had the highest selectivity at younger ages with lower selectivity for older years. Year 2005 had a similar selectivity pattern observed in SEDAR 61 while 2014 had the lowest selectivity at younger ages with selectivity increasing for older ages.

4.4 Retention

The retention functions for the fleets are shown in Figures **Figures 28-31**. All retention parameter estimates and associated uncertainty are listed in **Table 12** and shown in **Figure 19** with the Label prefix "Retain_". All retention parameters appeared well estimated. For the commercial fleets, the size limit switched from 20 inches total length (TL) (50.8 cm TL, 48.80 cm FL) to 18 inches TL (45.7 cm TL, 43.97 cm FL) in 2009. The inflection point was estimated below the minimum size limit for both the Commercial Handline and Commercial Longline fleets for the time block beginning in 2010.

4.5. Recruitment

Steepness (CV) was estimated at 0.661 (0.086) which differed from the specification in the SEDAR 61 Standard Base Model (discussed in **Section 3.1.5**). The corresponding Beverton-Holt stock-recruit relationship is shown in **Figure 32**. The SEDAR 88 OA Base Model estimated a ln(R_0) (CV) at 10.713 (0.005) (**Table 12**), which equates to 44.93 million age-0 Red Grouper. The SEDAR 88 OA Base Model estimated σR (CV) at 0.647 (0.094) (**Table 12**).

Annual recruitment estimates (age-0, 1,000s of fish) from 1986 to 2022 are provided for the Gulf of Mexico (**Table 15**). The highest recruitment estimated by the SEDAR 88 OA Base Model occurred during 2006 (165.96 million age-0s), 1999 (134.54 million age-0s), 2002 (87.26 million age-0s), 1996 (82.16 million age-0s), and 2020 (68.22 million age-0s; **Table 15**; **Figures 32-33**). Between 1993 and 2022 (when recruitment deviations were estimated), estimated recruitment averaged 43.21 million Red Grouper and peaked in 2005 at 4.56 million Red Grouper (**Figure 33**). This high was followed by a sharp drop before increasing again in recent years. Recruitment trajectories were very different than those estimated in SEDAR 61, likely due to the combination of changes to input data and model settings for recruitment (**Figure 33**).

Recruitment deviations exhibited rough 1- to 2-year cycles, until 2005 where estimated deviations hit a record low before increasing and then fell below average from 2010 till 2013 while recent years have been above average except for 2021 (**Figure 34**). Recruitment deviations were relatively well estimated with the exceptions of 1993, 2000, 2016 and 2022 (CV > 1) in the SEDAR 88 OA Base Model (**Table 12**). The SEDAR 61 Standard Base Model had greater uncertainty with 8 recruitment deviations exhibiting CVs exceeding 1 where recruitment deviations were estimated (2003, 2009, 2011-2012, 2014-2017). The asymptotic SEs for recruitment deviations estimated by the SEDAR 88 OA Base Model averaged 0.21 between 1993 and 2022 and ranged from 0.063 in 2006 up to 0.539 in 2022 (**Figure 35**). Variability in recruitment was higher in SEDAR 61 Standard Base Model, where σR was estimated at 0.815 (0.137). The estimated (and applied) recruitment bias adjustment ramp is shown in **Figure 36**. Full bias adjustment was implemented for a relatively long time period.

4.6. Biomass and Abundance Trajectories

The estimated annual total biomass (metric tons), exploitable biomass (ages 0+, metric tons), SSB (relative number of eggs), SSB ratio (SSB/virgin SSB) and exploitable abundance (1,000s of fish) from 1986 to 2022 are provided in **Table 15**. Total biomass averaged 29,805 metric tons, and ranged from 23,358 metric tons in 2015 to 37,535 metric tons in 2011 (**Figure 37**). Exploitable biomass and numbers, which were comprised of Red Grouper age-0 or older, averaged 29,805 metric tons and 87,512,827 Red Grouper, respectively. Exploitable biomass was lowest in 2015 at 23,358 metric tons and peaked in 2011 at 37,535 metric tons, whereas exploitable numbers ranged from 43,743,100 Red Grouper in 2013 to 191,927,000 Red Grouper in 2006 (**Table 15**). SSB averaged 661,742 relative number of eggs, and ranged from 468,037 relative number of eggs in 2017 to 955,002 relative number of eggs in 2012 (**Figure 38**). Both total biomass and SSB show an overall relatively flat trend between 1986 and 2022 with large increases prior to the red tide years of 2005 and 2014 followed by sharp declines.

The SSB ratio averaged 0.41, and ranged from 0.29 in 2017 to 0.59 in 2012 (**Table 15**, **Figure 39**). Spawning stock biomass in the most recent year (2022) is predicted to be at 41% of the corresponding unfished spawning stock biomass (**Table 15**).

Predicted numbers at age and mean age over the entire time series for both SEDAR 61 and SEDAR 88 are shown in **Figure 40**.

4.7. Model Fit and Residual Analysis

4.7.1. Landings

Landings for the commercial fleets were fit exactly in many years given their relatively small log-scale SEs (**Tables 16-18**), however the fits for SEDAR 88 were better estimated for the commercial fleets as compared to SEDAR 61 which has higher SEs (**Figure 41**). The SEDAR 88 OA Base Model predicted higher landings in an early year for the Recreational fleet, whereas the SEDAR 61 Standard Base Model predicted lower landings during that year (**Table 19** and **Figure 41**). The Recreational fleet SEs were slightly below the fixed 0.3 yearly SEs that were used in SEDAR 61. Most landings were attributed to the Commercial Longline fleet and Recreational fleet (**Figure 42**).

The model fit the mean body weight of the recreational retained catch very well, fitting the observed mean values most years (**Figure 43**). The model slightly overestimated the body sizes before the 1990 Florida size limit and then underestimated the body size in recent years. This represents an improvement to SEDAR 61 which consistently underestimated the mean body weight of landings throughout the entire assessment period.

The mean weight of Red Grouper landed by the Commercial Longline fleet was the largest of the fleets, averaging 8.1 gutted pounds and ranged from 5.5 in 1986 to 9.3 from 2017 (**Table 17**). The Commercial Handline fleet and Recreational fleet had similar mean weights of Red Grouper, with the mean weight for Commercial Handline averaging 6.8 gutted pounds and ranging from 5.4 in 1986 to 8.3 in 2016 (**Table 16**). The mean weight of Red Grouper landed by the Recreational fleet averaged 6.3 gutted pounds and ranged from 3.9 in 1986 to 7.7 in 2015 (**Table 19**). The mean weight of Red Grouper landed by the Commercial Trap fleet averaged 6.1 gutted pounds and ranged from 4.3 in 1986 to 6.9 in 1990 (**Table 18**).

4.7.2. Discards

The time series of discards for the commercial fleets begins in 1990 (**Tables 20-22**, **Figures 45-47**). The model was generally able to fit discard observations well throughout the time series, with almost no years showing predictions falling beyond the confidence limits of the data. The exception to this is the commercial trap fleet in 1996 and 1997 as the model greatly underpredicted the observed discards.

The time series of discards for the recreational fleet began in 1986 (**Table 23**, **Figures 48**). The model was generally able to fit discard observations well throughout the time series, with only a few years showing predictions falling beyond the confidence limits of the data.

Looking at discards as a percent of total catch (**Figures 49-52**), the commercial Commercial Handline and Commercial Longline fleets exhibited a sharp drop in discard rates in 2014 and

2015. The commercial trap observed discard rate was far more variable than the modeled rates while the recreational discard rate exhibited some variability, with declines in the late 1990's, mid 2000's and the most recent years in the model.

4.7.3. Indices

Observed and expected CPUE are provided in **Tables 24-29** and **Figures 53-54**. Fits to the commercial fleet indices were reasonable in both SEDAR 88 and SEDAR 61, as the expected relative abundance fits generally followed the slight increase of the input data (**Figure 53**). The Commercial Handline was the most correlated of the fishery dependent indices (0.75) with the expected SSB. A slight reduction in fit was detected since SEDAR 61 (RMSE of 0.285 vs 0.273).

The Commercial Longline index exhibited a lower RMSE value (0.135), and a lower correlation of 0.66 with the expected SSB. The fit was slightly improved compared to SEDAR 61.

The Recreational index fit was better in SEDAR 61; however, the SEDAR 88 index was truncated in 2007 unlike in SEDAR 61 (0.504). The Recreational index had the highest RMSE of the fishery dependent indices.

Of the fishery-independent indices, the Combined Video Index had the lowest RMSE = 0.196. The fits between the SEDAR 88 and SEDAR 61 are not exactly comparable due to the updated Video index approach (SEDAR88-WP-16). The SEDAR 88 OA Base Model predicted increases in the Combined Video Survey in the most recent years, however the recent increases are below the overall trend highs (**Figure 54**).

The NMFS Bottom Longline was the most correlated of the fishery independent indices (0.73) with the expected SSB. SEAMAP Summer Groundfish Survey and Combined Video Survey indices were similarly correlated with the expected SSB (SEAMAP Summer Groundfish Survey = 0.52; Combined Video Survey = 0.53). The Combined Video Survey and SEAMAP Summer Groundfish Survey exhibited a gradual increase while the NMFS Bottom Longline trend in recent years was relatively flat.

4.7.4. Length Compositions

Aggregate model fits to the discarded length composition data for all fleets are presented in **Figure 55**. Annual fits along with residuals are presented in **Figures 56**.

Annual fits to discarded length compositions for the Commercial Handline fleet were poor in the earliest years with fits improving in recent years **Figure 57**). The Pearson residuals were reasonable (min = -1.74, max = 3.54), and some patterns were evident such as large positive residuals (underpredicting Red Grouper) around 40-50 cm TL in early part of the timeseries (**Figure 58**). Overall, the aggregated fit showed adequate correspondence to the input data with some mismatch in the smallest size classes.

Annual fits to the discarded length compositions for the Commercial Longline fleet were good, with expected and observed peaks corresponding in many years (**Figure 59**). The Pearson residuals were relatively small (min = -1.18, max = 1.65), but clusters of large positive residuals (underpredicting Red Grouper) occurred around 40 cm TL in the 2010s (**Figure 60**). Overall, the aggregated fit showed good correspondence to the input data with the exception to the fit to the smallest fish.

Annual fits to retained length compositions for the Recreational fleet were good, with expected and observed peaks corresponding recent years (**Figure 61**). The Pearson residuals were large (min = -2.12, max = 6.42), and some patterns were evident such as large positive residuals (underpredicting Red Grouper) from 2005-2013 between 20-40 cm TL (**Figure 62**). Overall, the aggregated fit showed adequate correspondence to the input data.

Annual fits to length compositions for the Combined Video Survey were relatively good despite the large inter-annual variability in the underlying length composition data (**Figure 63**). The overall aggregated fit was good with a slight mismatch at the smallest fish. The Pearson residuals were relatively small (min = -2.84, max = 4.38) (**Figure 64**). No clear patterns in residuals were evident.

Annual fits to length compositions for the SEAMAP Summer Groundfish Survey were also poor due to the large inter-annual variability in the underlying length composition data, again with most years suffering from lower sample sizes (**Figure 65**). The overall aggregated fit was reasonable, as there was minimal data in the smallest size bins (**Figure 55**). The Pearson residuals were relatively large (min = -2.23, max = 10.77), exhibited no strong patterns except for large positive residuals (underpredicting Red Grouper) in the smallest size bins (**Figure 66**).

Annual fits to length compositions for the NMFS Bottom Longline were reasonable given the large inter-annual variability in the underlying length composition data (**Figure 67**). However, the overall aggregated fit was good (**Figure 55**) and was an improvement from SEDAR 61. The Pearson residuals (min = -2.23, max = 10.77) were smaller than those observed in the SEDAR 61 Standard Base Model. No strong patterns in residuals were evident (**Figure 68**).

4.7.5. Age Compositions

Aggregate model fits to the retained age composition data for all fleets are presented in **Figures 69 and 70**. Overall, the aggregated fits showed good correspondence to the input data and were an improvement to the aggregated fits shown in SEDAR 61.

Annual fits to the weighted retained age compositions for the Commercial Handline fleet showed considerable variability in the input data and varying levels of agreement between observed and expected compositions in early years (**Figures 71-72**). The Pearson residuals did not reveal any concerning magnitudes (min = -3.32, max = 6.45), but clusters of positive residuals occurred starting in 2009 for ages 3-7 Red Grouper (**Figure 73**). Mean age was highest in 2015, declined to the lowest values in 2010 and 2020 (**Figure 74**). Expected mean age (range: 6.5-8.5 years) was much less variable compared to observed mean age (range: 5-9), and remained within the 95% confidence intervals of observed mean age for nearly all years. Agreement between observed and expected mean length-at-age was generally better for later years (**Figure 75**). The Pearson residuals for the mean length-at-age were relatively large (max = 10), but some patterns were evident such as large positive residuals (underpredicted Red Grouper) in many age classes in the early 2000s (**Figure 76**).

Annual fits to the weighted retained age compositions for the Commercial Longline fleet showed considerable variability in input data and reasonable agreement between observed and expected compositions, particularly in recent years (**Figures 77-78**). Overall, the aggregated fit showed excellent correspondence to the input data. The Pearson residuals were relatively moderate (min = -2.52, max = 6.12) and did not have any obvious patterns (**Figure 79**). Mean age was highest around 2015 and stayed relatively consistent between the mid-1990s until 2006 (**Figure 80**). Differences in observed (range: 7 to 9 years) and expected (range: 5 to 10 years) mean age were evident, although the expected mean age remained within the 95% confidence intervals of the observed mean age for all years. Agreement between observed and expected mean length-at-age was good starting in 2003 (**Figure 81**). Large positive residuals (underpredicting Red Grouper) occurred from 1993-2002 (**Figure 82**).

Annual fits to weighted age compositions for the Commercial Trap had the poorest fit due to the low sample size and the need to treat the age composition as a super-period (**Figure 83**). The Pearson residuals did not reveal any concerning magnitudes (min = -1.1, max = 0.97) (**Figure 84**).

Annual fits to weighted age compositions for the Recreational fleet showed reasonable agreement between observed and expected compositions given the smaller sample size and patchiness of data (**Figures 85-86**). Overall, the aggregated fit showed adequate correspondence to the input data with the exception of the peak. The Pearson residuals had some concerning magnitudes (min = -2.68, max = 54.03), and a strong residual pattern of large positive residuals (underpredicting Red Grouper) between 4-10 years beginning in 2002 and another from 3-15 years starting in 2009 (**Figure 87**). Efforts were made to try to account for this residual pattern observed in Recreational compositions during the model building phase. There was no discernible improvement to the observed residual pattern by shifting from length-based selectivity to age-based selectivity individually for each fleet or by changing to age-based retention. Freeing the fixed parameters from SEDAR 61 did not change the pattern nor did re-fixing parameters at updated values. There is a less obvious residual pattern observed in the same two periods in SEDAR 61. Mean age was relatively constant and declined before 2005 and again in 2020 before increasing from 2010-2016 (**Figure 88**). Differences in observed (range: 5-8 years) and expected (range: 4-9 years) mean age were evident, although the expected mean age remained within the 95% confidence intervals of the observed mean age all years (**Figure 88**). Agreement between observed and expected mean length-at-age was generally poor given the lack of data for several ages (**Figure 89**). The Pearson residuals for mean length-at-age had some concerning magnitudes (max = 100), and strong patterns were evident such as large negative residuals (overpredicting Red Grouper) across the youngest ages (**Figure 90**).

4.7.6. Red Tide Mortality

Red tide was detected in all four years included in the model (2005, 2014, 2018 and 2021) (**Section 2.5.1; Figure 22**). Red tide mortality was estimated at 0.17, 0.2, 0.04 and 0.1, respectively. This corresponds to removals of 5.94, 5.04, 2.13 and 6.68 million Red Grouper, respectively.

4.8. Model Diagnostics

4.8.1. Correlation Analysis

Given the large numbers of parameters that were estimated within SEDAR 88 OA Base Model, some parameters were mildly correlated (correlation coefficient > 70%) and one combination displayed a strong correlation (> 95%; **Table 30**).

High correlation occurred between the growth parameters K and L_{Amax} which is to be expected. Moderate correlations occurred between the parameters defining the width of the ascending limb and the peak of the double normal size selectivity function for the Commercial Handline, and the parameters defining the descending limb and the width of the plateau of the double normal size selectivity function for the Recreational fleet.

4.8.2. Likelihood Profiles

The total likelihood component from the ln(R_0) likelihood profile indicates that the global solution for this parameter is approximately 10.7 (**Figure 91**), with the SEDAR 88 OA Base Model estimating ln(R_0) at 10.713, which is within one likelihood unit of the global solution.

The total likelihood component from the σR likelihood profile indicates that the global solution for this parameter is approximately 0.64 with the SEDAR 88 OA Base Model estimating σR at 0.647 (**Figure 92**).

The total likelihood component from the steepness likelihood profile indicates that the global solution for this parameter is approximately 0.65 (**Figure 93**), with the SEDAR 88 OA Base Model estimating steepness at 0.661, which is within one likelihood unit of the global solution.

The total likelihood component from the K likelihood profile indicates that the global solution for this parameter is approximately 0.0925 (**Figure 94**), with the SEDAR 88 OA Base Model estimating K at 0.092, which is within one likelihood unit of the global solution.

The total likelihood component from the L_{Amin} likelihood profile indicates that the global solution for this parameter is approximately 19.75 with the SEDAR 88 OA Base Model estimating L_{Amin} at 19.724 (**Figure 95**).

The total likelihood component from the L_{Amax} likelihood profile indicates that the global solution for this parameter is approximately 92.5 with the SEDAR 88 OA Base Model estimating L_{Amax} at 92.41 (**Figure 96**).

The total likelihood component from the initial fishing mortality likelihood profiles are shown in **Figures 97-100**).

The bivariate likelihood profile for σR and steepness parameters are shown in **Figure 101** and the bivariate likelihood profile for the L_{Amax} and K are shown in **Figure 102**.

4.8.3. Jitter Analysis

No jitter runs demonstrated a lower negative log-likelihood solution than the SEDAR 88 OA Base Model, and 34% and 37% of runs converged to the same likelihood solution or within 5 negative log-likelihood unit, respectively (**Figure 103**). For the remaining runs for the SEDAR 88 OA Base Model, given that the total negative log-likelihood values were much higher than that of the SEDAR 88 OA Base Model, it is probable that non-optimal solutions were found (i.e., the model search was stuck in local minima). Given these results, the jitter analysis indicates that the SEDAR 88 OA Base Model is relatively stable and reached the global solution.

4.8.4. Retrospective Analysis

Results from the retrospective analysis do not indicate any directional retrospective patterns. As the last few years of data are peeled off, the model estimates of SSB, recruitment and *F* in each successive terminal year do not change by a large margin and confidence intervals overlap (**Figures 104-106**).

Mohn's rho, which measures the severity of retrospective patterns, was equal to 0.08 and -0.20 for the SSB and *F* time series (**Table 31**), respectively, which is within or near the acceptable range (-0.15 to +0.20; see Hurtado-Ferro et al. (2015)).

4.8.5. Additional Diagnostics

The SEDAR 88 OA Base Model displayed acceptable RMSE (<30%) for the joint residuals for mean age and mean length data sources but not for the indices (**Table 32**). Residuals revealed some conflict in indices of abundance and mean age (evident by colored vertical lines in opposite directions) and trends in the residuals (evident by Loess smoothed line; **Figure 107**). The lowest RMSE was exhibited for the age composition, which exhibited the smallest residuals but did reveal some conflicts (**Table 32**; **Figure 107**).

Runs test results revealed evidence of non-randomly distributed residuals for the Handline, Recreational, Combined Video Survey and the SEAMAP Summer Groundfish Survey indices of abundance (**Figure 108**), Commercial Longline and SEAMAP Summer Groundfish Survey length compositions (**Figure 109**) and Recreational age compositions (**Table 33**; **Figure 110**). Outliers (evident by red points) were identified in the residuals for the Combined Video Survey index, residuals for mean age for Commercial Handline and Commercial Longline fleets, and in residuals for length compositions for the Commercial Handline, Recreational, and Combined Video Survey.

Superior prediction skill (<1) was evident over the naive baseline forecast for the mean age for the Commercial Handline fleet (**Figure 111**) and mean length for the Commercial Handline, Commercial Longline fleet, Recreational, and NMFS Bottom Longline (**Figure 112**; **Table 34**). The lowest predictive skills were from the Combined Video Survey index at the value of 1.98 (**Figure 113**).

4.8.6. Bridging Analysis

The general flow of model building runs that led to the SEDAR 88 OA Base Model is shown in **Table 35**. Changes in estimated quantities starting from the SEDAR 61 Standard Base Model are shown in **Figures 114-115**.

Model building occurred in phases, starting with replacing the MRIP private mode landings and discards from Florida with the SRFS estimates in the original SEDAR 61 Standard Base Model

(Step 1). The NLL increased and the virgin recruits decreased (**Table 35**). Steps 2 and 3 involved removing the indices that were recommended to be dropped from SEDAR 88 from SEDAR 61. Step 4 involved updating all data streams and maintaining the model structure of the SEDAR 61 Standard Base Model ("Continuity" model). Differences in key derived quantities were particularly evident since the late 1990s for the Continuity Model, with additional years of data causing SSB to decrease until about 2005 before returning to the SEDAR 61 Standard Base Model trend line (**Figure 114**). The Continuity model also estimated slightly higher σR and a lower ln(R_0) (**Table 35**). Changes in data streams (e.g., landings, compositions) were likely a large reason for these differences (see **Section 4.7.7**). Step 5 extended the data streams to the new terminal year of 2022 without changing the model structure (**Table 35**; **Figure 114**). This caused an increase of the spawning output at the start of the model and had the highest σR of any steps in the model building process. Step 6 added in the mean weight of the catch from the Florida private mode; **Table 35**) which had a minimal effect on the observed trends (**Table 35**; **Figure 114**).

The addition of Dirichlet-Multinomial parameters to the model for weighting age and length compositions in Step 7 shifted SSB lower (**Table 35**) and *F* slightly lower throughout the time series (**Figure 115**). Step 8 freed the parameters that had been previously fixed in SEDAR 61 Standard Base Model (except for the parameters in the earliest time block, as there was not sufficient data to estimate those) (**Table 35**; **Figure 115**). This increased the SSB across the time series. Step 9 updated the natural mortality point estimate and had a large effect on the overall model, greatly increasing the SSB across the time series. The estimated virgin recruits increased from 19,646 (thousands) to 55,066 (thousands) (**Figure 115**). Between step 9 and step 10 there were several intermediate steps of adjustments to selectivity patterns including attempting both length- and age-based selectivities on the same fleets or surveys. The model exhibited convergence issues as well as several bounding or poorly estimated parameters. Step 10 implemented age selectivity on three of the fishing fleets as there were poor agreement between the mean length at age for the three fleets with available data using length-based selectivity. Using dome-shaped selectivity for the longline fleet inflated the SSB and step 11 uses a more appropriate logistic selectivity for the longline fleet. Step 12 freely estimates the Linf parameter and Step 13 estimates the steepness parameter while the proposed base includes several refinements of adjusting initial parameter estimates with priors and the recruitment ramp bias adjustment.

4.8.7. SEDAR 61 Standard Base Model Sensitivity Runs

Results for the sensitivity runs summarized in **Section 3.4.7** for the SEDAR 61 Standard Base Model are presented in **Table 36**. The derived quantities for the sensitivity run using SRFS estimates in lieu of MRIP estimates, generally remained within the confidence intervals of estimates from the SEDAR 61 Standard Base Model with the exception of the time period of 1986 - 2005 (**Figure 116**). Inputting the SEDAR 88 natural mortality vector to SEDAR 61 Standard Base Model had a large impact on model results, as it changed the scale of the outputs (**Figure 117**). Updating the Combined Video Index had a minimal effect on model results (**Figure 118**). Length composition data was available from 2002 onwards for the Combined Video Index while length compositions began in 2008 for SEDAR 61; the inclusion of the earlier length composition samples and updated length compositions had a minimal effect on the trend.

4.8.8. SEDAR 88 OA Base Model Sensitivity Runs

Results for the sensitivity runs summarized in **Section 3.4.8** for the SEDAR 88 OA Base Model are presented in **Table 37** and discussed below.

Natural Mortality

Adjusting the point estimate used to develop the natural mortality vector had a significant effect on the final model estimates with large differences in scale, with the high natural mortality vector resulting in a greatly increased SSB (doubling the estimates using the SEDAR 61 vector). The effect on the *F* timeseries was not as pronounced and the low natural mortality and old natural mortality vector had similar results in the terminal year in recent years (**Table 37; Figure 119**).

Red Tide Mortality

The removal of the red tide from the model decreased the spawning out and fraction of unfished timeseries (**Tables 37**) and resulted in lower annual SSB, recruitment, or *F* estimates (**Figure 120**).

Modeling red tide age-selectivity at constant full selectivity starting at age 0 had minimal impacts on the overall timeseries with some difference observed in 2018 and 2021 for F (**Figure 121**). The mortality in 2005 was larger than 2014 with full selectivity most likely because of the empirical selectivity-at-age curve for 2014 (**Table 38**).

Steepness

Fixing the steepness value at the biologically plausible estimate obtained from FishLife had a minimal effect to the overall time series for SSB and F and slight reduction in the virgin recruits (**Figure 122**). Fixing the value at the upper bound also had a minimal impact on the results (**Table 37**). Small differences in trajectories were evident, with the higher steepness value resulting in a slightly higher SSB (but still within the confidence interval of the SEDAR 88 OA Base Model) and some discernible differences in *F* for years with red tide mortality included in the model (**Figure 123**).

Growth

Estimating $L\infty$ with the use of platoons had a slightly higher NLL than estimating $L\infty$ without the use platoons. Platoons should be further investigated for inclusion in models with length-based selectivities. Estimating $L\infty$ or fixing at the external growth model did not have significant effects to the overall timeseries (**Figure 124**).

Recruitment Deviation Method

Removing the constraint of forcing the recruitment deviations to sum to zero had a large effect on the scale of the SSB as well as the pattern observed in recruits (**Table 37** and **Figure 125**).

G-FISHER

Placing a time block in G-FISHER in 2020 reduces the spawning stock biomass at the end of the time series as well as the spawning stock ratio (**Table 37** and **Figure 126**).

Jack-knife Analysis on Indices of Abundance

The removal of one index at a time indicated that the Combined Video Survey index has a very large influence on estimates of key derived quantities (**Table 37**; **Figure 127**). The removal of the NMFS Bottom Longline index led to slightly lower SSB estimates (and SSB ratios, with a lower terminal value of 0.43), but fell within the confidence intervals of the SEDAR 88 OA Base Model.

5. Discussion

This Operational Assessment for Gulf of Mexico Red Grouper implemented a number of new or improved procedures and methodologies including the following:

- Revised estimates of commercial landings and discards
- Revised estimates of recreational landings and discards (via SRFS)
- Incorporated yearly error estimates in landings and discards to better reflect uncertainties
- Updating the age composition weighting procedures
- Re-evaluating and estimating steepness
- Estimating the growth curve internally within Stock Synthesis
- Utilized the Dirichlet-multinomial error distribution for composition data (Thorson et al. 2017)
- Updated the natural mortality point estimate to current best practices
- Used age selectivity on the fleets with weighted age compositions
- Used empirical selectivity-at-age for red tide years which were informed by the West Florida Shelf Ecospace Model
- Extended population age bin to maximum age of 29

Collectively, these changes to data inputs and model parameterization greatly affected the assessment results and improved many aspects of model performance.

Overall, the SEDAR 88 OA Base Model appears to perform well and exhibited some noticeable improvements in performance over the SEDAR 61 Standard Base Model, including more parameters that could be freely estimated, improved fits to age compositions, improved fits to discards and excellent fits to the mean weight of recreational landings. The SEDAR 88 OA Base Model fit most of the data sources well although some did exhibit the same residual patterns seen in the SEDAR 61 Standard Base Model.

The new data available since SEDAR 61 (terminal year of 2017) represented updated data analysis with the current best practices. Given the large number of changes in data inputs compared to SEDAR 61, particularly concerning landings, discards, surveys and compositions, the potential effects on model results were explored for the SEDAR 61 Standard Base Model. Using SRFS for estimating recreational landings and discards for the private mode led to slightly lower estimates compared to SEDAR 61 (detailed in SEDAR88-WP-02, SEDAR88-WP-08 and SEDAR88-WP-17); however, the use of this data set as a replacement for MRIP-FES estimates was only possible as the primary recreational fishery for Red Grouper occurs in Florida. The lower estimates of removals led to minor changes in the ending SSB however the differences in the fraction of unfished trajectory were most apparent in the time period between 1990 and 2005.

The two largest changes observed in model trends were from updating the natural mortality vector and using the updated Combined Video Index index with improved methodologies through the G-FISHER project. The natural mortality point estimate represents the current best practice for obtaining the natural mortality estimator. Research into other methods, including internally estimating M should be investigated further (and are listed in the Research Recommendations section). Using the updated Combined Video Index in SEDAR 61 increased the SSB trajectories slightly towards the end of the time series. The SEDAR 88 base model is closely tracking the trend observed in the Combined Video Index and the removal of that index in the jack-knife analysis further demonstrates the large influence it has on the model results. Of the three fishery-independent indices used in the model, the Combined Video Survey has the worst fit in the model. The inclusion of a time block coinciding with the implementation of the G-FISHER program in 2020 resulted in a lower spawning output at the end of the time series. The mortality due to red tide in 2018 was greatly increased with the use of the time block, which further highlights the high uncertainty still in the model around red tide. This could be the result of lack of contrast between data sources or that the most recent red tide years are very close to the terminal year. Additional years of data in the next assessment will hopefully clarify the effect of red tide. The implementation of the updated G-FISHER program may necessitate the use of time blocks given the updated methodology and survey design.

The dominant data inputs were the length and age compositions as these produced the greatest impact on the model fit (as measured in the total likelihood). The overall total likelihood was much higher than in SEDAR 61 with the additional years of data, largely due to the use of the Dirichlet-multinomial error distribution. One of the improvements observed in SEDAR 88 was the inclusion and fitting to the mean length at age data for each fleet with the light lambdas applied and fitting to the mean body weight of landings for the recreational fleet. A concern noted during the interim analysis after SEDAR 61 was the underestimation of body size within the model as compared to what was observed in the ACL monitoring. During the model building phase, the model did underestimate the size of fish as evident in the mean length-at-age when only length selectivities were applied to the fishing fleets. Using age selectivity for the Commercial Handline, Commercial Longline and Recreational improved fits to the mean weight of recreational landings and improved the fits to the mean length at age. Using only length selectivity has the potential to underestimate the lengths of the oldest fish, particularly if there is a mismatch in the growth curve or the growth curve has changed due to fishing pressure.

The model estimated a larger $L\infty$ than the externally estimated growth curve which was fitted during SEDAR 61. This could be the result of the effect of the size selective fishing pressure that Red Grouper has experienced over time. The red grouper fishery in the Gulf of Mexico has records dating back to the mid-1880s (SEDAR 12, WP–DW-11), and contemporary data have the potential to underestimate the population level growth parameters (McGarvey et al, 2024). Faster growing fish tend to be more vulnerable to the fishery at a younger age and, as a consequence, the fish that survive the fishery tend to be smaller than the projected growth of the fish that have not entered the fishery. It is possible to capture the variability of the distribution of size-at-age within Stock Synthesis with the use of platoons while estimating the growth curve internally. However, this approach relies heavily on length data and has yet to be used within a Stock Assessment in the Gulf. More investigation is warranted on the effectiveness of platoons within a model with age-based selectivity and more focused on age compositions than length compositions.

A residual pattern in the recreational age composition was observed beginning around 2003 to 2010 and another period beginning in 2013, which suggests that the model is underpredicting a cohort. A similar misfit was also evident in SEDAR 61, and it remains difficult to determine whether this is an issue with the data, or if this cohort may have been selected by another fleet.

SEDAR 88 has slightly smaller uncertainty surrounding the SSB trajectories as compared to SEDAR 61 (**Figure 38**). The use of year specific CVs for both the recreational and commercial landings and the discard estimates had slightly smaller CVs than those utilized in SEDAR 61.

While the overall uncertainty is lower, it does exist within the model. Uncertainty arises from recruitment estimates. In particular, the jitter shows several possible runs with a lower negative log likelihood within recruitment however this did not translate into a lower total negative log likelihood (**Figure 103**). During model building, recruitment deviations were not forced to sum to zero and these runs estimated higher, very uncertain levels of age-0 recruits in recent years. Recruitment estimates and their deviations are often the place where the model absorbs noise, which is what is likely happening in those errant jitter runs.

During model building, the inclusion of 2018 and 2021 as red tide years yielded low and uncertain amounts of mortality, particularly for 2018. When recruitment deviations were not forced to sum to zero, red tide mortality was observed in 2018 and 2021 with lower levels of uncertainty, however, the CVs were still above 1 and the uncertainty around the recruits for those years was quite high. Once the model was more appropriately configured, the uncertainties observed around red tide mortality in 2018 and 2021 were greatly reduced but still high. However, there is still the possibility that there is some noise or conflict in the model that the red tide fleets are capturing, or that additional data collection will reveal more information for the red tide estimates (e.g., age compositions from the fishery which are lagged by a few years).

The red tide years of 2005 and 2014 in SEDAR 61 had significant estimated mortality as in SEDAR 88. The dead biomass was similar in 2005 and 2014 (14% and 13% biomass, respectively) but a greater percentage by numbers of fish killed was observed in 2005 (12%) compared to 2014 (6%). However, in 2021 the biomass killed due to red tide (5%) was lower than 2005 but the numbers killed much larger (6,682) suggesting that smaller and younger fish were disproportionately impacted in 2021 than in the other red tide years. This is reflected in the selectivity curves used for the 2021 red tide pseudo-fishing fleet as younger age classes have the higher proportion of selectivity. This selection of young fish is not solely the result of the empirical age-at-selectivity curve as the run with constant full selectivity exhibited a similar pattern. The mortality due to red tide in SEDAR 61 was greater in 2005 and 2014 than observed in SEDAR 88.

A key modeling uncertainty for the Gulf of Mexico Red Grouper stock assessment and most assessment models in general, is the stock-recruit relationship. During model building, steepness was initially fixed at a biologically plausible value obtained from FishLife. Diagnostic sensitivity runs showed that steepness was estimable with a low CV and its estimation was further explored. Steepness was fixed at the upper bound for the SEDAR 61 Standard Base Model to allow projections using recent recruitment, but steepness was estimated in two sensitivity runs. The steepness value of 0.735 ($CV = 0.083$) estimated without a prior had a similar value to the steepness estimated with a prior, 0.728 ($CV = 0.079$). While the estimated steepness parameters had low CV, the diagnostics for the sensitivity runs had poorer overall diagnostics. The SEDAR

61 Standard Base Model had a larger number of years (2003, 2009, 2011-12, 2014-17) with high uncertainty (CV > 1) around recruitment deviations than observed in SEDAR 88 OA Base Model (1993, 2000, 2016, 2022). For this assessment report, benchmarks were determined through projections (see **Section 6**) using the stock-recruit curve.

In the past, the argument that an inability to estimate steepness meant that MSY-based reference points are not supported by the results. However, as steepness is estimated in the assessment, it is possible to provide MSY-based benchmarks and provide a comparison with the proxy(ies) currently used or under consideration. While the current proxy for Red Grouper is 30% SPR, this decision should be re-evaluated considering recent changes to proxies for Gulf of Mexico Scamp Grouper (from 30% SPR to 40% SPR) and Gag Grouper (from FMax to 40% SPR). Simulations conducted by Harford et al. (2019) suggest that SPR ratios of 40% or 50% led to the highest probabilities of achieving long-term MSY for hermaphroditic stocks. They found that more conservative fishing mortality proxies were required to achieve MSY-based fishery objectives when steepness was “least certain” (i.e., uniform prior).

While some aspects of the model were greatly improved upon, some outstanding issues remain and would benefit from future investigation. A number of research questions were raised during the SEDAR 88 assessment process. While attempts were made to address these questions through sensitivity runs and preliminary data exploration, the timeframe of this assessment did not leave enough time to thoroughly evaluate each and every one of these questions. The SEFSC recommends that these topics (listed in **Section 8**) be more thoroughly examined during a future assessment with targeted topical working groups.

Overall, the SEDAR 88 OA Base Model is an improvement over the SEDAR 61 Standard Assessment, it incorporates the best available data and practices and addressed some of the issues evident in the Standard Assessment. According to the SEDAR 88 OA Base Model, the Gulf of Mexico Red Grouper resource is not overfished nor undergoing overfishing in 2022. Further, some concerning trends in recent recruitment warrant careful consideration for management implementation. As shown in **Figure 33**, recruitment estimates in the late years of the assessment (2015-2022) are much higher than previous years (2005-2012).

6. Projections

6.1. Introduction

Two sets of projections were run: one using the SPR proxy specified in the Terms of Reference and the other using MSY given steepness was estimable. For each set, projections were run for two key fishing mortality scenarios: $F_{MSYproxy}$ or F_{MSY} and 0.75 * Directed *F* at $F_{MSYproxy}$ or F_{MSY}. Both an MSY proxy of 30% SPR ($SPR_{30\%}$) and the OY (0.75 * MSYproxy) were specified for Red Grouper in Amendment 44 (GMFMC 2017) and provided in the SEDAR 88 Terms of Reference.

6.2. Projection Methods

The simulated dynamics used for projections assumed nearly identical parameter values and population dynamics as the SEDAR 88 OA Base Model. **Table 39** provides a summary of projection settings. Projections were run assuming that relative *F* and selectivity associated with the last three years (2020-2022) would remain the same into the future. Forecast recruitment values were derived from the model-estimated Beverton-Holt stock-recruit relationship.

The terminal year of SEDAR 88 was 2022 and the first year of management advice will be 2027. Retained catch for the interim years (2023-2026) used landings estimates for 2023 and the average of the last three years of retained catches (2021-2023) for 2024 through 2026 (**Table 39**).

$F_{30\%SPR}$ and F_{MSY} were determined using a long-term 100-year projection assuming that equilibrium was obtained over the last 10 years (2113-2122). For the OFL projection, the $F_{30\%SPR}$ or F_{MSY} was applied to the stock starting in 2027. The fleet allocations for Red Grouper are 59.3% commercial and 40.7% recreational per Amendment 53 (GMFMC 2021).

The status determination criteria for Gulf of Mexico Red Grouper were updated in Amendment 44 (GMFMC 2017). The minimum stock size threshold (MSST) was determined by multiplying the reference spawning stock biomass, SSB_{MSY} or $SSB_{30\%SPR}$, by 0.5 (per Amendment 44 and the SEDAR 88 Terms of Reference) and was used to determine stock status (**Table 40**). The maximum fishing mortality threshold (MFMT) was equivalent to the harvest rate ($F_{30\%SPR}$ or F_{MSY}; total biomass killed all ages / total biomass age 0+) that achieved $SSB_{30\%SPR}$ or SSB_{MSY} and was used to assess whether overfishing was occurring in a given year (**Table 41**). A stock is considered overfished when $SSB_{Current}$ < MSST and undergoing overfishing if $F_{Current}$ > MFMT, where $F_{Current}$ is defined as the geometric mean of the fishing mortality over the most recent three years (2020-2022).

Once the proxy values were calculated, 2022 stock status was used to determine whether a rebuilding plan was required (i.e., if SSB < MSST then Gulf of Mexico Red Grouper would be considered overfished, and a rebuilding plan would be required).

6.3. Projection Results

Benchmarks and reference points were calculated assuming an SSB defined in terms of relative number of eggs.

6.3.1. Biological Reference Points

The status determination criteria for Red Grouper based on an MSY proxy of 30% SPR were: (**Table 40**; **Figure 128**).

- MSY proxy = yield at $F_{30\%SPR}$ = 7,210,540 pounds gutted weight
- MSST = 0.5*$SSB_{30\%SPR}$ = 159,395 relative number of eggs
- MFMT = $F_{MSYproxy}$ ($F_{30\%SPR}$) = 0.203
- OY = 0.75*MSY proxy = 6,489,486 pounds gutted weight

The status determination criteria for Red Grouper were: (**Table 41**; **Figure 129**).

- MSY proxy = yield at F_{MSY} = 7,976,205 pounds gutted weight
- MSST_MSY = 0.5*SSB_{MSY} = 313,206 relative number of eggs
- MFMT = F_{MSY} = 0.13

- OY = 0.75*MSY = 7,178,584 pounds gutted weight

6.3.2. Stock Status 30%SPR

Benchmarks and reference points are shown in **Table 40**. Detailed time series of derived quantities and benchmarks with SSB defined as relative number of eggs are presented in **Table 42**. As of 2022, the Gulf of Mexico Red Grouper stock is not undergoing overfishing ($F_{Current}$ > MFMT) and is not overfished (SSB_{2022} > MSST) according to the SEDAR 88 OA Base Model. The terminal year SSB (2022) is above $SSB_{30\%SPR}$ (**Figure 128**) at 207% of the biomass level needed to support MSY (**Table 42**). From 2020 to 2022 the estimated stock harvest rate, using the geometric mean, was 0.085, which was equivalent to 42% of $F_{30\%SPR}$.

The Kobe plot (**Figure 130**) indicates that over the time horizon of the assessment (i.e., 1986-2022), the stock has not been overfished in any year since 1986 but has experienced overfishing for one year (**Table 42**).

6.3.3 Stock Status MSY

Benchmarks and reference points are shown in **Table 41**. Detailed time series of derived quantities and benchmarks with SSB defined as relative number of eggs are presented in **Table 43**. As of 2022, the Gulf of Mexico Red Grouper stock is not undergoing overfishing ($F_{Current}$ > MFMT) and is not overfished (SSB_{2022} > MSST) according to the SEDAR 88 OA Base Model (**Table 41**). The terminal year SSB (2022) is above SSB_{MSY} (**Figure 129**) at 105% of the biomass level needed to support MSY (**Table 43**). From 2020 to 2022 the estimated stock harvest rate, using the geometric mean, was 0.085, which was equivalent to 65% of F_{MSY} (**Table 41**).

The Kobe plot (**Figure 131**) indicates that over the time horizon of the assessment (i.e., 1986-2022), the stock has not been overfished in any year since 1986 but has experienced overfishing for multiple years (**Table 43**).

6.3.4. Overfishing Limit and Acceptable Biological Catch Projections 30%SPR

OFL and ABC projection results **assuming predicted recruitment follows the stock-recruit curve** are provided in **Tables 44-46** and **Figure 132**.

6.3.5. Overfishing Limit and Acceptable Biological Catch Projections MSY

OFL and ABC projection results **assuming predicted recruitment follows the stock-recruit curve** are provided in **Tables 45-47** and **Figure 133**.

7. Acknowledgements

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8. Research Recommendations

Recommendations for considerations of future research are provided below and do not indicate any particular order of priority.

Stock Structure
- Better understanding of the population genetics throughout the Gulf of Mexico and connectivity with the Atlantic

Age and Growth
- Investigate methods to better collect age structure samples randomly and systematically from all fishing sectors including surveys - Continue collaboration with ageing facilities throughout the Gulf of Mexico and South Atlantic. These efforts will include the annual reading of references sets for Red Grouper and other reef fish, and annual meetings to review the interpretation of ageing structures and the timing of annual band deposition

Natural Mortality
- Explore more direct approaches to estimating natural mortality (e.g., Mark-recapture approaches (conventional, telemetry, or close-kin))
- Explore ways to better reflect uncertainty around the mortality at age vector

Reproduction
- Continue data collection for maturity, sex transition, and fecundity as detailed in the SEDAR 42 Benchmark Assessment DW Report Recommendations
- Investigate implications of estimating internal growth curve on length and age bases fecundity vector

Discard Mortality
- Continue data collection from observer programs or electronic monitoring programs (e.g., SEDAR88-WP-14)

Commercial Landings
- Explore approaches for assigning uncertainty estimates to commercial landings and revisit estimation of historic landings

CPUE Indices
- Consider developing indices of relative abundance from observer program data (e.g., SEDAR68-AW-04). Observer data would provide finer spatial resolution, a more accurate measure of CPUE, size frequency and discard information

Age and length composition
- Quantify and evaluate appropriate modeling and weighting procedures of length and age compositions to ensure age and length composition inputs are representative of the segment of the population being modeled

Selectivity and catchability
- Further investigate and quantify changes in selectivity/catchability through time to improve fit to the length and age compositions

Surveys
- Improve precision in survey abundance indices by increasing the number of samples - Increase collection of length and age information for compositions
- Investigate effect of survey design changes on overall model time series

Incorporating Red Tide - Explore alternative methods to model red tide mortality with SS, including applying different assumed length- or age-based selectivities based on outputs from ecosystem based models

9. References

Atkinson, Sarina and Kevin Thompson. 2024. CPUE Expansion Estimation for Commercial Discards of Gulf of Mexico Red Grouper (Epinephelus morio). SEDAR88-WP-04. SEDAR, North Charleston, SC. 34 pp.

Binion-Rock, Samantha M. 2024. Gulf of Mexico Red Grouper (*Epinephelus morio*) length and age compositions from the recreational fishery. SEDAR88-WP-06. SEDAR, North Charleston, SC. 41 pp.

Carvalho F, H Winker, D Courtney, M Kapur, L Kell, M Cardinale, M Schirripa, T Kitakado, D Yemane, KR Piner and MN Maunder. 2021. A cookbook for using model diagnostics in integrated stock assessments. Fisheries Research 240:105959. *https://doi.org/10.1016/j.fishres.2021.105959*

Cheshire, Robin T., Kenneth Brennan, and Matthew E. Green. 2024. Headboat Data for Red Grouper in the US Gulf of Mexico. SEDAR88-WP-01. SEDAR, North Charleston, SC. 24 pp

Dichmont CM, RA Deng, AE Punt, J Brodziak, YJ Chang, JM Cope, JN Ianelli, CM Legault, RD Methot, CE Porch and MH Prager. 2016. A review of stock assessment packages in the United States. Fisheries Research 183:447–460. *https://doi.org/10.1016/j.fishres.2016.07.001*

Fitzpatrick, Eric and Williams, Erik. 2021. Evaluation and Limitations of MRIP Intercept Data for Developing a Gray Triggerfish Abundance Index. SEDAR81-RD01. SEDAR, North Charleston, SC. 18 pp.

Francis RICC. 2011. Data weighting in statistical fisheries stock assessment models. Canadian Journal of Fisheries and Aquatic Sciences 68:1124–1138. *https://doi.org/10.1139/f2011-025*

Gulf of Mexico Fishery Management Council (GMFMC). 2017. Minimum Stock Size Threshold (MSST) Revision for Reef Fish Stocks with Existing Status Determination Criteria. Final Amendment 44 to the Fishery Management Plan for Reef Fish Resources of the Gulf of Mexico including Environmental Assessment and Fishery Impact Statement. 124 pp. Available at: *https://www.fisheries.noaa.gov/s3//dam-migration/sero_final_am44_msst_gom_reef_fish.pdf*

Gulf of Mexico Fishery Management Council (GMFMC). 2021. Red Grouper Allocations and Annual Catch Levels and Targets. Final Amendment 53 to the Fishery Management Plan for

Reef Fish Resources of the Gulf of Mexico including Environmental Assessment and Fishery Impact Statement. 323 pp. Available at: *Red Grouper Allocations and Annual Catch Levels and Targets*

Hulson P-J, D Hanselman and T Quinn. 2012. Determining effective sample size in integrated age-structured assessment models. ICES Journal of Marine Science 69:281–292. *https://doi.org/10.1093/icesjms/fsr189*

Hurtado-Ferro F, CS Szuwalski, JL Valero, SC Anderson, CJ Cunningham, KF Johnson, R Licandeo, CR McGilliard, CC Monnahan, ML Muradian and K Ono. 2015. Looking in the rear-view mirror: bias and retrospective patterns in integrated, age-structured stock assessment models. ICES Journal of Marine Science 72(1):99–110. *https://doi.org/10.1093/icesjms/fsu198*

Hyndman RJ and AB Koehler. 2006. Another look at measures of forecast accuracy. International Journal of Forecasting 22(4):679–688. *https://doi.org/10.1016/j.ijforecast.2006.03.001*

Kell LT, R Sharma, T Kitakado, H Winker, I Mosqueira, M Cardinale and D Fu. 2021. Validation of stock assessment methods: is it me or my model talking?. ICES Journal of Marine Science 78(6):2244–2255. *https://doi.org/10.1093/icesjms/fsab104*

Lewis, Justin P., Heather M. Christiansen, Theodore S. Switzer, Sean F. Keenan, Kate E. Overly, Matthew D. Campbell. 2024. Combined indices of abundance for Red Grouper (Epinephelus morio) in the eastern Gulf of Mexico using data from three historic video surveys and unified GFISHER program. SEDAR88-WP-16. SEDAR, North Charleston, SC. 21 pp.

Lorenzen K. 2000. Allometry of natural mortality as a basis for assessing optimal release size in fish-stocking programmes. Canadian Journal of Fisheries and Aquatic Sciences 57(12):2374–2381. *https://doi.org/10.1139/f00-215*

McGirl, Maria, Jessica Carroll, and Bridget Cemak. 2024. Size and age information Red Grouper, Epinephelus morio, collected in association with fishery-dependent projects along Florida's Gulf of Mexico coast. SEDAR88-WP-07. SEDAR, North Charleston, SC. 14 pp.

Methot RD and IG Taylor. 2011. Adjusting for bias due to variability of estimated recruitments in fishery assessment models. Canadian Journal of Fisheries and Aquatic Sciences 68(10):1744–1760. *https://doi.org/10.1139/f2011-092*

Methot RD and CR Wetzel. 2013. Stock Synthesis: a biological and statistical framework for fish stock assessment and fishery management. Fisheries Research 142:86−99. *https://doi.org/10.1016/j.fishres.2012.10.012*

Methot RD, CR Wetzel, IG Taylor and K Doering. 2023. Stock Synthesis User Manual Version 3.30.21. NOAA Fisheries, Seattle Washington. 251 pp.

Nuttall, Matthew A. and Samantha Binion-Rock. 2024. General Recreational Survey Data for Red Grouper in the Gulf of Mexico. SEDAR88-WP-02. SEDAR, North Charleston, SC. 56 pp.

Nuttall, Matthew A. 2024. Proxy Discard Estimates of Red Grouper (Epinephelus morio) from the US Gulf of Mexico Headboat Fishery. SEDAR88-WP-05. SEDAR, North Charleston, SC. 10 pp.

Nuttall, Matthew A., Kevin Thompson, and Michaela Pawluk. 2024. Standardized Catch Per Unit Effort for Gulf of Mexico Red Grouper from the Southeast Region Headboat Survey. SEDAR88-WP-10. SEDAR, North Charleston, SC. 30 pp.

Palmer, Chris, Laura Thornton, Steve Garner, and Beverly Barnett. 2024. A Review of the Gulf of Mexico Red Grouper (Epinephelus morio) Age-Length Data, 1978-2022. SEDAR88-WP-11. SEDAR, North Charleston, SC. 52 pp.

Pawluk, Micki and Sarina Atkinson. 2024. Commercial Landings of Gulf of Mexico Red Grouper (Epinephelus morio) from 1986-2022. SEDAR88-WP-03. SEDAR, North Charleston, SC. 14 pp.

Pawluk, Michaela. 2024. Gulf of Mexico Red Grouper (Epinephelus morio) Commercial Landings Length and Age Compositions. SEDAR88-WP-09. SEDAR, North Charleston, SC. 34 pp.

Pollack, Adam G., Kristin Hannan, William Driggers, and David S. Hanisko. 2024. An Index of Relative Abundance for Red Grouper Captured During the NMFS Bottom Longline Survey in the Northern Gulf of Mexico. SEDAR88-WP-12. SEDAR, North Charleston, SC. 20 pp.

Ramsay, Chloe, Tiffanie A. Cross, Colin P. Shea, and Beverly Sauls. 2024. A ratio-based method for calibrating estimates of total landings (numbers and pounds of fish), releases (numbers of fish), and total trips from MRIP-FCAL to SRFS for Red Grouper (Epinephelus morio) in the Gulf of Mexico. SEDAR88-WP-17. SEDAR, North Charleston, SC. 14 pp.

Ramsay, Chole, Tiffanie A. Cross, Colin P. Shea, and Beverly Sauls. 2024. A ratio-based method for calibrating estimates of total landings (numbers and pounds of fish), releases (numbers of fish), and total trips from MRIP-FCAL to SRFS for Red Grouper (Epinephelus morio) in the Gulf of Mexico. SEDAR88-WP-17. SEDAR, North Charleston, SC. 14 pp.

Saul, Steven. 2006. Quantitative Historical Analysis of the United States and Cuban Gulf of Mexico Red Grouper Commercial Fishery. SEDAR 12-DW-11. SEDAR, North Charleston, SC. 27 pp.

SEDAR (Southeast Data Assessment and Review). 2019. SEDAR 61: Gulf of Mexico Red Grouper Stock Assessment Report. SEDAR, North Charleston, SC. 285 p. Available at: *http://sedarweb.org/sedar-61*.

SEDAR (Southeast Data Assessment and Review). 2021. SEDAR 68: Gulf of Mexico Scamp Grouper Stock Assessment Report. SEDAR, North Charleston, SC. 601 p. Available at: *http://sedarweb.org/sedar-68*.

Steidinger KA and GA Vargo. 1988. Marine dinoflagellate blooms: dynamics and impacts. *In* Algae and Human Affairs. Edited by C. Lembi and J.R. Waaland Cambridge University Press. pp. 373–401.

Taylor IG, KL Doering, KF Johnson, CR Wetzel and IJ Stewart. 2021. Beyond visualizing catch-at-age models: Lessons learned from the r4ss package about software to support stock assessments. Fisheries Research 239:105924. *https://doi.org/10.1016/j.fishres.2021.105924*

Thorson JT, SB Munch, JM Cope and J Gao. 2017a. Predicting life history parameters for all fishes worldwide. Ecological Applications 27(8):2262–2276. *https://doi.org/https://doi.org/10.1002/eap.1606*

Thorson JT, KF Johnson, RD Methot and IG Taylor. 2017b. Model-based estimates of effective sample size in stock assessment models using the Dirichlet-multinomial distribution. Fisheries Research 192: 84–93. *https://doi.org/10.1016/j.fishres.2016.06.005*

Thorson, J.T., Maureaud, A.A., Frelat, R., Mérigot, B., Bigman, J.S., Friedman, S.T., Palomares, M.L.D., Pinsky, M.L., Price, S.A., Wainwright, P., 2023. Identifying direct and indirect associations among traits by merging phylogenetic comparative methods and structural equation models. Methods Ecol. Evol. n/a. *https://doi.org/10.1111/2041-210X.14076*

Winker H, F Carvalho and M Kapur. 2018. JABBA: Just Another Bayesian Biomass Assessment. Fisheries Research 204:275–288. *https://doi.org/10.1016/j.fishres.2018.03.010*

Vilas D, J Buszowski, S Sagarese, J Steenbeek, Z Siders and D Chagaris. 2023. Evaluating red tide effects on the West Florida Shelf using a spatiotemporal ecosystem modeling framework. Scientific Reports 13(1):2541. *https://doi.org/10.1038/s41598-023-29327-z*

10. Tables

Table 1. Conversion factors from the SEDAR 42 Benchmark Assessment used to convert total length in centimeters (cm FL) to gutted weight (gw) in kilograms, whole weight (ww) in kilograms to gw in kilograms, and fork length (FL) in centimeters to total length for Gulf of Mexico Red Grouper males and females combined. Model fit criteria listed under statistic.

Model	N	Statistic	Range
GWT= 5.99e-06 * (FL^3.25)	37414	RSE = 0.3499	FL (cm): 23.0-93.5; G WT: 0.26-16.96
GW = WW / 1.048	-	-	-
FL = 5.71 + nat_TL * 0.95	3,901	R2=0.9909	Nat TL (cm): 15.1-95.7; FL (cm): 14.9-91.0

Table 2. Growth parameters (and associated standard deviation, SD) recommended for Gulf of Mexico Red Grouper during the SEDAR 61 Standard Assessment. The von Bertalanffy parameters (Linf, K, and t0) and CV estimates were not updated for the SEDAR 88 Operational Assessment.

Parameter	Value	SD
Lmin	19.5200	-
Linf (cm TL)	79.9950	0.8
K (per year)	-0.8700	0.8
t0 (year)	0.1311	-
CV at age (young)	0.1423	0.05
CV at age (old)	0.1636	0.05

Table 3. Ageing error matrices (standard deviations associated with mean age) recommended for Gulf of Mexico Red Grouper during the Standard Assessment (1986-2017 age data) and for the Operational Assessment (2018-2022 age data) to incorporate uncertainty at age.

Age	SEDAR 61	SEDAR 88 (curvilinear CV)
0	0.06	0.00
1	0.06	0.00
2	0.27	0.06
3	0.34	0.15
4	0.41	0.26
5	0.47	0.40
6	0.54	0.54
7	0.61	0.70
8	0.68	0.86
9	0.74	1.02
10	0.81	1.19
11	0.88	1.35
12	0.94	1.51
13	1.01	1.67
14	1.08	1.83
15	1.15	1.99
16	1.21	2.15
17	1.28	2.30
18	1.35	2.46
19	1.41	2.61
20	1.48	2.76
21	1.55	2.91
22	1.62	3.06
23	1.68	3.20
24	1.75	3.35
25	1.82	3.50
26	1.89	3.64
27	1.95	3.79
28	2.02	3.93
29	2.09	4.07

Table 4. Age-specific natural mortality (*M*, per year) for female Red Grouper in the Gulf of Mexico used in SEDAR 61 and SEDAR 88 with values used for the high and low *M* sensitivity runs.

Age	SEDAR 61	SEDAR 88	S88 High M	S88 Low M
0	0.56	1.09	1.14	1.04
1	0.38	0.67	0.70	0.64
2	0.30	0.50	0.52	0.47
3	0.25	0.40	0.42	0.38
4	0.22	0.34	0.36	0.33
5	0.20	0.30	0.32	0.29
6	0.18	0.27	0.28	0.26
7	0.17	0.25	0.26	0.24
8	0.16	0.23	0.24	0.22
9	0.16	0.22	0.23	0.21
10	0.15	0.21	0.22	0.20
11	0.15	0.20	0.21	0.19
12	0.14	0.19	0.20	0.18
13	0.14	0.19	0.19	0.18
14	0.14	0.18	0.19	0.17
15	0.13	0.17	0.18	0.17
16	0.13	0.17	0.18	0.16
17	0.13	0.17	0.17	0.16
18	0.13	0.16	0.17	0.16
19	0.13	0.16	0.17	0.15
20	0.13	0.16	0.16	0.15
21	0.12	0.16	0.16	0.15
22		0.15	0.16	0.15
23		0.15	0.16	0.14
24		0.15	0.16	0.14
25		0.15	0.16	0.14
26		0.15	0.15	0.14
27		0.15	0.15	0.14
28		0.15	0.15	0.14
29		0.15	0.15	0.14

Table 5. Gulf of Mexico Red Grouper commercial landings in pounds gutted weight. Landings by “Other” gears were lumped into Handline for input into the stock assessment model. In the absence of uncertainty estimates accompanying the submitted data, commercial landings for 1986-2009 were assigned a log-scale SE based on expert opinion and weighted by state landings (**Table 6**). A log-scale SE of 0.01 was used for 2010-2022 after implementation of the IFQ program.

Year	Handline	Longline	Other	Trap
1986	3,129,868	2,513,835	10,530	712,377
1987	2,515,194	3,765,278	10,615	446,611
1988	2,439,596	2,543,670	5,701	627,274
1989	4,383,571	3,721,892	12,298	671,219
1990	2,880,562	2,372,132	5,618	385,411
1991	2,174,604	3,165,508	34,605	549,486
1992	1,901,001	2,647,002	12,705	651,271
1993	1,480,029	5,015,319	47,261	864,483
1994	1,418,561	3,138,479	44,904	1,079,339
1995	1,356,729	2,818,135	18,261	1,242,160
1996	1,014,401	3,410,430	11,938	635,231
1997	1,104,348	3,516,099	7,967	794,927
1998	853,726	3,071,125	5,821	347,107
1999	1,409,793	4,430,842	20,213	868,359
2000	1,738,134	2,937,321	30,722	1,036,041
2001	1,555,780	3,398,932	21,223	742,169
2002	1,625,231	3,139,833	18,446	978,268
2003	1,125,251	2,974,432	12,384	704,796
2004	1,408,497	3,450,090	14,466	763,873
2005	1,440,273	3,295,572	12,727	628,745
2006	1,375,345	3,011,463	8,956	585,510
2007	1,563,383	1,981,901	13,084	24,451
2008	1,877,751	2,807,031	24,690	0
2009	2,452,470	1,116,593	122,276	0
2010	1,337,440	1,300,792	272,738	0

Table 5 Continued. Gulf of Mexico Red Grouper commercial landings in pounds gutted weight. Landings by "Other" gears were lumped into Handline for input into the stock assessment model. In the absence of uncertainty estimates accompanying the submitted data, commercial landings for 1986-2009 were assigned a log-scale SE based on expert opinion and weighted by state landings (**Table 6**). A log-scale SE of 0.01 was used for 2010-2022 after implementation of the IFQ program.

Year	Handline	Longline	Other	Trap
2011	1,686,450	3,046,722	50,481	0
2012	2,228,029	2,967,981	23,123	0
2013	1,523,788	3,057,081	18,132	0
2014	1,908,846	3,658,404	34,655	0
2015	1,857,099	2,921,941	18,120	0
2016	1,198,291	3,283,191	16,100	0
2017	1,001,228	2,315,569	11,473	0
2018	660,169	1,695,246	7,864	0
2019	581,509	1,443,483	12,054	0
2020	737,043	1,616,223	15,056	0
2021	1,070,904	1,862,046	17,742	0
2022	798,443	1,621,032	9,463	0

Table 6. Uncertainty estimates for Gulf of Mexico commercial landings based on expert opinion derived from changes in reporting, following the approach taken in the South Atlantic and presented during the SEDAR 68 Gulf of Mexico Scamp Grouper Research Track Assessment (SEDAR 2021). ALS = Accumulated Landings System.

Year Range	Texas	Louisiana	Mississippi	Alabama	Florida	Description
1986-1999	0.10	0.10	0.10	0.10	0.05	Florida starts state trip ticket, used in ALS 1986
2000-2001	0.10	0.05	0.10	0.10	0.05	Louisiana starts state trip ticket 1997; used in ALS 2000
2002-2009	0.10	0.05	0.10	0.05	0.05	Alabama starts state trip ticket, used in ALS 2002
2010+	0.10	0.05	0.10	0.05	0.05	Shallow Grouper IFQ starts 2010
2014+	0.05	0.05	0.05	0.05	0.05	Texas (2008) and Mississippi (2012) state trip tickets begin; used in ALS 2014 [MS may change to 2015]

Table 7. Gulf of Mexico Red Grouper recreational landings in numbers and weight and discards in numbers with associated yearly CV values as well as landings by mode in numbers (Cbt = charter boat, Pr = Private, Hb = headboat). Discards by mode can be found in their respective working papers (S88_WP_01, S88_WP_02 and S88_WP_17).

Year	Landings	CV Landings	LBS	Discards	CV Discards	Cbt N	Hbt N	Pri N
1986	911,543	0.28	2,606,510	670,707	0.33	102,295	24,029	785,218
1987	611,700	0.25	1,936,610	549,637	0.21	49,618	18,566	543,516
1988	1,137,330	0.23	3,514,339	1,423,756	0.21	40,248	19,656	1,077,425
1989	1,643,459	0.26	5,694,713	4,634,565	0.25	28,982	34,785	1,579,691
1990	421,230	0.26	2,788,967	3,144,638	0.26	67,723	10,865	342,641
1991	426,596	0.26	2,854,577	3,888,373	0.21	32,274	6,811	387,510
1992	661,821	0.21	4,634,437	3,658,641	0.18	45,709	6,437	609,675
1993	475,053	0.26	3,040,609	2,242,919	0.21	15,529	6,170	453,353
1994	409,339	0.24	2,918,039	2,359,867	0.22	27,455	6,856	375,028
1995	407,885	0.27	2,758,258	2,868,386	0.22	54,190	10,678	343,017
1996	114,165	0.25	746,848	1,110,068	0.23	19,422	12,055	82,687
1997	128,545	0.31	891,858	1,534,517	0.23	12,696	3,394	112,455
1998	154,447	0.2	1,178,049	2,482,342	0.16	17,755	3,195	133,497
1999	350,137	0.21	2,602,099	4,115,352	0.14	23,559	4,927	321,651
2000	454,012	0.21	3,377,904	3,350,643	0.16	71,972	6,565	375,475
2001	268,711	0.2	1,898,915	2,648,296	0.15	34,900	4,071	229,741
2002	326,133	0.23	2,446,393	2,877,005	0.15	26,178	3,182	296,773
2003	265,578	0.19	1,745,564	2,975,400	0.14	32,222	5,596	227,760
2004	888,642	0.22	6,085,460	5,528,631	0.15	62,643	9,946	816,053
2005	366,584	0.22	2,452,285	2,135,457	0.15	65,135	10,544	290,906
2006	273,237	0.32	2,035,348	1,616,308	0.3	29,143	3,352	240,742
2007	225,583	0.23	1,541,921	1,216,459	0.21	15,198	3,023	207,363
2008	192,793	0.18	1,279,571	4,586,268	0.15	33,471	3,738	155,583
2009	153,594	0.22	1,242,371	4,672,455	0.15	18,799	3,415	131,380
2010	251,029	0.24	1,558,266	4,154,498	0.17	37,557	3,676	209,796
2011	210,727	0.18	1,212,169	4,517,500	0.18	33,592	5,502	171,634

Table 7 Continued. Gulf of Mexico Red Grouper recreational landings in numbers and discards in numbers with associated yearly CV values. Landings and discards by mode can be found in their respective working papers (S88_WP_01, S88_WP_02 and S88_WP_17).

Year	Landings	CV Landings	LBS	Discards	CV Discards	Cbt N	Hbt N	Pri N
2012	512,227	0.2	3,233,938	3,463,187	0.16	69,701	9,960	432,567
2013	647,499	0.19	3,930,772	3,946,668	0.16	103,547	10,451	533,502
2014	633,195	0.24	4,138,821	3,338,548	0.14	73,995	5,911	553,289
2015	400,641	0.2	2,965,212	2,074,000	0.14	55,863	4,406	340,372
2016	355,680	0.19	2,211,351	2,494,694	0.15	58,069	4,977	292,633
2017	137,564	0.17	988,945	1,470,510	0.12	27,346	1,501	108,717
2018	158,032	0.21	1,274,294	1,690,860	0.13	25,516	1,245	131,271
2019	153,604	0.19	1,163,297	864,442	0.12	28,757	1,676	123,171
2020	267,355	0.21	2,019,931	1,438,712	0.14	52,052	3,499	211,805
2021	388,307	0.15	3,030,177	2,381,871	0.11	168,148	10,265	209,894
2022	212,146	0.18	1,584,829	1,533,157	0.1	46,163	1,798	164,184

Table 8. Gulf of Mexico Red Grouper recreational private mode landings from SRFS in whole weight (WW) and numbers (N). Mean body weight of fish in whole weight (WW) calculated from weight and numbers, whole weight (WW) converted to gutted weight (GW) using conversion factor of 1.048 and associated coefficient of variation (CV).

Year	Landings (WW)	Landings (N)	Mean WW	Mean GW	CV
1986	1,919,162	663,879	2.89	2.76	0.49
1987	1,441,367	464,938	3.1	2.96	0.43
1988	2,893,858	945,803	3.06	2.92	0.37
1989	4,896,968	1,395,336	3.51	3.35	0.39
1990	2,013,415	283,847	7.09	6.77	0.42
1991	2,305,555	333,927	6.9	6.59	0.41
1992	3,618,443	529,037	6.84	6.53	0.34
1993	2,575,727	399,214	6.45	6.16	0.40
1994	2,322,492	324,706	7.15	6.82	0.38
1995	1,925,507	287,487	6.7	6.39	0.48
1996	440,215	66,024	6.67	6.36	0.39
1997	650,169	95,627	6.8	6.49	0.51
1998	868,079	113,010	7.68	7.33	0.36
1999	2,105,929	278,793	7.55	7.21	0.34
2000	2,269,404	312,834	7.25	6.92	0.36
2001	1,388,568	193,703	7.17	6.84	0.36
2002	1,932,140	253,425	7.62	7.27	0.38
2003	1,269,747	188,939	6.72	6.41	0.36
2004	4,962,190	699,399	7.09	6.77	0.37
2005	1,672,670	237,862	7.03	6.71	0.44
2006	1,587,716	205,272	7.73	7.38	0.54
2007	1,248,720	179,762	6.95	6.63	0.38
2008	853,907	128,539	6.64	6.34	0.35
2009	923,303	110,790	8.33	7.95	0.39
2010	1,080,569	174,460	6.19	5.91	0.43
2011	840,610	142,246	5.91	5.64	0.34

Table 8 Continued. Gulf of Mexico Red Grouper recreational private mode landings in whole weight (WW) and numbers (N). Mean body weight of fish in whole weight (WW) calculated from weight and numbers, whole weight (WW) converted to gutted weight (GW) using conversion factor of 1.048 and associated coefficient of variation (CV).

Year	Landings (WW)	Landings (N)	Mean WW	Mean GW	CV
2012	2,329,230	363,083	6.42	6.12	0.35
2013	2,760,513	443,920	6.22	5.93	0.34
2014	3,177,241	469,397	6.77	6.46	0.41
2015	2,173,032	284,752	7.63	7.28	0.37
2016	1,004,837	168,808	5.95	5.68	0.28
2017	596,853	83,185	7.18	6.85	0.29
2018	855,791	106,782	8.01	7.65	0.34
2019	824,733	101,405	8.13	7.76	0.31
2020	1,553,469	201,584	7.71	7.35	0.33
2021	2,075,833	253,500	8.19	7.81	0.24
2022	922,310	124,426	7.41	7.07	0.31

Table 9. Gulf of Mexico Red Grouper commercial discards in numbers with associated yearly SE values in numbers.

Year	Handline	Longline	Handline SE	Longline SE
1993	83,940	501,888	6,147	77,213
1994	99,040	401,072	7,069	61,703
1995	101,625	371,606	7,242	57,170
1996	92,714	485,855	6,590	74,746
1997	99,735	519,788	7,193	79,967
1998	89,242	498,047	6,119	76,622
1999	118,027	623,631	8,482	95,942
2000	132,828	471,426	9,593	72,527
2001	144,545	577,922	10,613	88,910
2002	151,885	524,725	11,127	80,726
2003	122,886	506,581	8,209	77,935
2004	132,082	555,138	9,070	85,405
2005	125,725	509,507	9,084	78,385
2006	126,092	518,717	9,622	79,802
2007	146,641	370,882	16,199	57,058
2008	150,377	408,240	16,611	62,806
2009	184,424	175,821	20,372	37,265
2010	172,362	153,157	42,687	17,613
2011	201,629	341,082	26,279	22,361
2012	153,513	313,854	16,175	43,051
2013	92,270	206,516	16,508	23,491
2014	53,355	238,140	9,506	43,061
2015	81,745	205,810	14,414	35,977
2016	88,329	235,615	19,775	29,032
2017	68,589	314,514	17,515	35,703
2018	69,066	276,746	15,113	31,416
2019	61,951	260,984	13,556	29,626
2020	54,158	237,383	18,604	26,947
2021	55,598	223,972	19,099	25,425
2022	32,242	188,264	8,600	21,371

Table 10. Standardized indices of relative abundance (catch per unit of effort, CPUE) and associated log-scale standard errors (SE) for Red Grouper in the Gulf of Mexico. ComHL = Commercial Handline, ComLL = Commercial Longline, Rec = Recreational (Headboat), Vid = Combined Video Survey, GF = SEAMAP Summer Groundfish Survey, BLL = NMFS Bottom Longline Survey.

Year	Com HL	Com HL SE	Com LL	Com LL SE	Rec	Rec SE	Vid	Vid SE	GF	GF SE	BLL	BLL SE
1986					0.981	0.624						
1987					1.856	0.568						
1988					1.420	0.554						
1989					1.668	0.580						
1990					0.688	0.664						
1991					0.519	0.684						
1992					0.395	0.702						
1993	0.731	0.309	0.979	0.332	0.604	0.657	0.721	0.194				
1994	0.716	0.306	0.724	0.294	0.600	0.648	0.638	0.198				
1995	0.789	0.309	0.774	0.305	0.737	0.637	0.537	0.246				
1996	0.491	0.318	1.040	0.319	0.636	0.668	0.754	0.155				
1997	0.565	0.319	0.907	0.266	0.400	0.696	0.974	0.124				
1998	0.519	0.317	0.955	0.274	0.522	0.674						
1999	0.740	0.311	0.997	0.272	0.530	0.664						
2000	0.991	0.304	0.898	0.289	0.403	0.703						
2001	1.347	0.295	1.056	0.278	0.804	0.635					0.869	0.284
2002	1.387	0.295	1.060	0.292	0.861	0.618	0.954	0.127				
2003	0.947	0.291	0.928	0.281	1.325	0.538					1.142	0.204
2004	1.274	0.286	1.112	0.273	2.499	0.471	1.237	0.119			1.802	0.195
2005	1.417	0.288	1.444	0.283	2.509	0.464	1.317	0.093			0.617	0.394
2006	1.143	0.291	1.093	0.270	0.903	0.610	1.129	0.104			0.581	0.380
2007	1.207	0.288	0.780	0.312	1.139	0.573	0.755	0.122			0.955	0.443
2008	1.531	0.287	1.181	0.308			1.129	0.104			0.641	0.316
2009	1.206	0.286	1.073	0.453			1.591	0.082	2.118	0.228	1.007	0.261
2010							1.155	0.077	1.273	0.241	1.382	0.262
2011							1.387	0.059	1.156	0.267	2.565	0.181

Table 10 Continued. Standardized indices of relative abundance (catch per unit of effort, CPUE) and associated log-scale standard errors (SE) for Red Grouper in the Gulf of Mexico. ComHL = Commercial Handline, ComLL = Commercial Longline, Rec = Recreational (Headboat), Vid = Combined Video Survey, GF = SEAMAP Summer Groundfish Survey, BLL = NMFS Bottom Longline Survey.

Year	Com HL	Com HL SE	Com LL	Com LL SE	Rec	Rec SE	Vid	Vid SE	GF	GF SE	BLL	BLL SE
2012							1.175	0.068	1.426	0.201	2.574	0.257
2013							1.056	0.090	0.819	0.256	1.176	0.310
2014							0.793	0.078	1.026	0.234	0.650	0.372
2015							0.587	0.098	0.793	0.267	0.845	0.349
2016							0.821	0.064	1.000	0.239	0.378	0.418
2017							0.923	0.061	0.701	0.302	0.792	0.333
2018							0.971	0.075	0.361	0.320	0.487	0.411
2019							1.090	0.063	0.328	0.317	0.488	0.440
2020							1.047	0.063			0.696	0.390
2021							1.144	0.056	0.990	0.278	0.850	0.433
2022							1.115	0.060	1.008	0.260	0.501	0.460

Table 11. Mortality estimates for age classes across red tide years calculated by West Florida Shelf Ecospace model (Vilas et al. 2023). (Note: values scaled to maximum for each year).

Age	2005	2006	2014	2018	2021
0	0.924	1.000	0.342	1.000	0.916
1	0.951	0.639	0.422	0.976	1.000
2	0.940	0.541	0.516	0.764	0.776
3	1.000	0.552	0.623	0.725	0.507
4	0.884	0.301	1.000	0.865	0.471
5+	0.869	0.186	0.810	0.568	0.339

Table 12. List of Stock Synthesis parameters for Gulf of Mexico Red Grouper. The list includes expected parameter values, lower and upper bounds of the parameters, associated standard deviations (SD) and coefficients of variation (CV), prior type and densities (value, SD) if applicable, and phases. Parameters designated as fixed were held at their initial values and have no associated range or SD.

Label	Value	Range	SD	CV	Prior	Phase
NatM_Lorenzen_averageFem_GP_1	0.186					Fixed
L_at_Amin_Fem_GP_1	19.724	(1,40)	0.4	0.020		3
L_at_Amax_Fem_GP_1	92.41	(60,100)	3.305	0.036		3
VonBert_K_Fem_GP_1	0.092	(0.05,0.3)	0.006	0.066		3
CV_young_Fem_GP_1	0.142					Fixed
CV_old_Fem_GP_1	0.164					Fixed
Wtlen_1_Fem_GP_1	5.99e-06					Fixed
Wtlen_2_Fem_GP_1	3.25					Fixed
Mat50%_Fem_GP_1	2.8					Fixed
Mat_slope_Fem_GP_1	-1.15					Fixed
Eggs_scalar_Fem_GP_1	4.47e-08					Fixed
Eggs_exp_len_Fem_GP_1	5.48					Fixed
CohortGrowDev	1					Fixed
FracFemale_GP_1	1					Fixed
SR_LN(R0)	10.713	(1,40)	0.052	0.005		1
SR_BH_steep	0.661	(0.2,0.99)	0.057	0.086		1
SR_sigmaR	0.647	(0,2)	0.061	0.094		5
SR_regime	0					Fixed
SR_autocorr	0					Fixed
Main_RecrDev_1993	0.062	(-5,5)	0.192	3.082		4
Main_RecrDev_1994	0.626	(-5,5)	0.14	0.223		4
Main_RecrDev_1995	-0.828	(-5,5)	0.406	-0.490		4
Main_RecrDev_1996	1.014	(-5,5)	0.091	0.090		4
Main_RecrDev_1997	-0.454	(-5,5)	0.227	-0.499		4
Main_RecrDev_1998	-1.06	(-5,5)	0.335	-0.316		4
Main_RecrDev_1999	1.459	(-5,5)	0.072	0.049		4

Table 12 Continued. List of Stock Synthesis parameters for Gulf of Mexico Red Grouper. The list includes expected parameter values, lower and upper bounds of the parameters, associated standard deviations (SD) and coefficients of variation (CV), prior type and densities (value, SD) if applicable, and phases. Parameters designated as fixed were held at their initial values and have no associated range or SD.

Label	Value	Range	SD	CV	Prior	Phase
Main_RecrDev_2000	-0.116	(-5,5)	0.227	-1.954		4
Main_RecrDev_2001	-0.821	(-5,5)	0.362	-0.441		4
Main_RecrDev_2002	1.019	(-5,5)	0.112	0.110		4
Main_RecrDev_2003	-0.863	(-5,5)	0.323	-0.374		4
Main_RecrDev_2004	0.218	(-5,5)	0.126	0.579		4
Main_RecrDev_2005	-1.966	(-5,5)	0.426	-0.217		4
Main_RecrDev_2006	1.663	(-5,5)	0.054	0.032		4
Main_RecrDev_2007	0.62	(-5,5)	0.098	0.158		4
Main_RecrDev_2008	-0.792	(-5,5)	0.239	-0.302		4
Main_RecrDev_2009	-0.339	(-5,5)	0.132	-0.391		4
Main_RecrDev_2010	-0.509	(-5,5)	0.141	-0.277		4
Main_RecrDev_2011	-0.771	(-5,5)	0.152	-0.198		4
Main_RecrDev_2012	-0.141	(-5,5)	0.104	-0.738		4
Main_RecrDev_2013	-1.077	(-5,5)	0.184	-0.171		4
Main_RecrDev_2014	0.627	(-5,5)	0.082	0.131		4
Main_RecrDev_2015	0.738	(-5,5)	0.085	0.115		4
Main_RecrDev_2016	-0.05	(-5,5)	0.155	-3.078		4
Main_RecrDev_2017	-0.287	(-5,5)	0.193	-0.672		4
Main_RecrDev_2018	0.433	(-5,5)	0.162	0.375		4
Main_RecrDev_2019	0.574	(-5,5)	0.179	0.313		4
Main_RecrDev_2020	0.806	(-5,5)	0.198	0.246		4
Main_RecrDev_2021	0.622	(-5,5)	0.279	0.448		4
Main_RecrDev_2022	-0.408	(-5,5)	0.534	-1.308		4
InitF_seas_1_flt_1comm_HL	0.064	(0,1)	0.013	0.199		1
InitF_seas_1_flt_2comm_LL	0.062	(0,1)	0.013	0.203		1
InitF_seas_1_flt_3commTrap	0.011	(0,1)	0.004	0.356		1
InitF_seas_1_flt_4Rec	0.097	(0,1)	0.011	0.114		1

Table 12 Continued. List of Stock Synthesis parameters for Gulf of Mexico Red Grouper. The list includes expected parameter values, lower and upper bounds of the parameters, associated standard deviations (SD) and coefficients of variation (CV), prior type and densities (value, SD) if applicable, and phases. Parameters designated as fixed were held at their initial values and have no associated range or SD.

Label	Value	Range	SD	CV	Prior	Phase
F_fleet_5_YR_2005_s_1	0.174	(0,2.9)	0.093	0.533		1
F_fleet_9_YR_2014_s_1	0.196	(0,2.9)	0.089	0.455		1
F_fleet_10_YR_2018_s_1	0.042	(0,2.9)	0.086	2.040		1
F_fleet_11_YR_2021_s_1	0.099	(0,2.9)	0.159	1.606		1
LnQ_base_comm_HL(1)	-9.47	(-25,25)				Float
LnQ_base_comm_LL(2)	-9.272	(-25,25)				Float
LnQ_base_Rec(4)	-7.913	(-25,25)				Float
LnQ_base_CmbVid(6)	-9.103	(-25,25)				Float
LnQ_base_SEAMAP_GF(7)	-10.219	(-25,25)				Float
LnQ_base_NMFS_BLL(8)	-8.651	(-25,25)				Float
Retain_L_infl_comm_HL(1)	0					Fixed
Retain_L_width_comm_HL(1)	0.25					Fixed
Retain_L_asymptote_logit_comm_HL(1)	10					Fixed
Retain_L_maleoffset_comm_HL(1)	0					Fixed
DiscMort_L_infl_comm_HL(1)	-15					Fixed
DiscMort_L_width_comm_HL(1)	1					Fixed
DiscMort_L_level_old_comm_HL(1)	0.19					Fixed
DiscMort_L_male_offset_comm_HL(1)	0					Fixed
Retain_L_infl_comm_LL(2)	0					Fixed
Retain_L_width_comm_LL(2)	0.25					Fixed
Retain_L_asymptote_logit_comm_LL(2)	10					Fixed
Retain_L_maleoffset_comm_LL(2)	0					Fixed
DiscMort_L_infl_comm_LL(2)	-15					Fixed
DiscMort_L_width_comm_LL(2)	1					Fixed
DiscMort_L_level_old_comm_LL(2)	0.415					Fixed
DiscMort_L_male_offset_comm_LL(2)	0					Fixed
Size_DblN_peak_commTrap(3)	50.572	(10,85)	1.032	0.020		2
Size_DblN_top_logit_commTrap(3)	-0.941	(-15,15)	0.91	-0.968	Normal(-1.3,2)	3

Table 12 Continued. List of Stock Synthesis parameters for Gulf of Mexico Red Grouper. The list includes expected parameter values, lower and upper bounds of the parameters, associated standard deviations (SD) and coefficients of variation (CV), prior type and densities (value, SD) if applicable, and phases. Parameters designated as fixed were held at their initial values and have no associated range or SD.

Label	Value	Range	SD	CV	Prior	Phase
Size_DblN_ascend_se_commTrap(3)	5					Fixed
Size_DblN_descend_se_commTrap(3)	5					Fixed
Size_DblN_start_logit_commTrap(3)	-999					Fixed
Size_DblN_end_logit_commTrap(3)	-999					Fixed
Retain_L_infl_commTrap(3)	0					Fixed
Retain_L_width_commTrap(3)	0.25					Fixed
Retain_L_asymptote_logit_commTrap(3)	10					Fixed
Retain_L_maleoffset_commTrap(3)	0					Fixed
DiscMort_L_infl_commTrap(3)	-15					Fixed
DiscMort_L_width_commTrap(3)	1					Fixed
DiscMort_L_level_old_commTrap(3)	0.1					Fixed
DiscMort_L_male_offset_commTrap(3)	0					Fixed
Retain_L_infl_Rec(4)	38.352					Fixed
Retain_L_width_Rec(4)	0.5					Fixed
Retain_L_asymptote_logit_Rec(4)	10					Fixed
Retain_L_maleoffset_Rec(4)	0					Fixed
DiscMort_L_infl_Rec(4)	-15					Fixed
DiscMort_L_width_Rec(4)	1					Fixed
DiscMort_L_level_old_Rec(4)	0.116					Fixed
DiscMort_L_male_offset_Rec(4)	0					Fixed
Size_inflection_CmbVid(6)	41.5	(0,85)	0.897	0.022		2
Size_95%width_CmbVid(6)	16.646	(0,20)	0.727	0.044		2
Size_DblN_peak_SEAMAP_GF(7)	13.879	(10,85)	0.092	0.007		2
Size_DblN_top_logit_SEAMAP_GF(7)	-4.352	(-15,15)	1.537	-0.353	Normal(-3.7,2)	3
Size_DblN_ascend_se_SEAMAP_GF(7)	-1.102					Fixed
Size_DblN_descend_se_SEAMAP_GF(7	7.7	(-15,15)	0.3	0.039	Normal(7.08,2)	3
Size_DblN_start_logit_SEAMAP_GF(7)	-999					Fixed
Size_DblN_end_logit_SEAMAP_GF(7)	-999					Fixed

Table 12 Continued. List of Stock Synthesis parameters for Gulf of Mexico Red Grouper. The list includes expected parameter values, lower and upper bounds of the parameters, associated standard deviations (SD) and coefficients of variation (CV), prior type and densities (value, SD) if applicable, and phases. Parameters designated as fixed were held at their initial values and have no associated range or SD.

Label	Value	Range	SD	CV	Prior	Phase
Size_inflection_NMFS_BLL(8)	46.191	(10,85)	1.29	0.028		2
Size_95%width_NMFS_BLL(8)	11.85	(0,20)	1.17	0.099		3
Age_DblN_peak_comm_HL(1)	6.137	(1,20)	0.125	0.020		2
Age_DblN_top_logit_comm_HL(1)	-9.16	(-15,15)	1.999	-0.218	Normal(-9.16,2)	3
Age_DblN_ascend_se_comm_HL(1)	1.076	(-15,15)	0.102	0.095	Normal(0.87,2)	3
Age_DblN_descend_se_comm_HL(1	1.763	(-15,15)	1.208	0.685		3
Age_DblN_start_logit_comm_HL(1)	-999					Fixed
Age_DblN_end_logit_comm_HL(1)	1.543	(-15,15)	0.486	0.315		4
Age_inflection_comm_LL(2)	4.966	(1,20)	0.097	0.020		2
Age_95%width_comm_LL(2)	2.237	(0,15)	0.127	0.057		3
Age_DblN_peak_Rec(4)	2.921	(1,20)	0.056	0.019		2
Age_DblN_top_logit_Rec(4)	-3.226	(-15,15)	0.558	-0.173	Normal(-1.87,2)	3
Age_DblN_ascend_se_Rec(4)	0.018					Fixed
Age_DblN_descend_se_Rec(4)	1.43	(-15,15)	0.487	0.341		3
Age_DblN_start_logit_Rec(4)	-8.25	(-15,15)	1.435	-0.174		2
Age_DblN_end_logit_Rec(4)	-1.02	(-15,15)	0.138	-0.135		4
AgeSel_P1_RedTide_2005(5)	2.503					Fixed
AgeSel_P2_RedTide_2005(5)	2.973					Fixed
AgeSel_P3_RedTide_2005(5)	2.757					Fixed
AgeSel_P4_RedTide_2005(5)	9					Fixed
AgeSel_P5_RedTide_2005(5)	2.028					Fixed
AgeSel_P6_RedTide_2005(5)	1.888					Fixed
AgeSel_P7_RedTide_2005(5)	1.888					Fixed
AgeSel_P8_RedTide_2005(5)	1.888					Fixed
AgeSel_P9_RedTide_2005(5)	1.888					Fixed
AgeSel_P10_RedTide_2005(5)	1.888					Fixed
AgeSel_P11_RedTide_2005(5)	1.888					Fixed
AgeSel_P12_RedTide_2005(5)	1.888					Fixed

Table 12 Continued. List of Stock Synthesis parameters for Gulf of Mexico Red Grouper. The list includes expected parameter values, lower and upper bounds of the parameters, associated standard deviations (SD) and coefficients of variation (CV), prior type and densities (value, SD) if applicable, and phases. Parameters designated as fixed were held at their initial values and have no associated range or SD.

Label	Value	Range	SD	CV	Prior	Phase
AgeSel_P13_RedTide_2005(5)	1.888					Fixed
AgeSel_P14_RedTide_2005(5)	1.888					Fixed
AgeSel_P15_RedTide_2005(5)	1.888					Fixed
AgeSel_P16_RedTide_2005(5)	1.888					Fixed
AgeSel_P17_RedTide_2005(5)	1.888					Fixed
AgeSel_P18_RedTide_2005(5)	1.888					Fixed
AgeSel_P19_RedTide_2005(5)	1.888					Fixed
AgeSel_P20_RedTide_2005(5)	1.888					Fixed
AgeSel_P21_RedTide_2005(5)	1.888					Fixed
AgeSel_P22_RedTide_2005(5)	1.888					Fixed
AgeSel_P23_RedTide_2005(5)	1.888					Fixed
AgeSel_P24_RedTide_2005(5)	1.888					Fixed
AgeSel_P25_RedTide_2005(5)	1.888					Fixed
AgeSel_P26_RedTide_2005(5)	1.888					Fixed
AgeSel_P27_RedTide_2005(5)	1.888					Fixed
AgeSel_P28_RedTide_2005(5)	1.888					Fixed
AgeSel_P29_RedTide_2005(5)	1.888					Fixed
AgeSel_P30_RedTide_2005(5)	1.888					Fixed
AgeSel_P1_RedTide_2014(9)	-0.655					Fixed
AgeSel_P2_RedTide_2014(9)	-0.315					Fixed
AgeSel_P3_RedTide_2014(9)	0.063					Fixed
AgeSel_P4_RedTide_2014(9)	0.502					Fixed
AgeSel_P5_RedTide_2014(9)	9					Fixed
AgeSel_P6_RedTide_2014(9)	1.447					Fixed
AgeSel_P7_RedTide_2014(9)	1.447					Fixed
AgeSel_P8_RedTide_2014(9)	1.447					Fixed
AgeSel_P9_RedTide_2014(9)	1.447					Fixed
AgeSel_P10_RedTide_2014(9)	1.447					Fixed

Table 12 Continued. List of Stock Synthesis parameters for Gulf of Mexico Red Grouper. The list includes expected parameter values, lower and upper bounds of the parameters, associated standard deviations (SD) and coefficients of variation (CV), prior type and densities (value, SD) if applicable, and phases. Parameters designated as fixed were held at their initial values and have no associated range or SD.

Label	Value	Range	SD	CV	Prior	Phase
AgeSel_P11_RedTide_2014(9)	1.447					Fixed
AgeSel_P12_RedTide_2014(9)	1.447					Fixed
AgeSel_P13_RedTide_2014(9)	1.447					Fixed
AgeSel_P14_RedTide_2014(9)	1.447					Fixed
AgeSel_P15_RedTide_2014(9)	1.447					Fixed
AgeSel_P16_RedTide_2014(9)	1.447					Fixed
AgeSel_P17_RedTide_2014(9)	1.447					Fixed
AgeSel_P18_RedTide_2014(9)	1.447					Fixed
AgeSel_P19_RedTide_2014(9)	1.447					Fixed
AgeSel_P20_RedTide_2014(9)	1.447					Fixed
AgeSel_P21_RedTide_2014(9)	1.447					Fixed
AgeSel_P22_RedTide_2014(9)	1.447					Fixed
AgeSel_P23_RedTide_2014(9)	1.447					Fixed
AgeSel_P24_RedTide_2014(9)	1.447					Fixed
AgeSel_P25_RedTide_2014(9)	1.447					Fixed
AgeSel_P26_RedTide_2014(9)	1.447					Fixed
AgeSel_P27_RedTide_2014(9)	1.447					Fixed
AgeSel_P28_RedTide_2014(9)	1.447					Fixed
AgeSel_P29_RedTide_2014(9)	1.447					Fixed
AgeSel_P30_RedTide_2014(9)	1.447					Fixed
AgeSel_P1_RedTide_2018(10)	9					Fixed
AgeSel_P2_RedTide_2018(10)	3.691					Fixed
AgeSel_P3_RedTide_2018(10)	1.176					Fixed
AgeSel_P4_RedTide_2018(10)	0.967					Fixed
AgeSel_P5_RedTide_2018(10)	1.854					Fixed
AgeSel_P6_RedTide_2018(10)	0.273					Fixed
AgeSel_P7_RedTide_2018(10)	0.273					Fixed
AgeSel_P8_RedTide_2018(10)	0.273					Fixed

Table 12 Continued. List of Stock Synthesis parameters for Gulf of Mexico Red Grouper. The list includes expected parameter values, lower and upper bounds of the parameters, associated standard deviations (SD) and coefficients of variation (CV), prior type and densities (value, SD) if applicable, and phases. Parameters designated as fixed were held at their initial values and have no associated range or SD.

Label	Value	Range	SD	CV	Prior	Phase
AgeSel_P9_RedTide_2018(10)	0.273					Fixed
AgeSel_P10_RedTide_2018(10)	0.273					Fixed
AgeSel_P11_RedTide_2018(10)	0.273					Fixed
AgeSel_P12_RedTide_2018(10)	0.273					Fixed
AgeSel_P13_RedTide_2018(10)	0.273					Fixed
AgeSel_P14_RedTide_2018(10)	0.273					Fixed
AgeSel_P15_RedTide_2018(10)	0.273					Fixed
AgeSel_P16_RedTide_2018(10)	0.273					Fixed
AgeSel_P17_RedTide_2018(10)	0.273					Fixed
AgeSel_P18_RedTide_2018(10)	0.273					Fixed
AgeSel_P19_RedTide_2018(10)	0.273					Fixed
AgeSel_P20_RedTide_2018(10)	0.273					Fixed
AgeSel_P21_RedTide_2018(10)	0.273					Fixed
AgeSel_P22_RedTide_2018(10)	0.273					Fixed
AgeSel_P23_RedTide_2018(10)	0.273					Fixed
AgeSel_P24_RedTide_2018(10)	0.273					Fixed
AgeSel_P25_RedTide_2018(10)	0.273					Fixed
AgeSel_P26_RedTide_2018(10)	0.273					Fixed
AgeSel_P27_RedTide_2018(10)	0.273					Fixed
AgeSel_P28_RedTide_2018(10)	0.273					Fixed
AgeSel_P29_RedTide_2018(10)	0.273					Fixed
AgeSel_P30_RedTide_2018(10)	0.273					Fixed
AgeSel_P1_RedTide_2021(11)	2.39					Fixed
AgeSel_P2_RedTide_2021(11)	9					Fixed
AgeSel_P3_RedTide_2021(11)	1.244					Fixed
AgeSel_P4_RedTide_2021(11)	0.027					Fixed
AgeSel_P5_RedTide_2021(11)	-0.117					Fixed
AgeSel_P6_RedTide_2021(11)	-0.666					Fixed

Table 12 Continued. List of Stock Synthesis parameters for Gulf of Mexico Red Grouper. The list includes expected parameter values, lower and upper bounds of the parameters, associated standard deviations (SD) and coefficients of variation (CV), prior type and densities (value, SD) if applicable, and phases. Parameters designated as fixed were held at their initial values and have no associated range or SD.

Label	Value	Range	SD	CV	Prior	Phase
AgeSel_P7_RedTide_2021(11)	-0.666					Fixed
AgeSel_P8_RedTide_2021(11)	-0.666					Fixed
AgeSel_P9_RedTide_2021(11)	-0.666					Fixed
AgeSel_P10_RedTide_2021(11)	-0.666					Fixed
AgeSel_P11_RedTide_2021(11)	-0.666					Fixed
AgeSel_P12_RedTide_2021(11)	-0.666					Fixed
AgeSel_P13_RedTide_2021(11)	-0.666					Fixed
AgeSel_P14_RedTide_2021(11)	-0.666					Fixed
AgeSel_P15_RedTide_2021(11)	-0.666					Fixed
AgeSel_P16_RedTide_2021(11)	-0.666					Fixed
AgeSel_P17_RedTide_2021(11)	-0.666					Fixed
AgeSel_P18_RedTide_2021(11)	-0.666					Fixed
AgeSel_P19_RedTide_2021(11)	-0.666					Fixed
AgeSel_P20_RedTide_2021(11)	-0.666					Fixed
AgeSel_P21_RedTide_2021(11)	-0.666					Fixed
AgeSel_P22_RedTide_2021(11)	-0.666					Fixed
AgeSel_P23_RedTide_2021(11)	-0.666					Fixed
AgeSel_P24_RedTide_2021(11)	-0.666					Fixed
AgeSel_P25_RedTide_2021(11)	-0.666					Fixed
AgeSel_P26_RedTide_2021(11)	-0.666					Fixed
AgeSel_P27_RedTide_2021(11)	-0.666					Fixed
AgeSel_P28_RedTide_2021(11)	-0.666					Fixed
AgeSel_P29_RedTide_2021(11)	-0.666					Fixed
AgeSel_P30_RedTide_2021(11)	-0.666					Fixed
ln(DM_theta)_Len_P1	3.64	(-5,10)	0.462	0.127	Normal(0,1)	6
ln(DM_theta)_Len_P2	1.601	(-5,10)	0.334	0.208	Normal(0,1)	6
ln(DM_theta)_Len_P3	2.207	(-5,10)	0.395	0.179	Normal(0,1)	6

Table 12 Continued. List of Stock Synthesis parameters for Gulf of Mexico Red Grouper. The list includes expected parameter values, lower and upper bounds of the parameters, associated standard deviations (SD) and coefficients of variation (CV), prior type and densities (value, SD)

if applicable, and phases. Parameters designated as fixed were held at their initial values and have no associated range or SD.

Label	Value	Range	SD	CV	Prior	Phase
ln(DM_theta)_Len_P4	3.267	(-5,10)	0.467	0.143	Normal(0,1)	6
ln(DM_theta)_Len_P5	3.938	(-5,10)	0.451	0.115	Normal(0,1)	6
ln(DM_theta)_Age_P6	1.503	(-5,10)	0.277	0.184	Normal(0,1)	6
ln(DM_theta)_Age_P7	-0.33	(-5,10)	0.137	-0.416	Normal(0,1)	6
Retain_L_infl_comm_HL(1)_BLK2repl_1990	45.252	(0,85)	0.349	0.008		3
Retain_L_infl_comm_HL(1)_BLK2repl_2010	44.663	(20,85)	0.222	0.005		3
Retain_L_width_comm_HL(1)_BLK2repl_1990	2.941	(0,20)	0.411	0.140		3
Retain_L_width_comm_HL(1)_BLK2repl_2010	1.429	(0,20)	0.164	0.115		3
Retain_L_asymptote_logit_comm_HL(1)_BLK2repl_1990	9.778					Fixed
Retain_L_asymptote_logit_comm_HL(1)_BLK2repl_2010	6.684	(-10,10)	1.732	0.259		3
Retain_L_infl_comm_LL(2)_BLK2repl_1990	50.218	(0,85)	0.427	0.008		3
Retain_L_infl_comm_LL(2)_BLK2repl_2010	47.048	(20,85)	0.236	0.005		3
Retain_L_width_comm_LL(2)_BLK2repl_1990	1.012	(0,20)	0.456	0.451		3
Retain_L_width_comm_LL(2)_BLK2repl_2010	0.927	(0,20)	0.181	0.195		3
Retain_L_asymptote_logit_comm_LL(2)_BLK2repl_1990	4.726	(-10,10)	2.661	0.563		3
Retain_L_asymptote_logit_comm_LL(2)_BLK2repl_2010	4.216	(-10,10)	0.71	0.168		3
DiscMort_L_level_old_comm_LL(2)_BLK4repl_2010	0.441					Fixed
Retain_L_infl_commTrap(3)_BLK3repl_1990	48.502					Fixed
Retain_L_width_commTrap(3)_BLK3repl_1990	0.056					Fixed
Retain_L_asymptote_logit_commTrap(3)_BLK3repl_1990	10					Fixed
Retain_L_infl_Rec(4)_BLK1repl_1990	48.795					Fixed
Retain_L_width_Rec(4)_BLK1repl_1990	1.039	(0,20)	0.15	0.144		3
Retain_L_asymptote_logit_Rec(4)_BLK1repl_1990	1.932	(-10,10)	0.232	0.120		3

Table 13. Estimates of annual exploitation rate (total biomass killed all ages / total biomass age 0+) combined across all fleets for Gulf of Mexico Red Grouper, which was used as the proxy for annual fishing mortality rate. Estimates are provided for the SEDAR 88 Operational Assessment and the SEDAR 61 Standard Assessment.

Year	SEDAR88	SEDAR61
1986	0.136	0.262
1987	0.123	0.207
1988	0.134	0.214
1989	0.253	0.379
1990	0.142	0.244
1991	0.157	0.268
1992	0.159	0.268
1993	0.171	0.280
1994	0.149	0.253
1995	0.147	0.241
1996	0.108	0.196
1997	0.110	0.205
1998	0.099	0.169
1999	0.162	0.250
2000	0.146	0.237
2001	0.124	0.203
2002	0.125	0.191
2003	0.108	0.157
2004	0.167	0.227
2005	0.265	0.453
2006	0.133	0.205
2007	0.084	0.146
2008	0.103	0.178
2009	0.078	0.128
2010	0.074	0.104
2011	0.104	0.145
2012	0.146	0.182
2013	0.170	0.191

Table 13 continued. Estimates of annual exploitation rate (total biomass killed all ages / total biomass age 0+) combined across all fleets for Gulf of Mexico Red Grouper, which was used as the proxy for annual fishing mortality rate. Estimates are provided for the SEDAR 88 Operational Assessment and the SEDAR 61 Standard Assessment.

Year	SEDAR88	SEDAR61
2014	0.321	0.429
2015	0.161	0.231
2016	0.143	0.218
2017	0.089	0.160
2018	0.102	
2019	0.058	
2020	0.074	
2021	0.140	
2022	0.059	

Table 14. Estimates of annual exploitation rate (total biomass killed all ages / total biomass age 0+) by fleet and combined across all fleets (Total) in the Gulf of Mexico for Red Grouper. Note: the annual exploitation rate for the red tide bycatch fleets are shown in a single column for reporting simplicity.

Year	Handline	Longline	Trap	Rec	Red tide	Total
1986	0.043	0.035	0.010	0.048	0.000	0.136
1987	0.036	0.053	0.006	0.028	0.000	0.123
1988	0.030	0.031	0.008	0.066	0.000	0.134
1989	0.054	0.046	0.008	0.144	0.000	0.253
1990	0.043	0.038	0.006	0.055	0.000	0.142
1991	0.033	0.053	0.009	0.063	0.000	0.157
1992	0.029	0.045	0.010	0.075	0.000	0.159
1993	0.021	0.086	0.014	0.051	0.000	0.171
1994	0.022	0.057	0.017	0.053	0.000	0.149
1995	0.021	0.050	0.019	0.057	0.000	0.147
1996	0.017	0.062	0.011	0.018	0.000	0.108
1997	0.017	0.058	0.012	0.022	0.000	0.110
1998	0.014	0.050	0.005	0.030	0.000	0.099
1999	0.021	0.071	0.012	0.058	0.000	0.162
2000	0.025	0.049	0.016	0.056	0.000	0.146
2001	0.023	0.057	0.011	0.032	0.000	0.124
2002	0.025	0.052	0.015	0.033	0.000	0.125
2003	0.016	0.047	0.010	0.035	0.000	0.108
2004	0.018	0.055	0.010	0.083	0.000	0.167
2005	0.021	0.054	0.009	0.036	0.144	0.265
2006	0.026	0.061	0.011	0.036	0.000	0.133
2007	0.024	0.034	0.000	0.025	0.000	0.084
2008	0.026	0.042	0.000	0.035	0.000	0.103
2009	0.033	0.016	0.000	0.029	0.000	0.078
2010	0.020	0.018	0.000	0.036	0.000	0.074
2011	0.022	0.042	0.000	0.040	0.000	0.104
2012	0.029	0.041	0.000	0.075	0.000	0.146
2013	0.021	0.045	0.000	0.104	0.000	0.170

Table 14 Continued. Estimates of annual exploitation rate (total biomass killed all ages / total biomass age 0+) by fleet and combined across all fleets (Total) in the Gulf of Mexico for Red Grouper. Note: the annual exploitation rate for the red tide bycatch fleets are shown in a single column for reporting simplicity.

Year	Handline	Longline	Trap	Rec	Red tide	Total
2014	0.030	0.059	0	0.098	0.133	0.321
2015	0.037	0.060	0	0.064	0.000	0.161
2016	0.024	0.067	0	0.053	0.000	0.143
2017	0.020	0.048	0	0.021	0.000	0.089
2018	0.013	0.035	0	0.024	0.030	0.102
2019	0.011	0.029	0	0.017	0.000	0.058
2020	0.013	0.030	0	0.032	0.000	0.074
2021	0.016	0.030	0	0.043	0.050	0.140
2022	0.012	0.025	0	0.022	0.000	0.059

Table 15. Expected biomass (metric tons) for all Red Grouper and exploited Red Grouper (0+ years), spawning stock biomass (relative number of eggs), exploited numbers (0+ years, 1,000s of fish), age-0 recruits (1,000s of fish), and SSB ratio (SSB/SSB_0) where SSB_0 = 1,618,300 relative number of eggs for Red Grouper in the Gulf of Mexico.

Year	Biomass (all)	Biomass (exploited)	SSB	Abundance (exploited)	Recruits	SSB ratio
1986	33,189	33,189	732,961	87,583.8	38,898.30	0.45
1987	32,417	32,417	717,155	84,779.7	38,689.20	0.44
1988	31,997	31,997	713,098	83,365.2	38,634.40	0.44
1989	31,296	31,296	704,669	82,016.2	38,519.10	0.44
1990	27,157	27,157	592,527	77,686.9	36,761.60	0.37
1991	26,902	26,902	582,327	77,117.6	36,578.00	0.36
1992	26,364	26,364	568,357	76,422.2	36,318.80	0.35
1993	25,903	25,903	559,693	72,099.7	32,438.70	0.35
1994	25,052	25,052	542,939	93,973.9	56,127.30	0.34
1995	25,763	25,763	546,516	59,278.6	13,069.00	0.34
1996	25,117	25,117	549,924	116,392.0	82,164.60	0.34
1997	27,612	27,612	580,986	74,123.0	19,227.70	0.36
1998	28,206	28,206	608,022	52,880.2	10,630.40	0.38
1999	28,200	28,200	650,561	166,487.0	134,543.00	0.40
2000	31,017	31,017	644,263	101,381.0	27,760.00	0.40
2001	31,555	31,555	638,902	69,925.6	13,693.70	0.40
2002	31,550	31,550	668,327	128,956.0	87,256.00	0.41
2003	33,668	33,668	709,434	75,347.4	13,495.70	0.44
2004	33,905	33,905	760,844	85,076.8	40,445.90	0.47
2005	32,809	32,809	762,408	49,084.1	4,556.96	0.47
2006	26,640	26,640	665,829	191,927.0	165,959.00	0.41
2007	31,167	31,167	661,892	140,884.0	58,404.30	0.41
2008	34,873	34,873	686,296	88,337.3	14,356.00	0.42
2009	36,012	36,012	720,300	75,863.8	22,873.60	0.44
2010	37,168	37,168	811,822	64,346.1	19,858.00	0.50
2011	37,535	37,535	910,971	53,495.8	15,661.70	0.56
2012	36,085	36,085	955,002	61,116.0	29,684.20	0.59

Table 15 Continued. Expected biomass (metric tons) for all Red Grouper and exploited Red Grouper (0+ years), spawning stock biomass (relative number of eggs), exploited numbers (0+ years, 1,000s of fish), age-0 recruits (1,000s of fish), and SSB ratio (SSB/SSB_0) where SSB_0 = 1,618,300 relative number of eggs for Red Grouper in the Gulf of Mexico.

Year	Biomass (all)	Biomass (exploited)	SSB	Abundance (exploited)	Recruits	SSB ratio
2013	33,464	33,464	920,249	43,743.1	11,551.2	0.57
2014	29,534	29,534	826,320	87,000.9	62,065.7	0.51
2015	23,358	23,358	592,275	100,347.0	63,720.6	0.37
2016	23,616	23,616	514,000	75,482.4	27,751.6	0.32
2017	23,591	23,591	468,037	61,939.5	21,248.2	0.29
2018	24,394	24,394	489,477	79,177.2	44,297.7	0.30
2019	25,389	25,389	528,078	91,386.1	52,255.9	0.33
2020	27,889	27,889	593,306	114,421.0	68,215.2	0.37
2021	30,838	30,838	646,624	116,012.0	59,353.1	0.40
2022	31,551	31,551	660,063	78,518.5	23,646.6	0.41

Table 16. Input (with log-scale standard errors, SE) and expected (Exp) landings for the Commercial Handline fleet in weight (W, million pounds gutted weight) and number (N, 1,000s of fish) for Red Grouper in the Gulf of Mexico. The expected mean weight (MW, gutted pounds per fish) was determined by dividing the expected landings in weights by expected landings in numbers of fish.

Year	Input W SE	Input W	Exp W	Exp N	Exp MW
1986	0.10	3.162	3.168	577.252	5.5
1987	0.05	2.538	2.540	465.655	5.5
1988	0.05	2.082	2.082	382.875	5.4
1989	0.05	3.766	3.758	682.040	5.5
1990	0.05	2.485	2.479	340.522	7.3
1991	0.05	1.901	1.895	266.267	7.1
1992	0.05	1.640	1.635	235.061	7.0
1993	0.05	1.361	1.170	171.950	6.8
1994	0.05	1.256	1.174	175.577	6.7
1995	0.05	1.176	1.144	171.835	6.7
1996	0.05	0.876	0.922	138.672	6.7
1997	0.05	0.963	1.005	150.799	6.7
1998	0.05	0.745	0.818	122.583	6.7
1999	0.05	1.233	1.247	187.783	6.6
2000	0.05	1.757	1.609	240.564	6.7
2001	0.05	1.578	1.544	236.553	6.5
2002	0.05	1.644	1.686	253.045	6.7
2003	0.05	1.138	1.123	166.319	6.7
2004	0.05	1.424	1.288	206.906	6.2
2005	0.05	1.454	1.448	228.596	6.3
2006	0.05	1.384	1.447	214.074	6.8
2007	0.05	1.577	1.621	238.388	6.8
2008	0.05	1.903	1.954	279.216	7.0
2009	0.05	2.575	2.545	347.019	7.3
2010	0.01	1.610	1.610	224.153	7.2
2011	0.01	1.737	1.737	275.375	6.3
2012	0.01	2.251	2.249	360.538	6.2

Table 16 Continued. Input (with log-scale standard errors, SE) and expected (Exp) landings for the Commercial Handline fleet in weight (W, million pounds gutted weight) and number (N, 1,000s of fish) for Red Grouper in the Gulf of Mexico. The expected mean weight (MW, gutted pounds per fish) was determined by dividing the expected landings in weights by expected landings in numbers of fish.

Year	Input W SE	Input W	Exp W	Exp N	Exp MW
2013	0.01	1.542	1.544	226.086	6.8
2014	0.01	1.943	1.942	257.918	7.5
2015	0.01	1.875	1.877	232.589	8.1
2016	0.01	1.214	1.216	145.697	8.3
2017	0.01	1.013	1.013	123.911	8.2
2018	0.01	0.668	0.668	85.759	7.8
2019	0.01	0.594	0.594	85.343	7.0
2020	0.01	0.752	0.752	116.246	6.5
2021	0.01	1.089	1.088	163.804	6.6
2022	0.01	0.808	0.807	114.544	7.0

Table 17. Input (with log-scale standard errors, SE) and expected (Exp) landings for the Commercial Longline fleet in weight (W, million pounds gutted weight) and number (N, 1,000s of fish) for Red Grouper in the Gulf of Mexico. The expected mean weight (MW, gutted pounds per fish) was determined by dividing the expected landings in weights by expected landings in numbers of fish.

Year	Input W SE	Input W	Exp W	Exp N	Exp MW
1986	0.10	2.542	2.545	459.269	5.5
1987	0.05	3.788	3.791	688.198	5.5
1988	0.05	2.165	2.164	393.105	5.5
1989	0.05	3.182	3.176	569.768	5.6
1990	0.05	2.026	2.021	218.745	9.2
1991	0.05	2.726	2.712	298.155	9.1
1992	0.05	2.282	2.272	254.550	8.9
1993	0.05	4.347	4.191	479.663	8.7
1994	0.05	2.695	2.679	313.120	8.6
1995	0.05	2.413	2.414	285.096	8.5
1996	0.05	2.908	2.927	347.517	8.4
1997	0.05	3.032	3.038	361.348	8.4
1998	0.05	2.661	2.676	317.614	8.4
1999	0.05	3.826	3.766	447.961	8.4
2000	0.05	2.915	2.884	341.916	8.4
2001	0.05	3.410	3.384	404.254	8.4
2002	0.05	3.140	3.128	376.213	8.3
2003	0.05	2.974	2.933	345.026	8.5
2004	0.05	3.450	3.373	408.107	8.3
2005	0.05	3.296	3.304	412.526	8.0
2006	0.05	3.012	3.097	375.600	8.2
2007	0.05	1.982	2.051	242.292	8.5
2008	0.05	2.808	2.837	329.927	8.6
2009	0.05	1.117	1.123	126.370	8.9
2010	0.01	1.301	1.298	158.419	8.2
2011	0.01	3.047	3.023	402.875	7.5
2012	0.01	2.968	2.969	413.013	7.2

Table 17 Continued. Input (with log-scale standard errors, SE) and expected (Exp) landings for the Commercial Longline fleet in weight (W, million pounds gutted weight) and number (N, 1,000s of fish) for Red Grouper in the Gulf of Mexico. The expected mean weight (MW, gutted pounds per fish) was determined by dividing the expected landings in weights by expected landings in numbers of fish.

Year	Input W SE	Input W	Exp W	Exp N	Exp MW
2013	0.01	3.057	3.058	404.415	7.6
2014	0.01	3.658	3.662	446.641	8.2
2015	0.01	2.922	2.926	332.008	8.8
2016	0.01	3.283	3.286	355.543	9.2
2017	0.01	2.316	2.325	249.767	9.3
2018	0.01	1.695	1.700	187.785	9.1
2019	0.01	1.443	1.447	174.184	8.3
2020	0.01	1.616	1.618	212.118	7.6
2021	0.01	1.862	1.865	246.397	7.6
2022	0.01	1.621	1.624	206.483	7.9

Table 18. Input (with log-scale standard errors, SE) and expected (Exp) landings for the Commercial Trap fleet in weight (W, million pounds gutted weight) and number (N, 1,000s of fish) for Red Grouper in the Gulf of Mexico. The expected mean weight (MW, gutted pounds per fish) was determined by dividing the expected landings in weights by expected landings in numbers of fish.

Year	Input W SE	Input W	Exp W	Exp N	Exp MW
1986	0.10	0.712	0.713	165.046	4.3
1987	0.05	0.447	0.447	103.914	4.3
1988	0.05	0.532	0.532	122.995	4.3
1989	0.05	0.580	0.579	132.956	4.4
1990	0.05	0.331	0.332	47.864	6.9
1991	0.05	0.477	0.481	70.407	6.8
1992	0.05	0.563	0.557	82.494	6.7
1993	0.05	0.737	0.740	110.919	6.7
1994	0.05	0.926	0.888	134.116	6.6
1995	0.05	1.062	1.044	157.772	6.6
1996	0.05	0.542	0.578	87.133	6.6
1997	0.05	0.684	0.718	107.646	6.7
1998	0.05	0.300	0.298	44.706	6.7
1999	0.05	0.748	0.737	110.284	6.7
2000	0.05	1.026	1.028	154.386	6.7
2001	0.05	0.742	0.744	112.878	6.6
2002	0.05	0.978	0.960	142.562	6.7
2003	0.05	0.705	0.697	105.257	6.6
2004	0.05	0.764	0.747	117.111	6.4
2005	0.05	0.629	0.631	96.675	6.5
2006	0.05	0.586	0.593	88.262	6.7
2007	0.05	0.024	0.024	5.424	4.5

Table 19. Input (with log-scale standard errors, SE) and expected (Exp) landings for the Recreational fleet in number (N, 1,000s of fish) and weight (W, million pounds gutted weight) for Red Grouper in the Gulf of Mexico. The expected mean weight (MW, gutted pounds per fish) was determined by dividing the expected landings in weights by expected landings in numbers of fish.

Year	Input N SE	Input N	Exp N	Exp W	Exp MW
1986	0.10	2.010	1.897	860.392	3.9
1987	0.25	1.349	1.070	485.325	3.9
1988	0.23	2.507	2.527	1,146.170	3.9
1989	0.26	3.623	5.339	2,421.680	4.0
1990	0.26	0.929	0.873	395.981	6.8
1991	0.26	0.940	1.004	455.197	6.6
1992	0.21	1.459	1.180	535.228	6.5
1993	0.26	1.047	0.793	359.774	6.5
1994	0.24	0.902	0.810	367.352	6.4
1995	0.27	0.899	0.902	409.211	6.4
1996	0.25	0.252	0.279	126.699	6.4
1997	0.30	0.283	0.372	168.807	6.4
1998	0.20	0.340	0.522	236.756	6.4
1999	0.21	0.772	0.987	447.795	6.4
2000	0.21	1.001	1.088	493.318	6.4
2001	0.20	0.592	0.641	290.692	6.3
2002	0.23	0.719	0.589	267.220	6.5
2003	0.19	0.585	0.701	317.765	6.3
2004	0.22	1.959	1.869	847.952	6.0
2005	0.22	0.808	0.759	344.384	6.3
2006	0.31	0.602	0.592	268.638	6.6
2007	0.23	0.497	0.491	222.859	6.5
2008	0.18	0.425	0.718	325.473	6.7
2009	0.22	0.339	0.519	235.275	7.0
2010	0.24	0.553	0.742	336.470	6.4
2011	0.18	0.465	1.006	456.295	6.0
2012	0.20	1.129	1.851	839.527	6.3

Table 19 Continued. Input (with log-scale standard errors, SE) and expected (Exp) landings for the Recreational fleet in number (N, 1,000s of fish) and weight (W, million pounds gutted weight) for Red Grouper in the Gulf of Mexico. The expected mean weight (MW, gutted pounds per fish) was determined by dividing the expected landings in weights by expected landings in numbers of fish.

Year	Input N SE	Input N	Exp N	Exp W	Exp MW
2013	0.19	1.427	2.216	1,005.080	6.9
2014	0.24	1.396	1.701	771.461	7.4
2015	0.20	0.883	0.823	373.418	7.7
2016	0.19	0.784	0.660	299.239	7.7
2017	0.17	0.303	0.250	113.276	7.4
2018	0.21	0.348	0.303	137.308	6.9
2019	0.19	0.339	0.269	121.835	6.3
2020	0.21	0.589	0.578	262.111	6.3
2021	0.15	0.856	0.826	374.595	6.6
2022	0.18	0.468	0.400	181.457	6.8

Table 20. Input (with log-scale standard errors, SE) and expected (Exp) discards for the Commercial Handline fleet in numbers (N, 1,000s of fish) and biomass (B, thousand pounds gutted weight) for Gulf of Mexico Red Grouper. Dead discards in numbers (discard mortality rate = 0.19), dead discards in biomass, and mean weight (MW, gutted pounds per fish) are included. Mean weight was determined by dividing the expected discards in weights by the expected discards in numbers.

Year	Input N SE	Input N	Exp N	Exp Dead N	Exp B	Exp Dead B	Exp MW
1993	0.073	83.940	108.997	20.709	256.477	48.731	2.4
1994	0.071	99.040	111.333	21.154	262.901	49.952	2.4
1995	0.071	101.625	107.180	20.365	253.833	48.228	2.4
1996	0.071	92.714	85.352	16.217	202.417	38.460	2.4
1997	0.072	99.735	92.355	17.548	218.024	41.425	2.4
1998	0.069	89.242	76.569	14.548	180.437	34.284	2.4
1999	0.072	118.027	115.023	21.854	272.504	51.776	2.4
2000	0.072	132.828	153.575	29.179	358.004	68.021	2.3
2001	0.073	144.545	149.741	28.450	359.939	68.390	2.4
2002	0.073	151.885	145.158	27.580	340.832	64.759	2.3
2003	0.067	122.886	125.401	23.826	275.908	52.424	2.2
2004	0.069	132.082	154.559	29.366	366.836	69.699	2.4
2005	0.072	125.725	127.141	24.157	316.098	60.058	2.5
2006	0.076	126.092	116.359	22.108	278.311	52.880	2.4
2007	0.110	146.641	131.338	24.954	320.887	60.969	2.4
2008	0.110	150.377	133.059	25.281	329.211	62.549	2.5
2009	0.110	184.424	189.324	35.972	422.758	80.314	2.2
2010	0.244	172.362	175.939	33.429	342.128	65.003	1.9
2011	0.129	201.629	205.569	39.058	437.229	83.074	2.1
2012	0.105	153.513	167.420	31.810	378.203	71.871	2.3
2013	0.178	92.270	70.811	13.454	161.786	30.739	2.3
2014	0.177	53.355	69.929	13.287	156.367	29.709	2.2
2015	0.175	81.745	67.301	12.787	145.172	27.584	2.2
2016	0.221	88.329	53.280	10.124	110.961	21.083	2.1
2017	0.251	68.589	59.468	11.299	119.202	22.648	2.0
2018	0.216	69.066	57.675	10.958	112.702	21.413	2.0
2019	0.216	61.951	64.842	12.320	133.155	25.300	2.1

Table 20 Continued. Input (with log-scale standard errors, SE) and expected (Exp) discards for the Commercial Handline fleet in numbers (N, 1,000s of fish) and biomass (B, thousand pounds gutted weight) for Gulf of Mexico Red Grouper. Dead discards in numbers (discard mortality rate = 0.19), dead discards in biomass, and mean weight (MW, gutted pounds per fish) are included. Mean weight was determined by dividing the expected discards in weights by the expected discards in numbers.

Year	Input N SE	Input N	Exp N	Exp Dead N	Exp B	Exp Dead B	Exp MW
2020	0.334	54.158	68.448	13.005	148.082	28.135	2.2
2021	0.334	55.598	72.738	13.820	158.395	30.095	2.2
2022	0.262	32.242	49.965	9.493	104.570	19.870	2.1

Table 21. Input (with log-scale standard errors, SE) and expected (Exp) discards for the Commercial Longline fleet in numbers (N, 1,000s of fish) and biomass (B, thousand pounds gutted weight) for Gulf of Mexico Red Grouper. Dead discards in numbers (discard mortality rate = 0.42), dead discards in biomass, and mean weight (MW, gutted pounds per fish) are included. Mean weight was determined by dividing the expected discards in weights by the expected discards in numbers.

Year	Input N SE	Input N	Exp N	Exp Dead N	Exp B	Exp Dead B	Exp MW
1993	0.153	501.888	677.237	281.052	1,689.753	701.246	2.5
1994	0.153	401.072	449.229	186.430	1,118.646	464.249	2.5
1995	0.153	371.606	400.437	166.181	1,004.623	416.916	2.5
1996	0.153	485.855	487.201	202.188	1,207.492	501.110	2.5
1997	0.153	519.787	499.483	207.285	1,241.355	515.176	2.5
1998	0.153	498.047	439.312	182.314	1,100.965	456.907	2.5
1999	0.153	623.631	625.629	259.635	1,544.292	640.883	2.5
2000	0.153	471.426	486.661	201.964	1,196.932	496.723	2.5
2001	0.153	577.922	587.981	244.012	1,465.764	608.299	2.5
2002	0.153	524.725	524.676	217.741	1,257.625	521.922	2.4
2003	0.153	506.581	555.870	230.686	1,327.578	550.935	2.4
2004	0.153	555.139	690.783	286.676	1,769.693	734.425	2.6
2005	0.153	509.507	540.118	224.149	1,433.929	595.071	2.7
2006	0.153	518.717	446.576	185.329	1,130.397	469.121	2.5
2007	0.153	370.882	289.966	120.336	733.067	304.224	2.5
2008	0.153	408.240	370.651	153.820	906.826	376.329	2.4
2009	0.210	175.821	158.384	65.729	359.723	149.286	2.3
2010	0.115	153.157	190.619	84.063	400.729	176.722	2.1
2011	0.066	341.082	449.699	198.317	1,050.149	463.125	2.3
2012	0.136	313.854	302.456	133.383	753.495	332.302	2.5
2013	0.114	206.516	201.408	88.821	513.191	226.326	2.5
2014	0.180	238.140	192.225	84.771	471.260	207.830	2.5
2015	0.174	205.810	157.044	69.256	352.938	155.646	2.2
2016	0.123	235.615	216.243	95.363	450.713	198.769	2.1
2017	0.114	314.514	207.268	91.405	413.058	182.168	2.0
2018	0.114	276.746	207.875	91.673	420.796	185.572	2.0
2019	0.114	260.985	208.723	92.047	451.903	199.289	2.2

Table 21 Continued. Input (with log-scale standard errors, SE) and expected (Exp) discards for the Commercial Longline fleet in numbers (N, 1,000s of fish) and biomass (B, thousand pounds gutted weight) for Gulf of Mexico Red Grouper. Dead discards in numbers (discard mortality rate = 0.42), dead discards in biomass, and mean weight (MW, gutted pounds per fish) are included. Mean weight was determined by dividing the expected discards in weights by the expected discards in numbers.

Year	Input N SE	Input N	Exp N	Exp Dead N	Exp B	Exp Dead B	Exp MW
2020	0.114	237.383	207.196	91.374	467.401	206.125	2.3
2021	0.114	223.972	192.001	84.672	427.732	188.629	2.2
2022	0.114	188.264	155.174	68.432	335.484	147.948	2.2

Table 22. Input (with log-scale standard errors, SE) and expected (Exp) discards for the Commercial Trap fleet in numbers (N, 1,000s of fish) and biomass (B, thousand pounds gutted weight) for Gulf of Mexico Red Grouper. Dead discards in numbers (discard mortality rate = 0.1), dead discards in biomass, and mean weight (MW, gutted pounds per fish) are included. Mean weight was determined by dividing the expected discards in weights by the expected discards in numbers.

Year	Input N SE	Input N	Exp N	Exp Dead N	Exp B	Exp Dead B	Exp MW
1993	0.29	169.87	158.028	15.803	366.408	36.641	2.3
1994	0.29	53.90	188.986	18.899	439.436	43.942	2.3
1995	0.29	124.73	219.568	21.957	506.844	50.684	2.3
1996	0.29	732.74	121.001	12.100	277.727	27.774	2.3
1997	0.29	598.57	152.376	15.238	350.464	35.047	2.3
1998	0.29	50.19	62.567	6.257	142.945	14.295	2.3
1999	0.29	106.19	154.600	15.460	359.351	35.933	2.3
2000	0.29	234.98	215.837	21.584	509.840	50.984	2.4
2001	0.29	167.62	156.062	15.606	337.000	33.700	2.2
2002	0.29	146.06	244.194	24.420	533.485	53.350	2.2
2003	0.29	134.70	185.223	18.522	445.227	44.525	2.4
2004	0.29	81.90	154.579	15.458	371.549	37.154	2.4
2005	0.29	122.09	114.318	11.432	268.763	26.877	2.4
2006	0.29	139.27	99.250	9.925	243.617	24.363	2.5

Table 23. Input (with log-scale standard errors, SE) and expected (Exp) discards for the Recreational fleet in numbers (N, 1,000s of fish) and biomass (B, thousand pounds gutted weight) for Gulf of Mexico Red Grouper. Dead discards in numbers (discard mortality rate = 0.12), dead discards in biomass, and mean weight (MW, gutted pounds per fish) are included. Mean weight was determined by dividing the expected discards in weights by the expected discards in numbers.

Year	Input N SE	Input N	Exp N	Exp Dead N	Exp B	Exp Dead B	Exp MW
1986	0.318	670.707	1,120.758	130.008	1,163.687	134.989	1.0
1987	0.209	549.637	632.385	73.357	658.901	76.434	1.0
1988	0.210	1,423.760	1,417.450	164.420	1,493.895	173.283	1.1
1989	0.242	4,634.560	3,041.690	352.830	3,164.952	367.135	1.0
1990	0.254	3,144.640	3,146.349	364.976	5,330.793	618.374	1.7
1991	0.210	3,888.370	3,658.243	424.357	6,228.537	722.520	1.7
1992	0.182	3,658.640	4,245.262	492.452	7,292.133	845.891	1.7
1993	0.207	2,242.920	2,811.286	326.109	4,844.256	561.936	1.7
1994	0.221	2,359.870	2,830.598	328.349	4,885.107	566.676	1.7
1995	0.221	2,868.390	3,094.539	358.966	5,346.578	620.204	1.7
1996	0.231	1,110.070	1,028.851	119.347	1,696.023	196.738	1.6
1997	0.226	1,534.520	1,312.943	152.301	2,312.611	268.263	1.8
1998	0.159	2,482.340	1,930.084	223.890	3,121.508	362.096	1.6
1999	0.143	4,115.350	3,721.055	431.642	6,438.505	746.859	1.7
2000	0.160	3,350.640	3,217.352	373.213	6,152.499	713.680	1.9
2001	0.146	2,648.300	2,548.588	295.637	3,664.186	425.049	1.4
2002	0.146	2,877.000	3,072.470	356.406	4,865.570	564.400	1.6
2003	0.137	2,975.400	2,735.305	317.295	5,257.697	609.895	1.9
2004	0.152	5,528.630	5,521.168	640.458	9,707.802	1,126.098	1.8
2005	0.150	2,135.460	2,166.106	251.268	3,873.061	449.264	1.8
2006	0.296	1,616.310	1,604.792	186.156	3,029.968	351.476	1.9
2007	0.208	1,216.460	1,183.901	137.333	2,220.262	257.548	1.9
2008	0.147	4,586.270	3,210.657	372.436	4,102.454	475.876	1.3
2009	0.151	4,672.460	3,850.195	446.623	5,669.039	657.607	1.5
2010	0.169	4,154.500	3,636.510	421.835	6,872.702	797.232	1.9
2011	0.179	4,517.500	2,241.595	260.025	4,921.924	570.930	2.2
2012	0.157	3,463.190	2,627.493	304.793	5,828.133	676.069	2.2

Table 23 Continued. Input (with log-scale standard errors, SE) and expected (Exp) discards for the Recreational fleet in numbers (N, 1,000s of fish) and biomass (B, thousand pounds gutted weight) for Gulf of Mexico Red Grouper. Dead discards in numbers (discard mortality rate = 0.12), dead discards in biomass, and mean weight (MW, gutted pounds per fish) are included. Mean weight was determined by dividing the expected discards in weights by the expected discards in numbers.

Year	Input N SE	Input N	Exp N	Exp Dead N	Exp B	Exp Dead B	Exp MW
2013	0.163	3,946.670	3,049.450	353.740	6,371.793	739.143	2.1
2014	0.139	3,338.550	3,214.709	372.909	5,845.572	678.097	1.8
2015	0.141	2,074.000	2,118.432	245.738	3,687.161	427.696	1.7
2016	0.148	2,494.690	2,719.671	315.482	3,895.850	451.903	1.4
2017	0.123	1,470.510	1,607.644	186.487	2,274.557	263.849	1.4
2018	0.127	1,690.860	1,781.342	206.636	2,960.686	343.440	1.7
2019	0.120	864.442	937.745	108.778	1,791.496	207.814	1.9
2020	0.144	1,438.710	1,483.449	172.080	2,722.181	315.772	1.8
2021	0.109	2,381.870	2,461.495	285.533	4,032.426	467.754	1.6
2022	0.101	1,533.160	1,601.073	185.724	2,514.960	291.735	1.6

Table 24. Observed (Obs) versus expected (Exp) standardized Commercial Handline (ComHL) catch-per-unit-effort (CPUE) indices for Red Grouper in the Gulf of Mexico. Values are normalized to the mean. CVs estimated by the standardization process were converted to log-scale SEs and scaled to a mean SE of 0.3. Indices end in 2009 due to the implementation of the IFQ program in 2010.

Year	ComHL (Obs)	ComHL (Exp)	ComHL (SE)
1993	0.731	0.829	0.309
1994	0.716	0.816	0.306
1995	0.789	0.822	0.309
1996	0.491	0.843	0.318
1997	0.565	0.880	0.319
1998	0.519	0.923	0.317
1999	0.740	0.957	0.311
2000	0.991	0.937	0.304
2001	1.347	0.954	0.295
2002	1.387	0.994	0.295
2003	0.947	0.956	0.291
2004	1.274	1.085	0.286
2005	1.417	1.151	0.288
2006	1.143	1.028	0.291
2007	1.207	1.064	0.288
2008	1.531	1.103	0.287
2009	1.206	1.046	0.286

Table 25. Observed (Obs) versus expected (Exp) standardized Commercial Longline (ComLL) catch-per-unit-effort (CPUE) indices for Red Grouper in the Gulf of Mexico. Values are normalized to the mean. CVs estimated by the standardization process were converted to log-scale SEs and scaled to a mean SE of 0.3. Indices end in 2009 due to the implementation of the IFQ program in 2010.

Year	ComLL (Obs)	ComLL (Exp)	ComLL (SE)
1993	0.979	0.865	0.332
1994	0.724	0.839	0.294
1995	0.774	0.843	0.305
1996	1.040	0.865	0.319
1997	0.907	0.907	0.266
1998	0.955	0.954	0.274
1999	0.997	0.984	0.272
2000	0.898	0.969	0.289
2001	1.056	0.972	0.278
2002	1.060	1.013	0.292
2003	0.928	1.013	0.281
2004	1.112	1.058	0.273
2005	1.444	1.112	0.283
2006	1.093	1.085	0.270
2007	0.780	1.121	0.312
2008	1.181	1.175	0.308
2009	1.073	1.174	0.453

Table 26. Observed (Obs) versus expected (Exp) standardized Recreational (Headboat only) (Rec) catch-per-unit-effort (CPUE) indices for Red Grouper in the Gulf of Mexico. Values are normalized to the mean. CVs estimated by the standardization process were converted to log-scale SEs. Indices end in 2007 due to the change in catchability from the use of circle hooks beginning in 2008 mandated by Reef Fish Amendment 27.

Year	Rec (Obs)	Rec (Exp)	Rec (SE)
1986	0.981	2.926	0.624
1987	1.856	2.923	0.568
1988	1.420	2.918	0.554
1989	1.668	2.600	0.580
1990	0.688	0.630	0.664
1991	0.519	0.634	0.684
1992	0.395	0.638	0.702
1993	0.604	0.638	0.657
1994	0.600	0.641	0.648
1995	0.737	0.642	0.637
1996	0.636	0.654	0.668
1997	0.400	0.675	0.696
1998	0.522	0.716	0.674
1999	0.530	0.739	0.664
2000	0.403	0.728	0.703
2001	0.804	0.780	0.635
2002	0.861	0.732	0.618
2003	1.325	0.761	0.538
2004	2.499	1.010	0.471
2005	2.509	0.937	0.464
2006	0.903	0.739	0.610
2007	1.139	0.764	0.573

Table 27. Observed (Obs) versus expected (Exp) standardized Combined Video Survey (Cmb Vid) index for Red Grouper in the Gulf of Mexico. Values are normalized to the mean. CVs estimated by the standardization process were converted to log-scale SEs.

Year	Cmb Vid (Obs)	Cmb Vid (Exp)	Cmb Vid (SE)
1993	0.721	0.917	0.194
1994	0.638	0.914	0.198
1995	0.537	0.925	0.246
1996	0.754	0.947	0.155
1997	0.974	1.011	0.124
2002	0.954	1.208	0.127
2004	1.237	1.248	0.119
2005	1.317	1.106	0.093
2006	1.129	1.002	0.104
2007	0.755	1.109	0.122
2008	1.129	1.227	0.104
2009	1.591	1.359	0.082
2010	1.155	1.445	0.077
2011	1.387	1.406	0.059
2012	1.175	1.255	0.068
2013	1.056	1.065	0.090
2014	0.793	0.826	0.078
2015	0.587	0.713	0.098
2016	0.821	0.740	0.064
2017	0.923	0.813	0.061
2018	0.971	0.894	0.075
2019	1.090	0.964	0.063
2020	1.047	1.036	0.063
2021	1.144	1.086	0.056
2022	1.115	1.144	0.060

Table 28. Observed (Obs) versus expected (Exp) standardized SEAMAP Summer Groundfish (GF) survey index for Red Grouper in the Gulf of Mexico. Values are normalized to the mean. CVs estimated by the standardization process were converted to log-scale SEs. Data were not collected in 2020 due to the COVID-19 pandemic.

Year	GF (Obs)	GF (Exp)	GF (SE)
2009	2.118	1.359	0.228
2010	1.273	1.101	0.241
2011	1.156	0.901	0.267
2012	1.426	0.737	0.201
2013	0.819	0.755	0.256
2014	1.026	0.586	0.234
2015	0.793	0.984	0.267
2016	1.000	1.265	0.239
2017	0.701	1.069	0.302
2018	0.361	0.904	0.320
2019	0.328	1.039	0.317
2021	0.990	1.452	0.278
2022	1.008	1.432	0.260

Table 29. Observed (Obs) versus expected (Exp) standardized NMFS Bottom Longline (NMFSBLL) survey indices for Red Grouper in the Gulf of Mexico. Values are normalized to the mean. CVs estimated by the standardization process were converted to log-scale SEs.

Year	NMFSBLL (Obs)	NMFSBLL (Exp)	NMFSBLL (SE)
2001	0.869	1.020	0.284
2003	1.142	1.186	0.204
2004	1.802	1.225	0.195
2005	0.617	1.117	0.394
2006	0.581	1.018	0.380
2007	0.955	1.023	0.443
2008	0.641	1.040	0.316
2009	1.007	1.153	0.261
2010	1.382	1.371	0.262
2011	2.565	1.510	0.181
2012	2.574	1.457	0.257
2013	1.176	1.267	0.310
2014	0.650	0.956	0.372
2015	0.845	0.736	0.349
2016	0.378	0.664	0.418
2017	0.792	0.684	0.333
2018	0.487	0.785	0.411
2019	0.488	0.909	0.440
2020	0.696	1.003	0.390
2021	0.850	1.026	0.433
2022	0.501	1.064	0.460

Table 30. Summary of correlated parameters with correlation coefficients > 0.7 for the Gulf of Mexico Red Grouper SEDAR 88 OA Base Model.

Parameter 1	Parameter 2	Correlation
Age_95%width_comm_LL(2)	Age_inflection_comm_LL(2)	0.737
Age_DblN_ascend_se_comm_HL(1)	Age_DblN_peak_comm_HL(1)	0.927
Age_DblN_descend_se_Rec(4)	Age_DblN_top_logit_Rec(4)	-0.929
Size_95%width_CmbVid(6)	Size_inflection_CmbVid(6)	0.802
Size_95%width_NMFS_BLL(8)	Size_inflection_NMFS_BLL(8)	0.833
Size_DblN_top_logit_commTrap(3)	Size_DblN_peak_commTrap(3)	-0.859
VonBert_K_Fem_GP_1	L_at_Amax_Fem_GP_1	-0.980

Table 31. Retrospective analysis and retrospective forecast spawning stock biomass (relative number of eggs) and fishing mortality (F, total biomass killed all ages / total biomass age 0+) for the last five terminal years and combined (grey rows) for the Gulf of Mexico Red Grouper SEDAR 88 OA Base Model. N = number of observations to compute each statistic. Values within -0.15 to 0.2 are highlighted in green and are considered acceptable levels of retrospective bias. Values outside the acceptable range of -0.15 to 0.2 for longer-lived species (Hurtado-Ferro et al. 2015) are highlighted in red and indicate an undesirable retrospective pattern. See Carvalho et al. (2021) for additional details.

Quantity	Statistic	Value	N
SSB (-2021)	Mohn's Rho	0.074	1
SSB (-2020)	Mohn's Rho	0.062	1
SSB (-2019)	Mohn's Rho	0.146	1
SSB (-2018)	Mohn's Rho	0.039	1
SSB (-2017)	Mohn's Rho	0.059	1
SSB (-Combined)	Mohn's Rho	0.076	5
SSB (-2021)	Forecast bias	0.127	1
SSB (-2020)	Forecast bias	0.074	1
SSB (-2019)	Forecast bias	0.167	1
SSB (-2018)	Forecast bias	0.103	1
SSB (-2017)	Forecast bias	0.082	1
SSB (-Combined)	Forecast bias	0.110	5
F (-2021)	Mohn's Rho	-0.396	1
F (-2020)	Mohn's Rho	-0.098	1
F (-2019)	Mohn's Rho	-0.123	1
F (-2018)	Mohn's Rho	-0.367	1
F (-2017)	Mohn's Rho	-0.010	1
F (-Combined)	Mohn's Rho	-0.199	5
F (-2021)	Forecast bias	0.005	1
F (-2020)	Forecast bias	0.099	1
F (-2019)	Forecast bias	-0.060	1
F (-2018)	Forecast bias	-0.012	1
F (-2017)	Forecast bias	-0.234	1
F (-Combined)	Forecast bias	-0.040	5

Table 32. Joint residual summary statistics for the Gulf of Mexico Red Grouper SEDAR 88 OA Base Model. N = number of observations to compute each statistic. RMSE = root mean squared error (as a percentage), with values above 30% for joint residuals (grey rows) highlighted in red if present and acceptable values below 30% highlighted in green. See Carvalho et al. (2021) for additional details.

Data Source	Statistic	Value	N
Index of Abundance			
Commercial Handline	RMSE(%)	28.5	17
Commercial Longline	RMSE(%)	13.5	17
Recreational (Hbt)	RMSE(%)	50.4	22
Combined Video Survey	RMSE(%)	19.6	25
SEAMAP Summer Groundfish	RMSE(%)	53.8	13
NMFS Bottom Longline Survey	RMSE(%)	41.2	21
Combined	RMSE(%)	36.8	115
Age			
Commercial Handline	RMSE(%)	6.1	31
Commercial Longline	RMSE(%)	7.5	29
Commercial Trap	RMSE(%)	5.3	1
Recreational	RMSE(%)	8.9	32
Combined	RMSE(%)	7.6	93
Length			
Commercial Handline	RMSE(%)	4	15
Commercial Longline	RMSE(%)	4.7	11
Recreational	RMSE(%)	7.3	16
Combined Video Survey	RMSE(%)	5.7	21
SEAMAP Summer Groundfish	RMSE(%)	10.8	13
NMFS Bottom Longline Survey	RMSE(%)	4.2	21
Combined	RMSE(%)	6.3	97

Table 33. Runs tests summary statistics for the Gulf of Mexico Red Grouper SEDAR 88 OA Base Model. N = number of observations to compute each statistic. P-values greater than 0.05% (in green) provide support for randomly distributed residuals whereas p-values less than 0.05% (in red) indicate non-randomly distributed residuals. See Carvalho et al. (2021) for additional details.

Data Source	Statistic	Value	N
Index of Abundance			
Commercial Handline	p-value	0.003	17
Commercial Longline	p-value	0.924	17
Recreational (Hbt)	p-value	0.005	22
Combined Video Survey	p-value	0.007	25
SEAMAP Summer Groundfish	p-value	0.001	13
NMFS Bottom Longline Survey	p-value	0.376	21
Age			
Commercial Handline	p-value	0.255	31
Commercial Longline	p-value	0.373	29
Commercial Trap	p-value		1
Recreational	p-value	0	32
Length			
Commercial Handline	p-value	0.242	15
Commercial Longline	p-value	0.001	11
Recreational	p-value	0.526	16
Combined Video Survey	p-value	0.249	21
SEAMAP Summer Groundfish	p-value	0.007	13
NMFS Bottom Longline Survey	p-value	0.841	21

Table 34. Hindcast cross-validation summary statistics for the Gulf of Mexico Red Grouper SEDAR 88 OA Base Model. N = number of observations to compute each statistic. MASE = mean absolute scaled error, with values < 1 (in green) indicative of superior prediction skill over a naïve baseline forecast (random walk) and values > 1 (in red) indicative of poor prediction skill.

Data Source	Statistic	Value	N
Index of Abundance			
Commercial Handline	MASE		0
Commercial Longline	MASE		0
Recreational (Hbt)	MASE		0
Combined Video Survey	MASE	0.858	5
SEAMAP Summer Groundfish	MASE	1.175	4
NMFS Bottom Longline Survey	MASE	1.883	5
Joint	MASE	1.444	14
Age			
Commercial Handline	MASE	0.639	5
Commercial Longline	MASE	1.404	5
Commercial Trap	MASE		0
Recreational	MASE	2.072	5
Joint	MASE	1.386	15
Length			
Commercial Handline	MASE	0.948	4
Commercial Longline	MASE	0.626	1
Recreational	MASE	0.616	5
Combined Video Survey	MASE	1.977	5
SEAMAP Summer Groundfish	MASE	1.664	4
NMFS Bottom Longline Survey	MASE	0.337	5
Joint	MASE	1.026	24

Table 35. Summary of key model building steps towards the SEDAR 88 OA Base Model for Gulf of Mexico Red Grouper and associated key estimates and derived quantities (NLL = negative log-likelihood, CV = coefficient of variation, R0 = virgin recruitment (log-scale)). Note that steps within each model progression are not shown due to the vast number of intermediate runs conducted.

Description	NLL	Gradient	Est. Parms (Bounded)	CV>1	ln(R0)	Steepness	SigmaR
SEDAR 61 Base Model	537	0.000	178 (0)	8	9.93	0.990	0.815
Step 1 + replace REC catches and discards with SRFS data same CV, TY S61	1,013	0.000	178 (1)	10	9.88	0.990	0.785
Step 2 + remove RTD survey	986	0.000	176 (0)	12	9.88	0.990	0.811
Step 3 + remove MRIP index	999	0.001	176 (0)	9	9.87	0.990	0.793
Step 4 + updated data	1,929	0.000	176 (0)	8	9.73	0.990	0.993
Step 5 + end year 2022	2,305	0.000	195 (3)	6	9.79	0.990	0.995
Step 6 + MW of private mode landings included	2,541	0.002	195 (1)	7	9.75	0.990	0.980
Step 7 + DM on comps	10,231	0.017	205 (2)	7	9.72	0.990	0.652
Step 8 + free sel parms	4,504	0.365	246 (6)	24	9.89	0.990	0.773
Step 9 + update M point estimate	5,381	0.182	249 (1)	19	10.92	0.990	0.818
Step 10 + age select	5,645	0.002	227 (1)	15	10.58	0.990	0.652
Step 11 + Logistic sel LL	5,706	0.000	221 (0)	8	10.31	0.786	0.652
Step 12 + estimate Linf	5,781	0.214	216 (0)	4	10.27	0.786	0.646
Step 13 + est steepness	5,740	0.001	218 (0)	9	10.69	0.660	0.620
Proposed Base	5,721	0.002	218 (0)	6	10.71	0.661	0.647

Table 35 Continued. Summary of key model building steps towards the SEDAR 88 OA Base Model for Gulf of Mexico Red Grouper and associated key estimates and derived quantities. Note that steps within each model progression are not shown due to the vast number of intermediate runs conducted.

Description	Target M	Linf	Virgin SSB	Virgin Recr (1,000s)	Depletion Start Yr	Depletion End Yr
SEDAR 61 Base Model	0.14	79.995	2,494,130	20,443	0.37	0.28
Step 1 + replace REC catches and discards with SRFS data same CV, TY S61	0.14	79.995	2,372,230	19,444	0.41	0.26
Step 2 + remove RTD survey	0.14	79.995	2,379,600	19,504	0.41	0.27
Step 3 + remove MRIP index	0.14	79.995	2,361,480	19,356	0.41	0.25
Step 4 + updated data	0.14	79.995	2,050,540	16,807	0.44	0.30
Step 5 + end year 2022	0.14	79.995	2,173,530	17,815	0.55	0.50
Step 6 + MW of private mode landings included	0.14	79.995	2,098,160	17,197	0.49	0.41
Step 7 + DM on comps	0.14	79.995	2,022,010	16,573	0.49	0.41
Step 8 + free sel parms	0.14	79.995	2,396,950	19,646	0.51	0.45
Step 9 + update M point estimate	0.18	79.995	3,131,020	55,066	0.59	0.72
Step 10 + age select	0.18	79.995	2,245,470	39,491	0.52	0.52
Step 11 + Logistic sel LL	0.18	79.995	1,707,470	30,030	0.44	0.33
Step 12 + estimate Linf	0.18	87.981	1,640,570	28,853	0.44	0.32
Step 13 + est steepness	0.18	92.234	1,657,330	43,929	0.44	0.38
Proposed Base	0.18	92.410	1,618,300	44,926	0.45	0.41

Table 36. Summary of sensitivity runs conducted with the SEDAR 61 Standard Base Model using new data inputs provided during the SEDAR 88 OA for Gulf of Mexico Red Grouper and associated convergence diagnostics (NLL = negative log-likelihood, CV = coefficient of variation, R0 = virgin recruitment (log-scale)).

Description	NLL	Gradient	Estimated Parameters (Bounded)	CV >1	ln(R0)	Steepness	Sigma R
SEDAR 61 Base Model	537	0.0001	178 (0)	8	9.93	0.99	0.815
SEDAR 61 with SRFS Data	1,013	0.0003	178 (0)	10	9.88	0.99	0.785
Update Combined Video Index and associated length compositions	548	0.0001	178 (0)	9	10.61	0.99	0.783
Update natural mortality vector with S88 point estimate	540	0.0001	178 (0)	9	10.61	0.99	0.792

Table 36 Continued. Summary of sensitivity runs conducted with the SEDAR 61 Standard Base Model using new data inputs provided during the SEDAR 88 OA for Gulf of Mexico Red Grouper and associated key estimates and derived quantities. SSB defined as relative number of eggs and Recr = recruitment. SSB ratio was calculated as annual SSB divided by SSB_0.

Description	Target M	Linf	Virgin SSB	Virgin Recr (1,000s)	Depletion Start Yr	Depletion End Yr
SEDAR 61 Base Model	0.140	79.9	2,494,130	20,443	0.37	0.28
SEDAR 61 with SRFS Data	0.140	79.9	2,372,230	967,430	0.41	0.26
Update Combined Video Index and associated length compositions	0.140	79.9	2,296,820	40,394	0.37	0.28
Update natural mortality vector with S88 point estimate	0.186	79.9	2,309,910	40,625	0.37	0.28

Table 37. Summary of sensitivity runs conducted for the SEDAR 88 OA Base Model for Gulf of Mexico Red Grouper and associated convergence diagnostics (NLL = negative log-likelihood, CV = coefficient of variation, R0 = virgin recruitment (log-scale)).

Description	NLL	Gradient	Estimated Parameters (Bounded)	CV>1	ln(R0)	Steepness	Sigma R
SEDAR 88 OA Base Model	5,721	0.0015	218 (0)	6	10.71	0.661	0.647
Steepness							
Fixed at 0.78 (FishLife)	5,723	0.0013	217 (0)	8	10.66	0.786	0.650
Fixed at 0.99 (S61)	5,729	0.0010	217 (1)	8	10.61	0.990	0.650
Natural Mortality							
Low M	5,719	0.0029	218 (0)	6	10.31	0.700	0.652
High M	5,725	0.0195	218 (0)	7	11.27	0.615	0.641
S61 M	5,731	0.0063	217 (0)	5	9.86	0.733	0.651
S61 with Estimated Linf	5,739	0.0329	218 (0)	4	9.92	0.741	0.646
Red Tide							
No red tide included	5,725	0.0006	214 (0)	4	10.72	0.596	0.715
Red tide S61 selectivity	5,720	0.0007	218 (0)	6	10.71	0.665	0.644
Growth							
Estimate Linf with platoons	5,742	0.0010	218 (0)	7	10.84	0.643	0.619
Fix Linf	5,732	0.0001	217 (0)	6	10.62	0.661	0.645
Recruitment Deviation Method							
Method 2	5,711	0.0012	218 (0)	5	10.74	0.614	0.834
G-FISHER							
Time block applied for G-FISHER	5,709	0.0003	220 (0)	6	10.72	0.644	0.653

Table 37 continued. Summary of sensitivity runs conducted for the SEDAR 88 OA Base Model for Gulf of Mexico Red Grouper and associated key estimates and derived quantities. SSB defined as relative number of eggs, Recr = recruitment. SSB ratio was calculated as annual SSB divided by SSB_0.

Description	Target M	Linf	Virgin SSB	Virgin Recr (1,000s)	Depletion Start Yr	Depletion End Yr
SEDAR 88 OA Base Model	0.186	92.41	1,618,300	44,926	0.453	0.408
Steepness						
Fixed at 0.78 (FishLife)	0.186	92.45	1,542,410	42,785	0.474	0.435
Fixed at 0.99 (S61)	0.186	92.78	1,463,740	40,688	0.503	0.467
Natural Mortality						
Low M	0.158	93.06	1,660,910	30,071	0.406	0.344
High M	0.225	91.38	1,611,260	78,588	0.521	0.510
S61 M	0.140	80.00	1,851,430	19,071	0.354	0.282
S61 with Estimated Linf	0.140	87.61	1,797,250	20,372	0.343	0.280
Red Tide						
No red tide included	0.186	92.61	1,618,470	45,227	0.457	0.383
Red tide S61 selectivity	0.186	92.41	1,616,990	44,942	0.452	0.382
Growth						
Estimate Linf with platoons	0.186	91.22	1,628,810	51,150	0.460	0.411
Fix Linf	0.186	80.00	1,700,370	40,772	0.439	0.405
Recruitment Deviation Method						
Method 2	0.186	92.24	1,658,410	45,958	0.461	0.447
G-FISHER						
Time block applied for G-FISHER	0.186	92.37	1,621,740	45,246	0.455	0.364

Table 38. Comparison of red tide quantities from the sensitivity run using full selectivity beginning at age 0 as compared to the SEDAR 88 OA Base Model with empirical selectivity-at-age derived from the West Florida Shelf Ecospace Model. Values in parentheses for biomass (metric tons) or numbers (1,000s of fish) are the percentages killed.

Years	Empirical Sel@age	Full Sel@age 0
F values (CV)		
2005	0.174 (0.533)	0.163 (0.506)
2014	0.196 (0.455)	0.128 (0.545)
2018	0.042 (2.04)	0.025 (2.519)
2021	0.099 (1.606)	0.122 (0.634)
Biomass killed		
2005	4,741 (14%)	4,870 (15%)
2014	3,918 (13%)	3,289 (11%)
2018	733 (3%)	618 (2.5%)
2021	1,539 (5%)	3,751 (12%)
Numbers killed		
2005	5,936 (12%)	5,853 (12%)
2014	5,042 (6%)	7,624 (8%)
2018	2,129 (3%)	1,425 (2%)
2021	6,682 (6%)	10,046 (8%)

Table 39. Settings used for Gulf of Mexico Red Grouper projections.

Parameter	Value	Comment
Relative F		Not used due to allocations below
Selectivity	Average from 2020-2022	Fleet specific selectivity estimated over terminal three years of model
Retention	Average from 2020-2022	Fleet specific retention estimated over terminal three years of model
Recruitment	Beverton-Holt stock-recruitment relationship	Derived from the model estimated Beverton-Holt stock-recruitment relationship
Interim Landings (2023-2026)	383.68/400.48 metric tons (Commercial Handline); 740.8/770.99 metric tons (Commercial Longline); 185.72/289.27 numbers (Recreational)	Landings provided for 2023; For 2024, 2025 and 2026 used 3-year average of landings (2021-2023)
Allocation Ratio	59.3:40.7	Commercial: Recreational

Table 40. Summary of Magnuson-Stevens Reauthorization Act benchmarks and reference points for the SEDAR 88 Gulf of Mexico Red Grouper Operational Assessment **assuming predicted recruitment from the stock-recruit curve throughout the projection period**. Spawning Stock Biomass (SSB) is in relative number of eggs, whereas *F* is a harvest rate (total biomass killed all ages / total biomass age 0+). An SPR proxy of 30% was specified in the SEDAR 88 Terms of Reference.

Criteria	Definition	Value
Base M	Target M for fully selected ages in the Lorenzen (2000) scaling	0.186
Steepness	Steepness of the Beverton-Holt stock-recruit relationship (fixed)	0.661
Unfished Recruitment (R0)	Unfished recruitment (1,000s)	44,927
Generation Time	Fecundity-weighted mean age	9.78
Unfished SSB (SSB0)	Unfished spawning stock biomass (Relative number of eggs)	1,618,300
	Mortality Rate Criteria	
FMSYproxy	Equilibrium F that achieves SPR30%	0.203
MFMT	FMSYproxy	0.203
Fcurrent	Geometric mean of the last 3 years of the assessment (F2020-2022)	0.073
Fcurrent/MFMT	Current stock status based on MFMT	0.363
	Biomass Criteria	
SSBMSYproxy	Equilibrium SSB at FSPR 30 %	318,790
MSST	0.5 * SSBSPR30%	159,395
SSBcurrent	SSB in 2022	660,063
SSBcurrent/SSBFMSYproxy	Current stock status based on SSBSPR30% (Equilibrium)	2.07
SSBcurrent/MSST	Current stock status based on MSST	4.14
SSBcurrent/SSB0	SSB ratio in 2022	0.41

Table 41. Summary of Magnuson-Stevens Reauthorization Act benchmarks and reference points for the SEDAR 88 Gulf of Mexico Red Grouper Operational Assessment **assuming predicted recruitment from the stock-recruit curve throughout the projection period**. Spawning Stock Biomass (SSB) is in relative number of eggs, whereas *F* is a harvest rate (total biomass killed all ages / total biomass age 0+).

Criteria	Definition	Value
Base M	Target M for fully selected ages in the Lorenzen (2000) scaling	0.186
Steepness	Steepness of the Beverton-Holt stock-recruit relationship (fixed)	0.661
Unfished Recruitment (R0)	Unfished recruitment (1,000s)	44,927
Generation Time	Fecundity-weighted mean age	9.78
Unfished SSB (SSB0)	Unfished spawning stock biomass (Relative Number of Eggs)	1,618,300
	Mortality Rate Criteria	
FMSY	Equilibrium F that achieves MSY	0.13
MFMT	FMSY	0.13
Fcurrent	Geometric mean of the last 3 years of the assessment (F2020-2022)	0.073
Fcurrent/MFMT	Current stock status based on MFMT	0.565
	Biomass Criteria	
SSBMSY	Equilibrium SSB at FMSY	626,411
MSST	0.5 * SSBMSY	313,206
SSBcurrent	SSB in 2022	660,063
SSBcurrent/SSBFMSY	Current stock status based on SSBMSY (Equilibrium)	1.05
SSBcurrent/MSST	Current stock status based on MSST	2.11
SSBcurrent/SSB0	SSB ratio in 2022	0.41
SPR at MSY	Equivalent SPR (%) at MSY	46.6

Table 42. Time series of fishing mortality (*F*) and SSB relative to associated biological reference points for Gulf of Mexico Red Grouper **assuming predicted recruitment from the stock-recruit curve throughout the projection period**. SSB is in relative number of eggs, whereas *F* is a harvest rate (total biomass killed all ages / total biomass age 0+). Reference points include $F_{30\%SPR}$ = 0.203, $SSB_{F30\%SPR}$ = 318,790 relative number of eggs, and $MSST_{F30\%SPR}$ = 159,395 relative number of eggs which was calculated as (0.5) * $SSB_{F30\%SPR}$. SSB ratio was calculated as annual SSB divided by SSB_0 where SSB_0 = 1,618,300 relative number of eggs. Red indicates overfishing and/or overfished states if present. An SPR proxy of 30% was specified in the SEDAR 88 Terms of Reference. The number in parenthesis in F and $F/F_{30\%SPR}$ represents the total exploitation rate excluding red tide mortality.

Year	F	F/F30%SPR	SSB	SSB/SSB30%SPR	SSB/MSST	SSB ratio
1986	0.136	0.672	732,961	2.299	4.598	0.453
1987	0.123	0.605	717,155	2.250	4.499	0.443
1988	0.134	0.661	713,098	2.237	4.474	0.441
1989	0.253	1.251	704,669	2.210	4.421	0.435
1990	0.142	0.702	592,527	1.859	3.717	0.366
1991	0.157	0.777	582,327	1.827	3.653	0.360
1992	0.159	0.787	568,357	1.783	3.566	0.351
1993	0.171	0.845	559,693	1.756	3.511	0.346
1994	0.149	0.735	542,939	1.703	3.406	0.335
1995	0.147	0.726	546,516	1.714	3.429	0.338
1996	0.108	0.535	549,924	1.725	3.450	0.340
1997	0.11	0.544	580,986	1.822	3.645	0.359
1998	0.099	0.49	608,022	1.907	3.815	0.376
1999	0.162	0.802	650,561	2.041	4.081	0.402
2000	0.146	0.722	644,263	2.021	4.042	0.398
2001	0.124	0.613	638,902	2.004	4.008	0.395
2002	0.125	0.619	668,327	2.096	4.193	0.413
2003	0.108	0.533	709,434	2.225	4.451	0.438
2004	0.167	0.824	760,844	2.387	4.773	0.470
2005	0.265 (0.12)	1.307 (0.594)	762,408	2.392	4.783	0.471
2006	0.133	0.656	665,829	2.089	4.177	0.411
2007	0.084	0.414	661,892	2.076	4.153	0.409
2008	0.103	0.507	686,296	2.153	4.306	0.424
2009	0.078	0.385	720,300	2.259	4.519	0.445

Table 42 Continued. Time series of fishing mortality (*F*) and SSB relative to associated biological reference points for Gulf of Mexico Red Grouper **assuming predicted recruitment from the stock-recruit curve throughout the projection period**. SSB is in relative number of eggs, whereas *F* is a harvest rate (total biomass killed all ages / total biomass age 0+). Reference points include $F_{30\%SPR}$ = 0.203, $SSB_{F30\%SPR}$ = 318,790 relative number of eggs, and $MSST_{F30\%SPR}$ = 159,395 relative number of eggs which was calculated as (0.5) * $SSB_{F30\%SPR}$. SSB ratio was calculated as annual SSB divided by SSB_0 where SSB_0 = 1,618,300 relative number of eggs. Red indicates overfishing and/or overfished states if present. An SPR proxy of 30% was specified in the SEDAR 88 Terms of Reference. The number in parenthesis in F and $F/F_{30\%SPR}$ represents the total exploitation rate excluding red tide mortality.

Year	F	F/F30%SPR	SSB	SSB/SSB30%SPR	SSB/MSST	SSB ratio
2010	0.074	0.368	811,822	2.547	5.093	0.502
2011	0.104	0.514	910,971	2.858	5.715	0.563
2012	0.146	0.719	955,002	2.996	5.991	0.590
2013	0.17	0.839	920,249	2.887	5.773	0.569
2014	0.321 (0.188)	1.584 (0.929)	826,320	2.592	5.184	0.511
2015	0.161	0.795	592,275	1.858	3.716	0.366
2016	0.143	0.708	514,000	1.612	3.225	0.318
2017	0.089	0.441	468,037	1.468	2.936	0.289
2018	0.102 (0.072)	0.503 (0.355)	489,477	1.535	3.071	0.302
2019	0.058	0.286	528,078	1.657	3.313	0.326
2020	0.074	0.367	593,306	1.861	3.722	0.367
2021	0.14 (0.09)	0.69 (0.444)	646,624	2.028	4.057	0.400
2022	0.059	0.293	660,063	2.071	4.141	0.408

Table 43. Results of the OFL projection (fishing set at $F_{30\%SPR}$) for Gulf of Mexico Red Grouper **assuming predicted recruitment from the stock-recruit curve throughout the projection period**. Recruitment (Recr) is in 1,000s of age-0 fish, *F* is a harvest rate (total biomass killed all ages / total biomass age 0+), SSB is in relative number of eggs, and OFL is the overfishing limit in millions of pounds gutted weight. Reference points include $F_{30\%SPR}$ = 0.203, $SSB_{F30\%SPR}$ = 318,790 relative number of eggs, and $MSST_{F30\%SPR}$ = 159,395 relative number of eggs which was calculated as (0.5) * $SSB_{F30\%SPR}$. SSB ratio was calculated as annual SSB divided by SSB_0 where SSB_0 = 1,618,300 relative number of eggs. An SPR proxy of 30% was specified in the SEDAR 88 Terms of Reference.

Year	Recr	F	F/F30 %SPR	SSB	SSB/ SSB30%SPR	SSB/ MSST	SSB ratio	OFL
2027	41,306	0.203	1	961,572	3.016	6.033	0.594	15.683
2028	40,101	0.203	1	835,153	2.620	5.240	0.516	13.928
2029	38,842	0.203	1	728,675	2.286	4.572	0.450	12.508
2030	37,658	0.203	1	646,185	2.027	4.054	0.399	11.397
2031	36,629	0.203	1	585,145	1.836	3.671	0.362	10.528
2032	35,786	0.203	1	541,081	1.697	3.395	0.334	9.853

Table 44. Results of the ABC projection (directed *F* = 0.75 * Directed *F* at $F_{30\%SPR}$ (0.203)) for Gulf of Mexico Red Grouper **assuming predicted recruitment from the stock-recruit curve throughout the projection period**. Recruitment (Recr) is in 1,000s of age-0 fish, *F* is a harvest rate (total biomass killed all ages / total biomass age 0+), SSB is in relative number of eggs, and yield in millions of pounds gutted weight. Reference points include $F_{30\%SPR}$ = 0.203, $SSB_{F30\%SPR}$ = 318,790 relative number of eggs, and $MSST_{F30\%SPR}$ = 159,395relative number of eggs which was calculated as (0.5) * $SSB_{F30\%SPR}$. SSB ratio was calculated as annual SSB divided by SSB_0 where SSB_0 = 1,618,300 relative number of eggs. An SPR proxy of 30% was specified in the SEDAR 88 Terms of Reference.

Year	Recr	F	F/F30 %SPR	SSB	SSB/ SSB30%SPR	SSB/ MSST	SSB ratio	Yield
2027	41,306	0.152	0.75	961,572	3.016	6.033	0.594	11.777
2028	40,647	0.152	0.75	888,979	2.789	5.577	0.549	11.025
2029	39,952	0.152	0.75	821,322	2.576	5.153	0.508	10.379
2030	39,295	0.152	0.75	764,465	2.398	4.796	0.472	9.849
2031	38,718	0.152	0.75	719,304	2.256	4.513	0.444	9.413
2032	38,238	0.152	0.75	684,771	2.148	4.296	0.423	9.056

Table 45. Time series of fishing mortality (*F*) and SSB relative to associated biological reference points for Gulf of Mexico Red Grouper **assuming predicted recruitment from the stock-recruit curve**. SSB is in relative number of eggs, whereas *F* is a harvest rate (total biomass killed all ages / total biomass age 0+). Reference points include F_{MSY}, SSB_{FMSY} relative number of eggs, and $MSST_{FMSY}$ = 159,395 relative number of eggs which was calculated as (0.5) * SSB_{FMSY}. SSB ratio was calculated as annual SSB divided by SSB_0 where SSB_0 = 1.6183^{6} relative number of eggs. Red indicates overfishing and/or overfished states if present. The number in parenthesis in F and F/FMSY represents the total exploitation rate excluding red tide mortality.

Year	F	F/FMSY	SSB	SSB/SSBMSY	SSB/MSST	SSB ratio
1986	0.136	1.046	732,961	1.170	2.340	0.453
1987	0.123	0.942	717,155	1.145	2.290	0.443
1988	0.134	1.03	713,098	1.138	2.277	0.441
1989	0.253	1.947	704,669	1.125	2.250	0.435
1990	0.142	1.092	592,527	0.946	1.892	0.366
1991	0.157	1.21	582,327	0.930	1.859	0.360
1992	0.159	1.225	568,357	0.907	1.815	0.351
1993	0.171	1.315	559,693	0.893	1.787	0.346
1994	0.149	1.143	542,939	0.867	1.733	0.335
1995	0.147	1.131	546,516	0.872	1.745	0.338
1996	0.108	0.833	549,924	0.878	1.756	0.340
1997	0.11	0.846	580,986	0.927	1.855	0.359
1998	0.099	0.763	608,022	0.971	1.941	0.376
1999	0.162	1.248	650,561	1.039	2.077	0.402
2000	0.146	1.124	644,263	1.028	2.057	0.398
2001	0.124	0.954	638,902	1.020	2.040	0.395
2002	0.125	0.964	668,327	1.067	2.134	0.413
2003	0.108	0.83	709,434	1.133	2.265	0.438
2004	0.167	1.283	760,844	1.215	2.429	0.470
2005	0.265 (0.12)	2.035 (0.924)	762,408	1.217	2.434	0.471
2006	0.133	1.021	665,829	1.063	2.126	0.411
2007	0.084	0.645	661,892	1.057	2.113	0.409
2008	0.103	0.789	686,296	1.096	2.191	0.424
2009	0.078	0.599	720,300	1.150	2.300	0.445

Table 45 Continued. Time series of fishing mortality (*F*) and SSB relative to associated biological reference points for Gulf of Mexico Red Grouper **assuming predicted recruitment from the stock-recruit curve**. SSB is in relative number of eggs, whereas *F* is a harvest rate (total biomass killed all ages / total biomass age 0+). Reference points include F_{MSY}, SSB_{FMSY} relative number of eggs, and $MSST_{FMSY}$ = 159,395 relative number of eggs which was calculated as (0.5) * SSB_{FMSY}. SSB ratio was calculated as annual SSB divided by SSB_0 where SSB_0 = 1.6183^{6} relative number of eggs. Red indicates overfishing and/or overfished states if present. The number in parenthesis in F and F/FMSY represents the total exploitation rate excluding red tide mortality.

Year	F	F/FMSY	SSB	SSB/SSBMSY	SSB/MSST	SSB ratio
2010	0.074	0.572	811,822	1.296	2.592	0.502
2011	0.104	0.8	910,971	1.454	2.909	0.563
2012	0.146	1.12	955,002	1.525	3.049	0.590
2013	0.17	1.307	920,249	1.469	2.938	0.569
2014	0.321 (0.188)	2.466 (1.446)	826,320	1.319	2.638	0.511
2015	0.161	1.237	592,275	0.946	1.891	0.366
2016	0.143	1.103	514,000	0.821	1.641	0.318
2017	0.089	0.686	468,037	0.747	1.494	0.289
2018	0.102 (0.072)	0.784 (0.553)	489,477	0.781	1.563	0.302
2019	0.058	0.445	528,078	0.843	1.686	0.326
2020	0.074	0.571	593,306	0.947	1.894	0.367
2021	0.14 (0.09)	1.074 (0.691)	646,624	1.032	2.065	0.400
2022	0.059	0.457	660,063	1.054	2.107	0.408

Table 46. Results of the OFL projection (fishing set at F_{MSY}) for Gulf of Mexico Red Grouper **assuming predicted recruitment from the stock-recruit curve**. Recruitment (Recr) is in 1,000s of age-0 fish, *F* is a harvest rate (total biomass killed all ages / total biomass age 0+), SSB is in relative number of eggs, and OFL is the overfishing limit in millions of pounds gutted weight. Reference points include F_{MSY}, SSB_{FMSY} = 318,790 relative number of eggs, and $MSST_{FMSY}$ = 159,395 relative number of eggs which was calculated as (0.5) * SSB_{FMSY}. SSB ratio was calculated as annual SSB divided by SSB_0 where SSB_0 = 1,618,300relative number of eggs.

Year	Recr	F	F/FMSY	SSB	SSB/ SSB MSY	SSB/ MSST	SSB ratio	OFL
2027	41,306	0.13	1	961,572	1.535	3.070	0.594	10.092
2028	40,867	0.13	1	912,232	1.456	2.913	0.564	9.656
2029	40,389	0.13	1	862,905	1.378	2.755	0.533	9.271
2030	39,932	0.13	1	819,472	1.308	2.616	0.506	8.950
2031	39,525	0.13	1	783,694	1.251	2.502	0.484	8.679
2032	39,185	0.13	1	755,571	1.206	2.412	0.467	8.453

Table 47. Results of the ABC projection (directed F = 0.75 * Directed F at F_{MSY}) for Gulf of Mexico Red Grouper **assuming predicted recruitment from the stock-recruit curve throughout the projection period**. Recruitment (Recr) is in 1,000s of age-0 fish, F is a harvest rate (total biomass killed all ages / total biomass age 0+), SSB is in relative number of eggs, and yield in millions of pounds gutted weight. Reference points include F_{MSY}, SSB_{FMSY} = 318,790 relative number of eggs, and $MSST_{FMSY}$ = 159,395 relative number of eggs which was calculated as (0.5) * SSB_{FMSY}. SSB ratio was calculated as annual SSB divided by SSB_0 where SSB_0 = 1,618,300 relative number of eggs.

Year	Recr	F	F/FMSY	SSB	SSB/SSB MSY	SSB/ MSST	SSB ratio	Yield
2027	41,306	0.098	0.75	961,572	1.535	3.070	0.594	7.575
2028	41,180	0.098	0.75	947,005	1.512	3.024	0.585	7.481
2029	41,001	0.098	0.75	926,837	1.480	2.959	0.573	7.391
2030	40,812	0.098	0.75	906,276	1.447	2.894	0.560	7.317
2031	40,635	0.098	0.75	887,725	1.417	2.834	0.549	7.252
2032	40,484	0.098	0.75	872,294	1.393	2.785	0.539	7.195

11. Figures

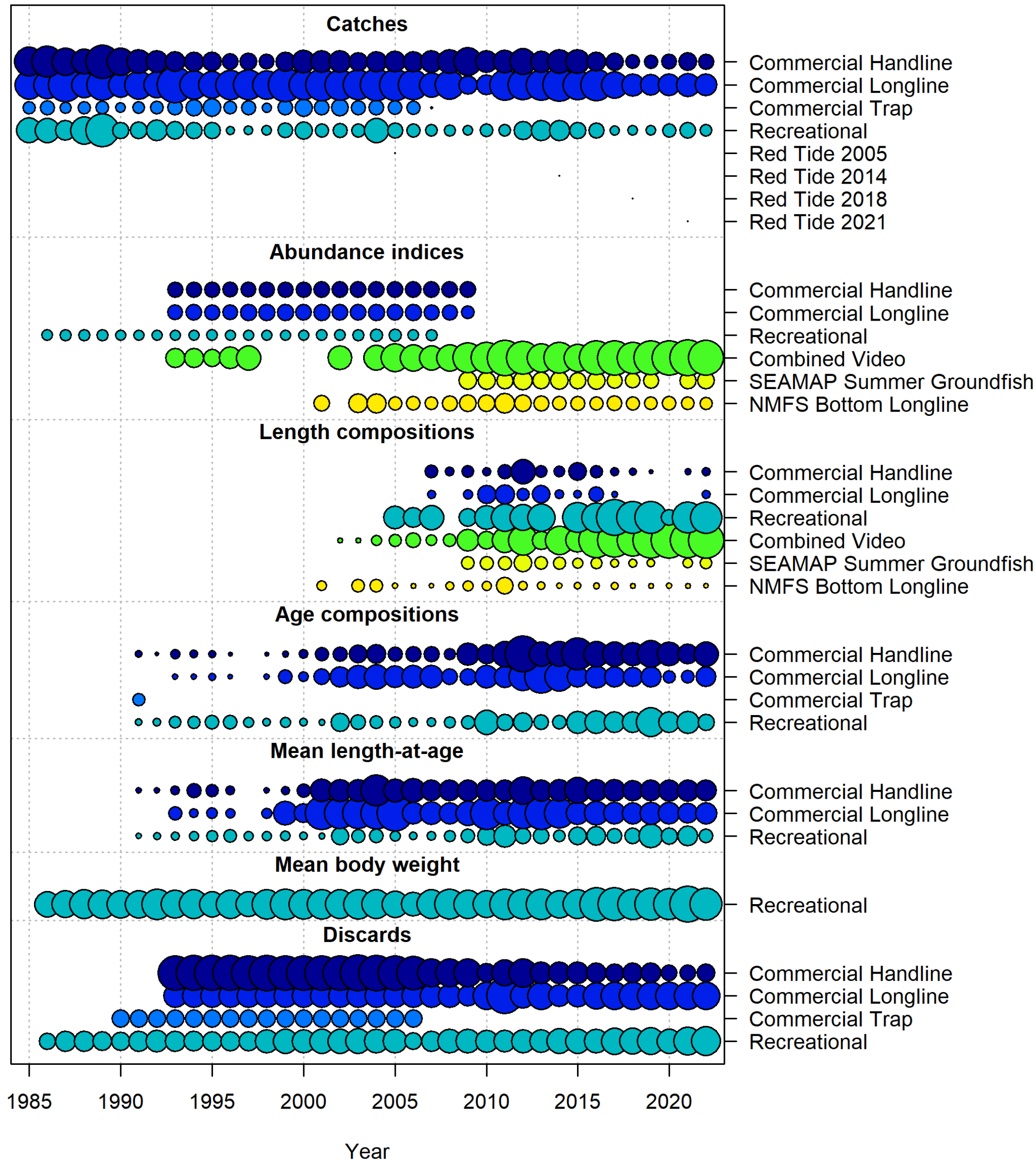


Figure 1. Data sources used in the Gulf of Mexico Red Grouper Stock Synthesis assessment model. Circle area is relative within a data type. Circles are proportional to total catch for catches; to precision for indices, discards, and mean body weight observations; and to total sample size for compositions and mean length-at-age observations. Note that since the circles are scaled relative to maximum within each type, the scaling between separate data types should not be compared. Commercial handline landings include Other landings.

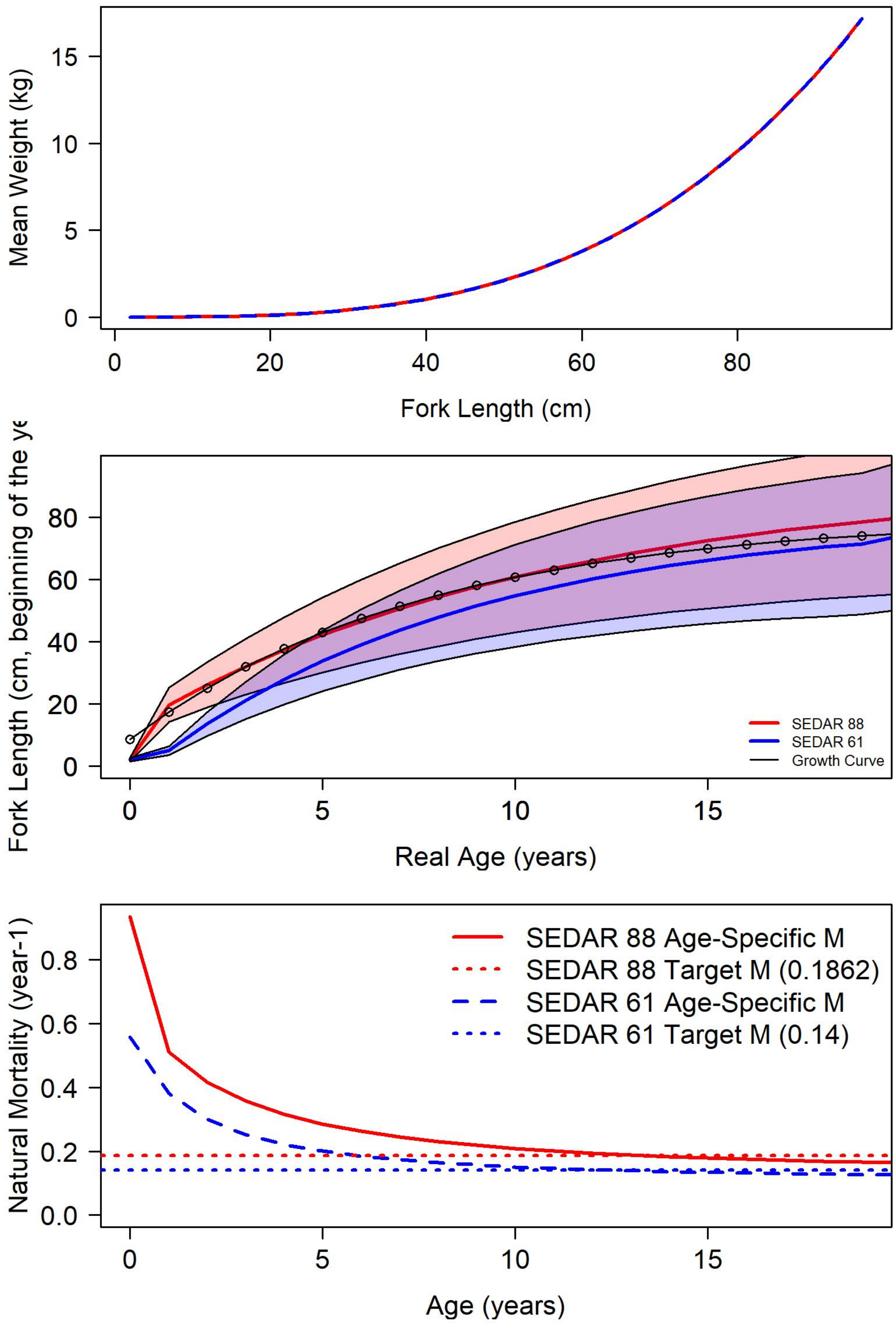


Figure 2. Mean weight-at-length (top panel), growth curves (with 95% confidence intervals; middle panel), and natural mortality (bottom panel) used in the assessment model for Gulf of Mexico Red Grouper. SEDAR 61 and SEDAR 88 inputs are presented for comparison.

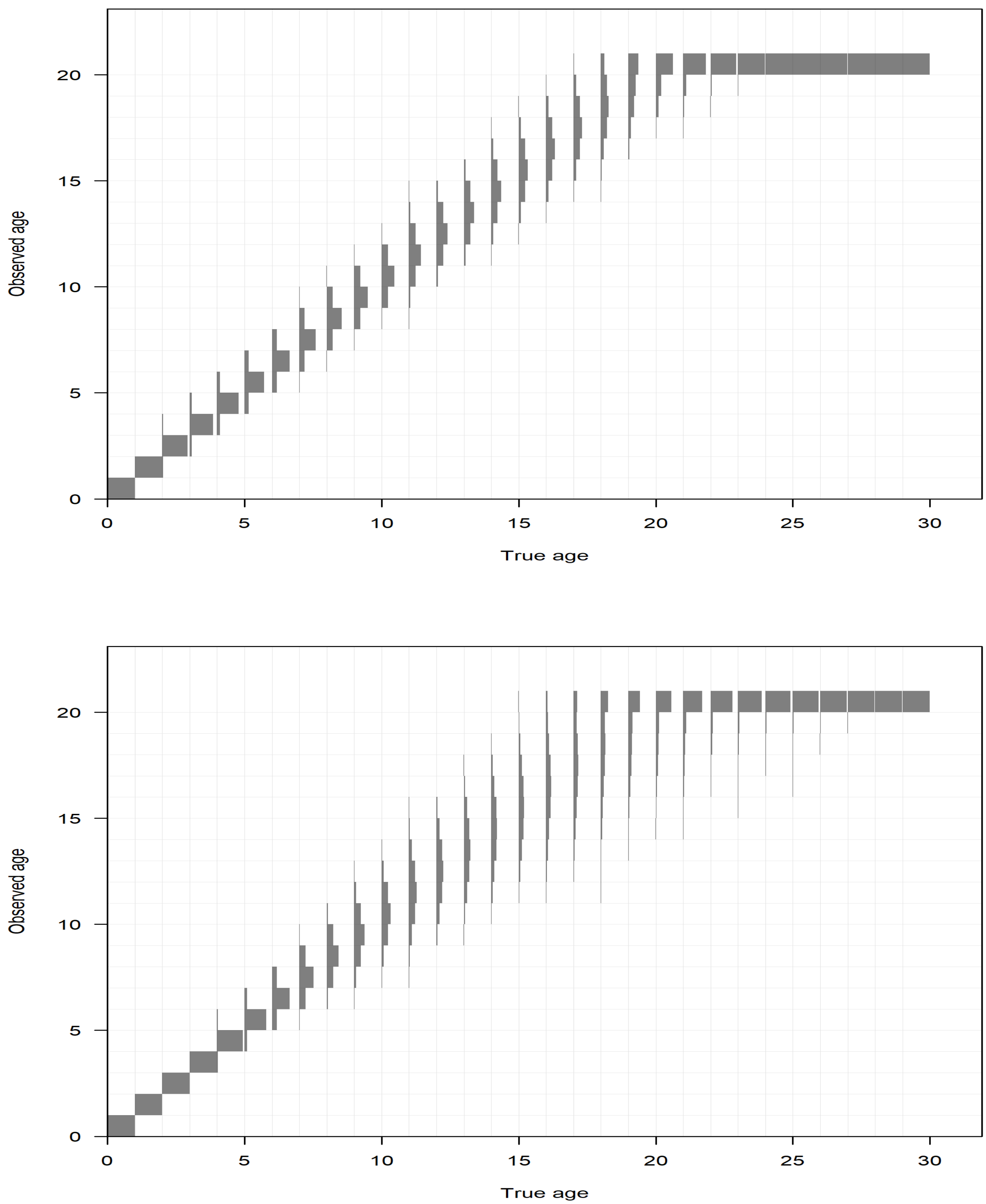


Figure 3. Distribution of observed age at true age based on ageing error matrices developed for the Standard Assessment (top; used for years 1986-2017) and the Operational Assessment (bottom; used for years 2017-2022) for Gulf of Mexico Red Grouper.

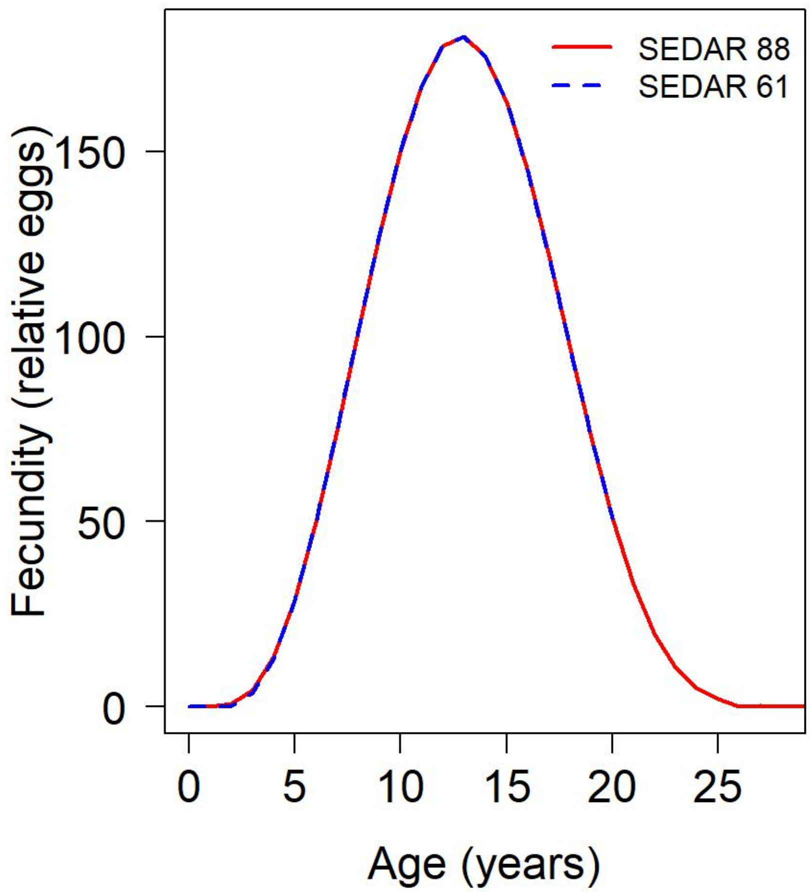


Figure 4. Fecundity at-age used in SEDAR 88 and SEDAR 61. Note that the SEDAR 88 vector extended out a maximum age of 29 years.

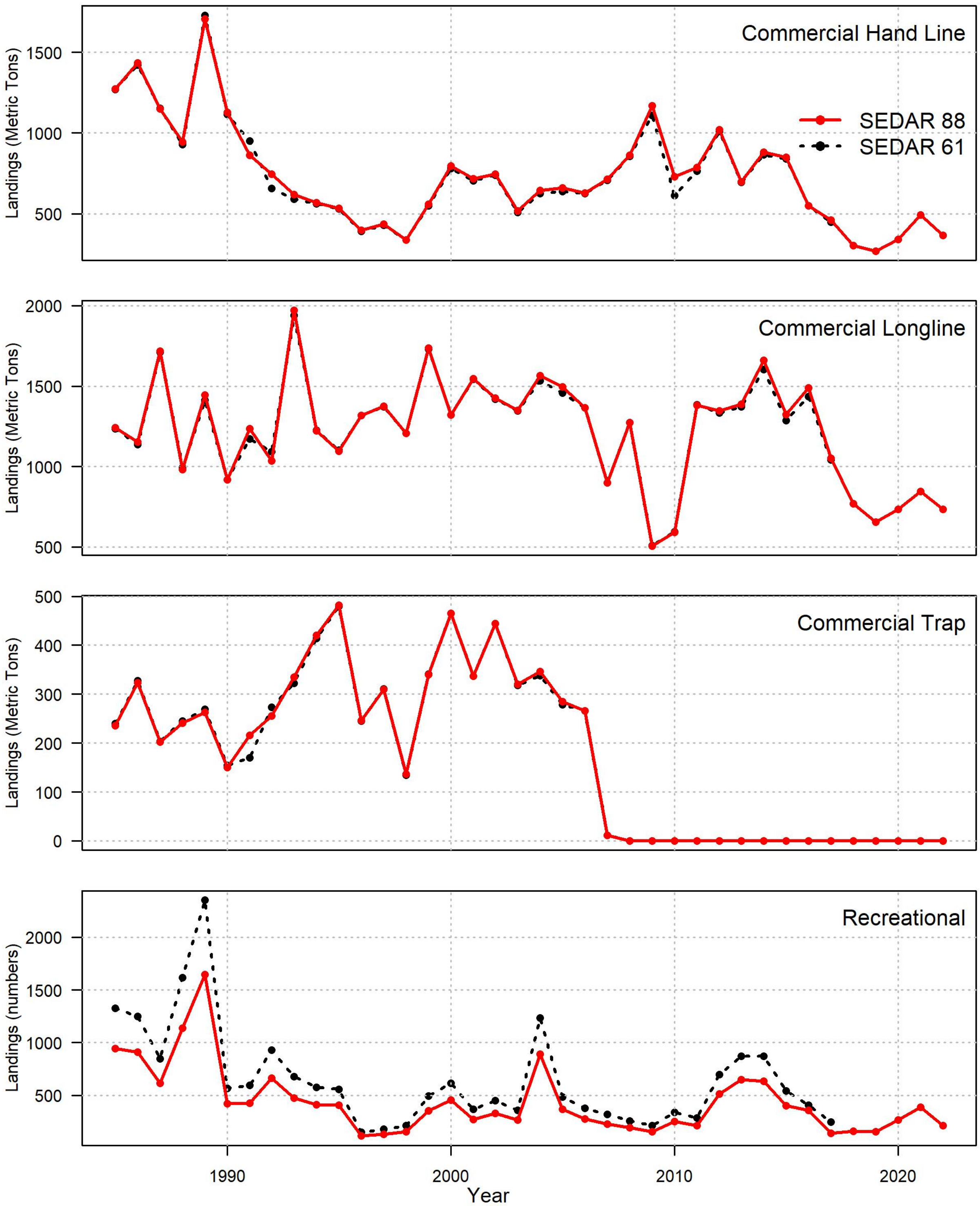


Figure 5. Gulf of Mexico Red Grouper observed landings by fleet for SEDAR 88 and SEDAR 61. Commercial and recreational landings are in metric tons and numbers of fish (1,000s of fosh), respectively. Note: The scale of the recreational landings is not directly comparable given the different currencies (SEDAR 61: FES; SEDAR 88: FL-SRFS).

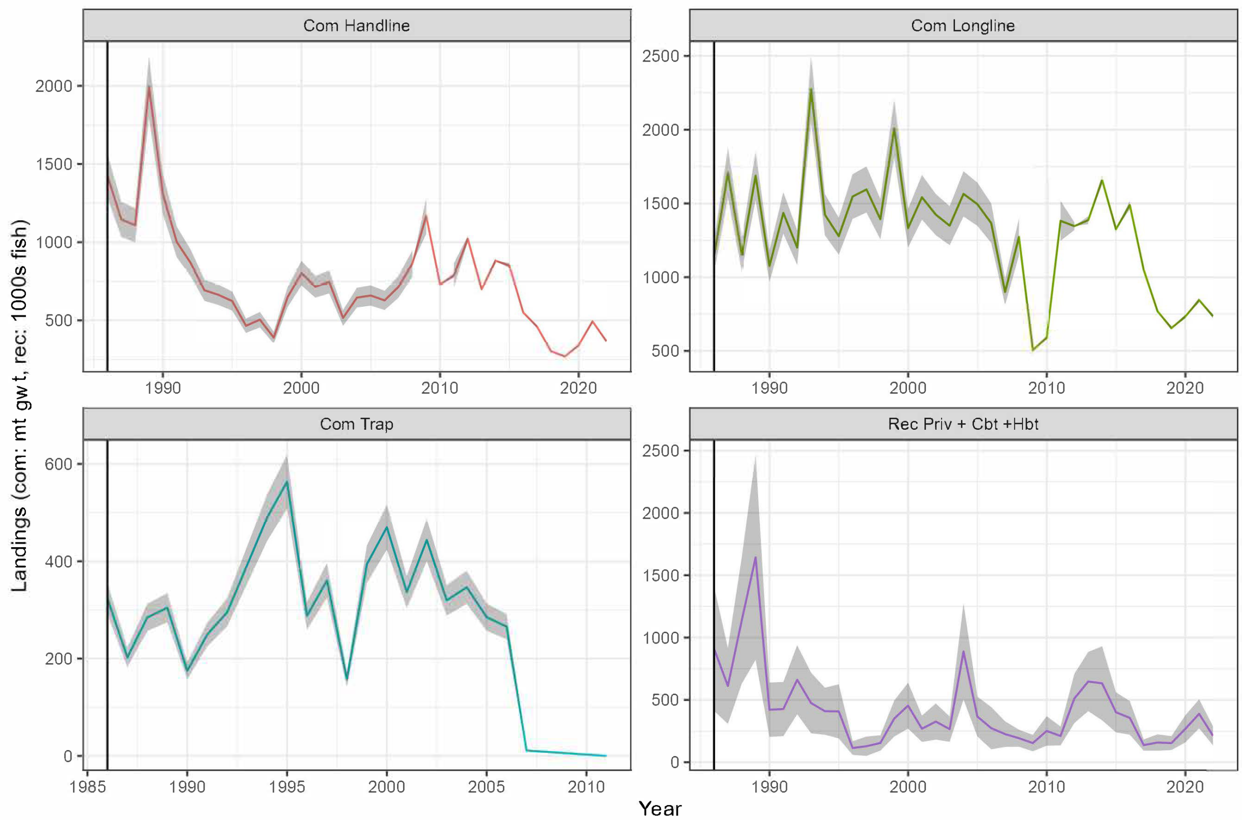


Figure 6. Gulf of Mexico Red Grouper landings data with 95% confidence intervals (shaded area) for each fleet.

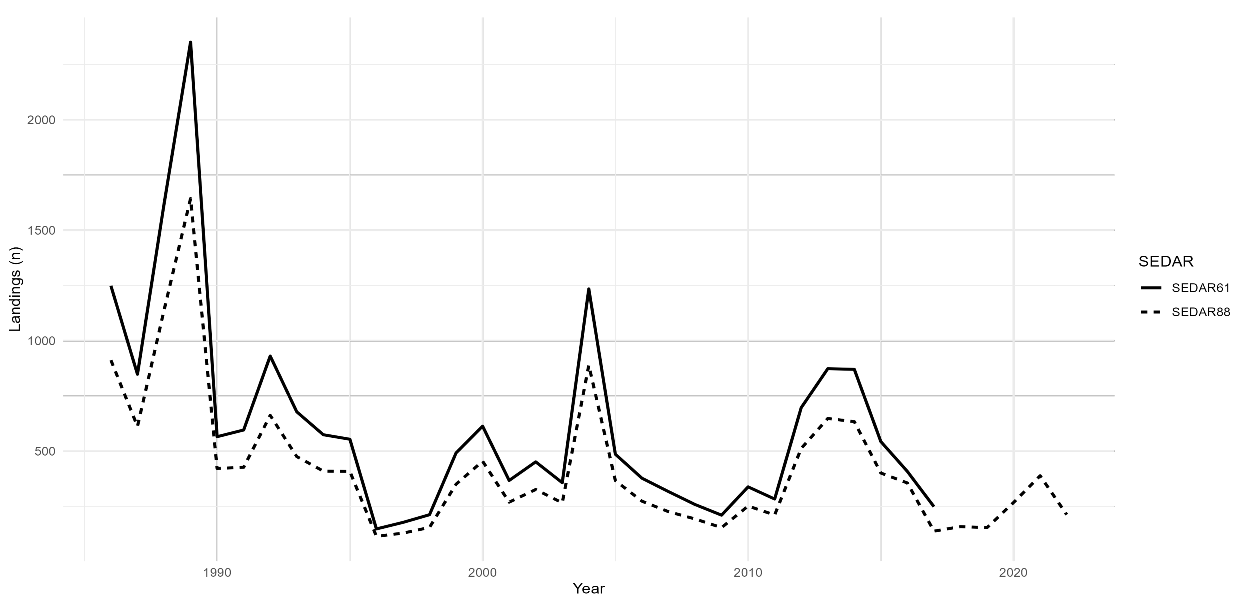


Figure 7. Differences in recreational landings between MRIP-FES (used in SEDAR 61) and FL-SRFS (used in SEDAR 88) based estimates.

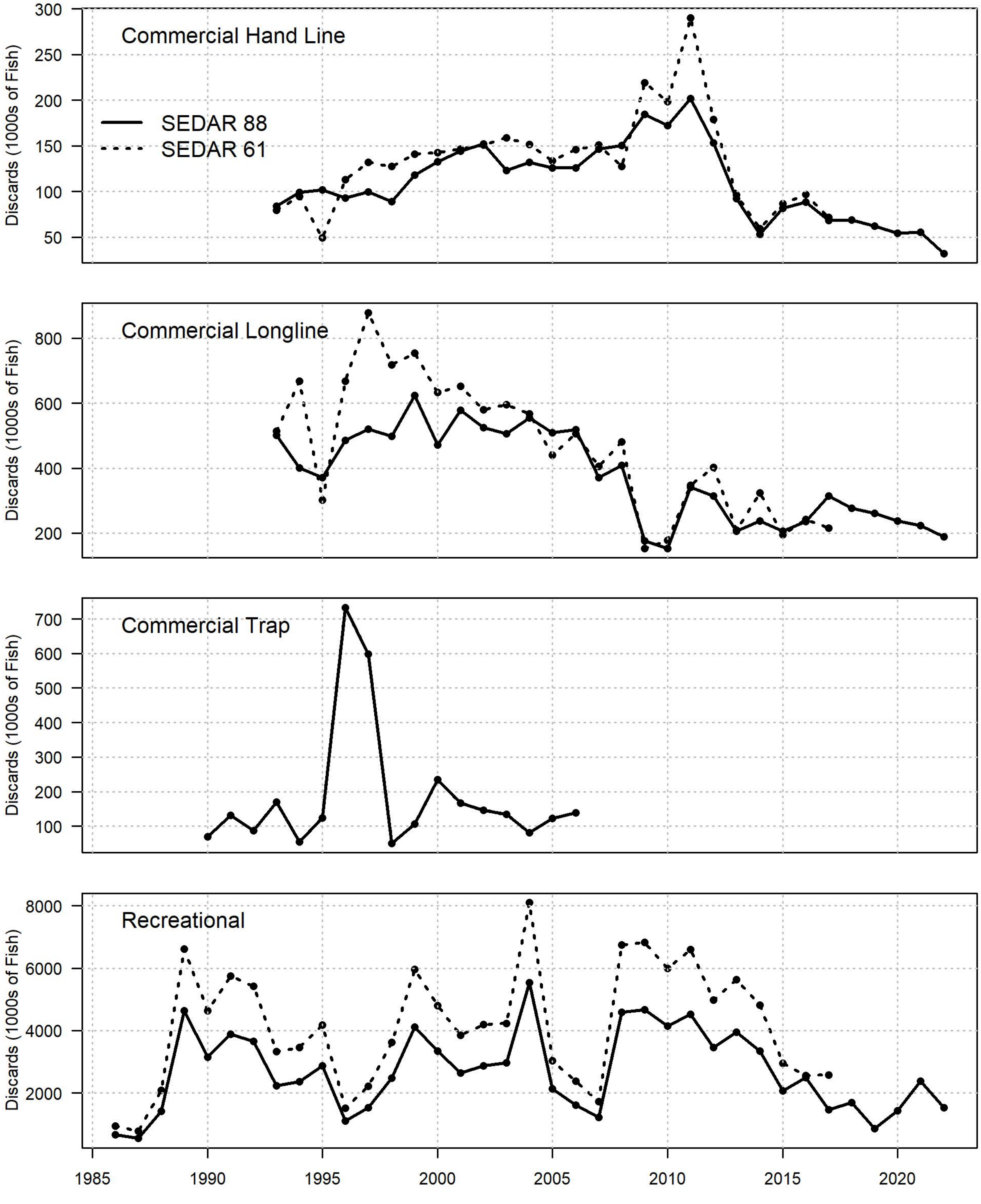


Figure 8. Gulf of Mexico Red Grouper observed discards by fleet for SEDAR 88 and SEDAR 61. Commercial and recreational discards are both in numbers of fish. Note: The scale of the recreational discards is not directly comparable given the different currencies (SEDAR 61: FES; SEDAR 88: FL-SRFS).

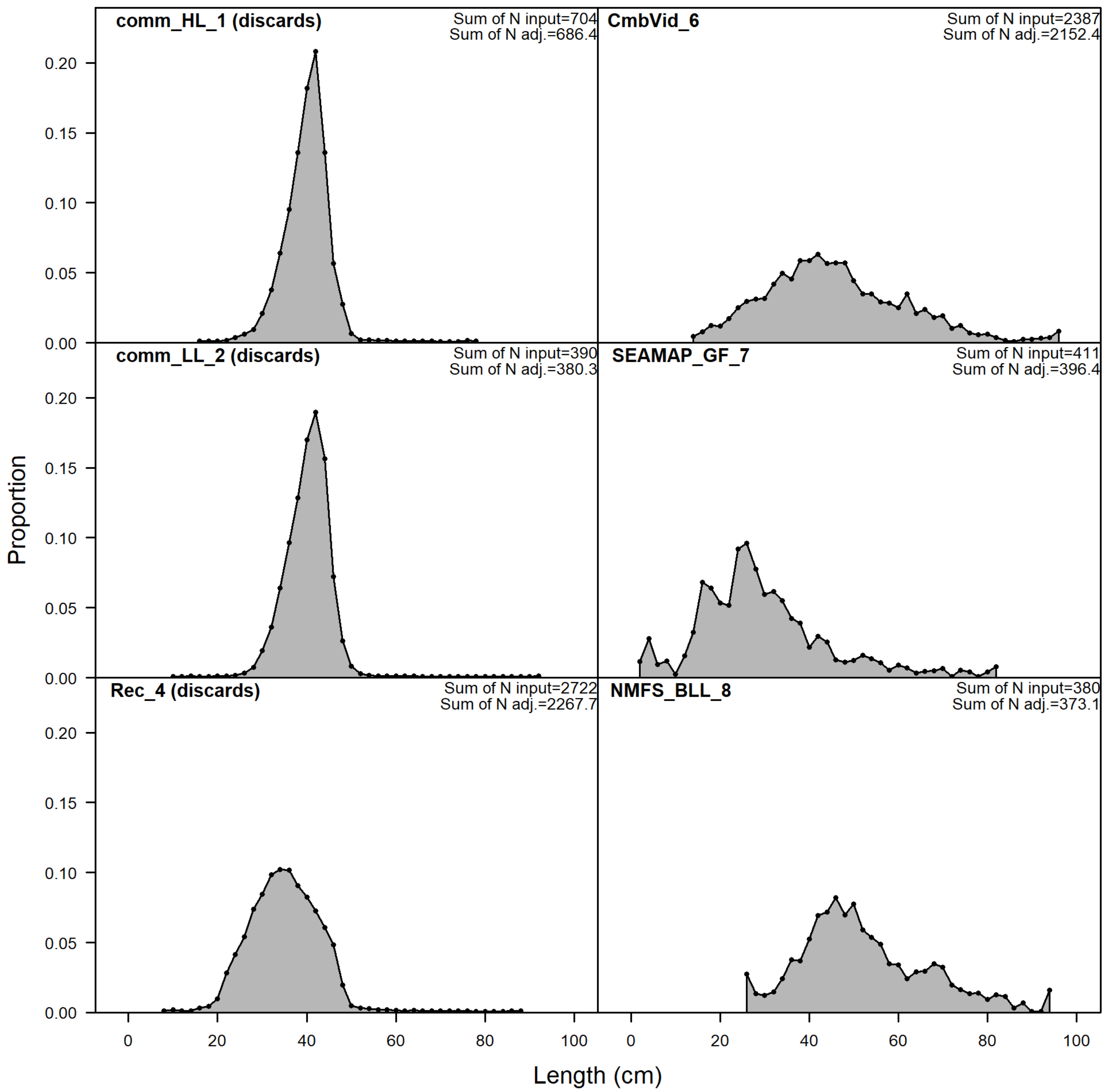


Figure 9. Length compositions aggregated across years for fishing fleets and surveys. N input = number of trips for fleets and number of stations for surveys.

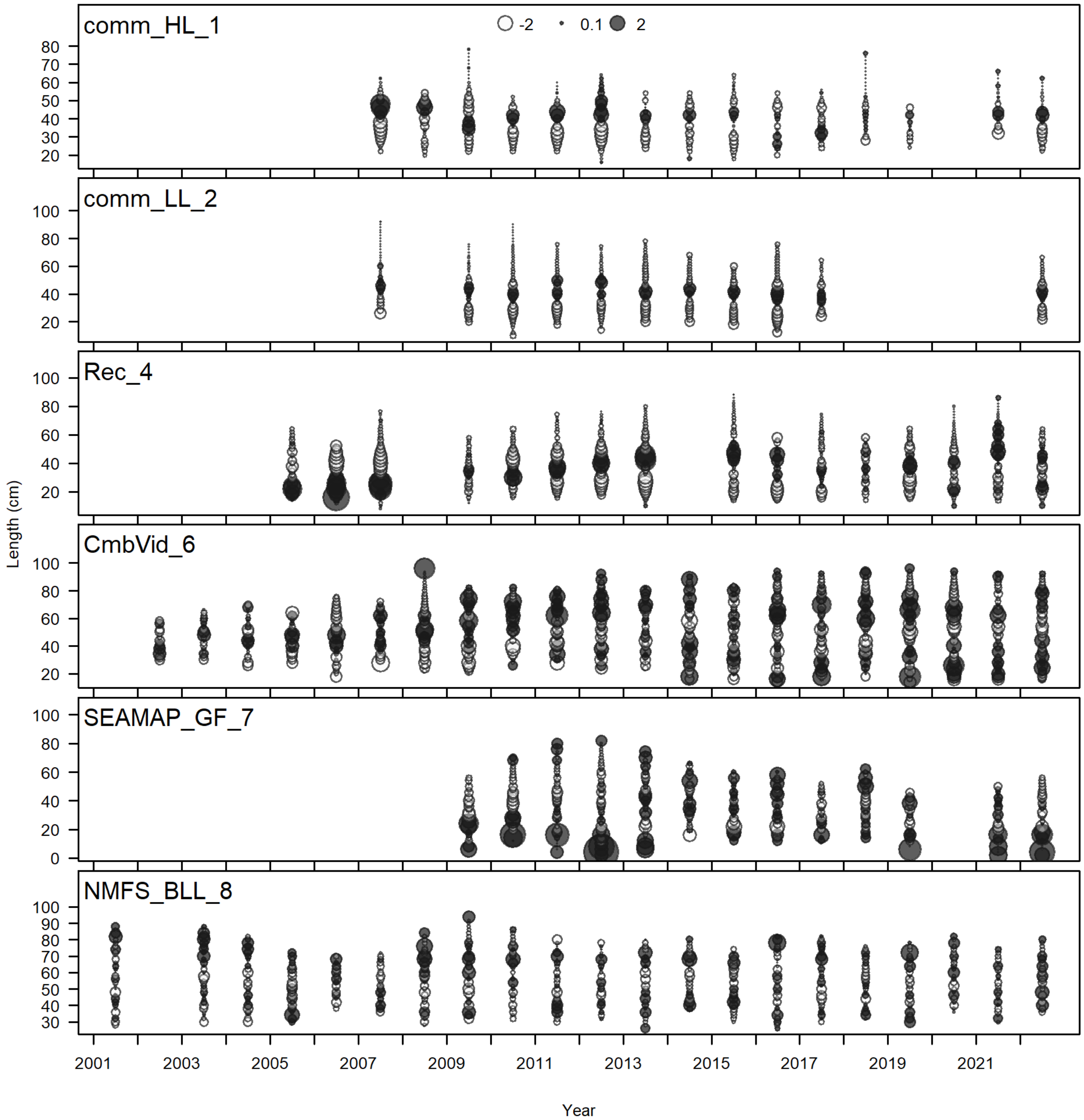


Figure 10. Length compositions aggregated across years for fishing fleets and surveys. N input = number of trips for fleets and number of stations for surveys.

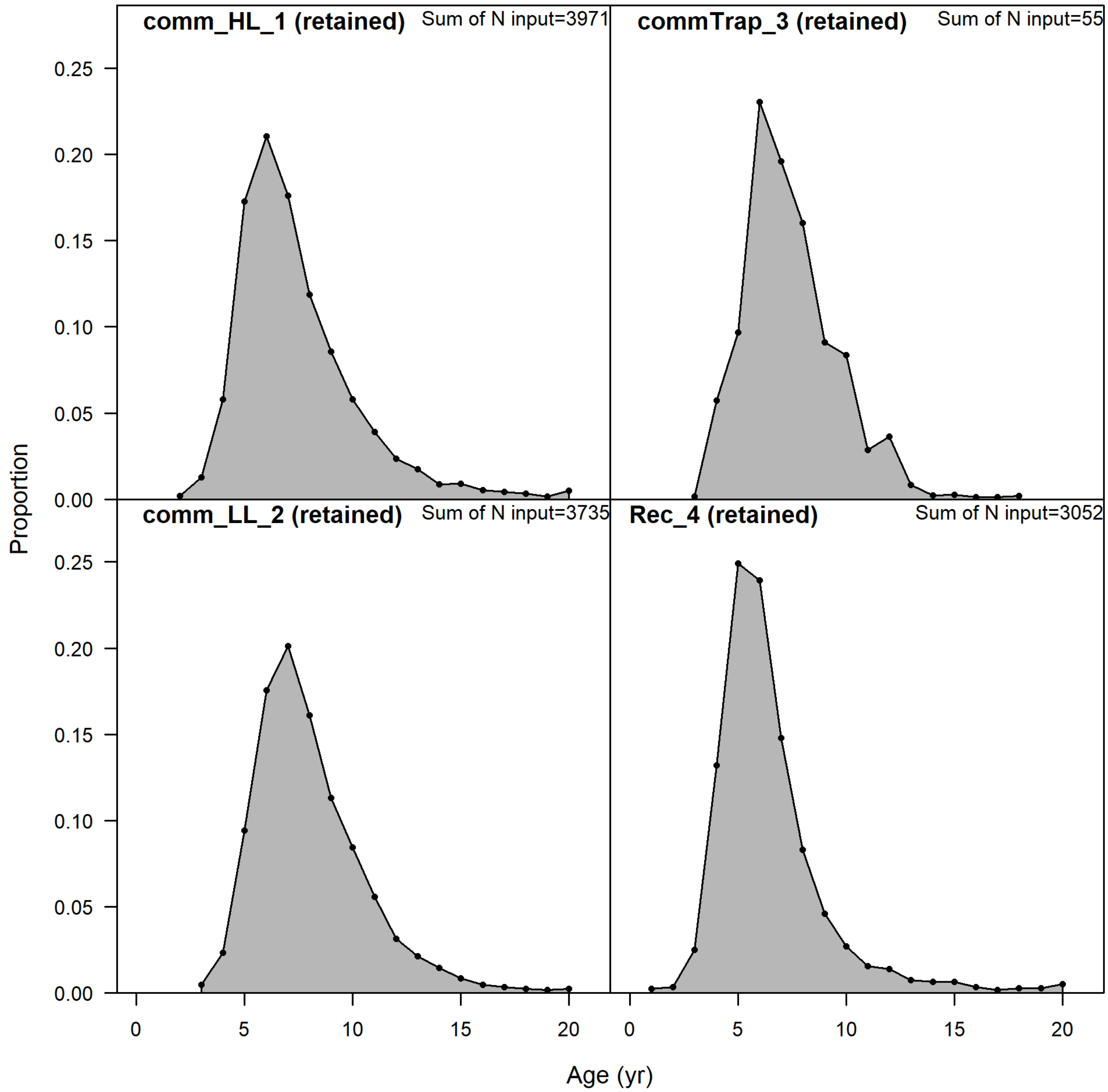


Figure 11. Age compositions of Red Grouper aggregated across years for fishing fleets. N input: number of ages.

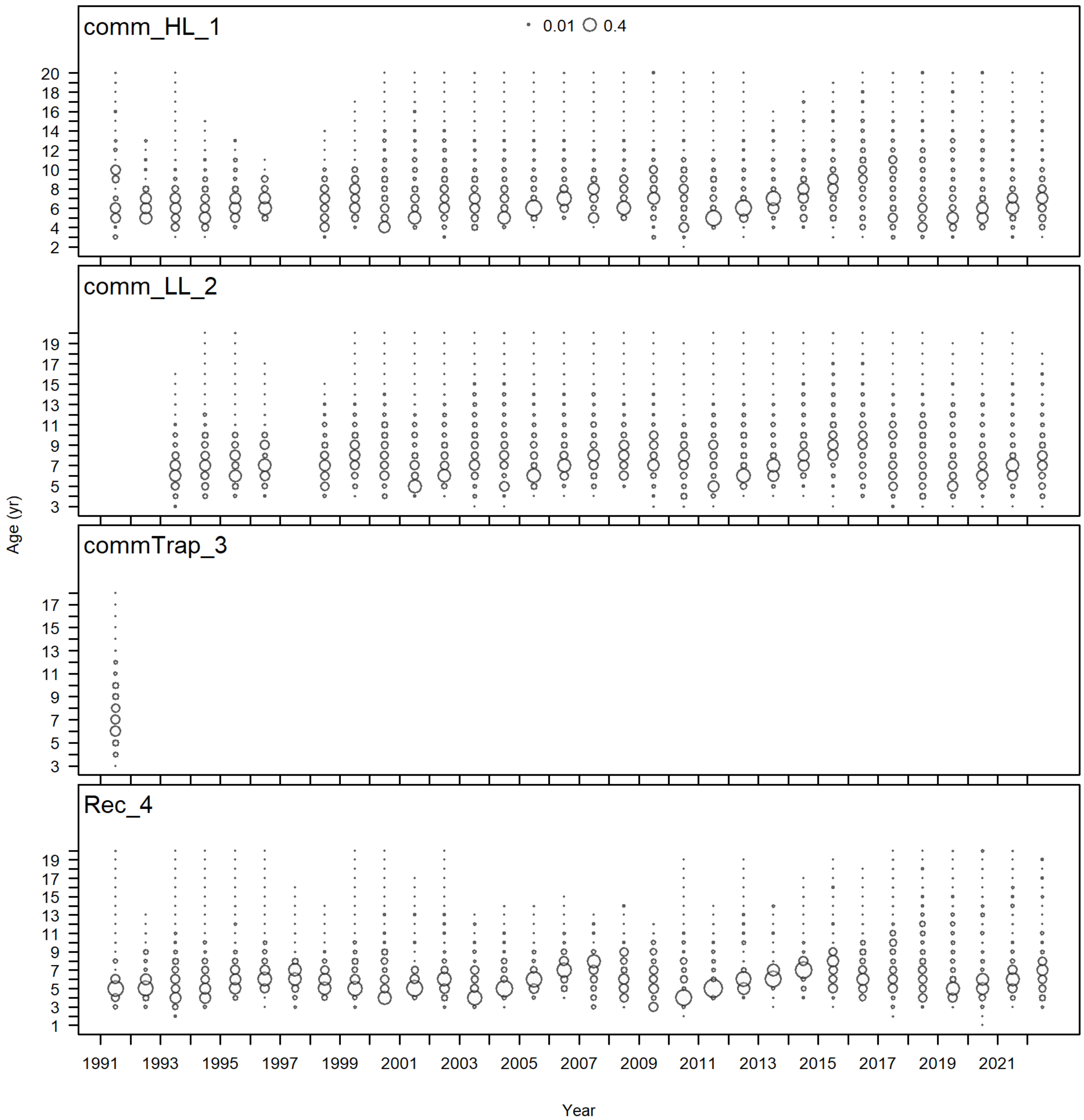


Figure 12. Age compositions of Red Grouper aggregated by years for fishing fleets. N input is the number of ages.

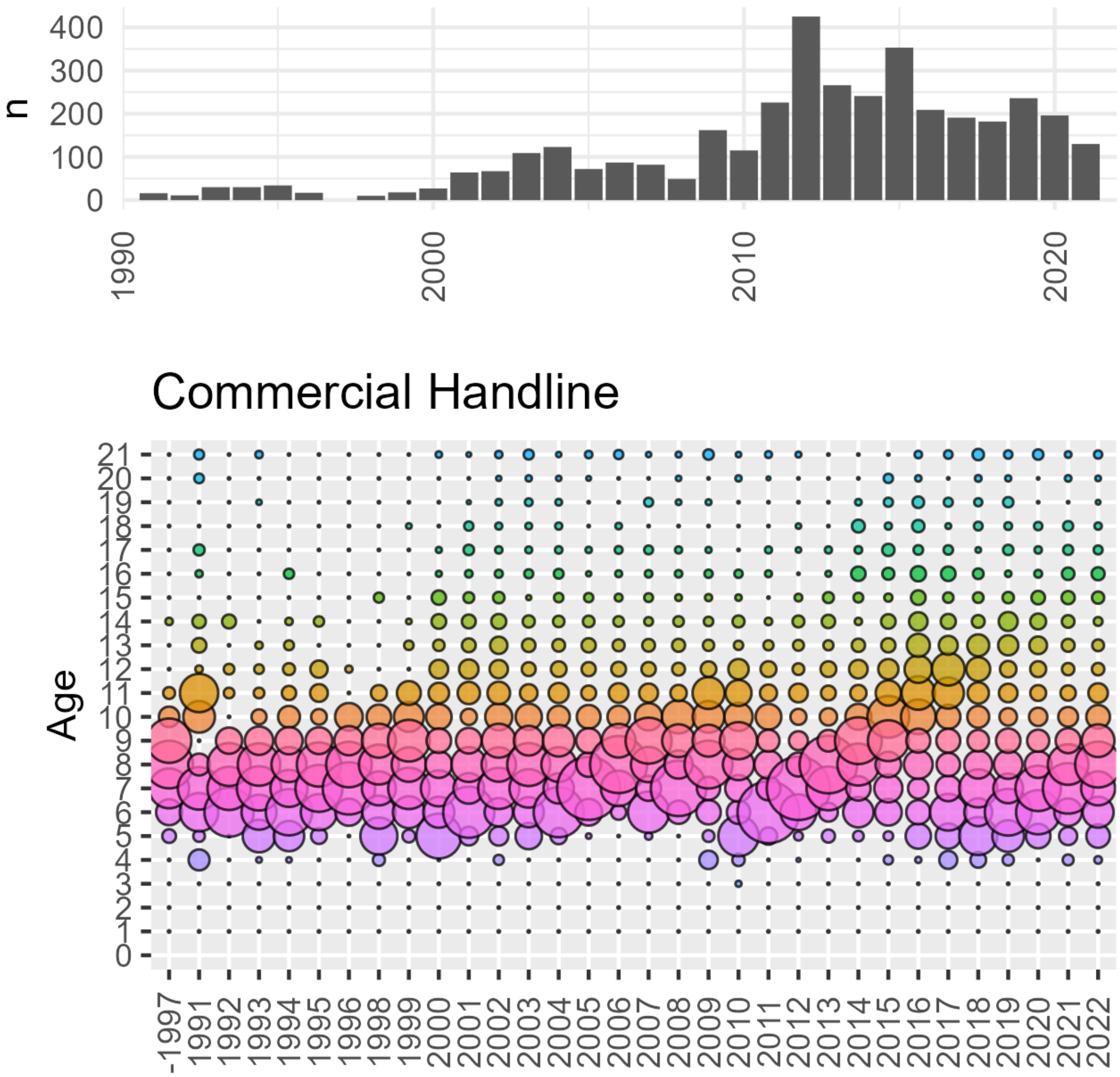


Figure 13. Observed relative age proportions (bubbles) in each year for Gulf of Mexico Red Grouper collected from the commercial handline fleet. The histogram shows annual sample sizes. Cohort progressions are evident.

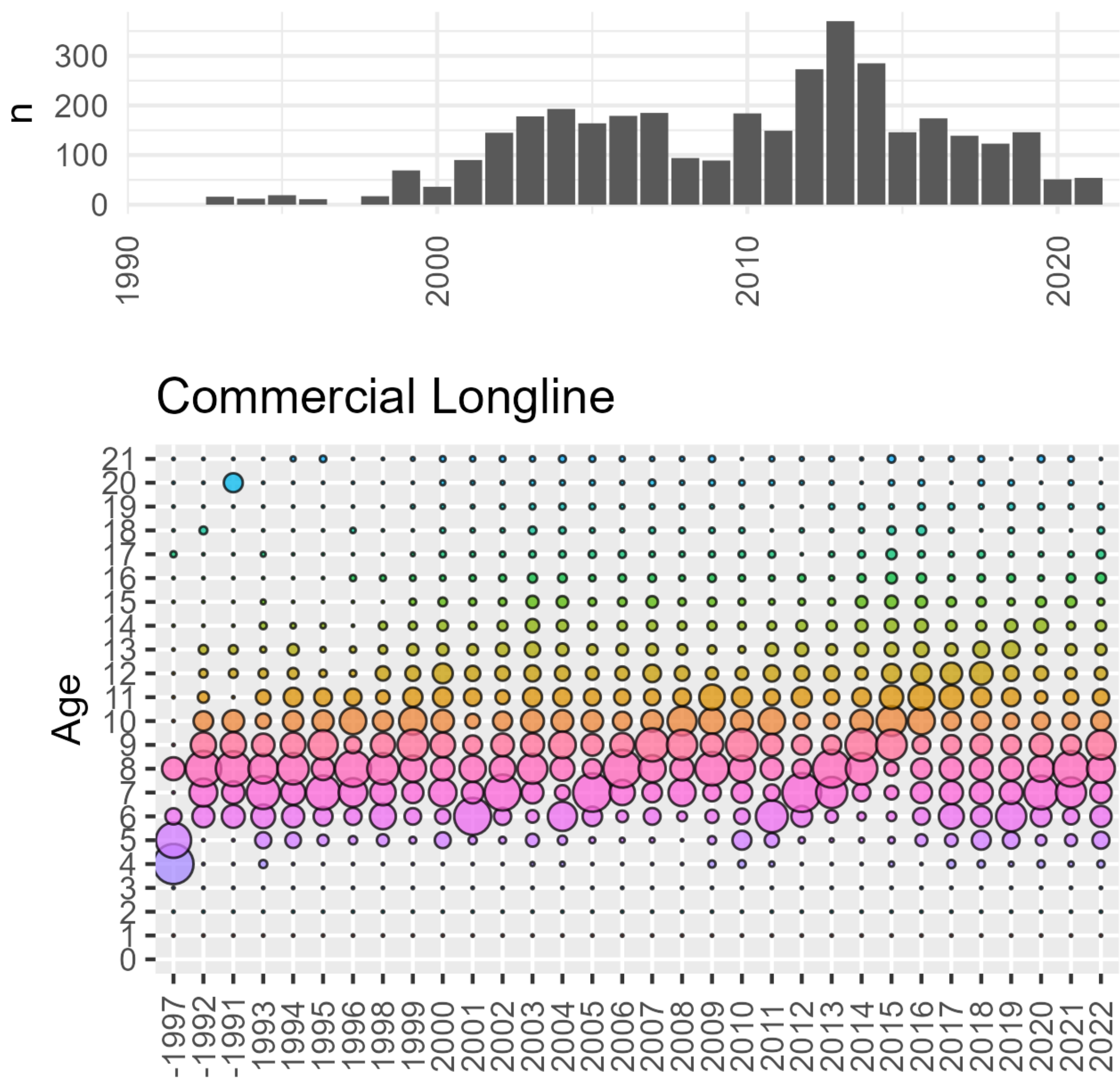


Figure 14. Observed relative age proportions (bubbles) in each year for Gulf of Mexico Red Grouper collected from the commercial longline fleet. The histogram shows annual sample sizes. Cohort progressions are evident.

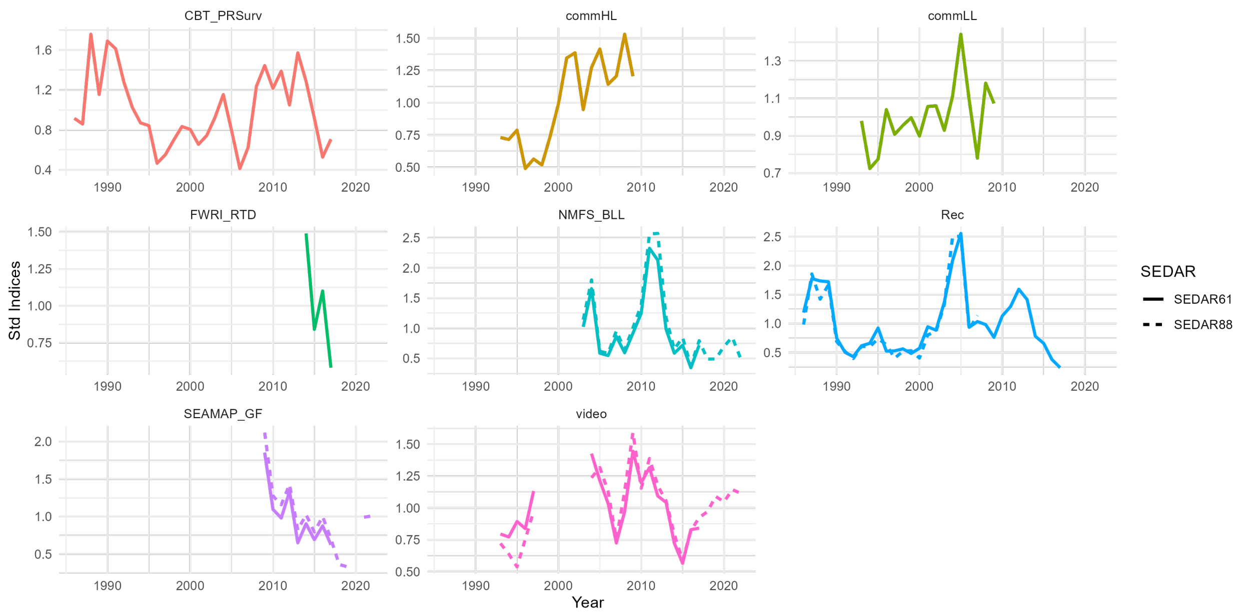


Figure 15. Gulf of Mexico Red Grouper indices for SEDAR 88 compared to SEDAR 61 .

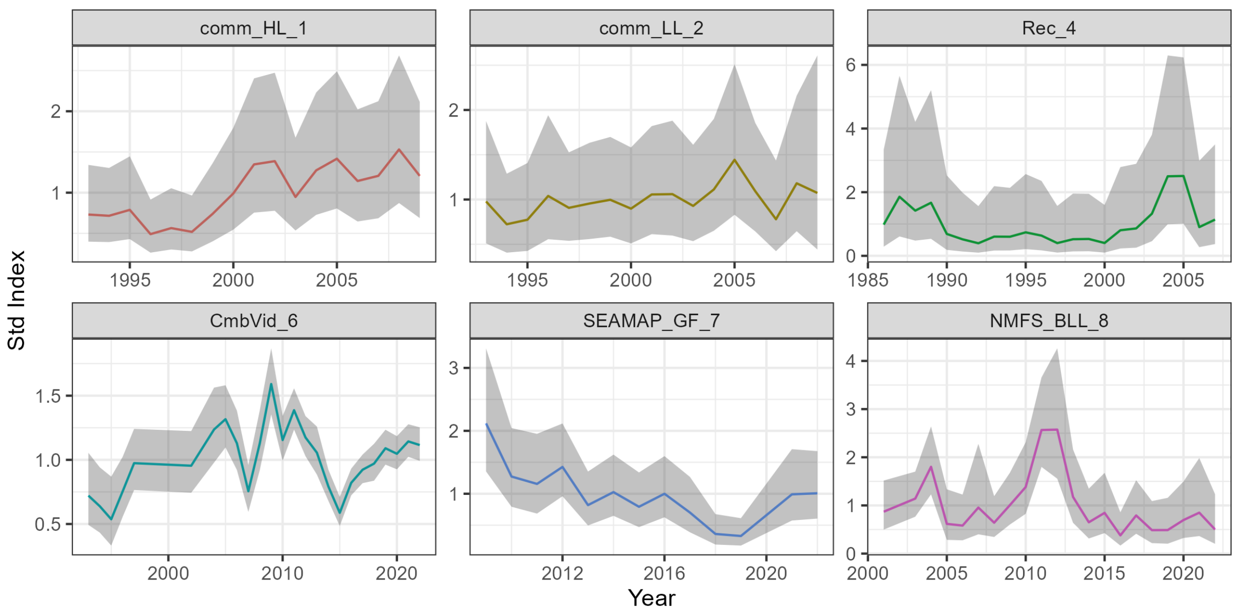


Figure 16. Gulf of Mexico Red Grouper indices for SEDAR 88 with associated error.

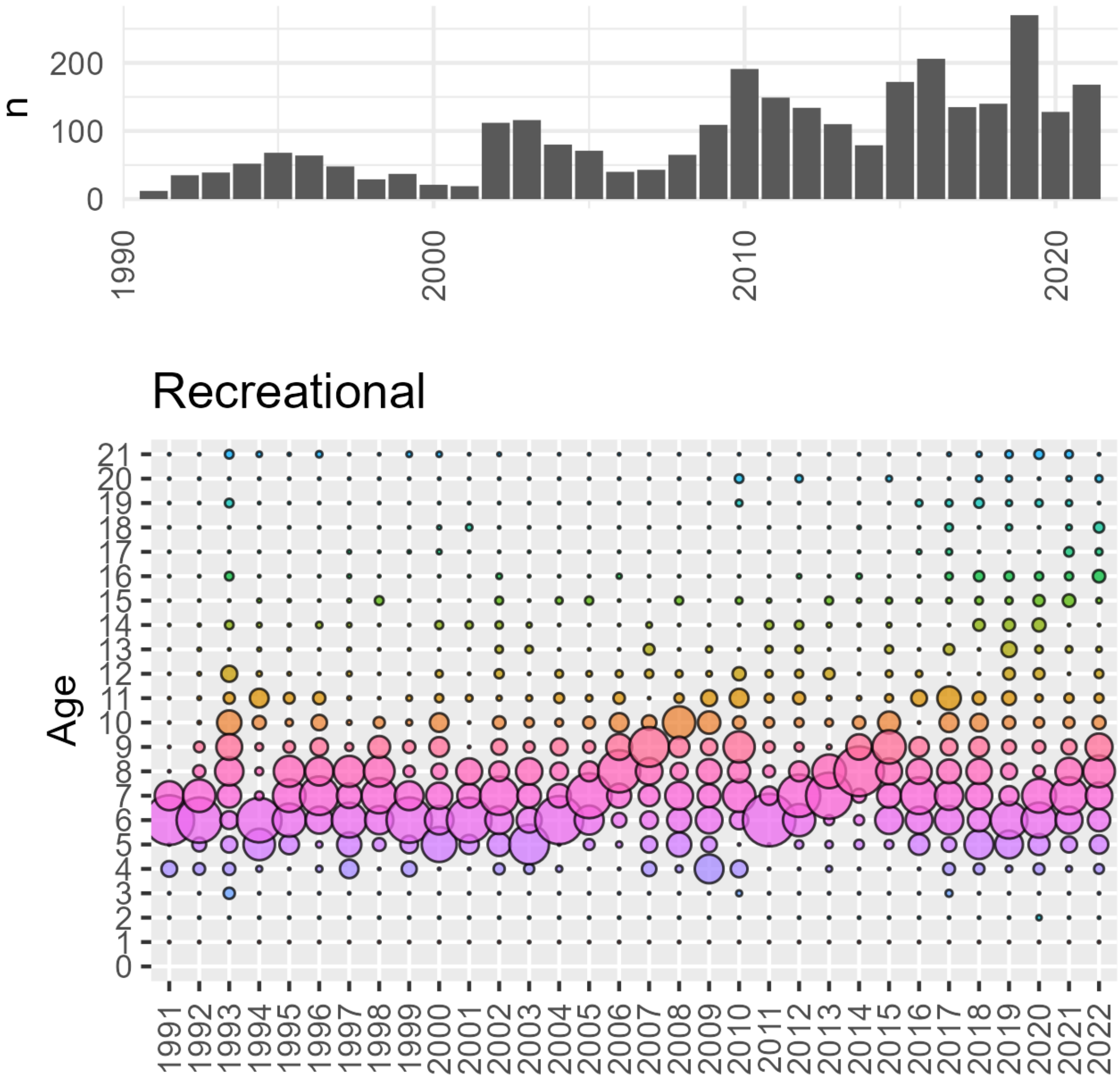


Figure 17. Observed relative age proportions (bubbles) in each year for Gulf of Mexico Red Grouper collected from the recreational fleet. The histogram shows annual sample sizes. Cohort progressions are evident.

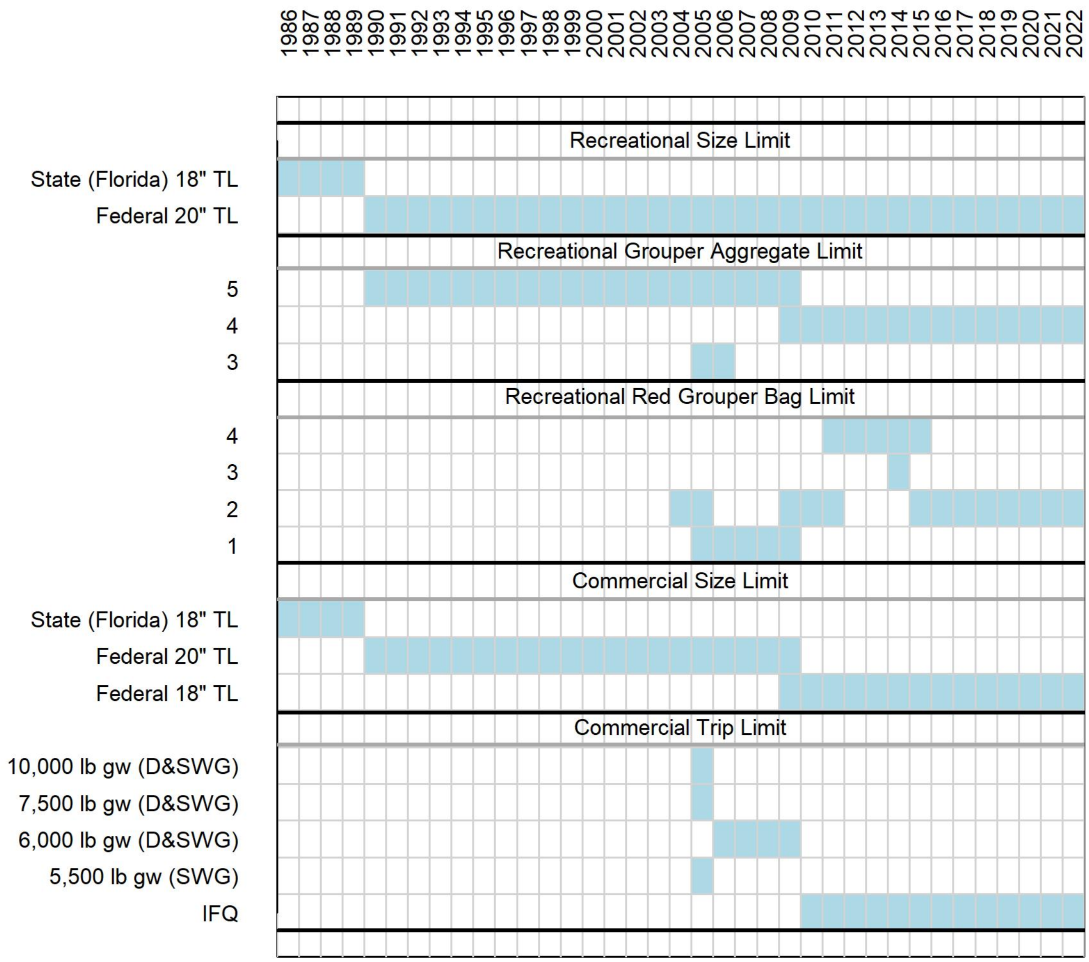


Figure 18. Summary of federal and relevant State (Florida) management regulations for Gulf of Mexico Red Grouper. Size limits shown are for inches total length (TL) and trip limits in pounds gutted weight (lb gw) are shown for deep and shallow-water grouper (D&SWG). IFQ refers to the implementation of the Individual Fishing Quota program. Not included are time or area closures.

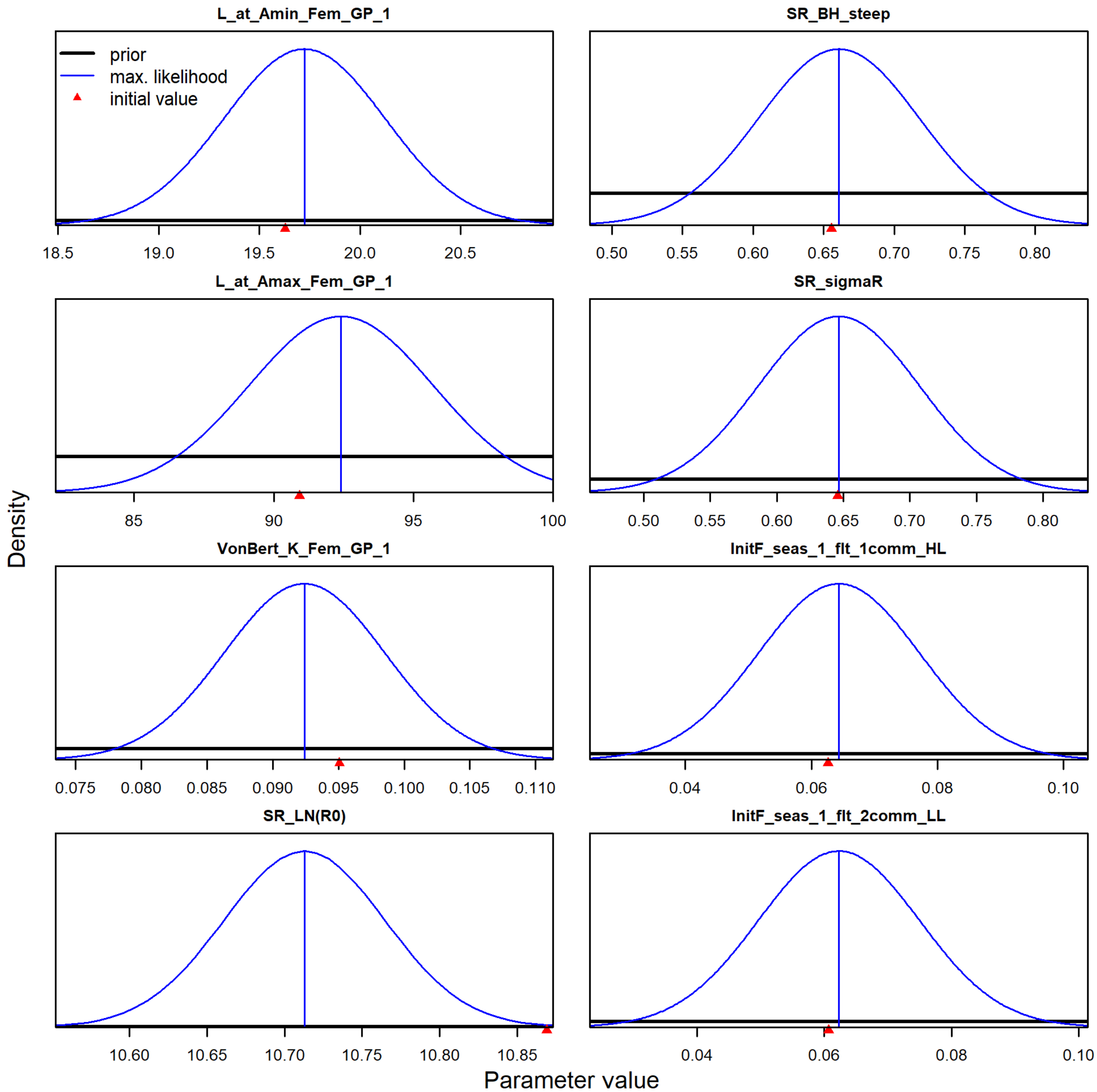


Figure 19. Parameter distribution (blue line) plots along with starting values (red arrow) and priors (black lines), x-axis does not reflect bounds as plot is zoomed in on distribution. Deviation parameters are not included. F parameters are not included. Note: parameter point estimates from a previous model fit were used as the starting values for this final model run.

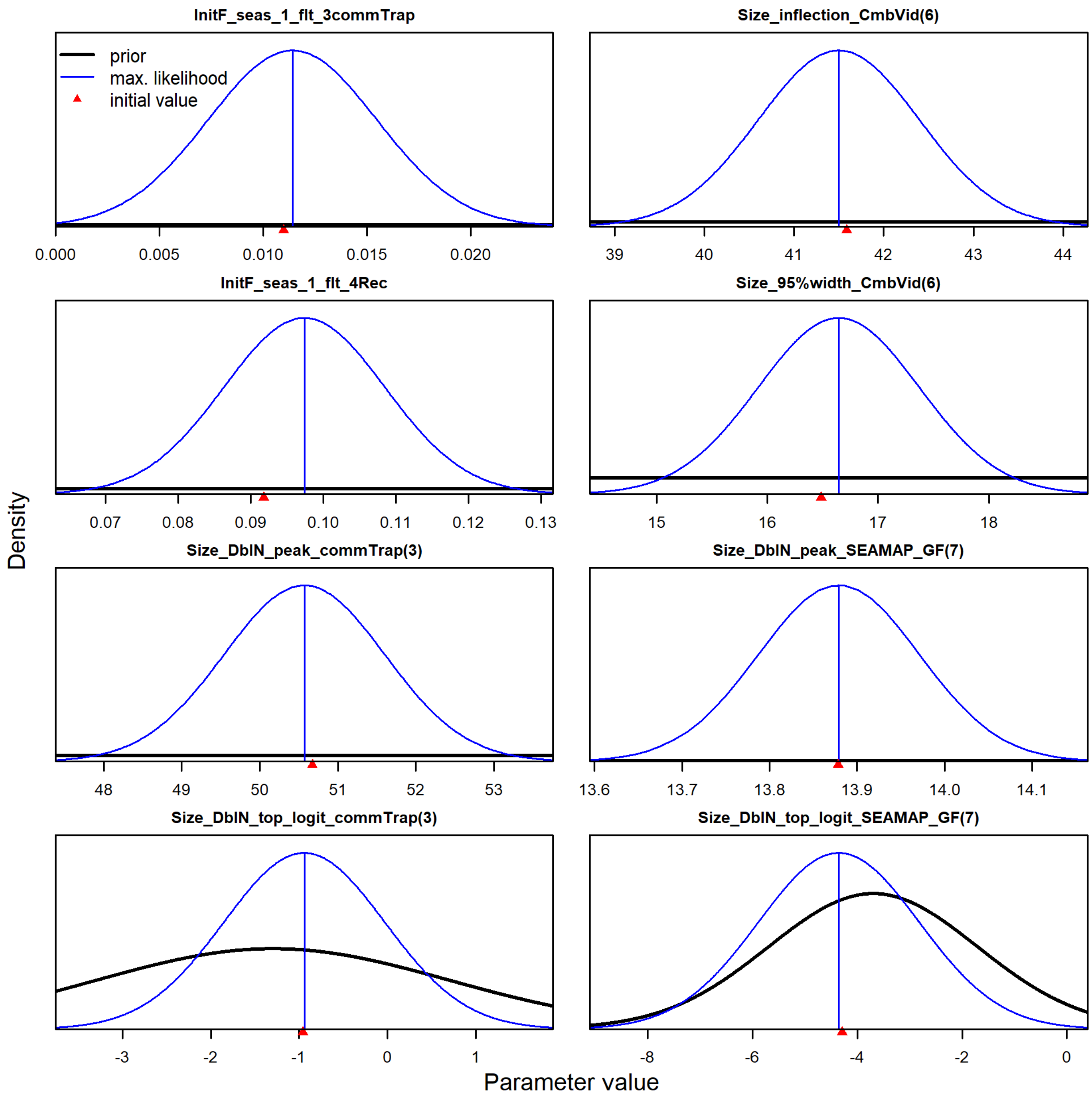


Figure 19 Continued. Parameter distribution (blue line) plots along with starting values (red arrow) and priors (black lines), x-axis does not reflect bounds as plot is zoomed in on distribution. Deviation parameters are not included. F parameters are not included. Note: parameter point estimates from a previous model fit were used as the starting values for this final model run.

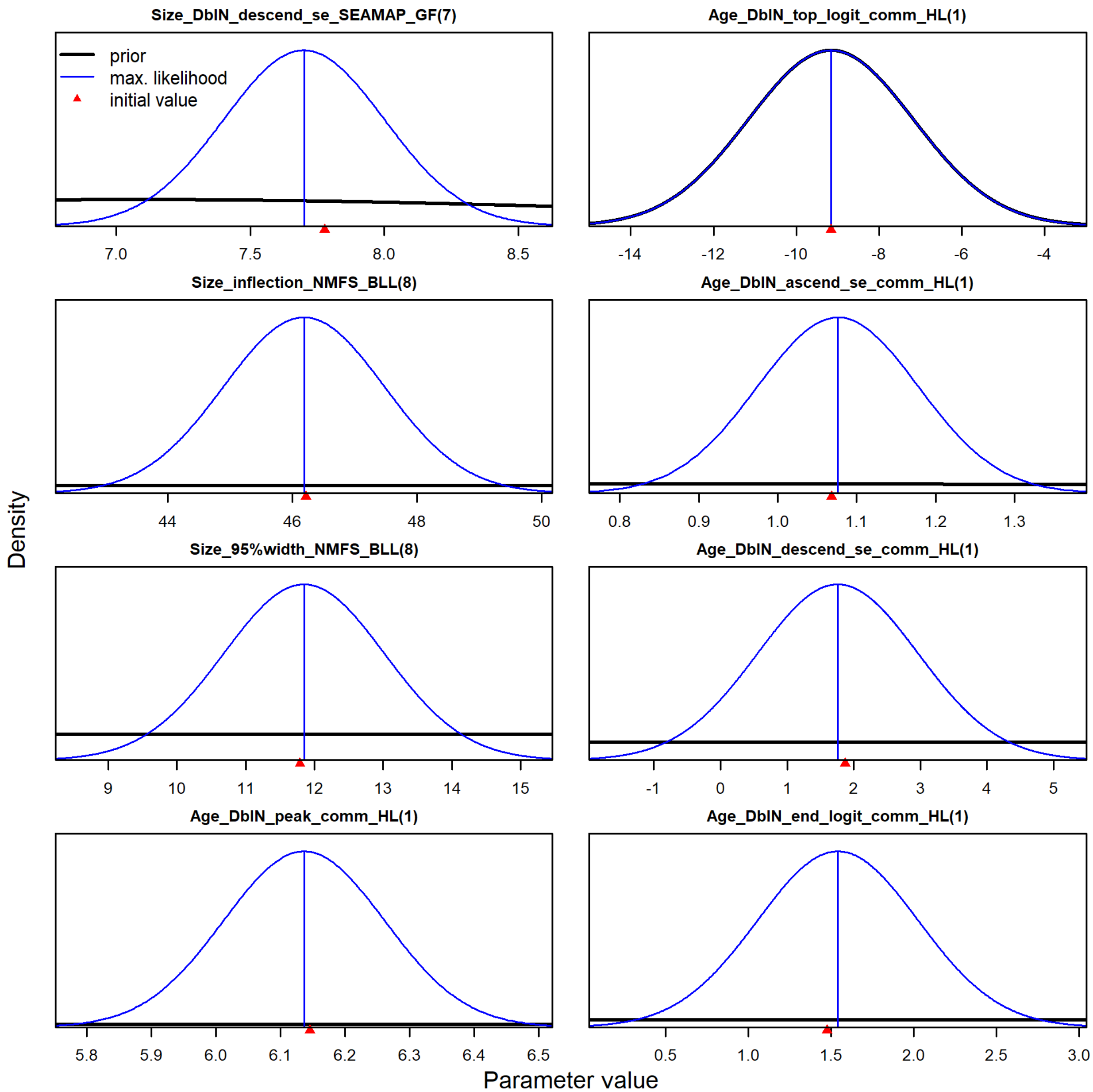


Figure 19 Continued. Parameter distribution (blue line) plots along with starting values (red arrow) and priors (black lines), x-axis does not reflect bounds as plot is zoomed in on distribution. Deviation parameters are not included. F parameters are not included. Note: parameter point estimates from a previous model fit were used as the starting values for this final model run.

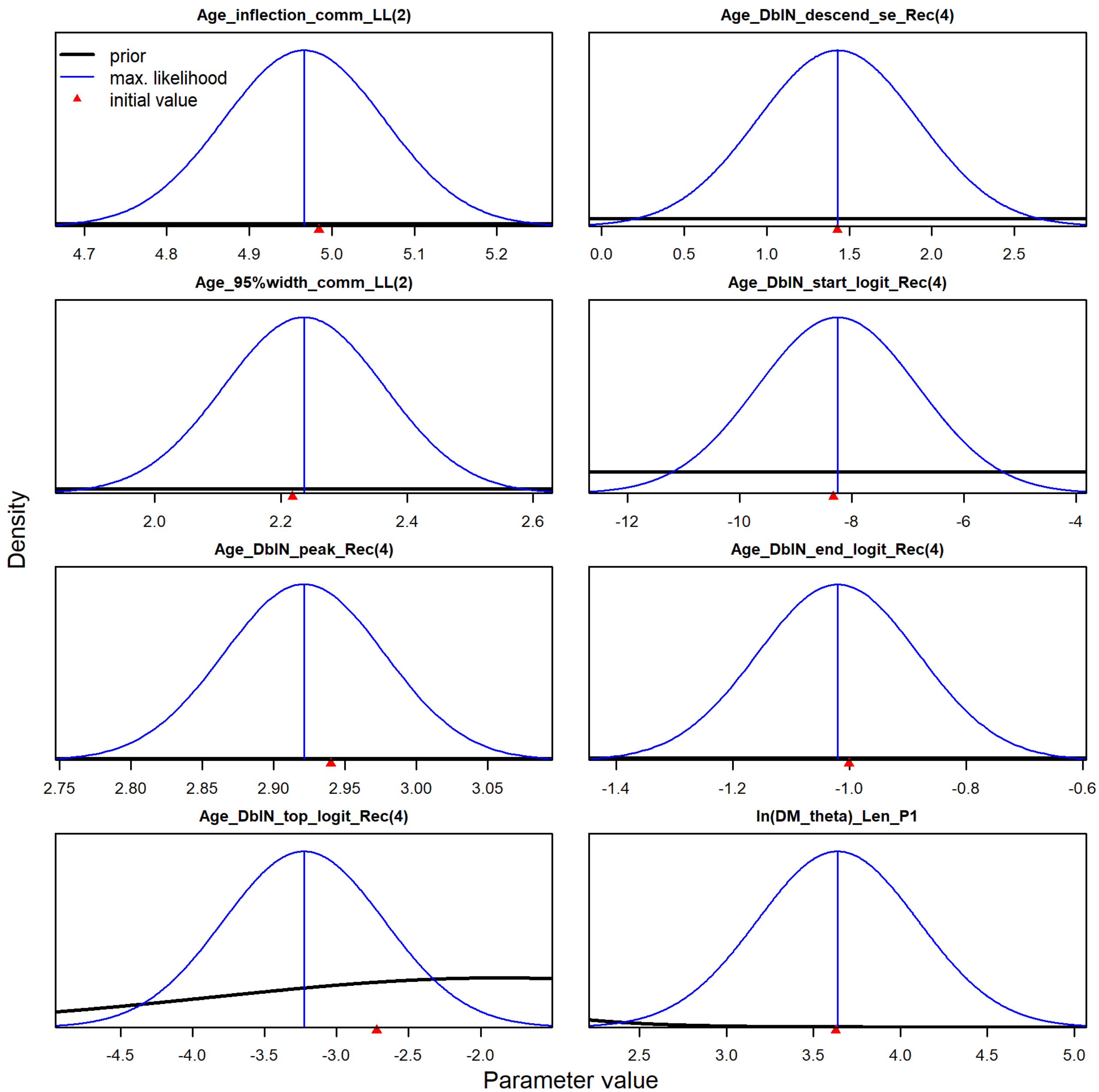


Figure 19 Continued. Parameter distribution (blue line) plots along with starting values (red arrow) and priors (black lines), x-axis does not reflect bounds as plot is zoomed in on distribution. Deviation parameters are not included. F parameters are not included. Note: parameter point estimates from a previous model fit were used as the starting values for this final model run.

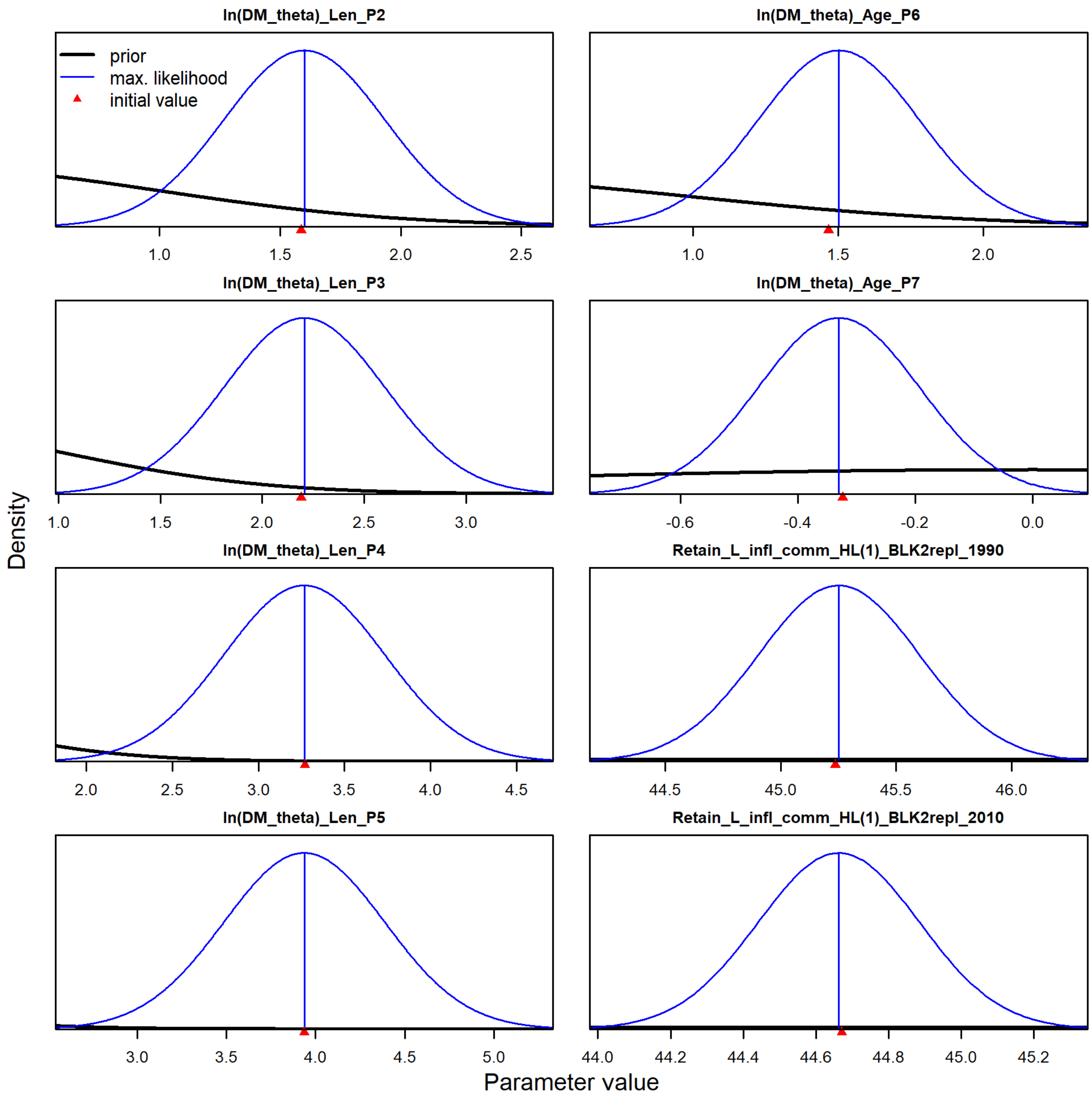


Figure 19 Continued. Parameter distribution (blue line) plots along with starting values (red arrow) and priors (black lines), x-axis does not reflect bounds as plot is zoomed in on distribution. Deviation parameters are not included. F parameters are not included. Note: parameter point estimates from a previous model fit were used as the starting values for this final model run.

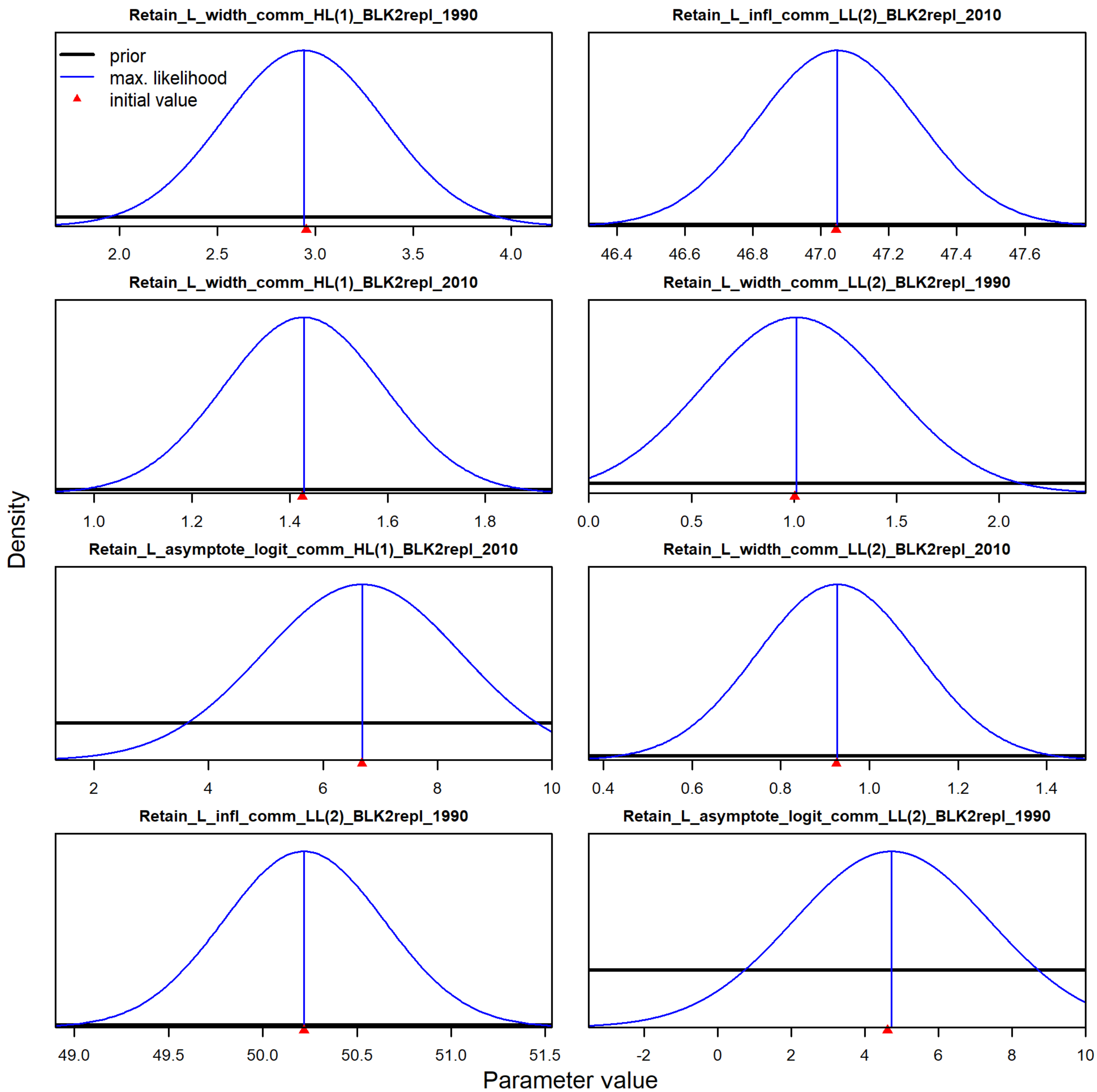


Figure 19 Continued. Parameter distribution (blue line) plots along with starting values (red arrow) and priors (black lines), x-axis does not reflect bounds as plot is zoomed in on distribution. Deviation parameters are not included. F parameters are not included. Note: parameter point estimates from a previous model fit were used as the starting values for this final model run.

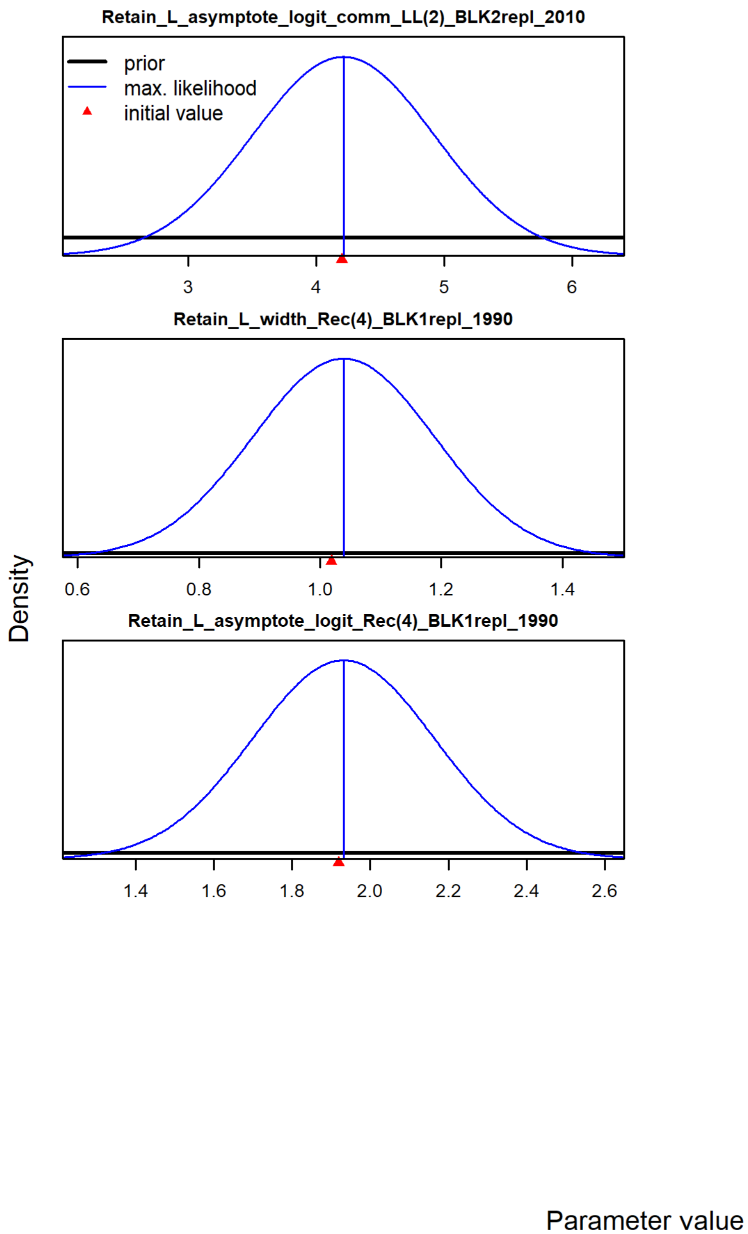
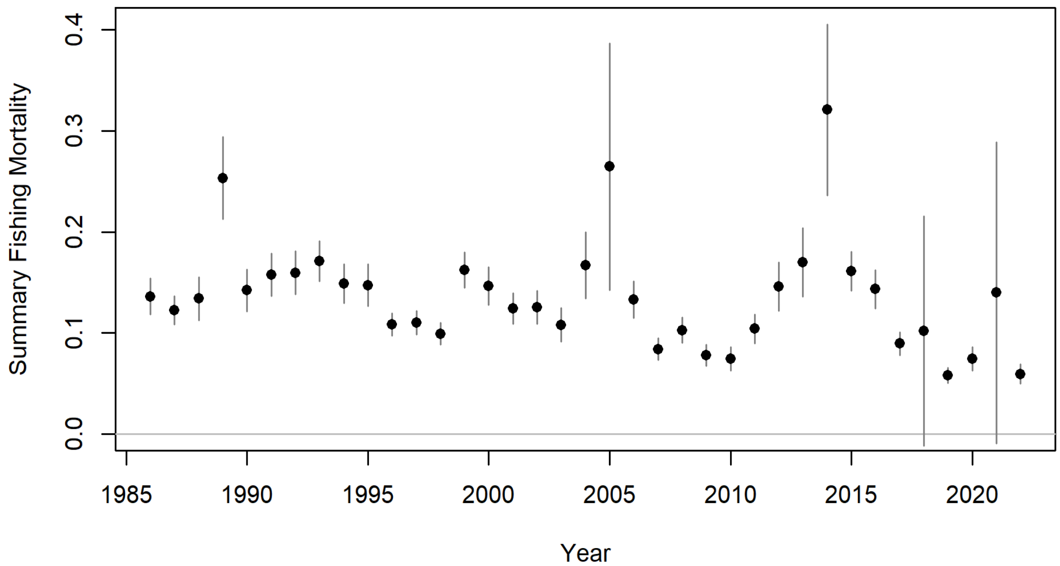


Figure 19 Continued. Parameter distribution (blue line) plots along with starting values (red arrow) and priors (black lines), x-axis does not reflect bounds as plot is zoomed in on distribution. Deviation parameters are not included. F parameters are not included. Note: parameter point estimates from a previous model fit were used as the starting values for this final model run.

SEDAR 88



SEDAR 61

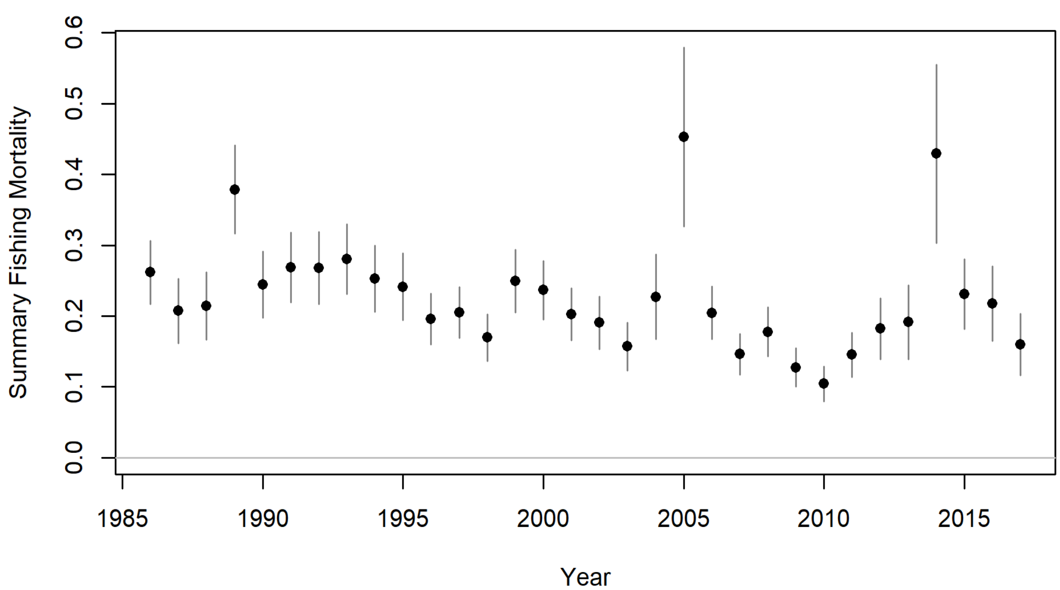
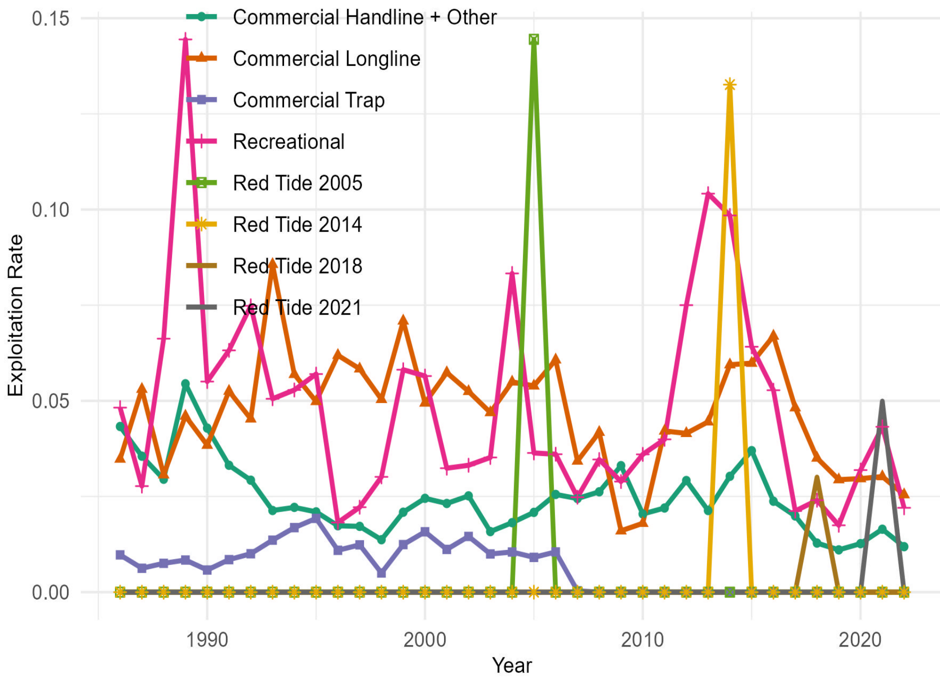


Figure 20. Annual exploitation rate estimates (total biomass killed / total biomass age 0+) for Gulf of Mexico Red Grouper.

SEDAR 88



SEDAR 61

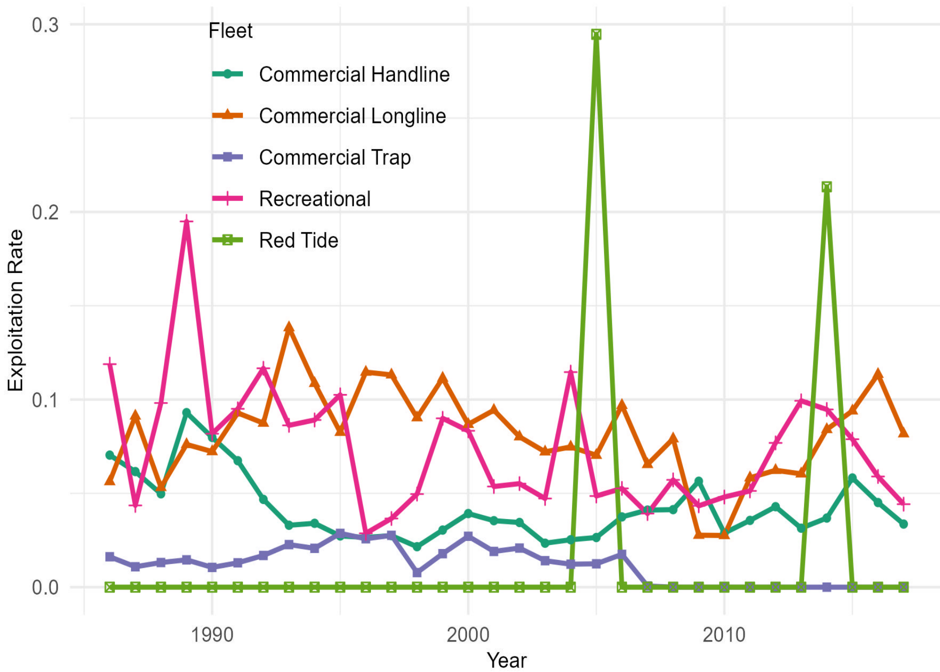


Figure 21. Annual exploitation rate (total biomass killed / total biomass age 0+) by fleet for Gulf of Mexico Red Grouper.

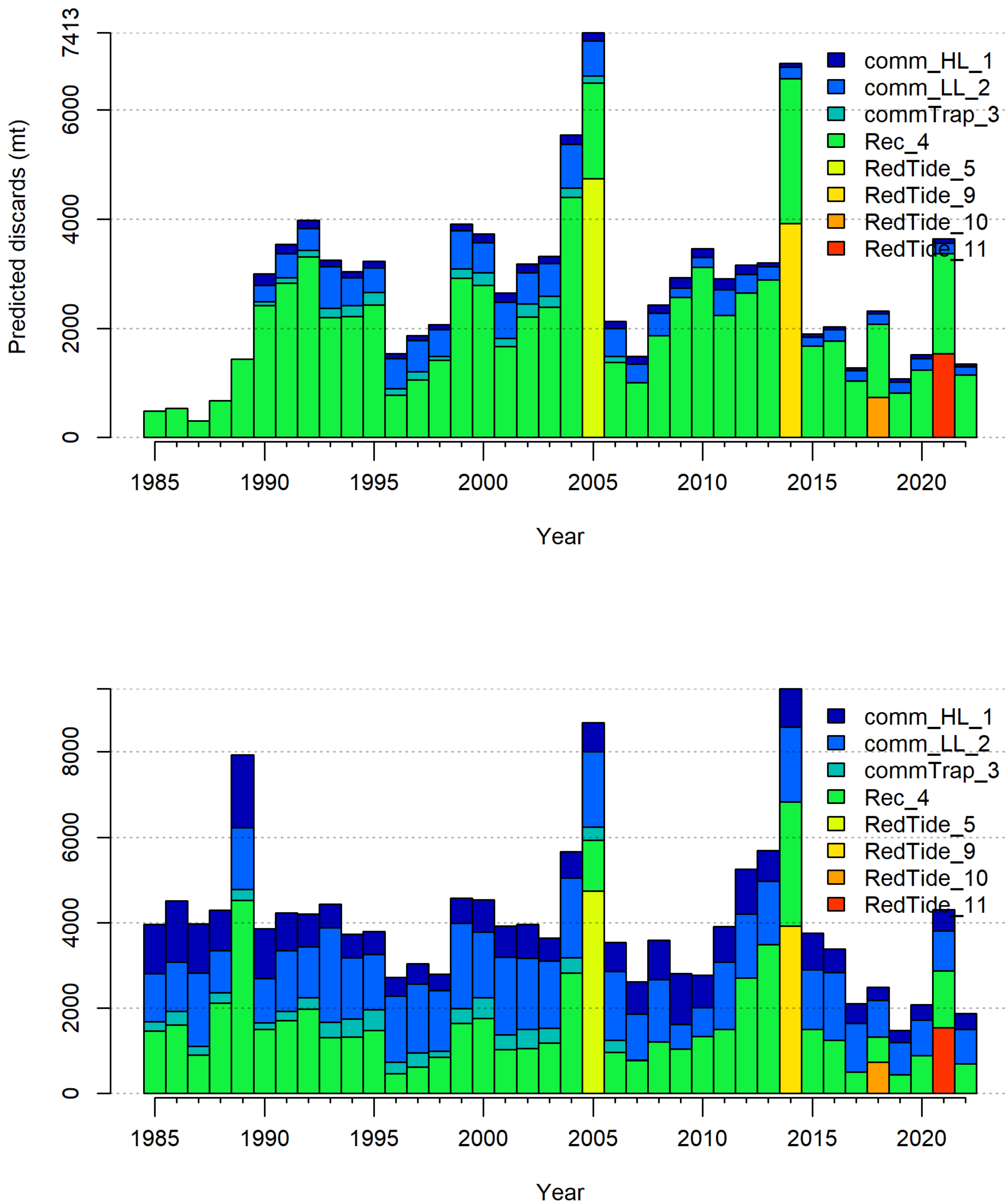


Figure 22. Predicted discards (top panel) and predicted landings + dead discards (bottom panel) by fleet for SEDAR 88.

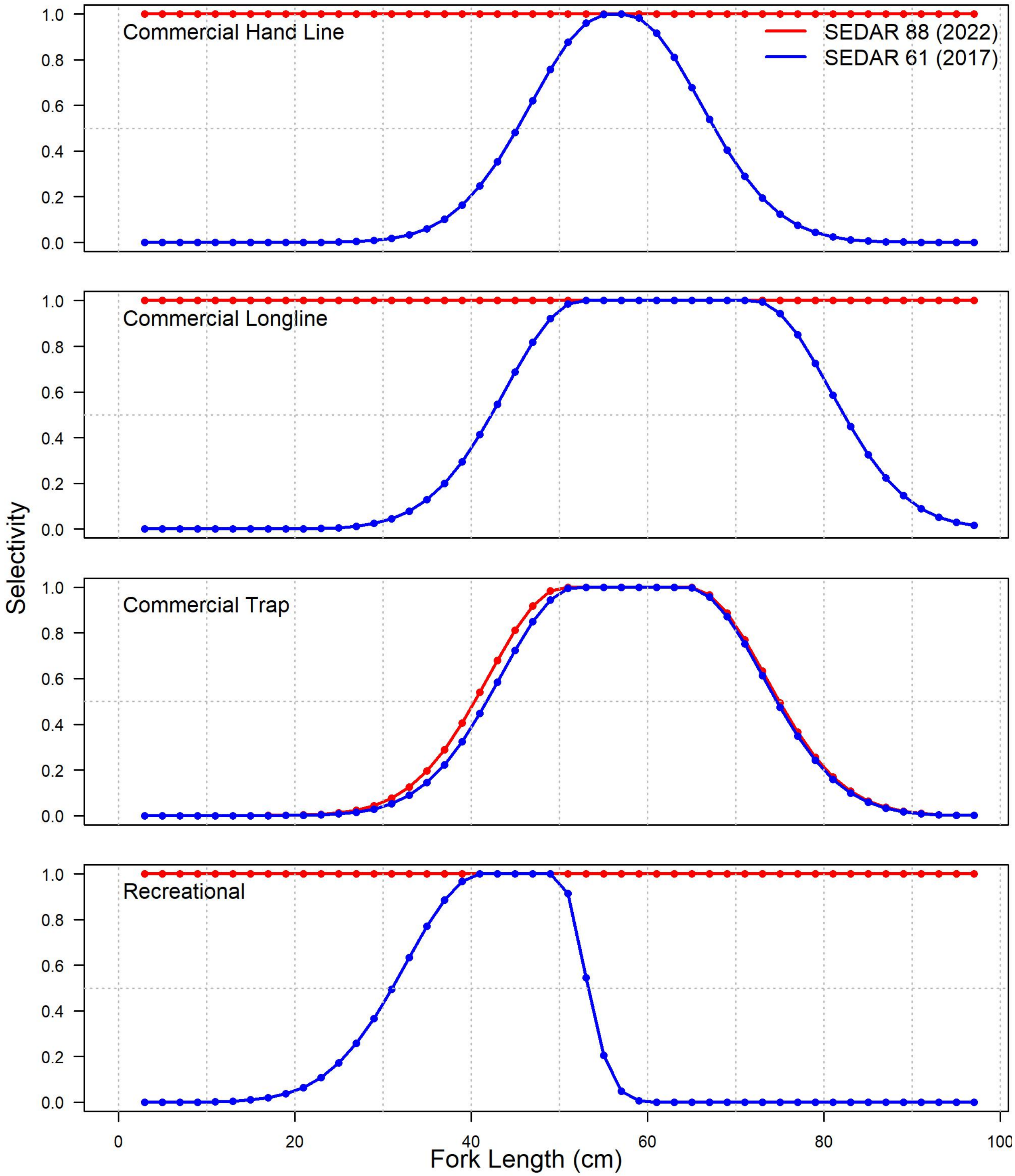


Figure 23. Length-based selectivity for each fleet for Gulf of Mexico Red Grouper in the terminal year of the assessment (given in parentheses). Dashed horizontal line indicates 50%.

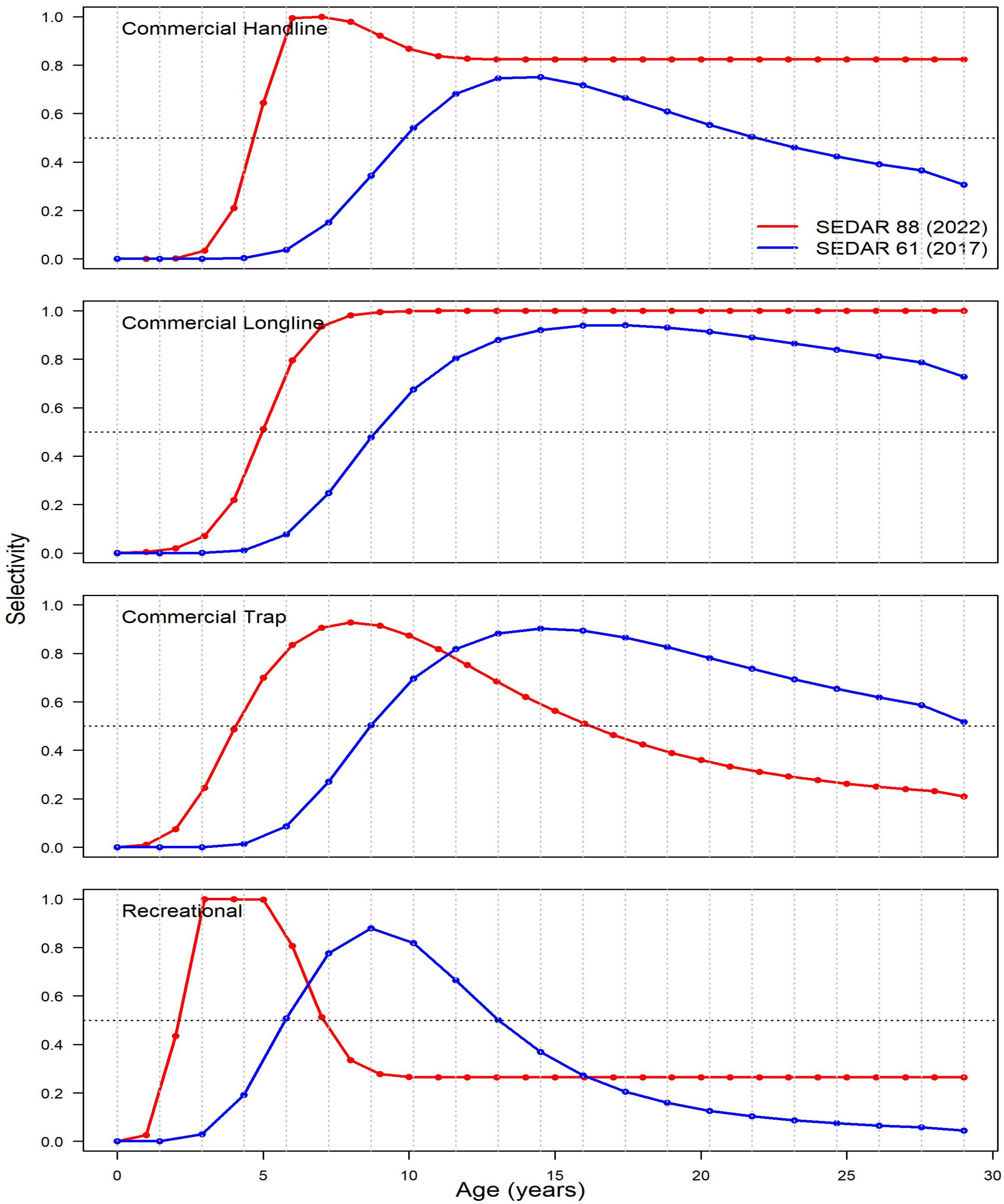


Figure 24. Derived age-based selectivity for each fleet for Gulf of Mexico Red Grouper in the terminal year of each assessment (given in parentheses). Dashed horizontal line indicates 50%.

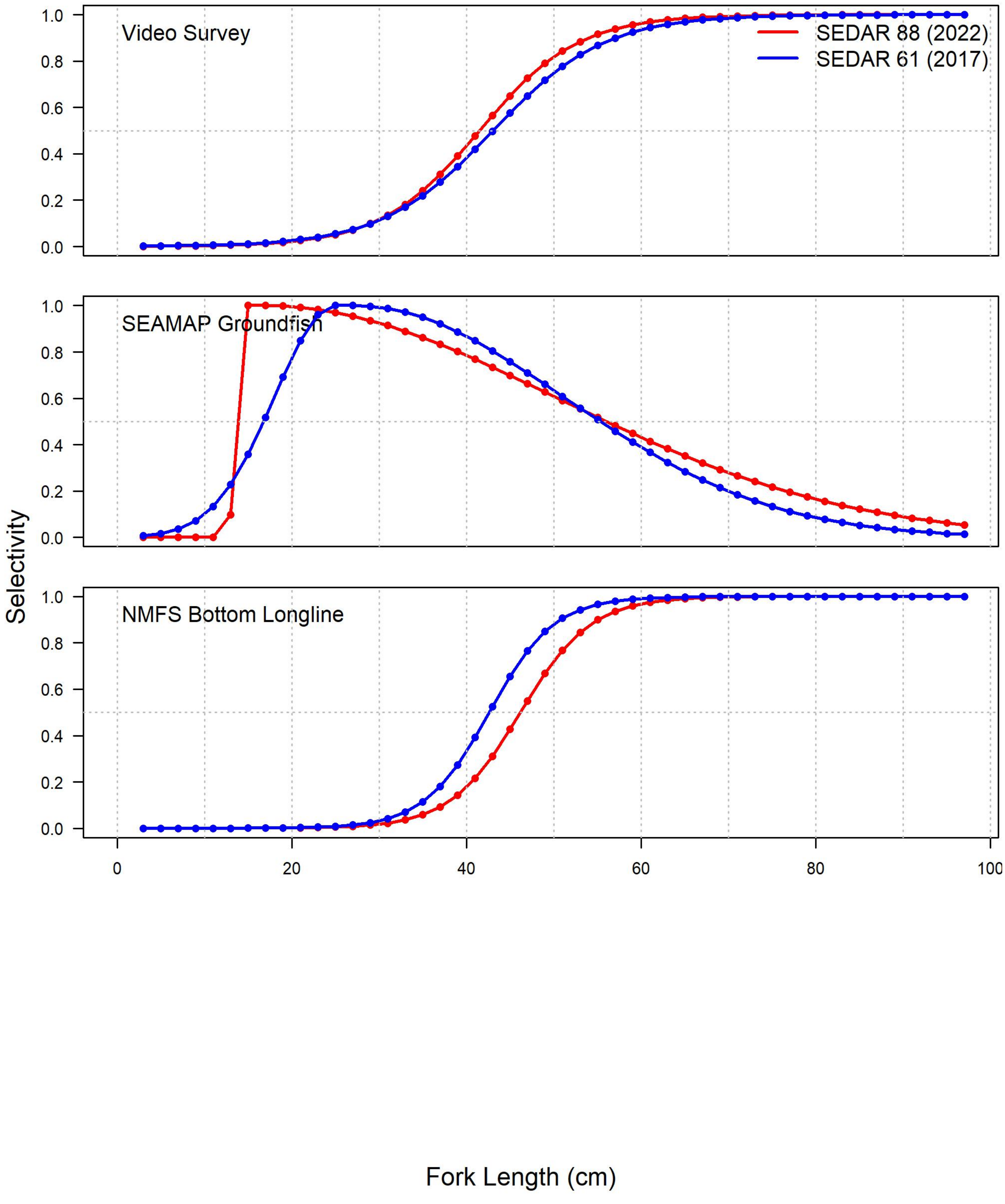


Figure 25. Length-based selectivity for each survey for Gulf of Mexico Red Grouper in the terminal year of each assessment (given in parentheses). Dashed horizontal line indicates 50%.

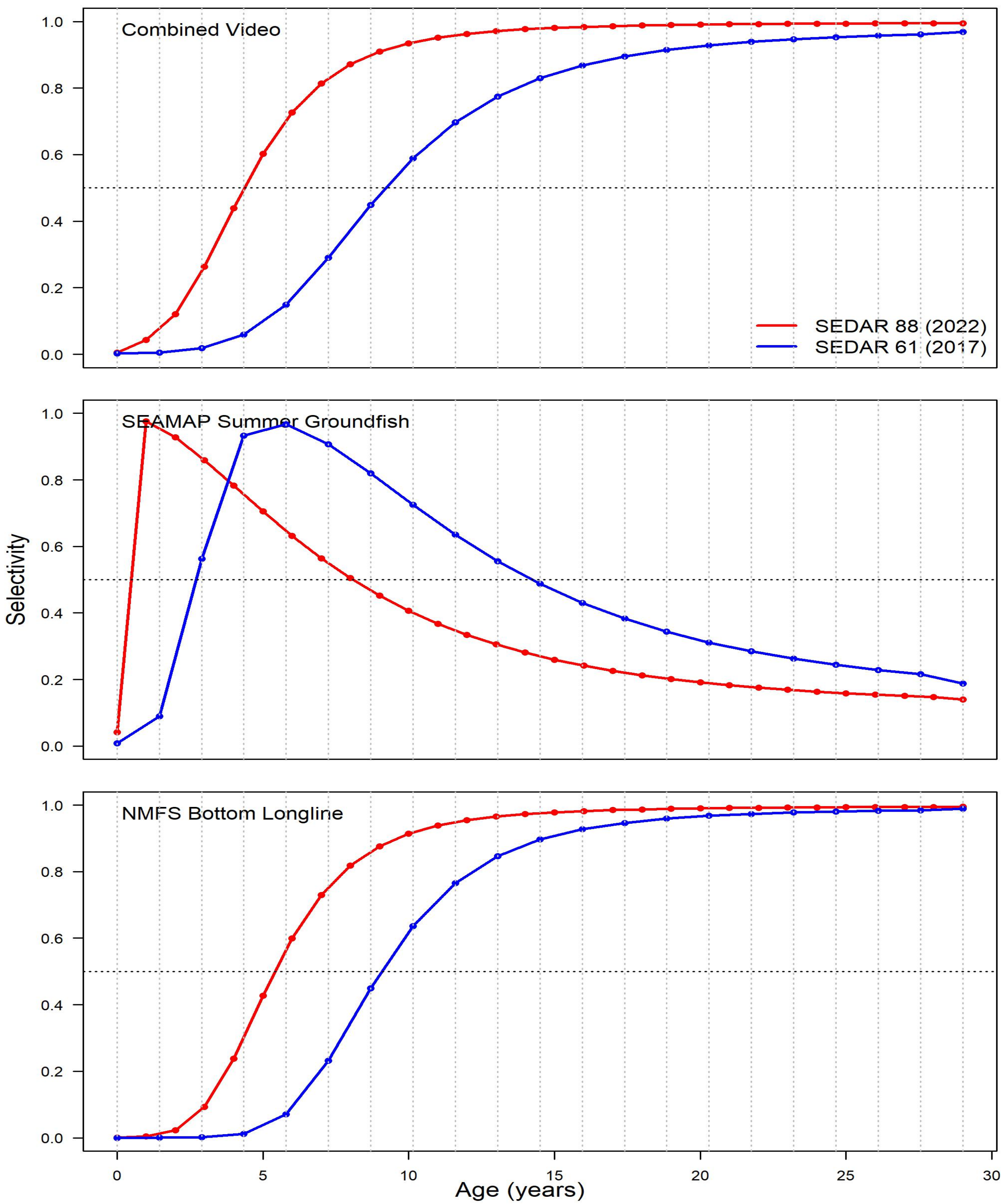


Figure 26. Derived age-based selectivity for each survey for Gulf of Mexico Red Grouper in the terminal year of each assessment (given in parentheses). Dashed horizontal line indicates 50%.

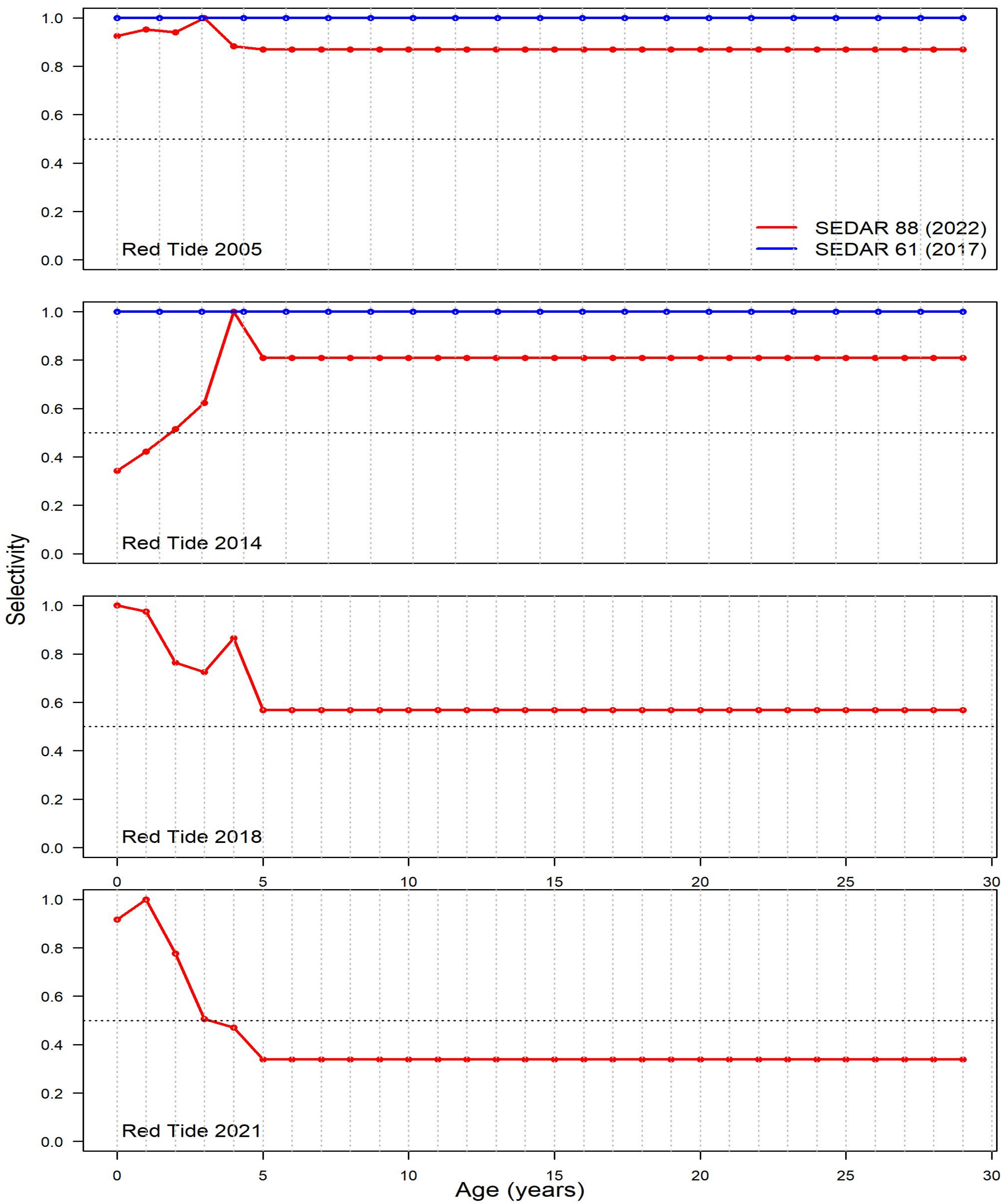


Figure 27. Derived age-based selectivity for each red tide bycatch fleet for Gulf of Mexico Red Grouper in the terminal year of each assessment (given in parentheses). Dashed horizontal line indicates 50%.

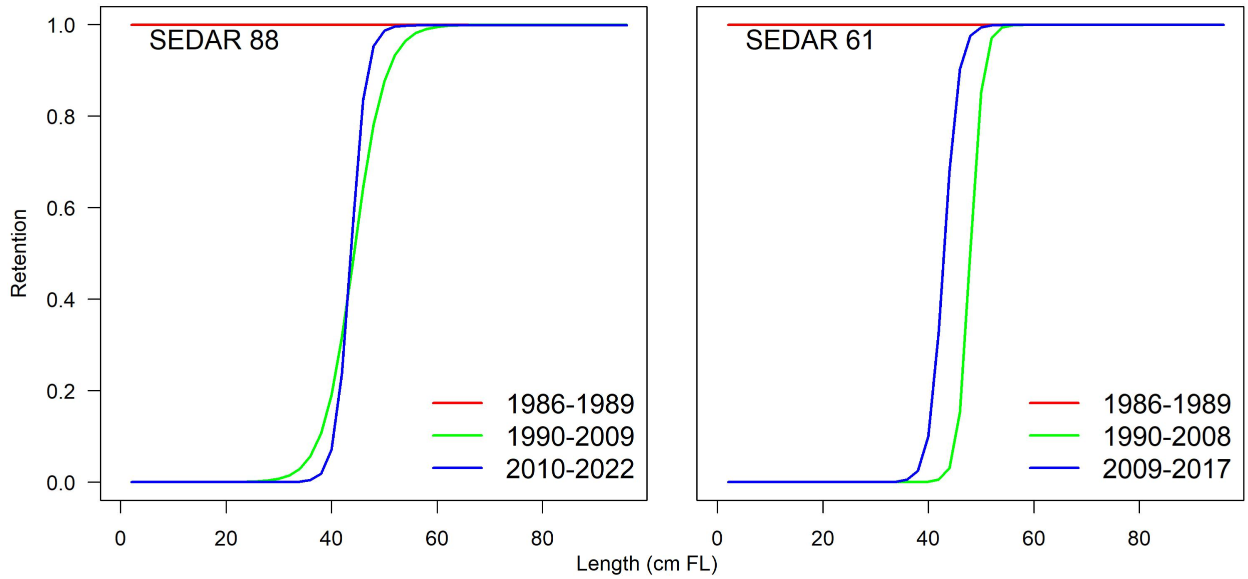


Figure 28. Retention functions for the Commercial Handline fleet for Gulf of Mexico Red Grouper from SEDAR 88 and SEDAR 61.

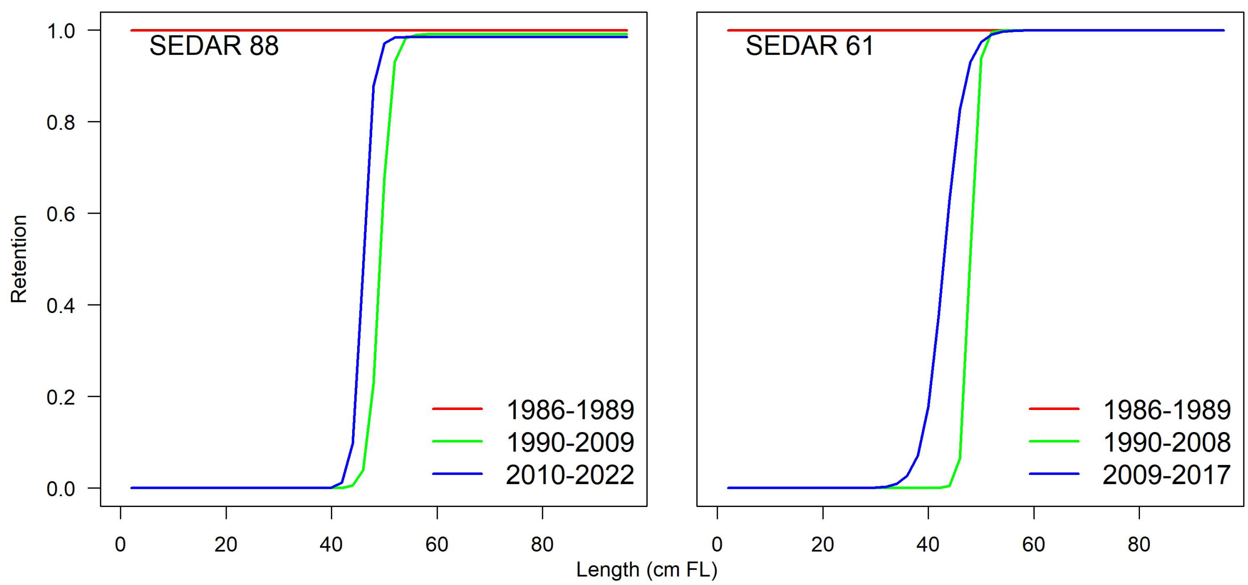


Figure 29. Retention functions for the Commercial Longline fleet for Gulf of Mexico Red Grouper from SEDAR 88 and SEDAR 61.

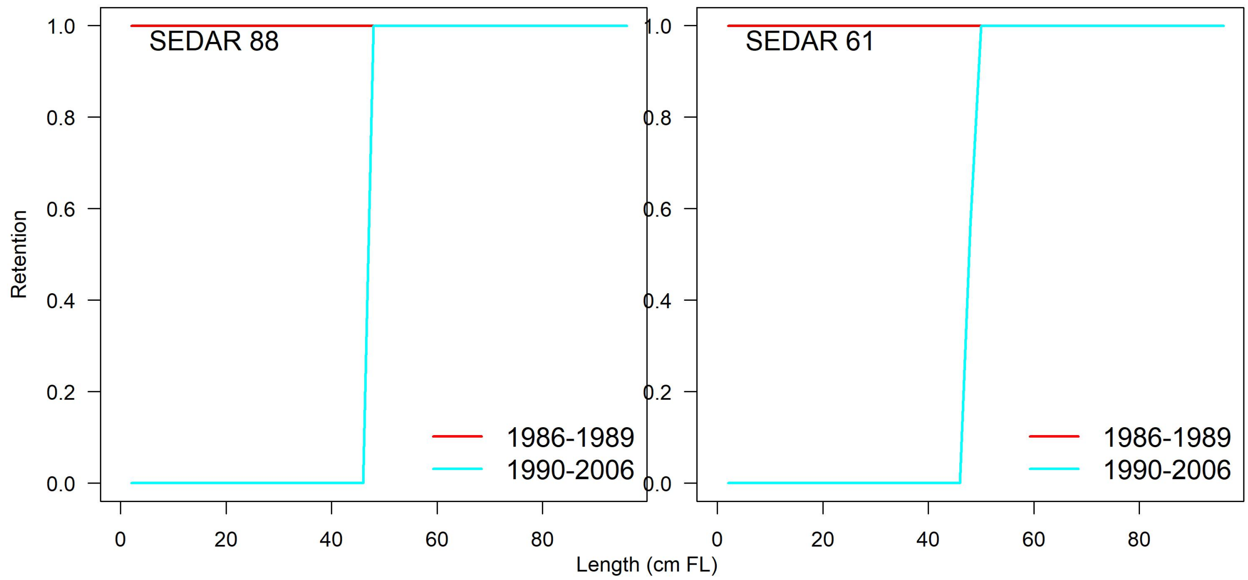


Figure 30. Retention functions for the Commercial Trap fleet for Gulf of Mexico Red Grouper from SEDAR 88 and SEDAR 61.

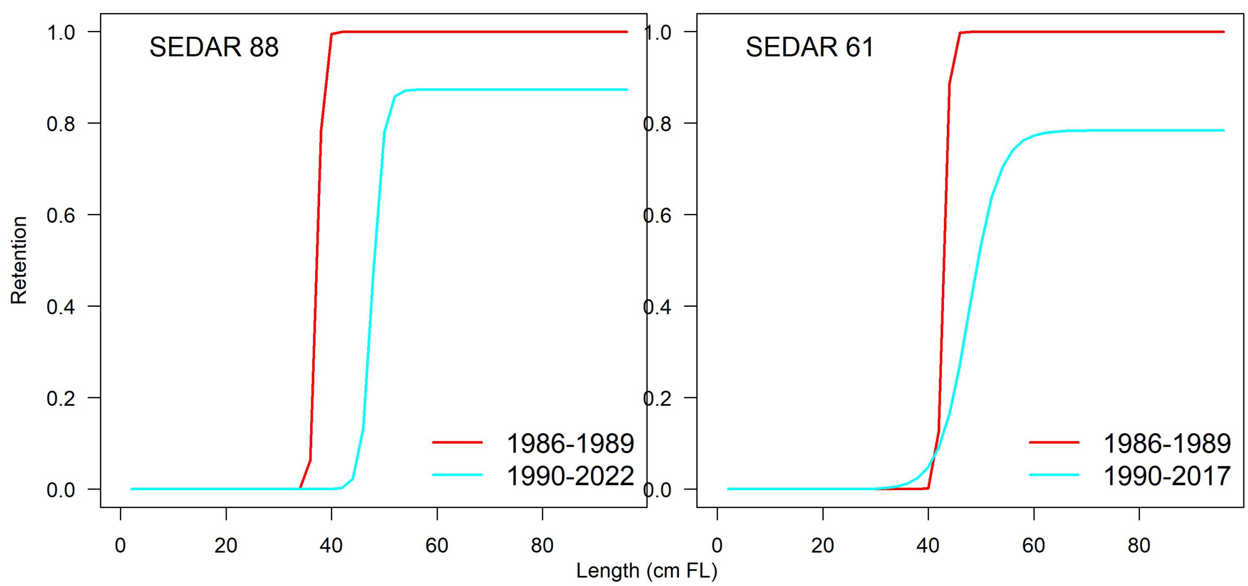


Figure 31. Retention functions for the Recreational fleet for Gulf of Mexico Red Grouper from SEDAR 88 and SEDAR 61.

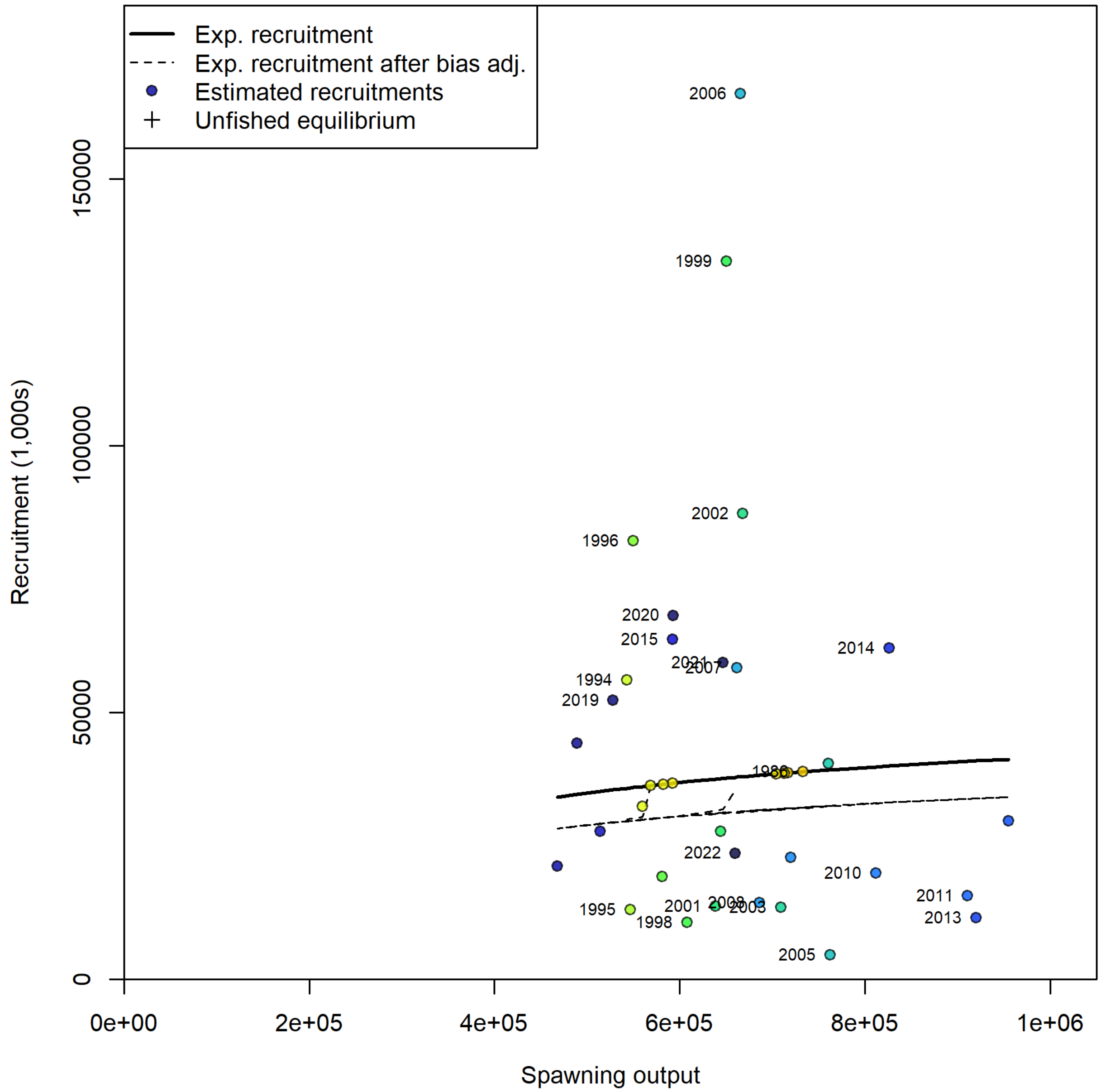


Figure 32. Predicted stock-recruitment relationship for Gulf of Mexico Red Grouper. Plotted are predicted annual recruitments from Stock Synthesis (circles), expected recruitment from the stock-recruit relationship (black line), and bias adjusted recruitment from the stock-recruit relationship (dashed line).

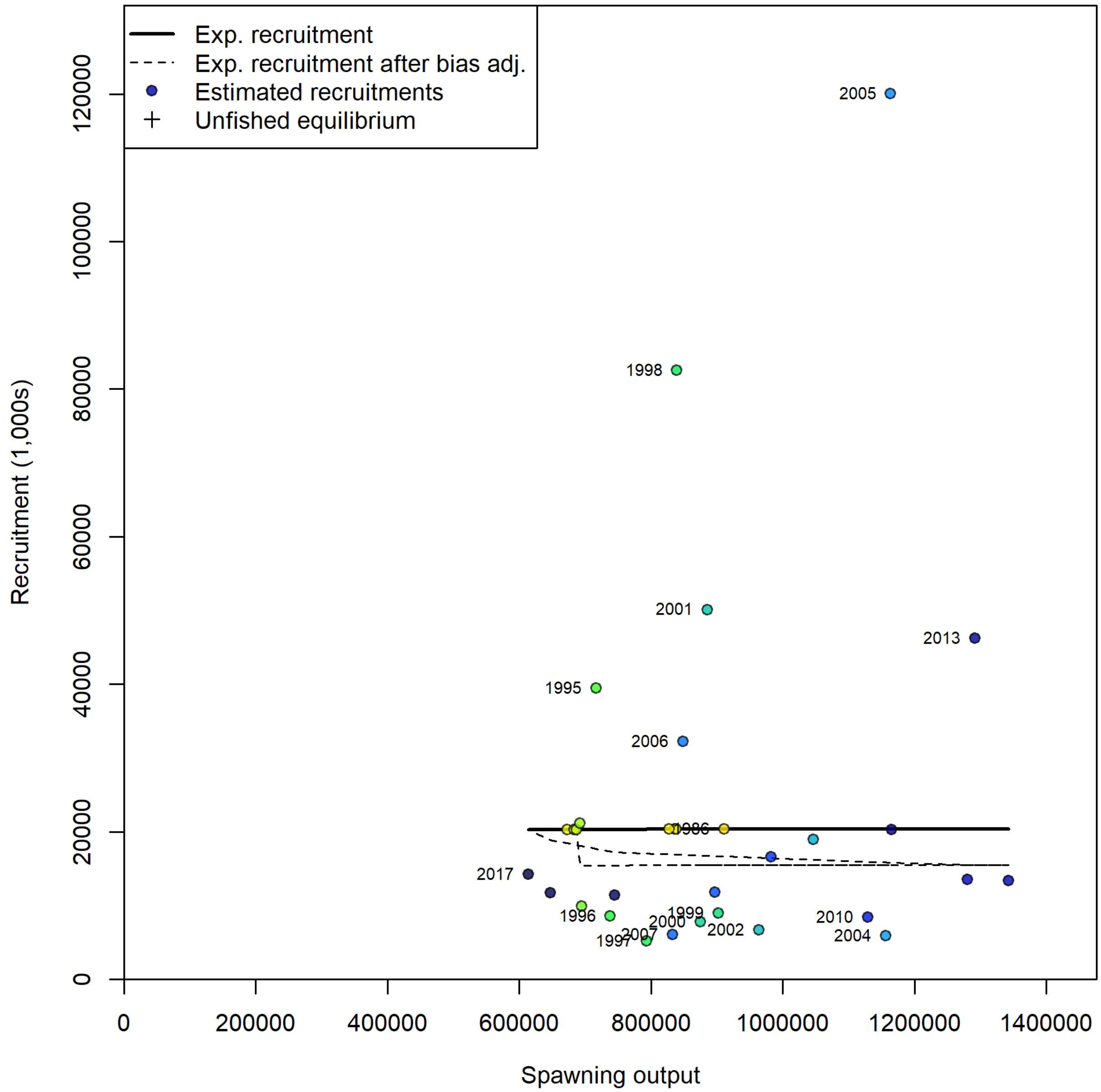
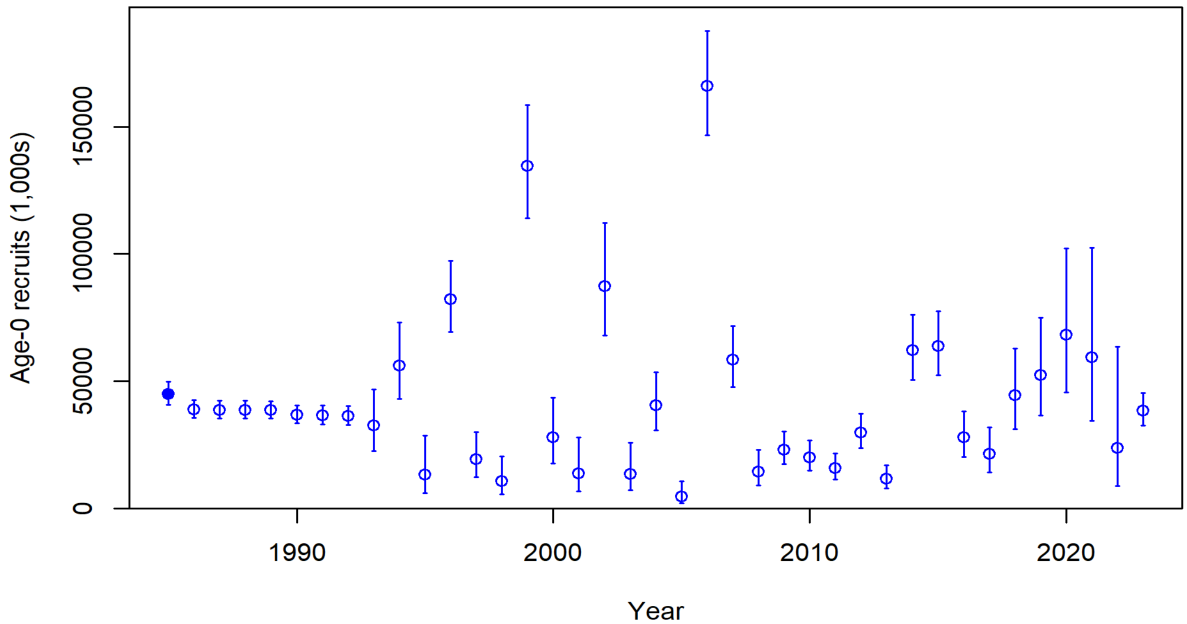


Figure 32 Continued. Predicted stock-recruitment relationship for Gulf of Mexico Red Grouper. Plotted are predicted annual recruitments from Stock Synthesis (circles), expected recruitment from the stock-recruit relationship (black line), and bias adjusted recruitment from the stock-recruit relationship (dashed line).

SEDAR 88



SEDAR 61

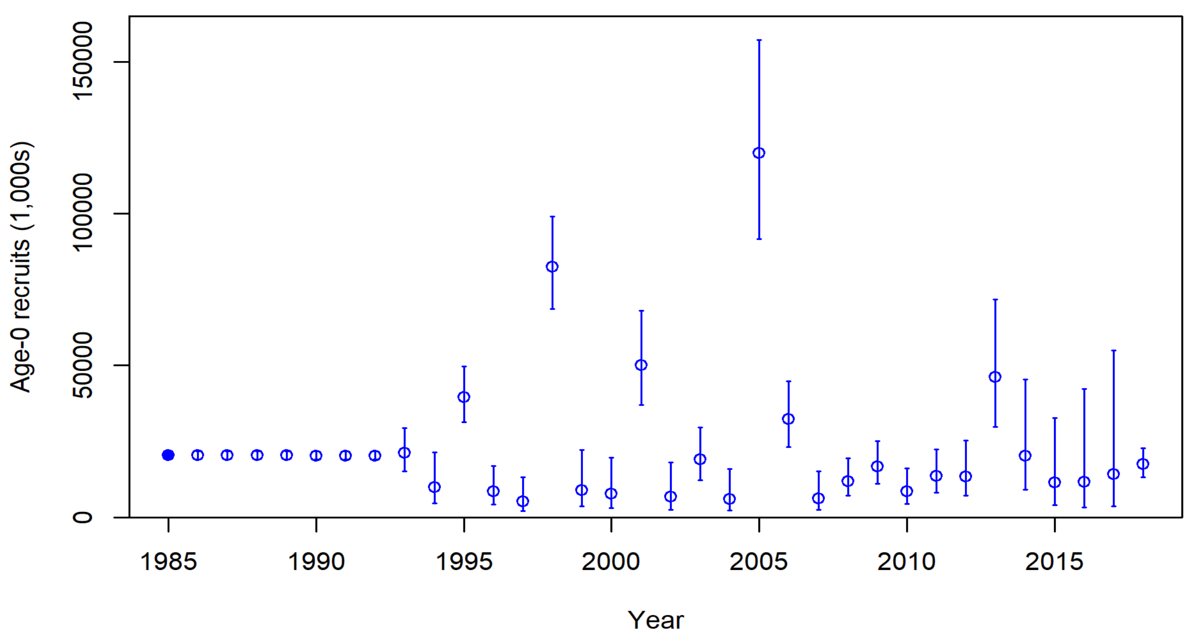
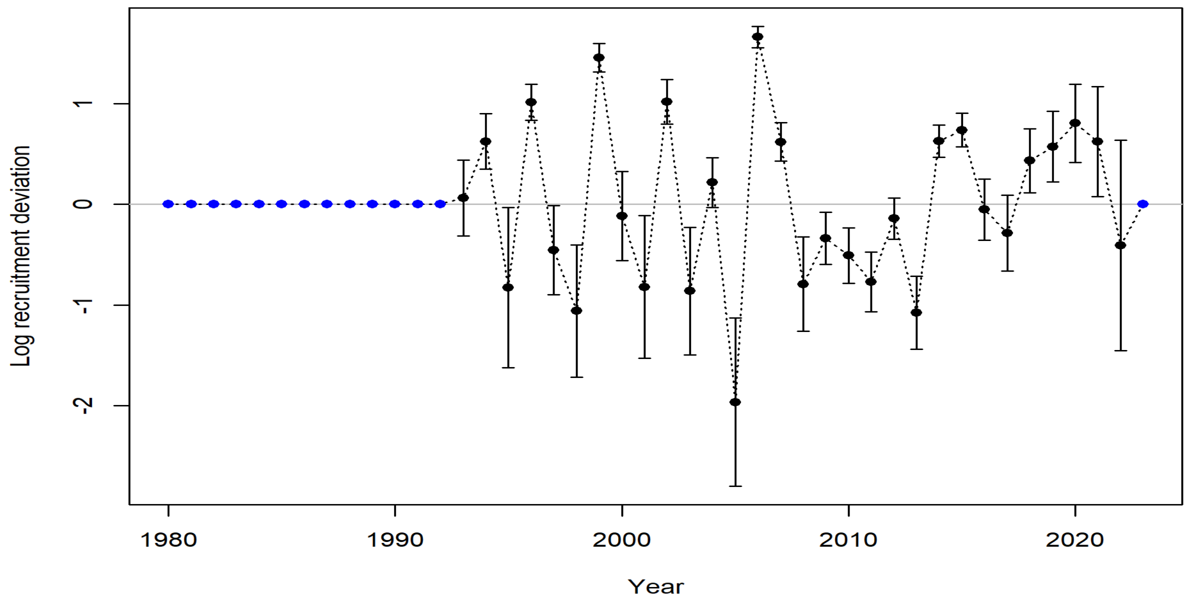


Figure 33. Estimated Age-0 recruitment with 95% confidence intervals for Gulf of Mexico Red Grouper.

SEDAR 88



SEDAR 61

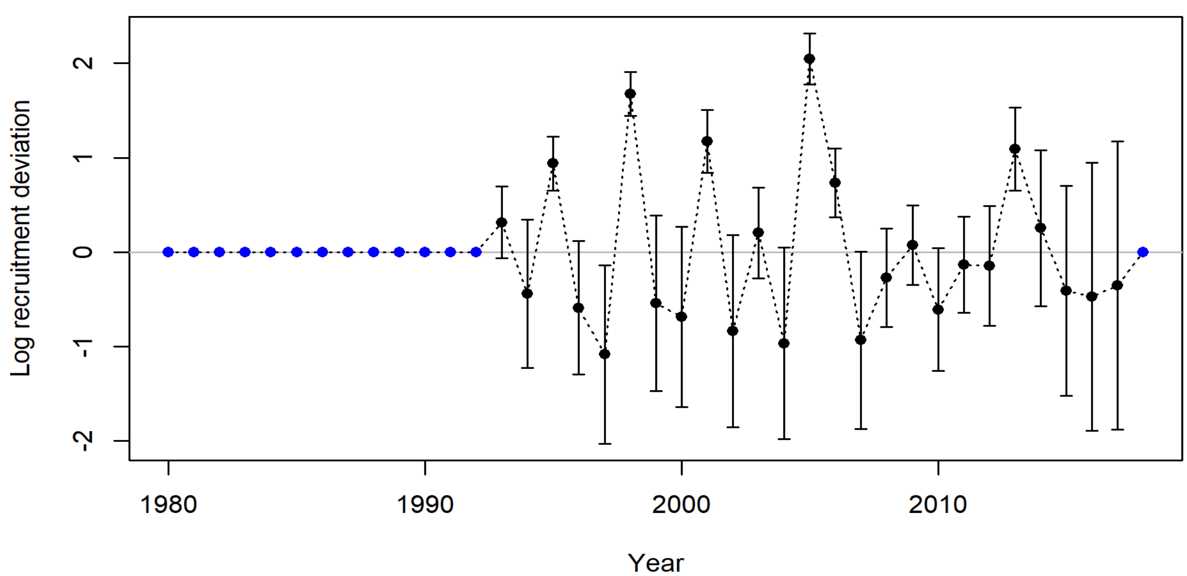
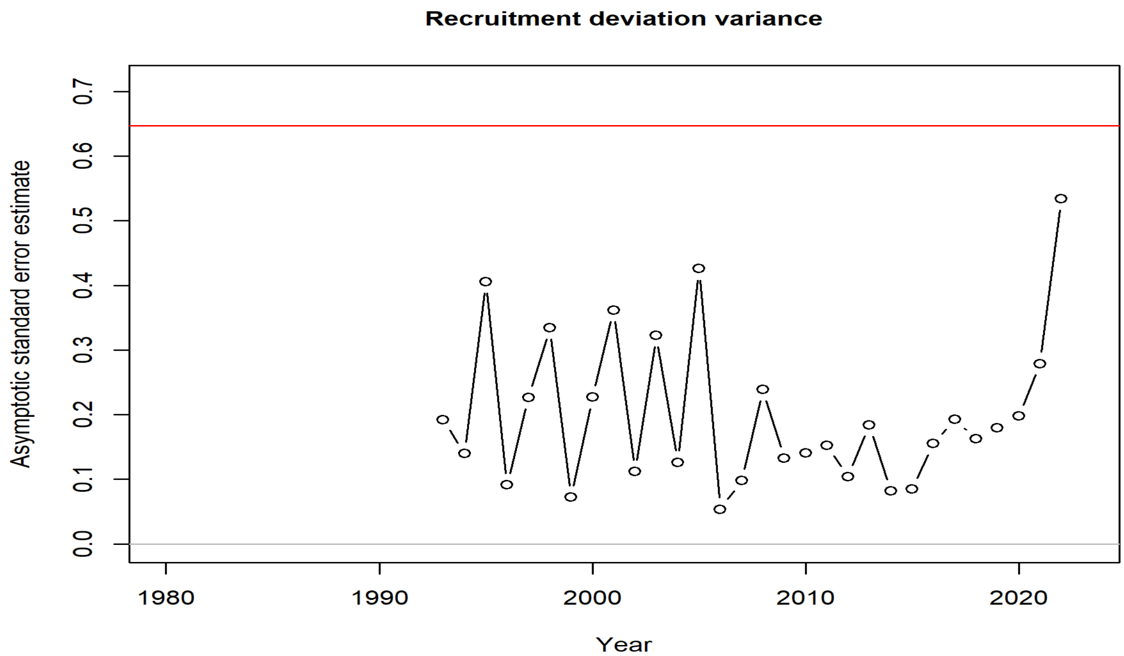


Figure 34. Estimated log recruitment deviations for Gulf of Mexico Red Grouper. Blue dots identify years where recruitment deviations were not estimated.

SEDAR 88



SEDAR 61

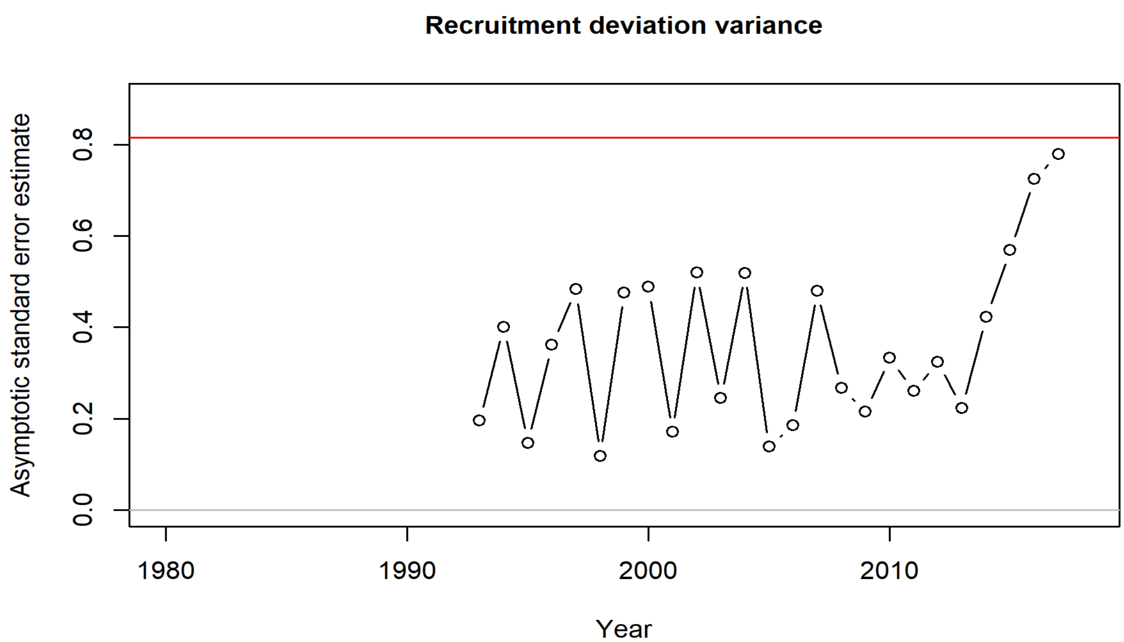


Figure 35. Asymptotic standard errors for recruitment deviations for Gulf of Mexico Red Grouper. The red line represents the values estimated SEDAR 88 and SEDAR 61 models, respectively.

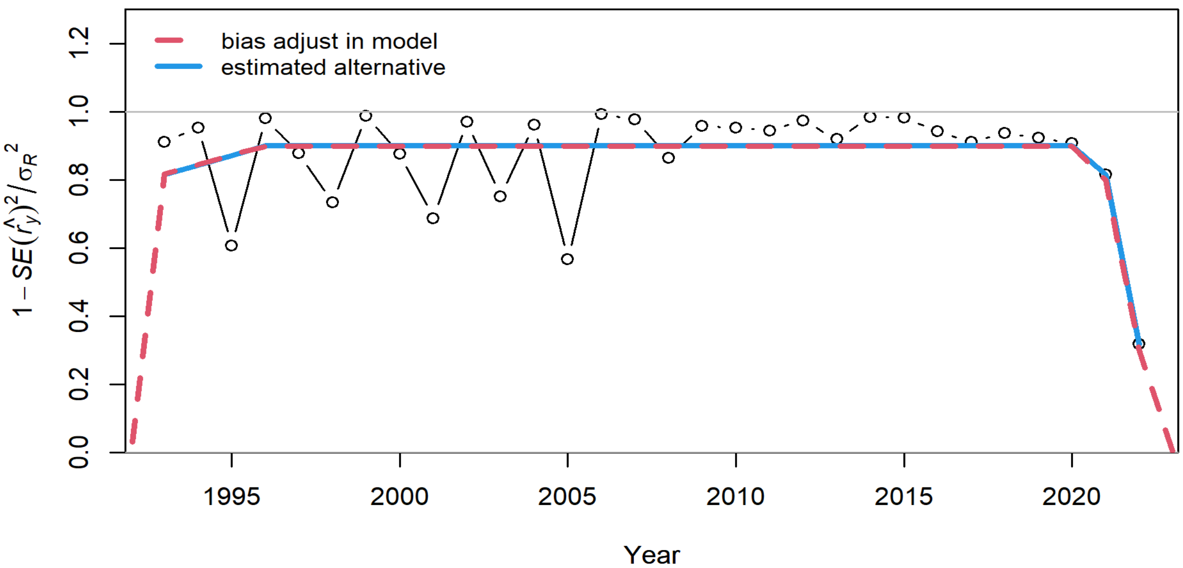


Figure 36. Points are transformed variances. Red line shows current settings for bias adjustment specified for the SEDAR 88 OA Base Model. For more information, see Methot and Taylor 2011.

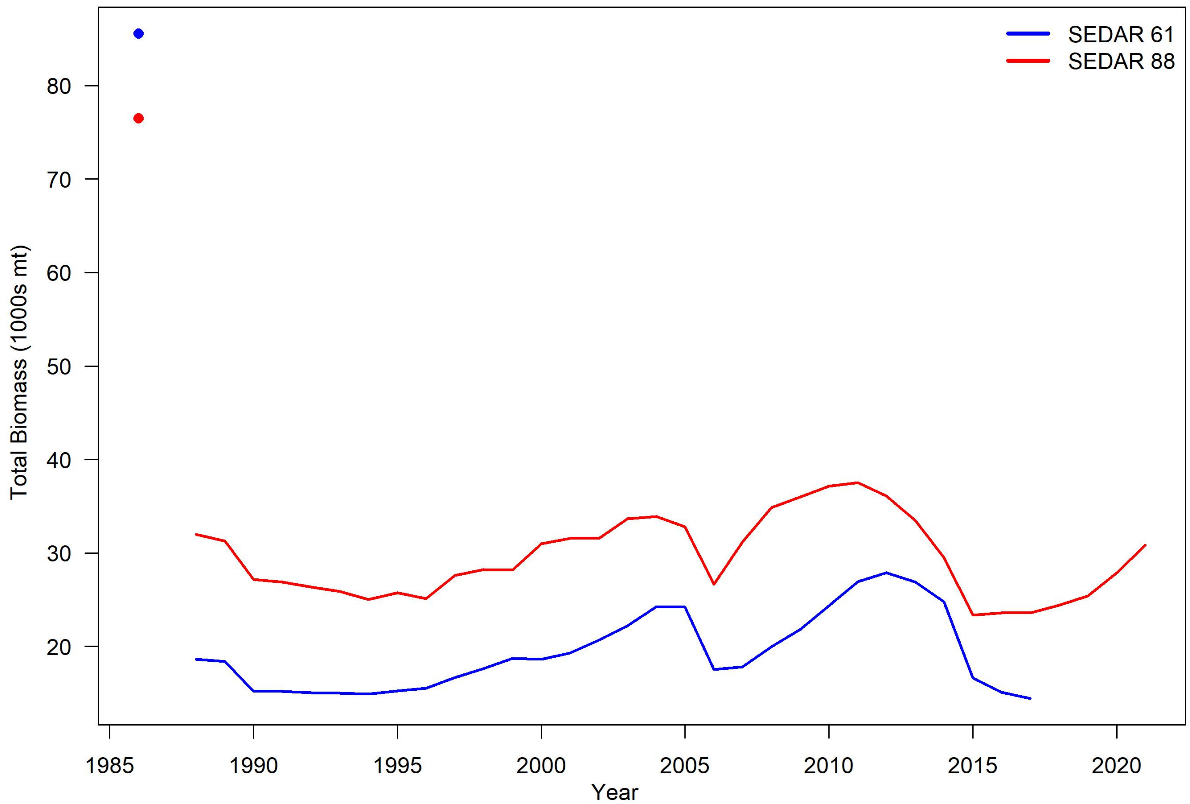


Figure 37. Estimates of virgin (dots) and annual total biomass (in 1000s of metric tons) for Gulf of Mexico Red Grouper between SEDAR 88 and SEDAR 61.

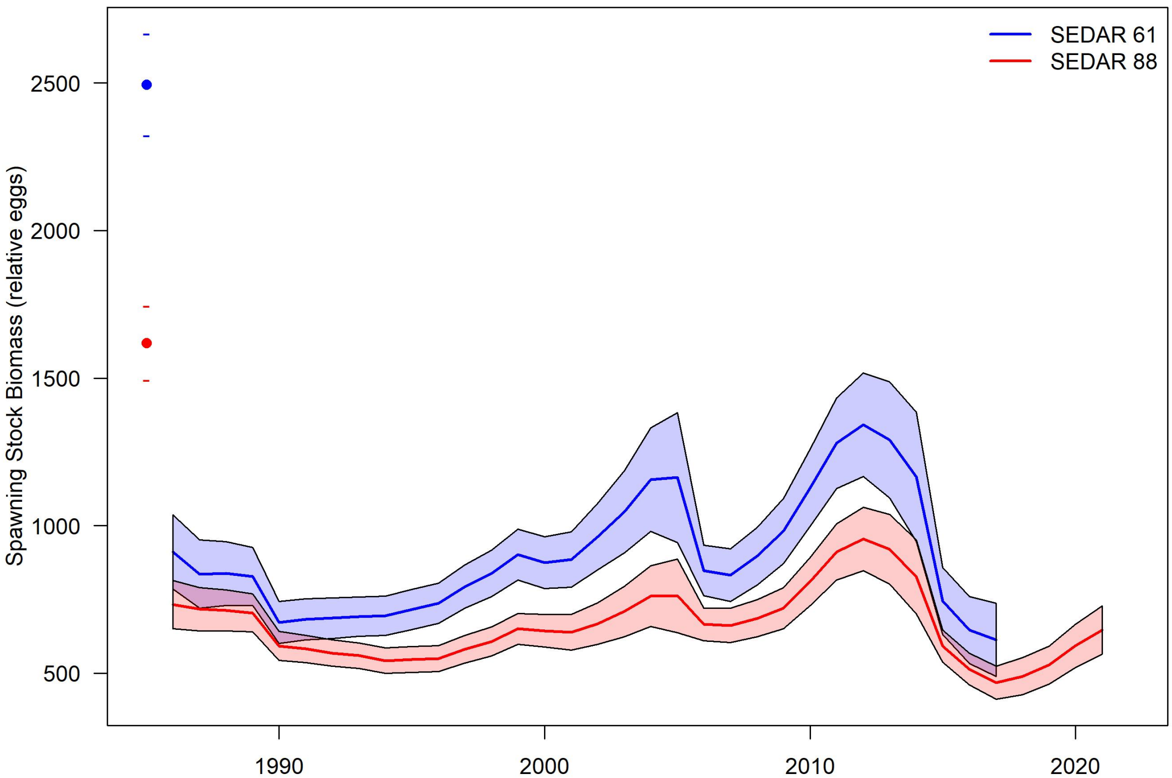


Figure 38. Estimates of virgin (dots) and annual spawning stock biomass (relative relative number of eggs) for Gulf of Mexico Red Grouper between SEDAR 88 and SEDAR 61. Associated 95% confidence intervals are provided.

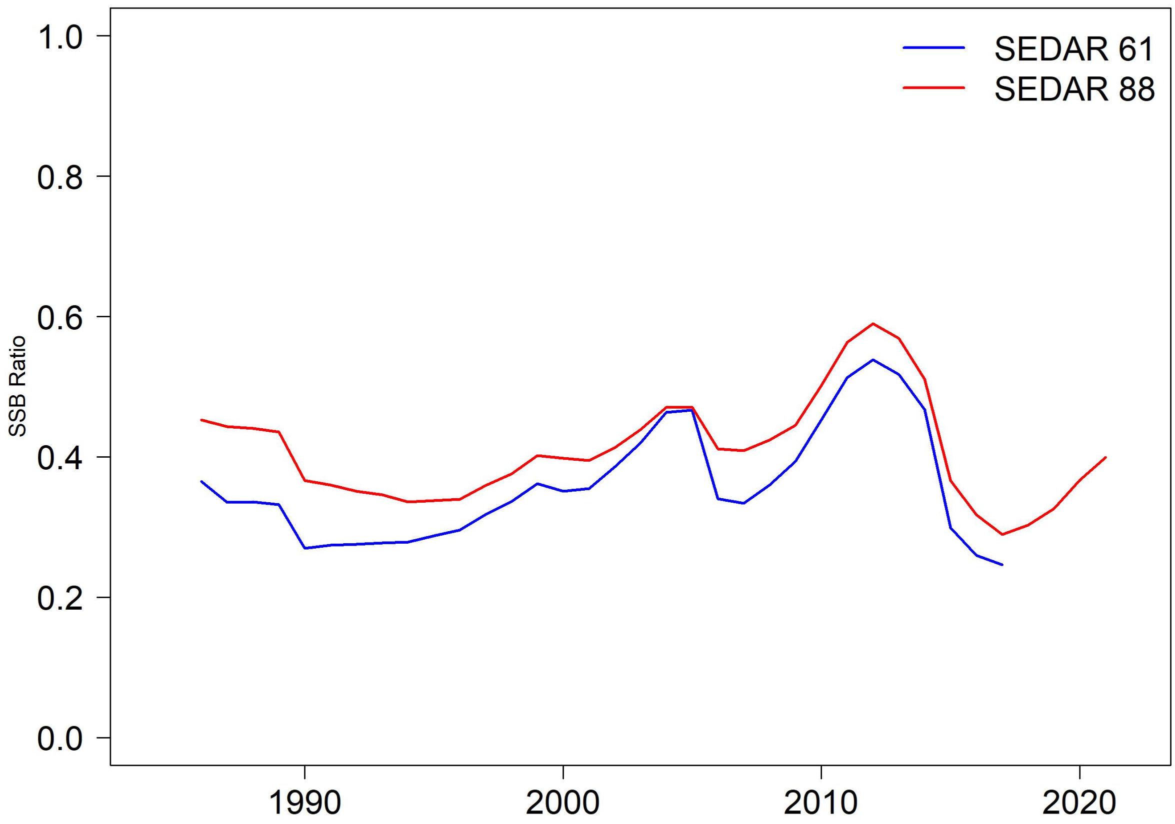


Figure 39. Differences in estimates of the fraction of virgin or unfished SSB (SSB/SSB0) for Gulf of Mexico Red Grouper between SEDAR 88 and SEDAR 61.

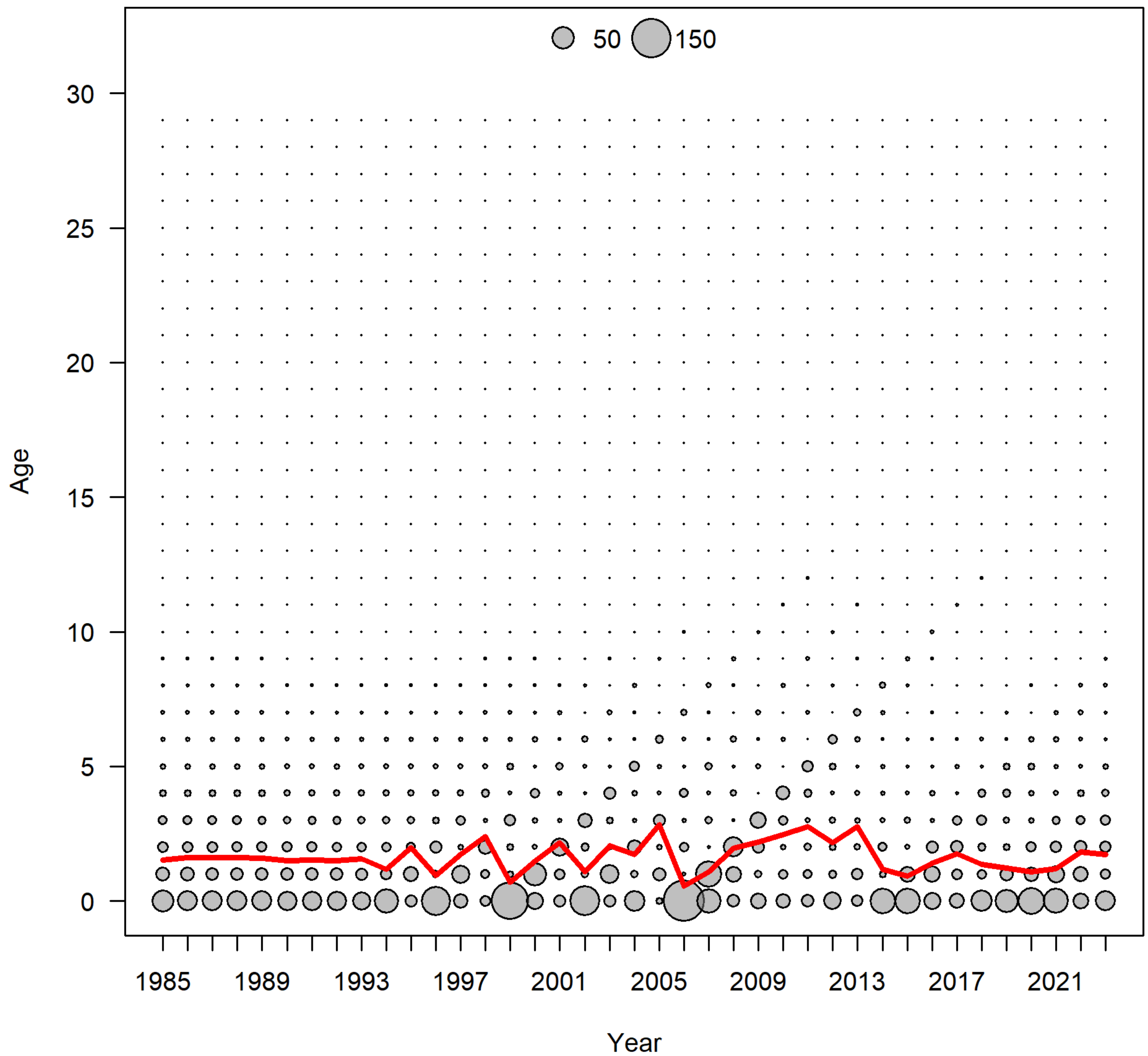


Figure 40. Predicted beginning of year mean age in the population for Gulf of Mexico Red Grouper

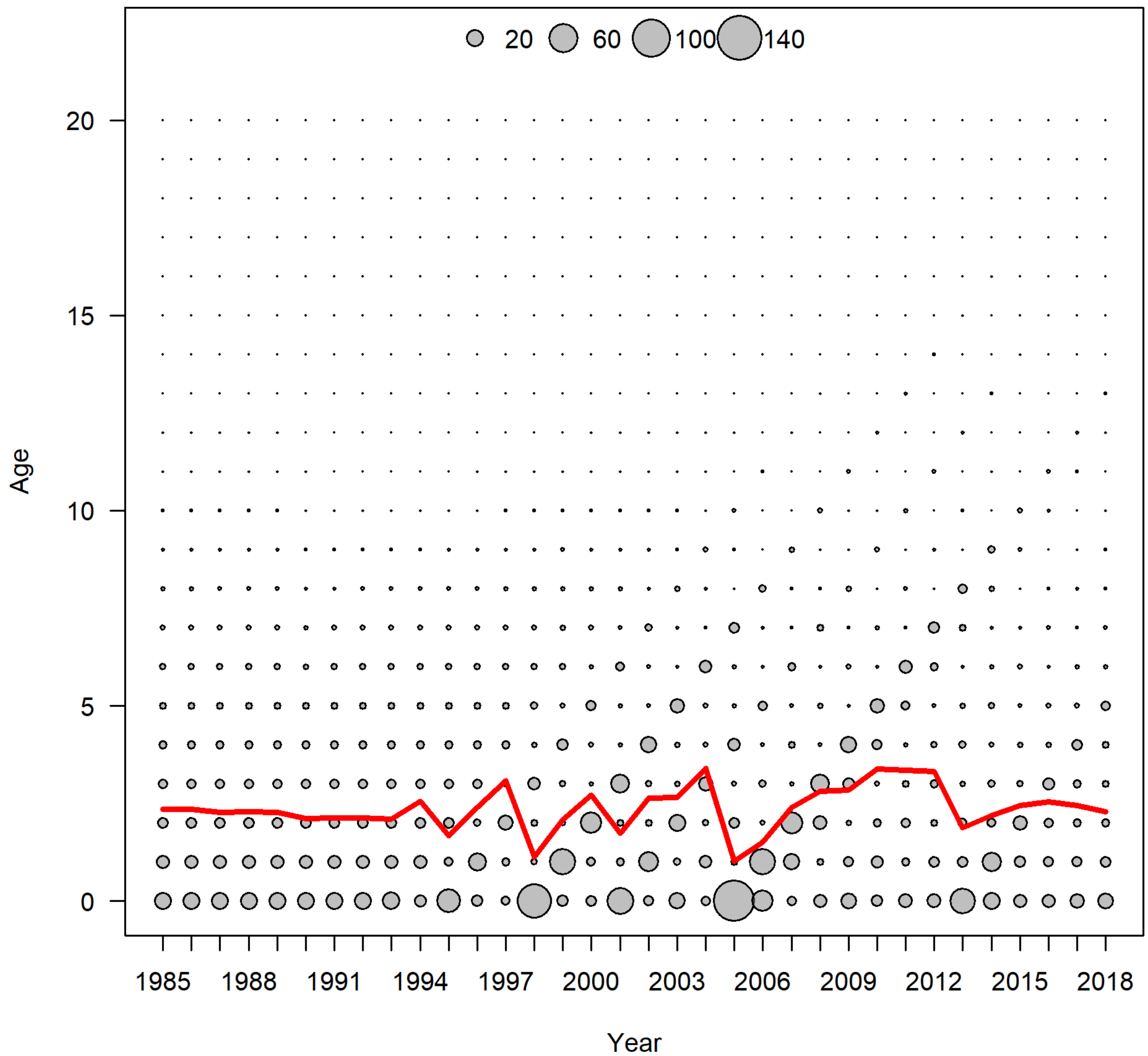


Figure 40 Continued. Predicted beginning of year mean age in the population for Gulf of Mexico Red Grouper.

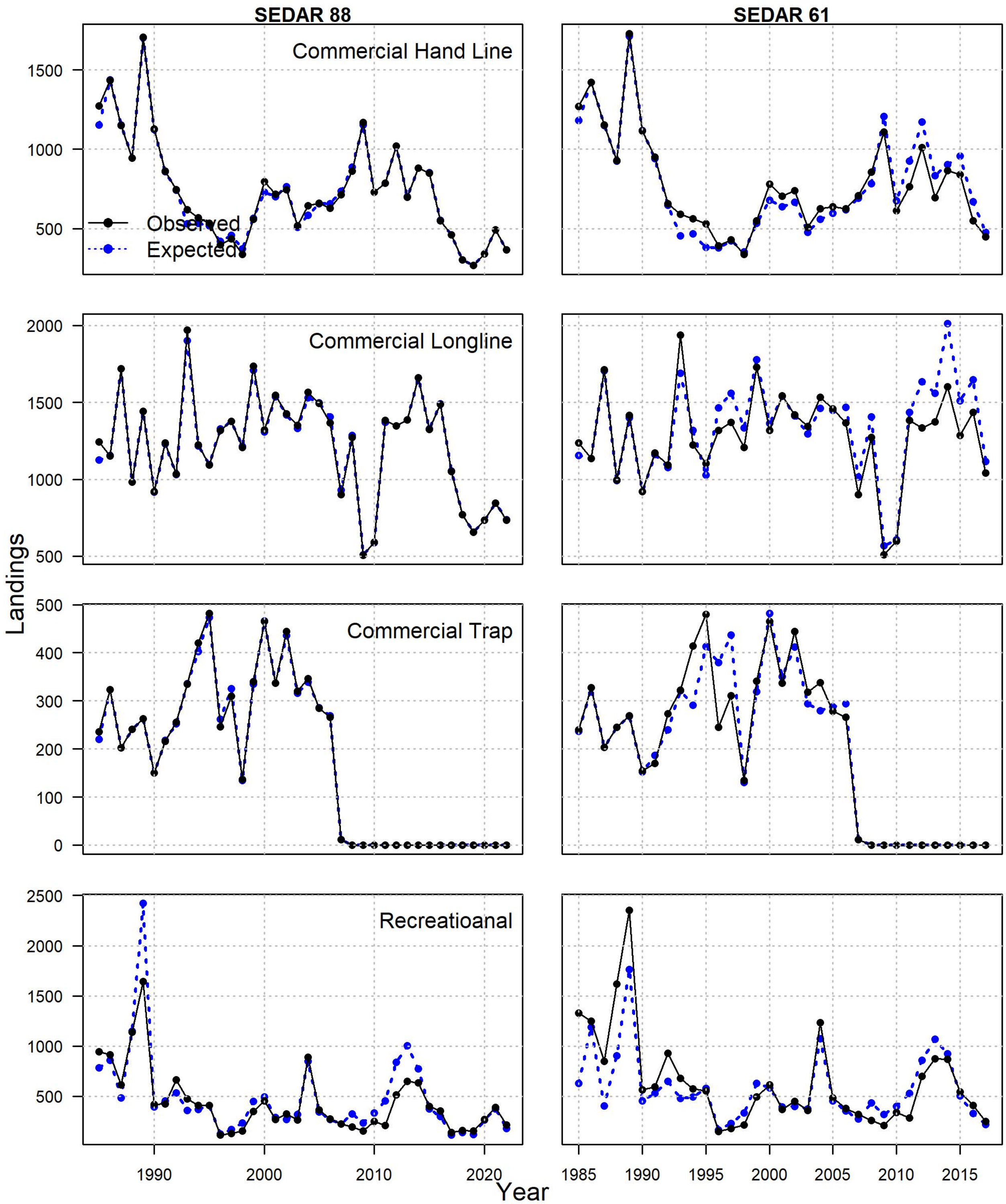
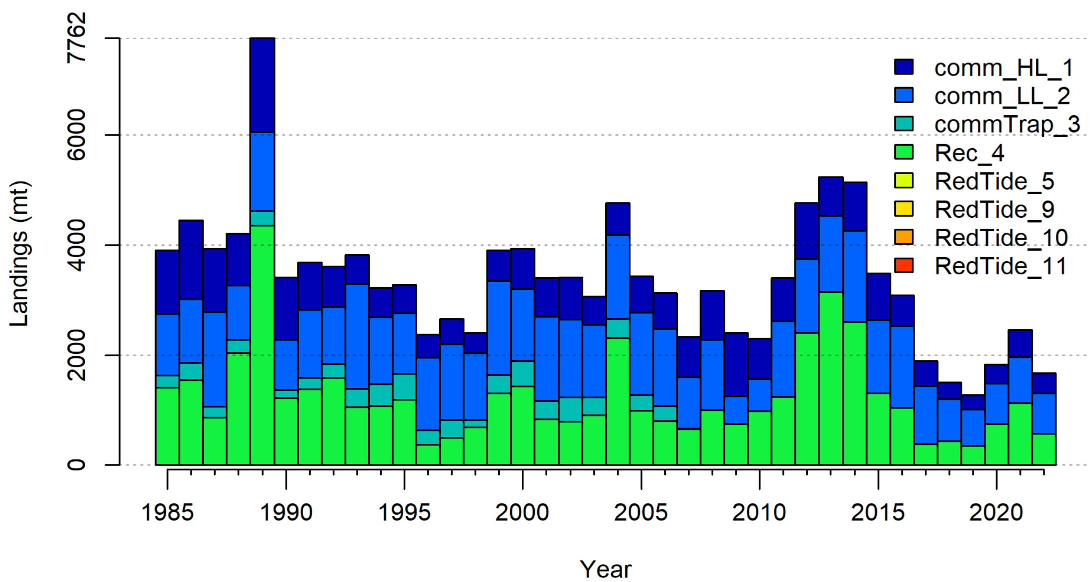


Figure 41. Gulf of Mexico Red Grouper observed and expected landings by fishery for SEDAR 88 (left panels) and SEDAR 61 (right panels).

SEDAR 88



SEDAR 61

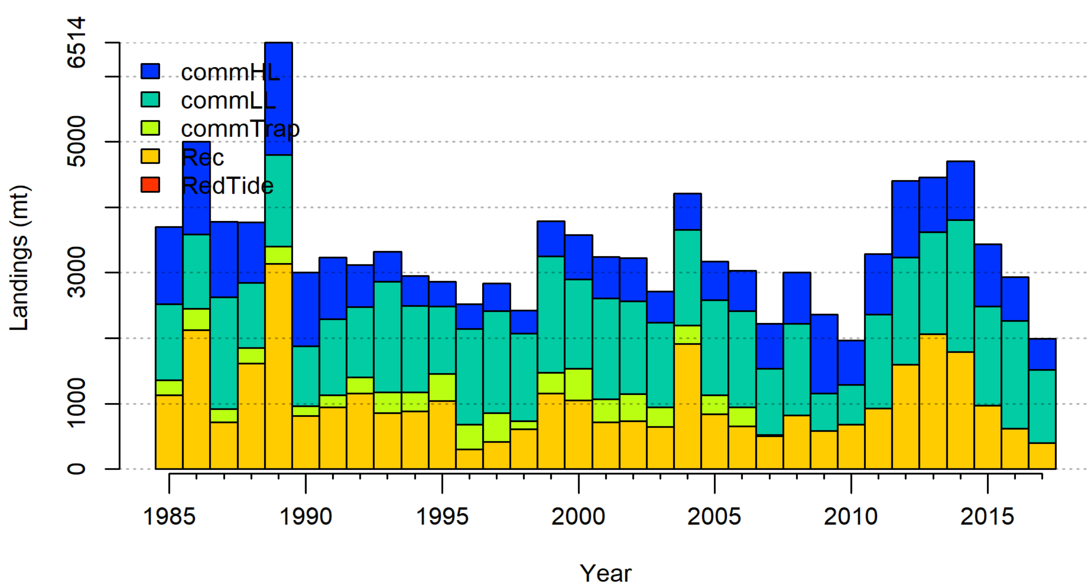


Figure 42. Expected landings by fleet for the SEDAR 88 OA Base Model and the SEDAR 61 Standard Base Model.

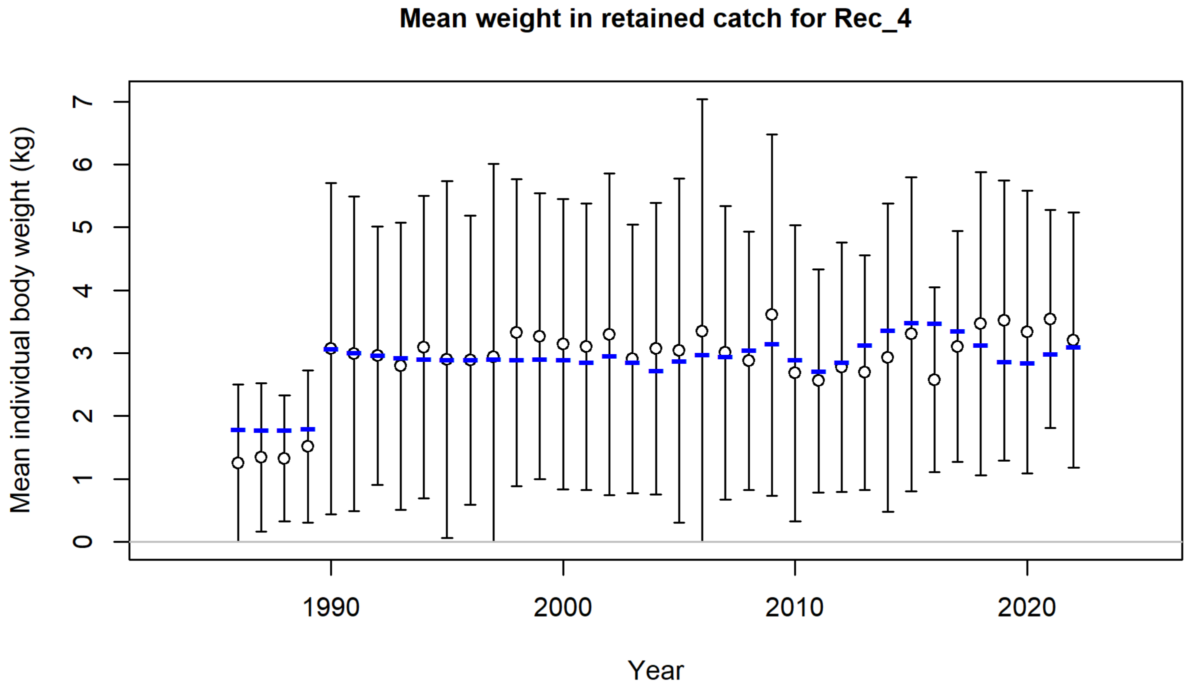


Figure 43. Fit (blue line) to mean body weight (open circle) with associated uncertainty for the retained catch for the Recreational fleet. Note that the SRFS private mode estimates were used as this is the dominant mode of landings.

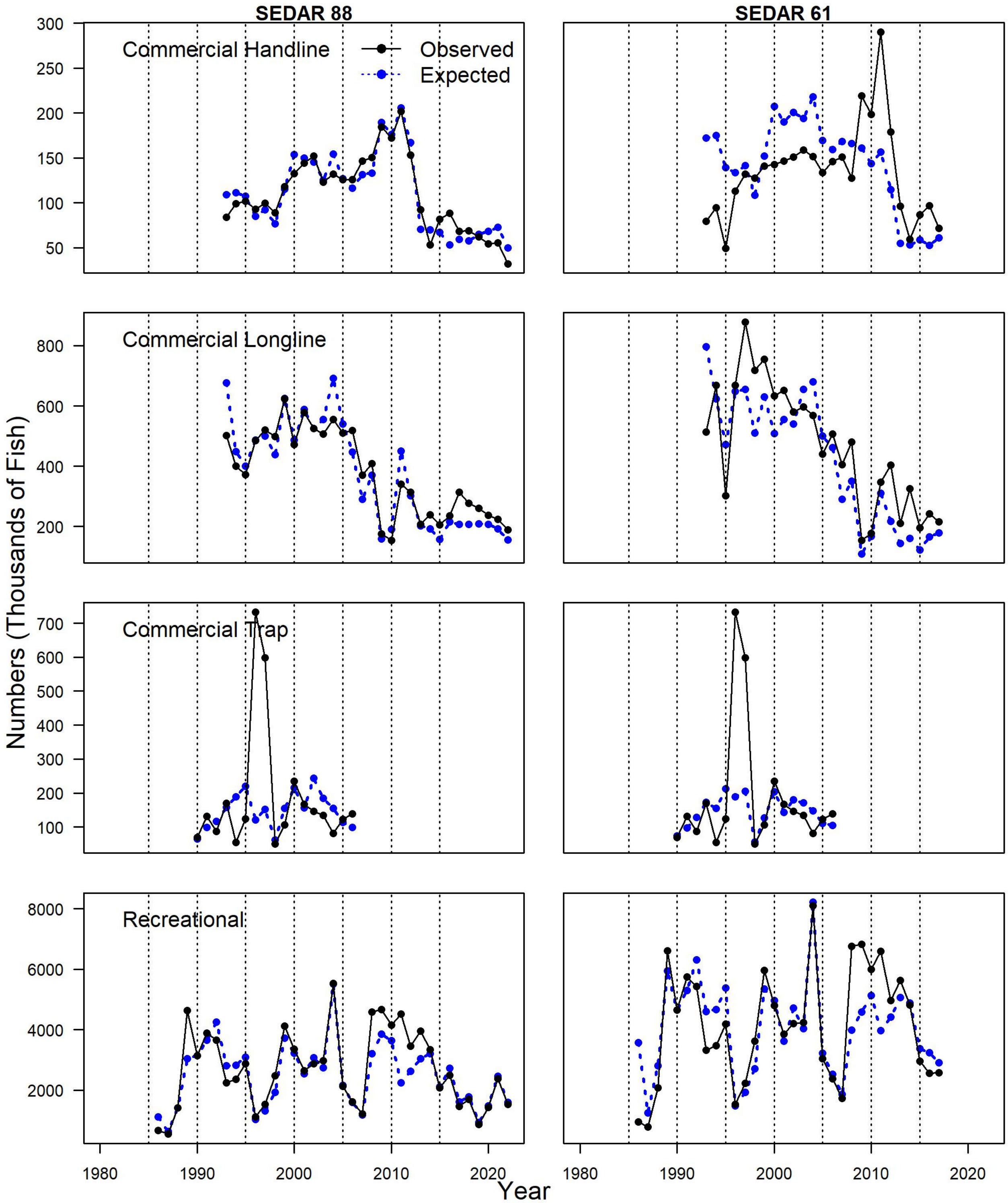


Figure 44. Gulf of Mexico Red Grouper observed and expected discards by fleet for SEDAR 88 (left panels) and SEDAR 61 (right panels). Commercial and recreational discards are in numbers of fish. Dashed vertical lines identify five year intervals.

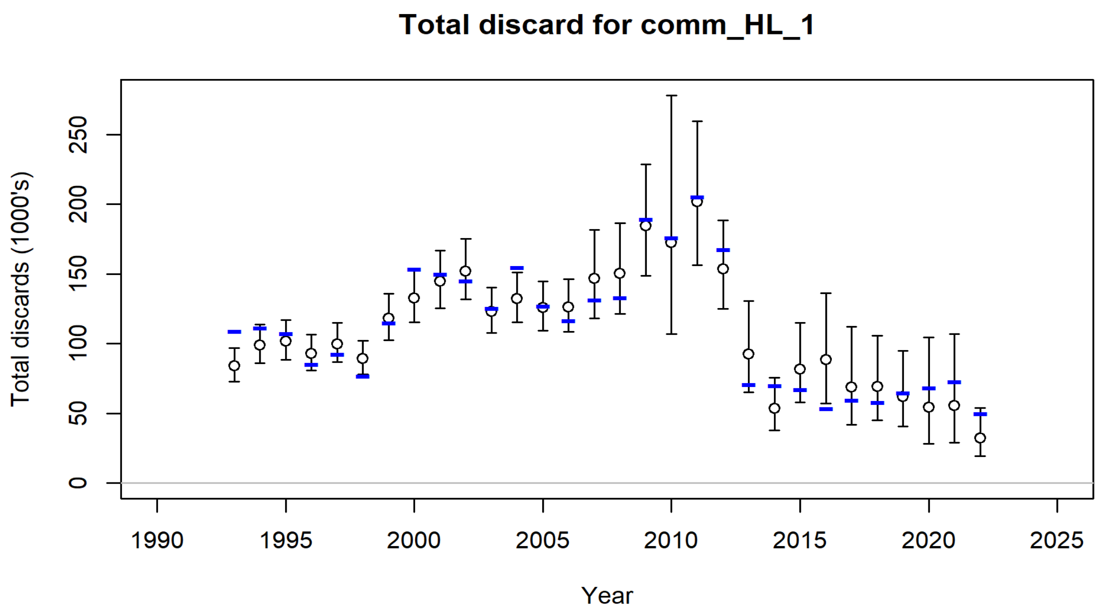


Figure 45. Input (dots with 95% confidence intervals) and expected (blue lines) discards by the Commercial Handline for Gulf of Mexico Red Grouper. Discards are in numbers of fish (1,000s) and reflect released fish (i.e., before discard mortality has been applied).

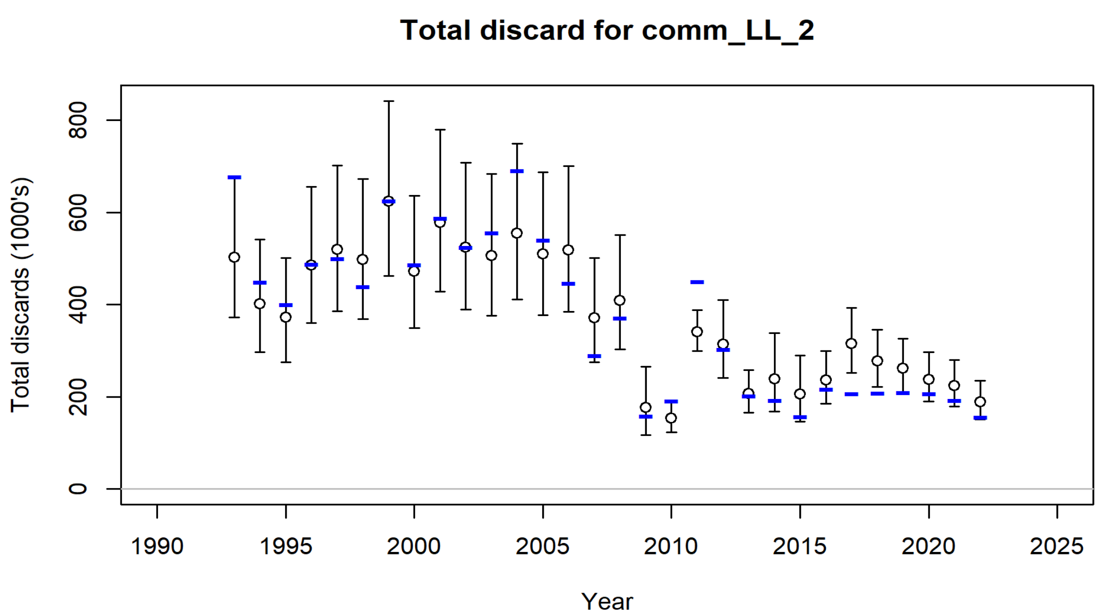


Figure 46. Input (dots with 95% confidence intervals) and expected (blue lines) discards by the Commercial Longline for Gulf of Mexico Red Grouper. Discards are in numbers of fish (1,000s) and reflect released fish (i.e., before discard mortality has been applied).

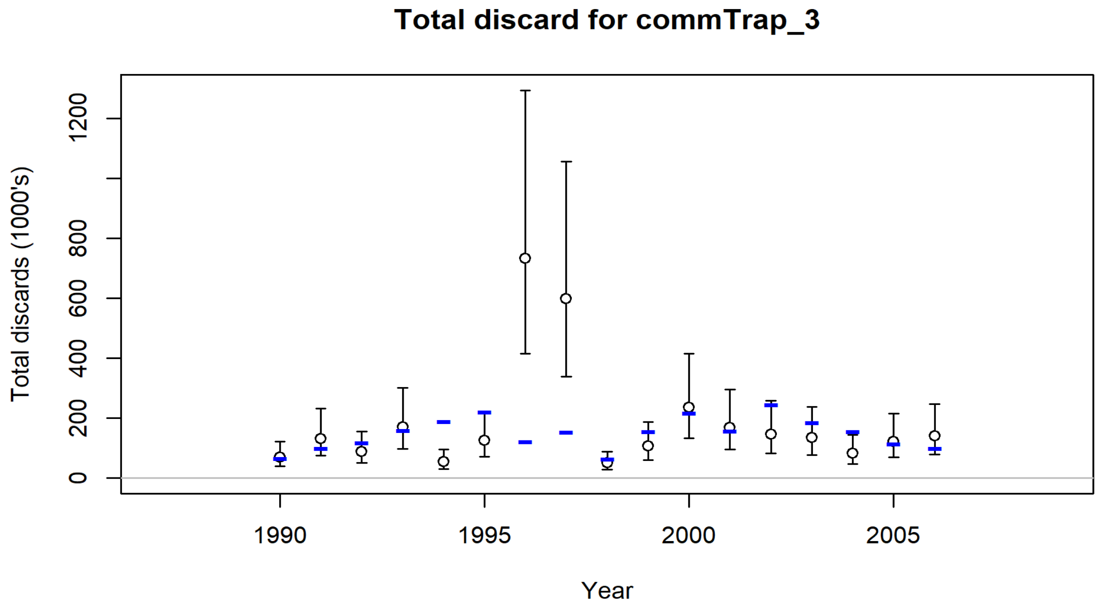


Figure 47. Input (dots with 95% confidence intervals) and expected (blue lines) discards by the Commercial Trap for Gulf of Mexico Red Grouper. Discards are in numbers of fish (1,000s) and reflect released fish (i.e., before discard mortality has been applied).

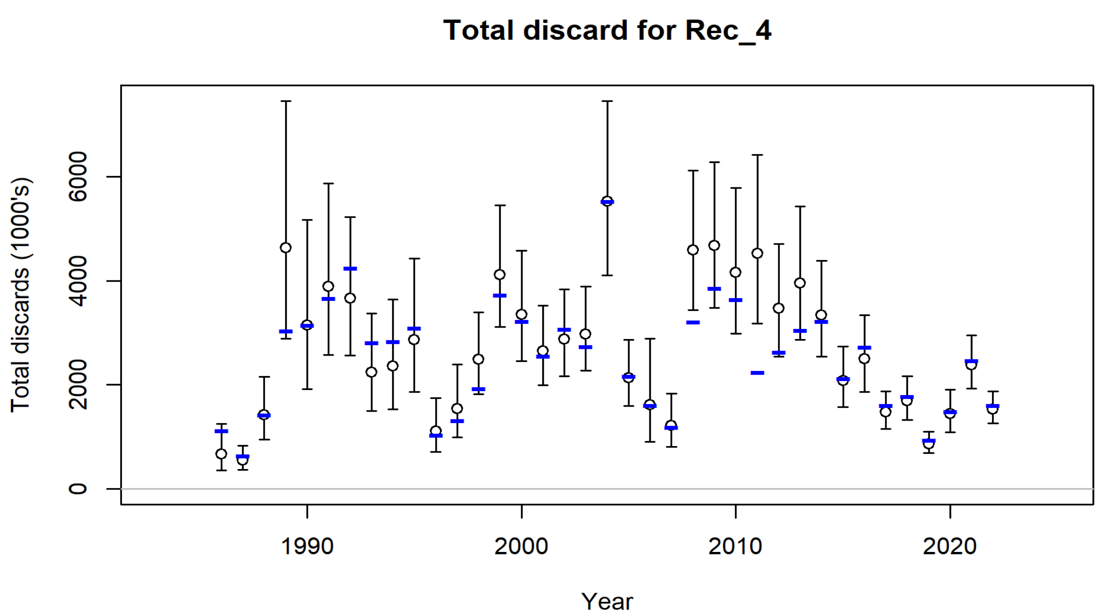


Figure 48. Input (dots with 95% confidence intervals) and expected (blue lines) discards by the Recreational for Gulf of Mexico Red Grouper. Discards are in numbers of fish (1,000s) and reflect released fish (i.e., before discard mortality has been applied).

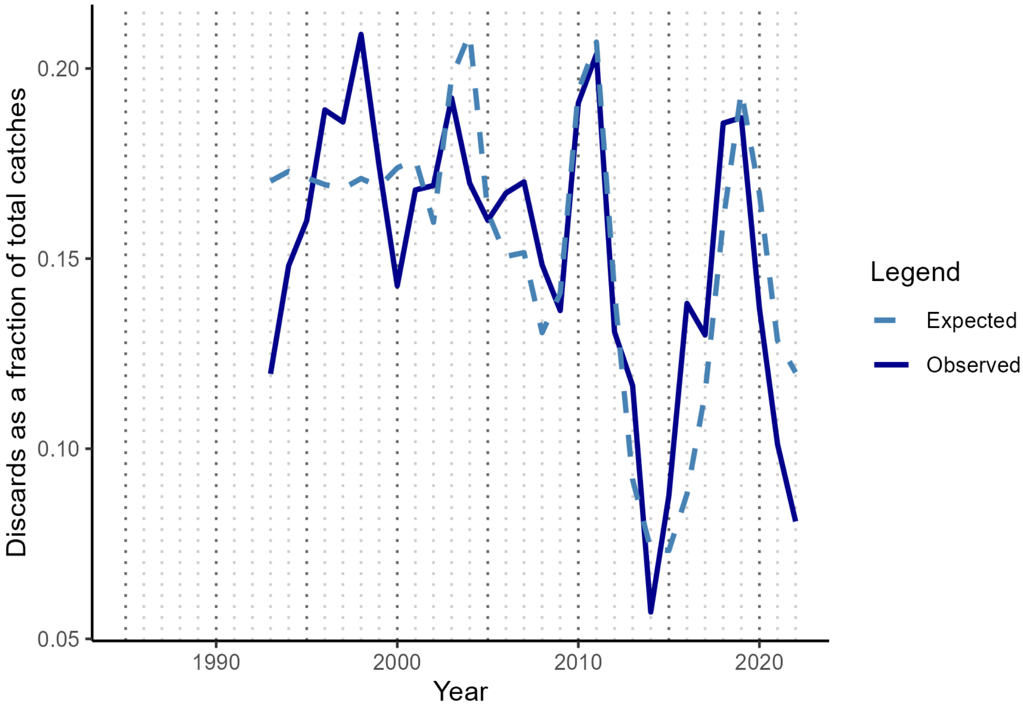


Figure 49. Observed and expected discard rates by the Commercial Handline fleet for Gulf of Mexico Red Grouper.

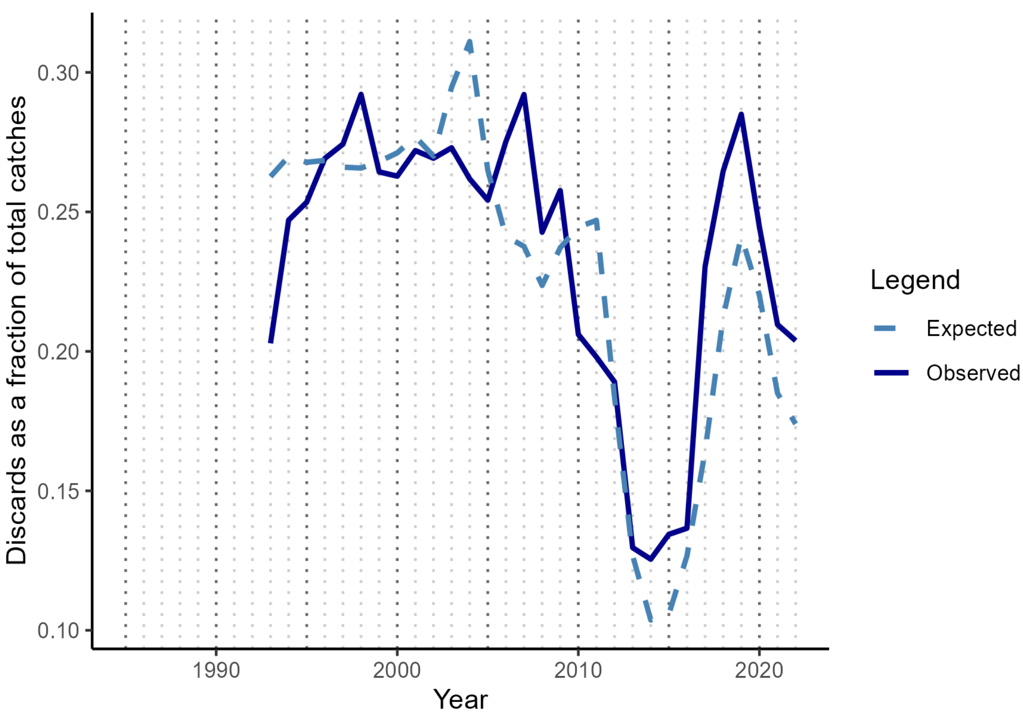


Figure 50. Observed and expected discard rates by the Commercial Longline fleet for Gulf of Mexico Red Grouper.

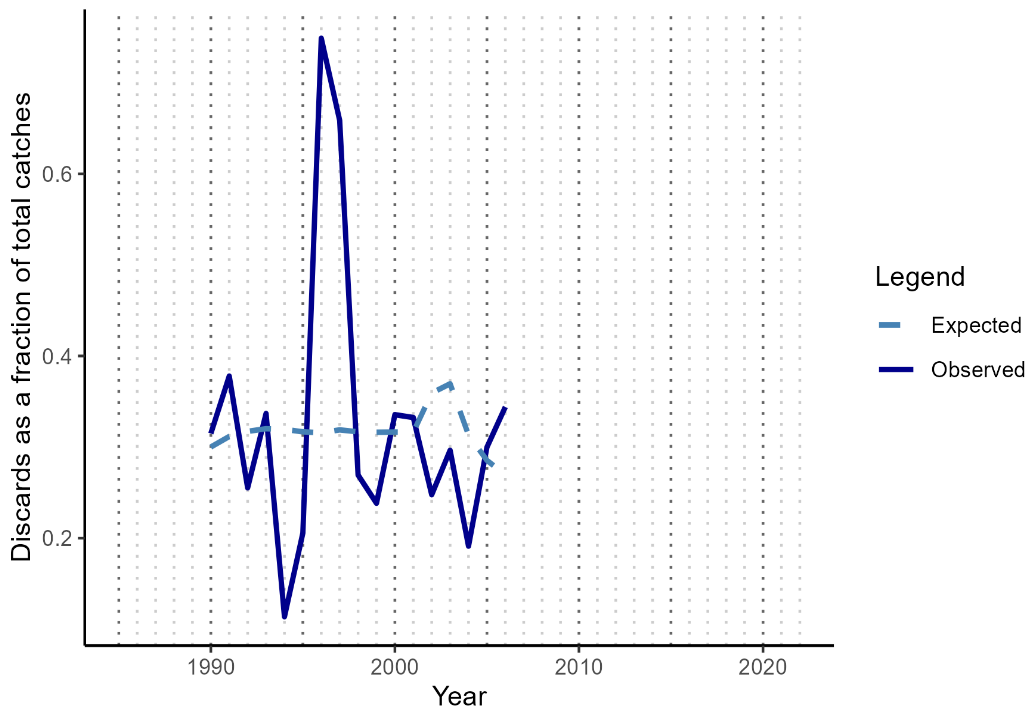


Figure 51. Observed and expected discard rates by the Commercial Trap fleet for Gulf of Mexico Red Grouper.

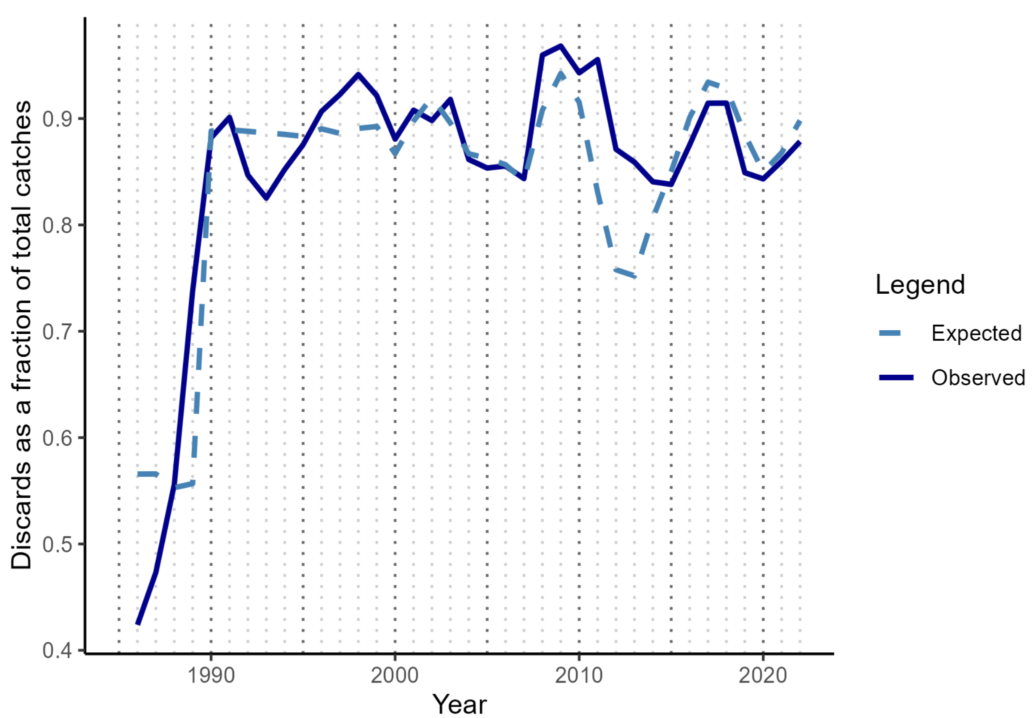


Figure 52. Observed and expected discard rates by the Recreational fleet for Gulf of Mexico Red Grouper.

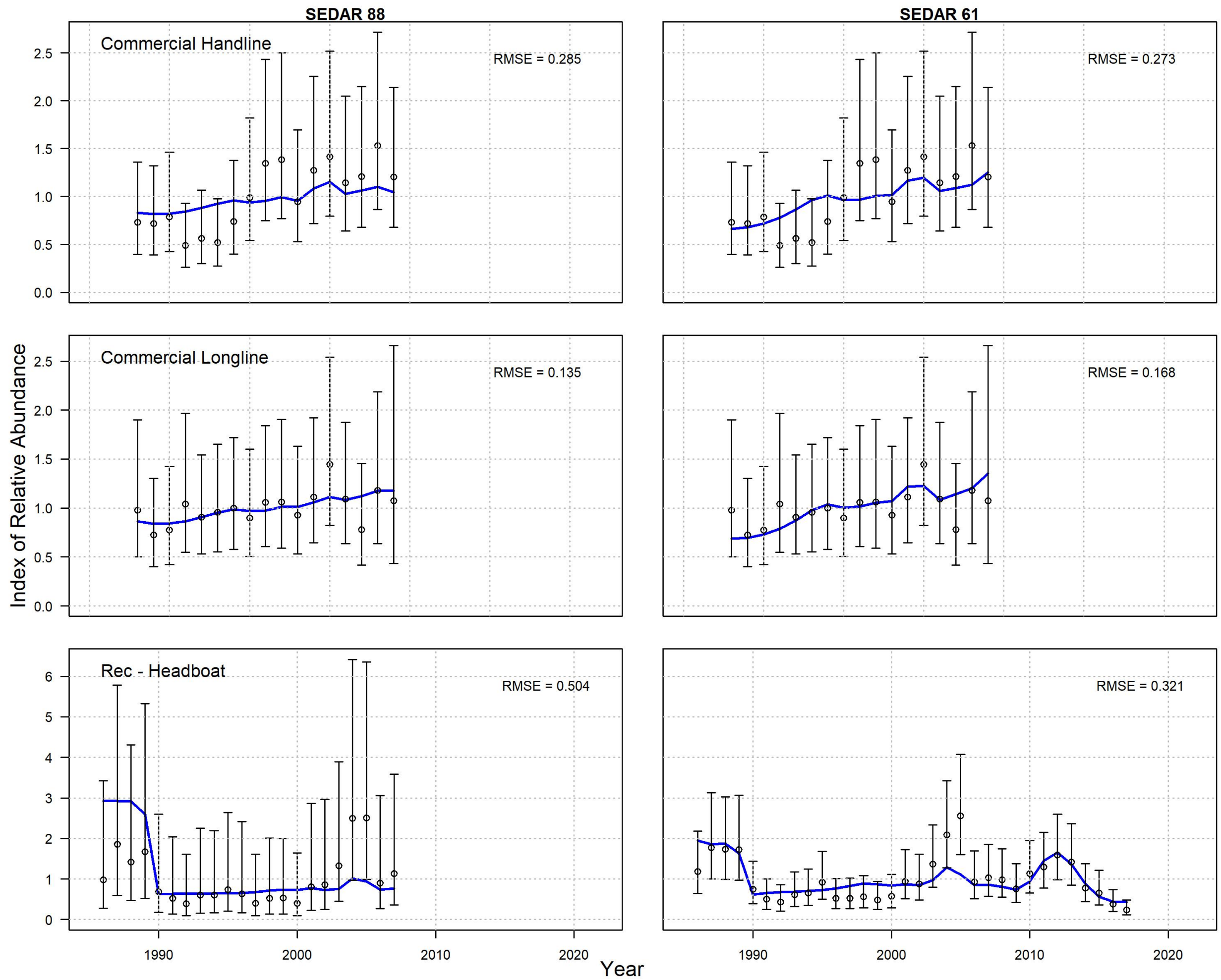


Figure 53. Gulf of Mexico Red Grouper observed and expected fishery dependent indices for SEDAR 88 (left panels) and SEDAR 61 (right panels). The root mean squared error (RMSE) is also provided.

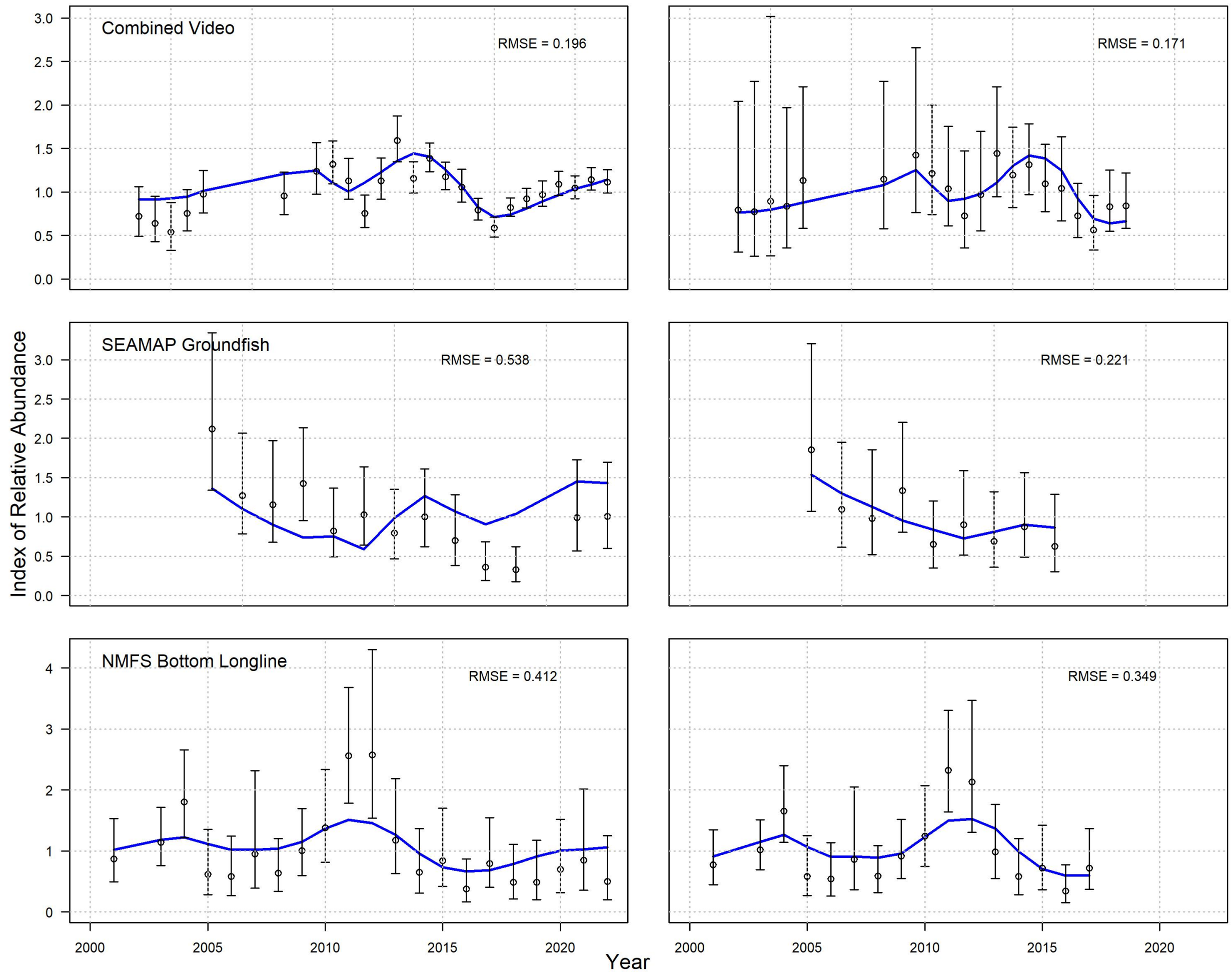


Figure 54. Gulf of Mexico Red Grouper observed and expected fishery independent indices for SEDAR 88 (left panels) and SEDAR 61 (right panels). The root mean squared error (RMSE) is also provided.

SEDAR 88

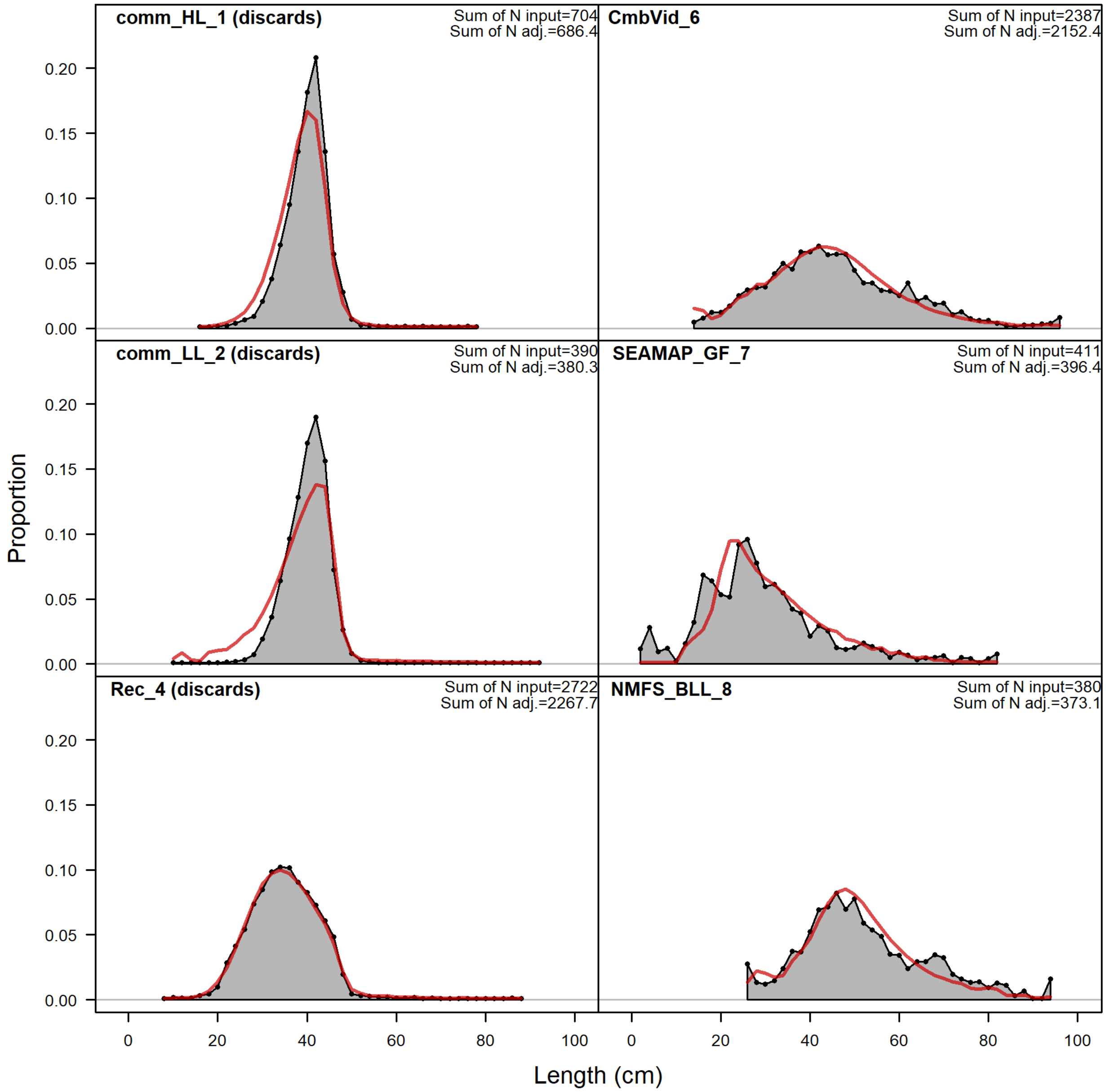


Figure 55. Model fits to the length composition of Red Grouper aggregated across years for SEDAR 88 and SEDAR 61. Red lines represent predicted length compositions, while grey shaded regions represent observed length compositions. For SEDAR 88, 'N input' is the input sample size (trips) and 'N adj.' is the sample size after adjustment by the Dirichlet-Multinomial parameter. For SEDAR 61, 'N adj.' is the input sample size as the square root of the number of length observations ('N eff.' was not used).

SEDAR 61

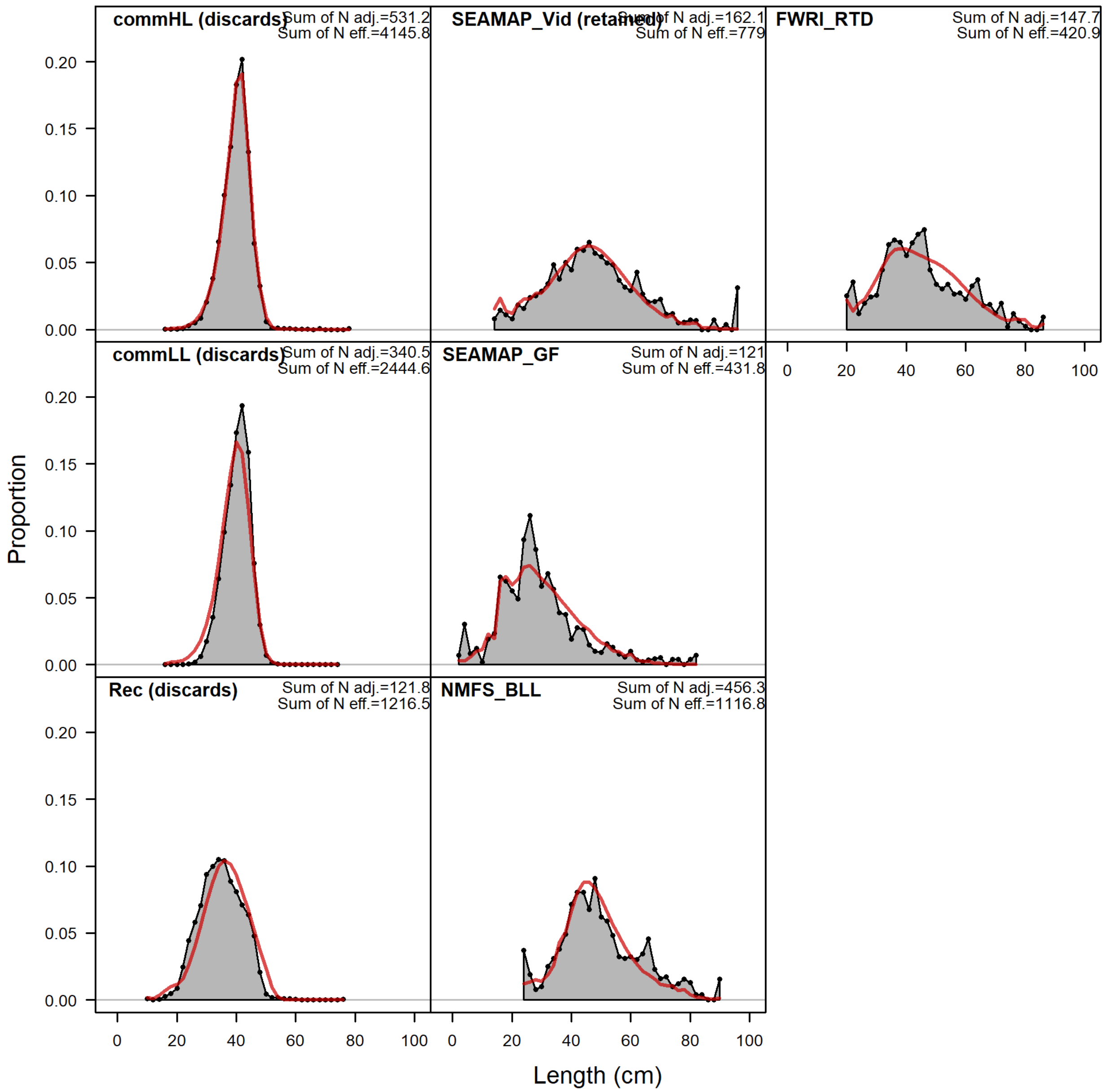


Figure 55 Continued. Model fits to the length composition of Red Grouper aggregated across years for SEDAR 88 and SEDAR 61. Red lines represent predicted length compositions, while grey shaded regions represent observed length compositions. For SEDAR 88, 'N input' is the input sample size (trips) and 'N adj.' is the sample size after adjustment by the Dirichlet-Multinomial parameter. For SEDAR 61, 'N adj.' is the input sample size as the square root of the number of length observations ('N eff.' was not used).

SEDAR 88

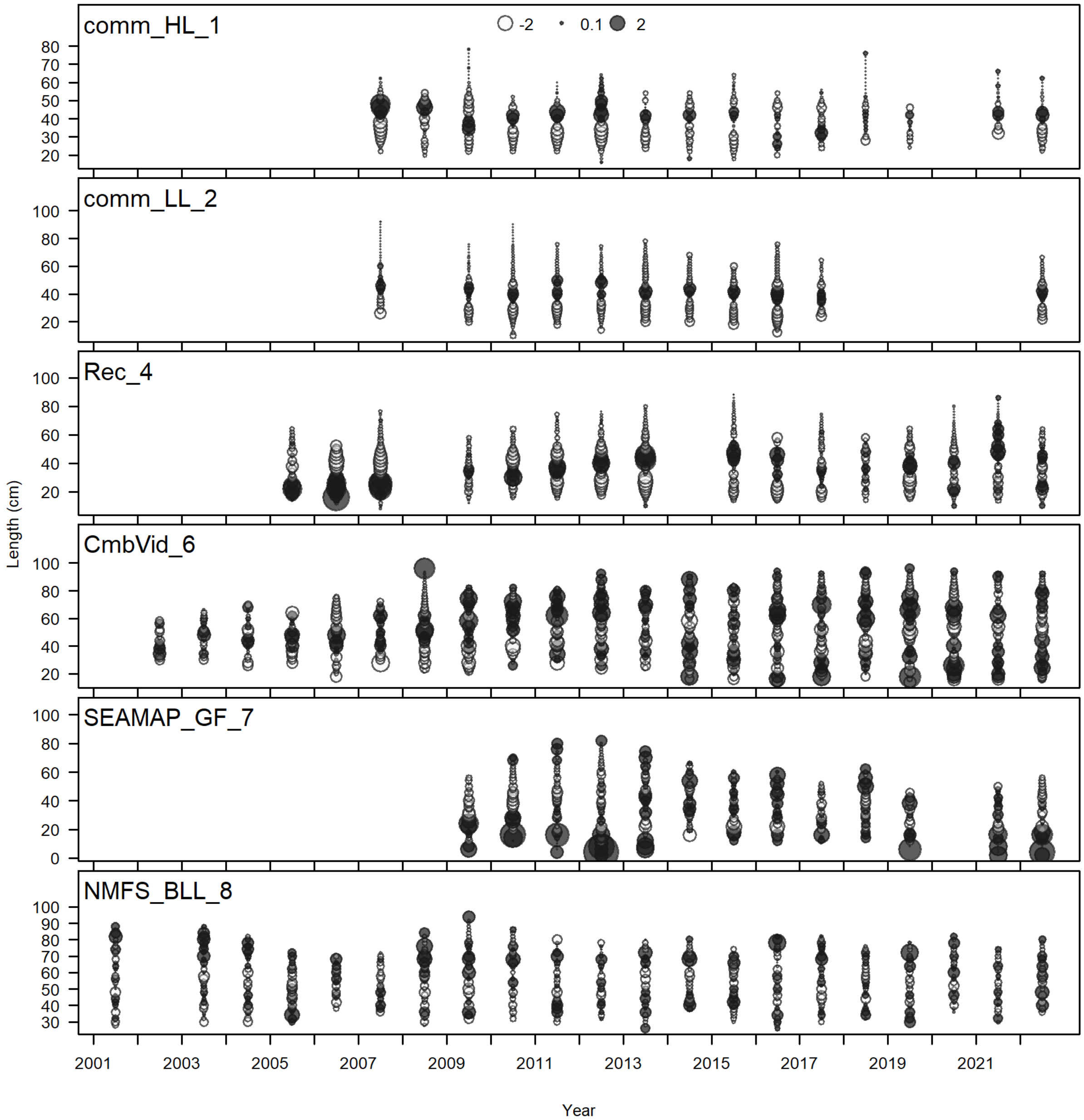


Figure 56. Model fits to the length composition of Red Grouper aggregated across years for SEDAR 88 and SEDAR 61. Red lines represent predicted length compositions, while grey shaded regions represent observed length compositions. For SEDAR 88, 'N input' is the input sample size (trips) and 'N adj.' is the sample size after adjustment by the Dirichlet-Multinomial parameter. For SEDAR 61, 'N adj.' is the input sample size as the square root of the number of length observations ('N eff.' was not used).

SEDAR 61

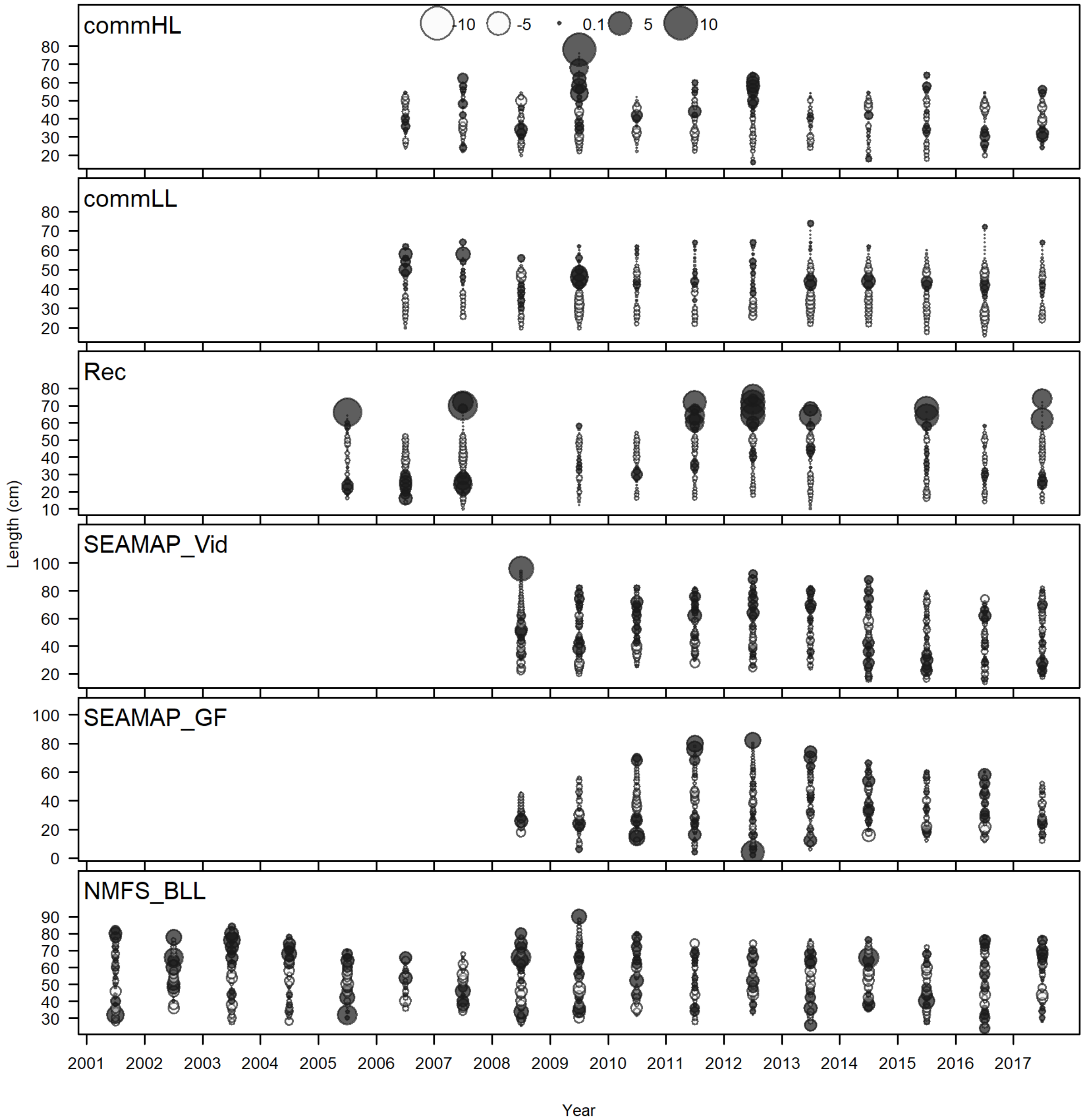
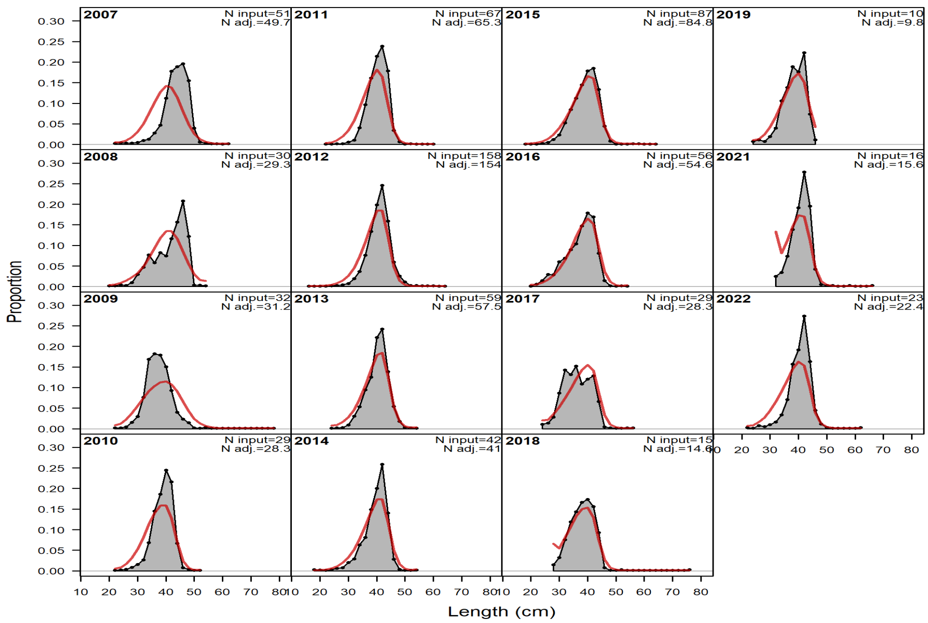


Figure 56 Continued. Model fits to the length composition of Red Grouper aggregated across years for SEDAR 88 and SEDAR 61. Red lines represent predicted length compositions, while grey shaded regions represent observed length compositions. For SEDAR 88, 'N input' is the input sample size (trips) and 'N adj.' is the sample size after adjustment by the Dirichlet-Multinomial parameter. For SEDAR 61, 'N adj.' is the input sample size as the square root of the number of length observations ('N eff.' was not used).

SEDAR 88



SEDAR 61

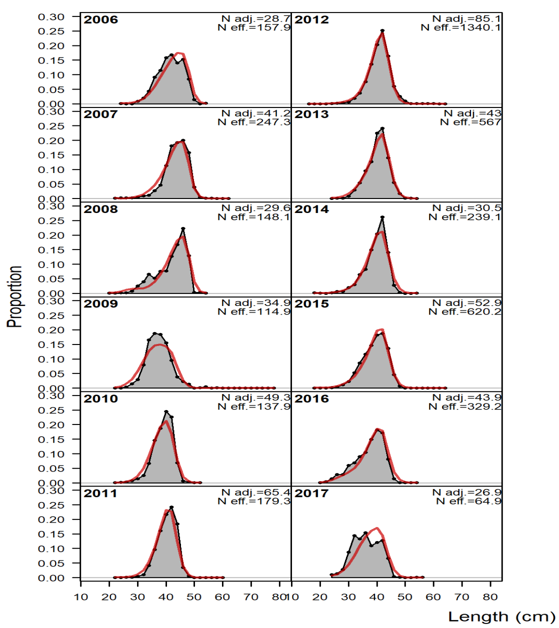
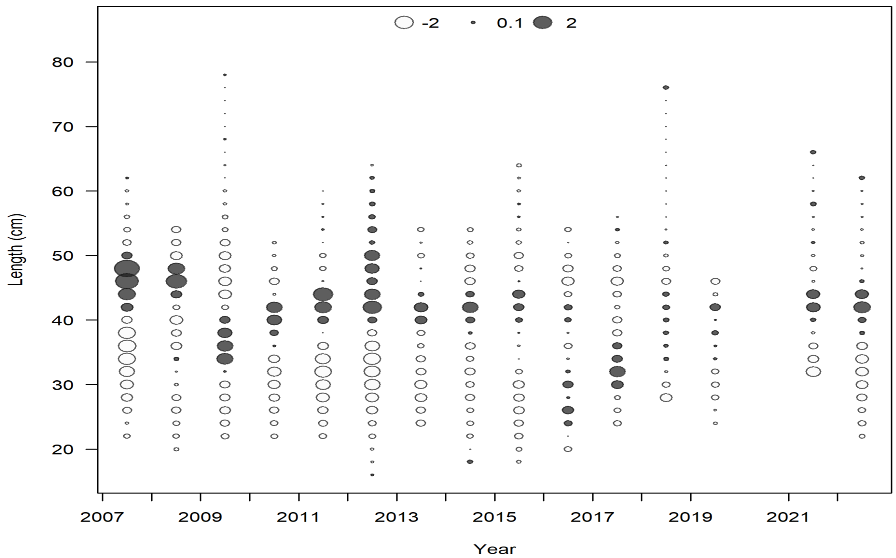


Figure 57. Observed and predicted length compositions for Gulf of Mexico Red Grouper in the Commercial Handline fishery for SEDAR 88 and SEDAR 61. Red lines represent predicted length compositions, while grey shaded regions represent observed length compositions. For SEDAR 88, 'N input' is the input sample size (trips) and 'N adj.' is the sample size after adjustment by the Dirichlet-Multinomial parameter. For SEDAR 61, 'N adj.' is the input sample size as the square root of the number of length observations ('N eff.' was not used).

SEDAR 88



SEDAR 61

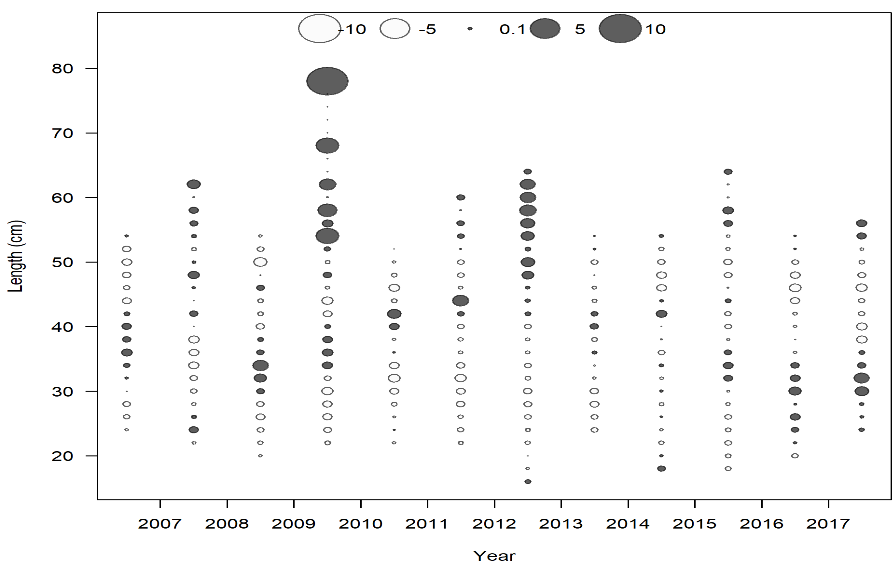
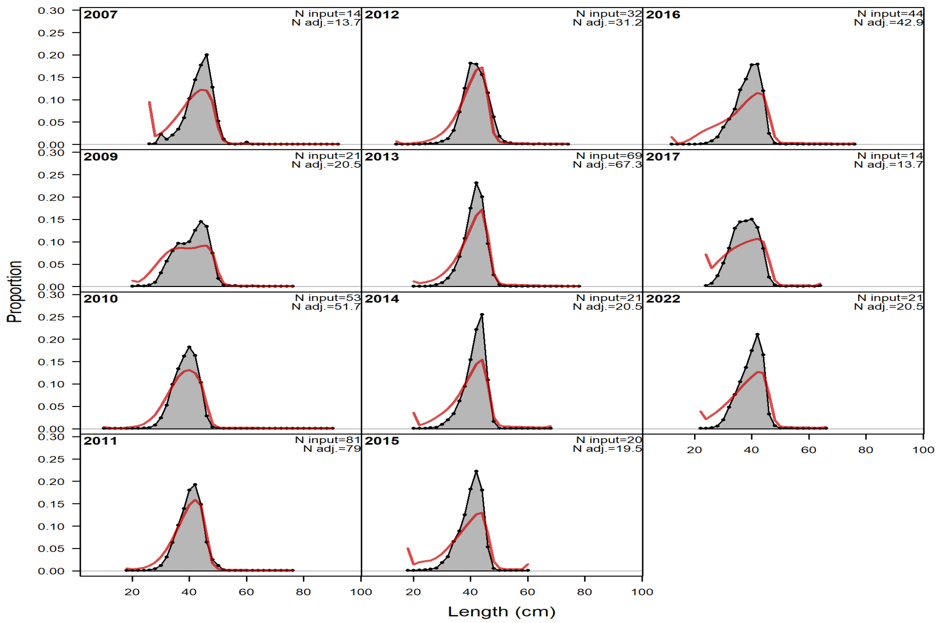


Figure 58. Pearson residuals for length compositions of Gulf of Mexico Red Grouper by the Commercial Handline fishery for SEDAR 88 (upper panel) and SEDAR 61 (lower panel). Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected).

SEDAR 88



SEDAR 61

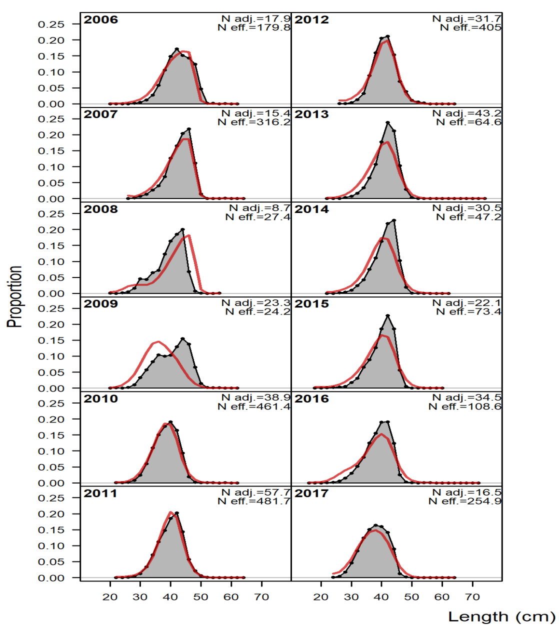
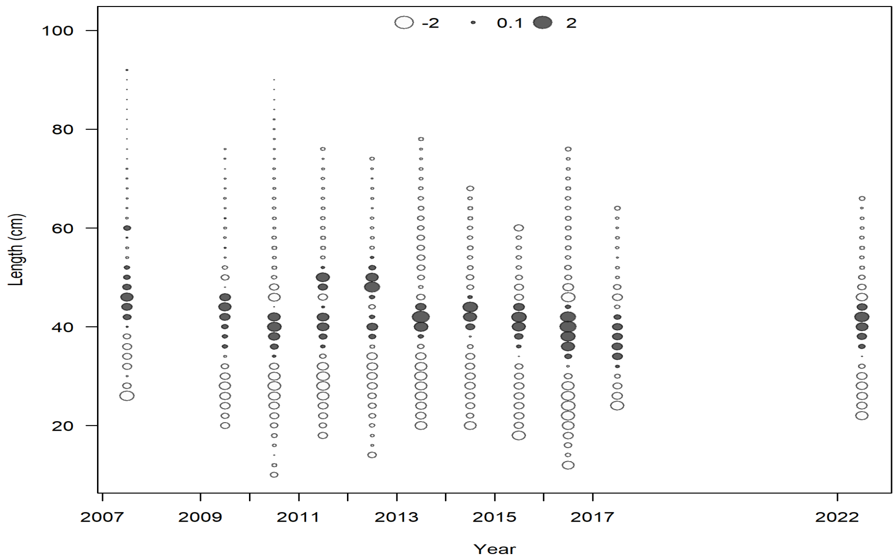


Figure 59. Observed and predicted length compositions for Gulf of Mexico Red Grouper in the Commercial Longline fishery for SEDAR 88 and SEDAR 61. Red lines represent predicted length compositions, while grey shaded regions represent observed length compositions. For SEDAR 88, 'N input' is the input sample size (trips) and 'N adj.' is the sample size after adjustment by the Dirichlet-Multinomial parameter. For SEDAR 61, 'N adj.' is the input sample size as the square root of the number of length observations ('N eff.' was not used).

SEDAR 88



SEDAR 61

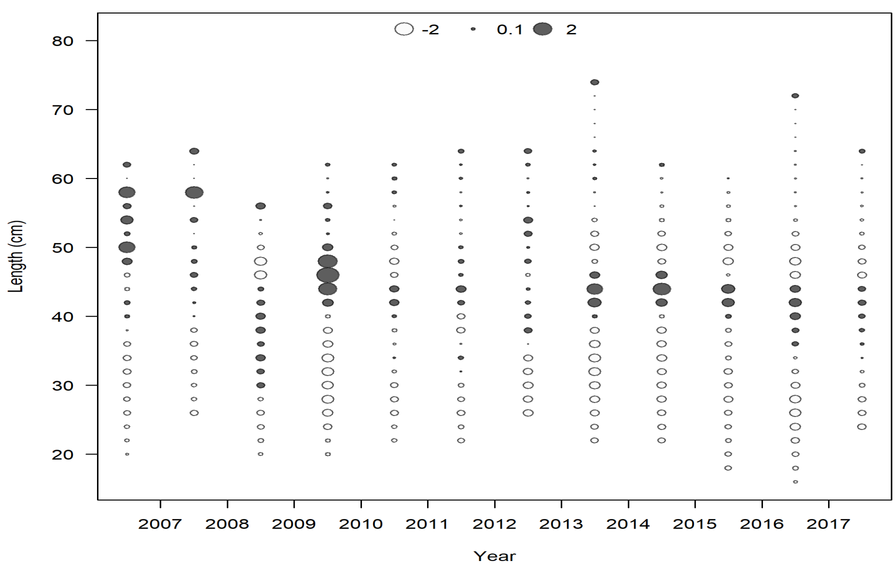
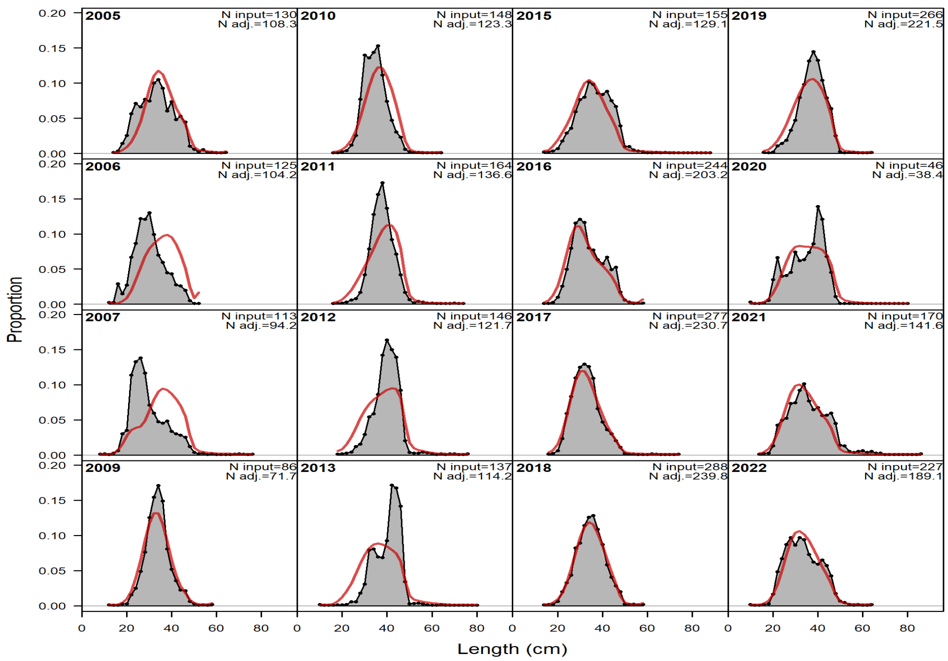


Figure 60. Pearson residuals for length compositions of Gulf of Mexico Red Grouper by the Commercial Longline fishery for SEDAR 88 (upper panel) and SEDAR 61 (lower panel). Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected).

SEDAR 88



SEDAR 61

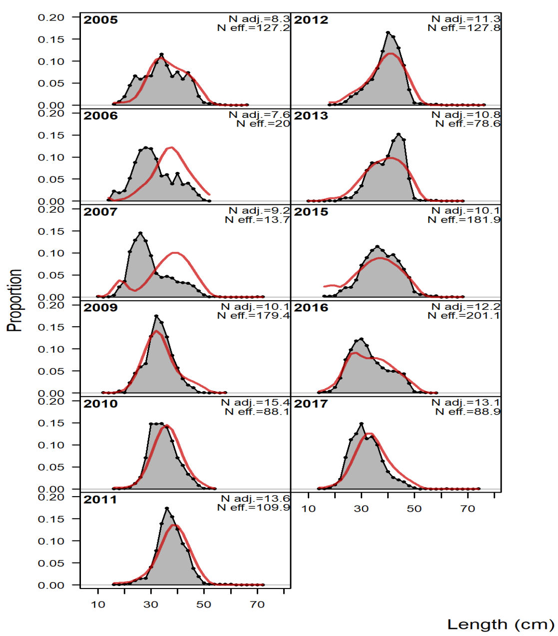
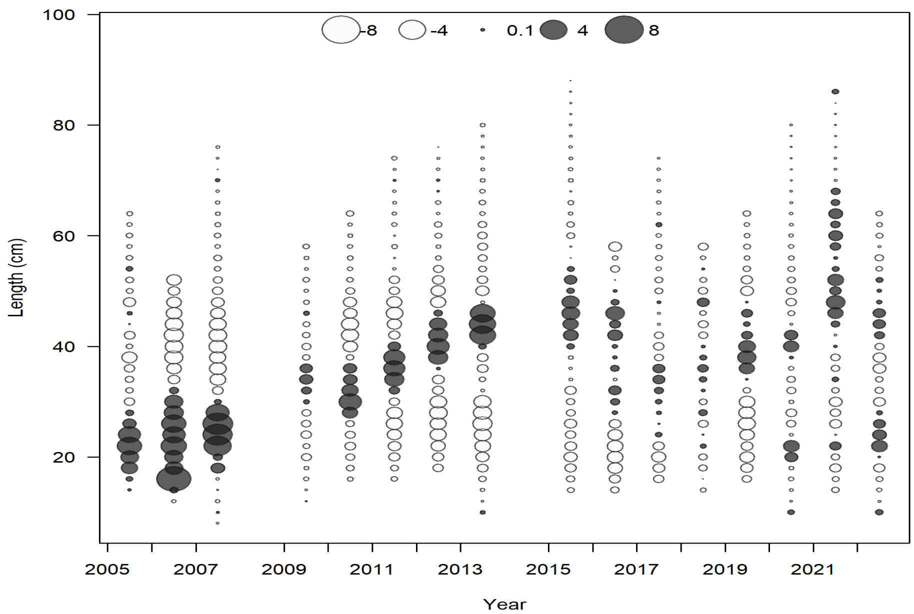


Figure 61. Observed and predicted length compositions for Gulf of Mexico Red Grouper in the Recreational fishery for SEDAR 88 and SEDAR 61. Red lines represent predicted length compositions , while grey shaded regions represent observed length compositions. For SEDAR 88, 'N input' is the input sample size (trips) and 'N adj.' is the sample size after adjustment by the Dirichlet-Multinomial parameter. For SEDAR 61, 'N adj.' is the input sample size as the square root of the number of length observations ('N eff.' was not used).

SEDAR 88



SEDAR 61

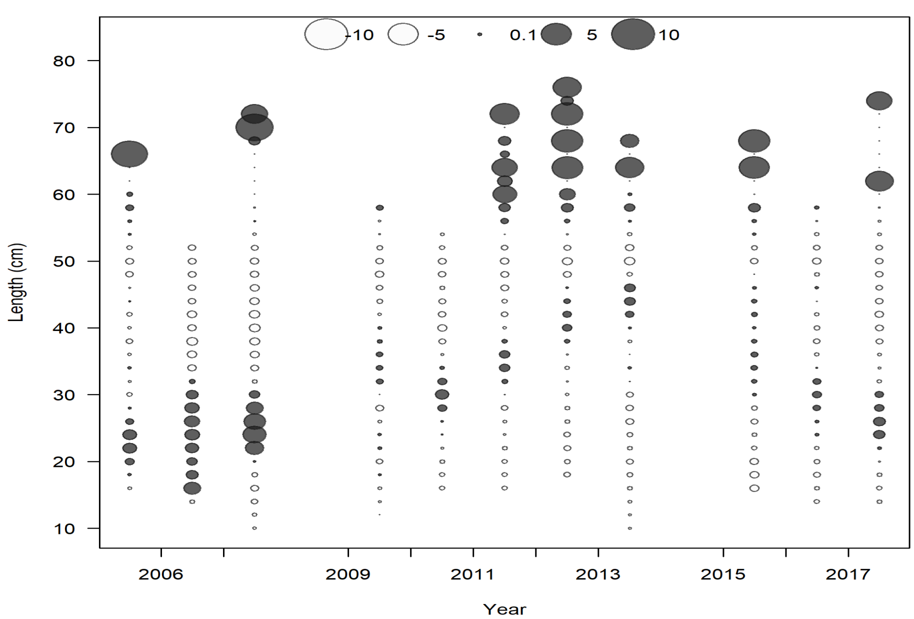
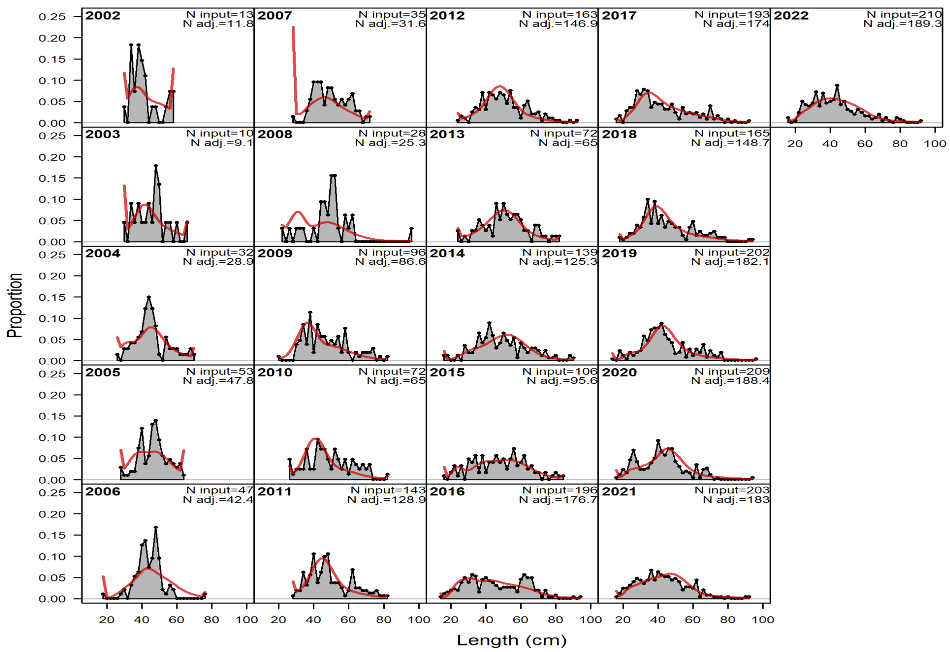


Figure 62. Pearson residuals for length compositions of Gulf of Mexico Red Grouper by the Recreational fishery for SEDAR 88 (upper panel) and SEDAR 61 (lower panel). Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected).

SEDAR 88



SEDAR 61

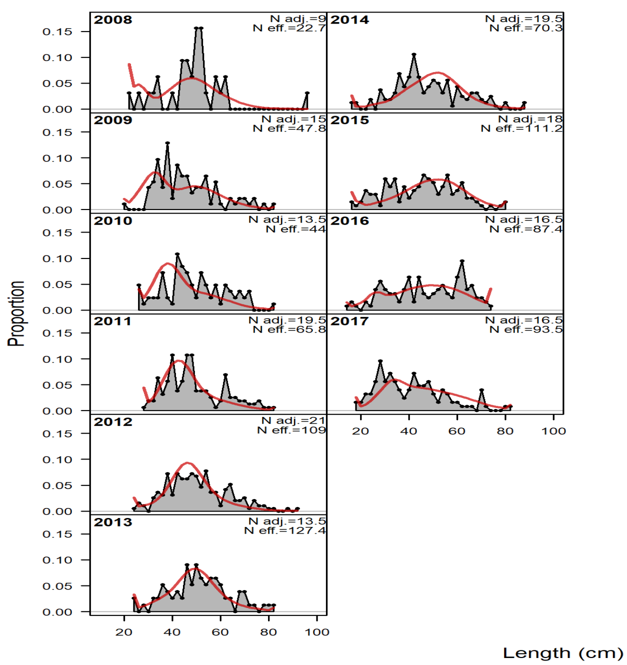
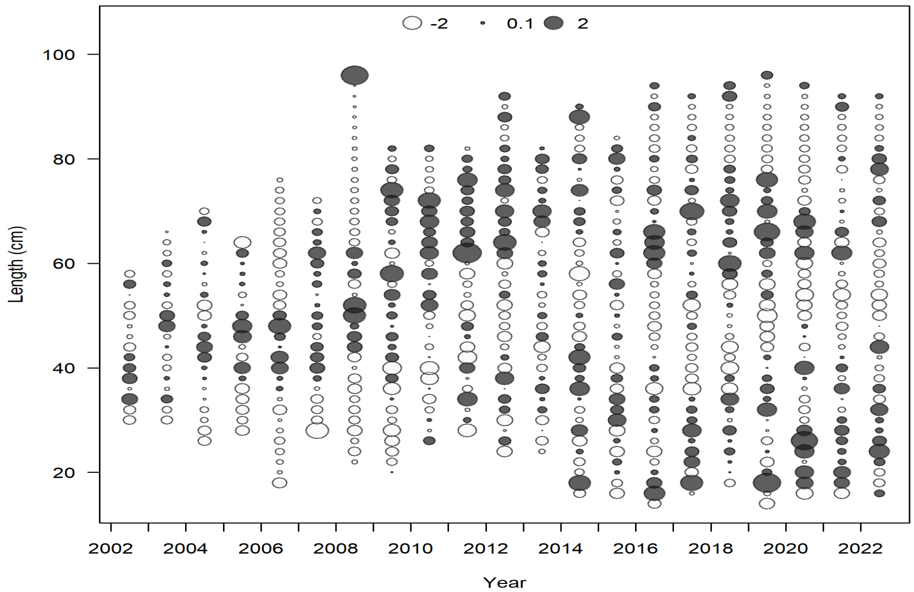


Figure 63. Observed and predicted length compositions for Gulf of Mexico Red Grouper caught in the Combined Video Survey for SEDAR 88 and SEDAR 61. Red lines represent predicted length compositions, while grey shaded regions represent observed length compositions. For SEDAR 88, 'N input' is the input sample size (trips) and 'N adj.' is the sample size after adjustment by the Dirichlet-Multinomial parameter. For SEDAR 61, 'N adj.' is the input sample size as the square root of the number of length observations ('N eff.' was not used).

SEDAR 88



SEDAR 61

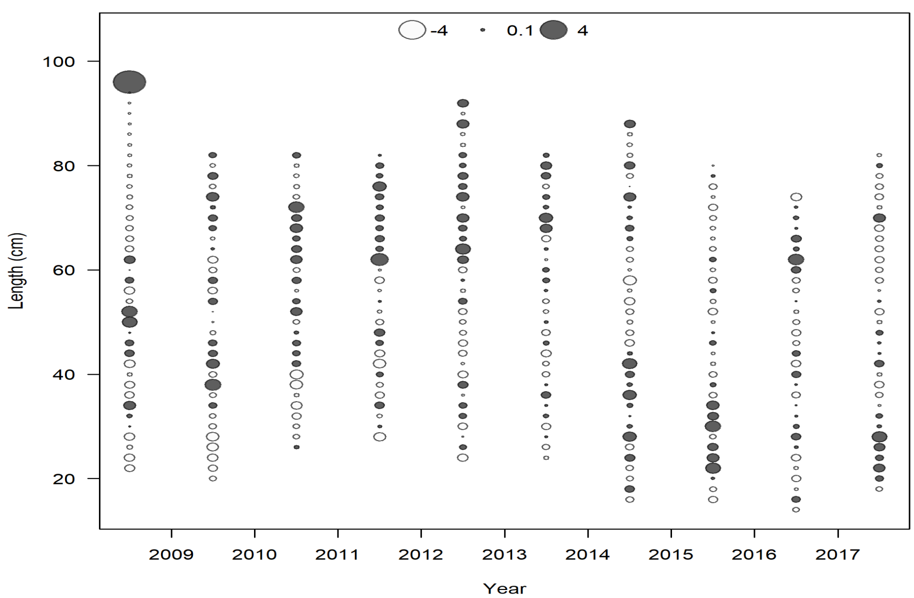
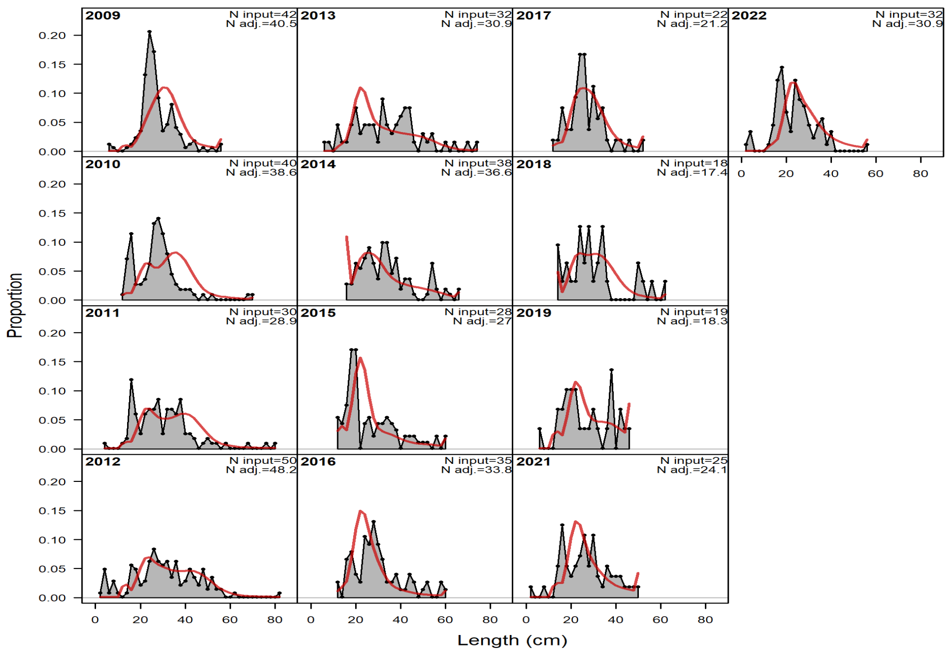


Figure 64. Pearson residuals for length compositions of Gulf of Mexico Red Grouper caught by the Combined Video Survey for SEDAR 88 (upper panel) and SEDAR 61 (lower panel). Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected).

SEDAR 88



SEDAR 61

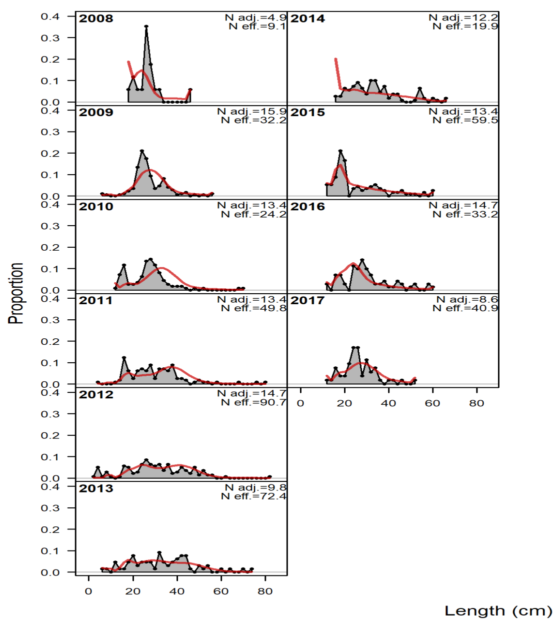
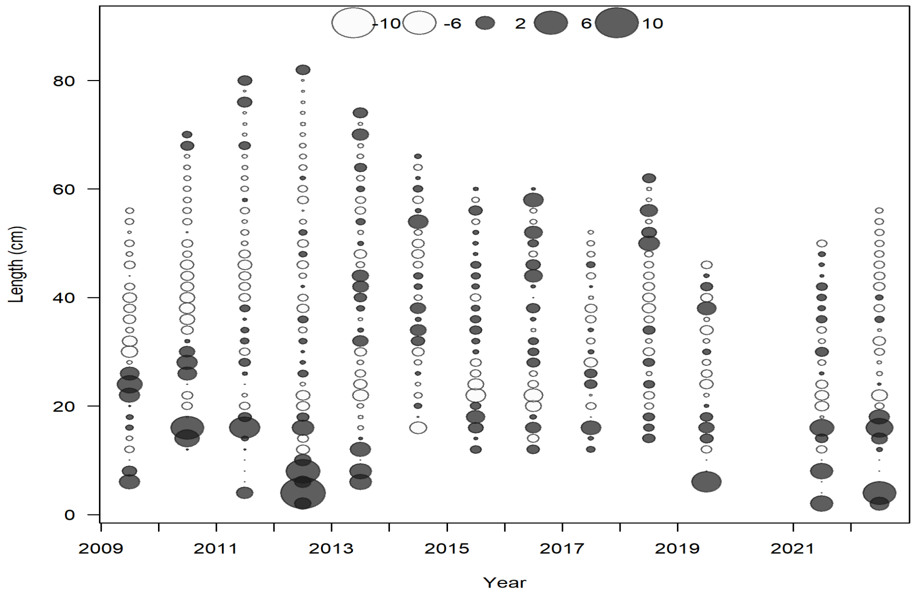


Figure 65. Observed and predicted length compositions for Gulf of Mexico Red Grouper caught in the SEAMAP Summer Groundfish Survey for SEDAR 88 and SEDAR 61. Red lines represent predicted length compositions, while grey shaded regions represent observed length compositions. For SEDAR 88, 'N input' is the input sample size (number of length observations) and 'N adj.' is the sample size after adjustment by the Dirichlet-Multinomial parameter. For SEDAR 61, 'N adj.' is the input sample size as the square root of the number of length observations ('N eff.' was not used).

SEDAR 88



SEDAR 61

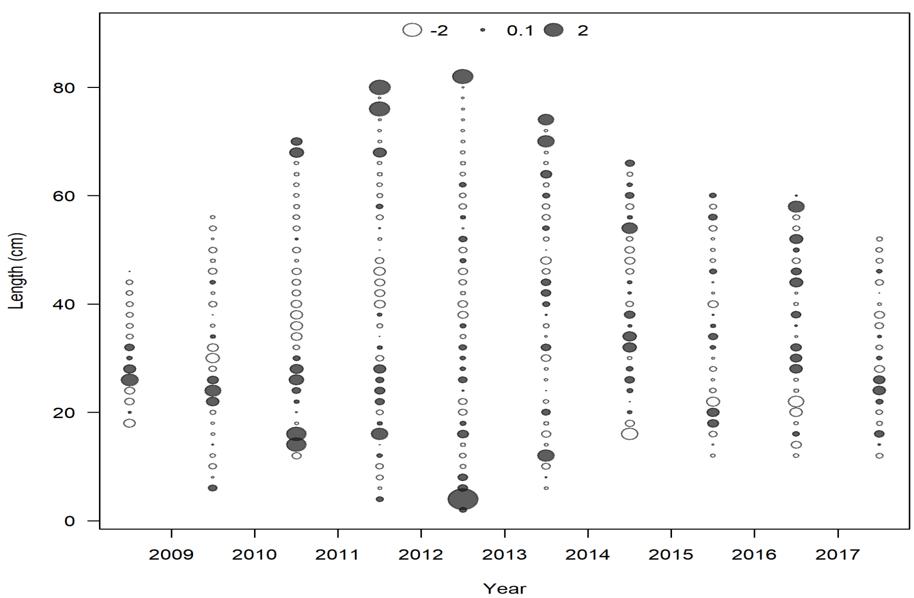
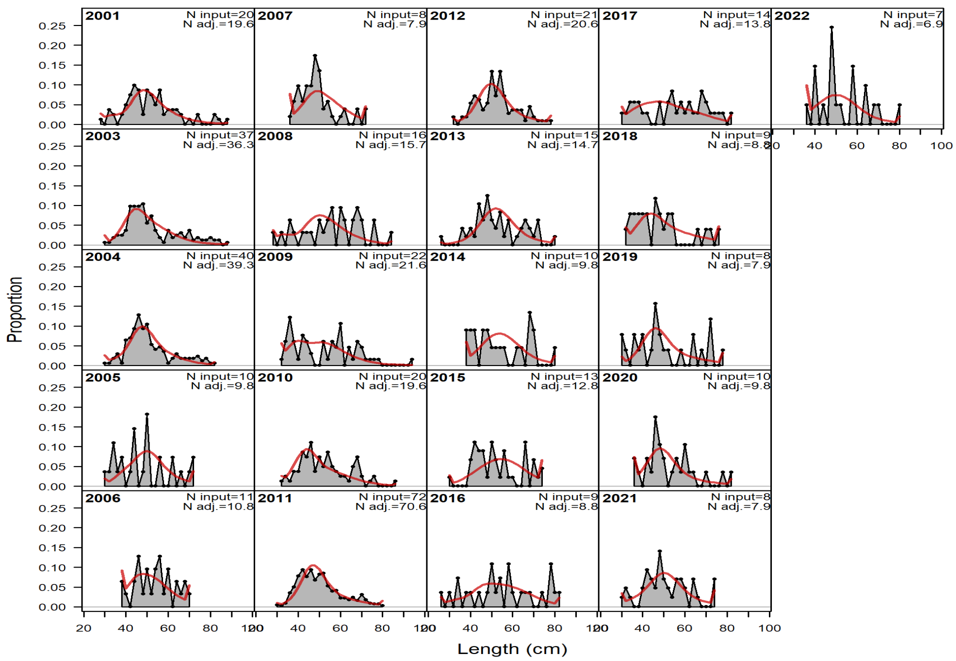


Figure 66. Pearson residuals for length compositions of Gulf of Mexico Red Grouper caught by the SEAMAP Summer Groundfish Survey for SEDAR 88 (upper panel) and SEDAR 61 (lower panel). Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected).

SEDAR 88



SEDAR 61

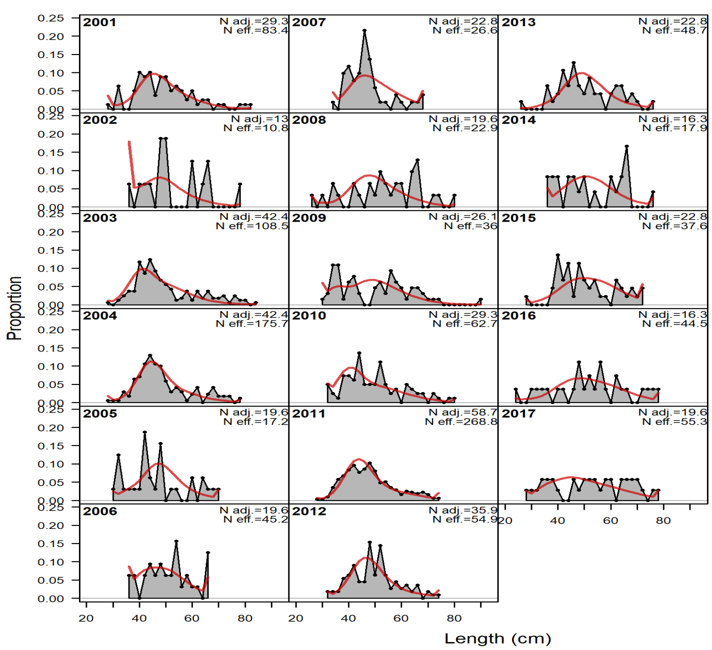
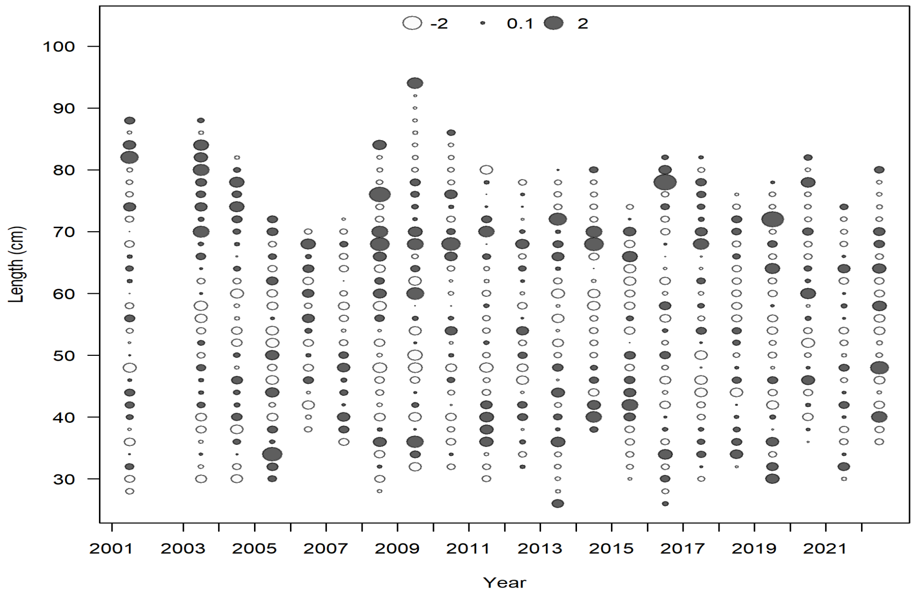


Figure 67. Observed and predicted length compositions for Gulf of Mexico Red Grouper caught in the NMFS Bottom Longline for SEDAR 88 and SEDAR 61. Red lines represent predicted length compositions, while grey shaded regions represent observed length compositions. For SEDAR 88, 'N input' is the input sample size (trips) and 'N adj.' is the sample size after adjustment by the Dirichlet-Multinomial parameter. For SEDAR 61, 'N adj.' is the input sample size as the square root of the number of length observations ('N eff.' was not used).

SEDAR 88



SEDAR 61

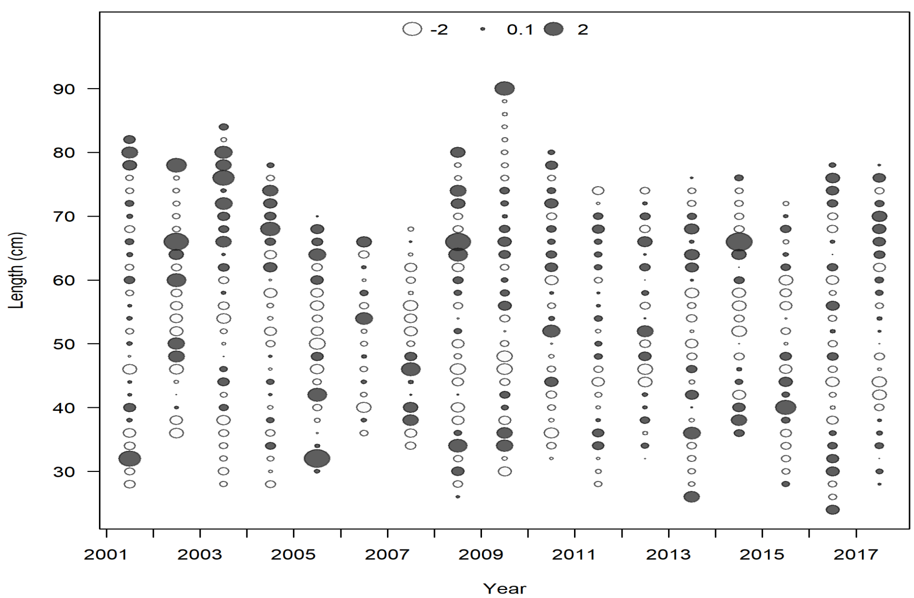
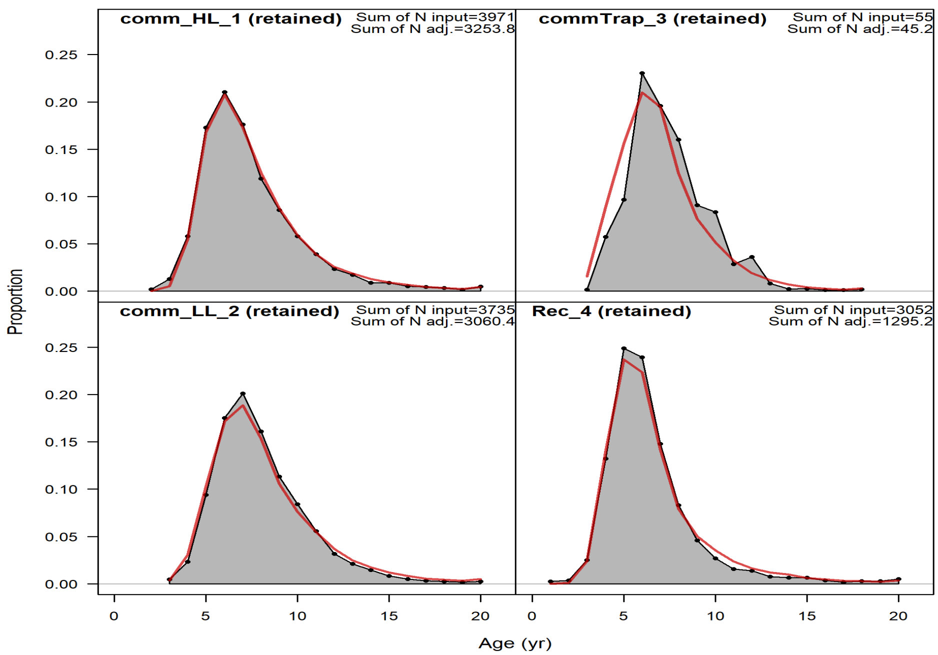


Figure 68. Pearson residuals for length compositions of Gulf of Mexico Red Grouper caught by the NMFS Bottom Longline for SEDAR 88 (upper panel) and SEDAR 61 (lower panel). Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected).

SEDAR 88



SEDAR 61

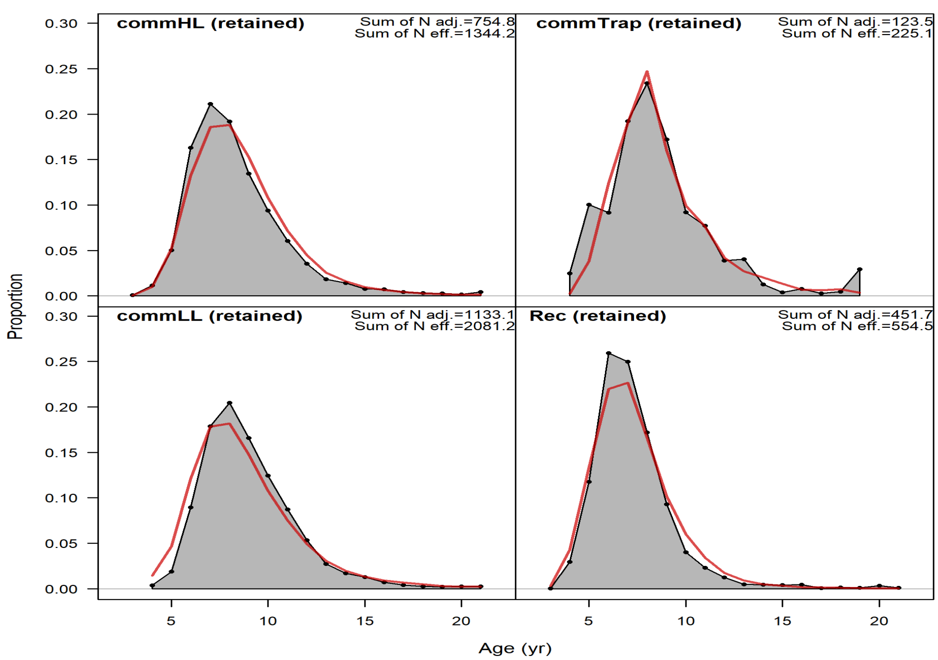
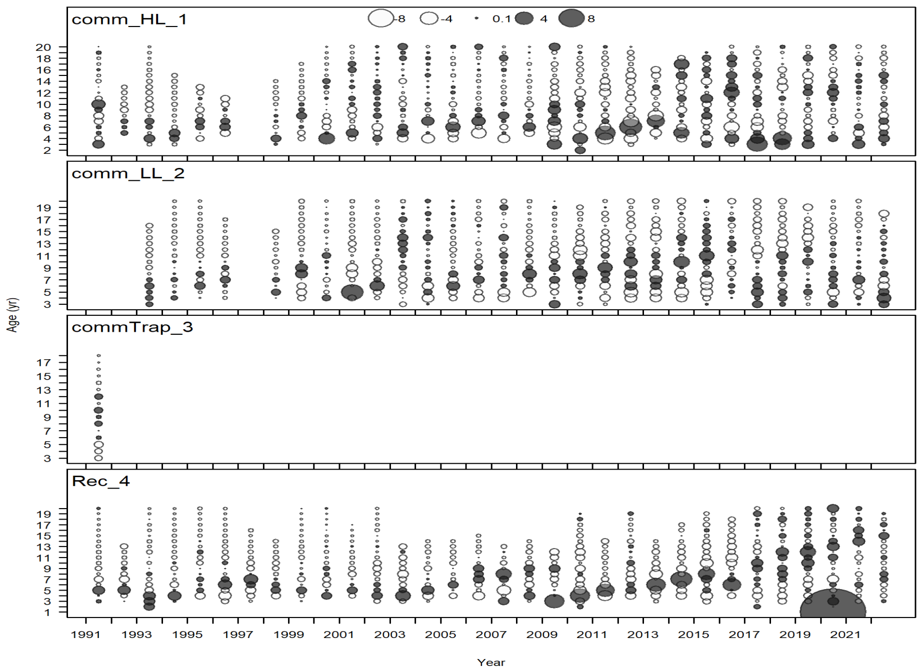


Figure 69. Model fits to the age composition of Red Grouper aggregated across years. Red lines represent predicted age compositions, while grey shaded regions represent observed age compositions. 'N input' is the input sample size (trips) and 'N adj.' is the sample size after adjustment by the Dirichlet-Multinomial parameter. For SEDAR 61, 'N adj.' is the input sample size as number of ages ('N eff.' was not used).

SEDAR 88



SEDAR 61

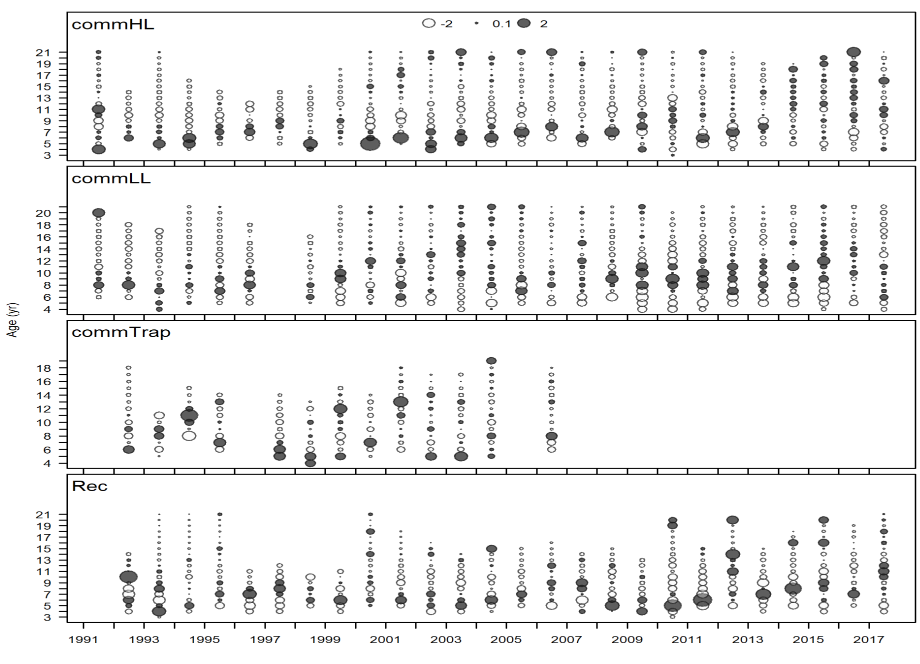


Figure 70. Model fits to the age composition of Red Grouper aggregated across years for SEDAR 88 and SEDAR 61. Red lines represent predicted age compositions, while grey shaded regions represent observed age compositions. For SEDAR 88, 'N input' is the input sample size (trips) and 'N adj.' is the sample size after adjustment by the Dirichlet-Multinomial parameter. For SEDAR 61, 'N adj.' is the input sample size as number of ages ('N eff.' was not used).

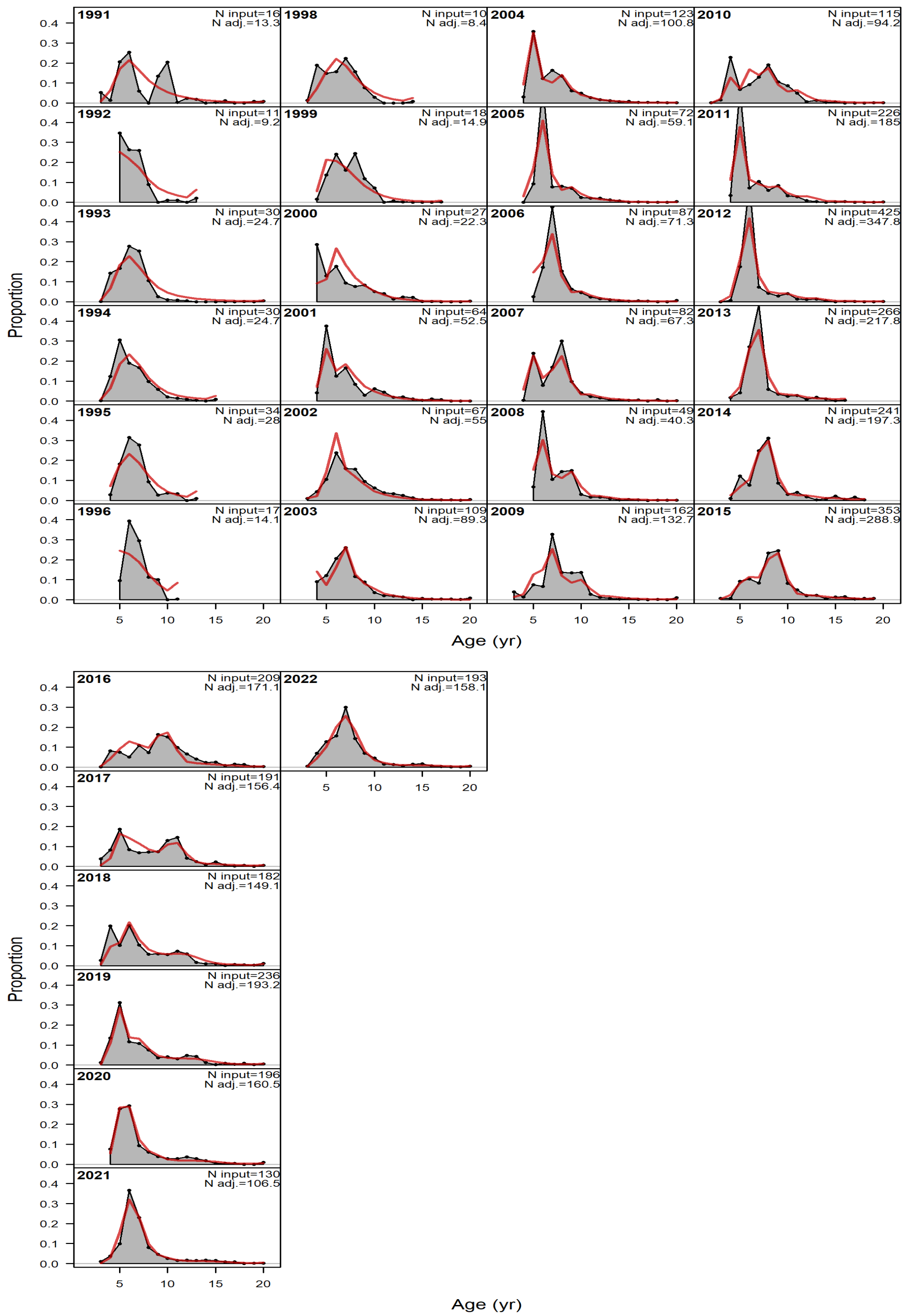


Figure 71. Observed and expected age compositions for Gulf of Mexico Red Grouper landed by the Commercial Handline fleet for SEDAR 88. Red lines represent expected age compositions, while grey shaded regions represent observed age compositions. Input sample sizes (N input, number of ages) and adjusted sample sizes (N adj) estimated by Stock Synthesis are also reported.

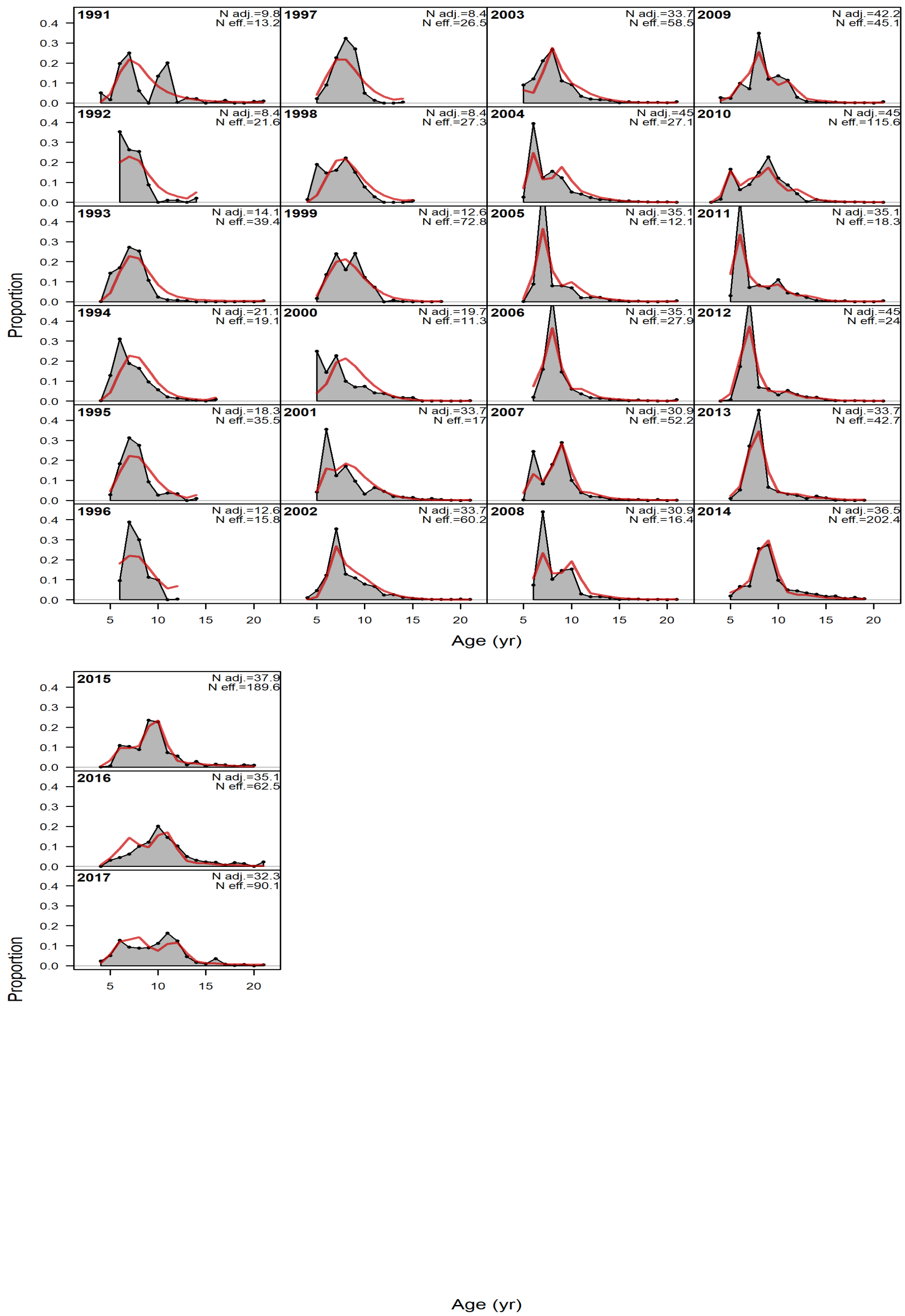
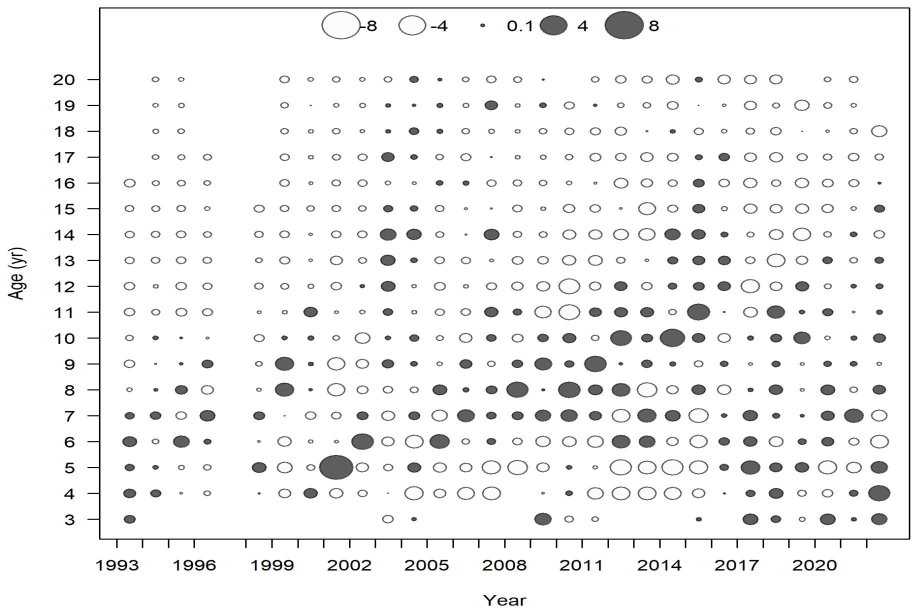


Figure 72. Observed and expected age compositions for Gulf of Mexico Red Grouper landed by the Commercial Handline fleet for SEDAR 61. Red lines represent expected age compositions, while grey shaded regions represent observed age compositions. Input sample sizes (N input, number of ages) and adjusted sample sizes (N adj) estimated by Stock Synthesis are also reported.

SEDAR 88



SEDAR 61

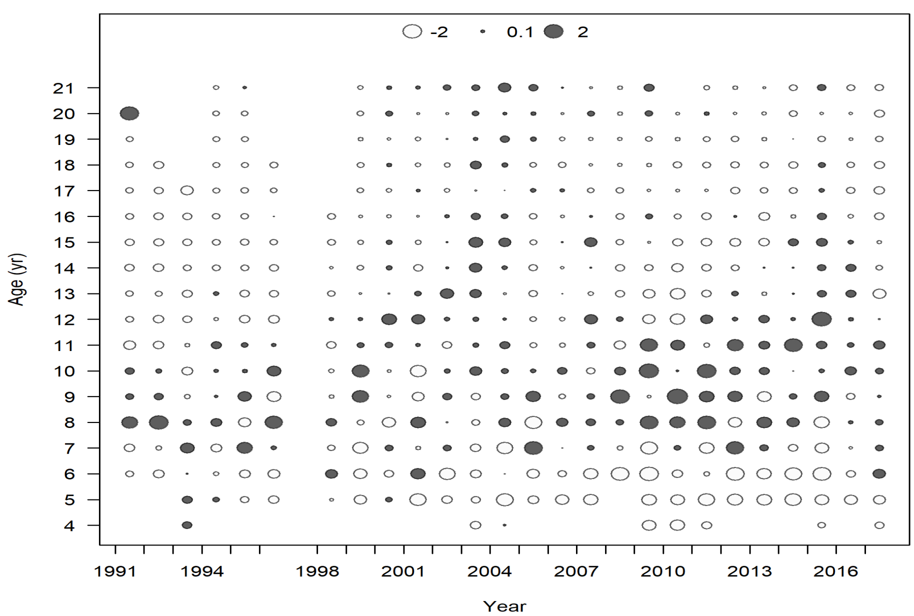
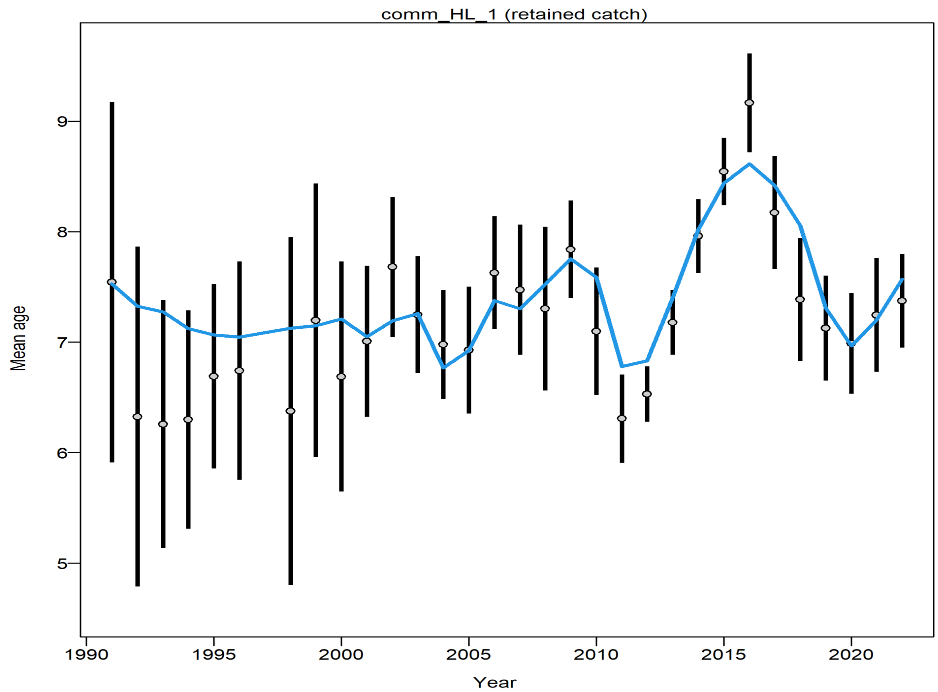


Figure 73. Pearson residuals for age compositions of Gulf of Mexico Red Grouper landed by the Commercial Handline fleet. Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected).

SEDAR 88



SEDAR 61

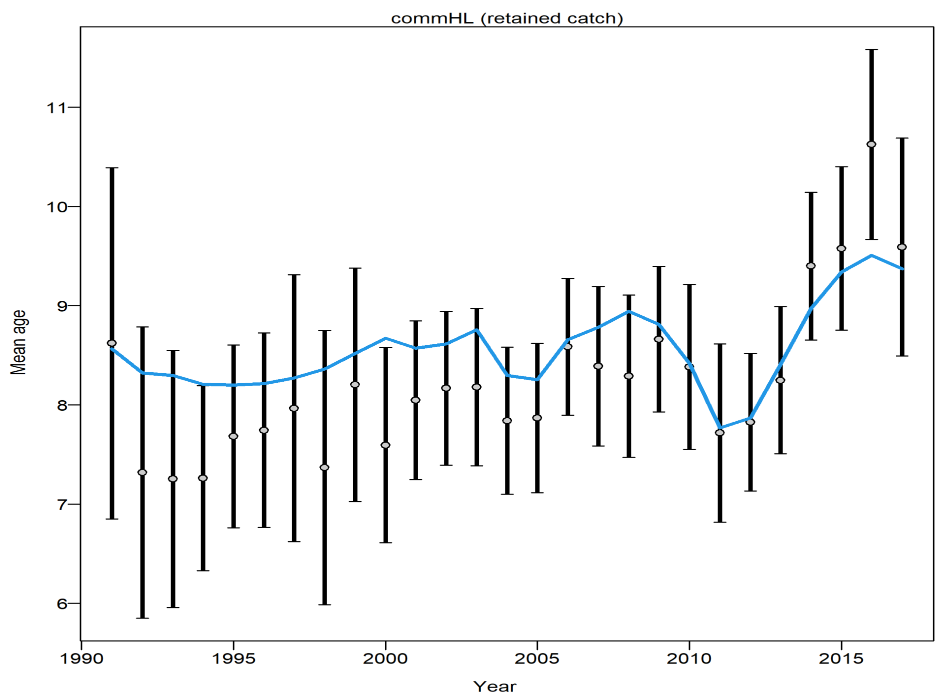


Figure 74. Mean age of Gulf of Mexico Red Grouper landed by the Commercial Handline fleet with 95% confidence intervals (thick bars) based on current sample sizes (including any Dirichlet Multinomial weighting).

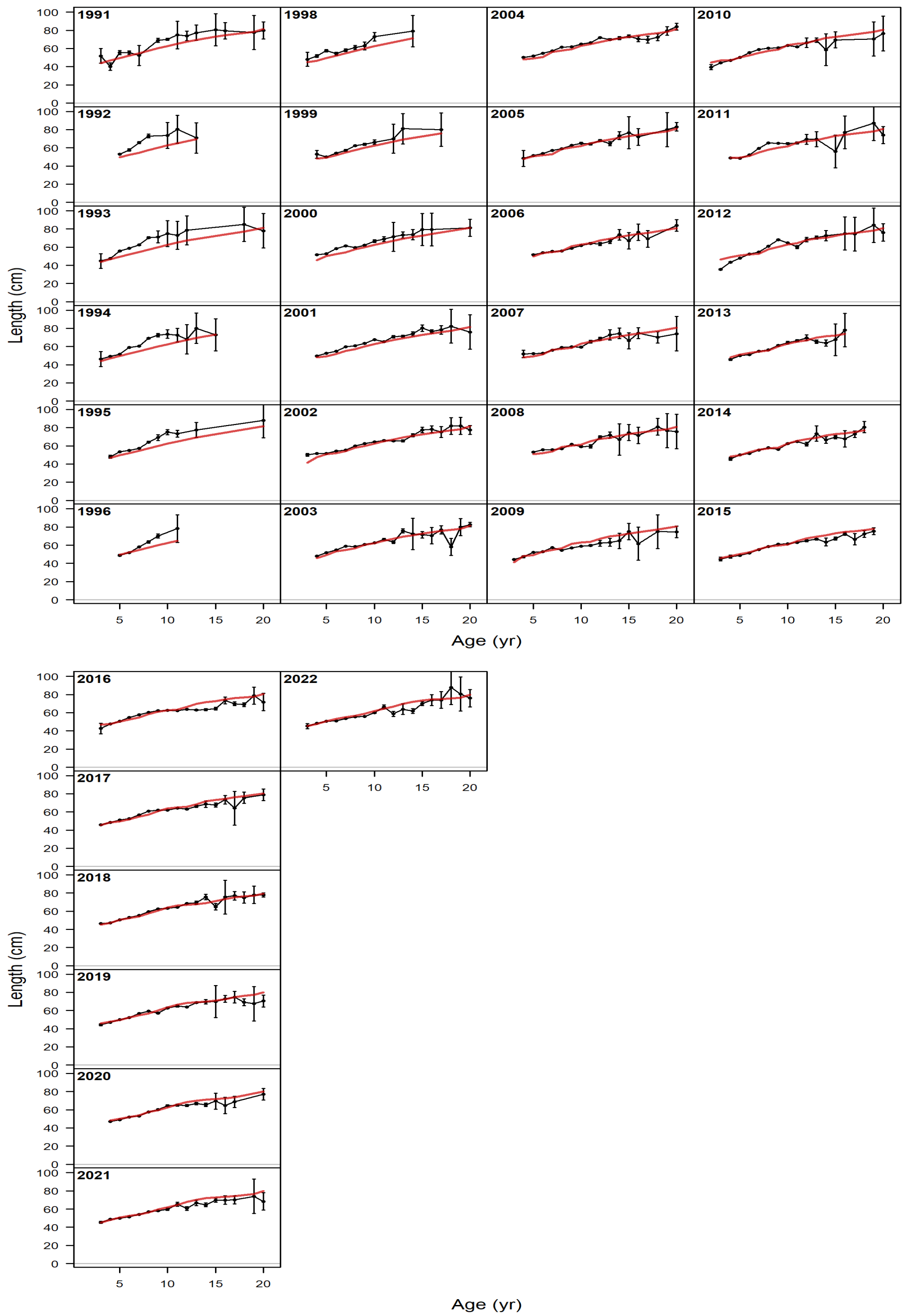


Figure 75. Observed and expected mean length-at-age for Gulf of Mexico Red Grouper landed by the Commercial Handline fleet. Red lines represent expected mean length-at-age, while solid lines with vertical bars represent observed mean length-at-age with error bars. Mean length-at-age is provided for comparison of trends and were included in the likelihood with a very low lambda.

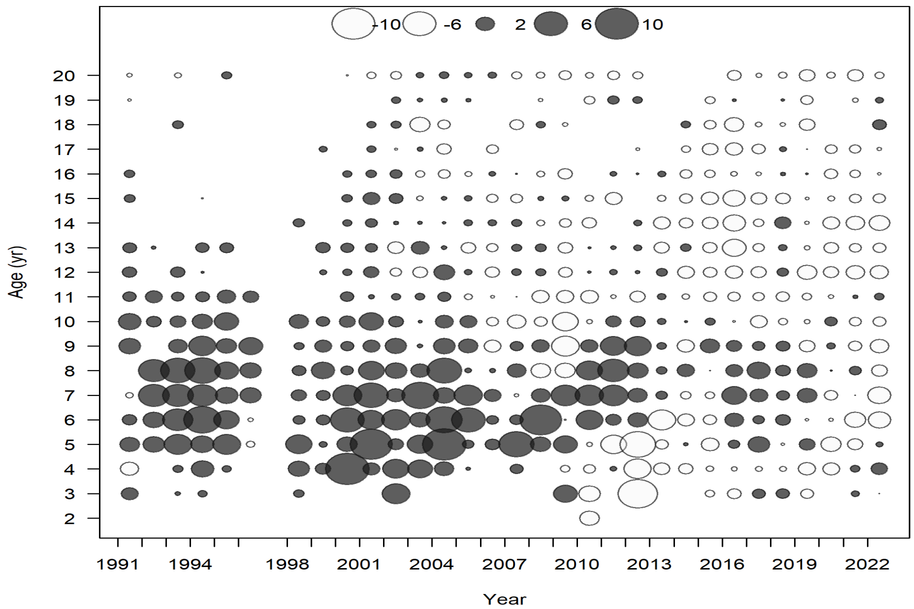


Figure 76. Pearson residuals for mean length-at-age of Gulf of Mexico Red Grouper landed by the Commercial Handline fleet. Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected).

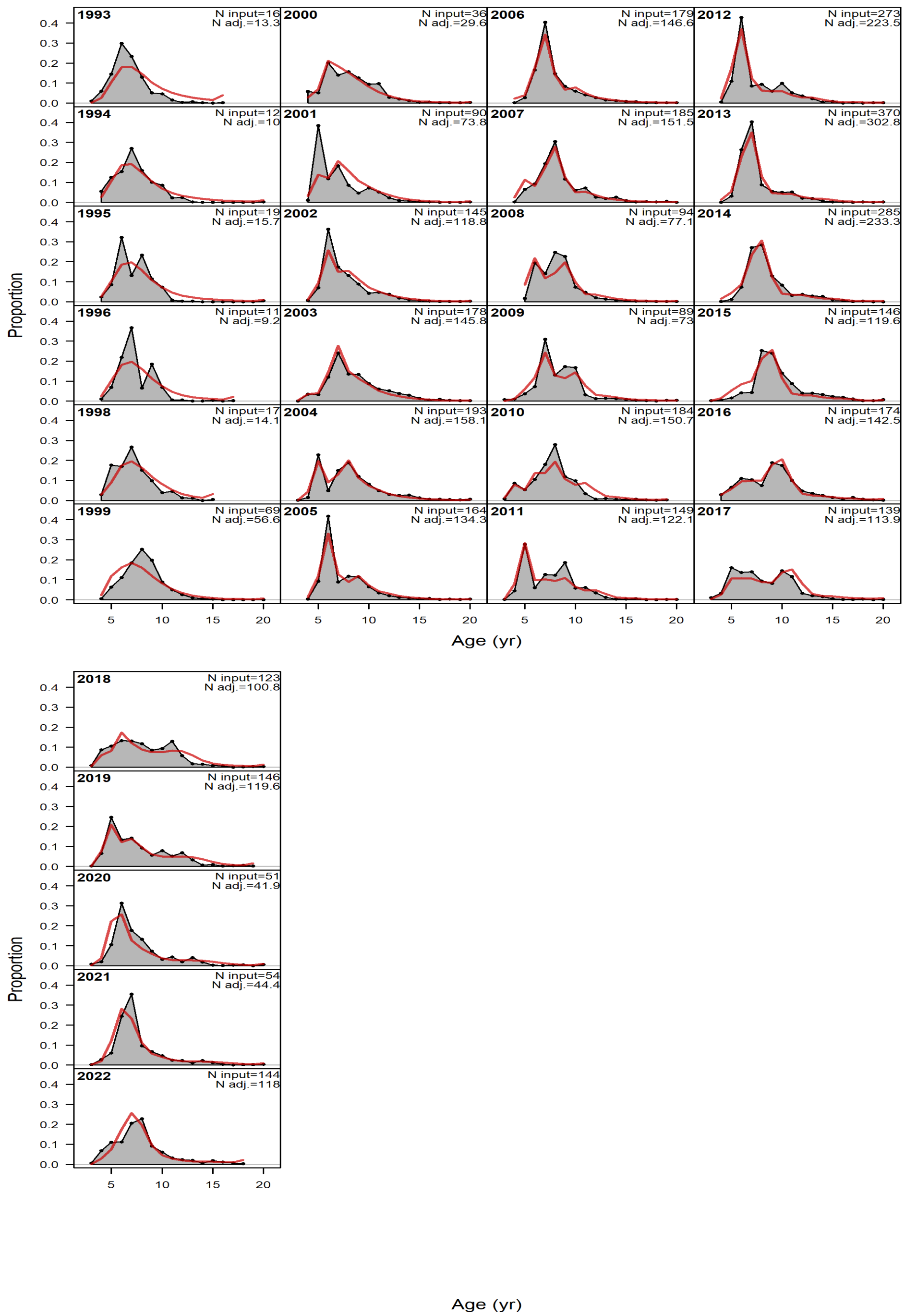


Figure 77. Observed and expected age compositions for Gulf of Mexico Red Grouper landed by the Commercial Longline fleet for SEDAR 88. Red lines represent expected age compositions, while grey shaded regions represent observed age compositions. Input sample sizes (N input, trips) and adjusted sample sizes (N adj) estimated by Stock Synthesis are also reported.

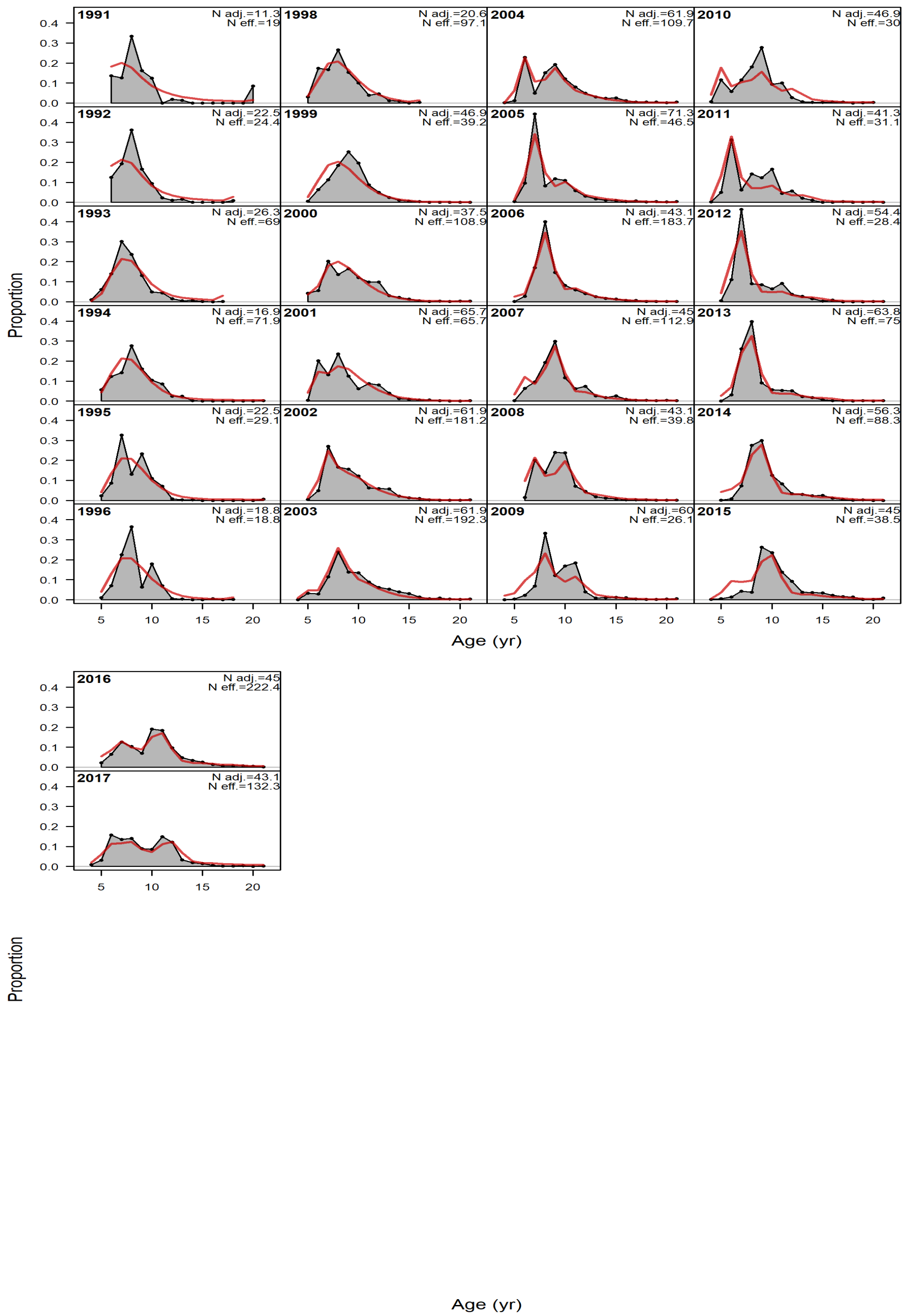
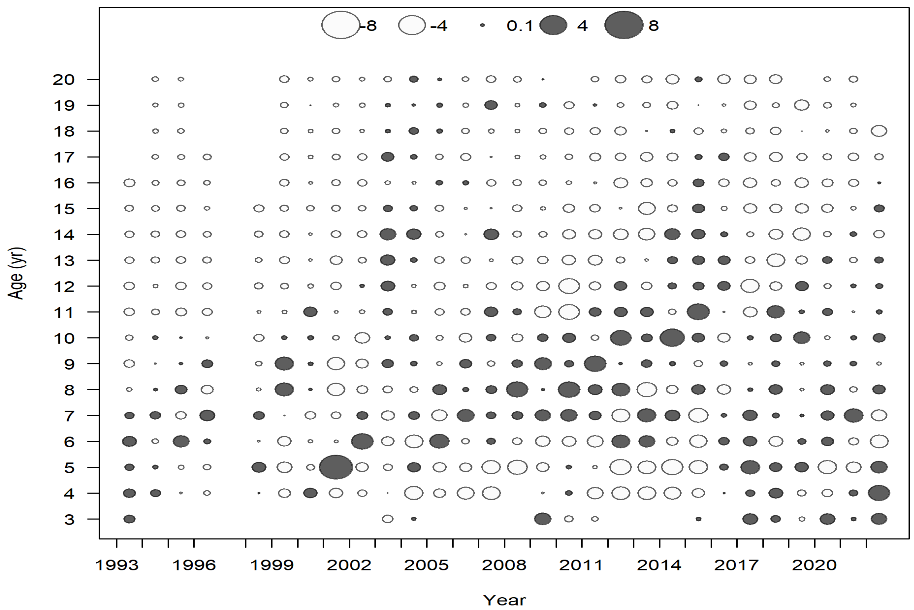


Figure 78. Observed and expected age compositions for Gulf of Mexico Red Grouper landed by the Commercial Longline fleet for SEDAR 61. Red lines represent expected age compositions, while grey shaded regions represent observed age compositions. Input sample sizes (N input, number of ages) and adjusted sample sizes (N adj) estimated by Stock Synthesis are also reported.

SEDAR 88



SEDAR 61

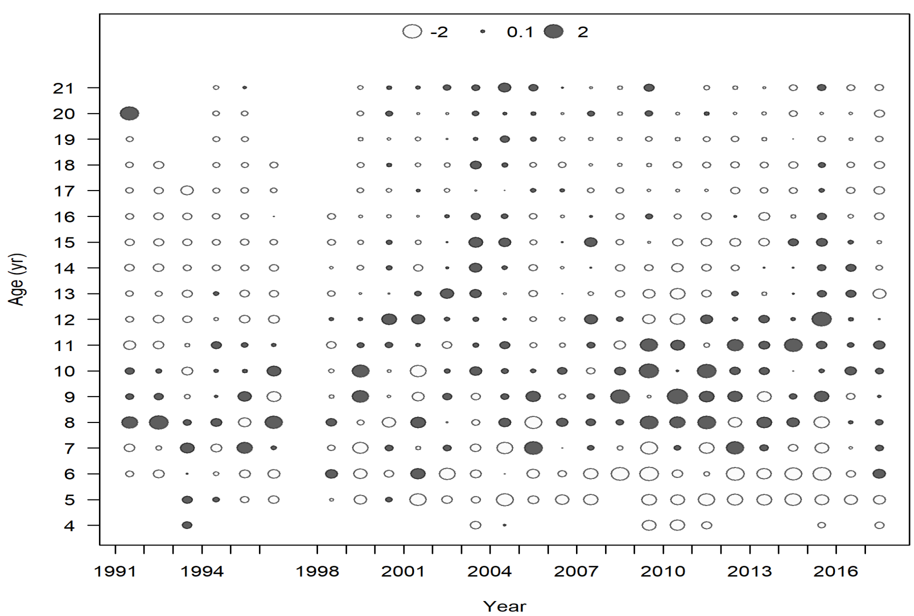
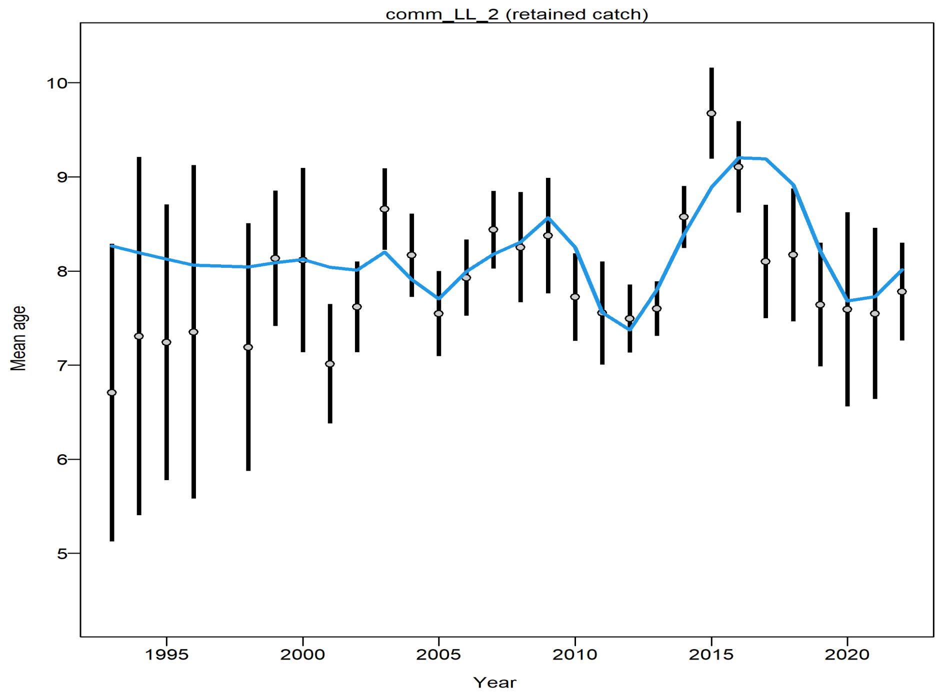


Figure 79. Pearson residuals for age compositions of Gulf of Mexico Red Grouper landed by the Commercial Longline fleet. Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected).

SEDAR 88



SEDAR 61

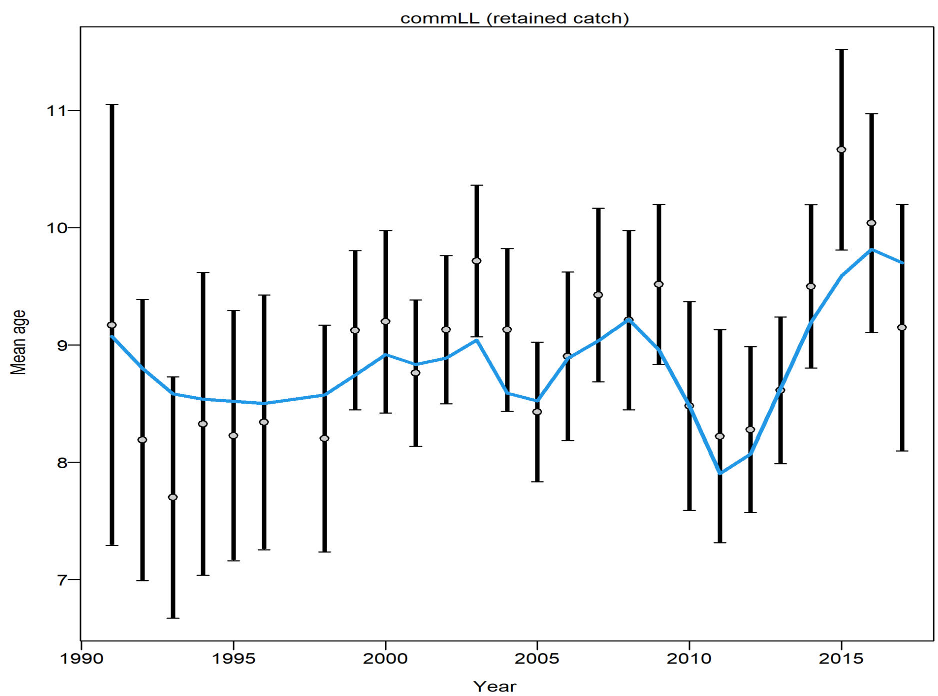


Figure 80. Mean age of Gulf of Mexico Red Grouper landed by the Commercial Longline fleet with 95% confidence intervals (thick bars) based on current sample sizes (including any Dirichlet Multinomial weighting).

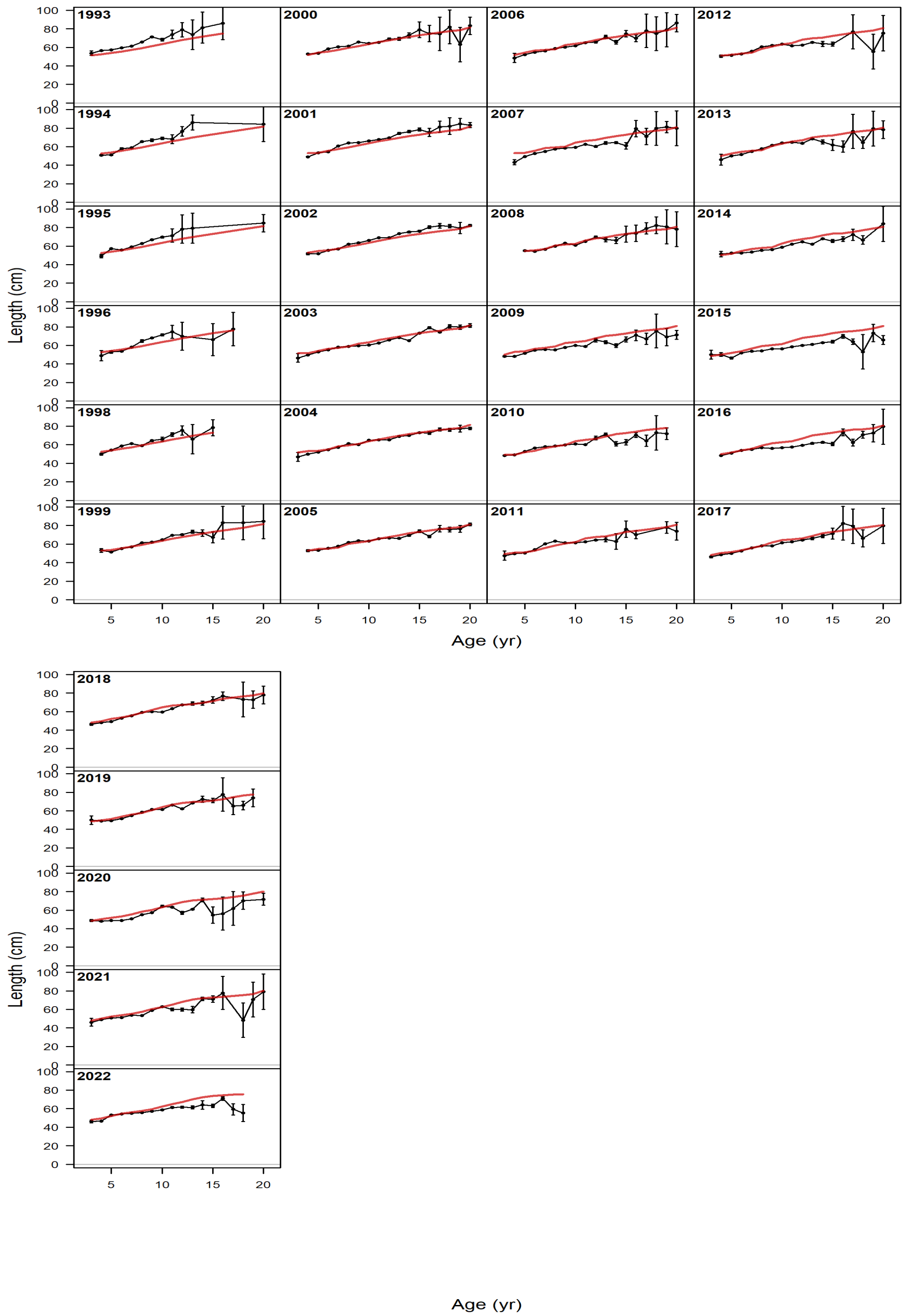


Figure 81. Observed and expected mean length-at-age for Gulf of Mexico Red Grouper landed by the Commercial Longline fleet. Red lines represent expected mean length-at-age, while solid lines with vertical bars represent observed mean length-at-age with error bars. Mean length-at-age is provided for comparison of trends and were included in the likelihood with a very low lambda.

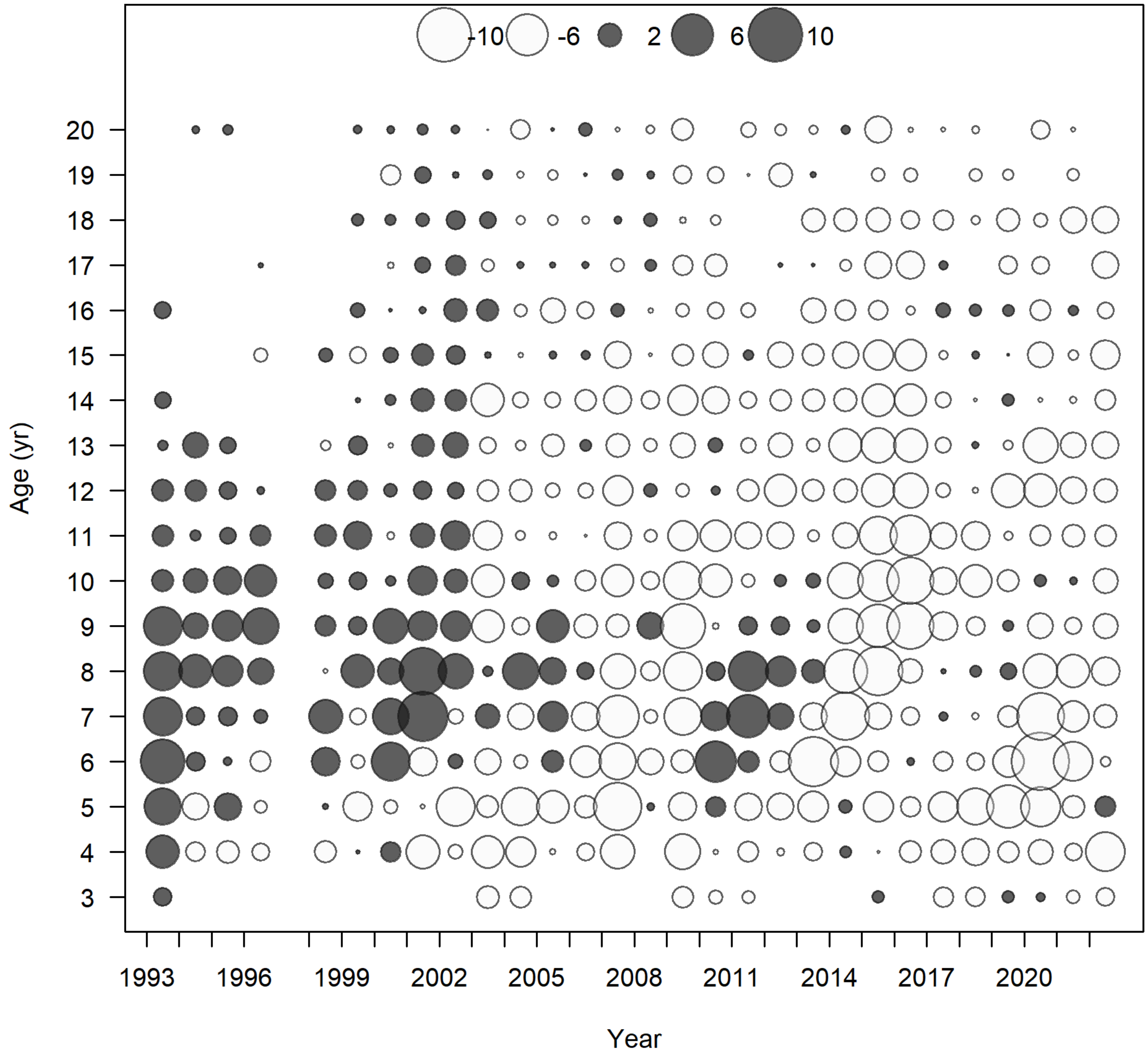


Figure 82. Pearson residuals for mean length-at-age of Gulf of Mexico Red Grouper landed by the Commercial Longline fleet. Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected).

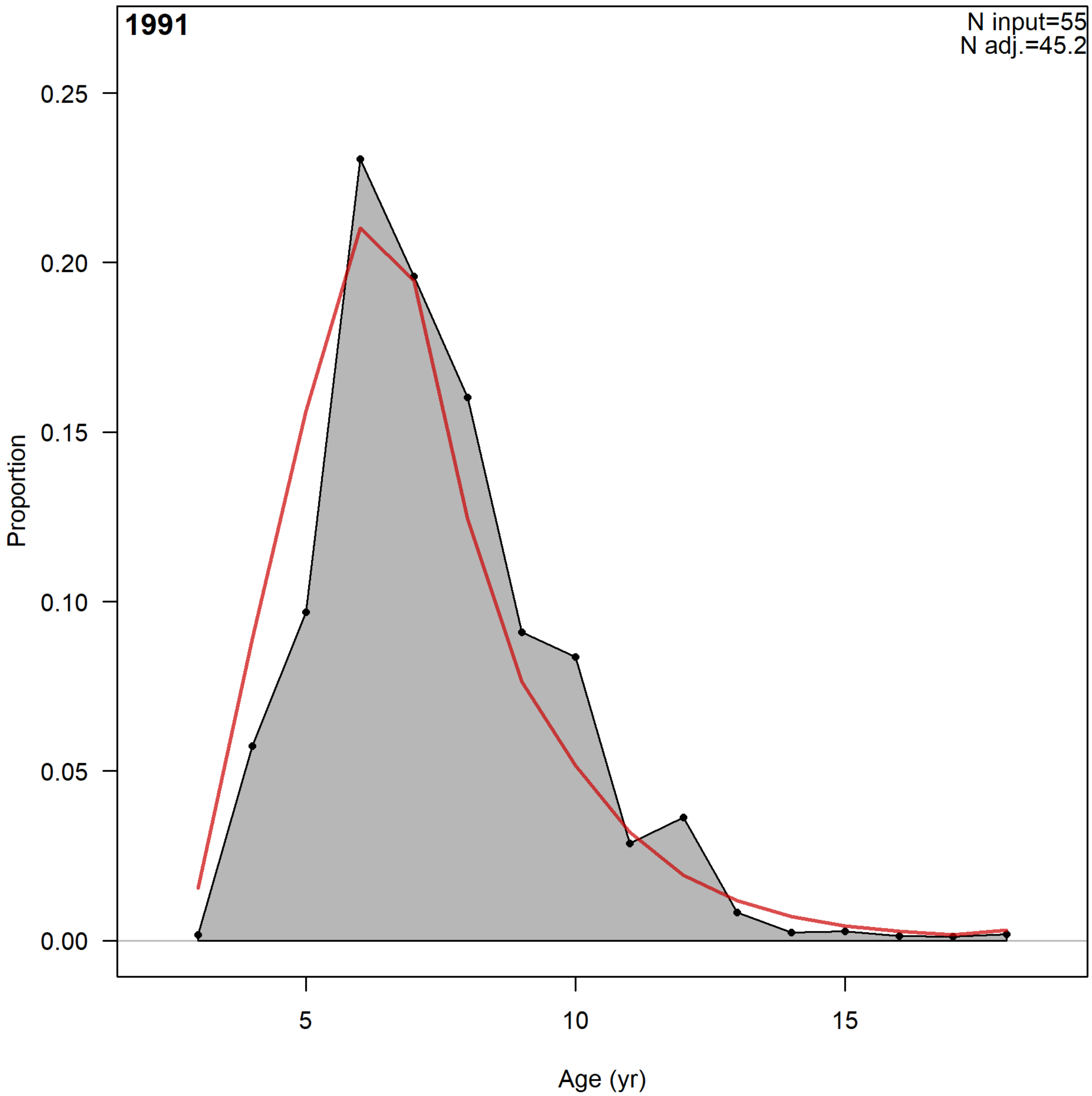


Figure 83. Observed and expected age compositions for Gulf of Mexico Red Grouper landed by the Commercial Trap fleet for SEDAR 88. Red lines represent expected age compositions, while grey shaded regions represent observed age compositions. Input sample sizes (N input, trips) and adjusted sample sizes (N adj) estimated by Stock Synthesis are also reported.

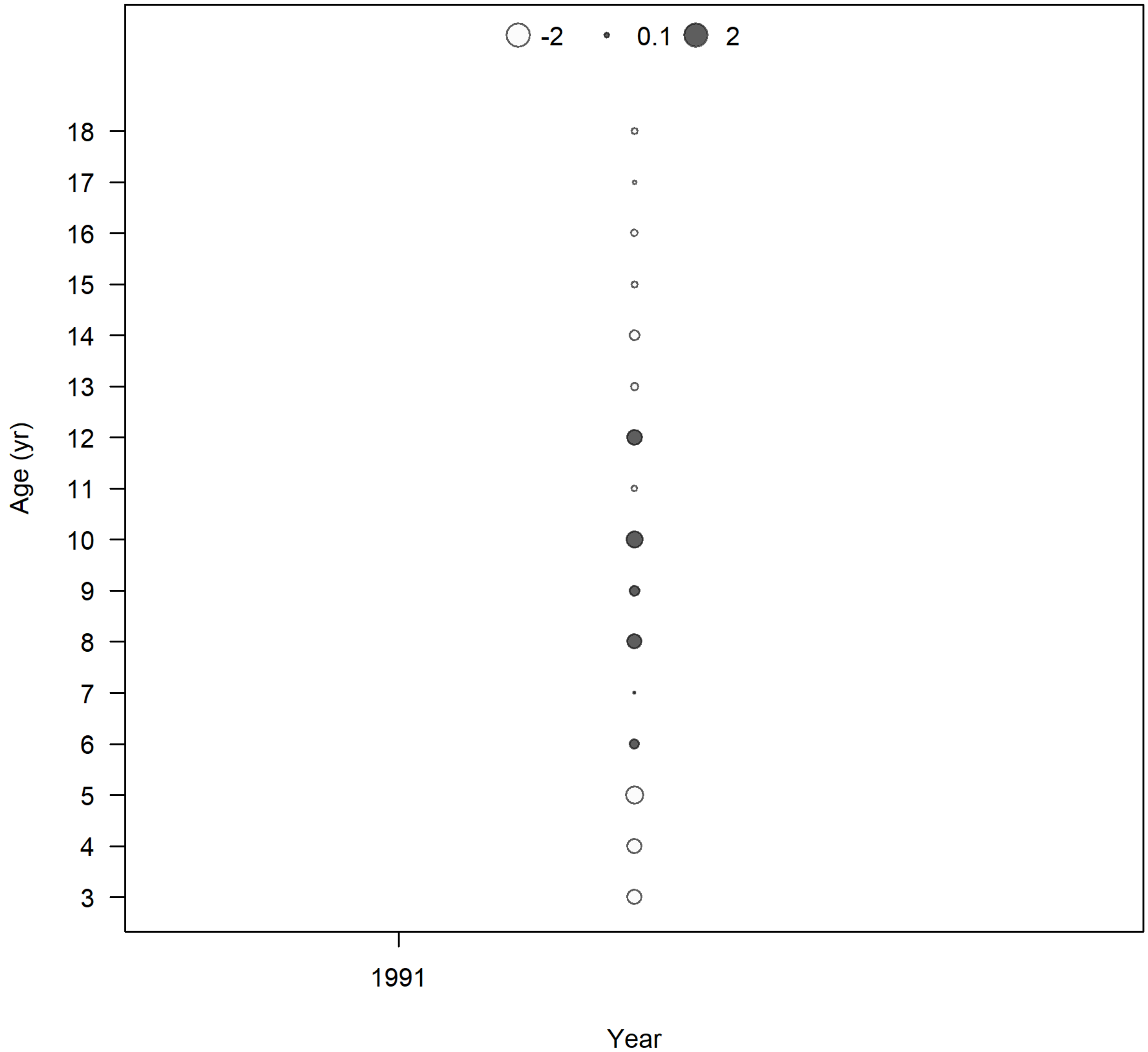


Figure 84. Pearson residuals for age compositions of Gulf of Mexico Red Grouper landed by the Commercial Trap fleet. Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected).

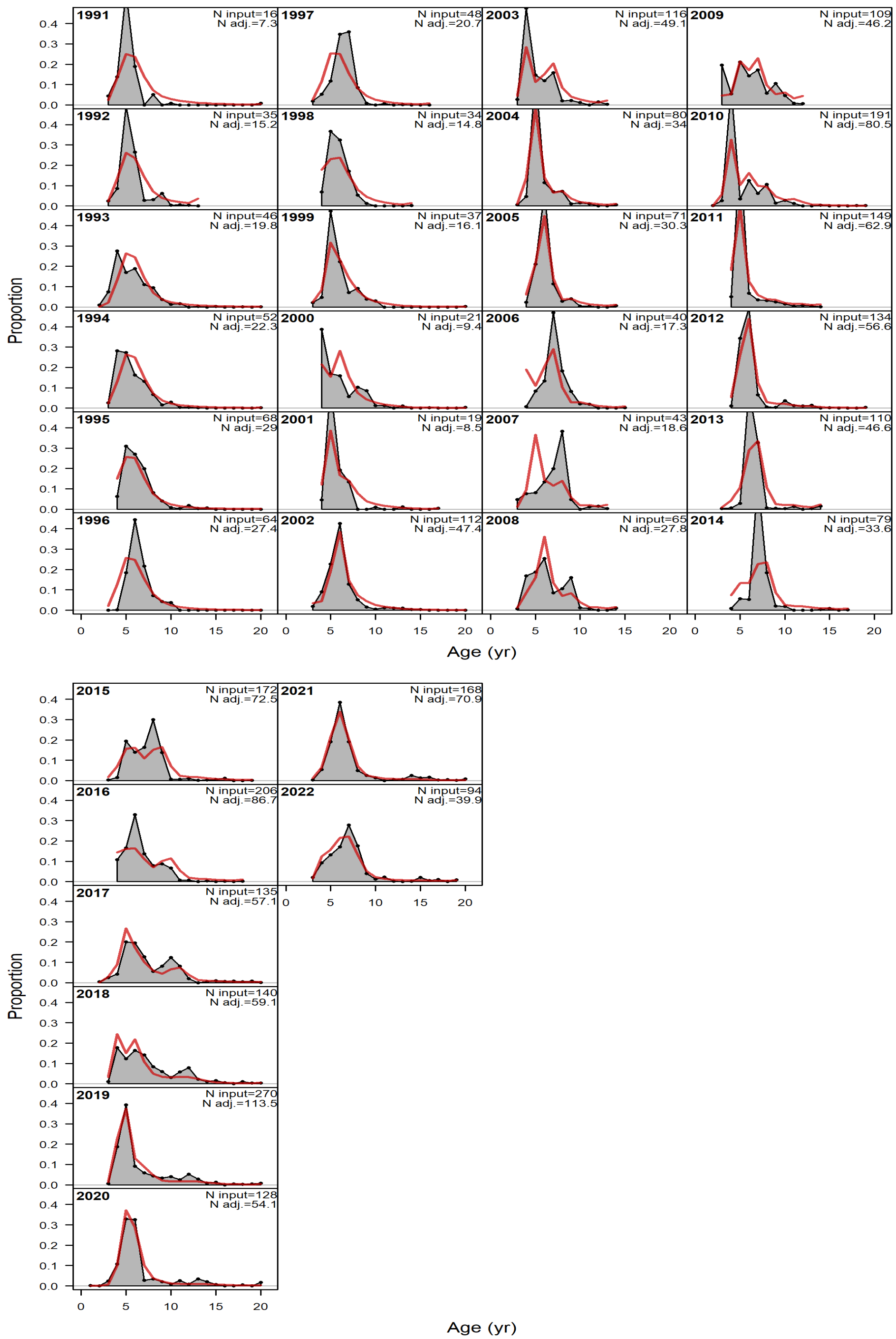


Figure 85. Observed and expected age compositions for Gulf of Mexico Red Grouper landed by the Recreational fleet for SEDAR 88. Red lines represent expected age compositions, while grey shaded regions represent observed age compositions. Input sample sizes (N input, trips) and adjusted sample sizes (N adj) estimated by Stock Synthesis are also reported.

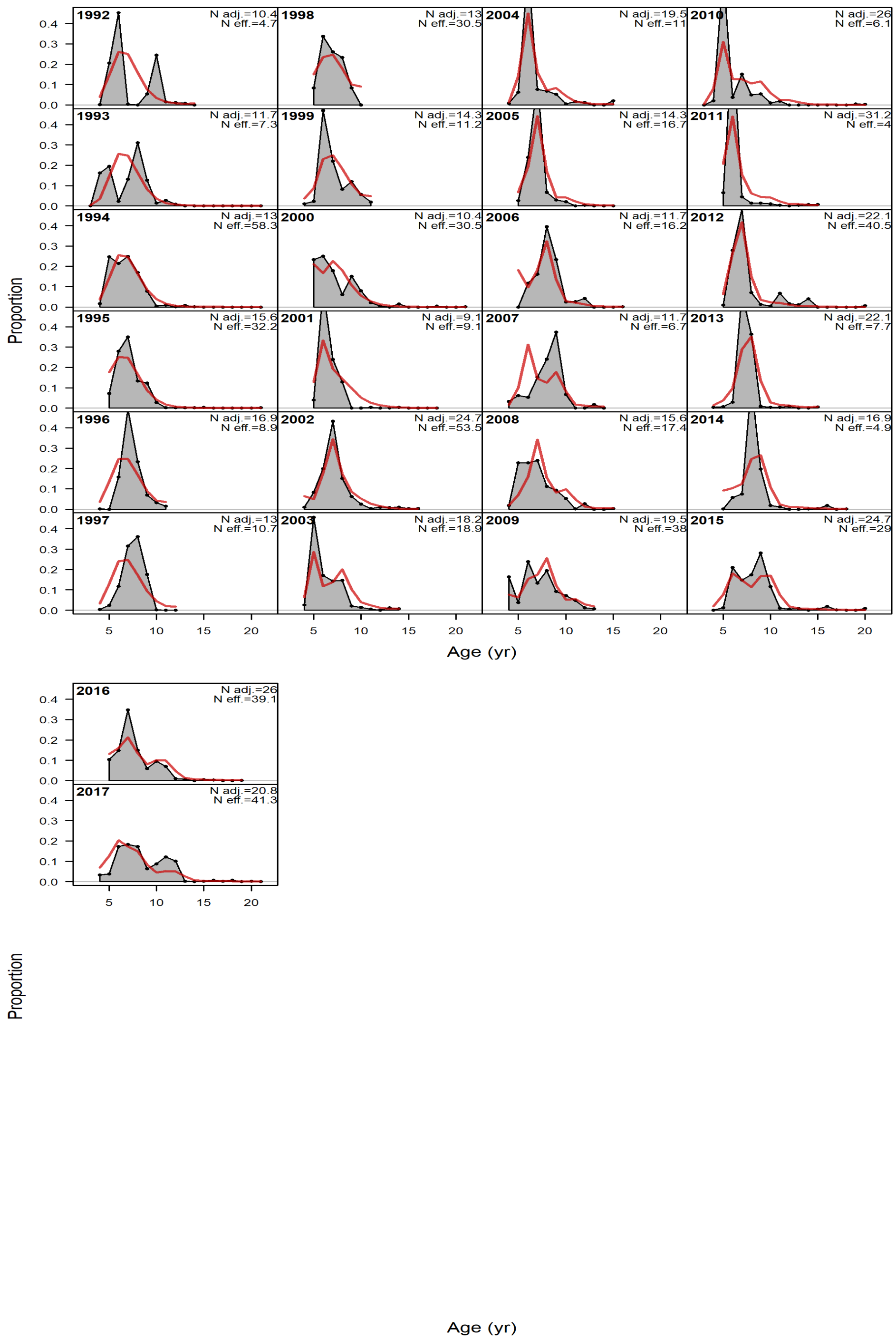
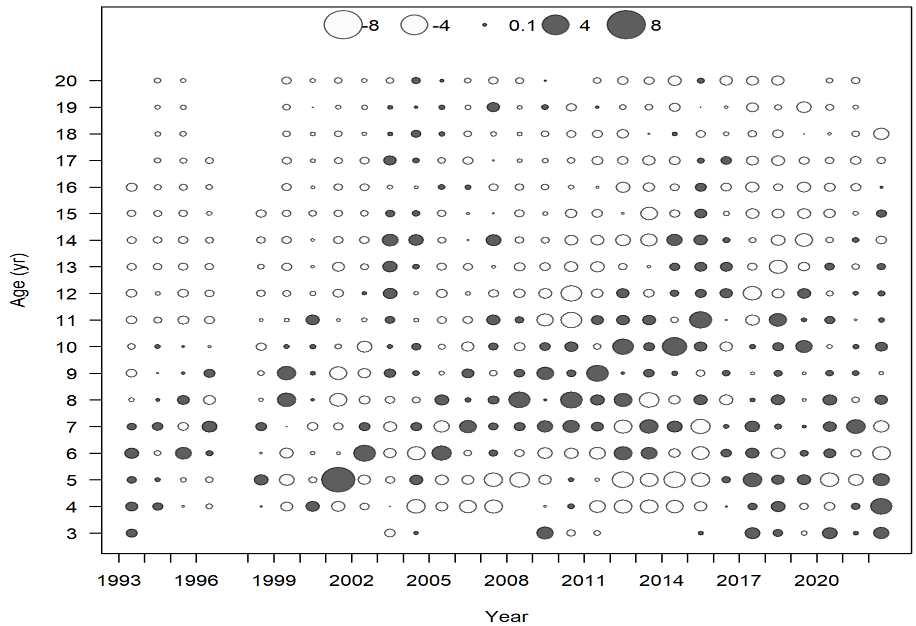


Figure 86. Observed and expected age compositions for Gulf of Mexico Red Grouper landed by the Recreational fleet for SEDAR 61. Red lines represent expected age compositions, while grey shaded regions represent observed age compositions. Input sample sizes (N input, number of ages) and adjusted sample sizes (N adj) estimated by Stock Synthesis are also reported.

SEDAR 88



SEDAR 61

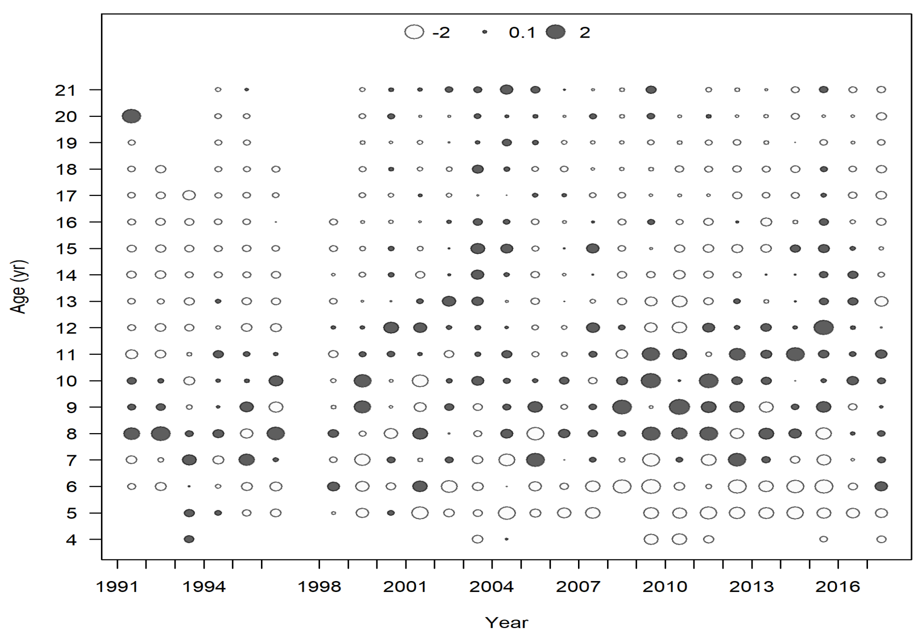
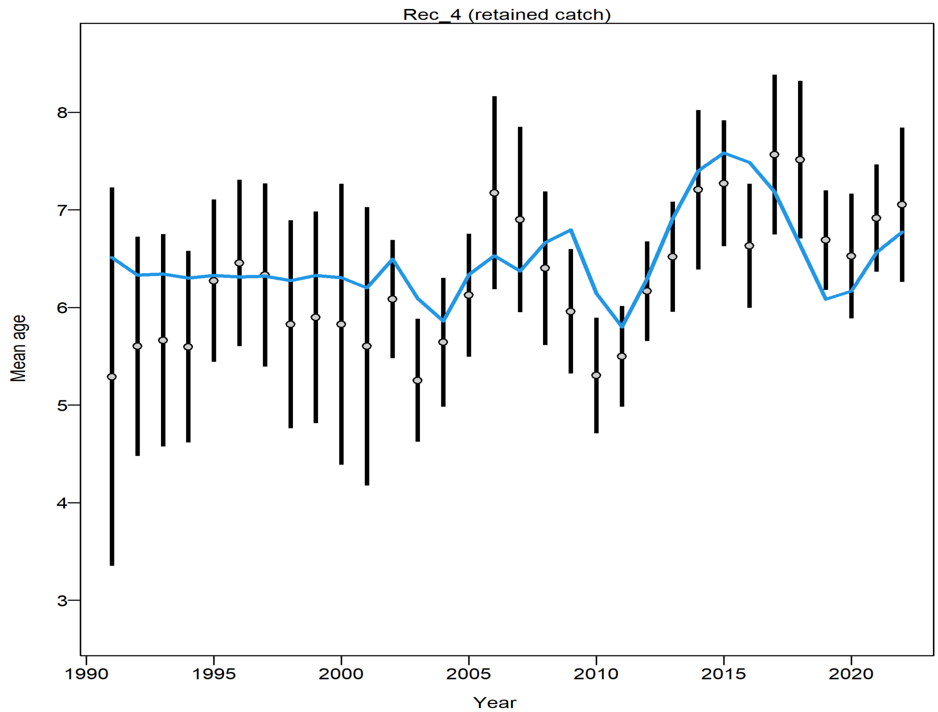


Figure 87. Pearson residuals for age compositions of Gulf of Mexico Red Grouper landed by the Recreational fleet. Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected).

SEDAR 88



SEDAR 61

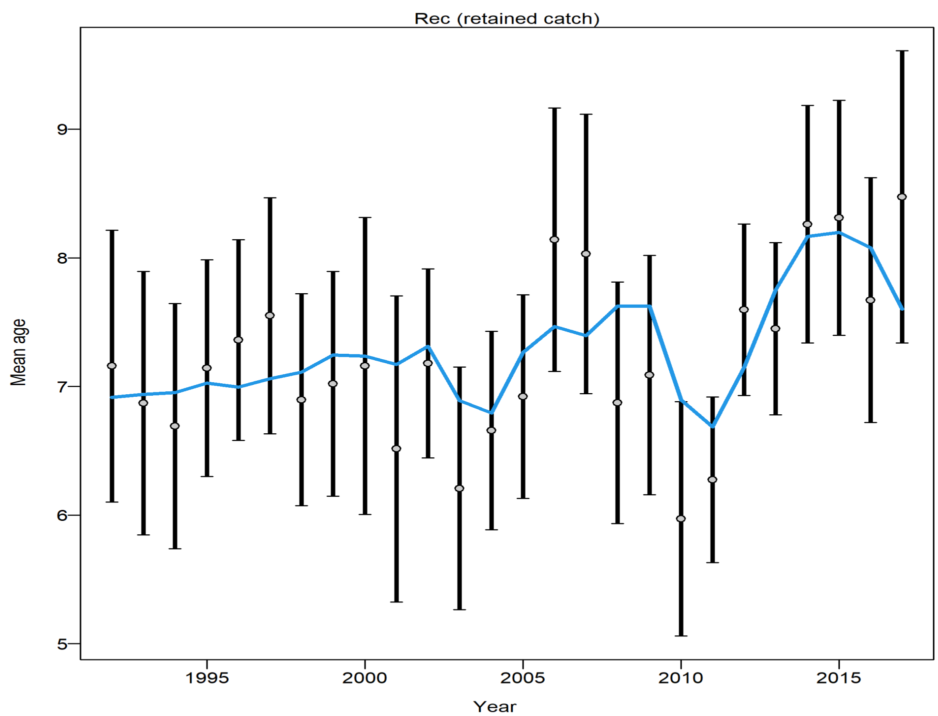


Figure 88. Mean age of Gulf of Mexico Red Grouper landed by the Recreational fleet with 95% confidence intervals (thick bars) based on current sample sizes (including any Dirichlet Multinomial weighting).

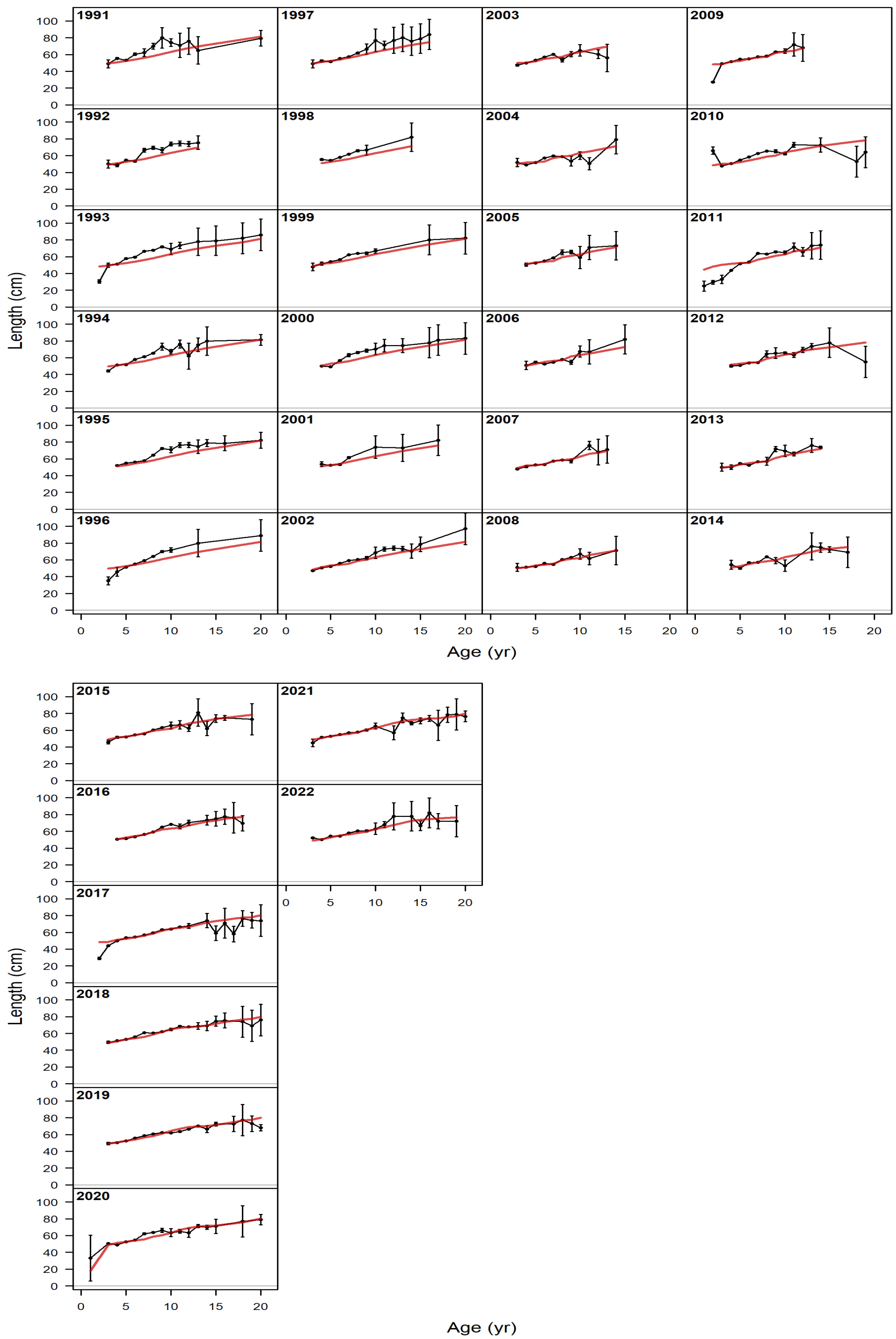


Figure 89. Observed and expected mean length-at-age for Gulf of Mexico Red Grouper landed by the Recreational fleet. Red lines represent expected mean length-at-age, while solid lines with vertical bars represent observed mean length-at-age with error bars. Mean length-at-age is provided for comparison of trends and were included in the likelihood with a very low lambda.

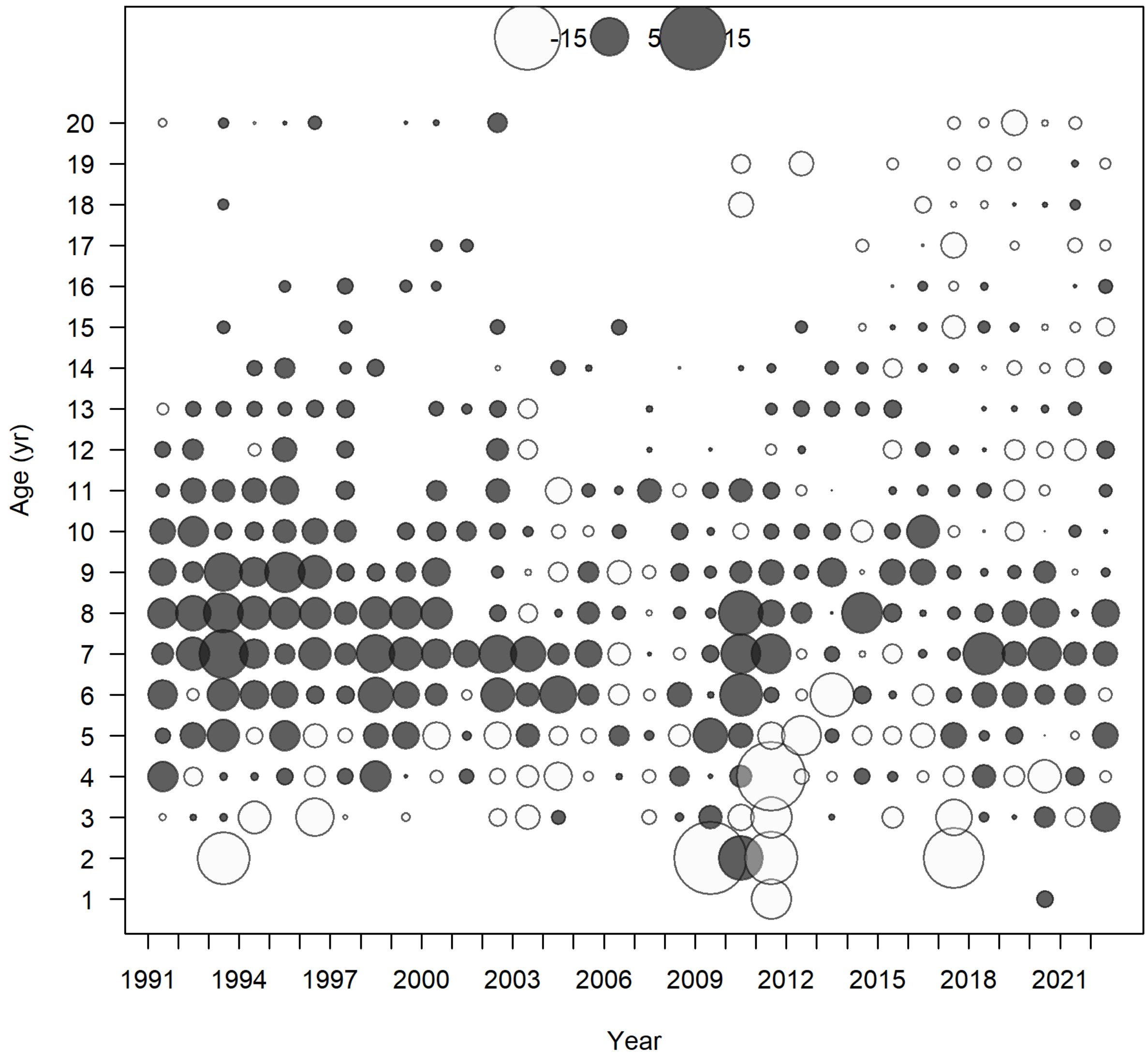


Figure 90. Pearson residuals for mean length-at-age of Gulf of Mexico Red Grouper landed by the Recreational fleet. Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected).

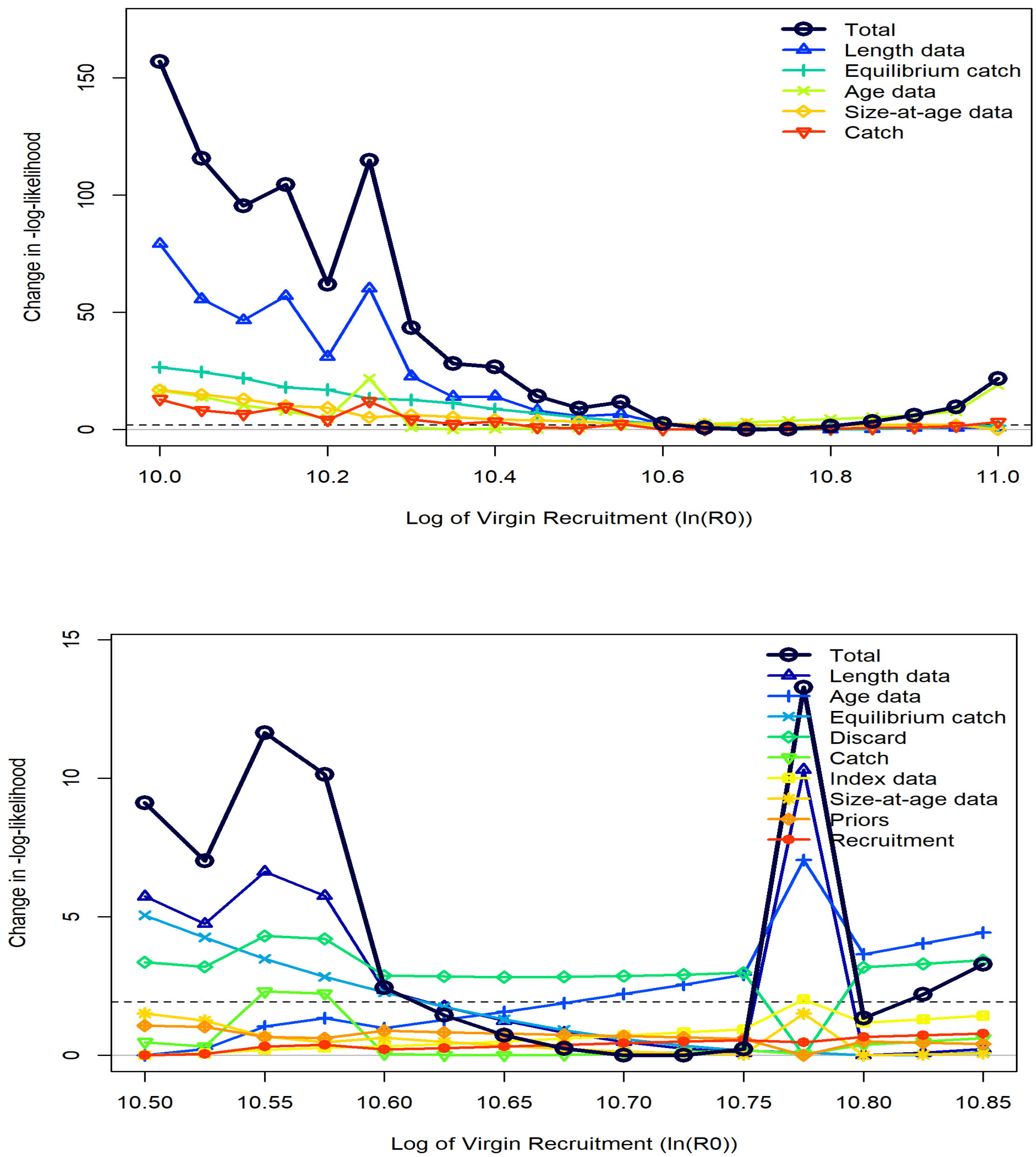
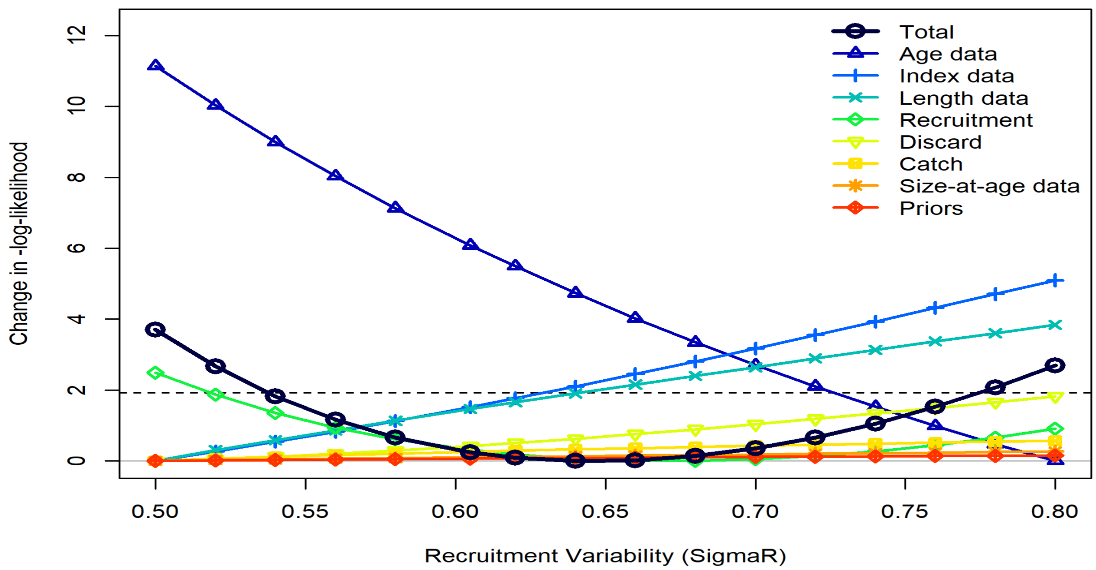


Figure 91. The likelihood profile for the natural log of the unfished recruitment parameter of the Beverton – Holt stock-recruit function for Gulf of Mexico Red Grouper. Each line represents the change in negative log-likelihood value for each of the data sources fit in the model across the range of fixed ln(R0) values tested in the profile diagnostic run. The MLE (CV) for the base model was 10.713 (0.005). The bottom panel shows a close up of the top panel to better detect significant differences between runs. The dashed horizontal line at ~1.92 indicates the 95% confidence interval.



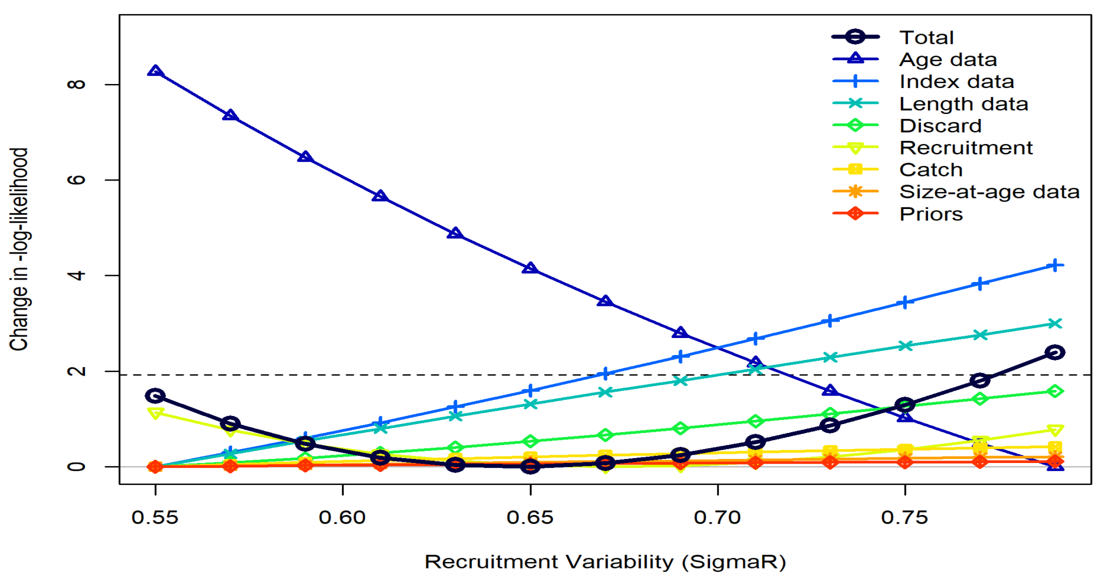


Figure 92. The likelihood profile for the recruitment variability for Gulf of Mexico Red Grouper. Each line represents the change in negative log-likelihood value for each of the data sources fit in the model across the range of fixed SigmaR values tested in the profile diagnostic run. The MLE (CV) for the base model was 0.647 (0.094). The bottom panel shows a close up of the top panel to better detect significant differences between runs. The dashed horizontal line at ~1.92 indicates the 95% confidence interval.

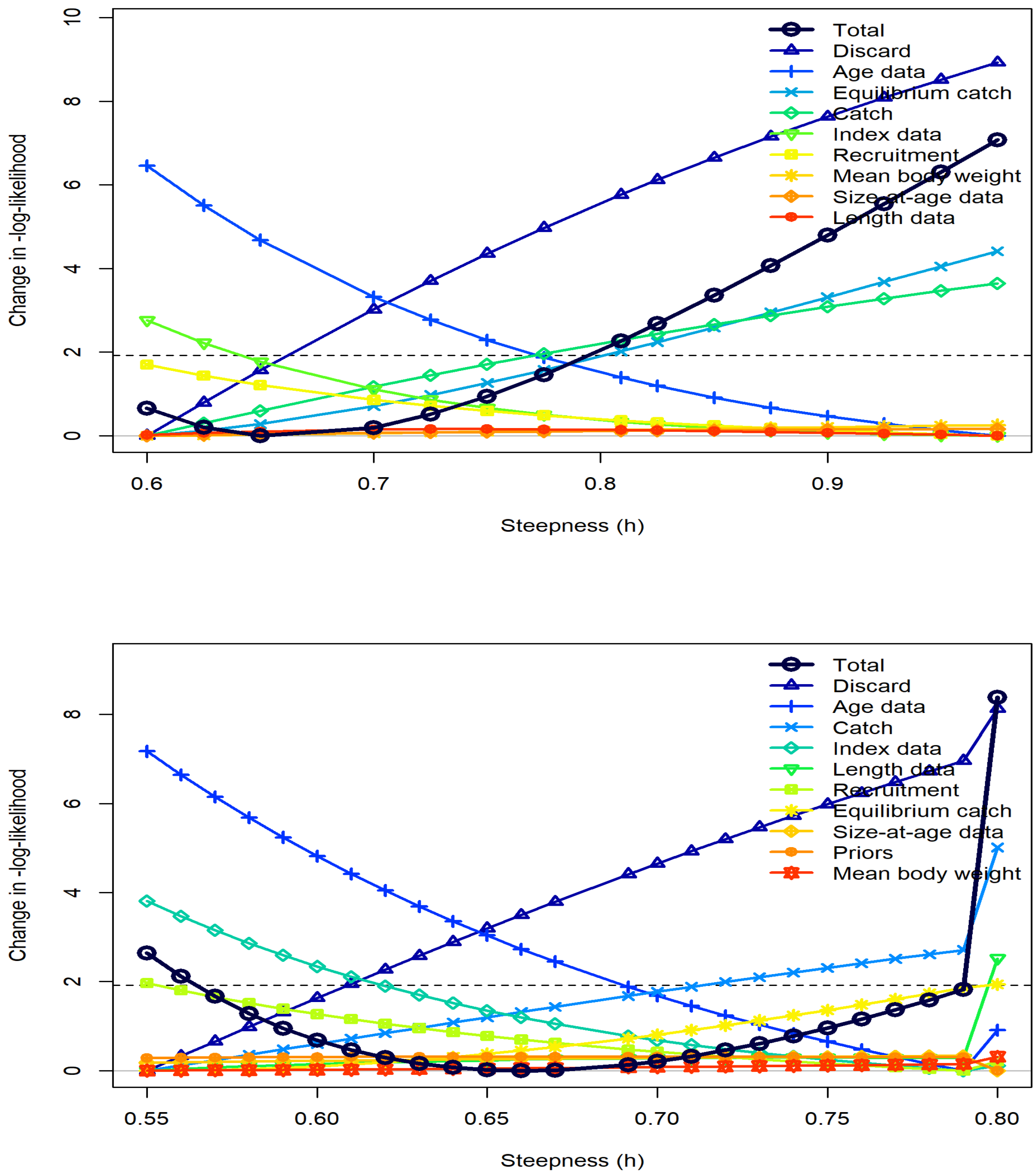


Figure 93. The likelihood profile for steepness for Gulf of Mexico Red Grouper. Each line represents the change in negative log-likelihood value for each of the data sources fit in the model across the range of fixed steepness values tested in the profile diagnostic run. The MLE (CV) for the base model was 0.661 (0.086). The bottom panel shows a close up of the top panel to better detect significant differences between runs. The dashed horizontal line at ~1.92 indicates the 95% confidence interval.

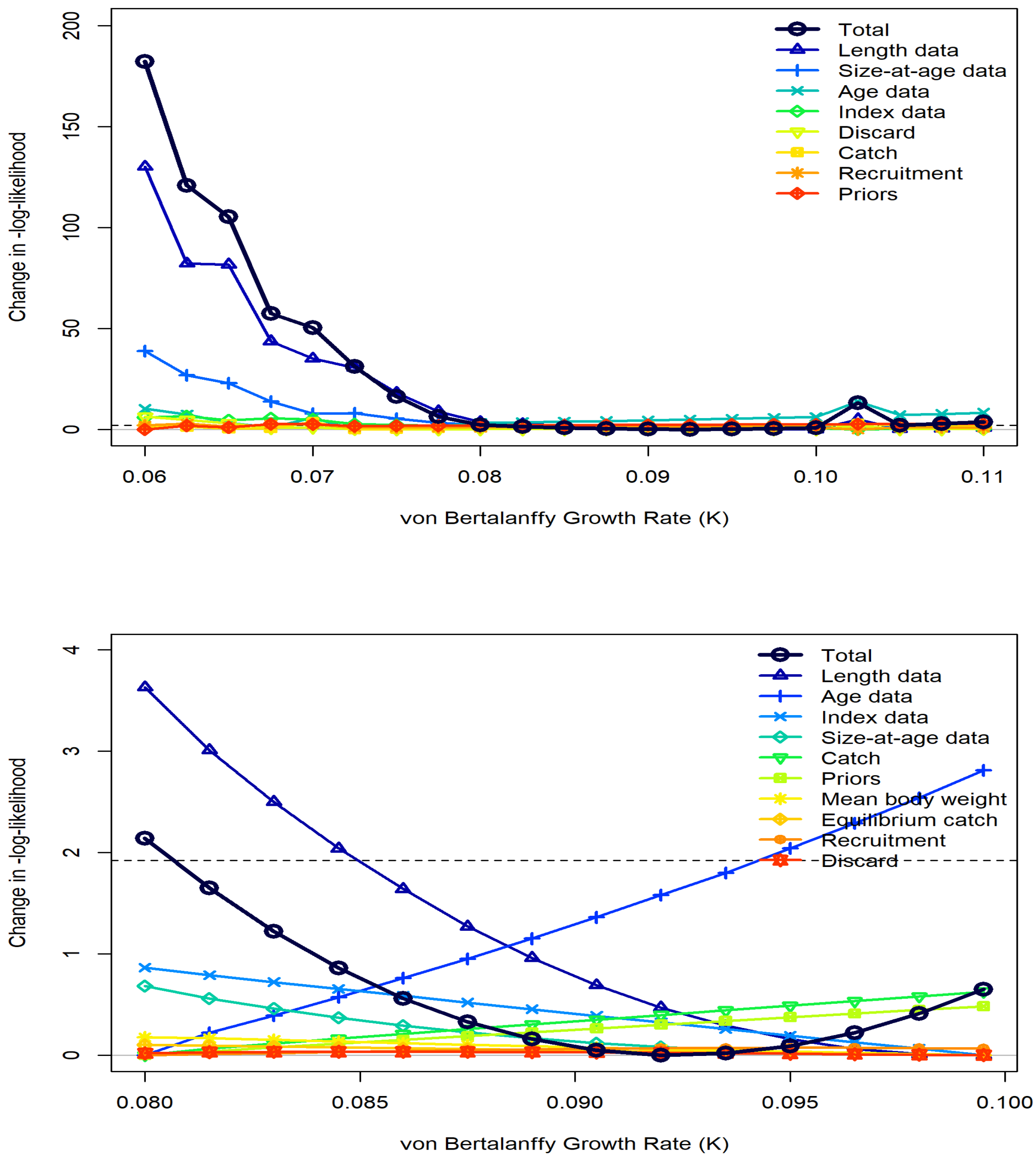


Figure 94. The likelihood profile for the Von Bertalanffy growth rate (k) parameter for Gulf of Mexico Red Grouper. Each line represents the change in negative log-likelihood value for each of the data sources fit in the model across the range of fixed k values tested in the profile diagnostic run. The MLE (CV) for the base model was 0.092 (0.066). The bottom panel shows a close up of the top panel to better detect significant differences between runs. The dashed horizontal line at ~1.92 indicates the 95% confidence interval.

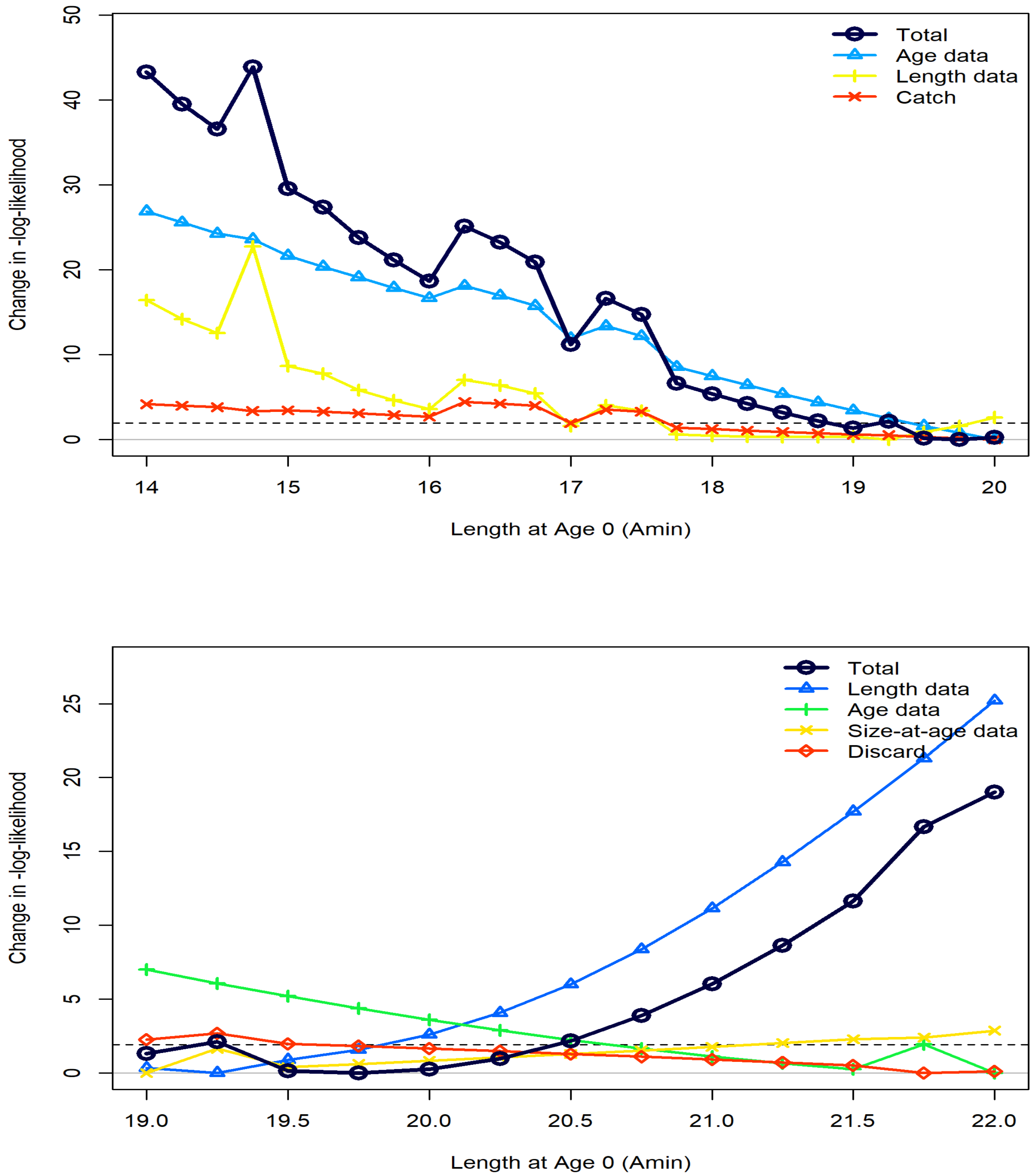
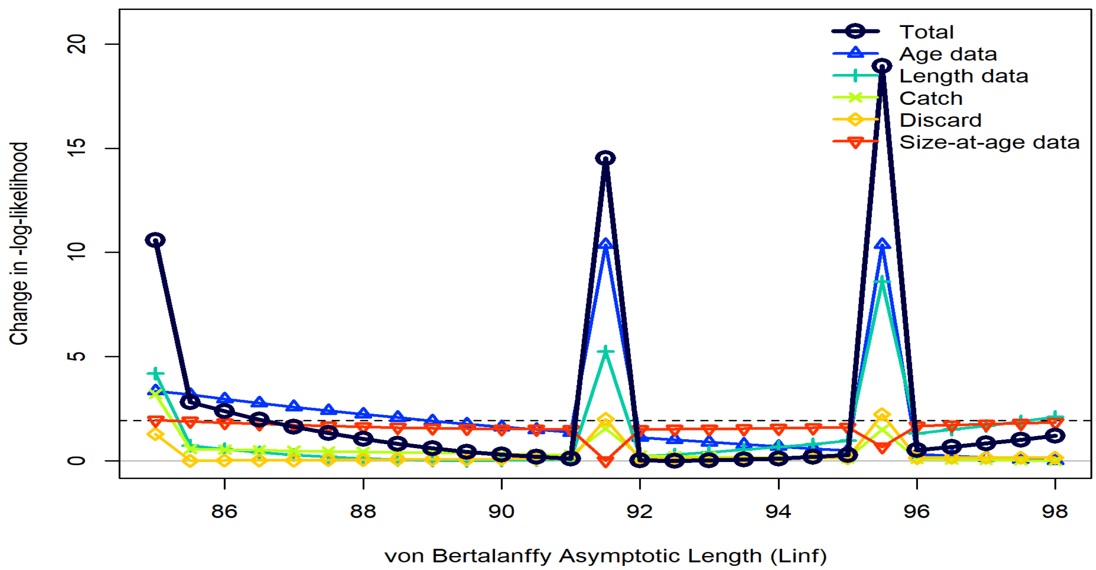


Figure 95. The likelihood profile for the length at age-0 (minimum age, Amin) for Gulf of Mexico Red Grouper. Each line represents the change in negative log-likelihood value for each of the data sources fit in the model across the range of fixed length at age-0 values tested in the profile diagnostic run. The MLE (CV) for the base model was 19.724 (0.02). The bottom panel shows a close up of the top panel to better detect significant differences between runs. The dashed horizontal line at ~1.92 indicates the 95% confidence interval.



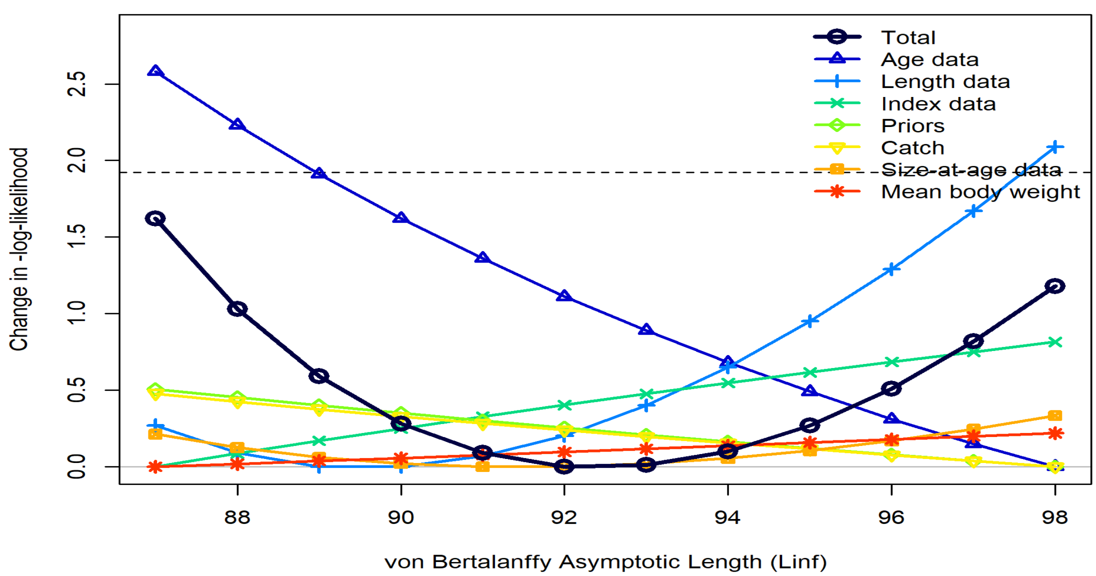


Figure 96. The likelihood profile for the von Bertalanffy asymptotic length (Linf) parameter for Gulf of Mexico Red Grouper. Each line represents the change in negative log-likelihood value for each of the data sources fit in the model across the range of fixed Linf values tested in the profile diagnostic run. The MLE (CV) for the base model was 92.41 (0.036). The bottom panel shows a close up of the top panel to better detect significant differences between runs. The dashed horizontal line at ~1.92 indicates the 95% confidence interval.

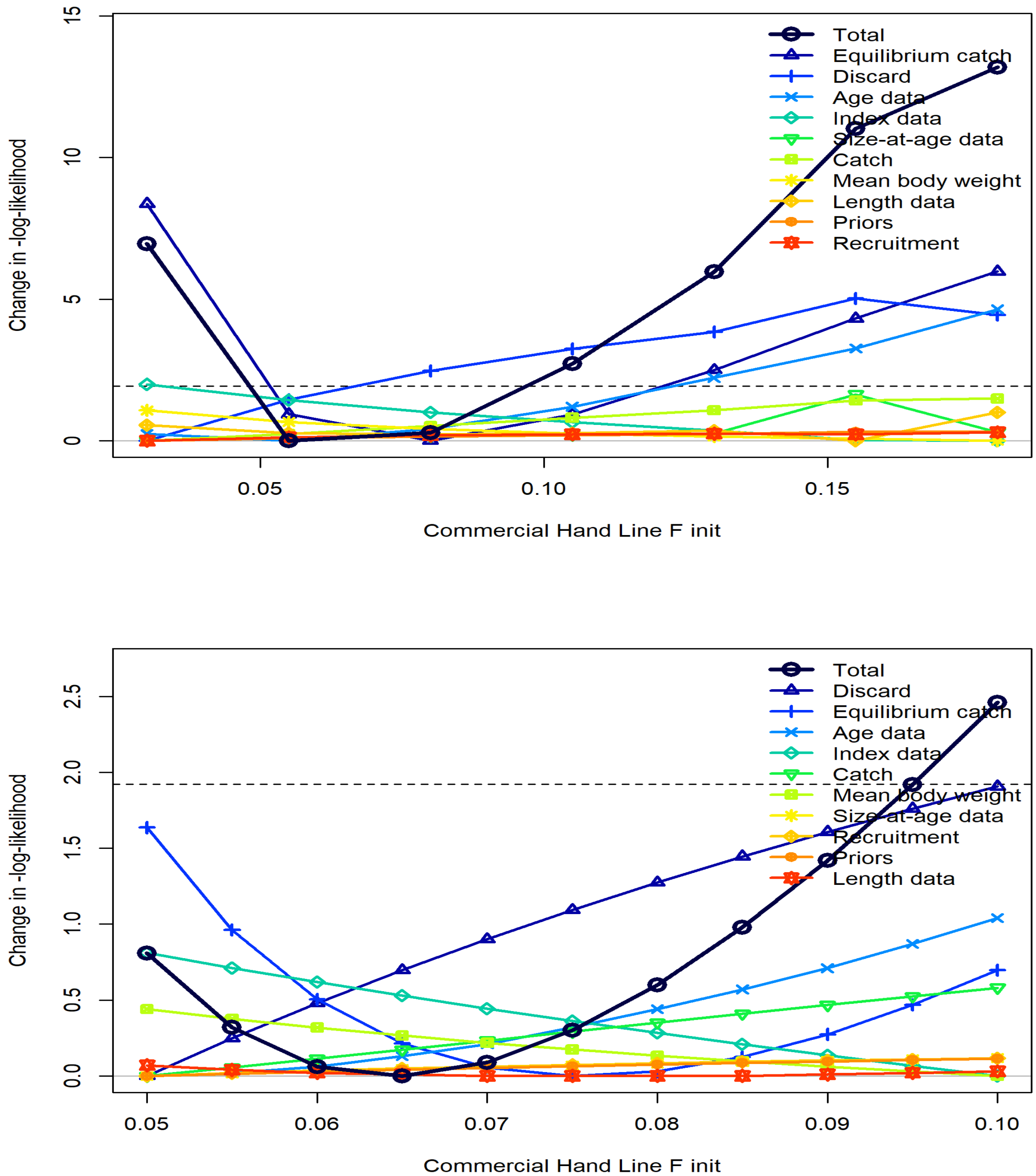
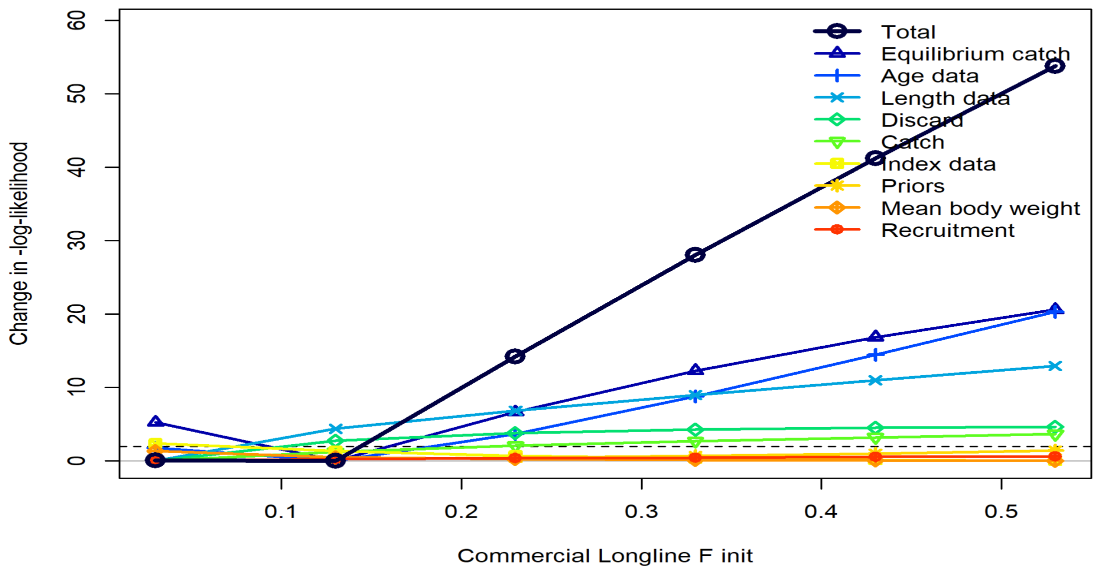


Figure 97. The likelihood profile for the initial fishing mortality for the Commercial Handline fleet for Gulf of Mexico Red Grouper. Each line represents the change in negative log-likelihood value for each of the data sources fit in the model across the range of fixed Finit values tested in the profile diagnostic run. The MLE (CV) for the base model was 0.064 (0.199). The bottom panel shows a close up of the top panel to better detect significant differences between runs. The dashed horizontal line at ~1.92 indicates the 95% confidence interval.



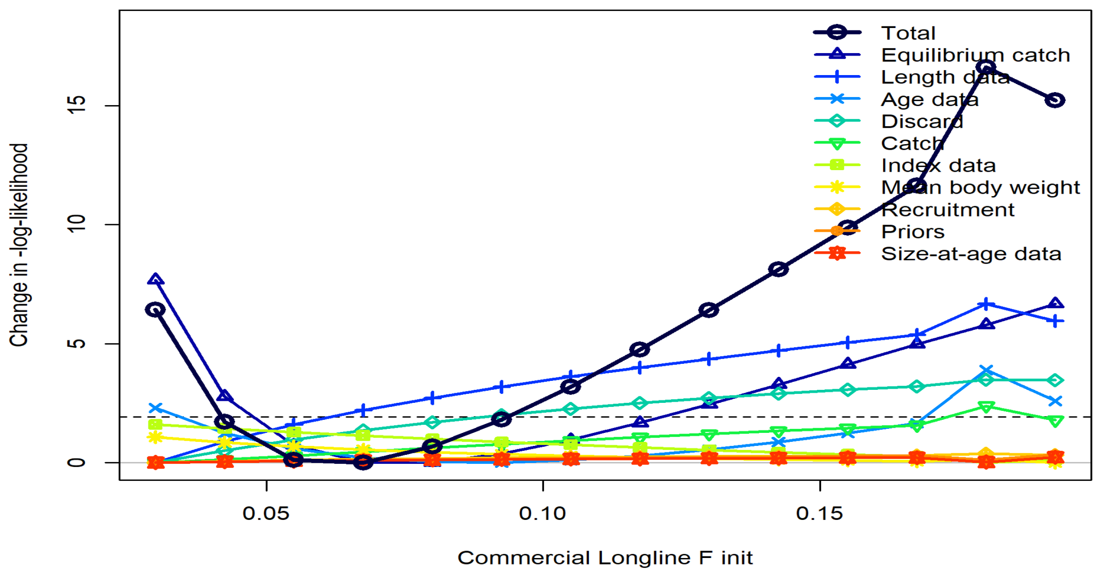


Figure 98. The likelihood profile for the initial fishing mortality for the Commercial Longline for Gulf of Mexico Red Grouper. Each line represents the change in negative log-likelihood value for each of the data sources fit in the model across the range of fixed Finit values tested in the profile diagnostic run. The MLE (CV) for the base model was 0.062 (0.203). The bottom panel shows a close up of the top panel to better detect significant differences between runs. The dashed horizontal line at ~1.92 indicates the 95% confidence interval.

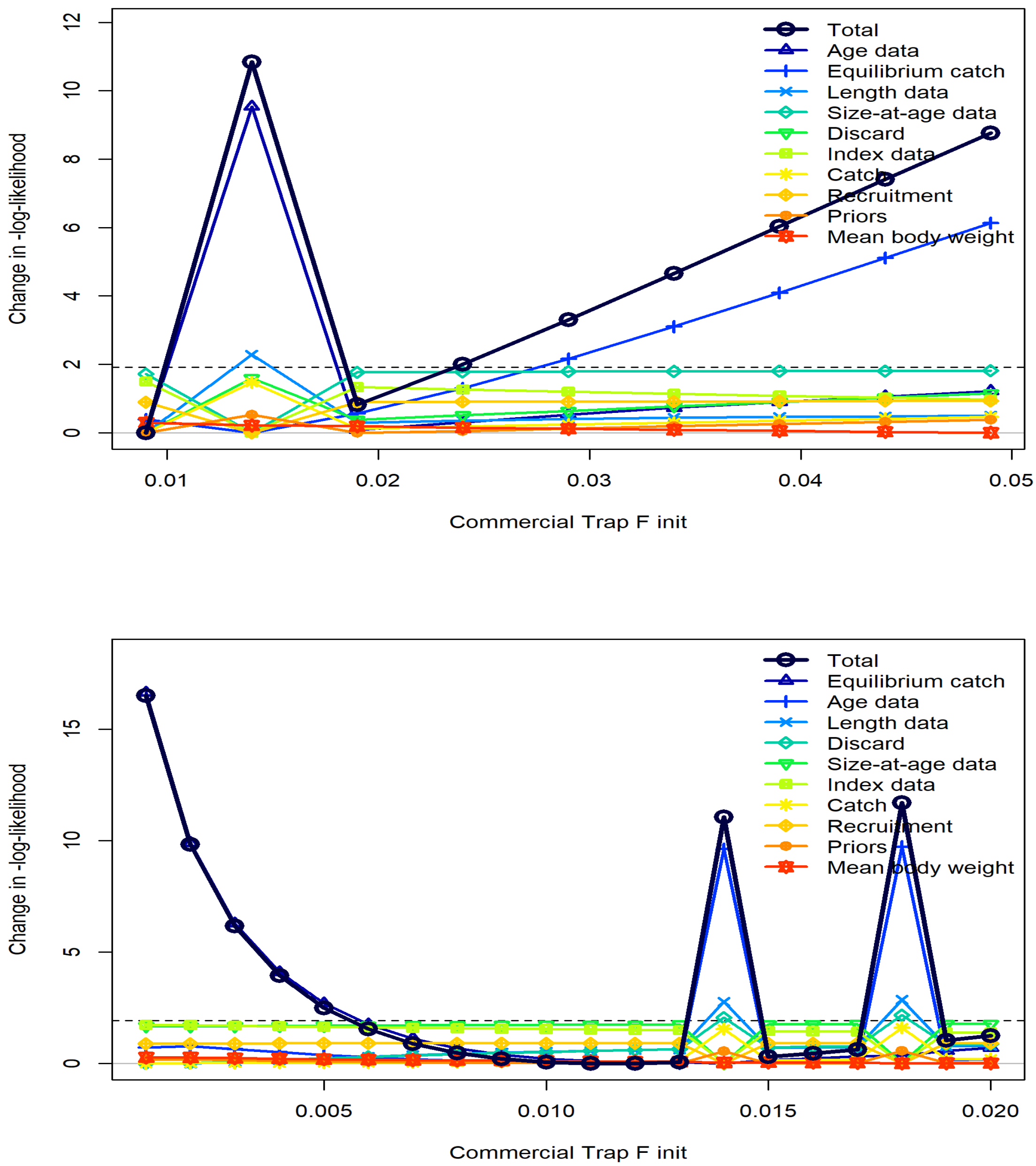
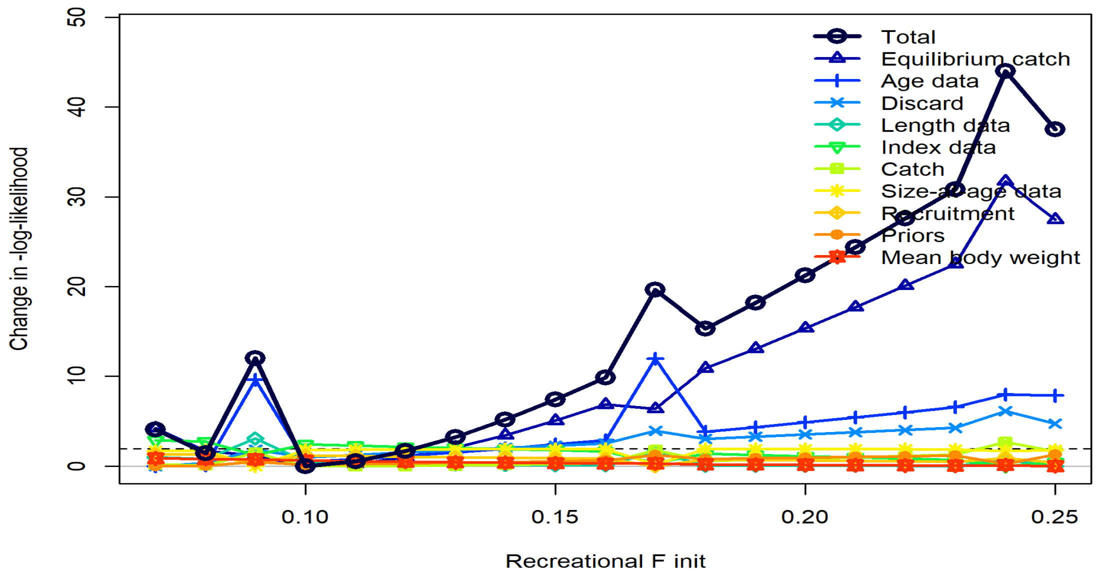


Figure 99. The likelihood profile for the initial fishing mortality for the Commercial Trap fleet for Gulf of Mexico Red Grouper. Each line represents the change in negative log-likelihood value for each of the data sources fit in the model across the range of fixed Finit values tested in the profile diagnostic run. The MLE (CV) for the base model was 0.011 (0.356). The bottom panel shows a close up of the top panel to better detect significant differences between runs. The dashed horizontal line at ~1.92 indicates the 95% confidence interval.



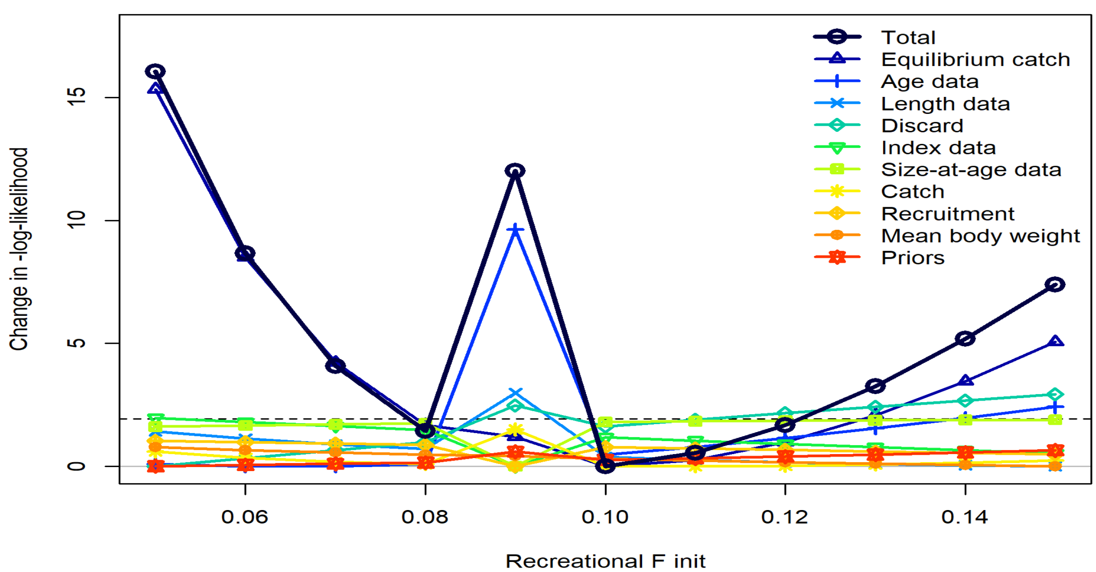


Figure 100. The likelihood profile for the initial fishing mortality for the Recreational fleet for Gulf of Mexico Red Grouper. Each line represents the change in negative log-likelihood value for each of the data sources fit in the model across the range of fixed Finit values tested in the profile diagnostic run. The MLE (CV) for the base model was 0.097 (0.114). The bottom panel shows a close up of the top panel to better detect significant differences between runs. The dashed horizontal line at ~1.92 indicates the 95% confidence interval.

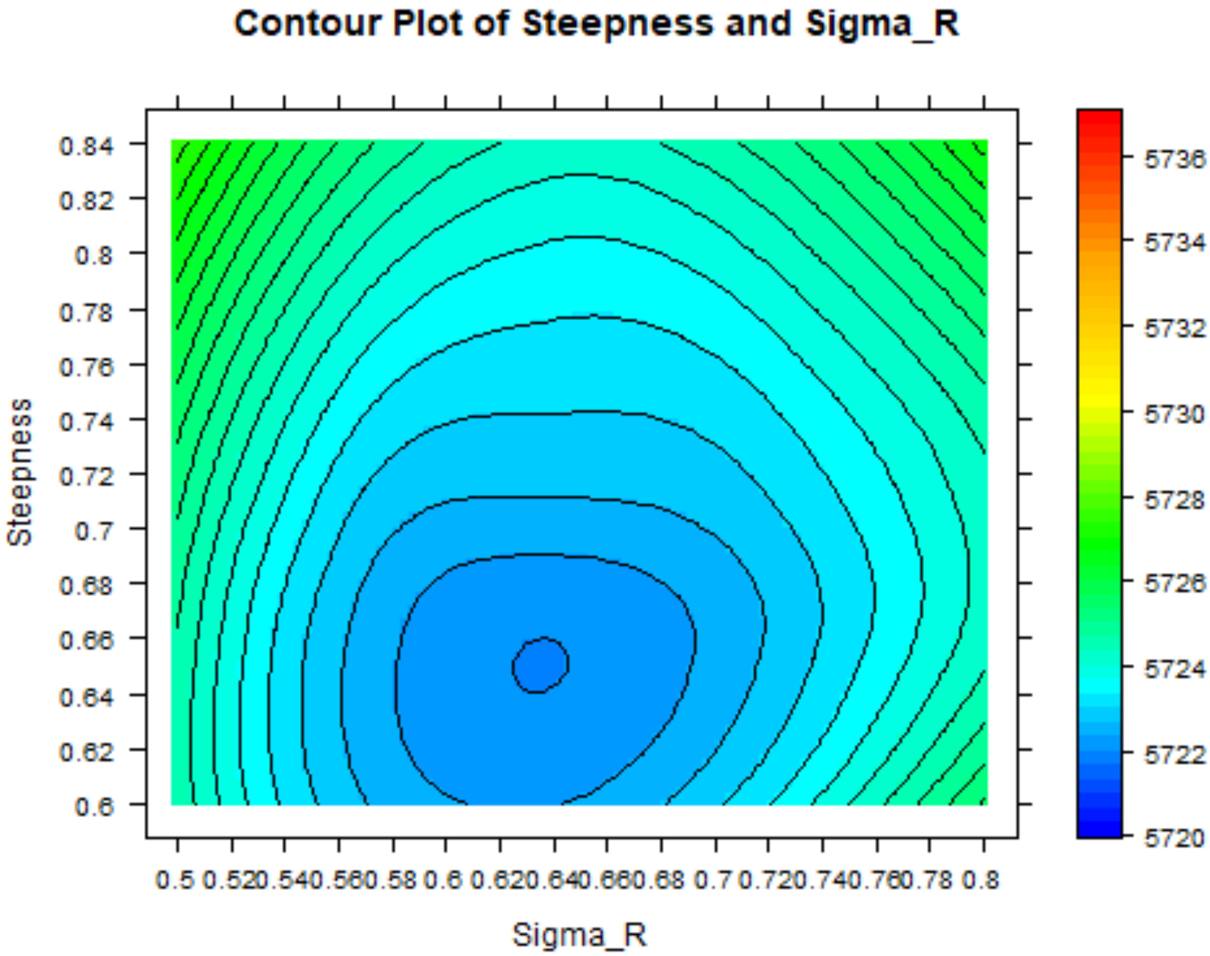


Figure 101. Bivariate likelihood profiles for steepness and recruitment variability across a range of fixed values for Gulf of Mexico Red Grouper. Contours illustrate negative log-likelihood values (lower values demonstrate stronger fit to the data).

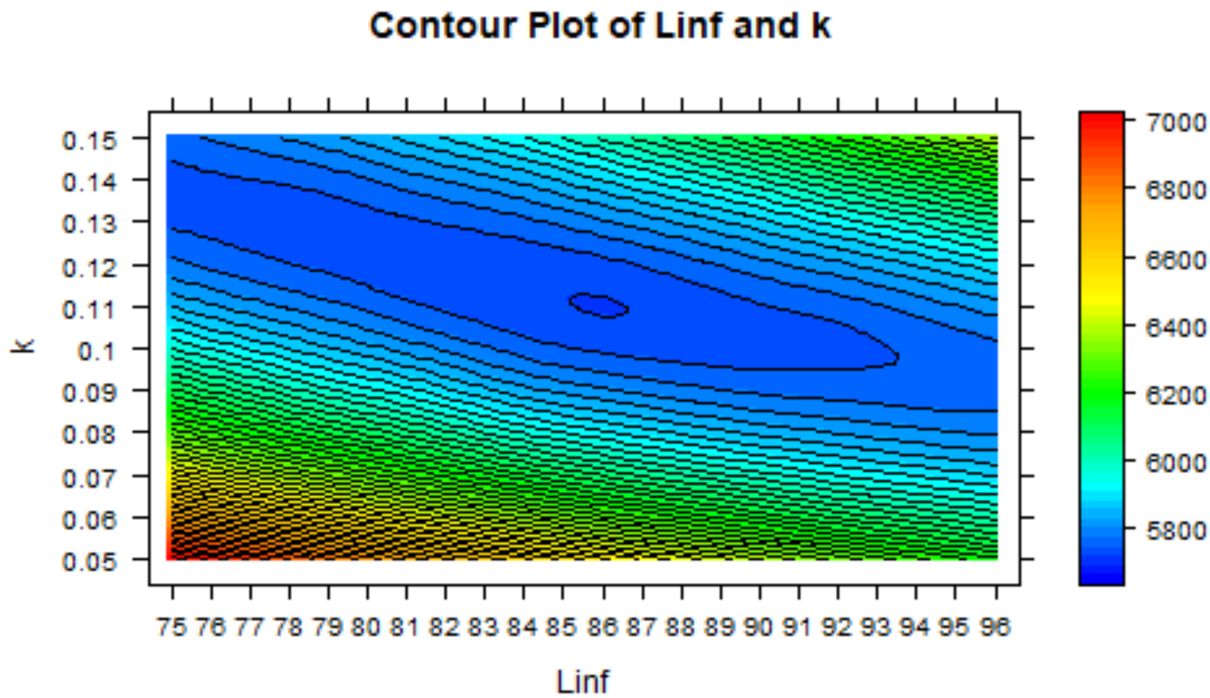


Figure 102. Bivariate likelihood profiles for Linf and k across a range of fixed values for Gulf of Mexico Red Grouper. Contours illustrate negative log-likelihood values (lower values demonstrate stronger fit to the data).

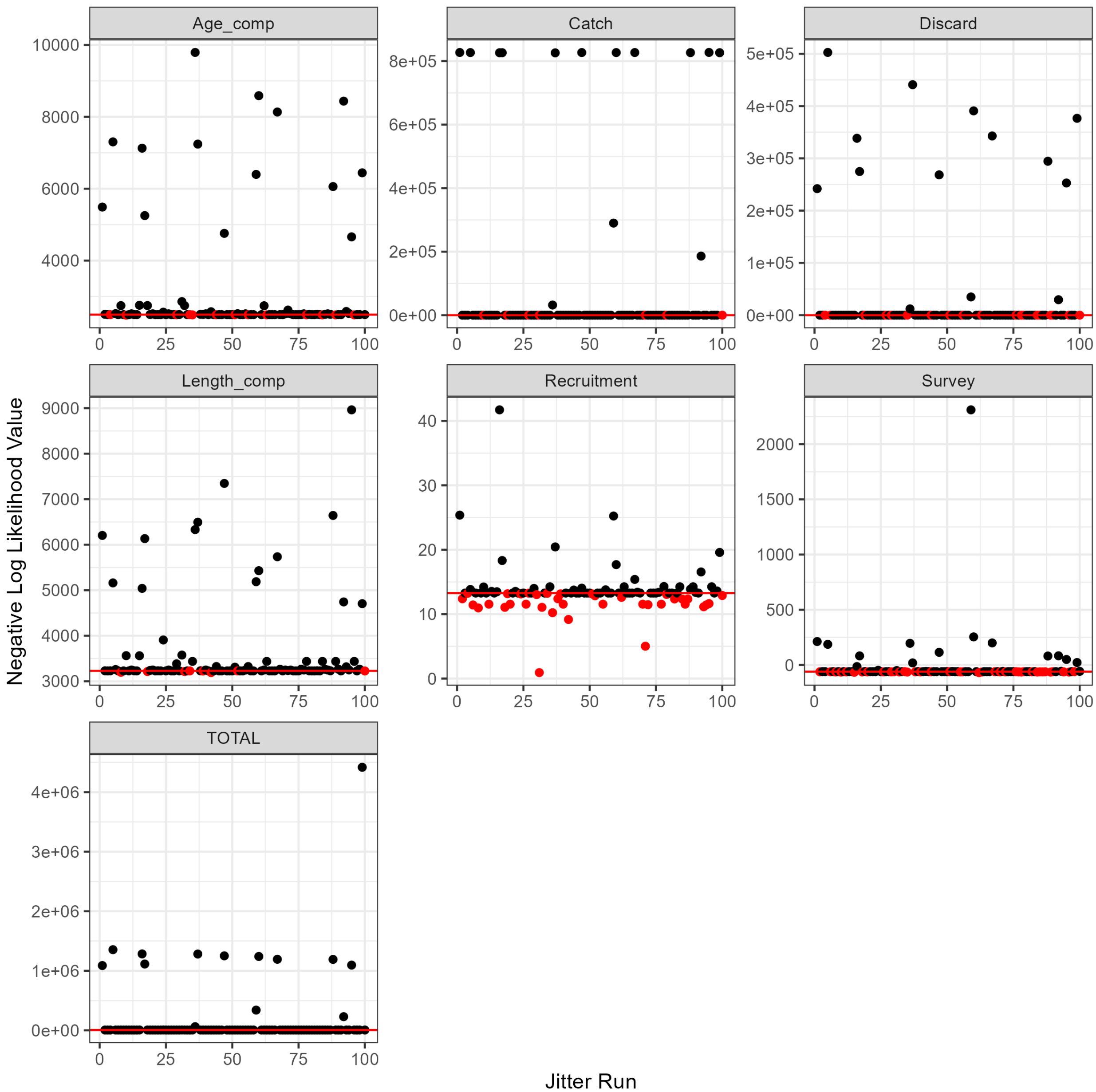


Figure 103. Results of the jitter analysis for various likelihood components for the Gulf of Mexico Red Grouper SEDAR 88 OA Base Model. Each panel gives the results of 100 model runs where the starting parameter values for each run were randomly changed ('jittered') by 10% from the base model best fit values. The Base Run value for each panel is indicated by a red line.

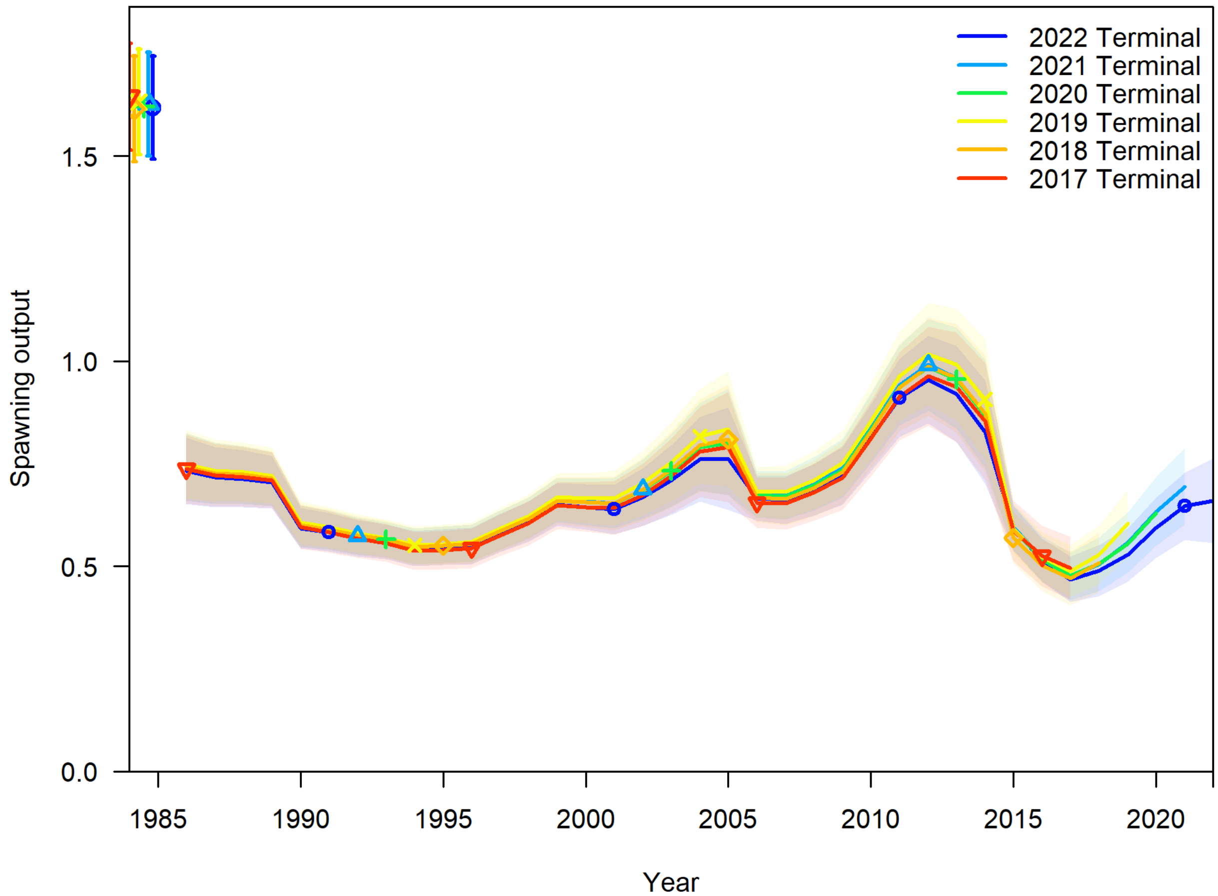


Figure 104. Results of a five year retrospective analysis for spawning biomass (relative number of eggs) for the Gulf of Mexico Red Grouper Base Model. There is no discernible systematic bias because each data peel is not consistently over or underestimating any of the population quantities.

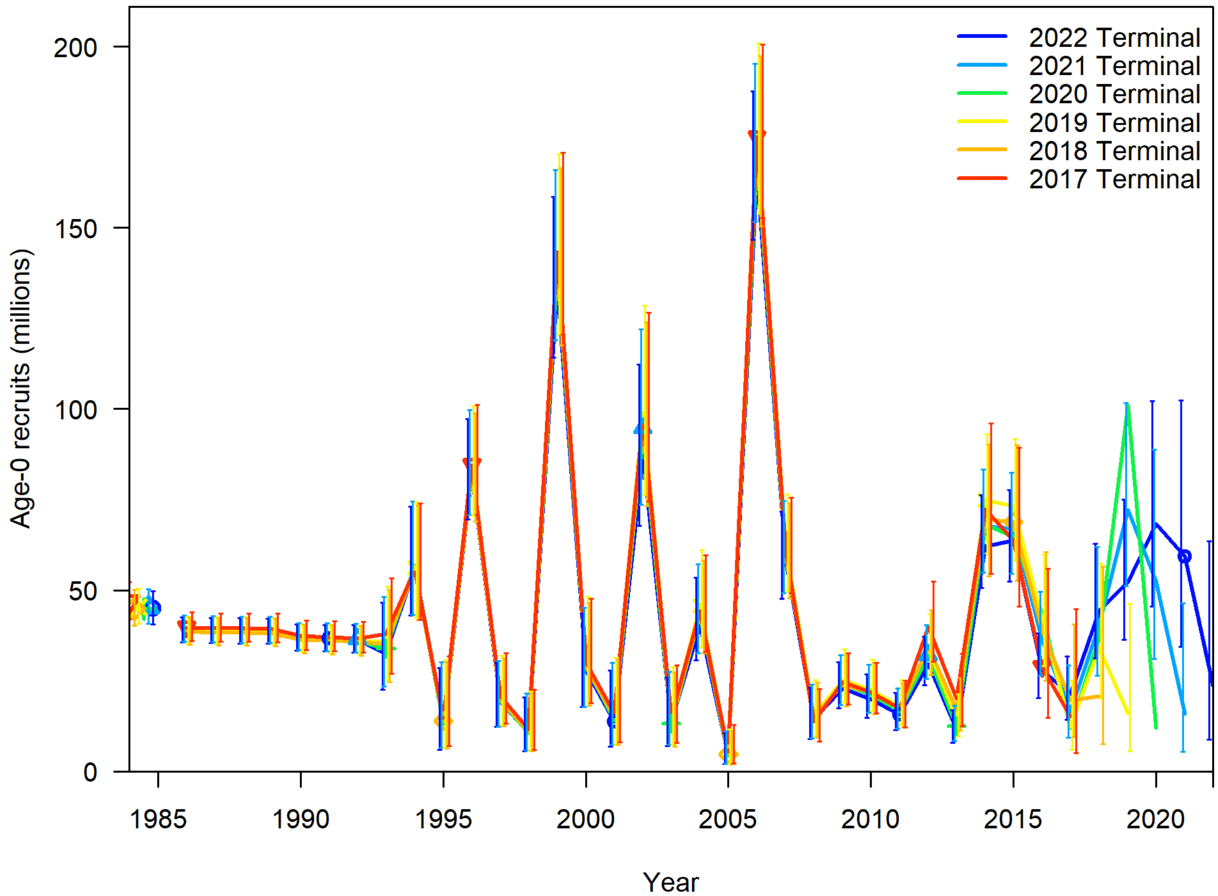


Figure 105. Results of a five year retrospective analysis for recruitment (millions of fish) for the Gulf of Mexico Red Grouper Base Model. There is no discernible systematic bias because each data peel is not consistently over or underestimating any of the population quantities.

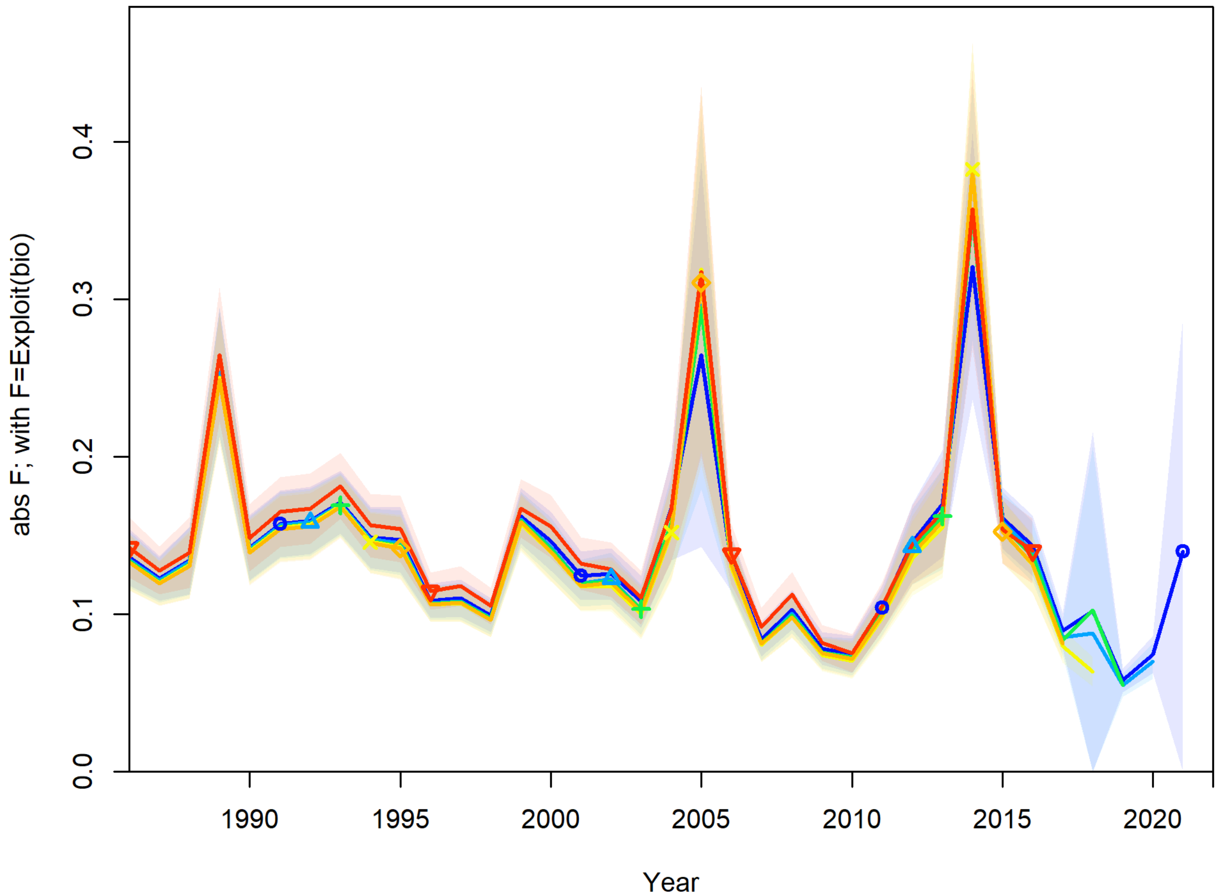


Figure 106. Results of a five year retrospective analysis for spawning biomass fishing mortality (total biomass killed all ages / total biomass age 0+) for the Gulf of Mexico Red Grouper Base Model. There is no discernible systematic bias because each data peel is not consistently over or underestimating any of the population quantities.

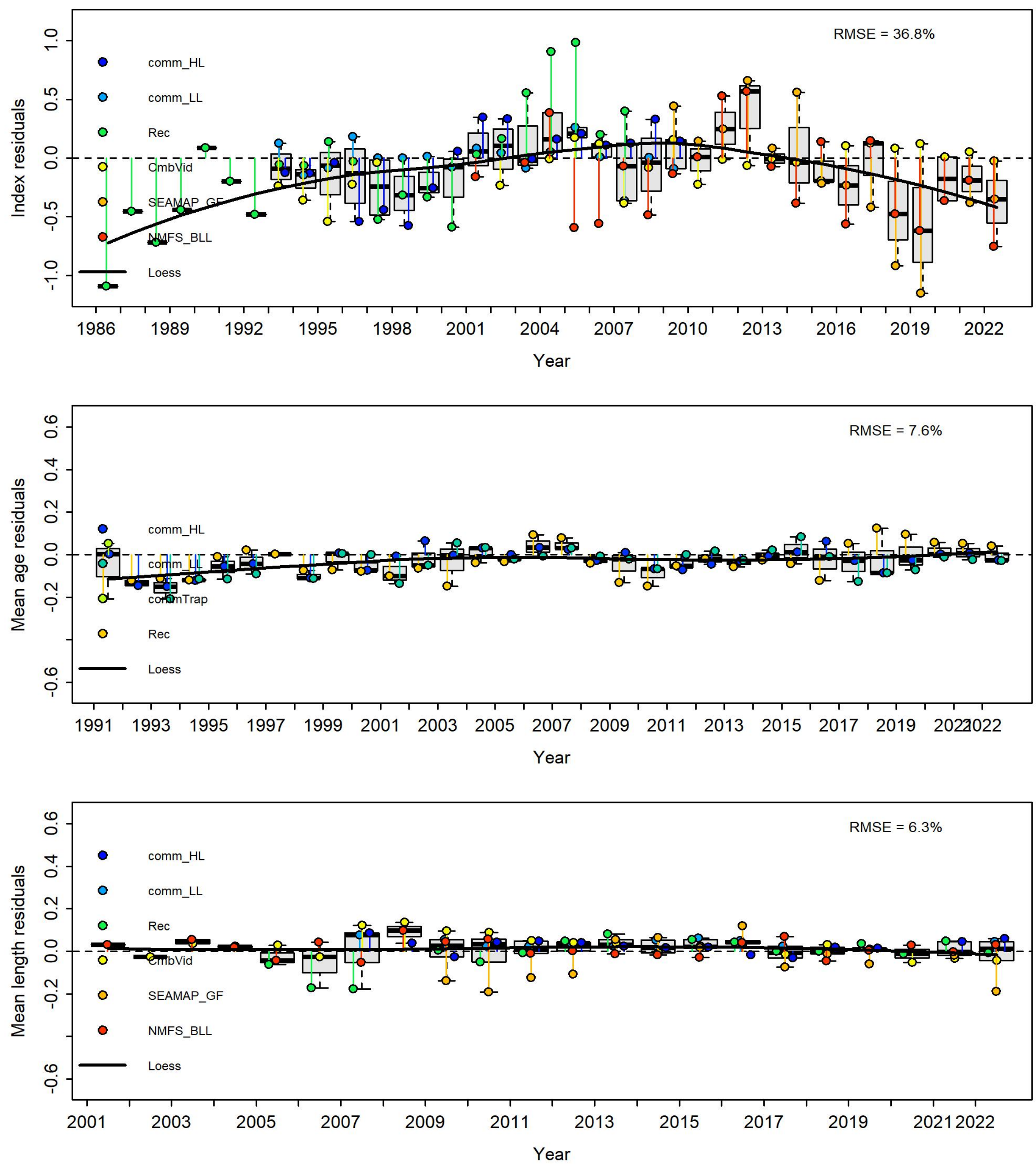


Figure 107. Joint residual plots for indices of abundance fits (top panel), annual mean age estimates (middle panel), and annual mean length estimates (bottom panel) for Gulf of Mexico Red Grouper. Vertical lines with points show the residuals (in colors by index), and solid black line reflects the loess smoother through all the residuals. Boxplots indicate the median and quantiles in cases where residuals from the multiple indices are available for any given year. Root-mean squared errors (RMSE) are included in the upper right-hand corner of each plot. See Carvalho et al. (2021) for additional details.

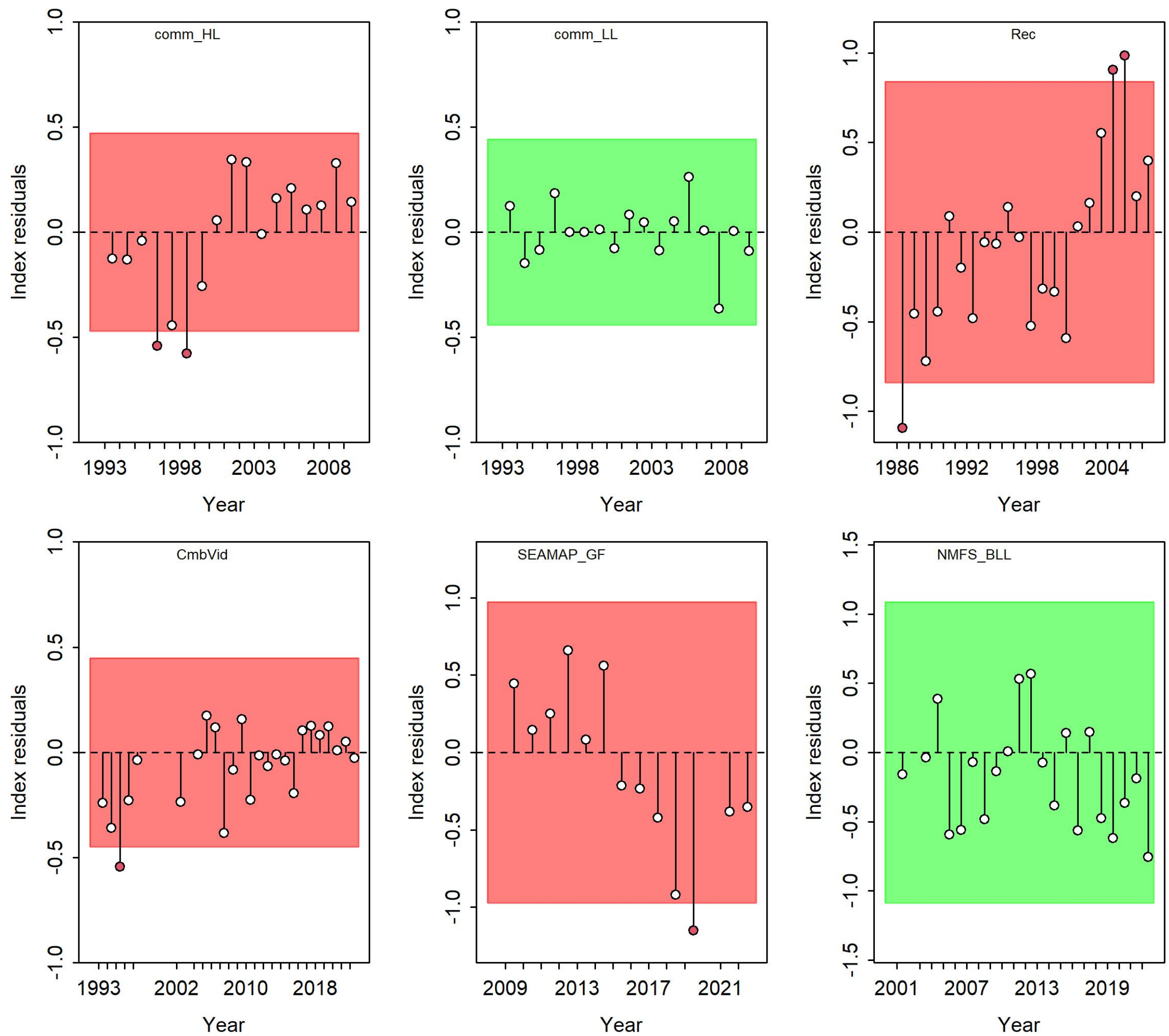


Figure 108. Runs tests results for the indices of relative abundance fits in the base model run. Green shading indicates no evidence ($p \geq 0.05$) and red shading evidence ($p < 0.05$) to reject the hypothesis of a randomly distributed time-series of residuals, respectively. The shaded (green/red) area spans three residual standard deviations to either side from zero, and the red points outside of the shading violate the 'three-sigma limit' for that series.

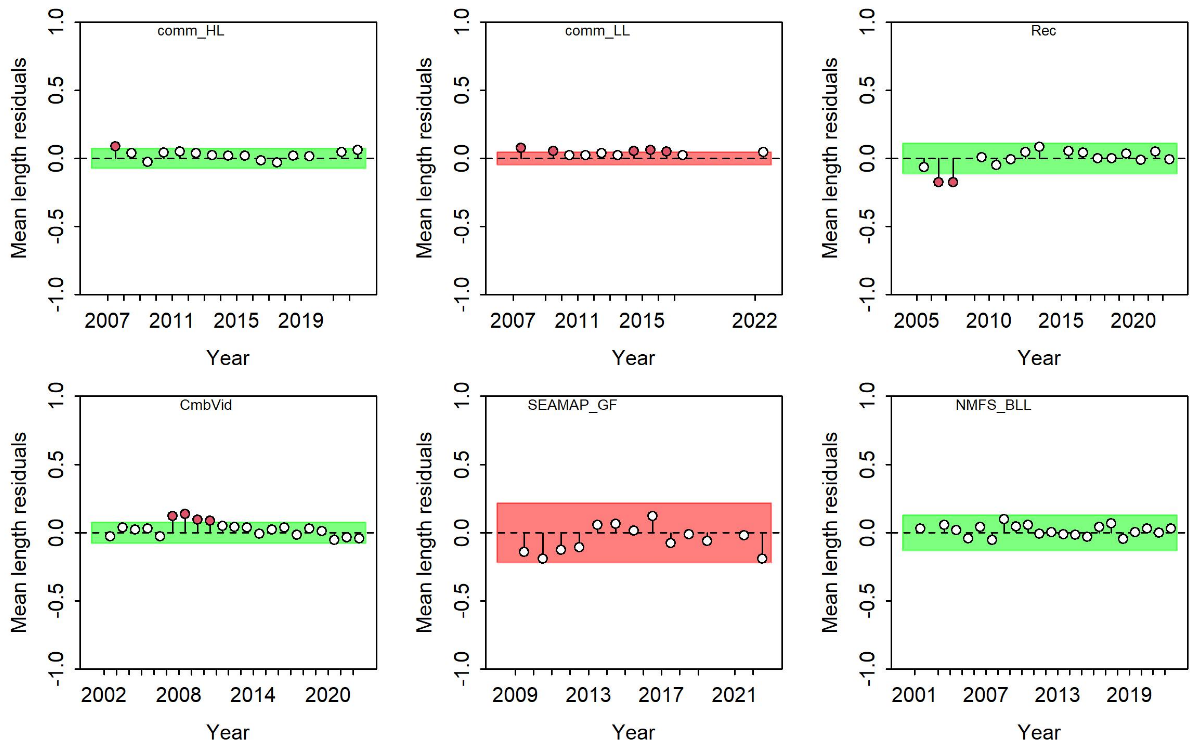


Figure 109. Runs tests results for the length composition fits in the base model run. Green shading indicates no evidence ($p \geq 0.05$) and red shading evidence ($p < 0.05$) to reject the hypothesis of a randomly distributed time-series of residuals, respectively. The shaded (green/red) area spans three residual standard deviations to either side from zero, and the red points outside of the shading violate the 'three-sigma limit' for that series.

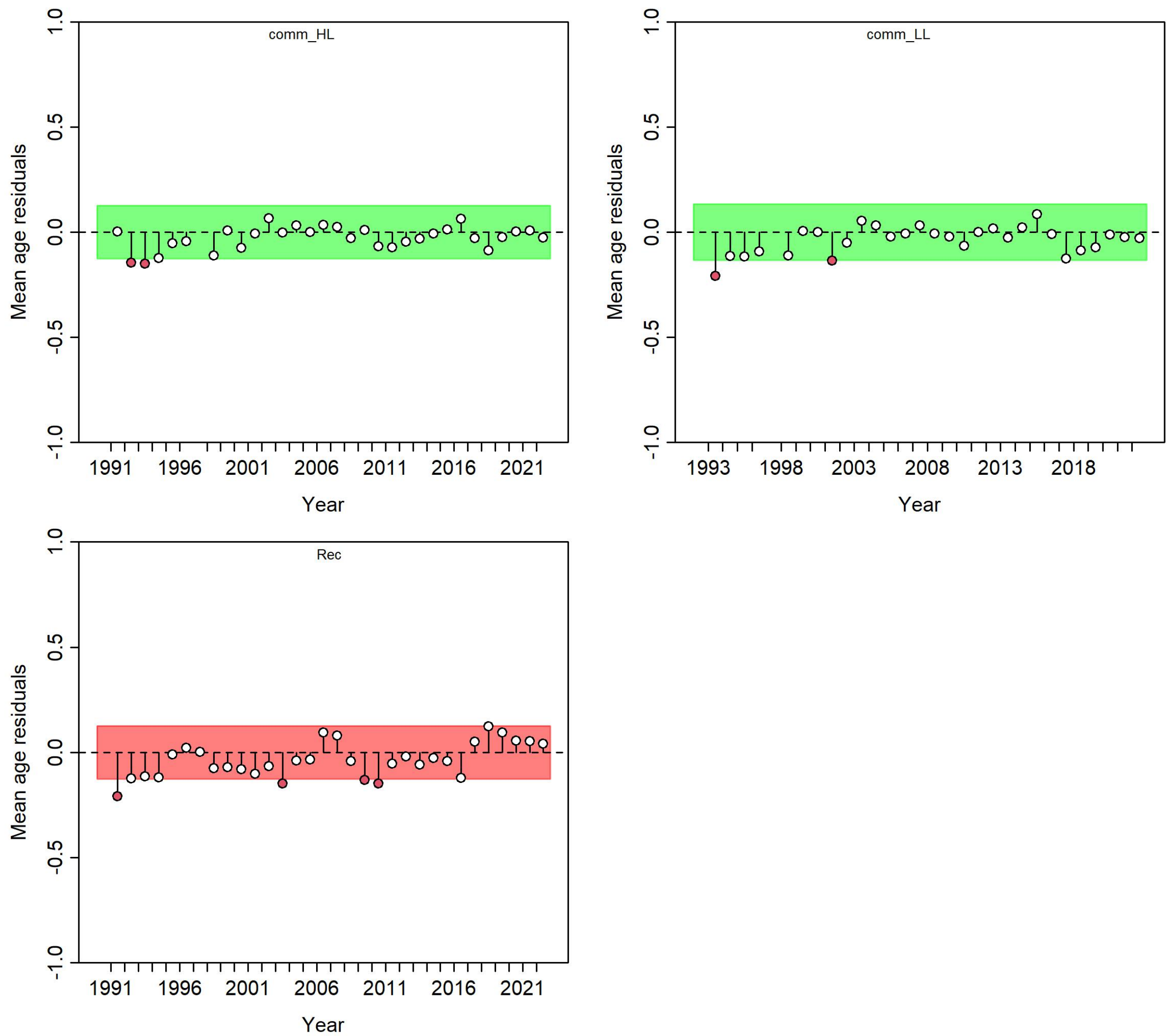


Figure 110. Runs tests results for the age composition fits in the base model run. Green shading indicates no evidence (p ≥ 0.05) and red shading evidence (p < 0.05) to reject the hypothesis of a randomly distributed time-series of residuals, respectively. The shaded (green/red) area spans three residual standard deviations to either side from zero, and the red points outside of the shading violate the 'three-sigma limit' for that series.

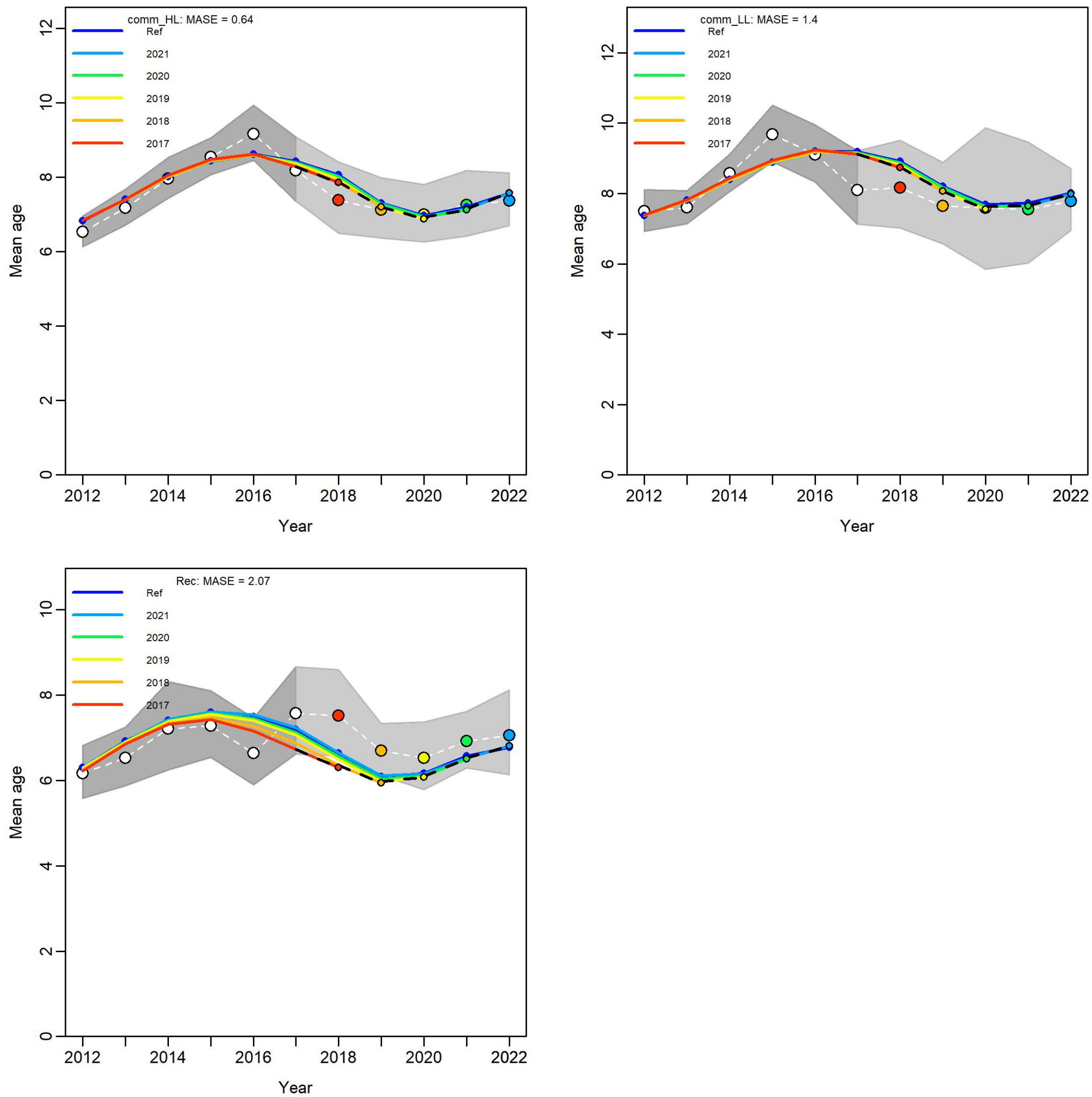


Figure 111. Hindcasting cross-validation (HCxval) results for Commercial Handline, Commercial Longline, and Recreational age composition fits, showing observed (large points connected with dashed line), fitted (solid lines) and one-year-ahead forecast values (small terminal points). HCxval was performed using one reference model (Ref) and five hindcast model runs (solid lines) relative to the expected catch-per-unit-effort. The observations used for cross-validation are highlighted as color-coded solid circles with associated 95 % confidence intervals (light-gray shading). The model reference year refers to the endpoints of each one-year-ahead forecast and the corresponding observation (i.e., year of peel + 1). The mean absolute scaled error (MASE) score associated with each CPUE and size composition time series is denoted in each panel.

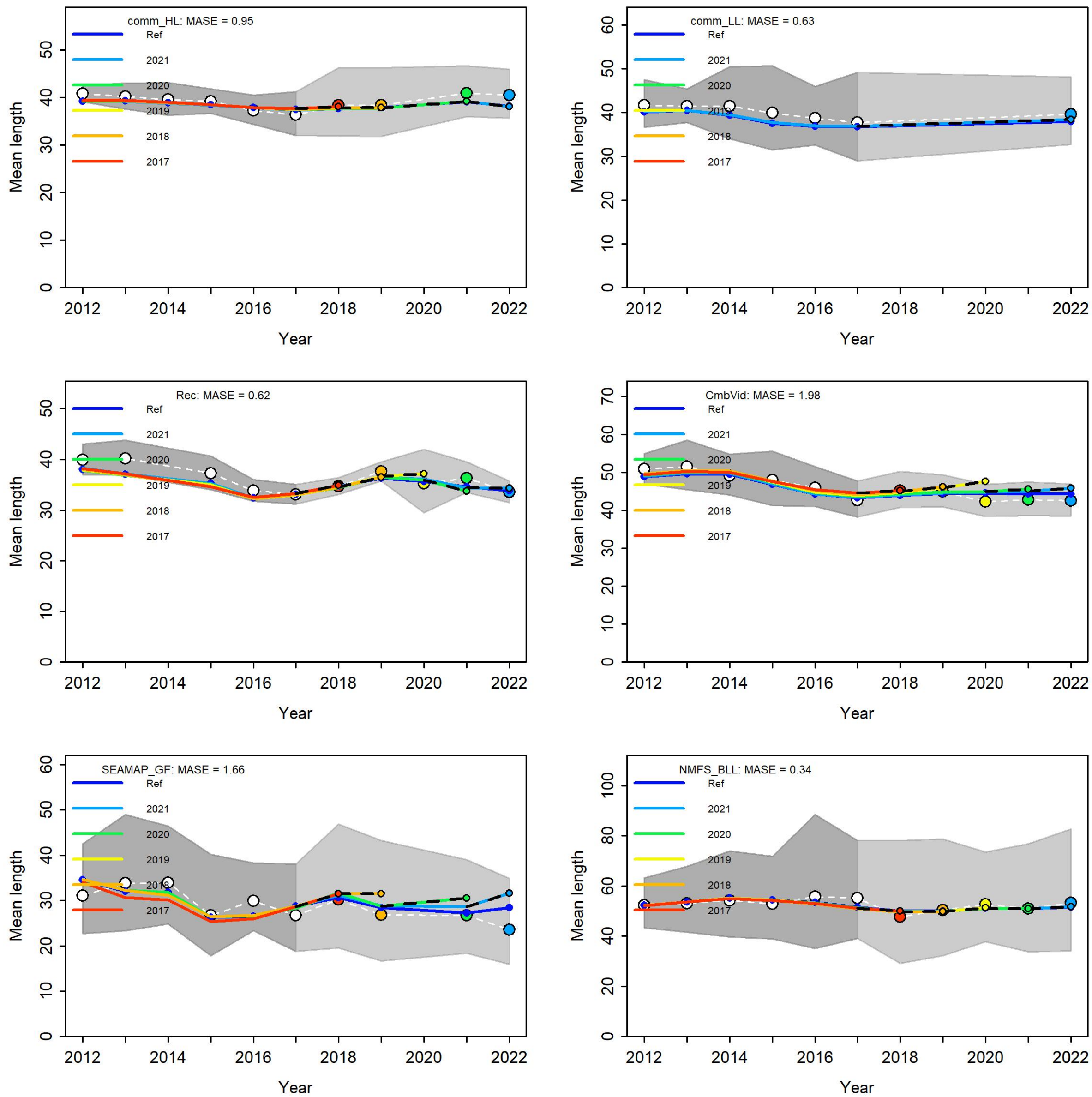


Figure 112. Hindcasting cross-validation (HCxval) results for Commercial Handline, Commercial Longline, Recreational, Combined Video Survey, SEAMAP Summer Groundfish Survey, and NMFS Bottom Longline length composition fits, showing observed (large points connected with dashed line), fitted (solid lines) and one-year-ahead forecast values (small terminal points). HCxval was performed using one reference model (Ref) and five hindcast model runs (solid lines) relative to the expected catch-per-unit-effort. The observations used for cross-validation are highlighted as color-coded solid circles with associated 95 % confidence intervals (light-gray shading). The model reference year refers to the endpoints of each one-year-ahead forecast and the corresponding observation (i.e., year of peel + 1). The mean absolute scaled error (MASE) score associated with each CPUE and size composition time series is denoted in each panel.

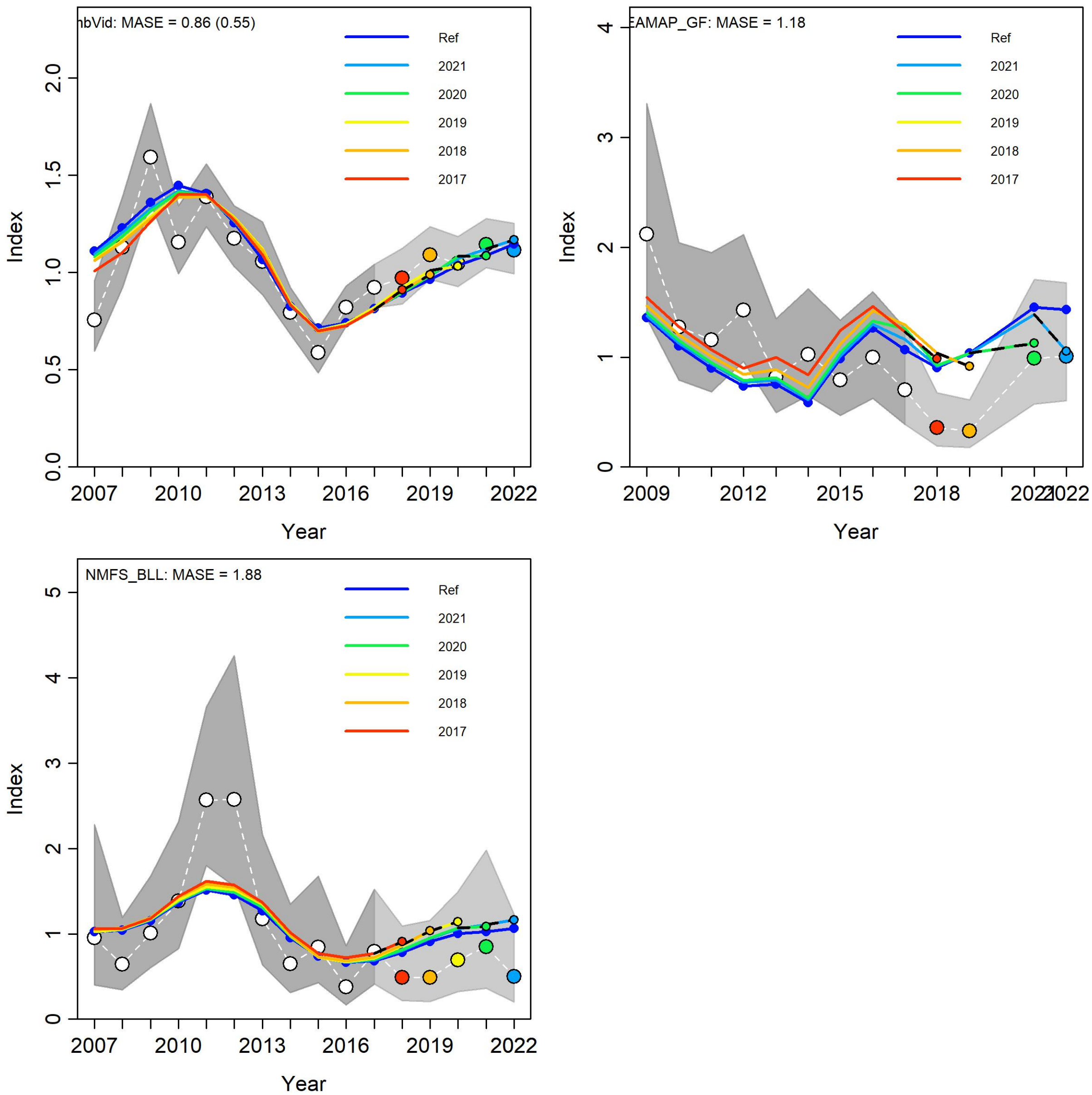


Figure 113. Hindcasting cross-validation (HCxval) results for the Combined Video Survey, SEAMAP Summer Groundfish Survey, and NMFS Bottom Longline Survey index fits, showing observed (large points connected with dashed line), fitted (solid lines) and one-year-ahead forecast values (small terminal points). HCxval was performed using one reference model (Ref) and five hindcast model runs (solid lines) relative to the expected catch-per-unit-effort. The observations used for cross-validation are highlighted as color-coded solid circles with associated 95 % confidence intervals (light-gray shading). The model reference year refers to the endpoints of each one-year-ahead forecast and the corresponding observation (i.e., year of peel + 1). The mean absolute scaled error (MASE) score associated with each CPUE and size composition time series is denoted in each panel.

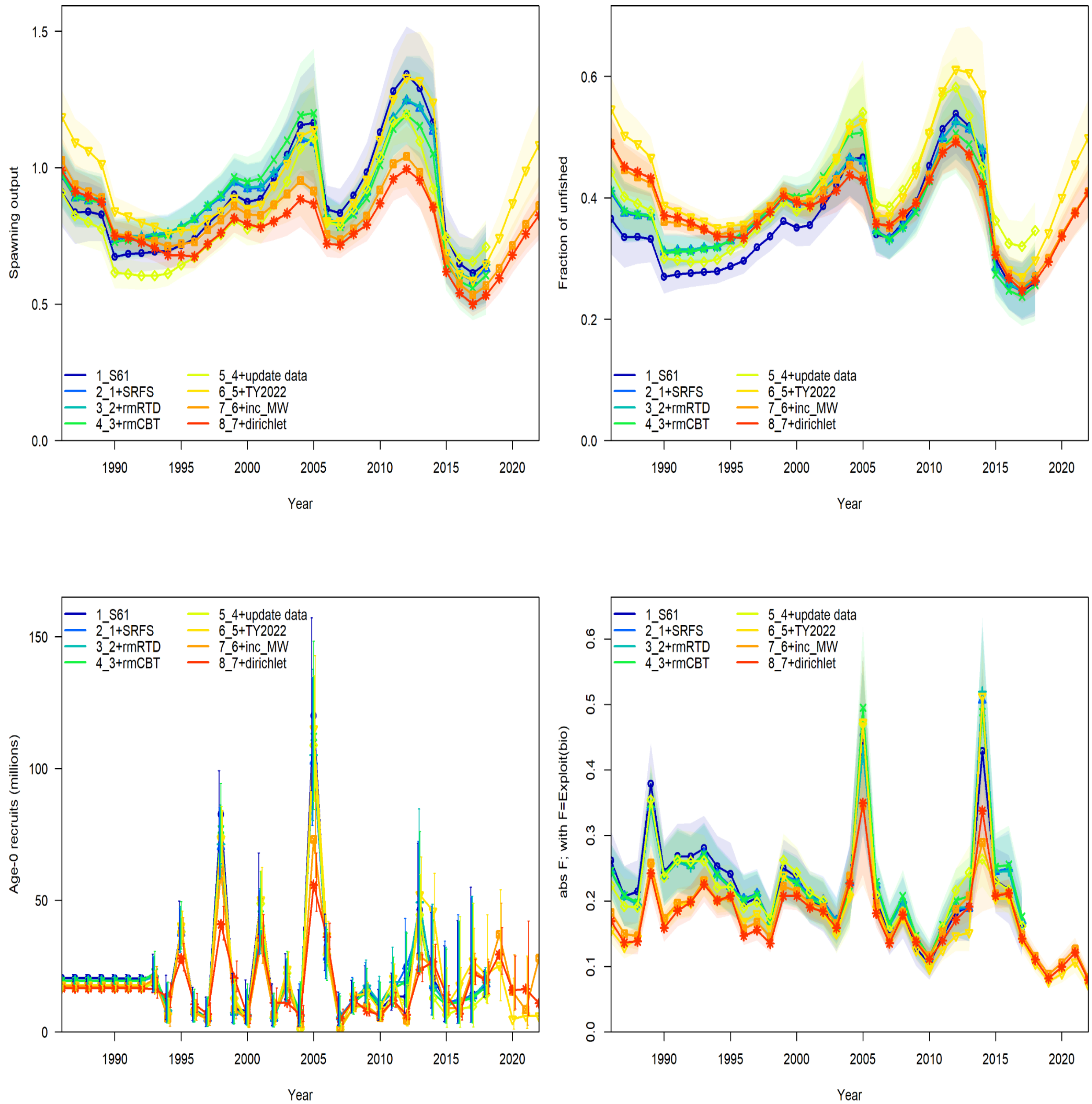


Figure 114. Bridging analysis showing data changes in estimates of spawning stock biomass (relative number of eggs; top left panel), the ratio of SSB to virgin SSB (top right panel), recruitment (millions of fish; bottom left panel), and fishing mortality (total biomass killed all ages / total biomass age 0+; bottom right panel) and associated uncertainty through each major data change step of model building between the SEDAR 61 Standard Base Model (Step 1) and up to (Step 8).

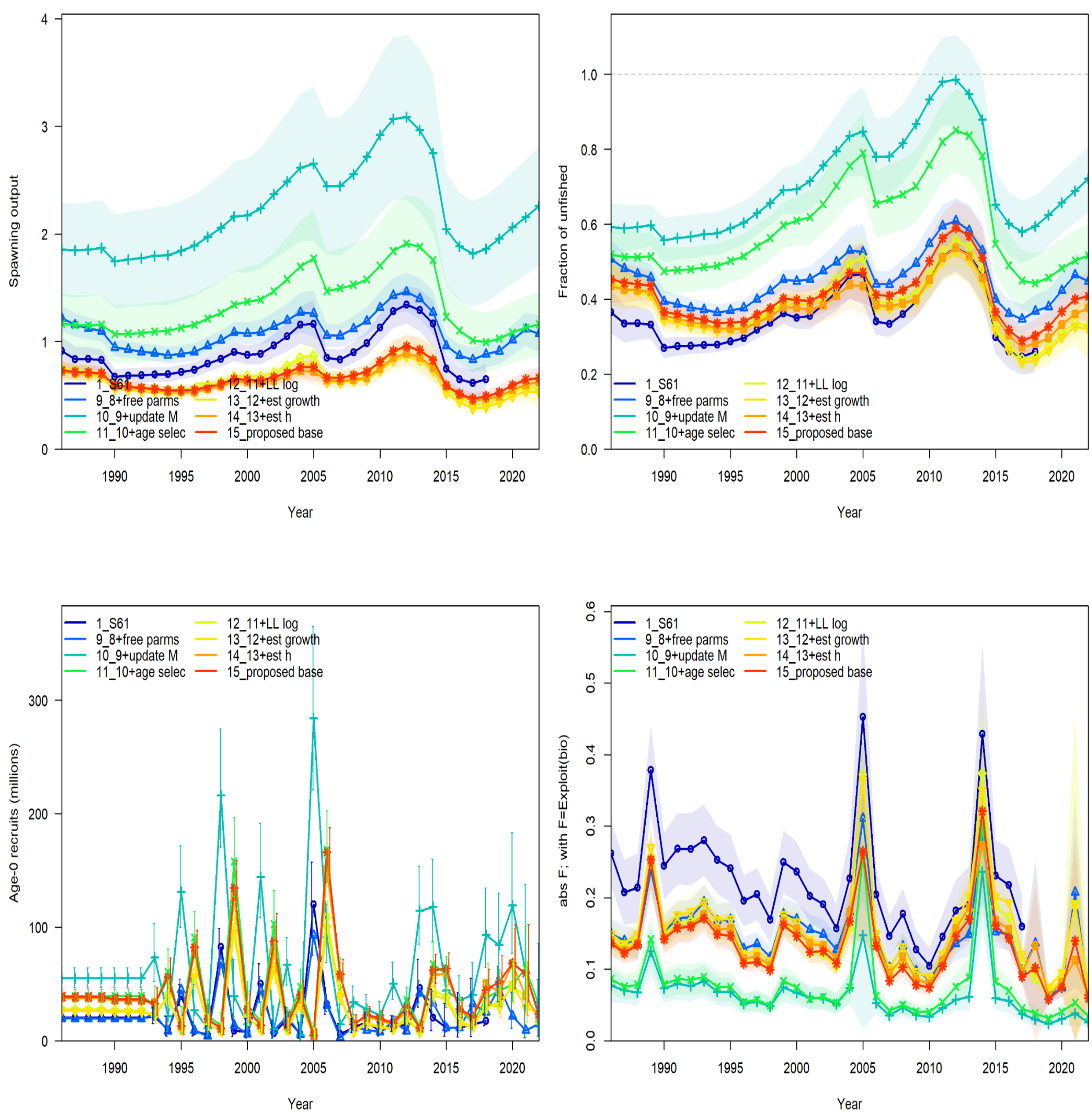


Figure 115. Bridging analysis showing model configuration changes in estimates of spawning stock biomass (relative number of eggs `; top left panel), the ratio of SSB to virgin SSB (top right panel), recruitment (millions of fish; bottom left panel), and fishing mortality (total biomass killed all ages / total biomass age 0+; bottom right panel) and associated uncertainty through each major step of model building between the SEDAR 61 Standard Base Model (Step 1) and the SEDAR 88 OA Base Model (Step 15).

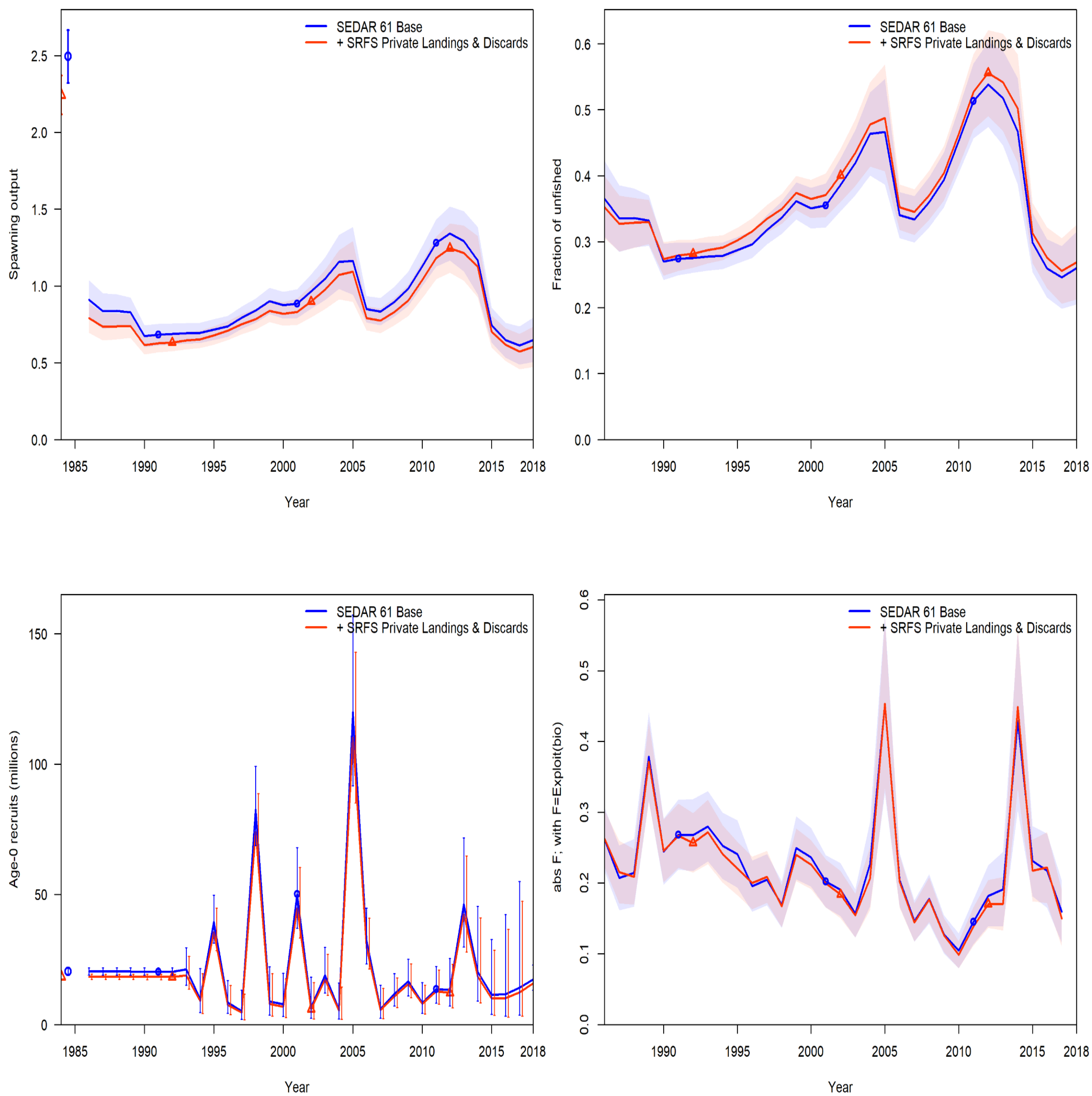


Figure 116. Estimates of spawning stock biomass (relative number of eggs; top left panel), the ratio of SSB to virgin SSB (top right panel), recruitment (millions of fish; bottom left panel), and fishing mortality (total biomass killed all ages / total biomass age 0+; bottom right panel) for the sensitivity run using the recreational private mode SRFS landings and discard estimates in SEDAR 61 for Gulf of Mexico Red Grouper.

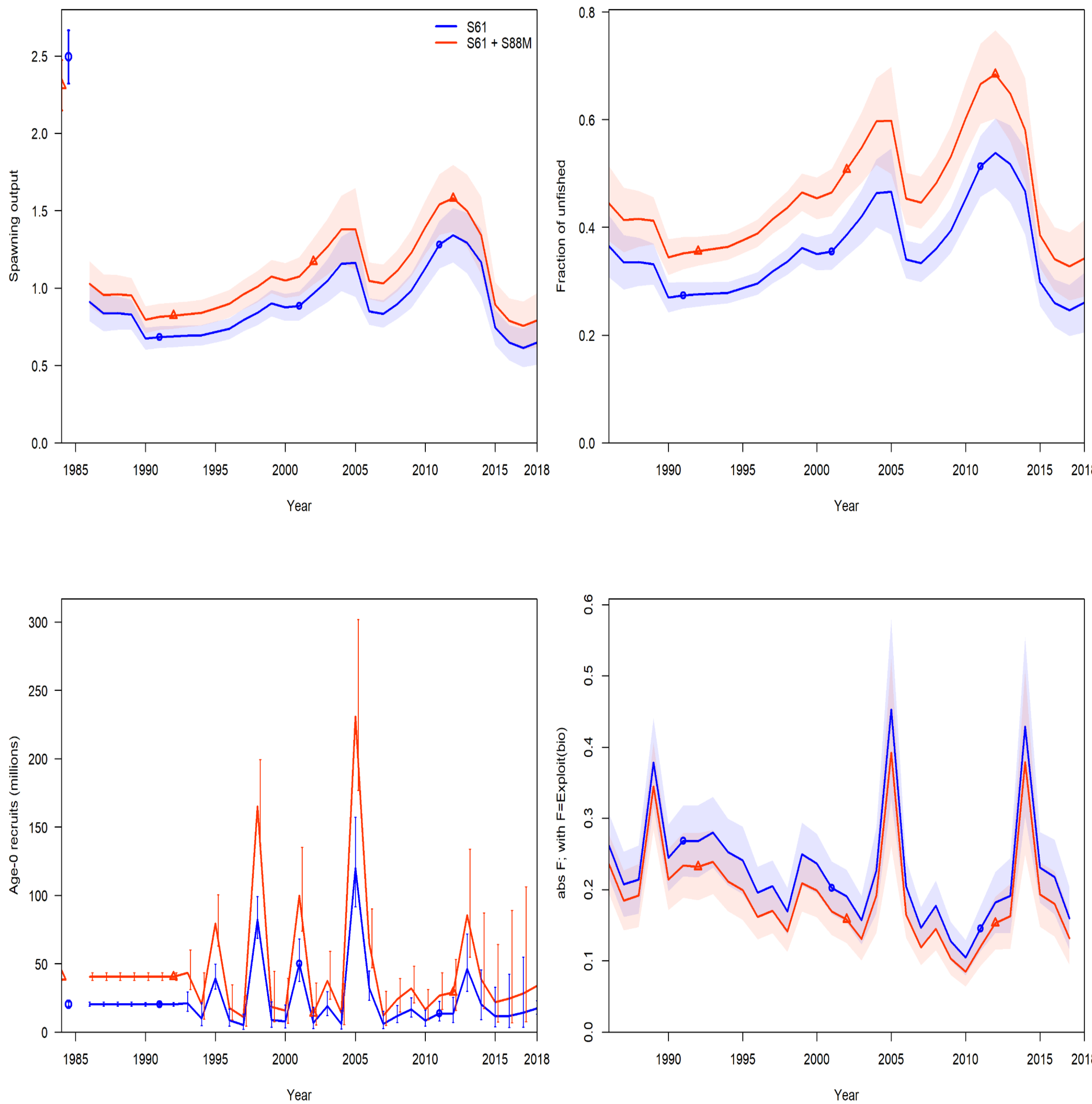


Figure 117. Estimates of spawning stock biomass (relative number of eggs; top left panel), the ratio of SSB to virgin SSB (top right panel), recruitment (millions of fish; bottom left panel), and fishing mortality (total biomass killed all ages / total biomass age 0+; bottom right panel) for the sensitivity run using the SEDAR 88 OA Base Model updated M point estimate in the SEDAR 61 Base Model for Gulf of Mexico Red Grouper.

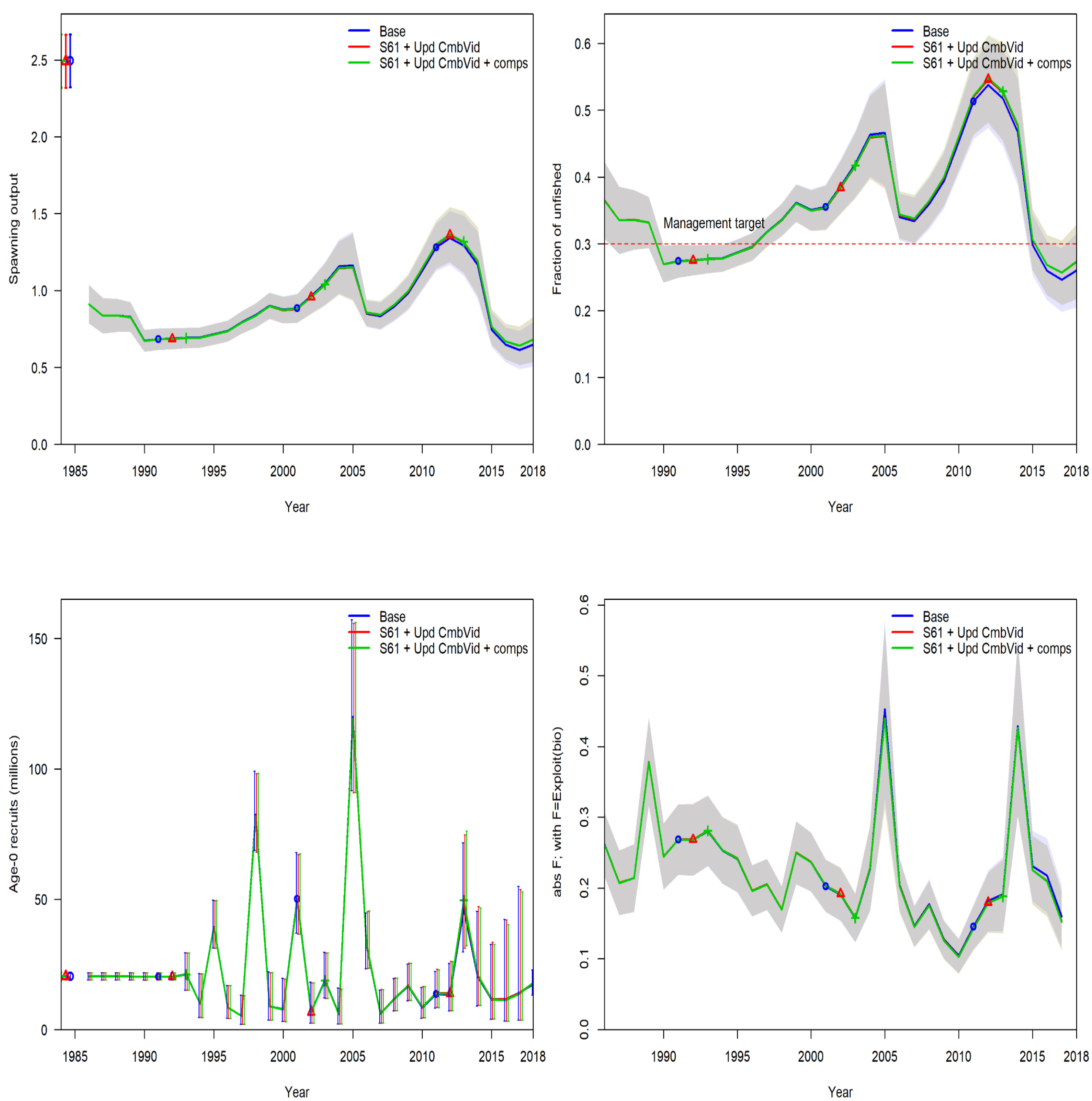


Figure 118. Estimates of spawning stock biomass (relative number of eggs; top left panel), the ratio of SSB to virgin SSB (top right panel), recruitment (millions of fish; bottom left panel), and fishing mortality (total biomass killed all ages / total biomass age 0+; bottom right panel) for the sensitivity run replacing the Combined Video Survey in SEDAR 61 with the Combined Video Survey index updated and used in SEDAR 88.

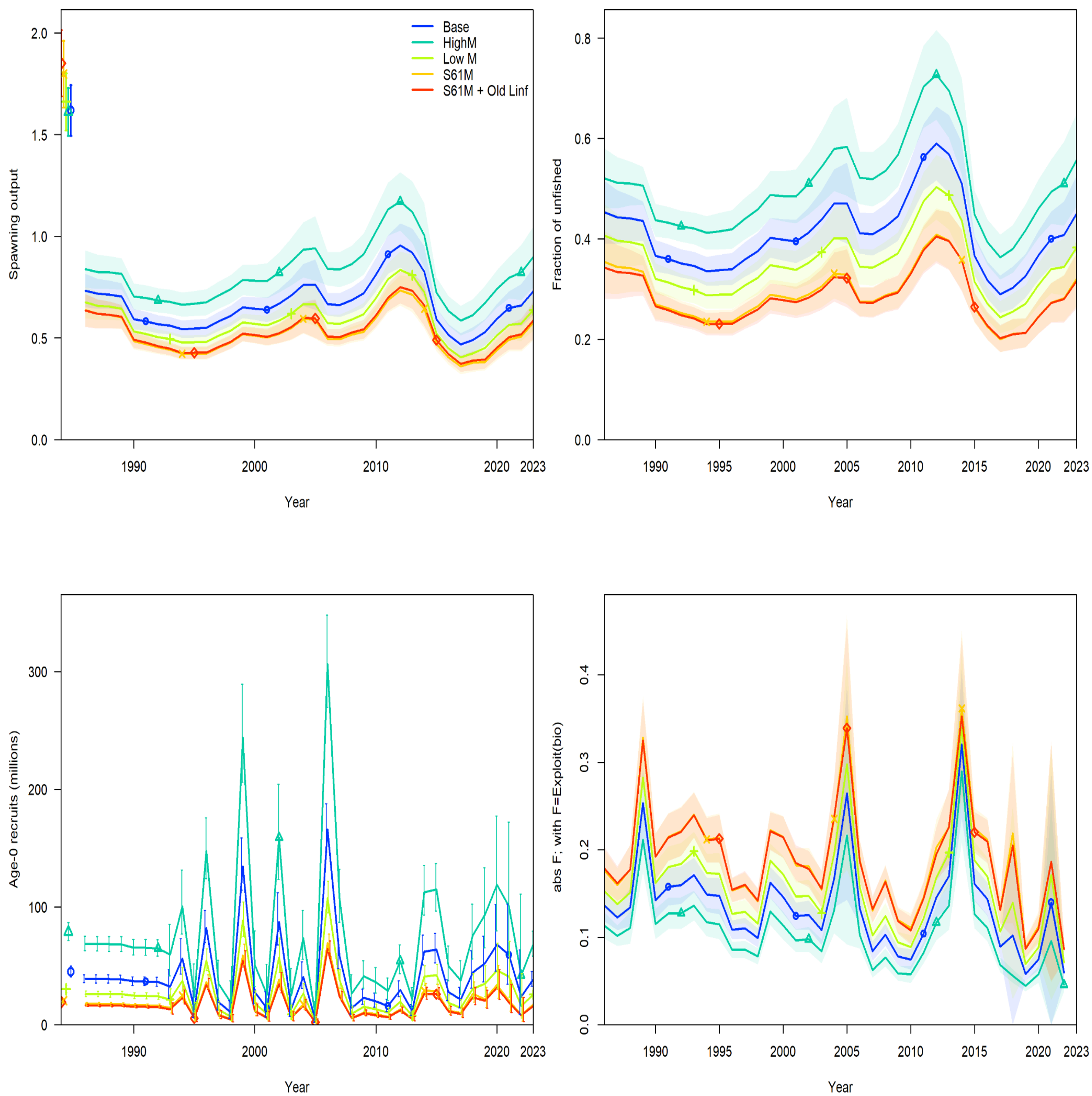


Figure 119. Estimates of spawning stock biomass (relative number of eggs; top left panel), the ratio of SSB to virgin SSB (top right panel), recruitment (millions of fish; bottom left panel), and fishing mortality (total biomass killed all ages / total biomass age 0+; bottom right panel) for the sensitivity run applying the high and low natural mortality estimates as well as the natural mortality vector from SEDAR 61 to the SEDAR 88 OA Base Model for Gulf of Mexico Red Grouper.

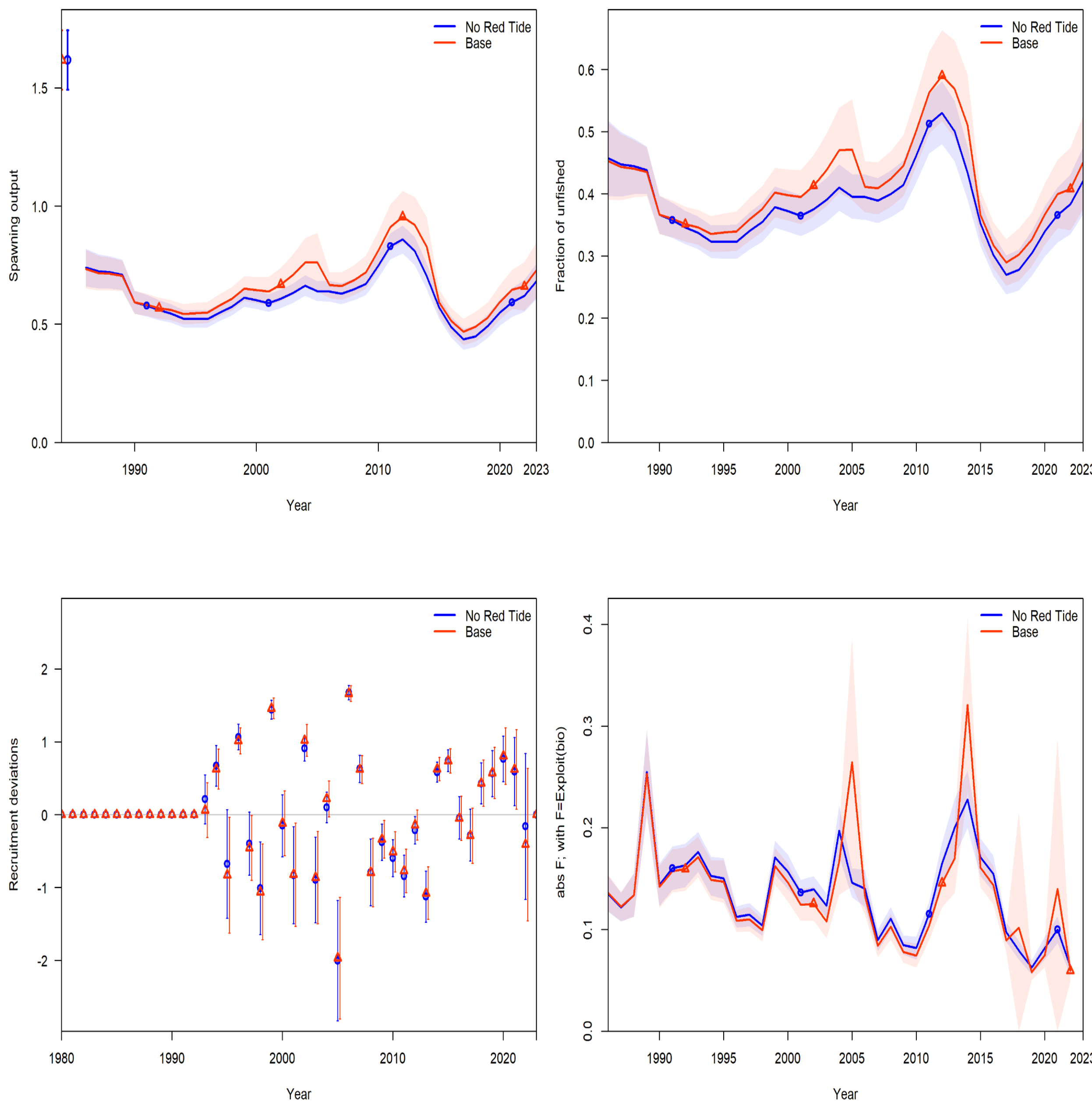


Figure 120. Estimates of spawning stock biomass (relative number of eggs; top left panel), the ratio of SSB to virgin SSB (top right panel), recruitment deviations (bottom left panel), and fishing mortality (total biomass killed all ages / total biomass age 0+; bottom right panel) for the sensitivity run removing red tide from the SEDAR 88 OA Base Model for Gulf of Mexico Red Grouper.

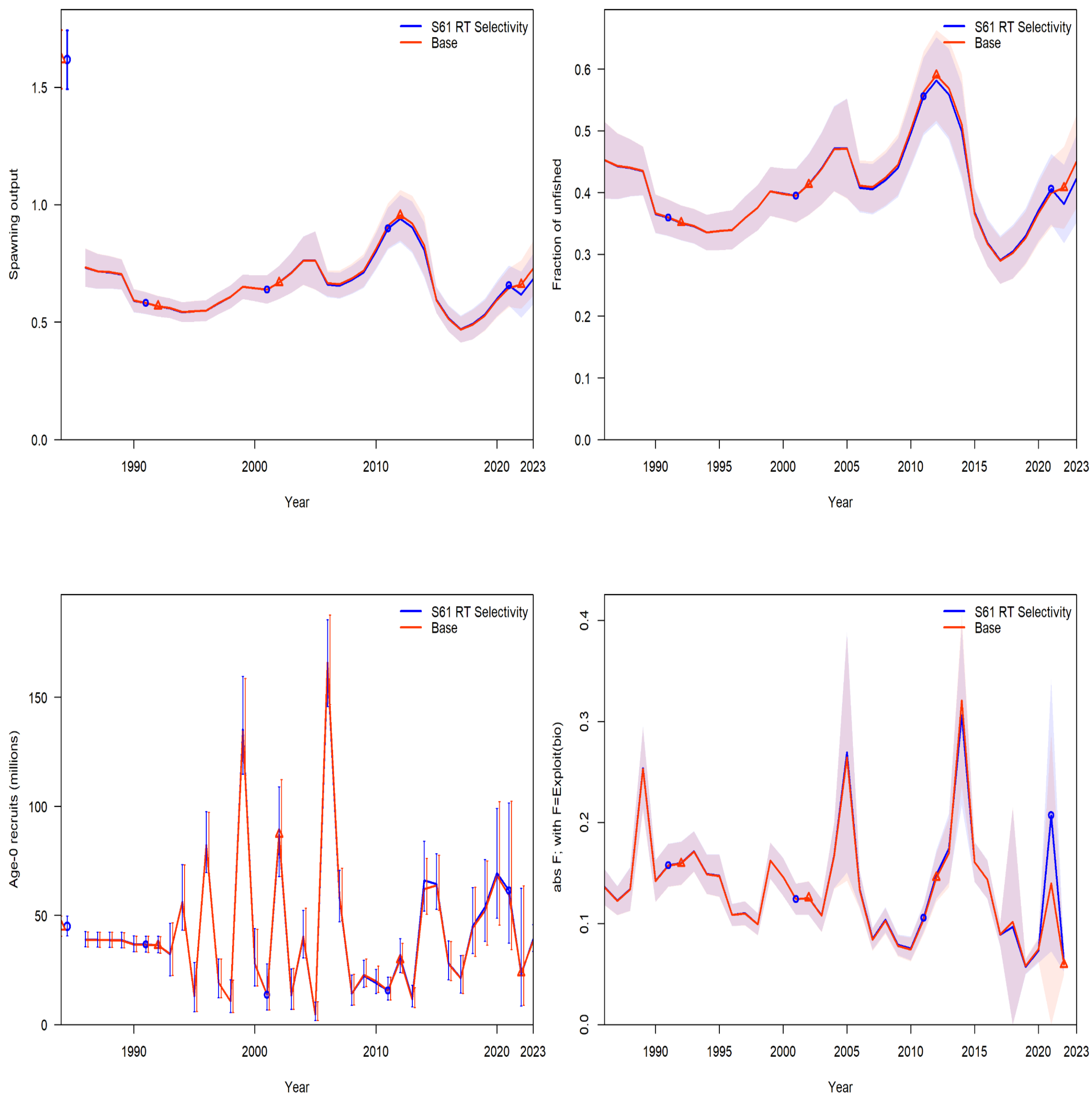


Figure 121. Estimates of spawning stock biomass (relative number of eggs; top left panel), the ratio of SSB to virgin SSB (top right panel), recruitment (millions of fish; bottom left panel), and fishing mortality (total biomass killed all ages / total biomass age 0+; bottom right panel) for the sensitivity run using the red tide selectivity approach from the SEDAR 61 Standard Base Model for Gulf of Mexico Red Grouper.

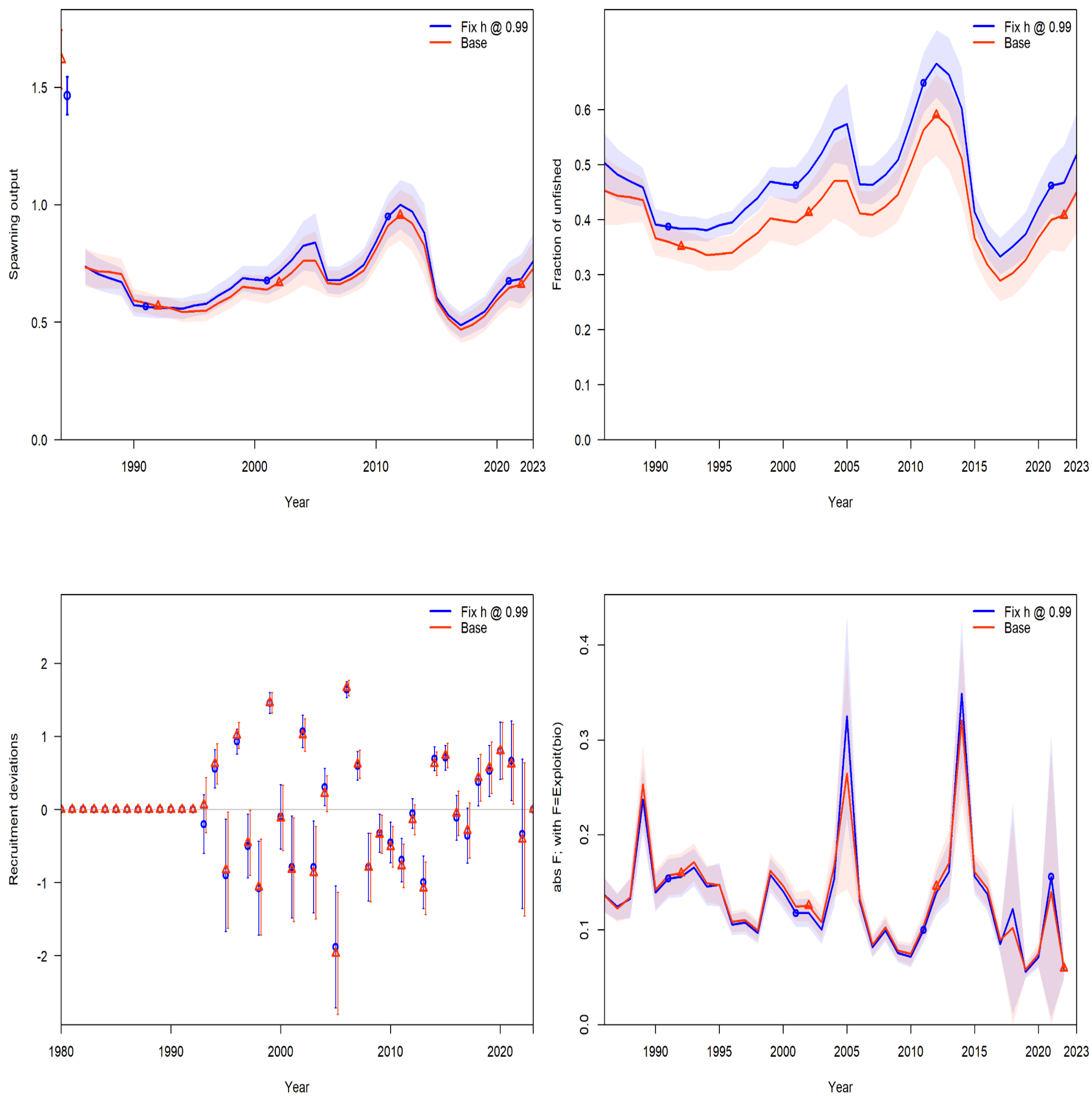


Figure 122. Estimates of spawning stock biomass (relative number of eggs; top left panel), the ratio of SSB to virgin SSB (top right panel), recruitment deviations (bottom left panel), and fishing mortality (total biomass killed all ages / total biomass age 0+; bottom right panel) for the sensitivity run fixing steepness at the upper bound.

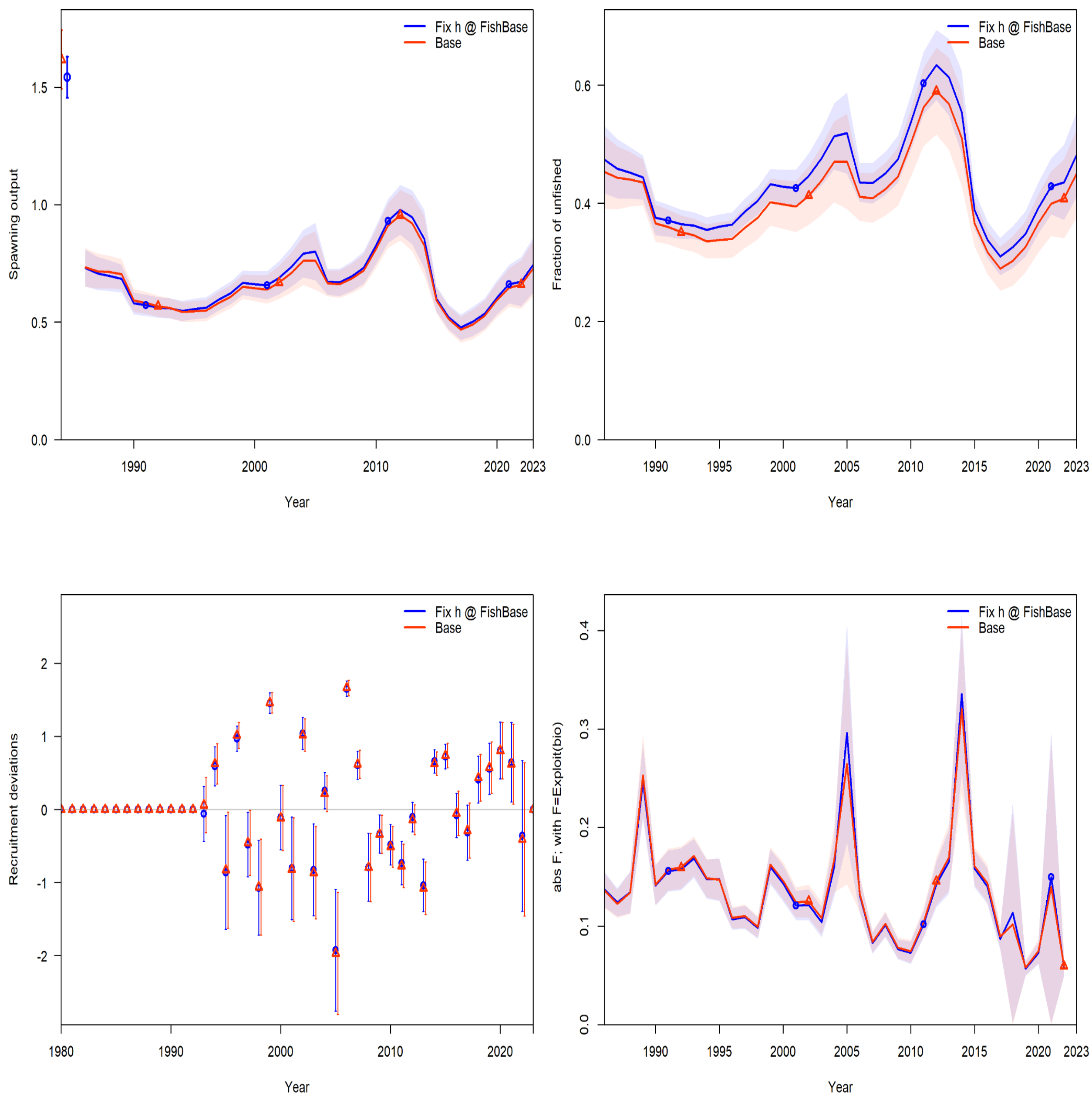


Figure 123. Estimates of spawning stock biomass (relative number of eggs; top left panel), the ratio of SSB to virgin SSB (top right panel), recruitment deviations (bottom left panel), and fishing mortality (total biomass killed all ages / total biomass age 0+; bottom right panel) for the sensitivity run using a fixed value of 0.78 obtained from FishLife for steepness.

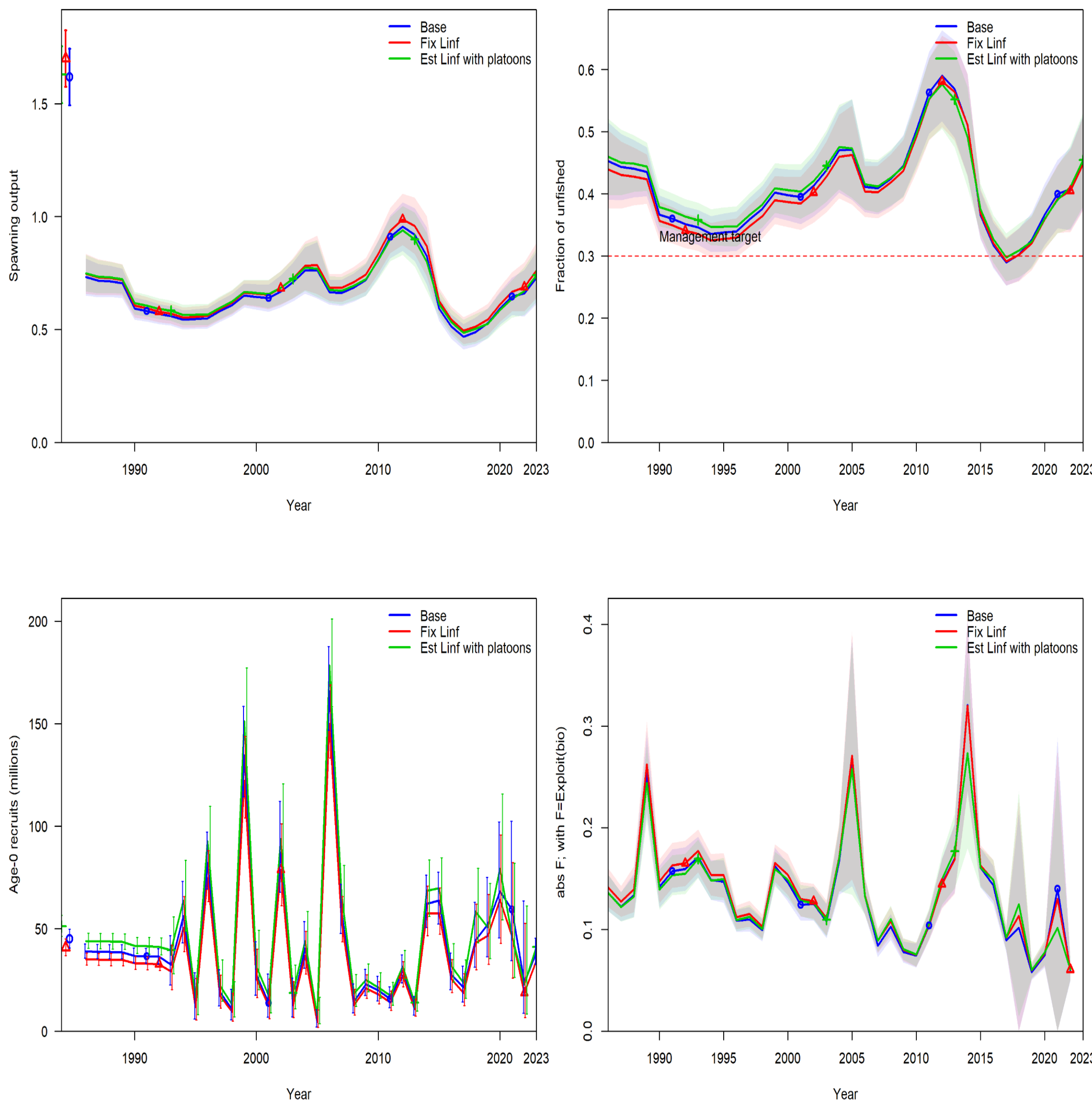


Figure 124. Estimates of spawning stock biomass (relative number of eggs; top left panel), the ratio of SSB to virgin SSB (top right panel), recruitment (millions of fish; bottom left panel), and fishing mortality (total biomass killed all ages / total biomass age 0+; bottom right panel) for the sensitivity runs estimating growth with platoons and fixing growth.

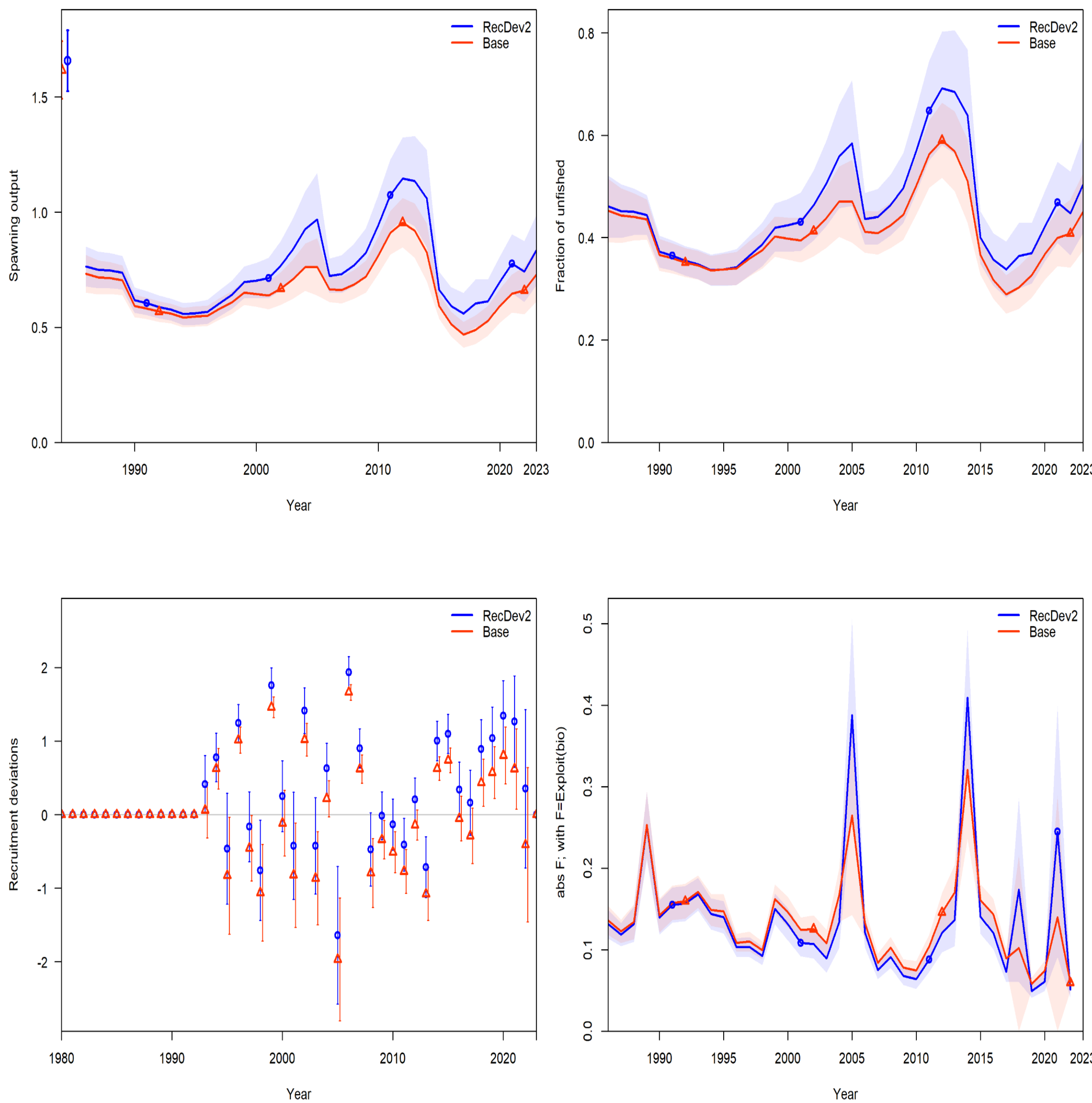


Figure 125. Estimates of spawning stock biomass (relative number of eggs; top left panel), the ratio of SSB to virgin SSB (top right panel), recruitment deviations (bottom left panel), and fishing mortality (total biomass killed all ages / total biomass age 0+; bottom right panel) for the sensitivity run using recruitment deviation method 2 in place of constraining recruitment deviations to sum to zero.

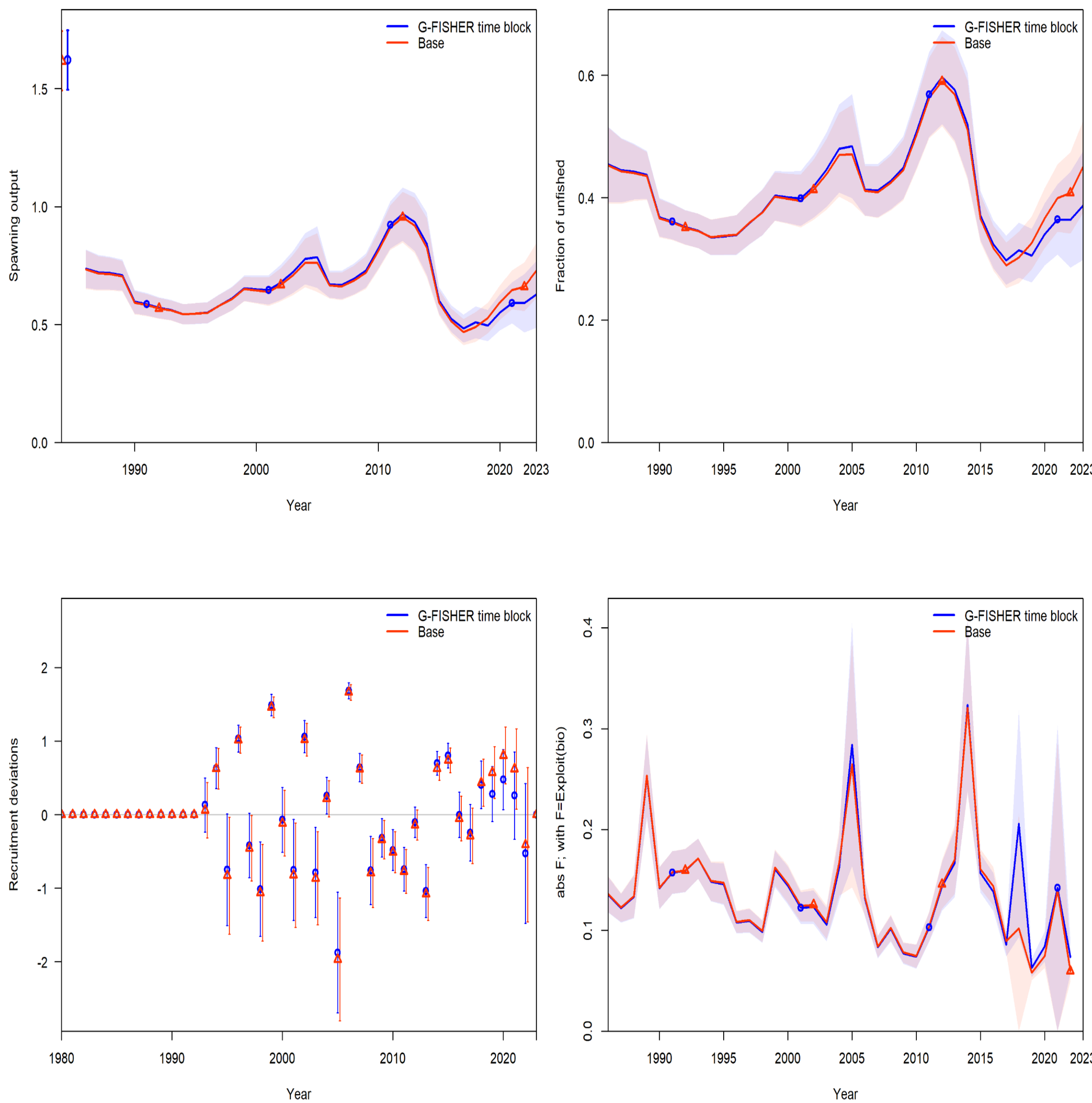


Figure 126. Estimates of spawning stock biomass (relative number of eggs; top left panel), the ratio of SSB to virgin SSB (top right panel), recruitment deviations (bottom left panel), and fishing mortality (total biomass killed all ages / total biomass age 0+; bottom right panel) for the sensitivity runs using a time block at the start of the G-FISHER survey.

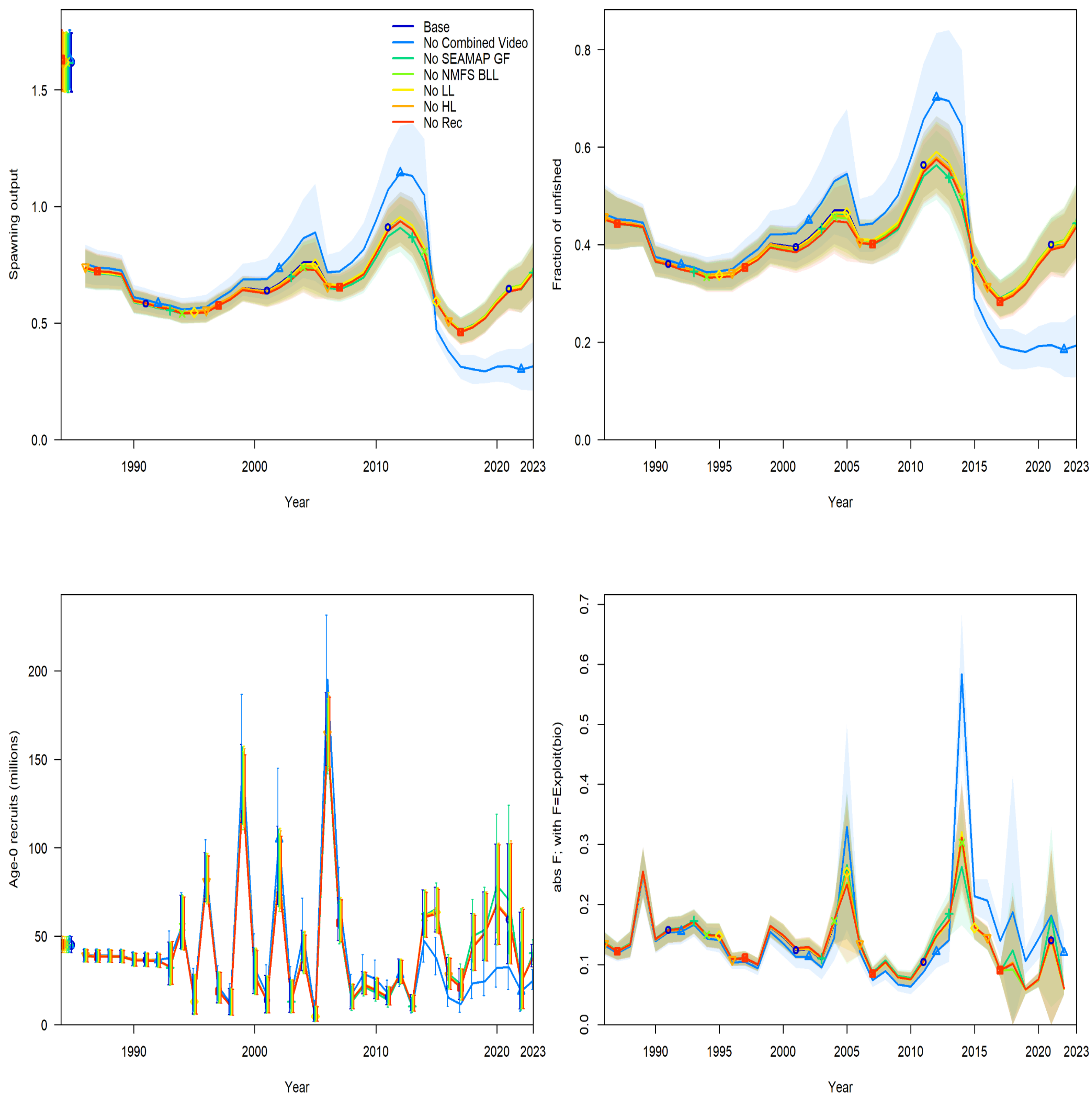


Figure 127. Estimates of spawning stock biomass (relative number of eggs; top left panel), the ratio of SSB to virgin SSB (top right panel), recruitment (millions of fish; bottom left panel), and fishing mortality (total biomass killed all ages / total biomass age 0+; bottom right panel) for jackknife runs peeling off indices of relative abundance.

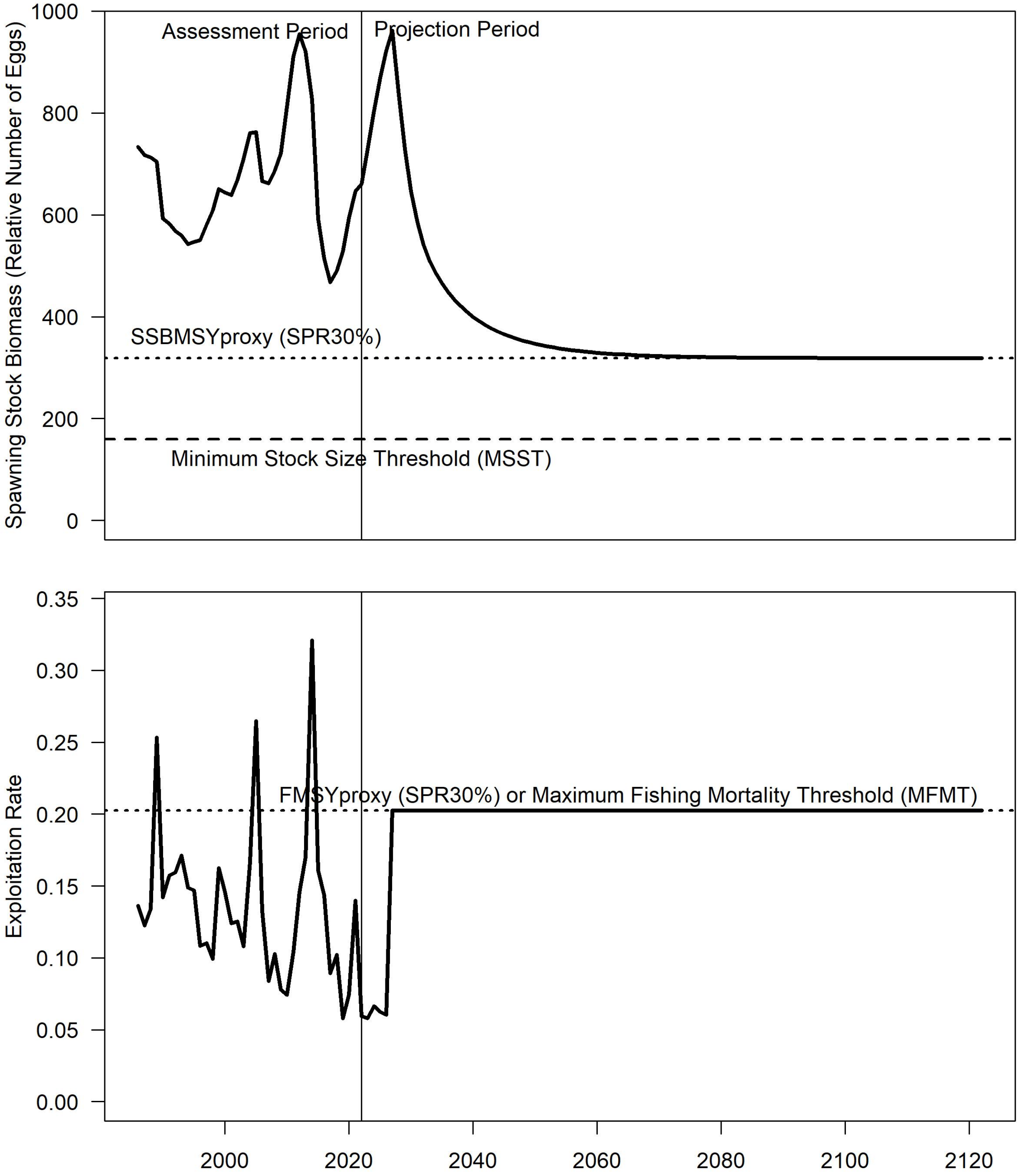


Figure 128. Time series of SSB and harvest rate (total biomass killed / total biomass age 0+) with respect to status determination criteria for the SEDAR 88 Gulf of Mexico Red Grouper Operational Assessment with recruitment predicted by the stock-recruit curve throughout the projection period. An SPR proxy of 30% was specified in the SEDAR 88 Terms of Reference.

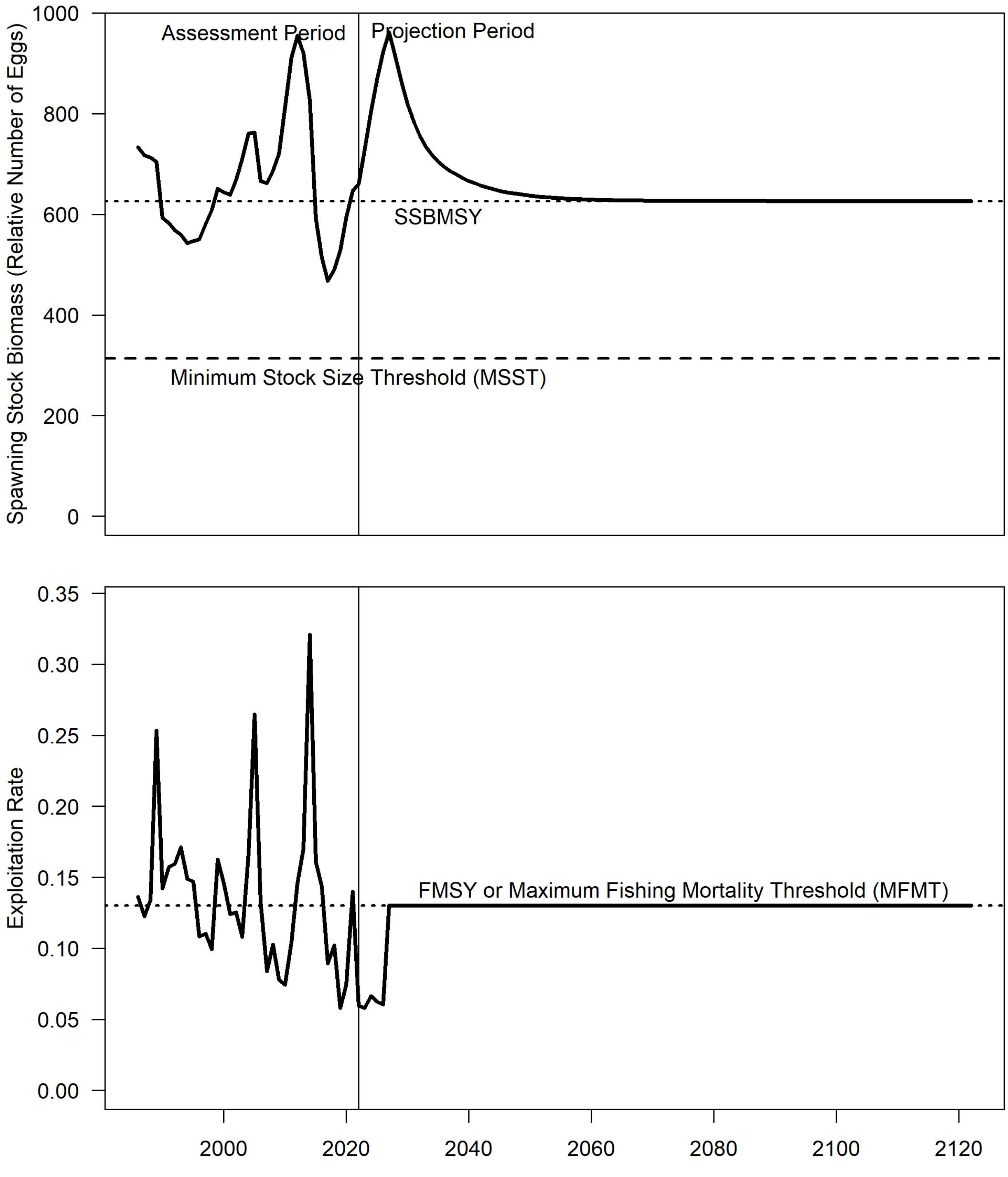


Figure 129. Time series of SSB and harvest rate (total biomass killed / total biomass age 0+) with respect to status determination criteria for the SEDAR 88 Gulf of Mexico Red Grouper Operational Assessment with recruitment predicted by the stock-recruit curve throughout the projection period.

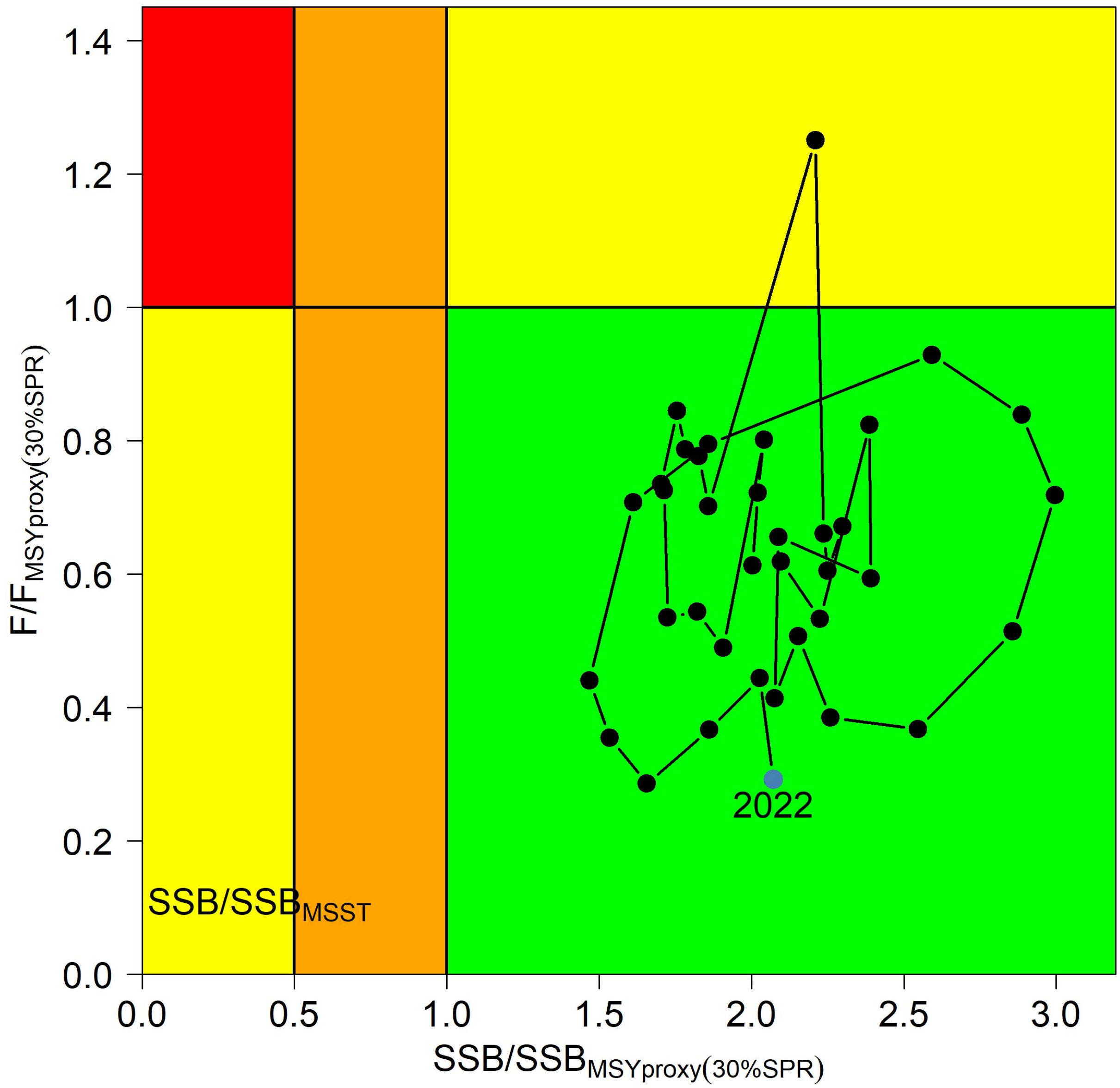


Figure 130. Kobe plot illustrating the trajectory of stock status Kobe plot illustrating the trajectory of stock status for Gulf of Mexico Red Grouper with recruitment predicted by the stock-recruit curve throughout the projection period. The orange coloring indicates regions where the stock is below the biomass target but above the biomass threshold (MSST =0.5 $SSB_{F30\%SPR}$). The 2022 terminal year stock status is indicated by the gray dot. See Table 42 for values. SSB defined in relative number of eggs. An SPR proxy of 30% was specified in the SEDAR 88 Terms of Reference.

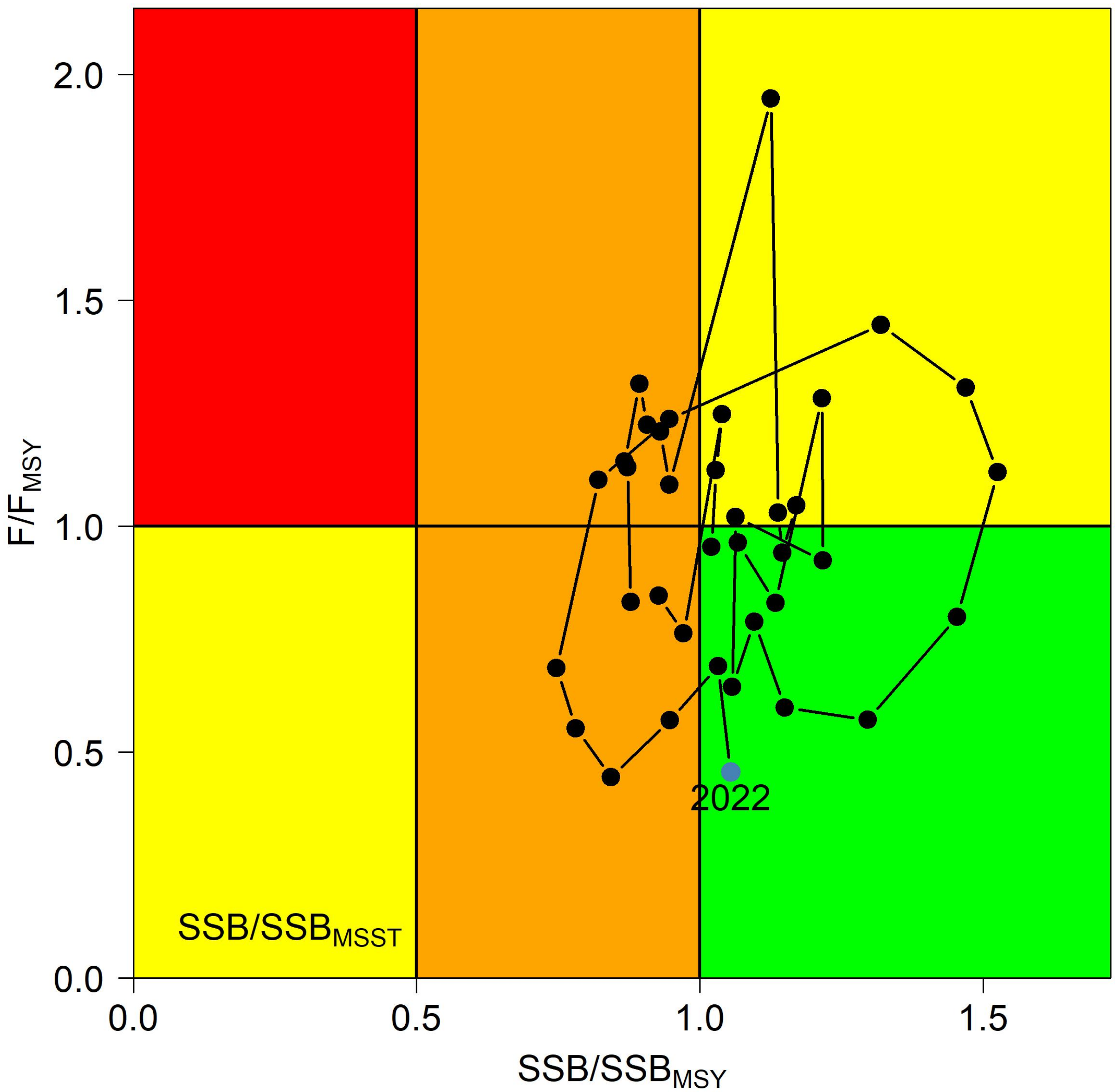


Figure 131. Kobe plot illustrating the trajectory of stock status for Gulf of Mexico Red Grouper with recruitment predicted by the stock-recruit curve throughout the projection period. The orange coloring indicates regions where the stock is below the biomass target but above the biomass threshold (MSST = 0.5 SSB_{FMSY}). The 2022 terminal year stock status is indicated by the gray dot. See Table 45 for values. SSB defined in relative number of eggs.

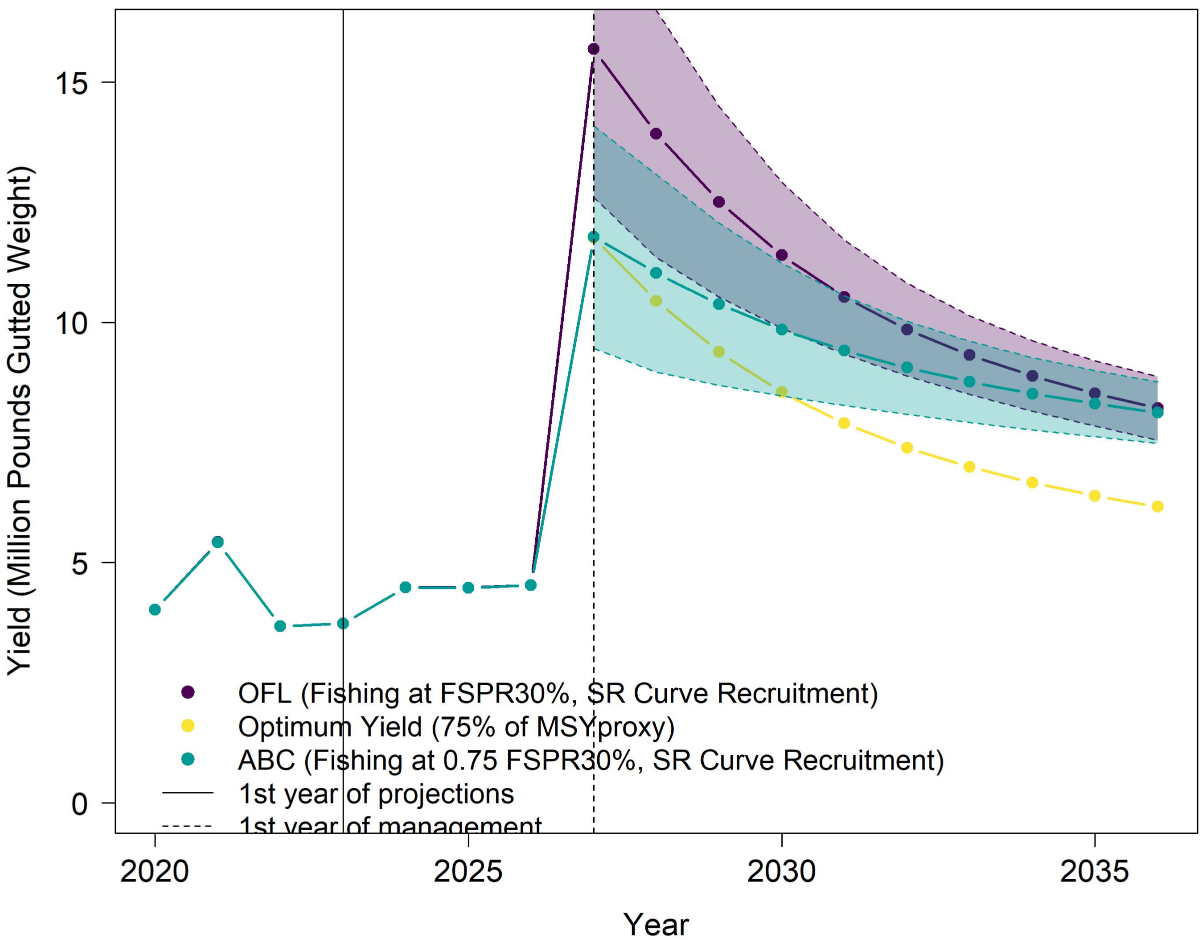


Figure 132. Historic (2020-2022), interim (2023-2026) and forecasted yields (2027+) for the OFL (fishing set at F30%SPR) and ABC (directed F = 0.75 x Directed F at F30%SPR) projections for Gulf of Mexico Red Grouper with recruitment predicted by the stock-recruit curve throughout the projection period. An SPR proxy of 30% was specified in the SEDAR 88 Terms of Reference.

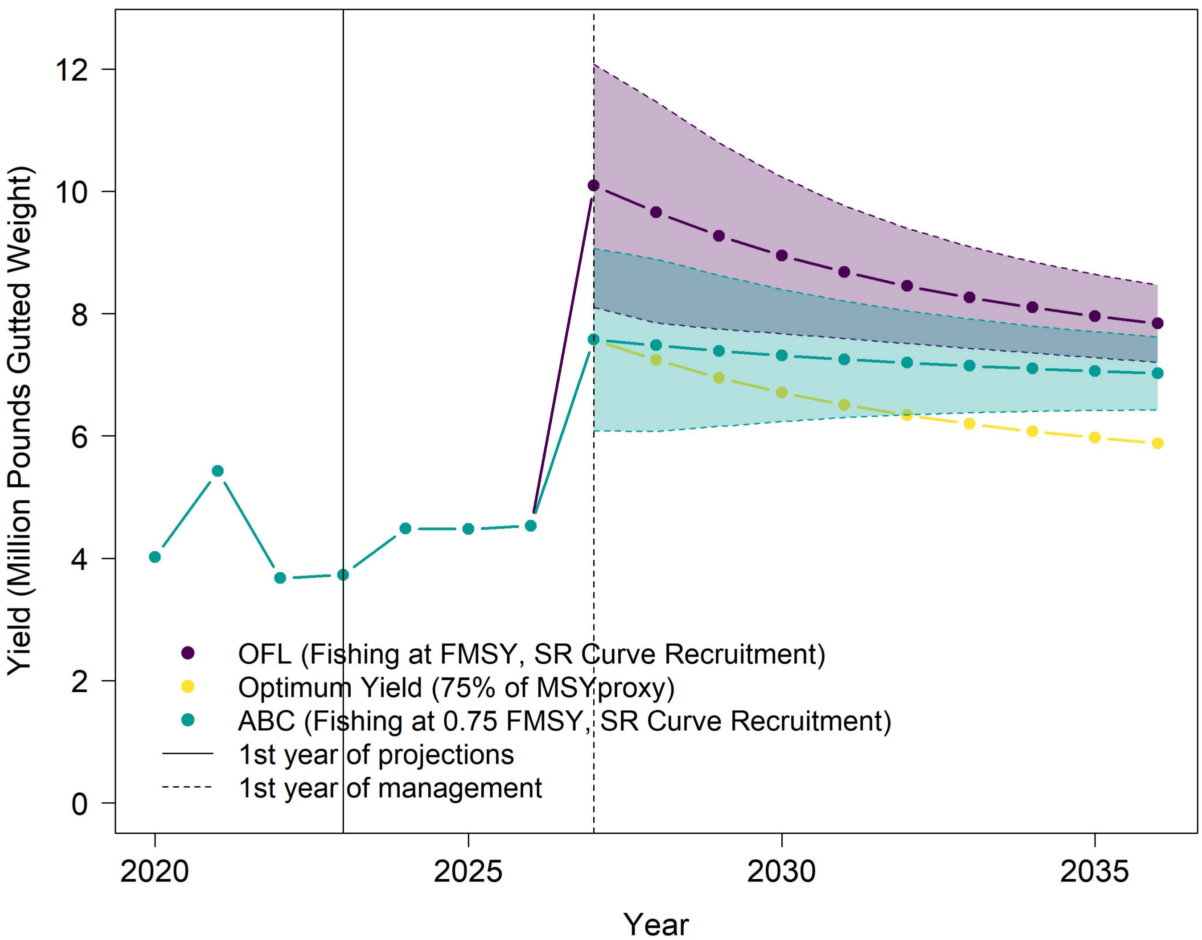


Figure 133. Historic (2020-2022), interim (2023-2026) and forecasted yields (2027+) for the OFL (fishing set at FMSY) and ABC (directed F = 0.75 x Directed F at FMSY) projections for Gulf of Mexico Red Grouper with recruitment predicted by the stock-recruit curve throughout the projection period.